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Public transport and the environment

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As private motorisation becomes pervasive across the world, transport has generated a wide range of negative environmental externalities. These include air pollution, noise pollution, water pollution, hydrologic impacts, habitat and ecological degradation, depletion of non-renewable resources and climate change (Chapman, 2007; Litman & Burwell, 2006; OECD, 1996). Among these negative impacts, the most prolonged and significant impacts are the increasing amount of carbon emissions that contribute to climate change. The global transport carbon emissions have increased significantly from 4,608 million metric tonnes CO$_2$ in 1990 to 8,145 million metric tonnes CO$_2$ in 2018 (Crippa et al., 2019), representing a 77 percent increase. Transport is also one of the major sources of global carbon emissions. As of 2018, transport contributed around a quarter of the carbon dioxide emissions in the world (International Energy Agency, 2019). In this context, Loo and Banister (2016) examined the transport decoupling pathways of the 16 countries that make up 64 percent of the global GDP and 63 percent of global CO$_2$ emissions. Their findings suggest that environmental decoupling in the transport sector has not made much progress in the past three decades.

To reverse the escalating trend of transport carbon emissions, developing mass public transport has been advocated to suppress car growth and encourage mode shift. According to UITP (2017), there were around 243 billion public transport journeys made in 39 countries of the world (mainly the developed and newly industrialised countries) in 2017, which is an 18 percent increase when compared to the figure in 2000. Moreover, the role of public transport in reducing carbon footprints is fundamental. Asian Development Bank (2010) conducted a study of the savings in CO$_2$ from its projects and concluded that railways, metro rail and bus rapid transit (BRT) can save over 2,000 tons of CO$_2$ per lane per kilometre every year.

In order to better understand how public transport can promote environmental sustainability, this chapter first highlights the three important environmental benefits of public transport, ranging from energy savings and greenhouse gas reductions to air quality improvement and climate change mitigation. It then examines the effective policy instruments in public transport that help decarbonise the transport sector. The successful global experience of public transport policies of (i) transit-oriented development, (ii) integrated public transport systems, (iii) public and active transport and (iv) public transport electrification is discussed. Figure 8.1 depicts the
relationship between public transport and the environment. This helps policymakers and practitioners develop a holistic policy toolkit of effective public transport policies.

**Environmental benefits of public transport**

**Energy savings and greenhouse gas reductions**

One of the key advantages of developing public transport is to reduce energy consumption and greenhouse gas (GHG) emissions, in particular carbon dioxide (CO₂). Multiple studies have quantified the energy consumption and GHG emissions of different transport modes. To allow for a consistent comparison across transport modes, these figures cannot be directly compared based on the absolute volume. Instead, specific indicators need to be evaluated with the normalisation of passenger-distance (e.g. passenger-kilometres and passenger-miles), fuel carbon intensity and energy intensity. Sims et al. (2014) consolidated the direct CO₂ emissions of major passenger transport modes per passenger distance from a range of international experiences. The typical ranges of CO₂ emissions in private and public transport modes are shown in Table 8.1. Overall, public transport generally has lower ranges of carbon emissions than private transport. As expected, rail has the lowest upper limit, largely because of its energy efficiency with higher capacity. Water passenger transport and BRT are similar, but the range between the lower and upper limits can be quite large (i.e. more than five times different). This suggests the number of passengers, choice of fuels and efficiency of engines can affect the level of direct CO₂ emissions. In some cases, the upper limit of public transport can be lower than the lower limit of private transport. This further indicates that the environmental benefits of public transport can only be effectively delivered under certain circumstances, such as high ridership, the use of less carbon-intensive fuels and better fuel efficiency.

