SUSTAINABLE URBAN TRANSPORT IN SINGAPORE: A BALANCED SCORECARD

Md. Habibur Rahman [a] and Hoong Chor Chin [b]
[a, b] Department of Civil and Environmental Engineering, National University of Singapore, Singapore
[a] Corresponding author: habibur@nus.edu.sg

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Abstract: Singapore is a city state nation with a small area of about 710 square kilometres yet a dense population of 5 million with higher economic growth and denser commercial activities. This Asian tiger nation is often recognized for its very high yet smartly maintained huge and smooth traffic flow on its urban streets. While the success and achievements of Singapore land transport case can be a role-model to follow for other cities there are still challenging areas in its urban transport without a proper address of which may hinder betterment of its sustainability in the long run. Therefore while on the one hand it is necessary to record the successful aspects and learn their root underlying factors it is also essential, on the other hand, to identify the major critical and challenging areas which may stand against its long term sustainability. In order to address these two key issues it is necessary to make a holistic evaluation of the sustainability performance of Singapore's urban transport. In the past, studies mainly focused on certain aspects while others remained ignored resulting in the lack of a balanced evaluation for urban transport of this city state. The aim of this study is to evaluate the sustainability of Singapore's urban land transport in the framework of a Balanced Scorecard. The Balanced Scorecard reviews Singapore's land transport system with a holistic framework of sustainability. Results show that the efficient institutional structure, deployment of advanced technologies, a world class land transport infrastructure system, good level of air quality, innovative approaches towards problems and strict control over private vehicles are key areas of excellent performance whereas moderate performing areas include mainly energy consumption, global carbon emission and public participation. In addition to these, major good performing areas where further improvements are still needed include service level of public transport, especially buses, congestion management, facilitation of non-motorized transport and car sharing and promotion of green vehicles.

Keywords: Balanced Scorecard; Singapore; Sustainability; Sustainable Development; Urban Transport

I. INTRODUCTION

Singapore's urban transport has been recognized as a global landmark due to its consistent success in maintaining an excessively high level of traffic through its smart operation that ensures a smooth traffic flow on its urban streets. While Singapore's success and achievements in land transport sector have been a role-model to follow for other global cities there are challenging areas without a proper addressing of which may hinder betterment of its sustainability in the long run. Therefore while on the one hand it is necessary to record the successful aspects and learn their root underlying factors it is also essential, on the other hand, to identify the major critical and challenging areas which may stand against its long term sustainability. In order to address these two key issues it is necessary to make a holistic evaluation of the sustainability performance of Singapore urban transport.

In the past, studies mainly have been focused on certain aspects while others remained ignored resulting in the lack of a balanced evaluation for urban transport of this city state. For example, in the environmental aspect, the traffic noise level of Singapore was studied by Chui et al. [1] while the life-cycle emission of road transport was studied by Rahman et al. [2]. Similarly Eugene [3] conducted analysis on energy situation in Singapore. There were studies regarding social sustainability of urban transport, e.g., Housley and Atkins [4] and Chin and Tan [5] and on economic sustainability, e.g., Chin [6]. In addition, regarding the different modes of Singapore urban transport there were studies on MRT service, e.g., Chew and Chua [7]; on freight transport, e.g., Olszewski [8] as well as on non-motorized transport, e.g., Yuen and Chin [9]. Studies have also

been conducted on different policy impacts, for example, Looi and Tan [10] studied the fare regulation impacts whereas Lau [11] conducted an analysis of the affordability of commuters. Similarly, Menon and Chin [12] and Replogle [13] studied the policy impacts of the road pricing in Singapore. These studies reviewed different aspects of Singapore urban land transport from a pool of scattered angles. While environment, society and economy characterizes three key pillars of urban transport sustainability the institutional harmony, supportive physical built environment, innovative approaches and technological deployment often act as major enablers to materialize the goals of sustainability. Without a holistic and integrated understanding it is very difficult to identify critical areas of success and that of deficiency as well as to set off policies in an aim to achieve long-term sustainability in urban transport sector. Therefore there is an imperative need of a Balanced Scorecard for the strategic performance measurement and management of sustainable urban transport, which has recently been introduced by Rahman and Chin [14].

The aim of this study is to evaluate the sustainability of Singapore urban transport in the framework of a Balanced Scorecard. In particular, the Balanced Scorecard reviews Singapore's urban land transport system with a holistic framework of sustainability. Only urban land transport is considered and air and maritime transport are excluded. However the land transport portion of air traffic operation is considered, as it is also an integral part of urban land transport. Section II of this paper summarizes the methodology of Balanced Scorecard for sustainable urban transport which has been comprehensively illustrated in [14]. Development of the scoring approach and mechanism has been described in section III. The sections IV to VII present revision of Singapore's urban transport in sequence of the indicator sets of four perspectives of Balanced Scorecard, i.e., customer, financial, internal process and learning and growth. A total of 44 indicators under a set of 10 sustainability themes were reviewed sequentially. Finally, section VIII discusses the results of this case study.

II. The Balanced Scorecard for Sustainable Urban Transport

In order to ensure sustainability in the urban transport sector, it is the starting requirement to identify the essential components of sustainability. The most widely quoted definition of sustainability and sustainable development is from Brundtland Commission [15] which states "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This definition translates the concept of sustainability into its three essential components: economic, social and environmental. The economic component ensures the continuous economic operability while social sustainability protects the inter-generation needs for people of the society. The environmental sustainability ensures consumptions through activities and processes do not exceed the ecological capacity and local and global environment is liveable for generations.

