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## **Sustainable Smart Transportation System: Through the Lens of a Smart City in an Emerging Country**

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### **ABSTRACT**

Environmental and social sustainability continue to challenge urban development agendas, especially in emerging markets. Past literature on the topic of smart, sustainable cities has focused relatively less on developing countries – however, during the transient phase, such economies undergo several stages of development which this paper endeavors to investigate. The goal is to define key dimensions essential for evolving existing urban sites into a sustainable ecosystem. In this context, this study puts forward a framework consisting of five pillars: Scalability, Connection, Availability, Productivity, and Environment (SCAPE) to guide the implementation of sustainable cities in developing and tropical countries.

*Keywords:* Smart city, sustainable development, Malaysia.

### **INTRODUCTION**

Over the past decades, rapid economic development and migration of the population in search of better economic opportunities have led to the intensification of urbanization. This has led to the sprawling of urban townships, including ‘urban-ghettos’ globally. Urban townships and cities consume about 70% of the world’s resources and are key contributors to carbon emissions due to unsustainable energy use and poor development planning (Bibri & Krogstie, 2017).

Legacy transportation systems such as motorways and railways are still prevalent, especially in many of the emerging countries. Many of the cities have seen a surge in population due to economic migrants from rural localities, which have put pressure on existing infrastructure. Meanwhile, the dated transit services and facilities in these cities are also in urgent need of refurbishment. Lack of reliable, safe, and cost-effective transportation services are common deterrents that ultimately lead to the reliance of the urban population on personal motor vehicles.

As a response to the challenge of urban viability, the concept of smart, sustainable cities has been a key thrust in the United Nations Sustainable Development Goals (SDGs)- Goal 3 on ‘Good Health and Wellbeing’ and Goal 11 on ‘Sustainable Cities and Communities, that are two principal considerations directly linked to new urban development practices (United Nations, 2015). This global call-to-action provides an impetus for local policymakers and administrators to formalize the transition of legacy municipalities into smart, sustainable, and commutable cities.

Extant literature has largely focused on smart cities in developed countries, with limited empirical research from the developing countries (Walravens *et al.*, 2019; Larasati *et al.*, 2018). One of the research gaps that has been raised is the lack of coverage on the design and performance of smart cities conceived in emerging markets. This study investigates the evolution of brownfield developments toward sustainable urban transportation ecosystems, as well as the unique challenges/issues arising from such transitions.

The case study employed in this report concerns Sunway City Kuala Lumpur (SCKL) in Malaysia. Sunway City is a medium-sized township with a population of 200,000 residents (Sunway Group, 2020), developed from reclaimed quarry land in the 1980s, and has progressed from a low-to-medium-density residential cluster into a smart city. Sunway City’s private-sector-led development and administration have allowed its various transport sustainability programs to be mobilized quickly, though on a self-contained scale. These provided a research opportunity to assess both the adoption behavior as well as the performance

of key initiatives conceived in such a context. The specific initiatives investigated are the electric Bus Rapid Transit (BRT) system, elevated canopy walkway, and the smart parking system employing automation and sensor technology.

## LITERATURE REVIEW

There is extant literature on the attributes of a smart city and sustainable transportation (Bibri & Krogstie, 2017). Towards this end, many studies have assessed the smartness of the transportation systems (Garau, Masala, & Pinna 2016), sustainable urban mobility (Torrise *et al.*, 2020), environment (Nikitas *et al.*, 2021), and quality of life (Lionjanga & Venter, 2018). In this context, compared to the traditional urban bus, BRT has contributed to the transformation of urban transport by providing higher quality service in terms of better reliability, reduction of travel and waiting times, and improved user experience (Diaz *et al.*, 2004; Nadeem *et al.*, 2021). The implementation of BRT also reduced the emissions of air pollutants in the city (Bel & Holst, 2018).

