PUBLIC TRANSPORT AND BUS RAPID TRANSIT AS A TOOL OF DECARBONIZATION IN MALAYSIA

by Chandrima Mukhopadhyay

MIT-UTM Malaysia Sustainable Cities Program
Massachusetts Institute of Technology

Abstract

In Malaysia, the transport sector alone contributed an estimated 22.9 percent of all carbon emissions in 2015. With this statistic in mind, the federal government of Malaysia aims to achieve a 40 percent modal share of public transport by 2030—up from the current rate of approximately 10 percent. Taking 2005 as the base year, the government’s goal is to reduce emissions from the transport sector by 9.17 million metric tons of carbon dioxide by the year 2020. One relatively fast and effective solution is to retrofit or replace existing urban systems with public transport projects—and in particular, with Bus Rapid Transit (BRT) systems. This study investigates the potential of BRT systems as a tool of decarbonization, compared to other modes of public transport. In addition to focusing on decarbonization, the study also explores the co-benefits of promoting a Bus Rapid Transit system as a mode of public transport in Malaysia. The study investigates two regions—greater KL-Klang Valley and Iskandar—and three projects: Sunway BRT, KL-Klang federal highway BRT, and Iskandar BRT. The study estimates the reduction in carbon dioxide emissions or equivalent that would result if all proposed BRT systems were implemented, based on a combination of fuels (i.e., diesel, compressed natural gas, and electricity) for trunk and feeder routes. And finally, the study shows that while BRT is a fast solution to operationalize decarbonization, there are both barriers and facilitators to its implementation.
**Introduction**

What is the potential of a Bus Rapid Transit system for decarbonizing the transport sector in Malaysia?

The transport sector is known to be a significant contributor towards carbon emissions in cities and regions (Selvakkumaran & Limmeechokchai, 2015). As passengers shift from private vehicles to public transport, decarbonization in the transport sector becomes increasingly compelling. Rail is perceived as superior to bus service, due to its fast commuting time and comfort; however, bus allows for wider coverage than rail (Ben-akiva & Morikawa, 2002). Bus Rapid Transit (BRT) has been largely discussed as an urban innovation to solve the issue of mobility in cities and regions, under the framework of the UN Sustainable Development Goals. A BRT system can deliver the comfort and fast commuting time of a rail system, and the flexibility of a bus system. It can be conceived as an intermediary system between rail and bus. Due to its low construction costs and flexibility of implementation (i.e., the ability to implement a small-scale pilot project; easier exit options from the construction stage, etc.), BRT has proven financially sustainable for regions that do not have the volume and density needed to support rail infrastructure. Finally, due to its shorter implementation timeline, BRT is preferred when the fastest public transport solution is required.

The Institute of Transport and Development Policy (ITDP) defines BRT as “a high-quality bus-based transit system that delivers fast, comfortable, and cost-effective urban mobility through the provision of segregated right-of-way infrastructure, rapid and frequent operations, and excellence in marketing and customer service” (ITDP 2007). ITDP certifies BRT systems with a Gold, Silver, Bronze, or Basic ranking. A gold BRT system scores 85–100, based on criteria such as dedicated bus lanes throughout its route, a limited number of stops for rapid movement, bus way alignment so there is minimum conflict with other traffic, pre-boarding fare collection and verification, closed stations, low platforms for fast boarding and alighting, prioritized signals at traffic intersections, multiple routes, and absence of other mass transit corridors along the same route.¹

BRT systems perform better in networks, both in physical and institutional terms (Combs, 2017; Mejía-dugand, Hjelm, Baas, & Ríos, 2012). A BRT network can operate similarly to, and in parallel with, rail and bus networks. Prior studies have not explicitly discussed BRT systems as regional-level versus city-level infrastructure. However, both design guidelines published by transport authorities² and ITDP guidelines³ provide information on the length of various BRT corridors. BRTs can serve an area of relatively low demand, and—in contrast to rail infrastructure—relatively short BRT lines can be built and maintained.
even on a temporary basis. The aforementioned guidelines highlight differences among BRT systems used across the world, including (for example) which facilities should be available at BRT stations. While BRT systems in cities in the global South recommend closed stations and pre-boarding fare collection and verification, BRT systems mainly attracting choice users are encouraged to include more facilities similar to LRT stations (FDOT report). Clifton et al.’s 2014 study on the BRT system in a suburb of Sydney, Australia, raises questions about whether there are different kinds of BRT systems for “captive” users compared to choice users (Clifton, Mulley, & Hensher, 2014). While it is neither common nor ideal, the Sydney suburb’s BRT system—in its effort to decarbonize—uses single-seated buses to encourage choice users to leave their private cars behind.

Rogat, Dhar, Joshi, Mahadevia, & Mendoza, (2015) and Mahadevia et al (2012) evaluate BRT from urban planning, technical, and environmental perspectives. Cases from Latin American countries show that with strong political leadership, technological innovations in the transport system like BRT can successfully operate for long distances, and can perform better than Light Rail Transit (LRT) in terms of ridership.

Currie & Delbosc (2011) evaluate criteria that influence ridership on BRT systems. To build and retain ridership, BRT systems should maintain attractiveness (Hidalgo, Pereira, Estupiñán, & Luis, 2013). However, the case of Bangkok shows that BRT may fail to achieve sufficient ridership in competition with rail systems (Wu & Pojani, 2016). BRT is often successfully implemented in regions that do not yet have a modern rail system. Although technically possible, there are very few documented cases in which BRT systems have been upgraded to a LRT or Mass Rapid Transit (MRT) system. And although BRT are sometimes perceived to be is more affordable for riders, studies focusing on the actual social equity of BRT are limited.

**The Malaysian context**

**Background of decarbonization in Malaysia**

Malaysia committed to reducing its GHG emissions up to 40 percent by 2020 and 45 percent by 2030, having established 2005 as the base year (Ghadimzadeh et al., 2015). While a 35 percent reduction is considered a firm commitment, the remaining 10 percent will depend on the availability of climate financing. An ASEAN report prepared by the University of Kuala Lumpur-Malaysian Spanish Institute and Focus Applied Technology as part of the GIZ program on Cities, Environment,
and Transport (ASEAN report, n.d.) shows that the transport sector is the second-largest energy consumer—after electric power generation—in Malaysia. The transport sector consumes 40 percent of national energy output, and emits 50 million Mt of carbon dioxide each year (Energy Handbook, 2015).

As of 2015, 22.9 percent of national carbon emissions (42.43–50 million metric ton carbon dioxide) comes from the transport sector (Ghadimzadeh et al., 2015). The federal government of Malaysia has set a target for the transport sector to reduce GHG emission by 9.17 million metric tons by 2020, using 2005 as the base year. As of 2015, road transportation contributes 85 percent of total emissions in the transport sector. The ASEAN report (2016) shows that private cars and taxis contribute 59 percent of road transportation emissions. While the exact distribution is not available, taxis are the highest emitters, and private cars are the second-highest emitters. Because restrictions on private car use would encourage people to shift to taxis, it is important to have a strategy in place to restrict the use of taxis. Although there are equal numbers of private cars and motorcycles in Malaysia, the latter contribute only 11 percent of carbon dioxide emissions, indicating that the larger focus should be on shifting private car users to public transport (ASEAN Report, n.d.).

The current rate of private vehicle ownership in Malaysia is 500 cars per 1,000 persons, which is predicted to increase to 800 cars per 1000 persons in 2025, if no intervention is made (Low Carbon Society Blueprint, 2013). The federal government’s plans to restrict emissions from private vehicles are complete, and could be implemented in the near future. To some extent, they would control growth in the overall number of vehicles. Although private vehicles that use clean energy sources—such as electric vehicles (EV) and hydrogen cars—are either already in operation in Malaysia or are soon to be launched—there are challenges with large-scale implementation, such as high initial investment. Chuen et al. (2017) and Manjunath & Gross (2017) raise questions about decarbonization of the energy sources that power electric vehicles, as electricity is drawn from a national grid that uses conventional sources like coal.

In contrast, as mentioned by the ASEAN report (2016), one effective way to decarbonize is to shift passengers from private vehicles to more energy-efficient (automated and electric) rail and bus systems. As argued below, a BRT system with dedicated bus lanes built on existing private vehicle routes could be one of the most effective strategies. Studies have shown that it is important for mass transit projects to have a full-fledged feeder service in place to achieve ridership; this is especially
true in Malaysia, given the nation’s prevalent first mile/last mile connectivity challenge. Feeder services that connect people from their origin to mass transit stations, and from mass transit stations to their destination, address this challenge. While shifting from private vehicles to public transport is strictly a matter of users’ choice, users prefer to use public transport for trips with greater travel distance and travel time (Nurdden et al, 2007).