The key perspectives of the Balanced Scorecard include customer satisfaction, financial, internal process and innovation and improvement activities [16]. Although at its very initial stage the Balanced Scorecard was developed aiming mainly for use of the for-profit organizations the realization of its imperative necessity was increasingly understood and spread into non-profit and public sectors within a very short span of time and accordingly its structure was customized to suit for the needs of those organizations [17]. While in the for-profit sectors the strategic mission was mainly centred at financial achievements therefore financial perspective is placed on the top followed by customer, internal process and learning and growth perspectives, in the non-profit sector the sector's core mission and vision, rather than financial objectives drives the sector's strategy. For these non-profit sectors the mission is often to satisfy the customers rather than earning profit [17]. However realizing that in order to ensure a sustainable customer satisfaction it is also equally important to maintain a sustainable financial status, both customer and financial perspective took place on the top of the framework Although at the micro level urban transport may involve many private organizations as a sector it is essentially a public entity whose mission and vision is often to provide quality transport services to its users and at the same time protecting the environment and maintaining an operable economy. Therefore the Balanced Scorecard form for public sectors has been adopted in this study for urban transport sector.

In sustainable urban transport, the mission and vision is principally cantered at core sustainability objectives which means providing quality services to commuters in an economically viable and environmentally sustainable manner. While the economic enhancement is often targeted for the existence and survival of the sector itself the benefits of quality service and environmental protection is often realized by its customers. In other words, the objectives of economic sustainability remain embedded in the financial perspective of Balanced Scorecard whereas those of social and environmental sustainability are protected in the customer perspective. In this way the key pillars of sustainability incorporates into the Balanced Scorecard. Fig. 1 presents the framework of Balanced

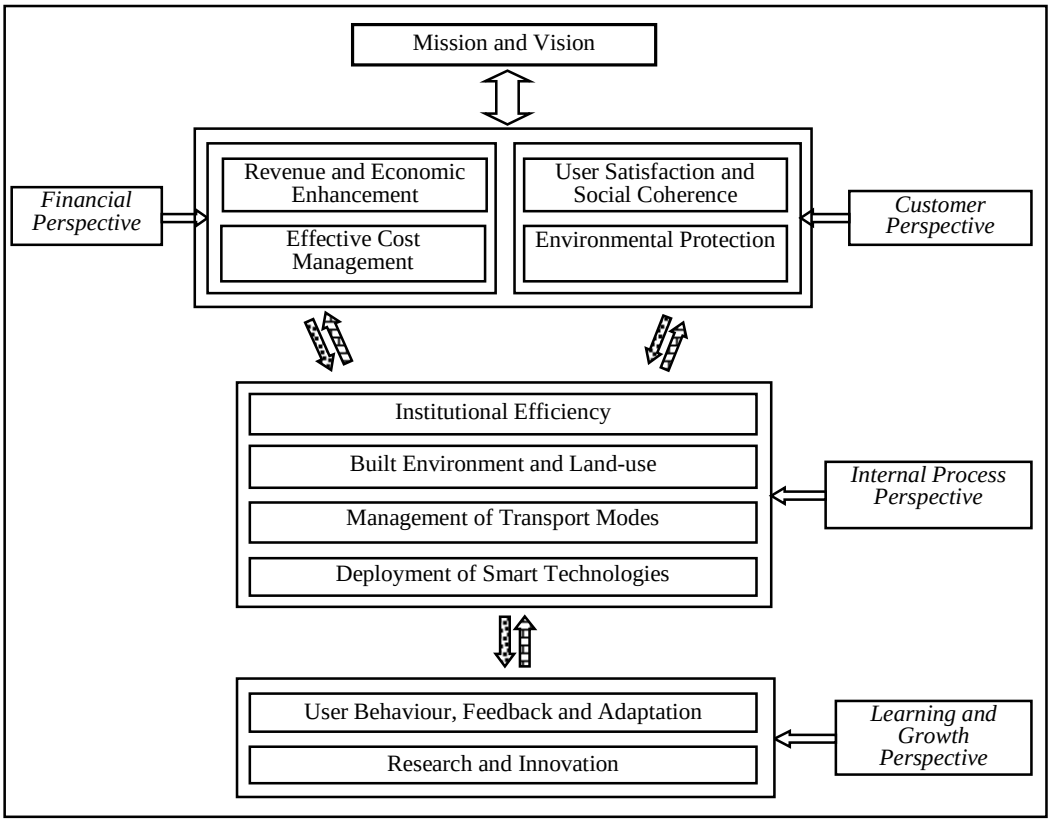

Figure 1: Framework of Balanced Scorecard for sustainable urban transport

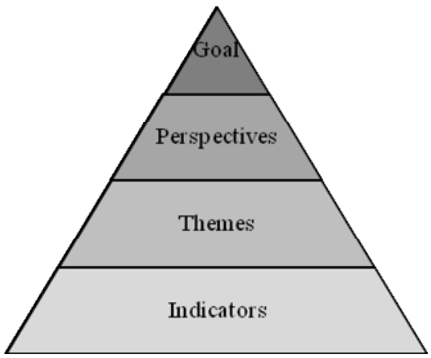

Figure 2: Directional flow of hierarchy in Balanced Scorecard

Scorecard for sustainable urban transport. As common for public sectors [17] the customer and financial perspectives are placed on the top followed by internal process and learning and growth perspectives. Comprehensive discussion on the Balanced Scorecard framework for sustainable urban transport can be accessed from [14].

Each perspective of Balanced Scorecard covers a set of sustainability themes in the urban transport sector. Furthermore, each of these sustainability themes holds a group of sustainability indicators which are significantly reflective of the strategic performance of sustainable urban transport. This directional flow of this hierarchy is illustrated in fig. 2. In the Balanced Scorecard there are a total of ten sustainability themes under four Balanced Scorecard perspectives. A total of 44 sustainability indicators constitute these sustainability themes. Table 1 enlists these essential set of indicators.

