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**Sustainable Urban Design Co-benefits-Role of EST in Air Pollution  
Reduction and Climate Change Mitigation**

**(Background Paper for EST Plenary Session-4)**

**Final Draft**

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This background paper has been prepared by Mr. Karlson Hargroves, for the Eleventh Regional EST Forum in Asia. The views expressed herein are those of the author only and do not necessarily reflect the views of the United Nations.

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# Sustainable Urban Design Co-Benefits

## *Role of EST in Reducing Air Pollution and Climate Change Mitigation*

*Background Paper for Eleventh Regional EST Forum in Asia. October 2018, Mongolia.*

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# ***1. Background***

## **1.1 Asia's trend of motorization**

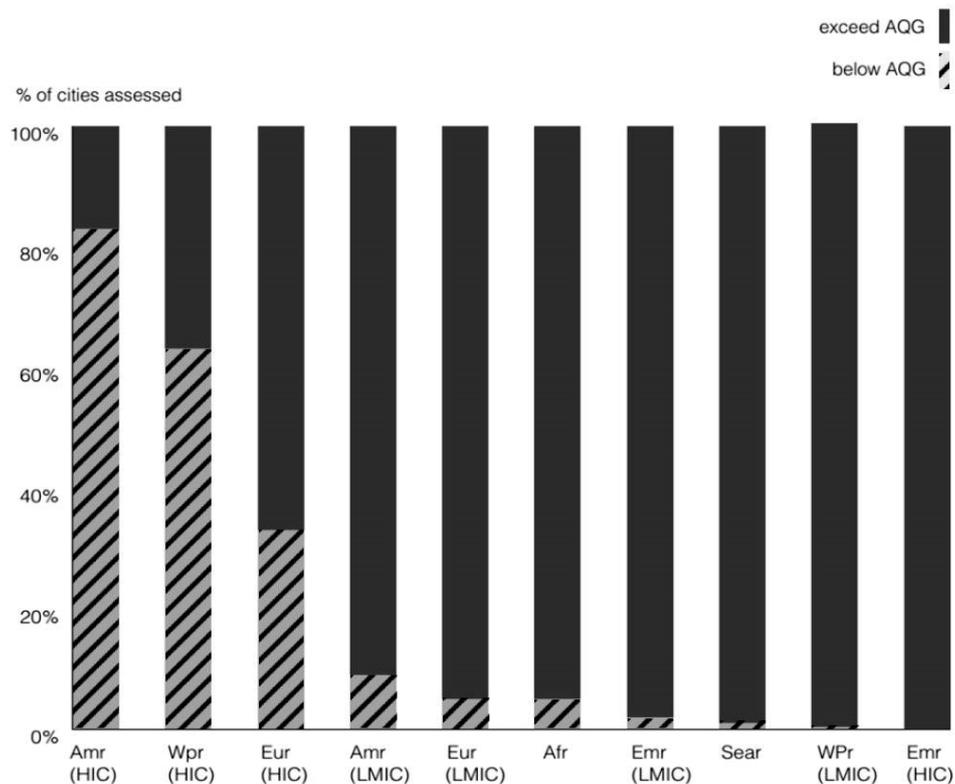
Since the mid-1900s, the majority of cities around the world have grown with the private automobile as the central mode of transport and transportation planning. This has led to a number of urban challenges, particularly in regard to global climate change as a result of greenhouse gas emissions, of which 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 (ADB, 2018). Transport pollution is resulting in severe health impacts as a result of air pollution, with 92 percent of the world's population living above the World Health Organisation's air pollution guideline limit (WHO, 2016). Cities and nations are also suffering detrimental economic inefficiencies due to congestion and long travel times. Asian cities are growing more rapidly than any other continent on earth, and this is happening on a large scale 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). 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). Asia is adding 120,000 people to its urban population every day (ADB, 2018).

The trend of motorization in Asia has increased substantially over the last two decades, with vehicle numbers doubling every 5-7 years (ADB, 2018). 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 (ADB, 2018). This is driven by increasing wealth, urbanisation and population growth, however excessive automobile-induced congestion and emissions come at a cost. It is estimated that 2-5 percent of GDP in Asian economies is lost due to road congestion (ADB, 2015). 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 and particulate matter cause numerous health issues for populations. Most notably are the impacts of air pollutants such as nitrous oxide, sulphur dioxide and particulate matter on pulmonary disease, ischemic heart disease and strokes (WHO, 2016). The World Health Organisation estimates that in 2012, 3 million deaths were attributable to ambient outdoor air pollution, and that 87% of these deaths occurred in low and middle-income countries (WHO, 2016). 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. 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 the majority of cities assessed exceeded the recommended levels, as shown in Figure 1, 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.*

**Figure 1:** Annual mean particulate matter concentration of selected measured towns and cities, compared to WHO Air Quality Guidelines (AQG)

*Source: WHO, 2016).*

Note: AQG = Annual Mean PM<sub>10</sub>: 20µg/m<sup>3</sup> and Annual Mean PM<sub>2.5</sub>: 10µg/m<sup>3</sup>

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. A reduction in the levels of ambient air pollution will generate further positive outcomes, known as co-benefits. For example, a reduction in noise resulting from motorised transport, an increase in physical activity i.e. walking and bicycle riding, a reduction in the urban heat island effect and an increase in exposure to green spaces. This paper will discuss the ability of sustainable urban design to produce co-benefits, focusing on the role of environmentally sustainable transport in the reduction of air pollution and climate change mitigation.

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 eradicating poverty. Sustainable urban design in the context of reducing polluting private vehicle use encompasses the idea that transport networks can be integrated into medium to high density mixed-use developments, centred around efficient and low-carbon public transit. These developments will provide sufficient infrastructure for

local residents, reducing the need to travel great distances and rely on motorised, private vehicles. Fostering sustainable urban development requires integrating the land-use and transport planning processes as is outlined the Bangkok Declaration, and will enable residents to decrease their dependence on motorisation and make better use of transport networks.

## 1.2 Urban Policies and Solutions for Environmentally Sustainable Transport (EST)

### 1.2.1 *The Bangkok 2020 Declaration for Environmentally Sustainable Transport*

There is a suite of solutions that can encourage Environmentally Sustainable Transport (EST), some with greater long-term benefits than others. This background paper aims to outline elements of EST that stand to deliver significant reinforcing co-benefits across environmental, health, economic, and other social measures. This paper is aimed to stimulate discussion among participants of the Eleventh UNCRD Regional EST Forum in Asia, hosted by Mongolia in Ulaanbaatar. As context, the Bangkok 2020 Declaration focuses on three main agendas within the transport sector to advance the sustainability of transportation networks and Asian cities more broadly (UNCRD, 2010):

1. *Avoid unnecessary travel and reduce trip distances:* It is crucial that cities integrate land-use and transport planning and strive to create mixed-use, dense development in cities. Historically around the world cities and their associated transport networks have grown with the private motorized vehicle (car) as the central transportation mode. This has created a necessity in many cities to travel long distances by car, leading to many environmental and social challenges such as climate change and air pollution. By overcoming institutional barriers related to cross-agency collaboration, governments must integrate transport and land use planning to achieve integrated developments that allow citizens to walk between mixed-use complexes to satisfy daily needs (such as shopping, hospitals, schools and entertainment) and also have access to efficient public transport facilities to travel longer distances for work and other needs.
2. *Shift towards more sustainable modes:* Transport is responsible for 80 percent of air pollution in Asian countries (ADB, 2018). Shifting commuters to active modes such as walking or cycling has a multitude of environmental and health benefits, and this is possible when mixed-use density is created. Transport master plans should also include non-motorized transport components to facilitate more cycling and walking where possible. Creating sustainable transport systems and healthier cities requires servicing the aforementioned dense, mixed-use developments with high quality mass transit systems. This is best done with heavy and light rail, and has also been achieved with Bus Rapid Transit (BRT) systems however these tend to leverage less land development potential. Such systems are not always affordable by governments and therefore innovative ways of constructing, operating and financing their development should be explored if the short time-frames required for climate action and health imperatives are to be met. This can be done in partnership with the private sector. Cities should also seek to implement transport demand management (TDM) policies that better manage the demand for travel.
3. *Improve transport practices and technologies:* Cities should also focus on harnessing emerging technology to advance sustainability goals. These technologies can often lead to significant economic and social benefits for cities. These include stipulating and enforcing a certain level of vehicle technology requirements and fuel quality, improving the efficiency of freight transport, and using inspection and maintenance (I/M) to monitor these levels of environmental and air quality. New technologies are emerging in the transportation sector in the realm of 'Intelligent Transport

Systems', driver-assisted and (eventually) autonomous vehicles, big data analytics and Internet of Things (IoT), artificial intelligence and blockchain technology (Hargroves et al 2016). There is much promise for such technologies to contribute to better planning and management of transport systems. It is necessary to consider whether autonomous vehicles will alleviate congestion woes in cities, or make matters worse (as there may be empty vehicles travelling throughout the network), and work to ensure that it is not the latter. Sustainable transport systems underpin prosperous, resilient, safe and healthy cities. Under the Bangkok 2020 Declaration cities should aim to achieve zero fatality, energy security, reduced health impacts from air pollution and social equity.

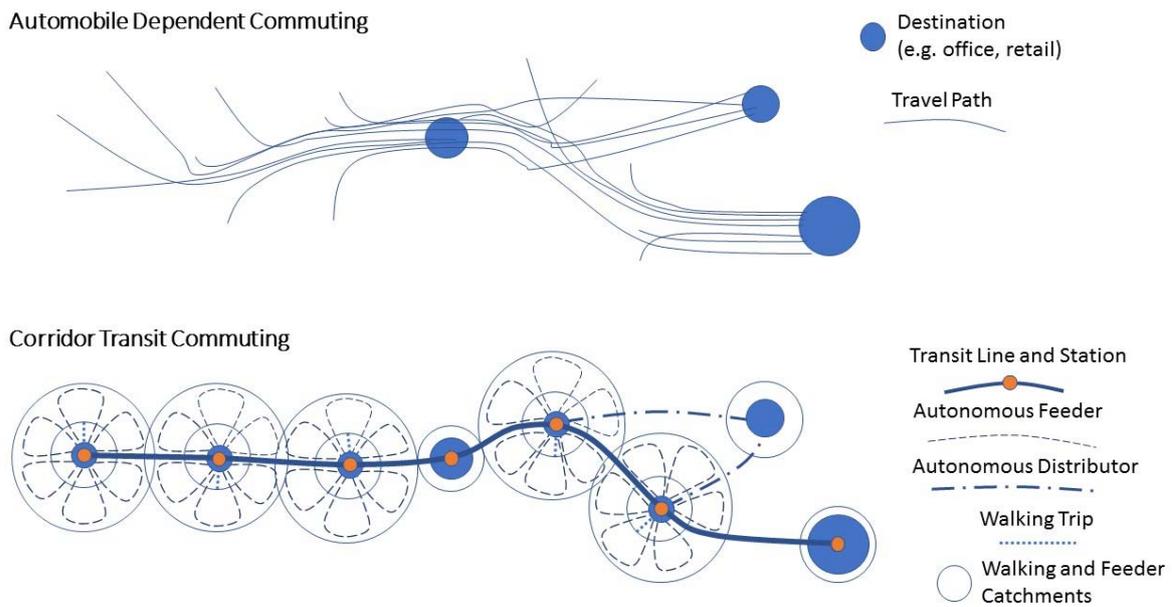
## ***2. Achieving Sustainable Urban Design and Development for Asian Cities***

### **2.1 Overview**

Asian cities are growing at a rapid pace as urbanization continues to increase. Given the sheer size and populations of many of the cities in Asia, they cannot afford to follow the same automobile-centric development pathways that were undertaken by Western countries. It would not be desirable given what is now known about the economic, social and environmental consequences of such urban design. Not only would this lead to significant urban sprawl and economic inefficiency, it would be highly detrimental to the environment and highly polluting for citizens. Given that 80 percent of the air pollution in Asian cities is as a result of transport, and Asian economies are suffering up to 2-5 percent of their GDP from road congestion (ADB, 2015), the future of transport systems and how they underpin the continued growth of cities will be pivotal for future prosperity. Many of the shortcomings of transport systems in the developed world are as a result of highly segregated government agencies, combined with an overwhelming assumption that private automobiles are the dominant and preferred mode of transport.