Historical data on modal share of public transport shows that its share declined over time in Malaysia; in Klang Valley, public transport’s modal share was 37 percent in 1970, 33 percent in 1980, 32 percent in 1990, and 10 percent in 1997 (Barter, 2004). Meanwhile, private vehicle ownership has drastically increased over time—from 4.7 million in 1990 to 18.6 million in 2010 (National Land Public Transport Master Plan)—and the forecasted population of the Greater KL-Klang region is 10 million people by 2030. At the national level, the number of trips made by car was 12 million in 1991, and 40 million in 2010. If the current 10 percent modal share of public transport remains constant, 110 million trips will be made by private vehicles in 2030. If the targeted 40 percent modal share of public transport is achieved, only 73.8 million trips will be made by private vehicles, and 49.2 million trips will be made by public transport. While modal shift from private vehicle to rail reduces carbon dioxide emissions by 13.3 percent and improves energy efficiency by 53 percent, modal shift from private vehicle to bus service reduces carbon dioxide emission by 10.1 percent, and improves energy efficiency by 40 percent in the Malaysian context (Briggs et al., 2016).

It is also argued that automated vehicles are more energy efficient. However, such calculations are based on assumptions like ridership of normal bus service and diesel buses. With articulated buses—which resemble LRT cars with more carrying capacity and with a pivoting joint allowing the car to turn at junctions—that allow for higher ridership and greater use of clean energy like compressed natural gas (CNG) or electric buses, reductions in carbon emissions and energy efficiency resulting from a modal shift from private vehicles to BRT would be even higher. Table 1b below shows the percentage of reduction in carbon dioxide emissions of various modal shift combinations, using data from the ASEAN Report (November 2016).

<table>
<thead>
<tr>
<th>Serial no.</th>
<th>Type of Modal Shift</th>
<th>Reduction in carbon dioxide emission (Mt CO2 reduction from a base point of 50 Mt)</th>
<th>Energy Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Car to rail</td>
<td>13.3</td>
<td>53%</td>
</tr>
</tbody>
</table>


**Table 1.** Reductions in carbon dioxide emissions and energy efficiency changes due to modal shift$^5$

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Car to bus</td>
<td>10.1</td>
</tr>
<tr>
<td>3</td>
<td>Car to motor bike</td>
<td>8.3</td>
</tr>
<tr>
<td>4</td>
<td>Bus to rail</td>
<td>0.3</td>
</tr>
<tr>
<td>5</td>
<td>Motor bike to rail</td>
<td>1.4</td>
</tr>
<tr>
<td>6</td>
<td>Motor bike to bus</td>
<td>0.5</td>
</tr>
</tbody>
</table>

**Physical context**

From an urban morphology perspective, Newman and Kenworthy (1989) formulate categories of the “automobile-dependent city” and the “traffic-saturated city.” Automobile-dependent cities are sprawled and low-rise in form. In quantitative terms, automobile-dependent cities have more road length per 1,000 persons. Traffic-saturated cities are planned to accommodate a moderate number of automobiles. Besides their compact form, such cities show less road length in kilometers per 1000 persons. Asian cities are mostly traffic-saturated cities. Barter (2004) argues that although Malaysian cities, (especially the Greater KL-Klang region) are not yet automobile-dependent cities, they have higher road length per 1,000 persons than other Asian cities. With agencies and institutions interested in delivering private vehicle infrastructure, Greater KL-Klang has the potential to become an automobile-dependent city. Barter associates automobile dependency with the “path dependency” of delivering private vehicle infrastructure to meet demand, which creates carbon lock-in. Unruh & Einstein (2000) use the notion of the “techno-institutional complex” to describe lock-in as an outcome of interaction between technological systems and governing institutions. In terms of decarbonization, automobile dependent-cities contribute towards higher global GHG emissions, while local air pollution is felt more in traffic-saturated cities.

There are at least two ways for policy-makers to deal with traffic saturation, reflecting the inherent competing interests: 1) deliver more road infrastructure to meet demand; and 2) deliver more and better public transport, and encourage a modal shift towards public transport. These competing approaches are evident in Malaysia, and especially in the greater KL-Klang region, which has seen both cooperation and conflict within the various departments of federal government and within city councils. For example, DBKL—the city council of Kuala Lumpur—started converting some of its on-street parking inventory to pedestrian infrastructure, whereas city councils in the surrounding Klang Valley,
where greater traffic demand is generated, are still delivering private vehicle infrastructure.

In the long run, it will be important for all city councils to adopt the same policy, if the goal is to encourage people to choose public transport instead of private vehicles at the point where traffic demand is generated. One city council in the greater KL-Klang region noticed that private developers were lobbying decision-makers to deliver superior quality private vehicle infrastructure, which in turn would negatively affect the ridership of proposed public transport projects (especially BRT). When apprised of the scheme, the BRT project promoters were able to strongly protest against the project. This example underscores the dynamic of conflict between agencies interested in delivering private vehicle infrastructure versus those advocating for public transport.

As recent studies indicate, BRT—or any mass transit project—has to be planned as a policy package, as shown in Figure 1 below (Filipe, 2014; Filipe & Macário, 2013); there must be policies in place at a broader level, such as a High Occupancy Vehicle lane, to discourage people driving their private vehicles. Both regions discussed in Malaysia have yet to implement such policies.
Figure 1. Policy package of BRT implementation

In the greater KL-Klang Valley region, the city of Kuala Lumpur (KL)—characterized by high rises—has a density of 6,890 per square kilometer as of 2016., and its suburbs have an average density of 2,600 per square kilometer. IPCC documents advocate reducing the number of trips as much as possible, which could be operationalized through land-use planning. Prior studies on sustainable mobility have also advocated for a reduction in the number of trips (Hickman, Hall, & Banister, 2013). For the Iskandar region, the urban form is both low-rise and sprawled. As of 2012, the density of Iskandar was 174 persons per square kilometer—a sharp contrast to KL. As noted, a lack of volume and density are two key challenges to the successful implementation of a mass transit project.

Institutional context

In 2009, Malaysia’s federal government launched the Government Transformation Program (GTP) and Economic Transformation Program (ETP), with the Prime Minister as its chair. Both programs addressed public grievances regarding increased traffic congestion caused by the ever-greater number of private vehicles. Such traffic congestion was increasing travel time, which had a negative impact on economic development. To counter traffic congestion, GTP and ETP outlined a target of 40 percent modal share of public transport by 2030—up from the then-current rate of 10 percent—promoted public transport projects to support economic development, and formed Suruhanjaya Pengangkutan Awam Darat (SPAD, or Land Public Transport Commission) as the main land public transport regulator directly under the Prime Minister’s office. Ultimately, SPAD prepared the Land Public Transport Master Plan for the Greater KL-Klang Valley region.

The establishment of SPAD, reporting directly to the Prime Minister’s office, signified that public transport delivery had been prioritized in the national agenda. While certain public transport projects were already in operation, SPAD sought to facilitate the integration of various modes of public transport to allow a seamless flow of users from their origin to destination. In that effort, however, SPAD soon encountered obstacles. The use of a public-private partnership (PPP) model—whereby private sector partners generate return on their investment from fare revenues—had not been historically successful. In addition, LRT construction was affected by the 1997 Asian financial crisis, during which inflation increased from 8 percent to 40 percent, and concessionaires were unable to pay back their bank loans. Prasarana, the main service provider...
operator of Malaysia’s public transport, was formed in 1998 directly under the Ministry of Finance to bear the demand risk. Prasarana’s role also includes expediting the delivery of public transport projects. Prasarana has six subsidiaries: rail and infrastructure projects, Pride (Prasarana Integrated Development Project Berhard), Prime, Rapidbus, Rapidrail, and Prism (Interview 01). Taken as a whole, Prasarana has run at a deficit. One reason is relatively low ridership of public transport. Another is debt service: the company borrowed to raise money to establish its public transport projects. In addition, in the greater KL-Klang region, all projects were developed from scratch as greenfield projects—without using existing rolling stock, and building multiple elevated sections. The lesson is that to ward off financial crisis, low-cost projects (using rolling stock, minimizing elevated sections, etc.) should be favored over high-cost projects, and companies and governments must carefully negotiate who will bear the financial risk in PPP models.

Public transport in Malaysia

As mentioned before, the main drivers of improving public transport besides decarbonization have been mitigating traffic congestion and promoting economic development. This study investigates the Greater KL-Klang Valley region and the Iskandar region. The Greater KL-Klang land public transport master plan (drafted by SPAD) and the Low Carbon Society Blueprint for the Iskandar region (drafted by the Iskandar Regional Development Authority) are two broad planning documents that outline strategies towards decarbonization, and describe how proposed public transport projects fit into the framework.