III. DEVELOPMENT OF THE SCORING MECHANISM

This section describes the scoring methodology of the Balanced Scorecard. This includes two key steps: (1) determination of the score for individual indicator and (2) aggregating the individual indicator scores to obtain aggregated score at the theme and perspective levels as well as to obtain a single score for the Balanced Scorecard.

III.1. Determination of Score for Each Indicator

In an objective to score indicators of the Balanced Scorecard a combined approach was undertaken which comprises (1) review of literatures, (2) guided questionnaire surveys and (3) expert judgements. In all cases, score was given to each of the indicators on a five-point Likert scale represented by: 1: Very poor, 2: Poor, 3: Moderate, 4: Good, 5: Excellent.

Review of literature: The comprehensive review of literature includes a review of the government policies and strategies as documented in master plans and policy books as well as government policy announcements; news articles; published works and information from relevant organization's web portals. The score was determined for each of the indicators based on subjective knowledge from literature review.

Field interview: Out of the 44 indicators in the Balanced Scorecard 19 were related to major commuter experience which are denoted by an asterisk (*) symbol in Table 1. The field interviews were conducted on these 19 indicators. A total of 71 interviewees (commuters) were interviewed out of which 24 interviews were in written questionnaire format, 4 were in a mix of written questionnaire and guided verbal questionnaire and 43 interviews were in fully guided verbal questionnaire format. The travellers were interviewed at 10 locations of Singapore out of which 3 were in CBD. Score from field interview was determined for each of the 19 indicators by averaging the scores obtained from the total number of interviews.

Expert judgement: A team of four experts consisting of professionals and academicians in the field of urban transport sustainability were interviewed for expert opinion and judgements. Score from expert feedback was determined for each of the indicators by averaging the scores obtained from four experts.

The overall score for each indicator related to major user experience was determined by averaging scores obtained from all of the three abovementioned approaches. For other indicators the overall score was determined by averaging scores obtained from literature review and expert judgement.

III.2. Determination of Aggregated Score

In determination of aggregated score, the linear additive model [18] was used in this study. One of the major difficulties in the additive model is the complexity in assigning weights to indicators. Traditionally weights are decided based on the specific scenario and needs and therefore can vary. Realizing this complexity of assigning weights Sayers et al. [19] suggests the usage of an averaging method instead of weighting and that the weighting may be left for the decision makers to decide based on their specific needs. Therefore, in this study the averaging method was adopted to determine the aggregate score. Score of a sustainability theme was calculated by averaging the scores of its sustainability indicators. Similarly, score of a perspective was calculated by averaging the scores of its sustainability themes. The aggregated score of the Balanced Scorecard was calculated by averaging the scores of all perspectives.

IV. CUSTOMER PERSPECTIVE OF SINGAPORE URBAN TRANSPORT

This section reviews the customer perspective of Singapore's urban land transport. Customer perspective comprises two key dimensions: social coherence and environmental protection. While social coherence is usually meant by the provision of transport facilities that are desirable and beneficial as well as affordable for the commuters the meaning of environmental protection is broader. This is because of the global realization of many local environmental impacts. Therefore the environmental aspect of the

customer perspective broadly involves the concerns of commuters, local communities as well as global humankind.

IV.1. User Satisfaction and Social Coherence

IV.1(a). Accessibility, connectivity and travel time: The vision of Land Transport Master plan [20] is to develop a more people-centred transportation system. As per, it was a requirement by Public Transport Council (PTC) to make direct connections linking housing estates with three major central corridors [21]. A bus service must reach within 400 meters of all developments in Singapore with few exceptions and must connect housing neighborhoods with a nearby Mass Rapid Transit (MRT) station or bus interchange. While MRT plays important role in serving major dense demanded corridors, the bus services facilitate a larger variety of trips dispersed throughout the island and Light Rail Transit (LRT) connects among few housing estates. The average trip distance for MRT (10.8 km per passenger-trip) and taxi (9 km per passenger-trip) is higher than that of bus (5.1 km per passenger-trip), as in 2009 [22]. With a higher average trip distance for MRT the average door-to-door journey time is also higher (52.2 minutes). This is followed by bus and car with the average door-to-door journey time of 42.6 and 24.9 minutes, respectively [22].

IV.1(b). Affordability: The Land Transport Master plan (2008) envisioned a more equitable fare structure based on the distance travelled, regardless of the number of valid transfers made [23]. Fares are regulated by PTC using a fare cap formula [24]. Average MRT fare is S$0.93 per passenger-trip which is similar to Tokyo, but much lower than Hong Kong, London and New York [22]. The average bus fare is S$0.70 per passenger-trip which is also much lower than those cities. The public transit fares are generally affordable [25, 26] which is further reflected in the steady decrease in the public transport affordability index over the past five years which has reduced from 5% for year 2005 to 3.9% for year 2009, leading to an annual reduction rate of 6% [27]. For the poor group, a public transport fund was set up in 2006 with contributions from the government and operators which aims to provide transitional relief for the needy to adjust to fare hikes [10]. However a recent three-day online survey conducted by Yahoo with total of 14,787 locals participated shows that 94% of the respondents are against the SBS Transit and SMRT's application for a fare increase [28].