Elevated canopy walkways, aside from facilitating movements, also protect pedestrians from air and noise pollutions (King *et al.*, 2016) and bad weather conditions (Yang, Qian, & Zhao, 2016). The elevated walkways have also been appropriated as an observation deck and a safe space for using the phone and chatting (Wang, Siu, & Wong, 2016).

The smart parking system established in San Francisco was able to reduce congestion (Krishnamurthy & Ngo, 2020). A similar system also reduced parking cruising by about 50% (Millard-Ball, Weinberger, & Hampshire, 2014). These studies highlighted that smart parking reduced parking congestion as vehicles cruising to look for available parking spots is one of the components of congestion. Apart from congestion, time is wasted, and circling for a parking lot burns fuel and increases carbon emissions.

In this study, five key pillars for a sustainable smart city have been identified based on the dimensions of sustainability encompassing environmental, economic, and social. The five pillars are Scalability, Connection, Availability, Productivity, and Environment (SCAPE) and are discussed below.

These smart city “SCAPE” dimensions are meant to provide a standardized qualitative metric to accommodate all developmental initiatives. Naturally, each undertaking will have its own emphases - targeted initiatives focused on a pinpoint resolution may contribute to one particular dimension; others may be enablers designed to facilitate interaction and synergies between two or more dimensions.

### **Pillar 1: Scalability**

Scalability implies the city’s ability to provide good quality service with increasing demand for facilities. A city must be consciously designed to accommodate high growth potential over a long-term period without affecting its quality of service. Minimizing friction arising from the introduction of new inhabitants and activities is essential and is often reflected through modularity in building, infrastructure, and spatial planning/design. Modern developments employ mixed-use zoning and spatial spheres demarcated by hybrid roles (residential, industrial, commercial, entertainment, institutional) and incorporate low-rigidity designs that can be more easily enhanced in the future.

### **Pillar 2: Connection**

Every social and commercial activity taking place in a city relies on the interaction between its inhabitants. A city’s design/administration will either encourage or hinder specific human interactions. Considerations here encompass the physical aspects of the city-spatial and service accessibility and the non-physical -digital infrastructure, policies, and legislation. Managing these factors well is essential to promoting communal collaboration, transparency, and bonding.

### **Pillar 3: Availability**

The livability of a city often correlates with the presence of more diverse facilities and services to benefit its inhabitants. Presence and resilience are the fundamental standards for gauging performance. While disruptions are inevitable over the course of a city’s lifespan, measures must be taken to ensure the long-term standard of living remains within acceptable bounds. The enforcement of well-defined policies should be complemented by redundancy in design to allow the usability of a city’s features to be rapidly restored from adverse events.

### **Pillar 4: Productivity**

By employing the right infrastructure, services, and policies, the city should allow individual and institutional inhabitants to pursue value-generating activities more efficiently. Such facilities provide a “leverage” for users to create and consume goods/services with minimal hindrances. The nature and cost of utilizing such facilities are major indicators of Productivity. Managing both facets well allows a city to have a competitive advantage to encourage new activities and long-term growth.

### **Pillar 5: Environment**

The interaction between humans to their surroundings is another crucial dimension in a city’s livability and the quality of life of the people. Comfort, aesthetics, and quality of nature are key indicators of a city’s performance and sustainability. More modern cities employ novel means of neutralizing their resource and waste footprints through passive systems such as sustainable materials and natural heating/cooling or active systems such as resource cycling and waste treatment. To be a truly sustainable city, reducing the burden of environmental impact through air pollution from vehicles on our natural ecosystems is important.

## METHODOLOGY

This study employed a purposive sampling with a total of 50 respondents split across 16 online focus group sessions to gauge the perception on the current state of the three local, sustainable transport systems, namely, the Bus Rapid Transit (BRT), Elevated Canopy walk (ECW) and Sunway smart parking (SSP). Respondents are a combination of residents, students, and working adults at Sunway City Kuala Lumpur.