Fortunately, cities in Asia have a much lower rates of automobile dependence than cities in America, Europe and Australia (Newman and Kenworthy, 2015), and are increasingly recognising the vital need to provide high quality, efficient public mass transit to satisfy growing urban populations, as suggested in Figure 2. However, there are still challenges, such as the integration of land use and transport planning, financing, effective evaluation tools and metrics, air pollution, climate change resilience, low uptake of intelligent transport technologies, and in some cases limited capacities to plan and manage urban transport systems (UN ESCAP, 2016). Innovative urban design is required in these cities, which consists of mass transit systems are planned in conjunction with the associated dense land uses that make this infrastructure much more efficient in economic and environmental terms.

Reducing automobile use is central to mitigating climate change and to reducing air pollution. Not only this, there are a range of other co-benefits for the economy and society that will be covered in subsequent chapters of this report. Smart growth describes urban development that does not contribute to sprawl (Aurand, 2010; Sabri *et al*, 2013), and features compact, transit accessible, pedestrian-oriented and mixed-use development patterns (APA, 2002). This type of growth should be undertaken in existing urban areas, also termed 'urban regeneration', whereby existing urban areas are redeveloped and revitalised in denser, transit-oriented form (rather than new greenfield expansion on the edge of cities).



**Figure 2:** Conception of ‘corridor transit commuting’ compared to ‘automobile dependant commuting’, with transit lines and stations underpinning development around station precincts

Source: Amended from Glazebrook & Newman, 2018

This section focuses on the link between land development and transit services as a method of undertaking urban design and development that responds to the challenge of increasing transit ridership and reducing automobile dependency. The section considers features of such an approach with an aim to inform urban designers and city planners of elements that should be incorporated into urban development projects. The section then outlines the primary benefits that integrating land and transit infrastructure delivers to urban form and function from a technical design perspective. Extensive detail on the environmental, economic and social benefits are covered in Section 3. The section on urban design benefits is then followed consideration of potential financing mechanisms that harness land development opportunities as part of the transport planning rather than after transit infrastructure is constructed to attract private investment. This will be critical given the significant infrastructure finance requirements that exists (approximately \$22.6 trillion between 2016 and 2030) in the Asia-Pacific for infrastructure – an amount of funds that governments do not have (ADB, 2017).

## 2.2 Integrating Land Development and Transit Services – Station Precincts

Public transport provision is important for sustainable, efficient, resilient and liveable cities, however considering transport in isolation is only half of the picture. The land use within a city is vitally important to how trips are generated and how citizens interact with the transport system. Projects need to be developed that deliver dense, liveable, mixed use and sustainable communities based around transit stations (Newman *et al*, 2017). By focusing development around transit stations, this creates higher population densities within transit catchments allowing citizens to walk to nearby stations in order to commute long distances (such as to the city centre). Such urban centres can increase transit ridership by 20-40 percent, with people within a station catchment being five times more likely to catch public transit than those outside (City of Winnipeg, 2011). By increasing the amount of commuters travelling by public transport, these centres create more sustainable urban environments that are not dependent on private vehicles. By incorporating a number of other

features, these centres can be lively, innovative and healthy places to live. Cities like Singapore, Hong Kong Special Administrative Region of China and Tokyo have had extensive success with integrating land development and transport services.

### 2.2.1 Transit Integration

Station Precincts are planned around transit access, and are conducive to commuters using mass transit. In the context of environmentally sustainable transport (EST), station precincts should be oriented around mass transit stations such as heavy or light rail. The transit that services a station precinct should be high frequency and high capacity to ensure it can satisfy the development's population. Bus rapid transit could also provide the types of capacities required to service commuters in a sustainable way however light rail or trackless trams provide greater patronage and comfort. Some authors have used the term 'Transit Oriented Development' to describe the creation of station precincts (Lefaver, 1997), however this is usually undertaken after the transit service and infrastructure has been designed and financed, missing a valuable opportunity (Newman *et al*, 2017). In regard to land use, Cervero and colleagues (2002), distinguish between what they refer to as Transit Oriented Developments (TODs) and Transit Adjacent Developments (TADs) – with the key distinction being that while both are within the vicinity of transit, TODs intend to encourage and enable citizens to use this transit. Station Precincts foster the use of active modes such as walking and cycling for 'last mile' trip journeys (commuting to and from the transit station), and also actively seek to reduce the amount of parking spaces within the development, such as shown in Figure 3.



**Figure 3:** Vision for revitalizing Kalupur railway station, Ahmedabad, India.

*Source:* Institute for Transport Planning and Development Policy, 2015.

### 2.2.2 Enhanced Walkability

Creating walkable urban environments is of increasing focus for urban planners as a way to reduce polluting motorized transport emissions, while also increasing physical activity of the population, resulting in multiple health benefits (Wey and Chiu, 2013; Evans-Cowley, 2006). Ensuring that walkability is a design factor of station precinct is important for their effectiveness, and appropriate design has been shown to increase the quantity and quality of walking (Hodgson, Page & Tight, 2004), with citizens in mixed use and dense developments exhibiting three times higher likelihood of walking than those in car-centric neighbourhoods (Cervero and Radisch, 1996). Interventions can be modest

strategies like improving road signage, introducing traffic calming measures (such as speed pumps), and creating safer and more distinct crossings and intersections. However, much more vibrant and walkable districts are created through ambitious measures such as allocating lanes of roads to pedestrians (as shown in Figure 4), vegetation or cycling; sharing slow-speed roads between pedestrians and cars; or creating pedestrian streets altogether (ARUP, 2016). All of these strategies should seek to streamline pedestrian and cyclist flow towards a transit station. Not only does a walkable street enhance a station precinct to reduce polluting vehicle use, it also provides co-benefits of more social and interactive spaces for people to meet, socialise and collaborate on ideas (Gehl, 2013).



**Figure 4:** Herald Square, New York, Before and After interventions to prioritise walkability

Source: ARUP, 2016).

### 2.2.3 Greater Urban Density

Densifying urban development is a critical component of addressing growing car use, climate change and air pollution in cities – and is a core feature of a station precinct. In order to facilitate walkability for citizens within a station precinct, and use this active mode as a means of completing ‘last mile’ trips associated with transit riding, the intensity of development is generally focused within a radius of between 400-800 meters (0.25-0.5 miles) from the transit station. This correlates to a comfortable walking distance for the average person. By focusing the majority of the development within this area, the need to use motorized vehicles to get from the station to the destination (and vice-versa) is removed. Density clusters larger numbers of people in sustainable districts serviced by transit, thus increasing the quantity of citizens who adopt a sustainable lifestyle, but also making the economics of the transit system much more feasible, as many more people are within the catchment to commute on the network. It is important for policy makers to ensure that appropriate zoning conditions are provided for dense development to occur in these areas.

### 2.2.4 Mixed-Use Developments

In order for station precincts to flourish and the need for motorised vehicle trips be significantly reduced in cities, not only must citizens be able to walk to transit stations they must also be able to walk to a variety of other destinations and services which contribute to an enjoyable quality of life. Mixed use areas comprise of places such as residential housing, shopping facilities, gymnasiums, schools, restaurants, public spaces and even result in station areas becoming community hubs. This goes hand-in-hand with density and enables the significant reduction in the amount of long distance trips that are required to be taken by motorized vehicles, as many origin-destination combinations fall

within walking distance of each other. The local accessibility within these developments decreases the incentive for car ownership and use, and encourages walking and cycling. The mixed land use within station precincts along rail corridors also makes the rail corridor and infrastructure itself more economically efficient, by creating destinations around stations (such as cinemas or sporting facilities) that attract transit riders at all times of day and from all directions, rather than just transporting commuters to and from work (Cervero *et al*, 2002).

### 2.2.5 Improved Public Space

By integrating inviting and functional public space into station precincts, like parks, public squares or wide pedestrian-centric streets, urban design can create a strong sense of community in these neighbourhoods. There are a range of benefits of this approach outlined in subsequent sections, but inviting public space contributes to walkability, transit use, face-to-face interaction and knowledge transfer, health and quality of life. Cervero (2002)<sub>2</sub> outlines a number of design provisions to make public space more inviting and engaging, including “*landscaping, weather protection, public art, street furniture, lighting, public phones, and other provisions in public spaces. Likewise, require all developments to provide for pedestrian and cyclist needs, such as benches, continuous awnings, bicycle racks, and street trees*”. Public spaces can make use of urban greenery to reduce air pollution and provide temperature regulation. The invitingness of public space is inversely proportional to the amount of motorized vehicles in the area. For example, Donald Appleyard’s seminal work showed that between streets that were selected to be as identical as possible, those with lighter traffic encouraged much more use of public space (with each citizen averaging three friends per person in the vicinity), while heavily trafficked streets had the opposite effect (with citizens averaging 0.9 friends per person) (Appleyard, 1981). In 2017 Mongolia released its National Program on Air and Environmental Pollution that includes the enhancement of green areas combined with the co-location of commercial and office spaces to make travelling between these destinations convenient for pedestrians and cyclists (WHO, 2017).

## 2.3 The design benefits of Station Precincts on urban form and function

The integration of land use and transport planning that can create station precincts that reduce automobile use and the associated greenhouse gas emissions and air pollution, have a range of benefits. This section will outline the benefits to urban form and the associated functionality of urban infrastructure of station precinct design. These urban design benefits are inherently linked with environmental and social co-benefits, to be covered in subsequent sections of this report.