IV.1(c). Level of service and comfort: Singapore has gained remarkable success in shaping its public transit system to a modern and high-quality operation. While MRTs represent a modern, high-comfort and high level of service public facility the modernized bus fleet provides air-conditioned comfort and reliability [22]. Service standards of buses apply in areas of reliability, maximum loading and availability of service [21]. According to the standard applied by PTC, loadings on buses must be within 95% of total bus seating and standing capacity [29]. However the lack of geographical overlap between bus operators has removed the norm of competition [30]. In addition to the crowd, boarding on buses still takes a lot of time due to on-board tapping of smart cards. The Rapid Transit System (RTS) provides less waiting time as compared to buses. Although the average maximum passenger loading on the trains is low (3.7 persons per square meter) by international standards, MRT are very crowded during the peak hours [31]. Nonetheless, the customer satisfaction with public transport facilities has improved over time, with more than nine in ten commuters satisfied with the public transport system represented by an increase from 84% in 2006 to 93.8% in 2008 [27].

IV.1(d). Safety enhancement: The road traffic crash rate in 2008 is 31.1 per 100,000 registered vehicles and the fatality rate was 45.7 per million populations [32]. The contribution of cars, motorcycles, pedal cycles and goods and other vehicles to total road traffic crashes were respectively 43.6%, 33.0%, 4.1%, and 19.3%. Pedestrians are another vulnerable road user group who account for about 28% of total road traffic deaths. Non-motorized vehicle (NMV) users (pedal cyclists, trishaw riders and passengers) are reported to account for 9.3 per cent of total killed and 5.3 per cent of total injured in road accidents in 2009 [33]. While traffic crashes are low by international standards, road safety remains a concern in the efficiency-conscious Singapore. Singapore has adopted world class traffic safety legislations and monitoring systems into the road transport network [31]. Initiatives undertaken cover a wide range of safety enhancement schemes including motorcycle safety, pedestrian safety, identification and improvement of black spot locations, installation of crash cushions at high-risk locations to reduce injury severity, ‘Enhanced School Zone’ design to improve traffic safety around schools, installation of real-time speed display signs etc. [34].

Table 1: Sustainability Themes and Indicators

Perspectives	Sustainability Themes	Sustainability Indicators
I. Customer	1. User Satisfaction and Social Coherence	a) Accessibility, connectivity and travel time* b) Affordability* c) Level of service and comfort* d) Safety enhancement* e) Social equity and coherence* f) Security enhancement* g) Employment growth*
	2. Environmental Protection	a) Impact on global environment b) Impact on local air pollution* c) Noise control* d) Sustainable waste management e) Sustainable energy consumption
II. Financial	1. Revenue and Economic Enhancement	a) Revenue enhancement b) Management of mobility and travel demand
	2. Effective Cost Management	a) Efficient cost distribution and cost control b) External cost savings
III. Internal Process	1. Institutional Efficiency	a) Institutional coverage and capacity b) Integration and efficiency of institutions
	2. Built Environment and Land-use	a) Land-use and transport integration b) Management and quality of transport infrastructure c) Management of parking facilities*
	3. Management of Transport Modes	a) Promotion of public transport* b) Control over private vehicles c) Facilitation of non-motorized transport* d) Integration among passenger modes* e) Efficiency of commercial goods transport f) Promotion of green vehicles g) Promotion of car sharing practices*
	4. Deployment of Smart Technologies	a) Vehicle emission standard b) Fuel standard c) Electronic fare collection d) Electronic road pricing e) Smart infrastructure technologies f) Smart vehicle technologies g) Advanced traveler information* h) Congestion and incident management
IV. Learning and Growth	1. User Behavior, Feedback and Adaptation	a) Awareness and education* b) Skill development and training c) Legislation and enforcement* d) Public participation* e) Leadership and political dynamics f) Adaptation with changing demographics and expectations*
	2. Research and Innovation	a) New innovations and practices b) Research and development

N.B: Asterisk (*) denotes indicators with major user-experience.

IV.1(e). Social equity and coherence: The land transport master plan envisions creating a transport system that meets the diverse needs of people [22]. The ERP system has made transport costs transparent [36] and equitable, as motorists pay for congestion costs imposed on others [22]. Under the vehicle quota system all vehicles except emergency vehicles and scheduled and school buses were subject to quota [22] which is an equitable mean as the vehicles would go to owners willing to pay the most, thus maximizing economic measures of social welfare [35]. However, Richmond [36] argues that subsidy-based contracts should be offered by competitive tender to operate low density services where costs cannot be fully recovered but social needs are served.

IV.1(f). Security enhancement: Singapore's security framework consists of three pillars: operations, capability and policy [37]. The Public Transport Security Committee (PTSC) has implemented extensive security measures at MRT stations, trains, depots and bus interchanges, including the installation of video surveillance systems and the deployment of Transit Security Officers (TSO) and police patrols at these facilities along with RTS stations and bus interchanges [38]. Tracking and traffic controls systems is in place to both detect abnormalities and provide the necessary deterrence, enhancing security at various custom checkpoints and ensuring limited and screened vehicle flows into restricted areas [37]. The Singapore Police Force has set up the Public Transport Security Command to better enhance security [39]. There are only few security violation records and insignificant security incidents. The Land Transport Authority (LTA) is strict regarding security issues. In August, 2011 LTA fined SMRT S$200,000 for lapses relating to the security breach at Bishan MRT depot [40] which is similar in nature to an earlier incident at Changi depot in May 2010 for which SMRT was fined S$50,000. In June, 2010, the PTSC initiated a comprehensive security review of the public transport network which finds a generally adequate and robust security measures for the overall public transport system [41].