The Greater KL-Klang Valley Region master plan develops a hierarchy of public transport in three categories: primary, secondary, and tertiary corridors. The primary corridor connects the region with KL city, and is designed for more than 25,000 persons per hour per direction (pphpd). Secondary corridors facilitate commuting in between the “districts” (the suburban areas of greater KL); connect the districts with the primary corridor; and are designed for 5,000-25,000 pphpd. Tertiary corridors use local streets to address first mile/last mile connectivity, and are designed for less than 5,000 pphpd. The master plan includes the Urban Rail Improvement Program (designed for the primary corridor with more than 25,000 pphpd, and highest length of route); the Bus Transformation Plan, including BRT (5,000-25,000 pphpd) and local buses (less than 5,000 pphpd); and the Taxi Transformation Plan, affectin local taxi service. Figure 2 below summarizes the evolution of various public transport modes in greater KL-Klang valley.
The current transport landscape around KL depends on rail for the primary corridor and uses bus mainly for the secondary and tertiary corridors. BRT has been conceptualized for 5,000 pphpd to 25,000 pphpd, while the potential remains to design for more than 25,000 pphpd. KTM Komuter is the oldest railway system in Malaysia and is operated by the public sector. New rail infrastructure was introduced in the region over the last decade, such as Monorail, LRT, and MRT. When assessed through the lenses of accessibility, affordability, and reliability, there are few options for good public transport in the region. Daily commuters do not use the Monorail route. The MRT and LRT stations have accessibility issues. The one-way fare for the train to Kuala Lumpur International Airport was raised by RM30 overnight, which its private sector concessionaire had the right to do. Tables 2 and 3 show the historical ridership of all public transport projects and a comparison of their construction costs.

<table>
<thead>
<tr>
<th>Type of Services</th>
<th>First Quarter</th>
<th>Second Quarter</th>
<th>Third Quarter</th>
<th>Fourth Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>LRT Kelana Jaya</td>
<td>20,137,667</td>
<td>19,999,248</td>
<td>21,893,742</td>
<td>21,554,755</td>
</tr>
<tr>
<td>LRT Ampang</td>
<td>14,279,935</td>
<td>14,375,835</td>
<td>15,693,082</td>
<td>15,114,180</td>
</tr>
<tr>
<td>MRT 1</td>
<td>1,505,856</td>
<td>1,161,218</td>
<td>9,318,373</td>
<td>10,365,061</td>
</tr>
<tr>
<td>KL Monorail</td>
<td>5,034,720</td>
<td>4,434,559</td>
<td>3,696,196</td>
<td>3,676,155</td>
</tr>
<tr>
<td>KLIA Express</td>
<td>581,046</td>
<td>558,512</td>
<td>584,375</td>
<td>551,717</td>
</tr>
</tbody>
</table>
Table 2. Ridership of all public transport modes in Greater KL-Klang Valley in 2017

<table>
<thead>
<tr>
<th>Mode</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>KLIA Transit</td>
<td>1,627,408</td>
<td>1,602,576</td>
<td>1,606,785</td>
<td>1,606,898</td>
</tr>
</tbody>
</table>

Table 3. Comparison of construction cost of various modes and elevated and at-grade section in Malaysia

<table>
<thead>
<tr>
<th>Mode</th>
<th>Construction Cost</th>
<th>Maintenance and Operation Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Elevated</td>
<td>At grade</td>
</tr>
<tr>
<td>MRT</td>
<td>RM 411 million/km (may be including land acquisition cost)</td>
<td>Not Applicable</td>
</tr>
<tr>
<td></td>
<td>Underground: RM 1 billion/km</td>
<td></td>
</tr>
<tr>
<td>LRT</td>
<td>RM 250 million/km</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Monorail</td>
<td>RM 36 million /km in 2003</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>BRT</td>
<td>RM 117 million/km in 2015 (Sunway BRT: Bronze rating)</td>
<td>RM 41 million/km</td>
</tr>
</tbody>
</table>

Similarly, in the Iskandar region, the projected population for 2030 is 3 million, which almost certainly will increase trip generation. Currently, public transport holds 10 percent modal share, cars hold 60 percent, and motorcycles hold 21 percent. Following the target set by the federal government, the Low Carbon Society Blueprint adopts the strategy to improve the modal share of public transport to 40 percent by 2030.

Table 4 lists all proposed public transport projects both in the greater KL-Klang valley region and the Iskandar region. The figures in the right column show how such projects would contribute towards reduction in carbon dioxide emission, allowing a comparison between various modes, i.e., MRT, LRT and BRT. While the forecasted ridership is adopted from master plans, BRT trunk routes (the main route with a dedicated bus
lane on the federal highway) are assumed to use electric buses, and feeder routes are assumed to use CNG buses. A detailed scenario analysis on BRT is presented later in Table 8, considering use of BRT in combination with rail or in combination with other bus systems, in terms of using alternative forms of clean fuel, and in combination of trunk and feeder services at varied timelines.
<table>
<thead>
<tr>
<th>Mode</th>
<th>Forecasted daily ridership</th>
<th>Actual daily ridership</th>
<th>Type of fuel</th>
<th>Reduction in carbon emission and energy efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>KTM Komuter</td>
<td>237,000</td>
<td>102,013</td>
<td>Electric 25 kV AC</td>
<td>291.75 (Actual)</td>
</tr>
<tr>
<td>Monorail</td>
<td>115,000</td>
<td></td>
<td></td>
<td>200 tons</td>
</tr>
<tr>
<td>LRT1</td>
<td>496,000</td>
<td>229,001</td>
<td></td>
<td>0.091 g Carbon dioxide equivalent/ passenger.km based on 2011 ridership. (Soon et al, 2011). The study used a life cycle approach based on a 30-year life span.</td>
</tr>
<tr>
<td>LRT2</td>
<td>352,000</td>
<td>162,910</td>
<td></td>
<td>132.65</td>
</tr>
<tr>
<td>LRT3</td>
<td>100,000</td>
<td></td>
<td></td>
<td>42.18 (projected)</td>
</tr>
<tr>
<td>KLIA</td>
<td>16,500</td>
<td>17,799</td>
<td></td>
<td>18.48 (Actual)</td>
</tr>
<tr>
<td>MRT1</td>
<td>445,000</td>
<td>117,379</td>
<td>TNB will supply a maximum of 116.5 MW. Supplied through seven 33KV main switching substation. TNB will construct two 133/32kV transmission main intakes.</td>
<td>337,800 t (Kwan et al., 2017)</td>
</tr>
<tr>
<td>MRT Circle Line</td>
<td>440,000</td>
<td></td>
<td></td>
<td>325.41 (projected)</td>
</tr>
</tbody>
</table>
PUBLIC TRANSPORT AND BUS RAPID TRANSIT AS A TOOL OF DECARBONIZATION IN MALAYSIA

<table>
<thead>
<tr>
<th>Public Transport Type</th>
<th>Ridership</th>
<th>Battery Type</th>
<th>Reduction in CO₂ emissions (projected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRT North South Line</td>
<td>500,000</td>
<td></td>
<td>555.59</td>
</tr>
<tr>
<td>BRT (all twelve corridors)</td>
<td>1,800,000</td>
<td>BYD K9. Lithium phosphate iron battery.</td>
<td>701.68</td>
</tr>
<tr>
<td>Sunway BRT</td>
<td>19,995</td>
<td>Serves more than 250 km per charge.</td>
<td>1.97 (Actual)</td>
</tr>
<tr>
<td>KL-Klang Federal Highway BRT</td>
<td>225,000 (400,000 according to SPAD tender document for the project accessed on scribd.com)</td>
<td>20% of BRT users on trunk route used to drive; 15% of feeder bus users used to drive; 10% of all users used motorbikes.</td>
<td>139.35</td>
</tr>
<tr>
<td>Iskandar BRT</td>
<td>105,000</td>
<td>Electric buses for trunk route.</td>
<td>97.55 (projected)</td>
</tr>
</tbody>
</table>

Table 4. Reduction in carbon emissions due to modal shift from private vehicles and motorbikes

Note on Table 4: Twenty percent (from single occupancy car) and 10 percent (from motor bike) (balance consisted of existing public transport users and new trip makers) of daily ridership is multiplied by km (passenger km); Following Elliot Fishman’s diagram, 243.8 gm CO₂ per person km is considered reduced for car to electric bus. For car to rail it is 215.2 gm. From motorbike to bus, it is 119.6, and from motorbike to rail, it is 91. Electric bus emission is considered zero. Although it is understood that some electric cars are already on the road in Malaysia, statistics show their share is about 0.35 percent (28.2 million registered cars in 2017 and 100,000 electric cars on road by 2030.). Hence, the share of electric car has been ignored in the calculation. In addition, for proposed projects, government forecasted ridership is considered for calculation, which is on the higher side and optimistic.
So far, the Iskandar region's rail infrastructure includes only KTM Komuter. The forecasted ridership for the Iskandar BRT project is 7,000 pphpd on the trunk route, which is exactly half of KL-Klang federal highway BRT’s projected ridership, due to reduced demand. The KL-Singapore High Speed Rail (HSR) project has been approved, with annual ridership estimated at 15.2 million by 2030. The intermodal transfer facility between the new BRT system and HSR to Singapore would help to improve mobility for many users who commute to Singapore daily for economic reasons.