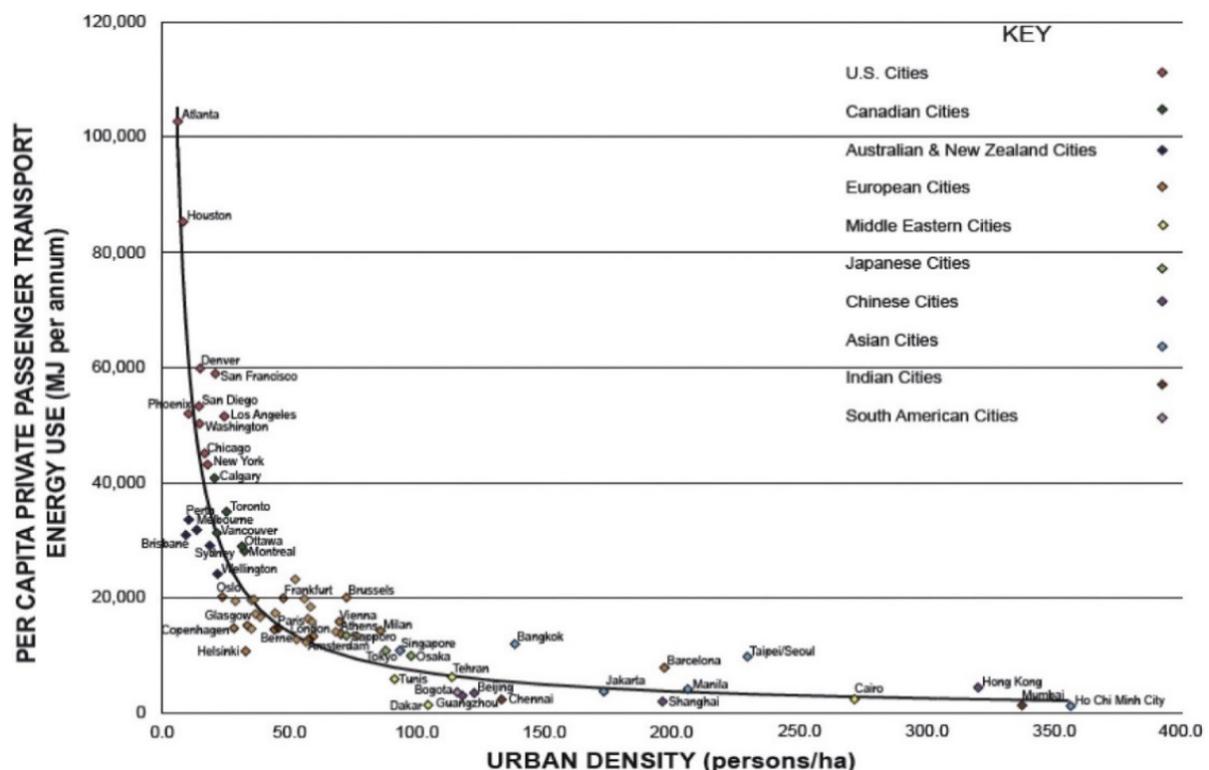
### 2.3.1 Congestion Reduction

Perhaps the most central benefit of dense, mixed use urban development that occurs around transit stations is the reduction of motorized car use and congestion. However, station precincts reduce the amount of distance travelled in motorized vehicles by quite a significant ratio. It is not that for each 1km travelled by transit, 1km of automobile travel is reduced. In fact, global cities data collected by Newman and Kenworthy (1999)<sub>2</sub> shows that for each 1km travelled by transit, between 5-7km of vehicle distance is avoided. This is a ratio of up to 1:7. This is because of the ‘transit leverage’ effect or ‘transit multiplier’ (Neff, 1996). Newman and Kenworthy (1999), outline the following reasons for this multiplier effect:

- When quality transit is available, citizens and businesses adjust by locating closer to the line.

- The concept of ‘trip chaining’, whereby commuters who walk and use transit combine several trips into one within mixed-use developments, such as collecting the groceries on the walk home from work – which in suburbs planned around cars means separate trips.
- Households in station precincts give up one of multiple cars and thus have less availability and desire to use the car.
- Transit users in station precincts build a lifestyle around walking and cycling to stations.

Figure 5 below shows the correlation between urban density and per capita energy use for transport (Newman and Kenworthy, 2015). It is clear that as urban density increases, there is a drastic reduction in energy consumptions per person for passenger transport, equating to significant greenhouse gas emissions reductions given that the majority of private vehicles source their energy from liquid fossil fuels, and also reduces associated air pollution.



**Figure 5:** Impact of Urban Density of Per Capita Private Transport Energy Use

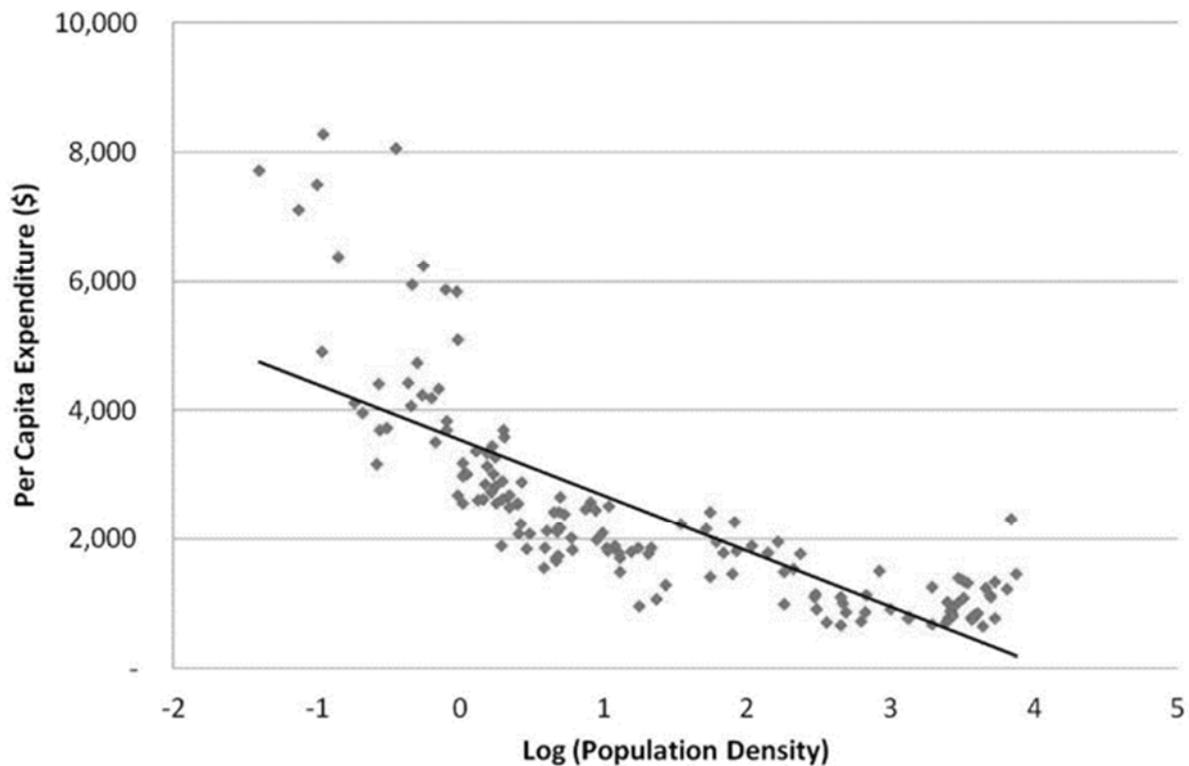
*Source:* Newman and Kenworthy, 2015)

This multiplier effect is important to remember when forecasting the impact of sustainable transport provision when coupled with proper surrounding land use, and is often overlooked in traditional engineering approaches. Similarly, by planning developments around stations (rather than ignoring the land use component), the use of transit at these stations increases by 20-40 percent (City of Winnipeg, 2014). All of these factors contribute to reducing care use and congestion reduction, creating cities that pollute less, have cleaner air, are less noisy, are more economically efficient due to less wasted time stuck in traffic, and have more sense of community.

### 2.3.2 Reduced cost of local infrastructure

The provision of local infrastructure such as water, sewerage, waste and roads is much more economically efficient to construct and maintain in station precincts given the increased density, in comparison to urban sprawl. In a study commissioned by the California Department of Transportation,

it was found that the compactness of station precincts combined with their often prior location with urban areas (rather than on the urban fringe) reduced the cost of infrastructure utility services such as water, sewage and roads by 25 percent (Parker, 2009). A study by SGS Economics and Planning in Australia showed that as population density increased, local government expenditure per capita decreased due to savings such as infrastructure, recreational and cultural, environment, governance and administration, public order, community services, education and housing, as shown in Figure 6.



**Figure 6:** Population Density vs. Local Government Spending Per Capita  
*Source:* SGS, 2013

### 2.3.3 Space savings from reduced urban sprawl

A major benefit that station precincts have to the shaping of cities is that they significantly reduce the amount of land surface space that is required for growing cities. Space is saved through the dense, mixed-use nature of station precincts generally, and secondly by the reduction in average parking space required to satisfy citizens. Station precincts create much more compact and densely populated areas, therefore reducing the requirement for new land on the fringe of cities, or ‘greenfield developments’ to take place. By adopting the approach of urban regeneration, where instead of building on the fringes of the urban area, land is re-developed in hubs around new or old station precincts, this kind of space saving is transferrable across an entire city. Given that many Asian cities are expected to continue growing significantly over the coming decades (UN DESA, 2018) – adopting a regenerative approach to facilitating station precincts will amount to enormous space savings and be crucial to ensuring growing cities can continue to function efficiently and competitively.

### 2.3.4 Space savings from reduced car parking

A major inefficiency for cities’ land use is car parking space. Global data collated by Newman and Kenworthy (1989; 2009), shows that most cities that have grown with cars as their primary transport option have resulted in the requirement of approximately 5 to 8 parking spaces per car. This equates

to over 30 percent of cities' surface area. As an example, according to the International Energy Agency (IEA), based on current trends India could require between 10,000-20,000 square kilometres of surface parking area to satisfy car dependency – equating to 35 times the size of Mumbai if not spread across multi-level carparks. In Transit-Oriented Developments however, parking provision is (or at least should and can be) much less. An example is Perth in Australia, where in station precincts there are approximately 4 parking spaces per person (Perth is still very car centric) and outer urban sprawled developments which average 10 parking spaces per vehicle (Newman and Kenworthy, 1999). While Asian cities have on average less car parking supply than Australian and US cities which have developed as more car-dependent with much less population densities, a similar ratio can be expected of parking provision between station precincts and fringe developments.

## 2.4 Financing Sustainable Transport through Land Development

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 public transport. There are different ways this can be done, however overwhelmingly there is potential to capture value from the increases in land values that occur when transit is provided. Again, this demonstrates the importance of the integrated nature of land use and transport planning. By introducing a transit station, the accessibility of 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 generally correlated with greater accessibility (Lari *et al*, 2009). By creating such value through sustainable transit-oriented development, some of this value can be redirected to finance the transit itself.

### 2.4.1 Traditional Approaches to Value Capture and Private Finance

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):

- *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 the majority of localities in the United States for various 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).
- *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.

As has been highlighted above, 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 as a result of the levies. 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 should think about how they can harness cross-departmental collaboration (between land use and transport agencies) to leverage private sector finance, innovation and know-how 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). 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 (Musa, 2018).

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)<sup>2</sup> 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.

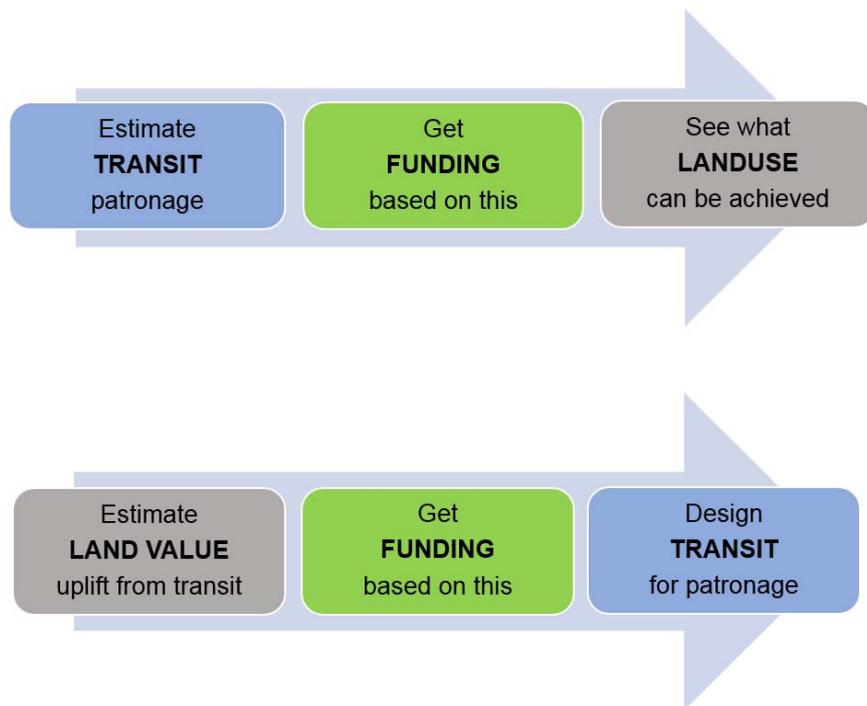
In Asia, such public private partnerships for transit and land use development are even more lucrative. Firstly, the average car use across the population is much less in Asian cities than in Western countries (Newman and Kenworthy, 2015), meaning that there is more of the population reliant on public transportation and as a result additional transit induces a greater increase in accessibility (Salon and Shewmake, 2011). Secondly, Asian cities are growing at a rapid pace when compared to Western cities (Chauvin, Glaeser, Ma and Tobio, 2017). 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 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). 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 (World Bank, 2000).