The average energy intensity of different passenger transport modes in the United States in three different years (i.e. 1990, 2000 and 2010) is shown in Figure 8.2. In most circumstances, the transport energy intensity of each transport mode per passenger mile has gradually decreased over time, largely due to the improvement in fuel-saving technologies. A lower energy intensity per passenger-mile indicates that less fuel is consumed for the same travel distance per passenger. When compared to other road transport modes, passenger cars have a higher energy...
Public transport and the environment

Table 8.1 Range of direct CO₂ emissions of different passenger transport modes (g CO₂/km)

<table>
<thead>
<tr>
<th>Transport modes</th>
<th>Lower range</th>
<th>Upper range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Private transport</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light-duty vehicles (diesel, hybrid)</td>
<td>80</td>
<td>220</td>
</tr>
<tr>
<td>Light-duty taxi (gasoline, diesel, hybrid)</td>
<td>140</td>
<td>&gt;250</td>
</tr>
<tr>
<td>Motorcycle</td>
<td>80</td>
<td>220</td>
</tr>
<tr>
<td><strong>Public transport</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coach, bus and rapid transit</td>
<td>25</td>
<td>140</td>
</tr>
<tr>
<td>Rail</td>
<td>30</td>
<td>120</td>
</tr>
<tr>
<td>Water</td>
<td>20</td>
<td>150</td>
</tr>
<tr>
<td>Air</td>
<td>95</td>
<td>&gt;250</td>
</tr>
</tbody>
</table>

Source: Sims et al., 2014

Figure 8.2 Energy intensity of different transport modes in the United States

Source: Bureau of Transport Statistics, 2018

intensity than other public transport modes such as bus and intercity rail (up to four times). Air travel traditionally possesses the highest energy intensity but has gradually decreased with more advanced fuel-saving technology. The energy intensity of public transport is quite similar to passenger cars, and public transport even had a higher energy intensity than passenger cars in 2000. The possible reason could be the lower ridership for public transport in the United States. This indicates that promoting public transport with sufficient ridership is key to reducing energy intensity and carbon emissions.

Another common indicator of evaluating the environmental benefits of public transport is fuel economy. Fuel economy is the ratio of total passenger distance to the total fuel consumption. The higher the ratio, the higher the energy efficiency per passenger-distance. Generally, an increase in public transport ridership and a decrease in fuel consumption can lead to higher fuel economy. Figure 8.3 depicts the average fuel economy of different transport modes per passenger mile in the United States in 2018. The unit is passenger-mile per gasoline-gallon equivalents (GGE). In 2018, the fuel economy of intercity rail was the highest, followed by domestic air,
transit rail, commuter rail and transit buses. It is noteworthy that public transport has a lower fuel economy than cars in the United States. The major reason is again largely due to the low ridership, which is usually less than 25 percent of the full capacity (U.S. Department of Energy, 2018). The demand response mode (e.g. taxis) usually has the lowest fuel economy because fuel is consumed to reach passengers.

The potential savings in energy consumption by public transport also display similar patterns in the European context. According to ODYSSEE-MURE (2019), an energy database co-funded by the European Union, the fuel consumption measured in kg of oil equivalents (koe) per passenger-kilometre of public transport is also lower than that of the private transport in three years (i.e. 2000, 2007 and 2017). With more fuel-efficient technologies, there has been a gradual decrease in energy consumption in different transport modes, with the greatest drop in domestic air, followed by cars and railways. However, there is a slight increase in energy consumption for buses (from 0.015 koe/pkm to 0.02 koe/pkm). In 2017, domestic air had the highest energy consumption rates (0.068), followed by cars (0.038), buses (0.021) and rail (0.007). The energy consumption for buses and rail is far lower than that of passenger cars. The energy consumption of buses and rail is typically half to one-fifth of that of cars.

This illustrates the benefits of public transport in reducing “direct” GHG emissions (i.e. fuel combustion in vehicle operations). Indeed, promoting public transport can also further reduce “indirect” energy consumption and hence maximise carbon savings in the lifecycle. Indirect carbon emissions from transport are composed of, but not limited to, vehicle manufacturing, maintenance and construction of infrastructure for storage. Overall, the difference between private vehicles and public transport is even more significant if we evaluate the environmental benefits from a lifecycle perspective. Chester and Horvath (2009) conducted a detailed analysis in the lifecycle energy and emission inventories of a wide range of transport modes in different cities of the United States. Their findings demonstrate that using public transport can reduce
carbon emissions significantly in vehicle manufacturing, vehicle maintenance, vehicle insurance and fuel production. Although infrastructure construction (e.g. stations and terminals) and public transport operations (i.e. daily energy consumed for operating terminals and parking) also contribute towards energy consumption, GHG emissions are significantly lower than their private counterparts. Overall, the reduction of GHG emissions (measured in CO₂ equivalent) is around two to four times. The reduction is particularly significant for carbon monoxide (CO), particulate matter of 10 micrometres or less in diameter (PM₁₀), volatile organic compounds (VOCs) and nitrogen oxides (NOₓ), including nitrogen dioxide (NO₂).