Before introducing three cases of proposed and implemented BRT systems in Malaysia, a brief summary of the prevailing attitude towards BRT systems in Malaysia—based on regions, stakeholders, and circumstances—might prove useful. In summary, the current government has relied on rail-based systems to serve as the primary corridor in greater KL-Klang valley region. While the general public may confuse feeder buses and BRT, the master plan differentiates between them in terms of pphpd, as discussed above. The trunk route of the BRT system uses a dedicated bus lane, while feeder buses share the road with traffic. Feeder buses do not commute between stations; their role is to bring people from neighborhoods to stations. Although there is support for a bus-based system for long distance travel or regional connectivity, many interest groups are either skeptical or not supportive of dedicated bus lanes, due to concerns of shrinking private vehicle infrastructure.

In contrast, Iskandar Malaysia does not have enough volume or density to support a rail-based system. Hence, despite many local people’s strong preference for rail-based system, the regional development authority opted for a BRT system with partial federal government support. Table 5 outlines the various stakeholders and their attitudes towards BRT systems under varying circumstances.

<table>
<thead>
<tr>
<th>Stakeholders</th>
<th>Greater KL-Klang Region</th>
<th>Iskandar Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPAD (Land Public Transport Regulator)</td>
<td>SPAD is highly supportive, as this would be a low-cost, high-efficiency public transport project, and would mitigate traffic congestion on the route. However, the project has been withdrawn, because the former government did not trust a bus system for the primary corridor. Although Sunway BRT is</td>
<td>Only regulator. Federal government is only partially funding. Balance has to be arranged by regional authority, with private sector partnership. IRDA is the main authority in this case.</td>
</tr>
</tbody>
</table>
implemented without disturbing existing traffic, the project raised question about the plan implementation process, especially regarding how decisions are made, and prompted concerns that federal government agencies do not have the capacity to deliver projects.

<table>
<thead>
<tr>
<th>Source</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prasarana</td>
<td>Mildly supportive. There will be problems during the construction stage, due to road closures. But the operators felt they had to speak with all other bus operators to coordinate, because other existing services would work as feeder services, and because the BRT system cannot be sustained on its own. Prasarana has concluded they may need a dedicated bus lane when they have automated buses, and when the BRT system is a city-level infrastructure and not regional-level infrastructure (distance of travel).</td>
</tr>
<tr>
<td>Ministry of Highway Planning</td>
<td>They were concerned about shrinking of the existing private car infrastructure. To reach a win-win situation, the decision was to keep three lanes, but narrowing them down. [An anonymous interviewee said the competing interest was to build an elevated expressway for private cars by private sector companies. The project was blocked, however, because an expressway would encourage people to use cars, and the BRT project along the same route would be affected.]</td>
</tr>
<tr>
<td>Political</td>
<td>Highly supportive of KL-Klang</td>
</tr>
</tbody>
</table>
**PUBLIC TRANSPORT AND BUS RAPID TRANSIT AS A TOOL OF DECARBONIZATION IN MALAYSIA**

<table>
<thead>
<tr>
<th>Opposition party</th>
<th>Federal highway BRT project that emerged with an NGO Transit Malaysia. Highly critical of Sunway BRT's high construction and maintenance cost due to elevated section.</th>
<th>Against it for shrinking private car infrastructure. Notably, the royal family doesn’t want this on their daily route.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private car community</td>
<td>Those who will always use private cars are not very supportive of shrinking of private car infrastructure.</td>
<td>Against it for shrinking private car infrastructure.</td>
</tr>
<tr>
<td>Captive users</td>
<td>This includes students who come from well-off families. They don’t want to use KTM due to its unreliability (and unattractiveness). It also includes those who don’t drive. Their sense is, “you use public transport if you have time to waste.” They think their mobility issue would have been solved.</td>
<td>Hard core public transport users strongly support, as they suffer from unreliable service, longer routes, but even drivers’ mindset. However, one group strongly raises a voice for LRT or MRT, as they think BRT is inferior. Many commute to Singapore directly, and wanted to know if this would help them.</td>
</tr>
<tr>
<td>Regional Planning authority</td>
<td>IRDA strongly promotes this, due to lack of mass and financial issues.</td>
<td></td>
</tr>
<tr>
<td>Local city councils</td>
<td>They were supportive of the project. They thought this was a good strategy to mitigate congestion. In spite of LRT and MRT proposals, they think BRT project was necessary, in light of future development and targeted modal shift.</td>
<td>They would be supportive. However, they will have to remove on-street parking in the neighborhoods, where locals will oppose.</td>
</tr>
<tr>
<td>Local planning organization/Heritage preservation</td>
<td>The state heritage office is supportive of the idea, and would like the BRT system to have a route through the heritage area. They also want to have better services during international tourism festivals, and better facilities within the buses to inform outsiders.</td>
<td></td>
</tr>
<tr>
<td>Public</td>
<td>They would benefit from</td>
<td>They would highly benefit from the</td>
</tr>
</tbody>
</table>
transport users | modernized and improved BRT system along the route. | project, if this is implemented properly.
--- | --- | ---
Other bus companies | They are supportive of more bus systems. | They still don’t know if this would disturb their route. However, they are in competition with blue buses that go closer to one’s house.
Other transport companies | KTM employees knew about the project. They did not have any negative reaction. | Some raised question about how the accountability of a public sector project can be maintained by private sector bus operators. They are not against the project, but they warn the authorities to not again deliver a non-effective project.
Taxi companies | Local taxi drivers don’t want to speak, as they are in tough competition with Uber and Grab anyway. Uber and Grab drivers think shrinking road infrastructure isn’t good. They also think it is too long distance. | Local taxi drivers are in hard competition with the Uber and Grab. It is difficult for them to keep their business.
Concessionaires for expressways | Their source of revenue from private cars would have been affected. KL-Klang is a non-tolled road, however. | This will be the same. However, in Malaysia, all freight vehicles take the expressways from outside the city, and not federal highways that run through cities.
Motor bike users | Some would still like to drive. But they are supportive of the idea, both for safety and guard from weather. | Authorities want to shift the motorbike users to BRT system.

**Table 5.** Stakeholder attitudes towards BRT projects

**Case study methods**

Three cases of BRT were studied: Sunway BRT in its operation stage; KL-Klang federal highway BRT in tendering stage (though this project has subsequently been withdrawn); and Iskandar BRT, in its initial public engagement stage. The study mainly uses qualitative methods,
such as document analysis, including media report, semi-structured interview of project promoters (21), open-ended survey of project users, potential users and non-users (85), participatory observation of public engagement meetings (three meetings of two hours each), and material from potential users on online platforms, images, and videos.

In addition, three routes of MRT feeder buses were visited, and bus captains and riders were interviewed in detail. In her conversations with both the project’s promoters and potential users, the researcher was able to serve as an advocate for BRT as a tool for decarbonization, and run through arguments regarding decarbonization. This may be seen as important, given that neither the project’s promoters nor its users tend to consider decarbonization or climate change as they make their decisions about delivering or using public transport projects. Instead, decisions are made based on more practical reasons, such as the increasing cost of fuel.

This same exercise—running through the logic of decarbonization—was repeated in public engagement meetings, and in attempts to successfully connect with NGOs working on environmental issues. This was, in a sense, a form of activism on behalf of low carbon infrastructure and sustainability.

**Cases**

**Sunway BRT**

Sunway BRT system is the only implemented BRT system in Malaysia. It was proposed as a secondary corridor in the greater KL-Klang valley region Land Public Transport Master Plan, to be implemented in the third phase of the plan. The project was intended to connect to the KL-Klang federal highway BRT, a primary corridor.

Sunway Group is a real estate company that built a township called Sunway City in the jurisdiction of Petaling Jaya and Subang jaya city councils. Since Sunway City faced severe traffic congestion, Sunway Group approached SPAD with the request to provide public transport in the area. Because Sunway Group had its own construction company, it was tasked with the design and implementation of the project. Prasarana, the main public transport service provider, is the asset owner. Sunway BRT was first implemented on a small scale (5.4 km stretch) as an urban experiment, in order to learn from the experience in hopes of replicating it on a larger later.

As it turned out, planners within federal and regional government agencies do not consider either the physical design or delivery model of the project ideal for Malaysia, on the ground that the project was not designed in an inclusive way, both in terms of not being integrated with its
surrounding, and in terms of the high fares that reflect its high construction costs. Moreover, since the project is implemented in a suburb of KL within the Sunway-built township, it raises questions about the replicability of the model in a “public” city, such as KL. The forecasted ridership for Sunway BRT was 2,400 per hour in 2015 and 5,200 per hour in 2025. In fact, the project’s ridership has been far lower, for which it has been sharply criticized. Table 6 summarizes the historical ridership on the project.