#### *2.4.2 From Transit Oriented Development to Transit Activated Development*

The challenge is now to create new, corridor-based mass transit systems in cities that feature many car-dependant suburbs, given that many cities have undergone development pathways that have been intrinsically linked with the private automobile as the central means of mobility. Fortunately, many Asian cities are of higher densities than many cities in the West, and therefore have more appropriate ridership quantities for potential transit services. However, there is still room for development to occur, which is made viable by the provision of transit services, and the development in-turn makes the transit affordable. The 'Entrepreneur Rail Model' (ERM) developed by Professor Peter Newman and colleagues at Curtin University Sustainability Policy (CUSP) Institute seeks to create mutually beneficial partnerships between entrepreneurial developers and governments. Given the long-term, fixed nature of rail-based transit systems (as opposed to bus networks), a certainty is created for the future of the station-centric locations which can generate investment confidence from developers, vendors, venues, hospitality, businesses and other community members. The ERM looks to collaboratively build on this confidence through a 'value creation' focus, rather than a 'value capture' afterthought. This approach shifts from only aiming to orient development around transit (Transit Oriented Development), to using transit as a basis for investment and collaboration, earning the title 'Transit Activated Development'. Figure 7 below provides a visual representation of the change in process from a traditional approach, to an entrepreneurial approach to transit corridor development:



**Figure 7:** A schematic comparison of the traditional transit planning process (top) and the entrepreneurial approach to corridor transit described by the Entrepreneur Rail Model (bottom).

*Source:* Adapted from Newman *et al*, 2017

One of the key requirements of this entrepreneurial approach to transit is a focus on building partnerships from the very beginning. The ERM seeks to bring together governments at appropriate levels and jurisdictions with land developers and financial institutions, even before the route is determined. The key to successful Public-Private partnerships (PPPs) is achieving ‘win-win’ outcomes (Smith, 1999). As is shown in Figure 7, rather than taking land use development potential as an afterthought, it becomes the basis for the transit configuration and the associated finance. Government certainly has a responsibility to ensure a suitable outcome is achieved for the society which it represents, however the project must also be financially feasible for the private sector collaborators. The transit configuration then becomes a co-creational process where alternate routes may be explored because they offer more opportunity for development, while still serving and activating a corridor. This shift in mindset opens up much more opportunity for the private sector who specialise in innovation, and should be allowed to do so given they are sharing the financial burden and the risk of the project. This approach is more bottom-up and co-creational than the top-down where the route is pre-determined and private sector parties bid to undertake the works.

## 3. *The Co-Benefits of Sustainable Urban Design*

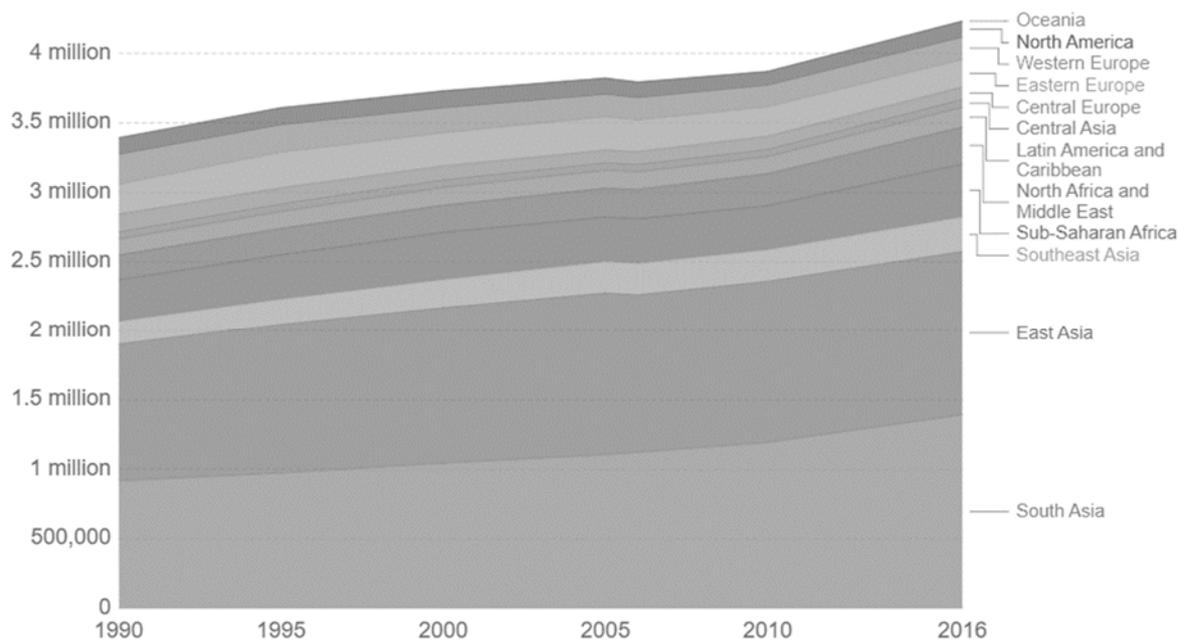
### 3.1 The co-benefits of Sustainable Urban Development (Particularly EST)

#### 3.1.1 Healthier cities

As has been mentioned earlier in this report, cities in the Asian region are facing significant challenges related to air pollution and excessive automobile dependency. Some have called responding to climate change “the greatest global health opportunity of the 21<sup>st</sup> Century” (Watts *et al*, 2015), and given that the significant portion of the air pollution in Asia is from the transport sector, Environmentally Sustainable Transport (EST) has a significant role to play in addressing this key issue. EST addresses the foremost challenge of air pollution by significantly reducing the number of fossil-fuel powered vehicles on the road. It also includes measures to encourage sustainable fuel sources and the electrification of the transport network. However, EST when integrated with land use in dense, mixed-use developments also promotes active modes (walking and cycling) and therefore encourages physically active lifestyles for the population who receive health benefits from such activity. The significance of the benefits to public health are outlined here.

#### Reduced negative health outcomes of air pollution

A large majority of the costs associated with ambient air pollution are due to health impacts (National Academy of Sciences, 2010). In 2010 in Europe, the European Environmental Agency tagged air pollution as the largest environmental health risk in Europe (Bhalla *et al*, 2014). In Asian countries, approximately 80 percent of air pollution is estimated to come from the transport sector, as a result of fossil-fuel based motorized vehicles (ADB, 2018). These health impacts disproportionately affect children and the elderly. Figure 8 shows annual death from air pollution per region over the past two decades (IHME, 2017). Although only up to 30 percent of air pollution in OECD cities has been attributed to motor vehicle emissions, this rises to as much as 60 percent in developing world cities (ARUP, 2014). In urban areas specifically, up to 75 percent of air pollution has been attributed to motor vehicle emissions (UNEP, n.d).



**Figure 8:** Absolute number of annual deaths by region attributed to ambient (outdoor) air pollution to particulate matter (PM) and ozone (O<sub>3</sub>)

Source: Ritchie and Roser, 2016

In 2015, 59 percent of the 4.2 million global deaths in 2015 caused by PM<sub>2.5</sub> particulate matter were from South and East Asia (Cohen *et al*, 2015). It has been estimated that expanding cycling in The People's Republic of China to reduce the Vehicle-Kilometres-Travelled (VKT) by Chinese residents by 5 to 10 percent could lead to the following decreases in annual average air pollutants; 1.56-3.11 percent reduction in Sulphur Dioxide (SO<sub>2</sub>) levels; 1.40-2.8 percent reduction in Nitrogen Dioxide (NO<sub>2</sub>) levels; between 3.09-6.18 percent reduction in PM<sub>2.5</sub>; between 2.93-5.86 percent reduction in PM<sub>10</sub>; and between 4.9-9.8 percent of CO<sub>2</sub> equivalent. In the same study, combining this decreased VKT with an increase in public buses to cause an overall reduction of approximately 40 percent of VKT, was estimated to result in up to 12.44 percent, 10.92 percent, 24.65 percent, 23.38 percent and 39.21 percent reductions in SO<sub>2</sub>, NO<sub>2</sub>, PM<sub>2.5</sub>, PM<sub>10</sub> and CO<sub>2</sub> respectively (He and Qiu, 2016). From a health perspective, this is a substantial co-benefit of EST, and would warrant consideration for implementation across any Asian city (not just The People's Republic of China) without even touching on all of the environmental and economic benefits.

Some of the health impacts that can be reduced through reduced private VKT as a result of sustainable urban design, mass-transit and active modes include:

- *Short-term health impacts reduced:* The majority of short-term health impacts of air pollution are related to issues involving the respiratory system. This results in more people taking sick-leave and more hospital admissions, as well as reducing the productivity of those who still go to work. Elevated air pollution levels over the course of a month have been associated with hospital admissions for pneumonia, chest infections and asthma. It has been estimated that, for a firm with 1000 employees, an increase in PM<sub>10</sub> by 10 units is associated with 2.3 more sick-leaves per day (Hansen 1997). The effects are more prominent in children with asthma, bronchitis, pneumonia

and pleurisy observed. Hospital admissions for children triple, and nearly double for adults, in months with 24-hour PM10 levels above 150. When the mean value for the month exceeded 50 micrograms/m<sup>3</sup>, hospital admission increased by 89 percent for children and 47 percent for adults (Pope, 1989).

- *Long-term health impacts reduced:* A majority of the health impacts of air pollution are due to long term exposure and can result in mortality. Air pollution has been conclusively linked to cardiovascular diseases (including stroke), lung cancer, chronic obstructive pulmonary disease, diabetes, asthma, obesity and reduced cognitive function. It has been estimated that PM2.5 alone resulted in 7.6 percent of all deaths in 2015. PM2.5 is the fifth leading cause of death globally (Cohen, 2018). In the People’s Republic of China, only dietary risk factors, high blood pressure and tobacco exposure cause more disease burden than ambient air pollution (Yang *et al*, 2010). Depending on the country, it has been estimated that air pollution is responsible for up to 41 percent of all ischaemic heart disease, 43 percent of strokes and 25 percent of lung cancer (Burnett, 2014). There is emerging evidence that long-term air pollution exposure may lead to an increased risk of low birth weight (Stieb, 2012), childhood Attention Deficit Hyperactivity Disorder (ADHD) (Perera, 2014), dementia, Alzheimer’s and Parkinson’s disease (Kioumourtzoglou, 2016).