**Air quality improvement**

A mode shift from private car to public transport usage is essential to improve air quality, in particular for areas of heavy traffic and dense population. The common assessment parameters include black carbon (BC), PM₁₀ and ozone (O₃). Although there is a theoretical debate as to the linkage between public transport supply and air pollution levels (Beaudoin et al., 2015; Harford, 2006), several empirical studies suggest that public transport can somehow alleviate air pollution. Lalíve et al. (2018) investigated the impacts of increasing public transport supply on air quality. Overall, increasing rail service by 10 percent can reduce CO and NO by approximately 1 percent and 2 percent, respectively, but there is no direct link to other air pollutants such as sulphur dioxide (SO₂) and ozone (O₃). Titos et al. (2015) evaluated the effect of public transport on the air quality in Spain and Slovenia and indicated that the implementation of a new public transportation system (including bus route rationalisation and the use of higher-capacity fleets) can lead to a reduction of BC and PM₁₀ by 37 percent and 33 percent, respectively. Chen and Whalley (2012) investigated the level of air pollutants after the introduction of a new metro line in Taipei, and the results illustrate a reduction of CO by 5 to 15 percent, although ground-level O₃ does not have a clear relationship with the new metro service. Sun et al. (2019) conducted a similar study on the increase in public transport on air quality in Chinese urban areas. Their findings suggest that marginal improvements of public transport such as increasing the number of buses by 1 percent can lead to a reduction of air pollution index by 0.08 percent.

Some studies examine the air quality during public transport disruption (e.g. public strikes) as a counterfactual scenario to demonstrate the benefits of public transport in reducing air pollution (i.e. the change of air quality without public transport service). Bauernschuster et al. (2017) examined the public transport strikes in several major German cities from 2002 to 2011. According to their study, there is generally an increase of particular pollutants (NOₓ and PM₁₀) by 14 percent during the morning peak hour of a strike day. Even for a more robust model that considers weather controls and city indicators, there is a 4.3 percent increase of NO₂ when compared to non-strike periods. Basagaña et al. (2018) examined the air quality impacts during public transport strikes (including bus and metro) in Barcelona from 2005 to 2016. Similarly, their findings after accounting for other types of strikes suggest that days of strike are associated with an increase of NOₓ and BC when compared to non-strike days, with more significant impacts in full-day strikes and metro strikes of multiple days.

Moreover, increasing public transport accessibility is suggested to be a way of reducing traffic congestion and further improving air quality. Road congestion exacerbates air quality when idling engines consume fuel energy, and the associated acceleration and deceleration can also lead to higher amounts of fuel combustion. A wide range of studies suggest that road congestion can generate more concentrated air pollution on roads and even at a neighbourhood scale (Barth & Boriboonsomsin, 2008; Zhang & Batterman, 2013). Several studies investigated the relationship between traffic congestion and air pollutants and found that an increase in rail and
bus mileage can reduce congestion costs, with a larger reduction for rail service (Nelson et al., 2007; Winston & Langer, 2006). The previous studies align with some counterfactual scenarios where a disruption of public transport can lead to an average increase in traffic delays (Anderson, 2014). The diverging results are explained in Beaudoin and Lawell (2017) – that the association of public transport investment, congestion and air quality of a total of 96 urban areas in the United States between 1991 and 2011 differed in magnitude across cities. The spatial heterogeneity can be attributed to different population densities, availability of public transport networks, initial modal share and level of transport investment (Anderson, 2014; Baum-Snow et al., 2005; Beaudoin et al., 2015; Winston & Langer, 2006). The empirical evidence suggests that public transport can greatly contribute to air quality improvement, and it has significant social implications because it reduces residents’ exposure to air pollutants and addresses public health issues.