IV.1(g). Employment growth: A sustainable urban transport has a role in local job creation and employment facilitation. Although a technology-equipped modern transport system adopts excessive automation thus cutting manpower requirement in its operation it can play beneficial and more impactful role in developing dispersed employment zones, facilitating job creations and meeting efficient and sustainable transport needs of employment. Singapore's LRT system is fully automated and driverless. Out of four MRT lines currently two are automated and driverless. All buses run on one man operation (OMO) principle. Singapore's MRT-tied urban structure emphasizes on linking nearest regional activity centers to facilitate both employment and commercial activity locally [36]. However redeveloping the Central Area into business districts and relocating the affected population to newer towns has resulted in a centre-based policy which has hindered the development of employment sub-centres. The fact that most jobs are located in the Central Area has resulted in a spatial mismatch [11]. The poor living in distant regions face problem of long travel times for employment in addition to problems related to job choice.

IV.2. Environmental Protection

IV.2(a). Impact on global environment: Urban transport affects global environment mainly by emitting Green house gases (GHG) from vehicles and other life cycle processes. Globally, the most significant contributor to transport GHG is carbon di-oxide (CO_2) emission which contributes to 95% of total GHG emission from transport [42]. In a 2005 estimate, the total CO_2 emission from transport sector of Singapore was 8 million tons which is 19% of the country's total CO_2 emission [43]. A life cycle GHG emission study conducted on road transport of Singapore estimated that in 2008, the total life cycle GHG emission from road transport sector is 7.8 million tons, among which operational phase and non-operational phases contribute about 55% and about 45%, respectively [2]. Climate change remains a concern for Singapore, as it has amongst the world's largest CO_2 emissions per capita [44]. The CO_2 emission per capita in Singapore is 9.2 ton while the world average is 1.3 ton only, making Singapore the top fourth carbon emitting country (according to per capita calculation). Singapore government is targeting to cut CO_2 emission by 16% of current within 2020 [45]. With its 2012 Green Plan and Climate Change strategy, Singapore is starting to take much needed climate change mitigation and prevention measures [44].

IV.2(b). Impact on local air pollution: Air pollution is fast becoming a high priority issue in the rapidly growing urban Singapore. Vehicular pollution is one of the main contributors to the state of air quality in Singapore. The air quality remains good, with the Pollutant Standards Index (PSI) remaining in the 'good' range for at least 85% of the year since 2003 [46]. Ambient concentration of most air pollutants, including sulfur di-oxide (SO_2), carbon monoxide (CO) and nitrogen oxides (NO_x) has remained within international standards of World Health Organization (WHO) air quality guidelines and United State's Environmental Protection Agency (USEPA) ambient air quality standards except for particulate matters

smaller than 2.5 microns in size ($PM_{2.5}$). Annual average $PM_{2.5}$ (21 $\mu g/m^3$) exceed USEPA standard of 15 $\mu g/m^3$ [47]. According to Inter-Ministerial Committee on Sustainable Development target Singapore plans to reduce $PM_{2.5}$ levels to 15 $\mu g/m^3$ by 2014 and 12 $\mu g/m^3$ by 2030 [46].

IV.2(c). Noise control: National Environmental Agency (NEA), Singapore has set the noise limit for residential apartments as 55-65 decibel (dBA) range [48]. The noise levels near the MRT stations are higher. According to LTA, currently the train noise is within 80-85 decibels [49]. As more trains-trips are added to MRT lines, the noise level increases near MRT stations, with SMRT receiving complaints from residents [50]. Another study [1] noted that for residents living in the high rise flats along the edge of expressways, the exposure to greater than 65 dBA was as high as 40%. It was also found that majority of the windows facing expressways were closed most of the time to keep out of the noise. In order to reduce noise level from MRT LTA has currently installed low noise-barriers near few MRT stations and planning to spread this to other stations [49]. LTA will also install tall barriers insulated with noise absorbing materials such as rock wool. These moves are expected to reduce noise by at least 5 dBA, to within 75-80 dBA [49]. The LTA is also currently embarking on an island-wide study to identify locations that require special attention to reduce noise [49].

IV.2(d). Sustainable waste management: Sustainable waste management in urban transport is increasingly becoming important from greater ecological concern. Singapore studies to use new alternative/ recycled waste material to supplement existing construction material for road pavement [24]. Currently this initiative is at the trial phase [51]. In addition, the newly implemented 'Green Rail Transit System' provides new energy saving measures in MRT Stations [52]. The regenerated energy from the braking train is either channeled through an inverter to be utilized by MRT stations or by an accelerating train.

IV.2(e). Sustainable energy consumption: Energy consumption in Singapore's urban transport is high. The energy consumption from the transport sector of Singapore is 37 kiloton oil equivalent (ktoe) per billion US$ according to 2009 estimate [53]. Among the road transport vehicles, private car contributed the most (36%) in energy consumption followed by commercial vehicles (25%), taxis (16%), buses (14.6%), RTS (4.5%) and motorcycle (3.5%) [43]. The energy consumption in Singapore is 12 ton oil equivalent (toe) per capita, which is the highest in the world according to a 2006 estimate by Energy Information Administration (EIA) [3]. Another estimate by International Energy Agency (IEA) for the same year presents a value of 6.8 toe per capita which places Singapore as the third most energy consuming country (according to per capita estimate) just after USA and Finland [3]. Both estimates present a world average value of 1.8 toe per capita. With implementation of improved vehicular technology the average petrol consumption per vehicle has only mildly decreased [54]. Nevertheless, Singapore targets to reduce energy intensity (energy used per dollar GDP) by 20% by 2020 and 35% by 2030 from its 2005 levels [46]. In the transport sector various initiatives are undertaken. A 'Fuel Economy Labelling Scheme (FELS)' was launched in 2003 which aim is to provide buyers of passenger cars with fuel economy information (showing number of kilometres per litre of fuel) at the point of sale. From April 2009, it is mandatory for car retailers to display fuel economy labels on their cars in their showrooms [55]. In addition to this, all traffic lights have been replaced by light emitting diode (LED), which demands less energy and green infrastructure and green vehicles initiatives are gradually being implemented, although it is currently in the very initial stage [52].