Despite this, these costs are largely invisible and often are not recognised as caused by pollution. This is in part due to the long latency of impacts of air pollution and the difficulty in attributing individual cases as resulting from air pollution. The result is that the full costs of pollution are not appreciated and are often not counted (National Academy of Sciences, 2010; Epstein *et al*, 2011). It is also important to note that the estimates of the total health impacts of pollution only include pollution-disease pairs for which there are robust quantifications of their contributions to the global burden of the disease. This excludes diseases for which there is an established link but that the link is not yet sufficient to provide a quantification of its burden. A good example is the link between air pollution and diabetes. Although there is a scientific consensus that “Long-term exposure to high levels of main air pollutants is significantly associated with elevated risk of Type 2 Diabetes Mellitus” (Wang *et al*, 2014) and “Air pollution is a leading cause of insulin resistance and incidence of type 2 diabetes mellitus” (Meo *et al*, 2015), these impacts are not included in aggregated air pollution health burden statistics. This suggests that current figures of the total health burden of air pollution are very likely to be grossly underestimating the true impact. It has been estimated that if air pollution in the People’s Republic of China was reduced to WHO recommended levels, annual total healthcare spending could be reduced by as much as 7 percent (Barwick, 2018). This figure does not include the benefits that would be gained by the increase in physical activity that would be necessary to achieve such a reduction in air pollution, nor the reduced motor vehicles accidents.

A first step in addressing air pollution is to ensure effective air quality monitoring in order to inform the management of air pollutants. For example, in Islamabad, Pakistan, high air pollution levels lead to a large portion of annual deaths (up to 20 percent of deaths are from pollution overall). Following the World Bank’s 2014 recommendations, Pakistan’s Climate Change Ministry installed 10 air quality monitoring stations in Islamabad, allowing the detailed measurement of air pollution. Factories have also been instructed to install air pollution filters (Reuters, 2018). Similarly, the Philippines has responded by making the reduction of air pollution one of their top priorities, of which 69 percent is derived from motor vehicles. The Philippines maintains an extensive air quality monitoring system and accurate air quality data. In 2016 their air pollution levels were 20 percent lower than previous levels (DENR, 2016).

The Kingdom of Bhutan has a Low Emission Development Strategy which aims to reduce the emissions of their transport sector over a 25 year period. To complement sustainable urban design and reduce air pollution, a Green Tax was imposed on imported vehicles. Electric vehicles, however, do not incur a tax and the tax imposed on hybrid vehicles is much less than the tax imposed on diesel and petrol motors (Royal Government of Bhutan, 2012). In addition to working to increase a greater public transport share (up to 30 percent), Vietnam is increasing energy efficiency and its share of biofuels through significantly reduced taxes for electric and hybrid vehicles (Sehlleier, 2018).

As of 2017, Sri Lanka has the highest level of air quality in South Asia, however air quality still poses a health risk, and a large portion of this air pollution is due to motorized vehicles, some 60 percent. Progress in Sri Lanka has been made through the implementation of The National Policy of Urban Air Quality Management which was adopted in 2000, including phasing out of leaded fuels in 2002, introducing low-sulphur diesel in 2003, banning the import of two-stroke three wheelers in 2008, and a vehicular emissions testing program in 2008 (Nandesena *et al*, 2010).

#### Increased physical activity (Walking and cycling)

Increasing active transportation reduces air pollution but also contributes to the substantial additional benefits of being active. This should be a core design consideration for transport and urban land use planners seeking to facilitate healthy, low-carbon cities. There is an important role for urban design and planning of transit-oriented developments to play in encouraging walking among citizens. In a systematic review of 46 studies, the quantitative evidence overwhelmingly concludes that the presence and proximity of mixed-use retail and services, combined with urban design factors like connected streets, is conducive to walking (Sugiyama *et al*, 2012). It is estimated that the value of health benefits from investment in cycling infrastructure is more than five to one. Learnings in Europe, who are leaders in the provision of cycling infrastructure, estimate that in 2017 the benefits of cycling infrastructure could be up to US\$136 billion annually (Gouldson *et al*, 2018). In regard to decreasing the number of mortalities within the population, encouraging cycling has been shown to be much more effective than simply focusing on promoting low-carbon vehicle fuel types.

The benefits of physical activity as a result of a modal shift may be much more beneficial than air pollution reduction. A study conducted by Wookcock *et al* (2009), assessed the public health impact of alternative transport scenarios in London and Delhi. In this study, comparisons between lower-emission motor vehicles were compared with a switch from motor vehicles to active modes. The findings indicated that the low-emission vehicle scenario would save 1,696 Disability-Adjusted Life Years (DALYs) in Delhi and 160 DALYs in London per 1,000,000 population. The modal shift scenario however, estimated savings of 7,322 DALYs in London and 12,516 DALYs in Delhi in a single year – a much higher portion than from solely reducing vehicle emissions, with the majority of preventable premature deaths attributed to increased physical activity. Rabl and de Nazelle (2012), estimated that for a commuter who chooses to switch to cycling for a 5km trip daily to work (5 days a week, 46 weeks a year), experiences personal health benefits that can approximate to US \$1,450 per year. While it could be argued that cyclists will have more exposure to air pollutants and traffic accidents, various studies show the health benefits of cycling far outweigh these potential risks (de Hartog *et al*, 2010; Mueller *et al*, 2015; Tanio *et al*, 2016; Gouldson *et al*, 2018).

The Government of India is implementing a Sustainable Urban Transport Programme, which is also supported by the World Bank, Global Environment Facility and the United Nations Development Programme. There are a number of demonstration projects occurring in cities across the country

(SUTP, 2018). For example, in Mysore, Southern India the Trin Trin Public Bike Sharing project facilitates access to bikes at stations for residents and visitors. The bikes are free for an initial short periods of time and then charged in accordance with the time they are used. There are over 450 bikes available from 52 hubs across the city. Trin Trin are committed to improving the health of the population by not only reducing air pollution from transport, but also encouraging citizens to be active through the promotion of cycling as an alternative to motorised transport methods.

Promoting walkability and active modes of transport can be done in engaging ways such as the “EcoMobility Festival” in The Republic of Korea. The festival educates attendees about the benefits of environmentally-friendly transportation, as shown in Figure 9. This engagement initiative supplements ambitious action being taken to address air pollution, with an order for urgent action to reduce air pollution being signed 5 days into the latest President’s term in office. Seoul has committed \$12.1 million to walkability and plans to ban all diesel vehicles by 2030 (Babinard, 2018; ISDP, 2017).



**Figure 9:** A range of innovative, low-carbon vehicles being showcased at EcoMobility Festival in Suwon City, The Republic of Korea

*Source:* Compliments of EcoMobility World Festival, 2013

#### Reduced road-based accidents

Low and middle-income countries are responsible for 90 percent of the world’s 1.3 million road deaths per year, despite having only 48 percent of the world’s registered vehicles (WHO, 2009). Allowing development to follow an automobile-dependent trajectory, coupled with increasing global populations and urbanisation, will likely continue to increase these numbers. Urban sprawl itself is directly proportional to increased crash casualty rates for a number of reasons including; an increase in total vehicle travel (and also young, elderly and drivers under the influence of alcohol); increased traffic speeds, resulting in a greater number of lethal crashes; and greater distance and thus longer times required for emergency vehicles to respond. Unfortunately, this problem is exacerbated in low-income countries, with traffic casualty rates reaching between 20-30 deaths per 100,000 residents

(WHO, 2015), compared to 10-20 in North American cities or 5 in high-income European and Asian cities (Hamilton 2014).

A report by the American Public Transportation Association (APTA, 2016) estimated that public transportation on the other hand produces a ten-fold decrease in crash rates on a per-distance basis. While initially, there can be a higher rate of traffic accidents from increased numbers of pedestrians and cyclists, as the numbers of active commuters increases to above approximately 20 percent the accident risks decreases. (Wei, 2012) Studies show that the initial increased risks are hugely offset by reduced personal health costs as a result of more active costs, equating to an average of US\$56 per capita for fatal crashes across the population, and US\$1,450 per person for the benefits of increased physical activity from active modes (Rabl, 2014). These benefits become much more significant as both cyclist and pedestrian numbers grow, and as TODs prioritise walking and cycling rather than cars, providing streamlined access to transit in safe and connected streets. Ewing *et al* (2003), show that an increase in compactness by 10 percent reduces traffic fatalities by 14.9 percent and pedestrian fatalities by 14.7 percent.

### 3.1.3 Climate resilience

Climate resilience encompasses the idea that people, governments and organisations can (and will be required to) build resilience to the impacts of climate change as they become more severe into the future. Scientists around the world agree that climate change poses risks such as the increased frequency and severity of extreme weather events such as floods, storms and hurricanes; increased flooding; and increased bushfires due to increased temperatures in already vulnerable regions. Cities and their inhabitants must have the ability to absorb the adverse impacts of climate change and continue to function without considerable disruption (Lee *et al*, 2016). Climate resilience will be of particular importance to developing nations who are likely to be the worst affected by the adverse impacts of climate change and concurrently the least equipped to deal with the impacts (IPCC, 2013). Smart growth and sustainable urban design strategies incorporating less automobile dependence, access to sustainable mobility choices and reduction in environmental and air pollutant factors all play a role in increasing the resilience of cities to climate change.

#### The importance of building resilience to climate change

Focusing on building resilience to climate change in cities, or climate adaptation, acknowledges that realistically the impacts of climate change cannot be avoided completely. Consequently, steps are taken to prepare for the impacts and ensure society and economies can continue to function. Lee and Lee (2016), emphasise the importance of implementing a policy framework that enables governments to plan, monitor and implement adaptation strategies. It is also important to consider the difference between impacts that pose an immediate threat and those that will develop slowly over time, in order to determine the most appropriate course of action. It is sometimes challenging for governments with shorter-term election horizons to plan effectively for climate resilience, as they often are drawn to quick, implementable projects that can provide political benefits.

Reducing dependency on motorised transport and also increasing the number of transport options available to residents can be highly valuable in times of climate emergency. For example, in Haiti, 8 percent of people and goods are transported via road. When Hurricane Matthew struck in 2016, this dependence on roads meant that residents as well as emergency services were reliant on the same transportation infrastructure and first aid and humanitarian resources were stuck in congested areas and sometimes inaccessible roads (Babinard, 2018). Communities can be more resilient if they have

options to travel by bicycle or on foot (Gouldson *et al*, 2018). The concept of medium and high density localities within urban centres is crucial to enabling residents to reduce the distances travelled and consequently resilience in the event of climate change induced disturbance (Zhao *et al*, 2016). In Afghanistan, it is estimated that up to 7 million people have been impacted by climate change over the last 20 years, and the countries transport infrastructure is considered particularly vulnerable. To respond to this, in 2017 Afghanistan revised the Afghanistan Transport Sector Master Plan in partnership with the Asian Development Bank, highlighting the importance of climate change adaptation as vital for transport network sustainability (ADB, 2017). Similarly, Myanmar's repetitive cyclones and floods have put climate resilience front of mind, leading to their comprehensive and holistic 15 year climate change action roadmap (MCCA/UN-Habitat, 2017).

Health and climate resilience are also closely intertwined, given that aspects of health are influenced by weather and climate conditions (WHO, 2015). Given the reduction in ambient air pollution achieved by reducing reliance on motorised transport, instances of disease and health conditions caused or exacerbated by ambient air pollution are also reduced. Subsequently, the burden placed on health services from air pollution is reduced, allowing the services to be redirected to other health issues in the instance of a climate change induced shock such as a heatwave. In 2010 the cost of ambient air pollution in the People's Republic of China was estimated at USD 1.4 trillion and USD 0.5 trillion in India respectively (OECD, 2016). It is estimated that by 2060 the cost of ambient air pollution will equate to 2.6 percent of the People's Republic of China's Gross Domestic Product (OECD, 2016). A reduction in ambient air pollution will increase the ability of nations to build resilience to climate change, by enabling them to divert resources to combat other climate related issues.