Table 6. Ridership for Sunway BRT
Source: Parliamentary website

As confirmed by interviewees from Prasarana, which is the asset owner company, Sunway BRT was designed as an alternative to LRT. Although initially an LRT project was proposed, the Subang Jaya City Council did not foresee enough volume to support investment in LRT. Additionally, there were design constraints in terms of the required turning radius of the rail track within the existing dense development (Interview 01). The project highlighted its use of electric buses from BYD Company. In designing the project, however, Sunway Group connected the stations only to Sunway properties. Public housing residents who had been living next to the new BRT stations for almost forty years were not informed or consulted during the planning and design stage, with the exception of one community where an elevated walkway under consideration would come very close to the houses in that community.
The project used a superficial model of PPP (Design-Build). In a real Design-Build model, design risk and construction risk remain with the private sector concessionaire. This means if the project has to undergo redesign or mobilize additional capital for design and construction, the private sector concessionaire is expected to bear the cost. Once designed and constructed by Sunway Construction Group, however, the Sunway BRT project was handed over to Prasarana as the asset owner, which now maintains the project. Prasarana paid back the Sunway group for constructing the project, except the 15 percent of the cost that paid by Sunway Group as their Corporate Social Responsibility goal. Prasarana has recently been retrofitting the project with additional walkways and stairs at their own cost (using public funds).

Sunway BRT is an example of two-stage retrofitting. First, its sponsors retrofitted the area with a public transport. Now, the project is being rebuilt to function as public infrastructure, with the main goal of improving ridership. Due to its fully elevated section, the construction cost of the project was high. The maintenance cost remains high, especially considering that ridership is low due to the high fare. For a one-way journey of 5.4 km, the fare is RM 5, which is unaffordable for many residents in Subang jaya area, including public housing residents. As an interviewee who lives in nearby public housing explains, they would pay the same to travel the same distance by Uber or Grab, but the private vehicles used by these ride-sharing apps would accommodate a total of four people, who could split the cost of the ride (Interview 19).

In spite of its inclusion in the initial plan, there is no dedicated feeder service for Sunway BRT. Sunway BRT has 10 electric buses in operation. The headway time—i.e., duration between two buses—is 4 minutes during peak hour and 6 minutes during off peak hour. The service time is 6 a.m. to 12 midnight. The capacity for each bus is 67 people. With a full charge, the buses can run travel in excess of 250 km.

**KL-Klang BRT**

KL-Klang federal highway BRT was proposed as a primary corridor in the greater KL-Klang region, connecting KL and the town of Klang on opposite sides of the region, which has a port-based economy. The project proposed to use the existing rolling stock of highway to improve the regional connectivity between KL and Klang Valley.

In the greater KL-Klang valley region, average travel time for commuters using private car between KL city and Klang has recently increased from 45 minutes to 1 hour and 20 minutes. The level of service for the main connecting federal highway (Federal Highway 2) is “F,” which is the lowest level. The traffic congestion of Federal Highway 2 makes that route unpopular, especially during peak hours. Although there is a network of other expressways from KL to Klang, Federal Highway 2 is the
only non-tolled highway. It is worth noting that the congestion is not caused by freight traffic, which generally uses the expressways that are under private sector concession agreement. The KL-Klang conurbation has a current population of 3 million, which is projected to reach 10 million by 2030. The project has a trunk route of 31 kilometers, with 24 stations. The estimated ridership of the project as shown in the tender document was 600,000 per day, which is transformed as 14,000 pphpd. The main rationale of the project was to mitigate traffic congestion on the highway, by providing an attractive public transport option on the same route that would relieve users from the stress of driving and save both travel time and fuel cost.

The federal government allotted RM 1.5 billion for construction of the KL-Klang federal highway BRT project in the 2016 budget. In the tender document, the proposed PPP model was conceived in terms of operation management, asset management, and information system implementation and management. This suggests that a private sector consortium should have been formed by three different kinds of private sector companies, but that was not the case.

Both KL-Klang federal highway BRT and Iskandar BRT are planned as open systems, as opposed to Sunway BRT, which is an entirely closed system. Sunway BRT’s fully elevated dedicated bus lane works exactly like a rail track. KL-Klang BRT and Iskandar BRT are designed as at-grade projects, with much lower construction costs, and with three types of services, i.e., trunk, feeder, and direct services. Trunk service is proposed along the federal highway, with a dedicated bus lane, mostly using the rolling stock except for some stretches with an elevated bus lane as a design constraint. Feeder services would use smaller buses to connect BRT stations with neighborhoods. Direct services are a combination of both trunk and feeder services. Direct services are considered especially beneficial for Malaysia, as they offer convenience for users to directly travel from origin to destination without changing modes.

These three types of services would have used three types of buses, including high capacity cantilevered buses on the trunk route to cater to high pphpd (estimated as 14,000 for trunk route). The stations on the trunk route were proposed on the median, with the dedicated bus lane next to the median for minimum conflict with other kinds of traffic. Stations would be connected to the surrounding land uses, and with feeder buses, through elevated walkways. The crucial point of the project was to communicate how the users would commute to their origin or destination after being dropped off on the median of the federal highway. In terms of operation, the project promoters should have had interactions with current bus operators on the route to explore coordination with feeder services, in order to assure that existing operators were not threatened. Such communication has not taken place yet.
This may be moot, since the project has been withdrawn from the tender stage. Some reasons are lack of political trust of buses for the primary corridor in the region, and competition with rail—i.e., the recent launch of MR and proposed LRT line along the same route—and decision-makers’ concerns over shrinking private vehicle infrastructure. The withdrawal of the KL-Klang BRT project also raises questions about the fate of 10 other BRT corridors in the region. For a total of 12 proposed BRT corridors in the greater KL-Klang region, the total length of trunk route—i.e., dedicated bus lanes—was 214 km, and overall ridership would have been 1.8 million daily. Table 8 shows the forecasted total reduction in carbon emission only on the trunk route in 2030, assuming the twelve proposed BRT corridors are implemented.

Iskandar BRT

The Iskandar BRT project has been proposed as the main public transport project in the Iskandar region to address increasing congestion. In the Iskandar region, commutes that used to take 40 minutes to 1 hour using private cars started taking 90 minutes to 2 hours in early 2010. Lacking a public transport option, commuters were more or less obligated to use their private vehicles, This had an obvious negative impact on the region’s economic activities.

With trunk, feeder, and direct service, the BRT project will cover 80 percent of the Iskandar region. The length of the trunk route for Phase-I is 51 km. While the people of the Iskandar region would welcome LRT or rail services, there is not enough volume or density to support rail infrastructure, and the investment required for LRT was not justified.

The estimated BRT project cost is 2.5 billion, with partial federal government funding of 1 billion. The balance will have to be generated by the regional government, in partnership with private sector actors. The forecasted ridership is 7,000 pphpd. However, while the authority, IRDA, plans to develop the BRT to provide comparable service to LRT, it also proposes to upgrade part of the project to actual LRT in future. One of their significant claims, as they tackle the challenge of land acquisition for public transport projects, especially in terms of conversion from one private vehicle lane to dedicated bus lane, is that they are now acquiring land for the sole use of public transport, which could be upgraded to LRT or MRT in the future. This has a strong implication for decarbonizing the built environment.

Bus Rapid Transit and decarbonization

The section introduces three frameworks to understand decarbonization through BRT systems. They are 1) frameworks used in an
IPCC document on Transport (Sims et al., 2014); 2) a framework that shows how decarbonization can be operationalized in three ways (as derived by the study); and 3) a whole life-cycle analysis, or the “cradle to grave” approach. While the first two frameworks are discussed in detail to explore decarbonization through BRT, the third framework is not elaborated upon, due to lack of data.

**IPCC framework**

The IPCC document (2008) shows that total GHG emissions for the transport sector are the sum of four factors: system-infrastructure modal choice (i.e. urban form, transport infrastructure, behavioral choice between modes); fuel carbon intensity (i.e. diesel, gasoline, CNG); energy intensity (i.e. light duty vehicle, heavy duty vehicle, occupancy/loading rate); and activity (number of journeys, journey distance,). Table 7 shows how a BRT system addresses these factors.

<table>
<thead>
<tr>
<th>Heading</th>
<th>Sub-heading</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>System-infrastructure modal choice</td>
<td>Urban form</td>
<td>BRT system, with its flexibility of a bus system, serves Malaysia’s first mile/last mile connectivity better.</td>
</tr>
<tr>
<td>Transport infrastructure</td>
<td>BRT stations can be built within densely developed parts of city due to reduced requirement of area (as opposed to LRT or MRT). LRT and MRT stations have accessibility issues, due to their location outside the city. Transport infrastructure for cleaner fuel (such as CNG bus and electric bus) is already in place.</td>
<td></td>
</tr>
<tr>
<td>Behavioral choice between modes</td>
<td>While transferring choice users to public transport, BRT system would be in competition with rail systems. With modernized new generation of bus system, there is potential for both choice users and captive users to use bus.</td>
<td></td>
</tr>
<tr>
<td>Fuel carbon intensity</td>
<td>Diesel, gasoline, CNG</td>
<td>BRT system can use both CNG and electric buses—i.e., clean energy.</td>
</tr>
<tr>
<td>Energy intensity</td>
<td>Light duty, heavy duty, occupancy/loading rate</td>
<td>Traditional buses have lower carrying capacity than rail. However, with articulated bus and more frequent buses, BRT system can achieve as high as 45,000 pphpd, which is far more than LRT.</td>
</tr>
<tr>
<td>Activity</td>
<td>Number of journeys</td>
<td>All mass transit projects in Malaysia are developed to encourage integrated development—i.e., mass transit projects serve health, education, recreational land uses, in addition to employment needs. There are both</td>
</tr>
</tbody>
</table>
weekday and weekend trips, even to recreational centers. There is flow of people from suburb to the city (KL), and city to the suburb. This assures there will be multiple numbers of trips for varying purpose.

| Journey distance | BRT system can serve both as city-level and regional-level infrastructure. Where there is modernized rail system, BRT system has the potential to improve regional connectivity. |

Table 7. Interpretation of IPCC document on transport

Three-step framework for decarbonization

Operationalizing decarbonization through a public transport modal shift—and through the adoption of Bus Rapid Transit (BRT) in particular—can be considered in three distinct steps: reducing carbon emissions through modal shift, reducing energy consumption through improved energy efficiency, and decarbonizing sources of energy.