V. Financial perspective of Singapore urban transport

This section reviews the financial perspective of Singapore's urban land transport. The objective of the financial perspective is to provide transport facilities in an economically sustainable manner. The fulfilment of this objective requires that, firstly, adequate revenue is earned through the services and the economy is also enhanced through efficient mobility management, and secondly, the costs are properly managed and efficiently distributed as well as external costs are minimized.

V.1. Revenue and Economic Enhancement

V.1(a). Revenue enhancement: Revenues from urban transport are generated in the form of taxes and toll roads. However, the revenue goes to the government general funds and is not hypothecated solely for transportation [12]. Singapore incurred 1,716 and 1,729 million Singapore dollar (SGD) (S$1 = US$0.80) of revenue collection in 2010 from vehicle quota premium and motor vehicle related taxes, respectively, the total of which holds 1.0% of total gross domestic product (GDP) and 8% of total government operating revenue [56]. The annual revenue from toll-roads in the form of Electronic Road Pricing (ERP) is about 100 million dollars [57]. The logistics and transport contribute 8% to GDP [8]. To purchase a vehicle in Singapore, owners pay a hefty sum comprising import duties, registration fees and a Certificate of Entitlement (COE) [58]. Further, vehicle usage imposes road tax and ERP, which also

serve as a fund raising source [59]. While annual operating cost of ERP system, as of 2003, was about S$16 million, revenue was five-times (about S$80 million) [36]. An analysis conducted by Willoughby [60] for the road transport sector for a period of 1961-1993 revealed that road revenues always were at least three to four times road expenditures. Apart from these, the bus operators are also reported to enjoy high profits [30]. SMRT and SBS Transit have returns on equity (ROE) of at least above 15% and for SMRT it has been above 20% in most years while, in contrast, the median ROE for a Singapore a listed company is about 9.5%.

V.1(b). Management of mobility and travel demand: Urban mobility is a key component of economic development. A good TDM has helped Singapore's economic growth [36]. Travel demand is increasing over years. In 2004, the number of daily journeys made was 8.9 million, which increased to 11 million in 2008 leading to a 5.5% yearly increase. It is forecasted that in 2020 this figure will reach 14 million [22]. Vehicle population is also increasing. The total number of road motor vehicles in 2000 was 692,800 which have increased to 945,800 in 2010, leading to an annual increase of 3.2% [22]. However, the public transport modal share has however fallen from 63% in 2004 to 59% in 2008 [27]. Average speed during peak hours in expressways and arterials are 62.3 km/hr and 28 km/hr in 2010 [22]. To ensure efficient mobility, the optimal speed threshold has been set as 45 km/hr on expressways and 20 km/hr at arterial roads [24]. The government has set out plans to increase the public transport mode share [27]. While Vehicle Quota System (VQS) controls the ownership of vehicles ERP helps in reducing the usage thus manages congestion in central business district (CBD). Singapore's housing estates are developed in a way that includes own shopping centers and easy connection to nearest regional centers in an aim to reduce both number and length of motorized travel.

V.2. Effective Cost Management

V.2(a). Efficient cost distribution and cost control: Total transport expenditure is handled by national government (central). While government bears expenses related to the infrastructural development (e.g., construction of MRT system, roads etc.), commuters pay for operating cost and operators extract efficiency dividends within the fare structure and service standards approved PTC. In the fiscal year 2010, the total expense in Singapore's urban land transport was 4,653 million SGD, which is 1.5% of the country's GDP, of which 4,186 and 467 million, respectively, are distributed for the development and operation purposes [56]. In the last decade more efforts have been made to increase RTS infrastructural capacity rather than the road system. Over the period 2002-2009 the MRT length has increased from 89.4 km to 118.9 km leading to an annual increase rate of 4.2% [22]. The LRT length has been increased even at a higher rate of 20.5% from 7.8 km to 28.8 km. However the length of roads has increased from 3150 km to 3355 km over the same period with a slower annual growth rate of 0.9%. Overinvestment in a rail system (LRT and MRT) has been accompanied by underinvestment in bus-system development thus depriving service efficiency that goes to diverse and low-density commuter ends [36]. Cost-cutting often has become the priority of the operators rather than experimenting with innovative services solutions. As an example of cost-saving innovations, bus operators invest in fleet management systems which enhance the efficiency of operations thus reduce cost while only less effort is placed that can bring service efficiency to the end user [36].

V.2(b). External cost savings: External cost savings mainly include cost savings from reduced congestion effects and accidents. The total cost of road traffic crashes in Singapore is about S$610.3 million for year 2003 which is 0.3% of GDP [6]. The cost per traffic fatality is S$1.273 million while that of a serious injury and a slight injury is S$163,000 and S$12,000 respectively [6]. However, there is no estimate on the cost of congestion in Singapore. In an aim to reduce congestion, Singapore government employs both ownership and usage restriction on vehicles through mainly deployment of VQS and ERP, respectively. These have helped ensure that at least 95% of the expressways and arterial roads are kept congestion-free during the peak periods in recent years [27]. To reduce congestion in the MRT during the morning peak and along certain stretches various efforts are undertaken including modification of certain MRT stations to accommodate the addition of new platforms and railway tracks, increasing MRT fleets at certain stretches, extension of rail networks and addition of new MRT lines, upgrading of signaling system to increase MRT frequency and reduce waiting times [27]. On the other hand, Singapore government's initiatives to improve road safety majorly include identification and improvement of black spot locations, installation of crash cushions at high-risk locations to reduce injury severity, 'Enhanced School Zone' design to improve traffic safety around schools, increasing motorcycle and pedestrian safety, installation of real-time speed display signs, installation of Platform Screen Doors at MRT stations above the ground to promote safety of commuters [34].