All respondents are at least high school graduates, with 48% of them having received tertiary education (diploma or higher). 20% of respondents are local to Sunway City, while the remaining 80% are regular intercity commuters. Each interview lasts for 60-90 minutes, posing open-ended questions on the perceived strengths and weaknesses of each commute system and incentivizing factors that would encourage greater usage.

Positive and negative sentiments were assigned a score of +1 or -1 and were mapped to the corresponding SCAPE dimension. The average score for each dimension would thus represent an aggregate sentiment/perception on each transport mode.

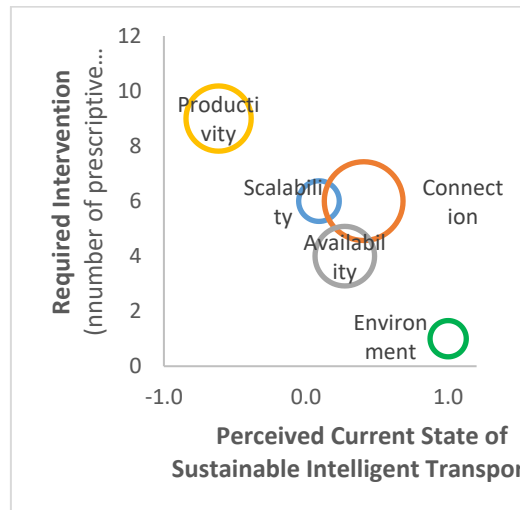
## DISCUSSION

This study synthesizes the sentiments of the respondents, and the scored excerpts are plotted into three charts indicating public perception on the three transit systems, namely the electric Bus Rapid Transit (BRT) system, elevated canopy walkway, and the smart parking system. Each chart is further segmented into the five SCAPE dimensions, thereby providing some indication of prevalent opinions concerning a particular service. The size of bubbles in each chart indicates the number of unique respondent inputs on a particular topic of discussion. Tables I, II, and III provide deeper summarized interpretations of the interview sessions.

### A. Sunway City Bus Rapid Transit (BRT)

**Current situation:** Respondents most actively commented on the Connection implications of service. While coverage and security have been considered adequate, the maintenance of stations and availability of information (e.g., maps, seasonal pricing) can be improved (see Figure1).

**Future outlook:** The strongest prescriptive feedback relates to the Productivity dimension, specifically on the higher-than-average fares charged by the BRT service relative to the distance traveled. To attract more BRT users from the lower-income strata, targeted incentives or subsidies for this group may be necessary. While most respondents compare this ratio to that of other rail services offered in the adjoining cities, it is worth noting that the service quality offered is not equal (see Table 1).



Source: This study.

Figure 1: Sunway city bus rapid transit (BRT)

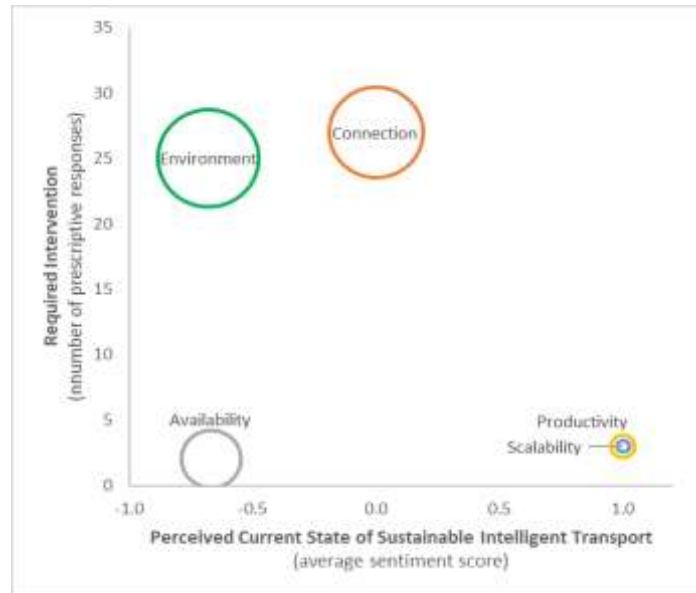
Table 1: Sunway city bus rapid transit (BRT)