**Climate change mitigation**

Encouraging public transport can also be an effective way to reduce carbon emissions per travel distance and contribute to climate change mitigation in the long run. In a study by Davis and Hale (2007), public transport was expected to reduce CO₂ emissions by 6.9 million metric tonnes and save an additional amount of 340 million gallons of gasoline due to reduced congestion, which is equivalent to three million metric tonnes of CO₂ emissions. Moreover, there was also a substantial decrease in other hazardous GHG such as hydrofluorocarbons (HFCs) and chlorofluorocarbons (CFCs) (Davis & Hale, 2007). According to a large-scale study of Latin American cities (Wright & Fulton, 2005), it was estimated that only a 5 percent increase in BRT mode share, a 1 percent decrease of private cars and taxis and a 2 percent decrease of minibuses can potentially reduce CO₂ emission by 4 percent. This can be essential, as a 1 percent reduction of car share can reduce around one million tonnes of CO₂ in the 20-year projection period (Wright & Fulton, 2005). According to Woodcock et al. (2009), with a significant increase in the development of public and active transport (i.e. walking and cycling), the increasing trend of CO₂ emission by 2030 can potentially slow down to only 235 percent above the 1990 level and 199 percent if there is a wider adoption of cleaner and fuel-efficient vehicles. Moreover, Shin et al. (2009) investigated the impacts of public transport on land consumption. Their findings suggest that developing a high-capacity public transport system to encourage mode shift is an effective policy to reduce the amount of land required for transport land use (i.e. road infrastructure). This helps protect rural land from being encroached, in particular for undeveloped green areas, forest reserves and natural habitats near cities.

Climate change cannot be tackled with only one single policy (such as an improvement or diversion to public transport). There needs to be a holistic framework to integrate various policy instruments in paving the way for decarbonisation (Loo & Tsoi, 2018). In fact, public transport can generate a wide range of synergies (or co-benefits) with other policy instruments. Kwan and Hashim (2016) conducted a comprehensive review of the co-benefits of public transport in climate change mitigation from 2004 to 2015. The commonly identified scenarios of potential mitigation strategies can produce co-benefits, which include the promotion of public transport, limit of car traffic, land-use policies, fuel technology advancement and modal shift initiatives. Some empirical examples include public transport accessibility and carbon tax policies (Fu & Kelly, 2012), metro expansion combined with introducing hybrid buses (McKinley et al., 2005), improved fuel efficiency and expansion of BRT (Chavez-Baeza & Sheinbaum-Pardo, 2014) and promoting modal shift and the use of non-motorised transport such as walking and cycling (Creutzig et al., 2012).
Public transport and the environment

Public transport policies and decarbonisation

Transit-oriented development

Transit-oriented development (TOD) is a community-based strategy highly dependent on public transport development. The key to TOD is to integrate dense and diverse land uses around a highly accessible public transport location with a walkable environment (Cervero, 2004; Curtis, 2012; Loo & Banister, 2016). The fundamental elements of TOD are the “3Ds” – density, diversity and design (Cervero & Kockelman, 1997). Overall, dense development, mixed land uses and a people-centric design of the built environment are favourable conditions. Essentially, TOD and public transport are used to be mutually reinforcing. On the one hand, TOD provides denser and more diverse opportunities around public transport stations, which can sustain public transport ridership and support its long-term viability, while, on the other hand, public transport provides sustainable, accessible and high-capacity travel modes to accommodate the travel demand of passengers and residents in TOD communities. To deliver the associated environmental benefits effectively, TOD needs to be supported by the use of sustainable transport alternatives (i.e. public and active transport) (Cervero & Sullivan, 2011; Loo & du Verle, 2017; Loo & Tsoi, 2018; Litman & Steele, 2017). In this context, Ewing and Cervero (2010) integrated two other components to make the “5Ds” (i.e. distance to transit and destination accessibility). “Distance to transit” and “destination accessibility” highlight the fundamental principle of developing an accessible public transport and pedestrian network for connecting to the transit location and nearby activity opportunities. The goal is to encourage public and active transport. Ogra and Ndebele (2014) also incorporated demand management to form the “6Ds”. “Demand management” refers to the ability to accommodate the existing and future demand of different transport modes, such as the allocation/expansion of public transport facilities and parking infrastructure. These three elements are largely related to the public transport dimension.