#### Reducing the urban heat island effect

The term 'urban island heat effect' describes a phenomenon that occurs in urban areas where temperatures are raised substantially in comparison with rural areas. The rise in temperature is attributed to a number of factors such as the use of fossil fuels to generate electricity, emissions from motorised transport, and changes in land use resulting in a reduction of green spaces (Dang *et al*, 2018). Additionally, many of the conventional building materials used in urban areas such as asphalt absorb heat more readily than natural landscapes or green spaces (Mohajerani *et al*, 2017). The Intergovernmental Panel on Climate Change has predicted a minimum average global temperature rise from human-induced impacts of 1.5 degrees Celsius (IPCC, 2013). Prolonged periods of raised temperatures or heat waves can be expected, intensifying the urban heat island effect and impacting the health of city dwellers (WHO and WMO, 2015). The poor, young and elderly are particularly vulnerable to the impacts of heat. Additionally, a number of diseases are recognised as being exacerbated by a prolonged rise in temperatures placing pressure on health services (WHO and WMO, 2015). It is well documented that residents of urban areas with access to green spaces report lower instances of psychological illness (Gouldson *et al*, 2018).

Achieving the UNFCCC's 2 degrees limit on climate change will contribute to limiting the urban heat island effect significantly. A number of mitigation strategies have evolved to combat the urban island heat effect, many of which make integral elements to effective Transit Oriented Developments. One of the most popular strategies involves the implementation of green landscapes or green cities. A green city incorporates green spaces such as parks, gardens, green walls and roofs. These areas are also beneficial in reducing air pollution, reducing the amount of carbon dioxide in the atmosphere (Gouldson *et al*, 2018). One of the simplest mitigation measures is the planting of green canopies. Research on the urban heat island effect in Ho Chi Minh city displayed that increasing green space by

1km<sup>2</sup> for 1000 residents could reduce 7.4 deaths (Dang *et al*, 2018). However, increasing populations in urban areas creates a conflict between the need for accommodation and infrastructure and the need for green spaces. This conflict can be avoided by ensuring that development in urban areas integrates the principles of medium and density development and low-carbon transport networks.

### 3.1.3 Economic productivity and innovation

#### Agglomeration economies

The productivity of urban economies is directly correlated to the knowledge sharing between humans that is facilitated by density in cities. By creating dense, mixed use developments, business and activity centres are located in much closer proximity and knowledge flows between knowledge-economy workers is much more potent, facilitating innovation and adding to the competitiveness of a city. The knowledge sharing that occurs via face-to-face interactions contributes to the productivity and innovation of metropolitan areas (Abel, Dey & Gabe, 2012). For example, one study that assess 280 metropolitan areas across the United States showed that doubling employment density can increase patent creation per capita by 20 percent (Carlino, Chatterjee and Hunt, 2007). Similarly, doubling the density across an entire country can increase GDP productivity by 6 percent. Agglomeration enables 'economies of scale' for skilled labour pools, markets and the supply of resources, goods and services (Kane and Whitehead, 2018). An example of the loss to productivity of not investing in density was estimated by Hsieh and Moretti (2014), who estimated that policies that limited density in large US cities cost the economy US\$1 trillion annually (13 percent of economic output).

The increased levels of innovation and productivity in dense agglomeration economies is due to the increased competitiveness of firms in these areas because of their access to closer, cheaper and more complementary suppliers. Innovation networks are fostered and firms can become more specialised, while high-talent labour is attracted to these areas and becomes more available for firms in these areas. Transit oriented developments enable convenient lifestyles that attracts individuals to live and work in this rich cluster of flourishing firms. Asian cities that have traditionally been the dominant industry forces of Asia such as Tokyo, Osaka, Seoul, Bangkok, Taipei and Shanghai will become increasingly expensive for land to undertake industrial activities due to their size. Between now and 2030, as new manufacturing cities emerge such as Jakarta, Delhi, Hanoi, and Chongqing, the traditional powerhouses will move up the value chain and increasingly add jobs in the business and financial service sectors, as manufacturing jobs leave. This presents an opportunity to leverage increasing densities and growing knowledge economy jobs to create more productive and innovative agglomeration economies (Oxford Economics, 2014).

### 3.1.4 Reduce social inequality

Low-income countries, and the poorest people across all countries, are disproportionately affected by the negative effects of current transport and urban development systems. Fortunately, this means that they can almost benefit the most from improvements in the status quo. Road crashes are estimated to reduce the GDP of developing countries by up to 5 percent (Bhalla *et al*, 2014). People with lower incomes typically spend more of their time (Rodríguez *et al*, 2006) and income, by a factor of two, (Echenique *et al*, 2012) commuting. In developing countries, those in urban areas spend between 8-16 percent of their total income on transport costs, but this is as high as 25 percent for poorer groups of the same countries (Glaeser, 2010). They have poorer average health but live in more polluted areas, resulting in lost income and higher health care costs for the poorest members of society, contributing to poverty continuing between generations (Gouldson, 2018). Neighbourhoods

of lower-socioeconomic status have the highest motor vehicle crash rates (Abdalla, 1996; Hewson, 2004). In addition to this, poorer communities are generally more dependent on non-motorized transit and travel higher risk routes (Rodríguez *et al*, 2006). Urban sprawl exacerbates these issues and, in some cases, even results in more distant residents being required to self-supply public services (Blais *et al*, 2010).

Public transportation systems can allow the poor to access jobs, education or other opportunities that would otherwise consume a large portion of their income and time to travel to, if not rendering work opportunities inaccessible for those who cannot afford a vehicle. Many cannot access these basic necessities as they have no choice but to walk or cycle. These factors have been linked to the growth of slums and creating a higher level of disparity between the rich and poor (Heinonen and Junnila, 2011).

## 4. Good Practice and Case Studies

### 4.1 Good practice case studies

#### 4.1.1 Case Study 1: Integrated transport provision in Tehran, Iran.

Tehran, the capital of Iran has a population of 8,300,000 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 88 percent is caused by private motorized vehicles, made worse by the mountains surrounding the city which block 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.)

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, increasing passenger trips by 17 million per year to a total of 459 million trips per year in 2010 (ITDP, 2011). Daily ridership has now increased to more than 2 million passengers per day (Omid and Maryam, 2018). Tehran's extensive rail network is estimated to cover approximately 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's expected completion in 2018 (Tehran Municipality, n.d.). 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 right-of-ways 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). This ridership share of the population is now among the highest in the world.

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 (IMO, 2012). Currently 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 public transport 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). 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 actually 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), highlights some of the benefits of The Bus Rapid Transit systems have also have great success, with BRT line 1 enabling a 46 percent decrease in air pollutants along the corridor, as shown in Figure 10. 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<sub>x</sub>, CO, SO<sub>2</sub>, and particulate matter (Allen, 2011; Hashemi, 2010).



**Figure 10:** Tehran BRT System

Source: ITDP, 2011

#### 4.1.2 Case Study 2: 'Trackless Tram' in ZhuZhou, Hunan Province, People's Republic of China

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 any fundamental transport problems, especially if they are not operated with greater focus on shared occupancy (image a large 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 11:** The Trackless Tram in ZhuZhou, The People’s Republic of China  
*Source:* Compliments of CRRC

Figure 11 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 1.

**Table 1:** Estimations of average patronage capacity for various transport modes

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

*Source:* Compiled from Newman and Kenworthy, 1999, 2009, 2015.

According to Newman and Hargroves *et al* (2018), 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 braking 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, a 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.

By combining these features, the trackless tram achieves 3-4 times lower costs than light rail (Bodhi Alliance and EDAB Consulting, 2017). However, it does not sacrifice the benefits to sustainable urban design and the co-benefits achieved. 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 substantially 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.

#### *4.1.3 Case Study 3: Bus Rapid Transit in Guangzhou, People’s Republic of China*

Guangzhou is located in the Guangdong Province in the People’s Republic of China and is one of the country’s largest cities, with a population as at 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 (CCAP, 2012). 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, shown in Figure 12. Approximately 805,500 people make use of the BRTS per day with 350 buses transiting in the same direction per hour (CCAP, 2012).

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 and level officials providing official endorsement of the system (ITDP, 2010). 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 12:** 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, 2011). 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 CO<sub>2</sub>, 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 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.

#### 4.1.4 Case Study 4: Transport Demand Management in San Francisco

San Francisco is a city located in the state of California in the United States of America with an estimated population of 884,363 (US Census Bureau, 2017). It is estimated by the Association of Bay Area Governments that by 2040, San Francisco will have 100,000 new homes and consequently an additional 600,000 motor vehicles on its roads (SFPC, 2017). In response to this, the City implemented a Transportation Sustainability Program in 2017. The Program includes a Transport Demand Management (TDM) component focused on integrating land development of the city with sustainable transport options such as Hybrid buses as shown in Figure 13 and reducing the extent of urban sprawl and greenfield developments (San Francisco Government, 2018),

The program is designed to manage transportation demand, influencing residents' transportation decisions by integrating the development and transport planning processes. The program encourages developers to provide sufficient amenities to allow residents to increase reliance on non-motorised transport such as walking and bicycle riding, ultimately decreasing Vehicle Miles Travelled (VMT) and air pollution (SFPC, 2018). More than 40 percent of energy consumed in the State of California is attributed to transport and of that 40 percent, 74 percent of emissions are attributed to passenger vehicles (San Francisco Government, 2018).



**Figure 13:** San Francisco Hybrid Bus  
Source: San Francisco Planning Commission, 2017

The TDM Program has been embodied in legislation that requires certain development projects to submit a TDM Plan which is reviewed by the San Francisco Planning Department. The TDM Program Standards require developments to categorise separate land uses into one of four categories encouraging mixed land use developments. The four categories comprise Retail, Office, Residential and Other, and form the basis of the number of car parking spaces that may be provided within the development. For example, a residential land use that proposes to provide 0-4 car parks, is assigned a target of 10 points.

The developer must then implement TDM menu options which are also assigned points, for example, implementing a bicycle repair station (1 point) to reach the car parking target (SFPC, 2017). Essentially, the developer is required to offset the number of carparks proposed by implementing measures that reduce reliance on passenger vehicle transport. Continuous reporting is required and implementation and compliance with the plan is monitored by the SFPD (2017). Developments that are 100 percent affordable housing can be exempt from the standards (City and Council of San Francisco, 2016). As at March 2018, a total of 86 TDM plans were under review by the SFPD (2018). Previously, some TDM were part of the city planning code but were voluntary. Figure 14 provides examples of measures developers can take to address TDM standards.