Step 1. Reducing carbon emission through modal shift

The first step is to reduce carbon dioxide emissions from vehicles during the operation stage, by making a modal shift from taxi, private car, and motorbike to BRT. A comparison is made between BRT and other modes of public transport such as rail. Prior studies show that private car users’ and motor-bike users’ willingness to shift to BRT varies across different contexts. For instance, as per Satiennam, Jaensirisak, Satiennam, & Detdamrong (2016), the percentage of private car users and motor-bike users willing to shift to BRT are 25 percent and 30 percent, respectively, in an Asian developing city; as per Bajracharya (2008), it is 12.2 percent and 30.9 percent in Ahmedabad, India; and for Wang et al. (2013), it is 3 to 8 percent in China, compared to 9 percent in Japan and Bogota. However, the same study shows, it is 20 to 30 percent for Australia, the Philippines, and Boston. In Malaysia, considering the current lack of sufficient public transport, the estimated potential shift from private vehicle and motorbike is on the higher side.

Table 8 displays a scenario analysis with various combinations of diesel-CNG-electric buses and trunk-feeder routes on implemented and proposed BRT corridors. It shows the reduction in carbon emission due to a shift to a BRT system from private cars and motor bikes, using various kind of cleaner form of fuels, and in various combination between trunk and feeder route, on varying timelines. The assumptions underlying Table 8 are detailed in the appendix.
## Project | Year | Scenario (combination of diesel, CNG and electric for BRT system) | Passenger-km in trunk route (Daily ridership* route length* 0.3) | Passenger-km in feeder service (Daily ridership <5,000pphpd (assumption=2000)* (number of routes for feeder service* route length (assumption=15m) * number of station)*0.3) | Daily reduction in carbon emission in Mt (or equivalent of CO\textsubscript{2} in case of GHG emission)\textsuperscript{21} |
--- | --- | --- | --- | --- | --- |
Sunway BRT | Current | Electric | 16,196 | No feeder exists | 0.98 |
| 2021 | Electric | 41,636 | No feeder exists | 2.53 |
| 2030 | Electric | 100,408 | No feeder exists | 6.10 |
KL-Klang BRT | 2021 | Diesel | 1,020,000 | 900,000 | 92.82 |
| | | All CNG | | | 97.46 |
| | | Trunk: Electric + Feeder: CNG | | | 102.20\textsuperscript{22} |
KL-Klang BRT | 2030 | Diesel | 4,080,000 | 900,000 | 256.26 |
| | | All CNG | | | 269.07 |
| | | Trunk: Electric and Feeder: CNG | | | 288.00 |
All 12 BRT corridor | 2030 | Diesel | 115,560,000 | Only trunk calculated | 6172.00 |
| | | All CNG | | | 6480.66 |
| | | Trunk: Electric and Feeder: CNG | | | 7016.80 |
Iskandar BRT | 2021 | Diesel | 2,295,000 | 1,404,000 | 145.62 |
| | | All CNG | | | 152.90 |
| | | Trunk: Electric | | | 190.40 |
Step 2. Reducing energy consumption through improved energy efficiency.

The transport sector remains one of the main consumers of electricity in Malaysia. The second step to decarbonizing the sector is reducing energy consumption through improving energy efficiency. While shifting from use of private vehicles to public transport already contributes towards reducing energy consumption (e.g. instead of 70 private cars, a single bus can transfer the same number of people), energy efficient public transport modes further reduce energy consumption: using electric buses or hydrogen fuel cell buses or even an automated rail system would consume less energy than diesel buses).

Step 3. Reducing carbon dioxide in sources of energy.

The third step to decarbonization is to remove carbon dioxide from the source of energy, which requires considering whether the type of energy used is conventional or renewable. In Malaysia, since electric buses draw electricity from a national grid that uses conventional sources of energy, the source of energy is not decarbonized.

Table 9, based on a MJB&A report (2013), evaluates diesel, hybrid electric, and CNG buses on the following criteria: efficiency (fuel economy), air quality, and climate change (carbon dioxide and GHG emission). The report is developed using cases from the United States of America. In Malaysia, instead of hybrid electric bus, electric buses are in operation; however, electric buses are in operation in only certain regions like KL, Putrajaya, and Malaka, and are operated by only few companies; hence, the percentage of electric buses is low.

<table>
<thead>
<tr>
<th></th>
<th>Diesel</th>
<th>Hybrid Electric</th>
<th>CNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency (fuel)</td>
<td>Better than CNG in</td>
<td>Higher than CNG</td>
<td></td>
</tr>
</tbody>
</table>
Table 9. Comparison of CNG, hybrid electric and diesel buses

As CNG buses are already in operation in certain regions of Malaysia, the BRT system can use clean energy, even in the absence of electric buses. CNG buses were introduced in the country in 2006 as the price of diesel went up, and many private sector bus companies opted for CNG. PETRONAS, Malaysia’s national oil and gas company, has a monopoly over CNG, and the lack of competition is a point of criticism for many.

Table 10 shows a list of companies in Malaysia that already manufacture and/or use CNG buses and electric buses. Electric buses were introduced in 2015, and Sunway BRT is one of the worldwide first BRT systems using electric buses. There are a total of 15 electric buses in operation by Prasarana, and there are plans to acquire 30 more by 2019.

Framework on life cycle analysis (LCA) or “cradle to grave” approach

The other comprehensive framework calculates carbon footprint using ISO (International Organization for Standardization) Life Cycle Analysis (LCA) from a much wider perspective (Cuia et al., 2010). An ISO LCA framework calculates GHG emissions throughout the life cycle.
(production, operation, and demolition/recycling/degradation stages), of three components of transportation: (infrastructure (e.g. road, station, charging center), vehicles (e.g. bus), and fuel (e.g. diesel).

**Infrastructure**

Assessing GHG emissions of the infrastructure component in the LCA (Life Cycle Analysis) approach indicates hard infrastructure. Infrastructure of a BRT system includes roads or dedicated bus lanes, bus stations, offices and depots, and bus charging infrastructure or stations. This approach calculates the total GHG emission throughout its life cycle (construction material, transfer of construction material to site, construction, maintenance, and recyclability). For comparison between bus and rail, GHG emissions of rail tracks and dedicated bus lanes should be calculated throughout the life cycle. A BRT system that uses at-grade design and uses rolling stock does not have to acquire an Environmental Impact Analysis (EIA) approval in Malaysia, given that there is no significant new construction.23

While it was not possible to calculate GHG emissions of Sunway BRT’s infrastructure—the only implemented project among the three cases studied—due to lack of data on quantity of construction material, evidence from other studies suggests that that GHG emissions of rail track would be higher than dedicated bus lanes, and GHG emissions of elevated dedicated bus lanes would be higher than at-grade dedicated bus lanes, where rolling stock is used.

Besides the above-mentioned LCA model, there are other ways to discuss the overall sustainability (beyond just the carbon footprint) of hard infrastructure of mass transit stations. Of the three cases discussed here, the Sunway BRT office and depot uses sustainable design guidelines in their buildings. Besides designing their buildings on sustainable principles—such as using rainwater harvesting and designing to allow natural light and air—the office complex also includes a depot where all electric buses are stationed and charged. Through the PPP agreement, Sunway Group assumes the significant expense of maintaining the depot. One main concern in using renewable energy and clean fuels is that there are not enough charging stations to meet users’ needs. From that perspective, Malaysia already has in place infrastructure both for CNG and electric buses.

While Sunway BRT stations are not integrated into their surrounding land uses, making maintenance expensive and discouraging additional ridership, by comparison Iskandar BRT proposes to not only integrate the stations with its surroundings—drawing on the private sector’s real estate expertise—but also to give ownership of stations to...
local communities, to avoid gentrification and have a sustainable financing model. Hence, instead of multinational construction companies, local communities are considered as part of the private sector.

**Vehicles**

The LCA framework calculates the GHG emissions of vehicles during their production, operation, and recycling.