VI. INTERNAL PROCESS PERSPECTIVE OF SINGAPORE URBAN TRANSPORT

This section reviews the internal process perspective of Singapore's urban land transport. The internal process perspective ensures that the sustainability goals are achieved through the successful management and processing of a pool of internal enablers. These enablers majorly include institutional efficiency, supportive built-environment and land-use, effective modal management and deployment of smart technologies.

VI.1. Institutional Efficiency

VI.1(a). Institutional coverage and capacity: The Ministry of Transport (MoT) is the principal regulating authority of Singapore transport. Over years, Singapore has made numerous changes in the ministries overseeing urban transport [61]. Under the Ministry of Transport, LTA is the key regulatory body for Singapore's urban land transport which spearheads land transport development in Singapore and plans, implements, manages and delivers urban land transport services. While land-use and transport planning and integration works of LTA are coordinated with various agencies under the Ministry of National Development, e.g., Urban Redevelopment Authority (URA) the environment and pollution related works are coordinated with agencies under MEWR, e.g., NEA. In Singapore, PTC, linked to LTA, is set up to regulate the public bus and rapid transit network in areas such as fares and service standards [61]. The Road Safety Engineering Unit of LTA is responsible to ensure good and sound road engineering practices, enhance road safety, and work with other agencies involved in road safety, e.g., Traffic Police under Ministry of Home Affairs. In security management LTA coordinates with Singapore Police Force. In 2004, the government established the PTSC [37] to identify weaknesses and gaps in the security system and implement solutions.

VI.1(b). Integration and efficiency of institutions: The existence of a single-layer government system in Singapore has promoted effective integration and efficiency among organizations [36]. For example, the URA which is responsible for planning is linked effectively to the Housing and Development Board (HDB) and the LTA in order to produce the conceptual integration of land use and transportation in Singapore. Singapore has an efficient institutional structure for transportation. The model adopted in Singapore is that whenever the need arises, an inter-ministry committee is set up to coordinate the different agencies involved in the program. While the mission and vision are formulated by LTA, there is involvement of both public and private sectors in an objective to better implement the vision with desired efficiency and effectiveness. For example, while government builds and maintains the infrastructural facilities, the operations of RTS, buses and taxis are left to the private sector.

VI.2. Built Environment and Land-Use

VI.2(a). Land-use and transport integration: Singapore is a densely populated city state with a successful track in integrated land use and transport planning. Singapore's land use and transport planning were consistently constrained by the small land area and therefore an optimal balance and integration among those were required [61]. The first strategic development plan was made in 1971 which aimed to decentralize population by developing residential blocks distant from CBD and connected through roads, expressways, and MRT lines. Later, the revised concept plan of 1991 [62] further decentralized economic and commercial activities by developing regional and sub-regional centers around MRT stations. Employment centers, industrial estates, business parks, and commercial centers were located near residential areas which reduced the people's need for travel, at the same time, resulted in a better utilization of the MRT network. For a better integration, a hierarchical system with well-defined roles for each transport mode was also designed. While MRT serves the long-haul travel, LRT and buses provide feeder services to connect areas in housing states to MRT stations. Those strategic plans not only restricted the development of urban sprawl but also reduced the number and length of trips of commuters [31]. Apart from this, the integrated bus interchanges link to almost all forms of surrounding public facilities, e.g., shopping malls etc. along with easy connection to MRT stations and taxi facilities [63].

VI.2(b). Management and quality of transport infrastructure: Singapore maintains a world-class land transport (road and rail) infrastructure. Roads occupy 12% of the total land space in Singapore. In general, the roads, RTS network and other traffic facilities are modern and equipped with latest technological innovations. Currently the total length of MRT and LRT are 118.9 and 28.8 km and there are 73 and 33 stations, respectively [22]. In year 2009, the length of Singapore's expressways, arterials, collector roads and local access roads were 161, 627, 521 and 2046 km, respectively contributing to a total road network of 3355 km. The density of roads in Singapore is 4.7 km per square km which is almost double than Hong Kong but 2, 2.5 and 3.5 times less than London, New York and Tokyo, respectively [22]. The number of flyovers, vehicular bridges and vehicular underpasses or tunnels is 114, 213 and 28, respectively. There are a total of 2080 traffic lights. In late 1998, the beginning of ERP era,

there was a total of 33 ERP gantries which has doubled in a decade to 66 in 2009 leading to a higher annual growth rate of 6.5% [22]. These gantries are installed in the CBD, outer ring roads and few expressway locations.

VI.2(c). Management of parking facilities: For parking in Singapore, there are both parking buildings and surface lots. These parking facilities are available both at residential and commercial premises. In order to better manage the parking spaces in the CBD area the smart parking guidance system is in place, which displays real-time information on available parking spaces thus ease finding available parking facilities and reduce unnecessary circulating of traffic within that area [34]. In order to encourage public transport in the CBD area, there are park and ride facilities. Currently Singapore has about 40 major public transport nodes with park and ride sites (about 5000 parking lots) where motorists can park their vehicles and take public transport to travel to the CBD [31]. Similarly most of the MRT stations and bus interchanges have bicycle parking facilities that encourage commuters to use bicycles from the housing estates to public transport nodes. To curb the illegal overnight parking of heavy vehicles along public streets, Vehicle Parking Certificate (VPC) has been introduced in 1994 [64]. Recently, to ease the shortage of parking lots near residential premises, HDB has planned to add 5,000 additional lots in over 100 car parks in the next three years [65]. Smart gantry systems are also being installed at housing estate's multi-storey car parks to refrain unauthorized season parking. Despite these initiatives it has been reported by residents that they are still lacking with demanded parking spaces [66].