Dimension	Current Perception			Proposed Improvements
	Score	Strengths	Areas for Improvement	
Scalability	+0.091	A modal shift from private to public transport facilitated by making public transport more attractive with a comprehensive plan that facilitates intermodal integration without compromising its service quality.	Increase size of bus fleet to accommodate larger, more frequent commuter throughput. Application for transit pass incentives is rather complex and time-consuming.	Improve fleet management to increase frequency of trips between hotspots during peak hours. Simplify and streamline the transit application process.
Connection	+0.450	Service coverage over key city hubs has significantly improved willingness to adopt. Station staff and patrolling guards confer a sense of safety and security to BRT users.	There is a need to educate potential commuters on incentives to offset cost of service. Faulty escalators and lifts at some stations diminish accessibility.	Use digital platforms to provide clear messages on the available incentives for alternative commuting. Introduce more stops in closer proximity to newer high-density locales within the city.
Availability	+0.273	Transit services offered by BRT have been consistently satisfactory in terms of punctuality, especially when compared to other rail lines. Overall comfort and convenience of each ride experience has been favorable, though this noticeably diminishes during peak hours.	Low turnaround for restoring faulty station equipment such as lifts and escalators; outdoor, exposed ones are especially prone to failure. BRT shuttles are often overcrowded during peak hours; some recommend skipping stops to overcome capacity constraints.	Increase size of bus fleet to accommodate larger, more frequent commuter throughput.
Productivity	-0.615	New monthly passes have significantly benefited regular users; due to BRT's high cost-per-ride, fixed payment structures provide a perceivable benefit to users. Student pricing incentives have benefited the communities of numerous local campuses; some hope for similar programs to be extended to other user communities (like office workers).	High cost of service remains a significant barrier to adoption, especially for irregular commuters. Locals who use public transport are typically price-sensitive due to their income/wealth profiles, and could not justify daily BRT use. Comparison of BRT's price-per-distance-travelled to other transit services enforces negative perception on cost.	Reduce price-per-distance of BRT fares to more closely align to other public rail services. Promote awareness of discounted passes and pricing campaigns among potential commuters through infostructure channels. Have commuter incentive programs to change commuter behavior (i.e. a mindset change)
Environment	+1.000	Reduction of reliance of personal vehicles of intracity and intercity commute, especially over longer distances, has reduced the environmental cost travel.	-	Continue to ensure environment is protected, increase number of bus fleets and incentivize commuters to use sustainable transport. Introduce vertical garden using the physical structures available

**B. Sunway City Elevated Canopy Walk**

**Current situation:** Respondents most actively commented on the *Environment* impact of the facility, closely followed by *Connection*. Overall, most users agree that protection against extreme weather conditions (often experienced in Malaysia’s tropical climate) can be improved further. Additionally, the linear layout makes traversal between specific locations challenging on foot, given the tropical climate in Malaysia. To encourage wider use of the infrastructure, especially among females, some respondents commented that improving the existing lighting during off-peak patrols will encourage high usage (see Figure 2).

**Future outlook:** The strongest prescriptive feedback relates to the *Connection* and *Environment* dimensions. Extended awnings, temperature controls, and enforced patrol frequency are the main improvements that respondents wish to see be implemented in the near future (see Table 2).



Source: This study.