Category	Measure	Points	Land Use Category			
			A	B	C	D
ACTIVE-1	Improve Walking Conditions: Option A; or	1 ●	☒	☒	☒	○
	Improve Walking Conditions: Option B	1 ●	☒	☒	☒	○
ACTIVE-2	Bicycle Parking: Option A; or	1 ●	☒	☒	☒	☒
	Bicycle Parking: Option B; or	2 ●●	☒	☒	☒	☒
	Bicycle Parking: Option C; or	3 ●●●	☒	☒	☒	☒
	Bicycle Parking: Option D	4 ●●●●	☒	☒	☒	○
ACTIVE-3	Showers and Lockers	1 ●	☒	☒	☒	☒
ACTIVE-4	Bike Share Membership: Location A; or	1 ●	☒	☒	☒	○
	Bike Share Membership: Location B	2 ●●	☒	☒	☒	○
ACTIVE-5A	Bicycle Repair Station	1 ●	☒	☒	☒	○
ACTIVE-5B	Bicycle Maintenance Services	1 ●	☒	☒	☒	○

**Figure 14:** Examples of TDM Menu Options  
 Source: San Francisco Planning Commission, 2016

#### 4.1.5 Case Study 5: Electronic Road Pricing in Singapore

Singapore is one of the most densely populated countries in the world and car ownership rates exceed population growth rates (Development Asia, 2016a). As of 2010, 12 percent of the total land area of Singapore was roads, indicating that building more roads is not a viable long-term solution. Singapore has implemented multiple policies seeking to discourage private vehicle ownership such as Additional Registration Fees, increasing the cost of car ownership, a Vehicle Quota System, and limiting the quantity of new vehicles introduced each month. While a combination of policies discouraging private vehicles and encouraging public and active transport result in a more comprehensive change of transport patterns, there are still a portion of the population who will continue to use cars (Pain *et al*, 2018). Therefore, in 1975 Singapore introduced the Area Licencing Scheme (ALS), a requirement to pay to enter certain highly congested areas. It is important to note that policies seeking to reduce car usage must be complimented by increased availability of alternative modes of transport.

Singapore's scheme achieved a reduction of traffic in the restricted area of 45 percent by 1997 with a subsequent increase in commute speeds and public transport usage (Phang, 1997). A 2016 paper (Agarwal, 2016) by Agarwal et al found that an increase in toll prices of S\$1 in the morning and S\$0.5-\$1 in the evenings increased modal shifts to public transport by 12-20 percent and 10 percent respectively. Similarly, high levels of success were achieved in 1995 with the introduction of a further Road Pricing Scheme at further sites of congestion outside CBD with a reduction in traffic volume of 41 percent and increase in public transport scheme of 16 percent. In 1998, the system was substituted by Electronic Road Pricing (ERP) to reduce the number of staff needed to manually charge vehicle owners, as shown in Figure 15. Traffic dropped by a further 17 percent (Goh, 2002).



**Figure 15:** One of the ERP system's many gantries

*Source:* Ministry of Transport Singapore

Singapore's ALS began as a paid paper certificate displayed in the car windshield, certifying a daily permission to drive in certain areas at peak times to reduce congestion. This was eventually substituted by ERP which is an automated system which includes drive-through overhead gantries. These communicate wirelessly with a dashboard-mounted device which charges a pre-paid cash card which can be credited at numerous physical locations. This system relies on automatic fines charged to vehicles entering without paying the charge through usage of mounted camera that record the vehicle's registration number.

#### *4.1.6 Case Study 6: CicloRuta Cycling System in Bogotá, Colombia*

CicloRuta is one of the most expansive cycling networks in the world, spanning 376km. Its construction was in the context of a fast-growing population (Marin, 2004), plagued by traffic congestion and the associated air pollution (UNDESA, 2012). Buses, despite Bogotá's world-famous, gold-standard bus rapid transit (ITDP, 2016), were facing issues of overcrowding. Most citizens of Bogota do not own a car, but more than half of households own a bicycle and cycling is historically a popular activity in Colombia. However, due to a lack of bicycle lanes, those who chose to cycle as a mode of transport faced high road accident rates.

The CicloRutas network features a mesh-type grid network follows the road design of the city and works within a hierarchy of main cycling corridors connecting main city centres, secondary corridors leading to the main network, and the complementary network which completes the grid-type network, as shown in Figure 16. Much has been said about Bogota's BRT system, and importantly for this case study, is the way in which the CicloRutas integrates with this network and enables commuters to flow between modes. This increased the use of the BRT and of bikes within the city.



**Figure 16:** CicloRuta Cycling System in Bogotá

*Source:* CicloRuta

CicloRutas resulted in reduced carbon dioxide emissions by 36,600 tonnes in 10 years and, in combination with other programs, an increase in the proportion of transportation done by bicycle, from 0.6 percent in 1996 (Jica, 1996) to 6 percent in 2014 (Bogotá cómovamos, 2014). Average speeds of cyclists along CicloRuta exceed average public transport speeds. In addition, the average family that uses CicloRuta saves \$165 a month on transport. 450,000 daily trips are conducted on CicloRutas (Development Asia, 2016b).

## 4.2 Discussion of enablers

### 4.2.1 Governance

#### Public sector championing

Implementing integrated sustainable transport and land development projects can often be a step away from the traditional design approach of many cities. It is different from the car-centric planning that many cities have become accustomed to. It is therefore crucial that there is ambitious leadership from the public sector in visioning and championing such projects. Tehran's 2025 vision was a bold statement for the future of the city that set a direction towards more sustainable urban design. Guangzhou's public officials provided high-level support for the Bus Rapid Transit system, and the Mayor of Bogota championed the bicycle network initially and subsequent governments were critical in ensuring that construction continued. In Singapore, effective communication to the public was crucial for acceptance and the success of the scheme, given the commonly low acceptance rates of road pricing schemes. Marketed as predominantly a congestion reducing scheme, particularly to areas with a high public perception of congestion, kept the focus on benefits rather than costs and has increased the public approval ratings for the scheme in Singapore and similarly in Milan, London and Stockholm.

#### Partnerships and collaboration – Between agencies and with research

Despite the important role of government, they do not have to do everything alone. Building partnerships is important for delivering integrated win-win outcomes for society while leveraging additional resources and expertise. For example, crucial to the success of Guangzhou's BRT in the People's Republic of China, was the collaboration between the Public Transport Management Office, Traffic Improvement Office, City of Guangzhou and the Institute for Transportation and Development Policy (ITDP). As mentioned in the case, the technical assistance from ITDP in planning and design, rider research and scheduling, coupled with the deployment of specialists to complement the public sector skillsets enabled the entire project to be completed within a year.

#### Partnerships and collaboration – With the private sector

The private sector can also make contributions to accelerating the sustainability of cities in partnership with municipalities, state governments and research institutions. The private sector can contribute finance, innovation, and share in the risk of implementing infrastructure, whilst governments can ensure that projects achieve the 'public good' as intended. In Tehran, Iran, partnership with the private sector was increasingly leveraged to provide high quality public transport services quicker than government could provide. Guangzhou's BRT was the first BRT system in The People's Republic of China to work with private sector operators setting an example for the rest of the country – and region – that may not have undertaken this type of venture before.

#### Partnerships and collaboration - Engage and empower communities

Not only should collaboration and partnerships, or governance more broadly, be focused purely on a top-down approach. Communities ultimately decide the success of such projects (through use of the services), and therefore should not only be engaged and consulted in the planning process, but also encouraged to take ownership and champion the initiatives themselves. Governments should actively seek to promote sustainable development initiatives to communities in ways that generate support. For example, the city of Bogota, Colombia, ran 'car-free days' to promote cycling and CicloRuta, which resulted in the formation of advocacy groups which supported the project (Development Asia, 2016c). Guangzhou also undertook a number of outreach activities including user surveys to understand the

public perception and optimise the service. Part of the success of Singapore's road pricing scheme is attributed to the effective marketing and communication which focused on improving the local districts for communities through reducing congestion (Vonk Noordegraaf *et al*, 2014).

#### 4.2.2 Finance

##### Public finance

There is a significant shortage of infrastructure finance globally, particularly in the Asia-Pacific region. A number of different approaches to financing have been employed throughout the cases identified above. For example, in the case of Singapore, the introduction of the ERP was financed by the government at a cost of USD \$110 million including fitting vehicles with a dashboard device at no cost to commuters. The operational and maintenance costs are USD \$18.5 million annually, largely due to fees of law enforcement. The revenue from the ERP is \$USD 100 million annually, and this revenue is used to finance public transport improvements (Development Asia, 2016c; Phang, 2004). It is appropriate for this type of system to be financed and operated by government rather than the private sector, as the revenue can be redirected into further developing sustainable transport options for the city, (rather than accruing to a private interest whom have provided no real service other than maintenance).

##### Partnerships - Private-sector operation

The operation of the system however exemplifies a more collaborative approach, which was the first of its kind in The People's Republic of China, whereby private bus operating companies are contracted to provide services on various routes. The infrastructure itself was publicly financed at approximately USD \$103 million (or USD \$4 million per kilometre). If operational savings of the system's efficiency are combined with public benefits such as reduced time lost to congestion and health benefits, the payback period of the project would be only two years. The operational savings alone achieve a payback of 13 years. For operation, contracted companies are paid with a percentage of total bus system revenue, which is adjusted in reference to several performance parameters such as punctuality, customer complaints and accidents. By ensuring that quality standards are met, and inducing competition between the 7 private operators employed along the BRT route, this public-private partnership promotes a win-win for the private interests and the government (whose intention is to benefit society) and increases use and operating efficiency of the BRT system.

##### Partnerships – Private sector capital and operation:

Tehran, Iran has been able to leverage private sector finance and operational innovation in order to significantly increase their public transport services across the city. The private financing of new bus routes has grown the private share of transport provision to 40 percent (Allen, 2011) . Similarly, a Build, Operate, Transfer model is used for approximately half of the railways in Tehran – with land development rights around stations provided to the private sector from the municipality. Meanwhile commuter satisfaction has also increased – indicating an increasing level of service quality. Increased accessibility in areas around railway stations and bus rapid transit facilities is a significant attractor for development (and higher land values) and some of the most extensive railway networks in the world have leveraged this opportunity to expand, such as Tokyo and the Hong Kong Special Administrative Region of China.

### 4.2.3 Technologies

#### The technologies are available

As the case studies have shown, much of the technology required to create sustainable urban development already exists. In the case of Guangzhou, in the People's Republic of China, the BRT system is a sustainable transport system taking full advantage of established and existing bus technology. The success of the BRT system has come through design, and specifically the effective use of 'corridors' through the city. Complementary technology on a people-scale include cameras and real time-guidance for buses, coordinated by a control centre, to increase safety. Crosswalks with countdowns allow pedestrians safer access to the BRT, as they must cross roads that still allow private vehicles to transfer from sidewalk to BRT terminal, and traffic guards are present during peak hours. All tickets are purchased prior to boarding to increase efficiency.

#### Emerging technologies

The Trackless Tram provides an example of an emerging technology that maintains the core functionality of a vehicle it's size (such as a tram), however overcomes implementation challenges. The Trackless Tram maintains a large capacity, and also still uses tram-like stations (rather than traditional bus stops). The Trackless Tram however has the tyres of a bus and therefore reduces the cost and disruption of initial implementation. Arguments can be made whether this vehicle is a bus, tram or train – but it does not matter. The focus of urban designers and transportation planners should be in providing the functional services that are relevant and appropriate for their cities. As technology continues to evolve more of these 'hybrid' modes shall likely emerge. The Trackless Tram provides a great example of a traditional light rail substitute at a third of the price, or a higher-capacity bus to integrate into existing BRT's to increase capacity. Both unlock land development potential given they rely on central stations, and thus are also attractive for private financiers.