The effectiveness of TOD in achieving transport decarbonisation has been examined by a wide range of researchers. The focus here is on the empirical studies of TOD and its association with transit ridership and travel distance. Multiple studies highlight that TOD can reduce travel by private vehicles, increase public transport ridership and promote active transport in different geographical contexts (Loo et al., 2010; Loo et al., 2017a; Kamruzzaman et al., 2013; Sung & Oh, 2011). Moreover, proximity of activity nodes to public transport locations can effectively reduce travel distance (Zhang, 2010; Lee et al., 2010; Bartholomew & Ewing, 2008), thus further reducing energy consumption of motorised travel and encouraging non-motorised access (i.e. walking and cycling). Loo et al. (2017a) investigated rail-based TOD (RTOD) communities in Hong Kong, and they found that RTOD is an effective policy instrument in increasing population and land-use density. Overall, the use of multi-modal rail and walking modes increased in both greenfield and brownfield sites after the opening of new railway stations (Loo et al., 2017a).

However, it is noteworthy that TOD is largely a “neighbourhood” concept. In other words, TOD strategies are not identical across different communities. They have to be highly place based and context specific. Using Hong Kong as an example, TOD in different parts of Hong Kong displays distinctive characteristics in terms of the 3Ds (i.e. density, diversity and design). According to principal component analysis (Loo & du Verle, 2017), there are five types of TOD communities, CBD-type, integrated community, balanced-type, residential-type and station-type. In these different neighbourhoods, the public transport settings and accessibility features can be very different. For example, CBD-type TOD neighbourhoods require the provision of
all hierarchies of public transport with a dense and well-connected street network. A station-type TOD neighbourhood features proximity to other transport modes and a good design of the metro station, such as covered walkways and car-free environment. An integrated community TOD neighbourhood usually has higher residential density and denser coverage of metro exits. Though there can be, to some extent, spatial heterogeneity of public transport planning and TOD, there are several common policy features based on empirical evidence (Bertolini et al., 2012; Cervero & Sullivan, 2011; Loo et al., 2010; Loo et al., 2017a; Renne, 2009). First, integrating public transport and land-use planning at a neighbourhood scale is a fundamental principle. The essence is to provide attractive public transport and well-coordinated land use. Appropriate land zoning strategies such as high-density residential or employment land use and mixed commercial, recreation and retail opportunities around the public transport stops are commonly found in the more effective TOD communities. Second, developing a well-connected pedestrian and cycling network offering a pleasant travel experience (i.e. safety, comfort and convenience) is essential. Non-motorised access and a reduction of pedestrian-vehicular conflicts around public transport stations are duly paramount. Third, high-frequency, efficient and good-quality public transport services are important for the success of TOD. Developing a sustainable public transport hierarchy by integrating different levels of transport modes in the public transport hub is vital.

An integrated public transport system

Developing an integrated public transport system is an important initiative to encourage modal shift and promote transport decarbonisation. An integrated public transport system integrates different public transport modes in a holistic network and offers fast, convenient, comfortable and accessible transfer between transport modes (Chowdhury & Ceder, 2016; Li & Loo, 2016; Ülengin et al., 2007) (see also Chapters 6 and 31). Offering attractive transfers within the same mode (e.g. metro lines, bus routes or tram routes) or multi-modal transfers (e.g. train–metro, train–bus or metro–bus) can help provide a door-to-door service and encourage modal shift. Earlier studies focus on the integration of air and road transport (Givoni & Banister, 2006; Li & Loo, 2016). If properly planned, the integration can foster a “complementary” arrangement between airlines and train operators, where trains can help serve areas that are not well connected by flight routes (Givoni & Banister, 2006). This suggests that a well-developed public transport interchange can play an important role in a hub-and-spoke network and foster seamless transfer between modes. Essentially, the transfer experience can affect the overall success of public transport to deliver the desired environmental benefits. As suggested by a wide range of literature (Iseki & Taylor, 2010; Guo & Wilson, 2011; Shrivastava & O’Mahony, 2009), transfers can generate different negative utilities such as uncertain waiting time and longer travel time. The negative factors can hinder the development of transport decarbonisation, as a low level of multi-modal integration can lead to lower willingness to use public transport and lower public transport ridership (see also Chapter 32).