Figure 2: Sunway city elevated canopy walk

Table 2: Sunway city canopy walk

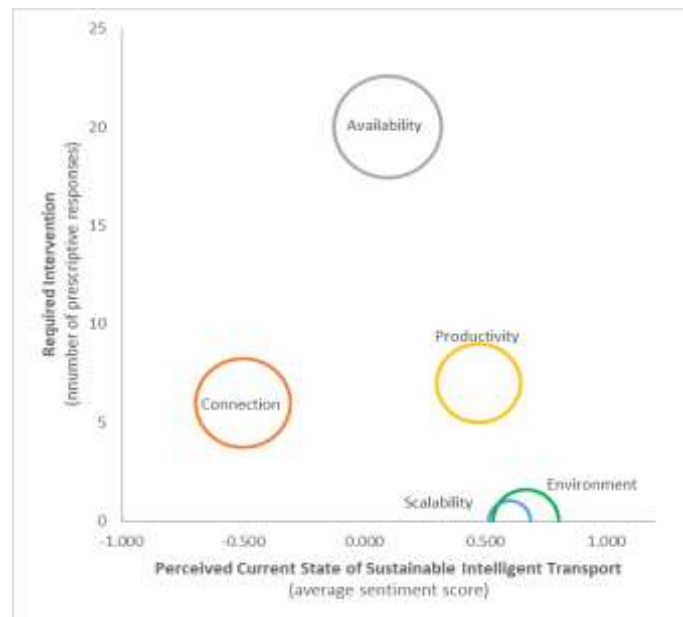
Dimension	Current Perception			Proposed Improvements by respondents
	Score	Positives	Negatives	
Scalability	+1.000	Allows intercity commuters to access key locales via mass transit system alone.	-	-
Connection	0.000	Good coverage of frequently visited hotspots, especially between campuses and commercial hubs. Safety features like panic buttons, CCTV, and guard patrols are present (but interspersed).	Reduce usability due to linear layout of footpaths requiring users to traverse large distances between specific destinations. Some major residential hotspots and campuses are too far away for practical, regular use of the Canopy Walk. Need more signage for easy navigation. Occasional low staff discipline among patrolling guards. Poor lighting. Flooring material prone to slippage, especially when wet.	Introduce shortcuts to bridge across distant a lighting points, and transform the current looped layout into a latticed one. Improve connectivity of Canopy Walk to residences and student hostels. Introduce and enforce better accountability KPIs for guard performance. Increase and standardize presence of patrols across the entirety of the Canopy Walk network
Availability	-0.667	Provides a means for pedestrians to move at a safe distance from busy roadways.	Pathways tend to become overcrowded in popular spots. Some areas are prone to leakage and drainage issues during rainfall.	Widen existing pathways near hotspots, or introduce parallel, alternative routes.

Productivity	+1.000	Provides a cost-free means of traversal between (a limited number of) high-density locales.	-	Introduce advertisements and informational banners across the Canopy Walk to increase utility.
Environment	-0.688	Provides scenic access to recreational/leisure hotspots and urban greenery. Provides (limited) protection from elements.	Common extreme weather (rainfall and heatwave) renders certain footpaths not conducive to use due to inadequate shielding/sheltering against elements.	Extend static roofing or walls to protect against extreme weather. Introduce climate control/air-conditioning at enclosed areas of the walkway. Introduce sensor-triggered weather screens that extend/retract/enclose based on prevailing weather. Introduce vertical garden

**C. Sunway City Smart Parking**

**Current situation:** Respondents most actively commented on the *Availability* dimension followed by *Connection*. Ticketless admission and payments have been agreed to be a significant boost to convenience, despite introducing some new technological barriers of entry and potential points of failure (see Figure 3).

**Future outlook:** The strongest prescriptive feedback relates to *Availability*. Respondents wish for better redundancies in the system by retaining some capacity for traditional ticketing and cash payments in case the smart parking features become unavailable/inaccessible. Some also noted intelligent navigation and capacity management to direct drivers quickly to allotted bays as an avenue for future improvement (see Table 3). Additionally, traffic feeds on surrounding motorways are also desirable. Key exits leading to specific thoroughfares can be color-coded to denote ongoing congestion, allowing users to preplan their exit route in the parking bays itself, allowing the smart parking infrastructure itself to help regulate vehicle on-boarding across the surrounding area.