**Fuel**

The fuel factor in LCA calculates the production, use, and recycling of fuel. This category also takes into consideration the decarbonization of energy sources. Table 10 compares various types of fuel.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Battery electric buses</th>
<th>CNG</th>
<th>Fuel cell</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG emission in production</td>
<td>Hybrid electric buses</td>
<td>3,655 g CO₂ per mile. [Tailpipe CO₂ emission 22% lower per gallon equivalent than diesel buses. Offset by greater fuel use by CNG bus and higher CH₄ emissions.] If leakage of fugitive methane from natural gas production were assumed to be zero, then GHG emission from CNG per mile would be 16% lower than new diesel buses. (based on Global Discussed in the context of Canada. 200% more efficient in terms of fuel than gasoline bus. If a renewable source of hydrogen is available, reduction in CO emission will approach 100%. Also tested in Orange County, California.</td>
<td>Discussed in the context of Canada. 200% more efficient in terms of fuel than gasoline bus. If a renewable source of hydrogen is available, reduction in CO emission will approach 100%. Also tested in Orange County, California.</td>
<td>3,840 g CO₂ per mile (well to wheel) [9% reduction from old diesel bus. Reduced PM and black carbon emission.]</td>
</tr>
</tbody>
</table>
**Public Transport and Bus Rapid Transit as a Tool of Decarbonization in Malaysia**

Chandrima Mukhopadhyay

Malaysia Sustainable Cities Program, Working Paper Series

© Chandrima Mukhopadhyay & Massachusetts Institute of Technology 2017

<table>
<thead>
<tr>
<th>Reduction in emission during operation</th>
<th>Zero emission</th>
<th>Only 5% less CO(_2) emission than diesel bus. However, reduce NO(_2) emission to great extent.</th>
<th>Reduces 90 tons of GHG emission than a gasoline powered bus per year.(^{24})</th>
<th>(243.8-17.7~216.1) gm of CO(_2) per passenger km for private car to diesel bus.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial investment for vehicle (USD)</td>
<td>800,000</td>
<td>525,000</td>
<td>1.3 million</td>
<td>500,000</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Lower than CNG. Saving of $39K per year for a lifetime of 12 years over diesel bus, excluding health benefit cost.</td>
<td>Higher than electric buses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance travelled per charge</td>
<td>Different companies may offer different solutions. This is one ground of competition. For Sunway BRT, BYD’s buses can run for more than 250 km per charge.</td>
<td>300 miles on single charge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy efficiency/ Fuel efficiency</td>
<td>Higher than CNG and diesel on medium and slow speeds.</td>
<td>Approximately 3000 g CO(_2) eq per mile. CNG reduces emission of particulate</td>
<td>200% more efficient than diesel bus. Will reduce 800</td>
<td>Approximately 3500 g CO(_2) eq per mile.</td>
</tr>
</tbody>
</table>
matter (PM$_{10}$), which is harmful (most health effects from PM$_{10}$). tons of CO$_2$ emission in its life-time of 12 years.\textsuperscript{25}

Approximately 1500 g CO$_2$ eq per mile.

| Fueling cost | $10,500 annually (lower maintenance than CNG) | $27,000 annually | $5.00-$8.00 per kg. $0.71-$1.14 per mile. Stations are built to be scalable, up to 10 times. |
| Source of electricity/fuel (GHG emission) | In Malaysia, recharged from national grid, which draws electricity from conventional sources. | Near zero emission | From electricity, 100% renewable energy source. |

Table 10. GHG emissions of vehicles and fuel\textsuperscript{26}

**Co-benefits of BRT system**

Besides decarbonization, there are multiple co-benefits to establishing a BRT system. These include directly mitigating traffic congestion; improving safety;\textsuperscript{27} improving urban mobility (in the case of Malaysia, this requires retrofitting urban stock and transforming human behavior); triggering spatial transformation away from car-centric development and towards a more walkable and liveable built environment; and improving public health through both improved physical activity and reduced air pollution.

As an intermediary mass rapid transit system between rail and bus in Malaysian cities and regions, BRT has the potential to achieve all of these co-benefits. A BRT system that uses the rolling stock of highways and expressways to introduce a dedicated bus lane will mitigate traffic congestion by shifting private vehicle users to bus, enabling them to travel their normal route in a much shorter time. Both by converting motorbike users—who are especially prone to fatal accidents—and by providing
dedicated bus lanes, the system will improve highway safety. In fact, studies have confirmed that BRT users on dedicated bus lanes are safer than they are in their private vehicles. BRT will improve mobility through feeder buses overcoming the first mile last mile connectivity; for instance, in the greater KL-Klang Valley region, there are many areas with low-rise sprawled urban form, where there is no public transport option. Also, the low density of the Iskandar region makes it a poor location for investment in rail infrastructure. As opposed to rail, BRT that uses the existing rolling stock of highway can trigger urban transformation along the route from a car-centric nature to a more human-centric nature—one that is more walkable and liveable due to the flexibility of buses. More pedestrian activity, reduced emissions, and reduced air pollution due to implementing BRT: all would contribute to improved public health.

Policy recommendations/discussion

From a policy maker’s perspective, the KL-Klang federal highway BRT has been viewed as a compelling project, on a corridor that has both the highest traffic volume in the region and one of the lowest levels of transport service.

Future planning will have to take into account the challenges on this route. There is no right of way available for extending the private vehicle infrastructure. The best way to design the project would be to convert one private car lane to a dedicated bus lane—a change that would require strong political leadership to, first, convince the private car users to share the road with buses; and second, to convince them to make the shift to public transport. The project also would generate wider benefits, by providing a much superior service to the existing bus users on the same route. In addition, a BRT system on this route could trigger spatial transformation on the car-centric highway in the long run. All in all, the proposal in the public transport master plan for the greater KL-Klang region to convert a 214 km stretch of one private vehicle lane (two-way) to sole use by public transport bus lane is notable and laudable.

As shown in Table 8, by using electric buses only on the trunk route, KL-Klang federal highway BRT can reduce 102.20 Mt CO₂ emissions daily, assuming that 20 percent of riders shift from private cars and 10 percent of riders shift from motor bikes (considering ridership as 225,000 while SPAD’s forecast is 400,000) by 2021—in other words, shortly after the proposed implementation. Moreover, for all 12 BRT corridors in the greater KL-Klang region, 7016.80 Mt CO₂ emission would be reduced daily by 2030 if electric buses were used on the trunk route. While it is also possible to use CNG buses on the trunk route, using CNG
buses for feeder services would reduce additional carbon emissions. Again, Table 8 provides a detailed breakdown of carbon emissions reduction for various combinations of fuel and routes, and at different time scales.

The overall BRT corridor network in Greater KL-Klang region can be developed over time, at low cost, and can generate wider benefits. Where there are rail systems in place, future users will have the option of either rail or bus, and many may prefer the bus at times due to its flexibility.

Iskandar BRT will support the Iskandar region’s goal to shift to a Low Carbon Society. Beyond public transport, a BRT system would deliver a more walkable and livable environment in the long run. In particular, the flexibility of a bus system that allows users to get off the bus at designated stations on the private car route itself would support Iskandar region’s low carbon footprint aspirations by making the use of public transport more convenient. Because BRT can be made competitive with LRT in terms of comfort, Iskandar BRT has been approved by the government—a decision that seems well taken. But because local people have voiced concerns about the proposed bus routes being too long and not adequately aligned with travellers’ needs, the project’s proponents should update their plan on the BRT route and stations to reflect current traffic flow and demand. For example, three trunk routes of Iskandar BRT are radial. It may be important to add additional routes connecting those radials to serve the existing demand, which is possible since BRT has the flexibility to be changed even during construction.

In short, BRT is seen as an effective short-term strategy to mitigate severe traffic congestion. Even though there could be feeder service connections between radial routes, such service will not be immune from congestion. Rather than develop Iskandar’s Puteri Harbour first—which will take time to reach a full occupancy rate—a better strategy would be to first develop the stretch with existing traffic.

While the Sunway BRT model is not considered the ideal model for BRT in Malaysia by either federal and regional planners, it is likely that Sunway Group will be a front-runner in competitions for future bids for BRT projects as they have technical expertise and experience in implementing such projects. For any future such projects, the PPP contractual agreement must incorporate greater public sector control in the design phase; otherwise, the private sector concessionaire will have the authority to make design decisions that may limit the project’s capacity to generate wider benefits. For the KL-Klang BRT project, the tender required private sector concessionaires to assess demand on their own while submitting a bid, and also to generate revenue from fares. Placing the demand-risk burden on private sector concessionaires is opposed by
many regional development authorities, who argue that since public transport is a social obligation, it should be the federal government’s responsibility to bear the demand risk. That risk should not be passed on to private sector, they argue, in part because private players may not be in a position to mitigate it. Given the challenges of realistic risk assessment, it is difficult to convert risk assessment into project cost.