Essentially, an integrated public transport system is not only about the physical integration of different transport modes at the same location but rather the integration of a wide range of attributes that affect the overall experience during transfer (Li & Loo, 2016). A people-centric design is essential. Preston (2012) proposed the concept of the “integration ladder” and highlighted that integration is a multifaceted concept that incorporates horizontal integration (e.g. information, physical integration, fares and ticketing and infrastructure) and vertical integration (e.g. passenger and freight, transport authorities, transport and land-use
planning and policies of transport and other sectors). This pinpoints the out-of-fleet experience during the journey which is conducive to modal shift and public transport ridership. Moreover, integration should consider the coordination between different transport modes so that the benefits of the large-capacity mass system can be delivered (Loo, 2020). The idea of integrating different mass transport modes into a comprehensive multi-modal “sustainable transport hierarchy” should be advocated. The hierarchy indicates the different orders of public transport, as defined by their carrying capacity and environmental impact per passenger. For example, commuters may take intercity trains for regional travel (higher-order) and take buses or paratransit (lower-order) as the last-mile journey to reach the final destination at local communities.

**Integration of public and active transport**

The linkage between public and active transport is essential to further promote non-motorised travel and support TOD. First, TOD requires a well-connected pedestrian network linking the public transport locations to nearby activity nodes (see also Chapter 6). Encouraging active transport can produce significant environmental advantages, as increasing walkability in the neighbourhoods can alleviate environmental harms per unit of transport volume (Loo & Tsoi, 2018). It has been emphasised that proximity to activity locations from public transport locations is important; however, proximity does not necessarily mean a shorter walking distance, as the street connectivity, junction density, road-crossing facilities and size of street blocks are all relevant parameters in affecting walking distance. Most importantly, walkability is not merely about walking distance but different aspects, such as safety, convenience and comfort of the pedestrian experience (Loo & Lam, 2012). Walking experience is about how people interact with the built environment and street landscape (Loo et al., 2017b; Wang et al., 2016). In relation, land-use diversity, residential density, street connectivity and aesthetics can affect walkability. Essentially, the walking experience between public transport locations or between activity points and public transport locations needs to be further investigated. The interface of the public transport and pedestrian fabrics is an important construct of sustainable mobility (Newman et al., 2016). Hence, a microscale assessment of walkability within the public transport station and around the station is required to bridge the pedestrian network and public transport network. The common parameter of walkability evaluation around the public transport station is 500 metres (Loo et al., 2010, 2017a). Moreover, interchange stations sometimes involve multilevel structures, with bridges and tunnels connecting to the concourse, platforms, waiting areas and nearby buildings. Therefore, the walkability assessment should also integrate the three-dimensional network (i.e. at-grade, elevated walkway and underground walkway). Bicycle-train integration that strengthens the linkage between public and active transport is also a popular measure to sustain public transport ridership (see also Chapter 31). In a case study of the Netherlands (Geurs et al., 2016), it was found that bicycle-train integration (such as better bicycle routes and parking, travel time and cost reductions) was essential to train ridership and job accessibility, especially at large stations with multiple train lines. Zhao and Li (2017) also examined the integration of bicycles and train stations in Beijing and found that the number of public bicycles, proximity to the city centre and the presence of public parks were associated with a higher level of cycling to metro stations. The acceptable range of cycling between the public transport locations and the activity nodes was also found to be around 1 and 5 km in Beijing (Zhao & Li, 2017).
Public transport electrification