Source: This study.

Figure 3: Sunway City Smart Parking

Table 3: Sunway city smart parking

Dimension	Current Perception			Proposed Improvements
	Score	Strengths	Areas for Improvement	
Scalability	+0.600	On-demand ticketing resolution via remote QR scanning reduces congestion at traditional booths.	The fundamental under-capacity of parking bays for peak volumes remains unresolved; ticketing digitalization simply shifts congestion from one point (physicals gates) to another	



			(inside the carpark, as drivers search for vacant bays).	
Connection	-0.500	Excellent coverage of payment QR codes throughout commercial venues allow for convenient, on-demand ticketing resolution. Elimination of physical queuing allows for minimal exposure or contact amid Covid-19 pandemic.	Unclear signage makes navigation in and out of parking bays difficult. Privacy and security concerns arise from disclosing linked personal financial details for electronic payments. No real-time indication of parking bay vacancy via sensors connected to Sunway lifestyle app results in drivers having to search for spots.	Integrate parking bay location intelligence infrastructure with Sunway lifestyle app to direct drivers to preallotted parking bays.
Availability	-0.667	Alternative means of payment eliminates the risk of misplacing physical tickets. Alternative means of payment reduce reliance of physical infrastructure, and their implicit bottlenecks.	Poor staff education during transition period to digital ticketing resulted in encounters demanding physical proof of payment.	Increase number of electronic payment options supported. Retain ability to receive traditional cash payments in case of system downtime. Retain capacity to receive traditional cash payments in proportion to senior citizen visitors who are more resistant to change.
Productivity	+1.000	Automated license plate scanning improves vehicle throughput and user experience. Digitalized payment options are integrated with mainstream eWallets and payment instruments.	License plate scanners can impair the smart parking system if they malfunction. Reliability of electronic payment options is inconsistent; system downtimes and poor network coverage in the car park sometimes disrupt service.	Implement temporary parking discounts to increase user traffic and by extension, encourage self-learning of new digital parking system.
Environment	-0.688	Paperless ticketing system reduces wastage.	Encourages increased use of personal vehicles	

### CONCLUSION

The performance of Sunway City's sustainable transport models within the metrics of Scalability, Connection, Availability, Productivity and Environment (SCAPE) has uncovered a combination of *technical*, *behavioral*, and *physical* strengths and areas of improvement to transform the city into a model for 'smart and sustainable green city' in the emerging world, aligned to the United Nations Sustainable Development Goals. A sound smart transportation system will lead to significant economic spillover benefits (Pradhan *et al.*, 2021).

Results from this study have important implications for cities in emerging countries in transforming their transportation systems to meet the needs of a digitally connected society. The study shows that recovery time objectives for addressing infrastructure degradation (for example, machinery repair and weatherproofing) need to be well-defined and are perceivably reliable enough to become the primary means of travel.

Behavior management is crucial in ensuring the critical adoption of sustainable transport alternatives. Targeted pricing incentives for key user communities (students, local white-collar workers) appear to be the best means of driving growth in utilization volumes. Another unexpected barrier is the resistance toward technological adoption, demonstrated by the lack of confidence of some users toward electronic payments. Hence, improved infrastructure frameworks for educating users cannot be overlooked when introducing major technological shifts to the status quo.

This study has provided the *SCAPE* framework to be validated as an overarching guideline for contextualizing developmental priorities in sustainable urban planning. Industry practitioners and policymakers should leverage these findings to systematically identify, test, and refine sustainability KPIs within the aforementioned five dimensions.

In summary, the *SCAPE* framework can be a tool to 'stress-test' the state of development of the transportation system in meeting the needs of a digitally connected society. It will provide valuable information and insights to design a smart infrastructure that will encourage seamless integration of the public transportation system and ensure it is a preferred choice of transportation for the population. This will have a significant positive spillover impact on the sustainable socioeconomic development agenda of

cities in emerging countries.

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