In terms of project financing, previous cases show that a BRT system should be planned using a business model that addresses the project’s whole life cycle. The maintenance phase, in particular, incurs heavy costs that depend on several factors, such as the number of buses, the maintenance of new generations of buses, the hiring and compensation of well-trained bus drivers, and so on (Filipe & Macário, 2013). Planners must also examine governance and finance issues when looking at maintenance of feeder services, and when defining the relationship between trunk and feeder services. For instance, while MRT feeder bus operators are currently demanding a fare increase from RM 1 to RM3—thus creating a political issue—fare integration between BRT main service and feeder services is an alternative. This means that the fare for both main/trunk and feeder service should be integrated, allowing passengers to travel on both services with the same ticket. It would allow the authority to share revenue generated from the mass transit project with the feeder service; and help to reduce the captive nature of taxis being used as feeder service.

The energy efficiency of feeder services can be improved by using CNG buses (which are already in place to some extent) and flexible service, where the number of trips is reduced if there are no passengers. Federal funding, even in part, is essential in order to assure political willingness and leadership for BRT systems. If PPPs must be used as tools to deliver public transport, the public sector partner should negotiate the risk-versus-return component carefully with the private sector partner, as public infrastructure also generates revenue for the public sector.

The proposed plan for Iskandar to form multiple partnerships with various private sector actors (e.g., real estate developers and systems engineers), and adjusting the PPP model to their context (rather than adopting mere “good practices”) is commendable. Financing for PPPs always involves series of interrelated contracts. One crucial point is to coordinate between various kinds of contracts. A contextualized PPP model would ensure that the public sector is not bankrupted in the event of another financial crisis.
Conclusion

In Malaysia, BRT should be conceptualized as an intermediary system between rail and bus, which will help policymakers view BRT as a less expensive alternative to rail. When assessing BRT’s impact on decarbonization, assumptions should be made based on ridership of a rail system and energy efficiency of an electric bus or CNG bus. Considering the sprawled urban form and low density of cities and regions in Malaysia, policy makers should aim for a high demand corridor—instead of a high-density corridor—during the initial stage of planning and designing public transport projects. BRT stations in Malaysia should include facilities similar to LRT stations, especially to attract choice users. Mass transit projects that bring large investment should generate wider benefits, and aim for wider urban transformation (Mejía-dugand et al., 2012). Future studies on public transport and BRT in Malaysia may explore such dimensions as the correlation between automated vehicles (currently rail, and bus in the future) and energy efficiency, use of Intelligent Transport Systems in improving efficiency of public transport modes, and the role of big data.
Acknowledgments

I would like to acknowledge the MIT-UTM Malaysia Sustainable Cities Program for supporting the research, which included a one-semester stay at Universiti Teknologi Malaysia and an additional semester at the Department of Urban Studies and Planning, Massachusetts Institute of Technology. I am grateful to all my interviewees from the government (SPAD, Prasarana, Iskandar Regional Development Authority, MIROS, Highway Planning Unit, City councils in the greater KL-Klang region) and non-governmental sectors (Transit Malaysia and Opposition party), and users and non-users of public transport, who kindly took out time for the study. I am thankful to my research assistants from UTM and UNITEN, without whose help I would not have successfully conducted fieldwork. I am grateful to faculties from UTM who helped me with their experience and contact. I am thankful for research help received from Sharon Lin. I would especially like to thank the MSCP team, and particularly Jungwoo Chun, for help with research and in reading drafts of the paper.

References


https://doi.org/10.1080/13504509.2010.490657


Appendix: Assumptions for ridership composition calculations

Traffic volume and composition of two points on federal highway 2 (Source: Highway Planning Unit)

Two points of data on KL-Klang federal highway 2: B806 and B807.
B806: 222,575 (Total in 16-hours); 18,923 (peak hour); 62%, i.e., 137,996 for private car; 27%, i.e., 60,095 for motor bikes in 16 hours.
B807: 260,288 (Total in 16 hours); 23,716 (peak hour); Private car 72%, i.e. 187,407 in 16 hours; motor bike 20%, i.e., 52,057 in 16 hours.

From prior studies
25 percent private cars moves to BRT and 30 percent motorbikes moves to BRT (Average of all data available). However, the shift is 20-30 percent of private cars in Australia, where there were limited public transport options.

Assumptions for the study
KL-Klang BRT: (Private car: 35% of current private car volume. (optimistic, considering there is lack of public transport now) of 187,407 ~ 65,592). (Motor bike: 40% of 52,057 ~ 20,822). The study considers the numbers to calculate reduction in carbon emission with immediate effect. Highway Planning Unit considers 1.9 percent of annual growth to forecast their traffic volume, which is adopted to forecast increase in ridership of BRT system too, considering the project is effective.

Composition of BRT system ridership: 20 percent of BRT users were using car before for trunk route. 15 percent of feeder service users were using car before. 10 percent of BRT users were using motor-bike before. Due to unavailability of data on passenger’s trip, 0.3 is used as multiplying factor to calculate passenger-miles or passenger-kms.

To calculate reduction in emission due to modal shift:
243.8 gm of CO2 per passenger km for private car to Electric bus, no emission
(243.8-17.7~ 216.1) gm of CO2 per passenger km for private car to diesel bus
(216.1*1.05~ 226.905) gm of CO2 per passenger km for private car to CNG bus (CNG buses emit 5 percent less than diesel bus)
119.6 gm of CO2 per passenger km for motor bike to electric bus, no emission
(119.6-17.7~101.9) gm of CO2 per passenger km for motor bike to diesel bus

(101.9*1.05~106.995) gm of CO2 per passenger km for motor bike to CNG bus (CNG buses emit 5 percent less than diesel bus)
Notes

1 https://www.itdp.org/library/standards-and-guides/the-bus-rapid-transit-standard/the-scorecard/
2 http://www.fdot.gov/transit/Pages/Accessing_Transit_2017_Trainings_Registration.pdf
3 https://www.itdp.org/the-brt-planning-guide/
4 The percentage of current private car users that would shift to using BRT is different than the percentage of BRT users that move from private car use. In considering decarbonization potential, it is important to define the optimum composition of the shift from private car and motor-bike passenger miles to BRT using the most efficient fuel composition (electric bus and CNG) and assuming trunk and feeder service, and ways to minimize the captive behavior of taxis (such as tariff integration). See the appendix.
5 ASEAN report (2016)
6 Filipe and Macario (2014)
7 National Land Public Transport Master Plan
8 Newspaper account, as reported by the government and tender documents
9 BRT ridership in greater KL=Average 10,000 pphpd (range of 5000 to 25000 pphpd) and 12 BRT corridors
10 Since the ridership forecast is optimistic, reduction calculated based on actual ridership is low.
11 The percentage share of modal shift from private car and motorbike from existing traffic volume varies according to mode. Here are the assumptions based on prior studies: 35% from private cars and 30% from motorbikes.
12 The trunk route of BRT system is a closed system, with a dedicated bus lane, and restricted access of other vehicles and even other operators’ buses to encourage rapid movement.
13 The approximate number is 80,000-100,000, based on media reports. There are 300,000 daily commuters who walk across the border.
14 According to one interviewee, there is a Chinese company interested in investing in LRT in the Iskandar region. Considering there is a Chinese-Malay development dynamic in Malaysia, and it is also a question of public-private dynamic in investing on public infrastructure, it will be interesting to see if the Iskandar region opts to decline federal government’s financial support to implement the BRT system.
15 It was also claimed that Sunway Group lobbied with the government to acquire higher FAR for their other properties during the construction stage of Sunway BRT, which would be illegal in a concessionaire agreement.
16 The Highway Planning Unit uses a rating system of A to F, where A shows no congestion and free flow with low traffic volumes and high speed, and F shows extreme congestion, unacceptable congestion, stop-and-go traffic, and forced flow.
17 Here is a composition of traffic volume at BR607 on federal highway 2. 16-hour traffic (260,288), peak hour (23,716), cars and taxis 71.8%, vans and utilities 5.1%, medium lorries 1.6%, heavy lorries 0.6%, buses 0.3%, motorcycle 20.7%.
18 Sims et al., 2014
19 To adjust for trip length, the route length is multiplied by 0.3.
20 This is only an assumption. The number of feeder services for each station varies depending on the catchment area.
21 For electric bus: 243.8 gm per passenger km for private car; 119.6 gm per passenger km for motor bike. For CNG bus: reduction in PM pollutants by 1058 tonnes per annum as compared to diesel bus.
22 Well to wheel GHG emission (eq CO₂) 5% less than new diesel bus. (MJB&A, 2012).
It should be noted that the Highway Planning Unit from the Ministry of Works in Malaysia is already working to “green” the country’s highways through the choice of the construction materials it uses.


http://blog.ballard.com/how-can-fuel-cell-buses-reduce-co2-emissions


Malaysia has a higher rate of fatal accidents on road than other countries.

Many accidents take place as the buses move from the right lane to the left lanes near the station, intersecting with private vehicle traffic in that process. As private vehicular traffic declines, so too should these accidents.

In order to not to be too optimistic about ridership, the assumption on ridership is moderated. Forecasted ridership of 7,000 pphpd is also converted to 225,000 daily ridership.

In general, mass transit corridor projects, especially BRT corridors, are designed to transform the urban form (density, skyline) of the corridor in the long run. Urban transformation remains a wider benefit generated by the project, with a vision of “city-image” by architects and policy makers.