Electric mobility has been a recent initiative in transport decarbonisation. Indeed, electrifying public transport fleets can offer potential carbon savings in public transport operations. Recently, there has been research exploring the relationship between electrified/hybrid public transport and carbon emissions. Sánchez et al. (2013) conducted a lifecycle assessment of different fuel types of buses, including fuel cell hybrid, hybrid-diesel-electric, battery electric and combustion ignition engine. The findings indicate that the fuel cell hybrid and battery electric buses can potentially reduce 26 and 28 percent of energy consumption, with an equivalent carbon reduction by 29 and 31 percent. Lajunen and Lipman (2016) investigated the lifecycle costs of CO₂ emission of buses in two case scenarios of Finland and the United States and found that the energy efficiency of city buses can be improved by alternative powertrain technologies. When compared with traditional diesel buses, hybrid and full-electric buses can potentially reduce CO₂ emission up to 75 percent (Lajunen & Lipman, 2016). Dreier et al. (2018) conducted a case study in the BRT system in Brazil. The findings indicate that the adoption of hybrid bus and plug-in hybrid city buses can reduce 30 and 75 percent of fuel energy per distance when compared to a traditional bus, which is equivalent to around 1.12 kg of CO₂ well-to-wheel per kilometre (WTW/km) and 1.54 kg of CO₂e WTW/km. Ribau et al. (2014) investigated the lifecycle impact difference between hybrid electric and plug-in hybrid electric cars. They suggest that fuel cell buses can reduce the overall energy consumption by 58 percent and produce a two-thirds decrease in the CO₂ equivalent throughout the lifecycle.

With the advancement of technologies, the electrification of public transport becomes more feasible. However, several challenges may hinder the development of such initiatives, including the lack of charging infrastructure, prohibitive costs for operators and uncertainty in investment (Gallo, 2016; Loo, 2018). Multiple policy instruments need to be considered for the success of promoting low- or zero-emission vehicles. In a European project, “Electrification of public transport in cities” under Horizon 2020, three thematic pillars were identified – integration of electric buses, energy storage and multipurpose use of infrastructure (Glotz-Richter & Koch, 2016). An electric bus demonstration study by Miles and Potter (2014) illustrated that a new company can be developed to purchase electric buses and chargers can be beneficial. The company is responsible for leasing the fleet to the bus operators and maintaining the charging infrastructure (Miles & Potter, 2014). This is to reduce the financial burden and the risks entirely shared by the operators and increase the feasibility of putting the electrified fleet into practice.

Conclusion

In this chapter, the environmental implications of public transport on carbon emissions, air quality and climate change have been discussed. Developing a public transport system has been a common strategy to encourage sustainable travel in the past several decades. The common initiatives include transit-oriented development, integrated public transport systems, integration of public and active transport and public transport electrification. Though there are certain geographical discrepancies, these policy instruments can generally pave the way to transport decarbonisation by encouraging modal shift, reducing car travel distance and reducing transport energy intensities. To ensure that public transport can maximise its potential in carbon reductions, future research should examine the complementary effects of integrating different public transport modes in a network. Essentially, establishing a sustainable public transport hierarchy seems a promising trend – integrating different orders of public transport can help strengthen the mode shift initiatives and enhance the resilience of public transport networks. Moreover,
the synergies provided by public transport and other policy instruments need to be further investigated.

Since this chapter was devised, the COVID-19 pandemic outbreak has emerged and has impacted individual physical mobility which has had a knock-on effect on the environment. Indeed, reduced surface transport and fuel consumption, in particular by private vehicles, have manifested the potential environmental benefits. According to a global study of over 69 countries (Le Quéré et al., 2020), there was a reduction of activities in surface transport by 40 to 65 percent when compared to the pre-COVID-19 situation. The corresponding reduction of global emission ranges from 7.5 to 36 percent (equivalent to a decrease of 5.9 to 9.6 million metric tonnes CO₂), which is the largest contributor to the total emission change (even higher than the aviation sector).

However, the COVID-19 pandemic has also posed significant challenges to public transport. Since early 2020, public transport patronage has dropped significantly in different parts of the world. The Citymapper urban mobility index (Citymapper, 2020), which indicates the use of public transport, has rapidly declined in many big cities worldwide during COVID-19. Some cities had less than 10 percent of the mobility index they had previously. Even when some confinement measures have been loosened since mid-2020, the mobility index in most cities stayed at around one-third of the usual figures. With the COVID-19 associated health risk and uncertainty, adaptive strategies need to be implemented in public transport to enhance its resilience so that the environmental benefits can be delivered. In particular, this pandemic may encourage people to use private transport to reduce public interactions. Notwithstanding, a public transit society is not inconsistent with controlling public health risk, with public transport being a safe and sustainable travel option under a compact city environment (Cowling et al., 2020).

References


Public transport and the environment


Ka Ho Tsoi and Becky P.Y. Loo