#### Moving beyond 'mode-specifics'

Another role of technology, particularly digital, will be the integration of urban services to streamline user experience, optimise efficiency and encourage sustainable behaviour. For example, Bogota's "Biko" smartphone app provides a social network to share bicycle related tips and encourages bicycle usage by providing "bike miles" which can be redeemed for goods and services (Visit Colombia, 2018). This is only the beginning, as such platforms are integrated with BRTs, railways, and shared occupancy vehicles, 'Mobility-as-a-Service' emerges where modes are less important and moving from A to B is done in the most effective way. This of course creates the ability to integrate sustainability principles into these platforms. One of the promises of such a future will be the decreased reliance on personal vehicles. Urban design should reflect such a future, as in Bogota where bike paths were constructed along major roads with segregated bicycle lanes with the benefit of reducing the road space for private vehicles. Paths were incorporated into public spaces. CicloRuta includes two main, interconnected networks: one linking main residential areas with the city centre and one connecting residential areas with popular recreational sites and to the city's BRT. (Development Asia, 2016c). In San Francisco, the development codes provides a menu of options from which developers can draw from to form their own sustainable mobility solution.

#### Tech will enable, but not re-write the fundamentals

As new technologies emerge, business models and user preferences change. Often termed 'disruptive', the prospect of a new application or technology re-writing the status quo can be intimidating, particularly for city planners who are influencing infrastructure decisions that will last for

many decades – longer than these new technologies will likely be relevant for. A key takeaway for sustainable urban design in the context of the case studies presented and city planning more broadly, is that the fundamentals remain the same. For example, integrating bike share facilities with transit stations will enable sustainable mobility with or without multi-modal digital platforms. The emergence of such digital platforms will only increase the integration and usability of such services. Similarly, focusing on density and mixed-use around transit stations will encourage walkability, and local service provision, and will remain an attractive and healthy lifestyle with or without the ability to ‘share’ an autonomous vehicle that can carry commuters across town without a driver.

#### Emerging Technologies - Blockchain

In response to the 2008 global financial crisis, an anonymous programmer released the blueprints for what they called a ‘Bitcoin’ which is a form of digital currency. The digital currency is based on an online database that can store encrypted time stamped information that cannot be amended and can be backed up on millions of computers (Nakamoto, 2008). In simple terms, this is done by replicating the database over many computers and rewarding those that hold it to validate transactions and keep an unamended version of the full database to allow comparison with the many others also holding the database to identify hacking attempts. This presents for the first time in history the basic digital architecture that allows for financial transactions to be done directly between two strangers without the risk of default or double spending – eliminating the need for an intermediary like a credit card company or a bank. In April 2017 Japan eliminated consumption taxes on such ‘crypto-currency’ transactions and deemed them a legal tender. Chief Executive of the Australian Stock Exchange Elmer Funke Kupper reflects that, *‘Every now and then, something comes along that might just change everything. And this is one of those moments’* (Eyres, 2016). The World Economic Forum predicts that by 2027 some 10 percent of global GDP will be stored on Blockchains, in the order of \$8 trillion (WEF, 2015).

Blockchain technology when combined with artificial intelligence, machine learning and machine-to-machine protocols stands to revolutionise the way value is created and transferred around the world and has a number of tangible applications to transport. Early movers in this space include Toyota who has recently launched a collaboration with the MIT Media Lab and a selection of Blockchain based companies to explore the value of the technology to the car industry. The focus of the initiative is to explore four main areas, namely: How the advanced information technology software can assist uptake of automated vehicles, capturing and sharing trip data from driverless vehicles, offering applications to enable greater ride sharing, and offering pay-as-you- drive insurance products (Shieber, 2017).

The Blockchain in Transport Association (BiTA) which originated in the United States, brings together over 300 companies from across transport, logistics and relevant technology sectors including large players like FedEx, UPS and Schneider. According to the Australian National Transport Commission in the 2016 report ‘Land Transport Regulation 2040: Technology, trends and other factors of change, technologies such as the Blockchain stand to provide *‘conditions of stable, trusted, interoperable and secure data communications within transport, and between transport and other service providers’*. The NTC suggests that these conditions *‘may open the way for a fairer, more transparent, and more sustainable, transport charging and funding model’* (NTC, 2017).

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The sustainable urban design principles covered in this document provide a basis for steering cities towards greater efficiency and liability. A distinct feature of transport systems is their socio-technical nature (much more than a set of technologies, but a complex social system with user and market preferences and human interactions). The emergence of electric shared vehicles is often promoted as the solution to environmental and social transportation problems, given the removal of combustion emissions and the associated health benefits. The reality is that this ignores major social and economic elements of transport systems, as shared mobility (without a direct focus on shared occupancy) is likely to increase cars on the road rather than improve commutes. Technology should be seen as an enabler for a smart growth agenda whether through Trackless Trams to reduce capital and local disruptions, or the harnessing digital platforms for citizen engagement and encouragement towards cycling or mass transit. Integrated land use and transport planning, public transit provision and active modes remain just as important for liveable, competitive and sustainable cities and will have a reciprocally enhancing relationship with new urban technologies, regardless of the particular technological future that prevails.

## ***5. Conclusions and Recommendations***

### **5.1 Measure and identify pollution sources**

#### ***5.1.1 Measure pollution***

Develop accurate, regularly updated environmental monitoring systems, and collate this information in a central data coordination system. This information can be provided to the public, researchers, regulators and policy makers. On-the-ground monitors provide a low-cost measuring system (Ikram *et al*, 2012). These are typically used with atmospheric dispersion modelling (Tobiszewsk *et al*, 2015).

#### ***5.1.2 Set data-driven targets***

Develop specific, measurable targets for reducing various forms of air pollution in cities. This monitored information can be used to track progress.

### **5.2 Facilitate land use and transit integration**

#### ***5.2.1 Zone for density and compact development***

Ensure that appropriate zoning regulations are in place in areas that can facilitate medium to dense development, particularly in the impact zones in close proximity to stations. This is generally a radius of 400-800m.

#### ***5.2.2 Limit parking spaces***

Allow for much less car parking space per person in station precincts than normal urban-sprawl development. This has been shown to be make or break for station precincts in the United States. On-street parking should be prohibited within approx. 100 metre of the transit station and kept to a minimum within the remainder of the station precinct zone. If park and ride facilities are to be provided at the end station of the line (not the other nodes along the line) then they should be kept out of the station precinct zone (e.g. 200-400m radius).

#### ***5.2.3 Integrate last mile transport with informal transport***

Given that many Asian cities have informal modes of transport particularly for last mile, public transport networks can be integrated with these. For example, in Indian cities such as Mumbai and New Delhi there is space at stations for rickshaws to park and collect passengers, and the Ahmedabad G-Auto 'Uber' type rickshaw service is very successful.

#### ***5.2.4 Invest in vibrant public spaces***

Specify the requirement for public space to incorporate facilities such as bike racks, public telephones, benches and seating areas, greenery for shade and urban cooling, sculptures and artwork to add character.

#### ***5.2.5 Consider natural surveillance***

For safety reasons, particularly concerning women and children, consider the visibility of areas within station precincts as open spaces can contribute to safer environments.

### **5.3 Facilitate collaboration with the private sector**

#### ***5.3.1 Provide direction that facilitates confidence***

Set national or city-based strategic plans that are supported by legal frameworks and policies to give the private sector some indication of direction, and promote investor confidence.

### *5.3.2 Active participation in project facilitation*

Actively seek to collaborate on infrastructure projects with the private-sector, while still keeping public interest as paramount.

### *5.3.3 Be open to entrepreneurial proposals*

Rather than relying on traditional transport planning methods to determine optimum routes and then opening expressions of interest to the private sector, be open to new proposals or co-creation of routes based on land development opportunities.

### *5.3.4 Improve public administration and management*

Ensure that public-sector departments and agencies are collaborative and willing to foster and embrace innovation of the private sector (which is ultimately how they make their money). Overly bureaucratic governments can hinder the public-private relationship, and win-win outcomes must be kept paramount.

### *5.3.5 Induce competition between providers*

As was demonstrated by Guangzhou's BRT, by creating competition between private service providers, they are incentivized to deliver the optimum service to the public while also doing so at the most competitive price.

## **5.4 Encourage walking and cycling**

### *5.4.1 Reallocate lanes, or 'Road Diet'*

Begin to increase the walkability and cycling potential of areas by segmenting part of the road purely for active modes such as cycling and walking. This can be done on double lane roads by dedicating a single lane to cycling and walking, or by reclaiming road side parking space. This less-extreme intervention still allows cars to travel through the area however significantly increases the safety of active commuters.

### *5.4.2 Remove cars to create pedestrian streets*

Especially applicable within the inner zones of transit-oriented-developments, dedicate streets completely to pedestrians to dramatically increase activity and safety in these areas. While a more extreme intervention than road dieting, pedestrian streets can attract new stalls, shops, sculptures, and social areas for citizens – and is being used increasingly around the world given the benefits (e.g. Tehran).

### *5.4.3 Pop-up initiatives for engaging citizens*

Local municipalities can support local pop-up initiatives in zones where walking infrastructure exists however less people are accustomed to walk and cycle through these areas. By engaging the community and introducing them to the space in a socially-reinforcing, fun context, they are much more likely to walk through here in the future.

### *5.4.4 Economic incentives for walking and cycling*

Consider new incentive models for pedestrians and cyclists where such activities can be gamified or data can be harnessed for value. Much of these types of prospects are enabled by emerging technologies. As an example, researchers at MIT developed a blockchain token reward system that provides cyclists with micro-incentives to cycle (Jaffe, 2017).

## 5.5 Involve communities

### 5.5.1 *Facilitate community consultation for infrastructure projects*

Part of the role of government, particularly in public-private partnerships, can and should be to involve the community and ensure the best outcome is achieved for them. Governments should facilitate consultation rounds to ensure a desired, practical outcome is reached and significant ‘buy-in’ from the local citizens is achieved.

### 5.5.2 *Garner public support*

Target quick win, highly visible projects that can attract public interest and support for air pollution reduction projects. Senior Government leadership is important to educate the public and media about the actions being taken and the benefits being achieved.

## 5.6 Transition to cleaner fuel sources

### 5.6.1 *Enforce stricter emissions standards*

Ensure that emissions standards are in line with United Nations (UN) and Economic Commission for Europe (ECE) standards, for private vehicles and commercial vehicles.

### 5.6.2 *Strategically locate recharge/refuel stations*

Place charging stations for electric vehicles and other refuelling stations for sustainable fuels in primary spots in car parks (next to the entrance/exit etc.) to add a ‘reward’ (and incentive) for driving sustainable vehicles.

### 5.6.3 *Remove the most polluting vehicles*

Freight vehicles are responsible for a large share of pollutants. An American clean truck program, which implemented emissions standards and gradual removal of the most polluting trucks, reduced PM levels by 55 percent over 7 years (Lee, 2012).

## 5.7 Transport Demand Management

### 5.7.1 *Congestion pricing*

Cities can implement road user chargers to create a disincentive for private automobiles in the city. Congestion pricing has been proven in multiple cities to be an effective method of reducing traffic, congestion and travel times by 10-30 percent. (Gouldson, 2018). In London, congestion pricing has been estimated to have increased the life expectancy of those in priced zones by 1.83 years. (Leape, 2006). Funds raised from congestion pricing can be redirected to public transit, however implementing the scheme can be politically difficult – and governments must ensure there are adequate alternative transport options.

### 5.7.2 *Encourage shared occupancy*

Along similar lines as congestion pricing, if road users are to be charged, municipalities can provide a reduction (or removal) of this charge if vehicles have more than one passenger. Similarly, ride-sharing application fees can be waived if they are in ‘pool’ mode in cities as they implement taxes on these vehicles.

## ***6. The Way Forward***

To be added post EST Forum.

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