VI.3. Management of Transport Modes

VI.3(a). Promotion of public transport: Public road transport is served mainly by buses and taxis and rail transport by MRT and LRT. Singapore's two bus operators currently operate a fleet of 3,394 buses on about 339 bus routes [22]. There are 7 private taxi companies with a total fleet of 24,300 taxis. On road, public vehicles share only a small portion of road vehicle population with a total of 16,300 buses and 26,000 taxis in 2010 which share only 1.7% and 2.8%, respectively, of the total vehicle population. The number of public vehicles is increasing over years, but with a lower growth rate than private cars [22]. On the other hand, RTS network in Singapore consists of MRT and LRT. The current 159 km long RTS network in 2010 consists of 4 MRT lines (73 stations) and 3 LRT lines (33 stations). At present, Singapore's RTS density is 31 km per million persons which is similar to Hong Kong but slightly lower than Tokyo and New York and almost half of London [22]. Buses dominate the public transport ridership with 3.06 million daily trips in 2009 out of a total 5.84 million constituting a 52% share. In the same year the daily average ridership of MRT, taxi and LRT are 1.83 million (31%), 0.86 million (15%) and 0.09 million (1.5%), respectively. However, compared to road transport, the RTS ridership has increased at much higher rates over the period 2002-2009 [22]. The government's policy is to increase AM peak modal share on public transport from 59% in 2008 to 70% in 2020 [67]. Recent policies to improve and promote bus services include peak hour bus lanes, full day bus lanes, priority at signalized junctions, and mandatory give way to exiting buses from bus bays. To meet future demand, the MRT network has been planned to be doubled to 278 km by 2020. Despite the government investment in rail systems, bus systems are seen as the responsibility of bus-operators, and the lack of adequate service attention often forces commuters to taxi or private automobile modes [36].

VI.3(b). Control over private vehicles: With about 598,000 cars and 148,000 motorcycles on road, private vehicles dominate the road vehicle population with 63% and 16% share for cars and motorcycles, respectively in 2010 [22]. Compared to some mega cities of the world, Singapore's car density is low. Singapore has 10 cars per 100 people which are almost half than New York or Tokyo and a quarter than London. However, it is slightly higher than Hong Kong [22]. Singapore's car population has increased at an annual rate of 4.2% over the period 2000-2010 while this it is 1.15% for motorcycles and scooters. Singapore practices aggressive policies in controlling private motorization [13]. The control over growth of private motorization is mainly done through applying economic measures to control both ownership and usage. In controlling ownership, Singapore maintains a sustainable rate of growth (about 3% per annum.) of its vehicle population by vehicle quota system (VQS) policy since 1990. Recently the vehicle growth rate is set to 1.5% per annum to ensure long term sustainability [68]. On the other hand, in controlling usage, the road pricing approach is practiced which discourages use of expressways and main arterial roads towards CBD during peak hours to prevent congestion [59].

VI.3(c). Facilitation of non-motorized transport: Singapore is promoting cycling and pedestrian walkability. At the central level, cycle routes and parking facilities are planned both for commuting and recreational purposes [69]. In order to encourage commuters to cycle from housing estates to public transport nodes currently most of the MRT stations and bus interchanges are equipped with bicycle parking facilities. MRT and buses now also allow foldable bicycles on board during off-peak periods.

To improve connectivity of cycling park connectors are cycle-routed. By 2014 seven towns of Singapore will have dedicated cycling paths [70]. LTA maintains well designed footpaths, sheltered link ways, overpasses and underpasses over the whole island to provide pedestrians a comfortable and conducive walking environment between residential, commercial and institutional buildings and transport nodes, as well as serving as connections between the various transport modes themselves. Pedestrian overhead bridges are sheltered. Pedestrian crossing is facilitated by dynamic electronic displays [71]. Among some key hurdles for cycling in this city state include the limited land area that does not permit building cycling tracks over the island and lack of adequate cycle lanes from the beginning. In addition, walkways need to be widened to facilitate both bicycle and pedestrian movement and fitted with rain shelters to be useful in adverse weather conditions.

VI.3(d). Integration among passenger modes: To ensure more seamless and convenient for commuters, there has been a deliberate move towards integrating rail and bus services through coordinating network, physical facilities, fares, information and time-scheduling and enhancing accessibility and interconnectivity. MRT stations are closely linked to bus stations through well designed walkways for the convenience of commuters. Some MRT stations are also equipped with taxi stands and bicycle parking facilities. A common ticketing system in the form of a universal fare card named 'EZ-link' is in use on both trains and buses. To further improve transfers by removing the current fare penalty, a distance based through fare structure has been implemented recently. A centralized bus network planning integrates the bus operations.

VI.3(e). Efficiency of commercial goods transport: Freight movement involves export, import and transhipment goods as well as local freights in Singapore. Government supports for e-logistics [8] and smart technologies are employed in operations along with usage of Singapore's smart road infrastructure and connectivity. Commercial goods vehicles constitute 16.7% of the total road vehicle population in Singapore with a total of 157,500 vehicles in 2010 [22]. Out of the total commercial goods vehicles light goods vehicles (LGV), heavy goods vehicles (HGV), very heavy goods vehicles and goods-cum-passenger vehicles comprise 103,200 (65.5%), 35,100 (22.3%), 14,200 (9%) and 5,000 (3.2%), respectively. Over the period 2000-2010 the number of these vehicles has increased slowly with an annual growth rate of 1.5%, while the total vehicle population growth rate is 3.2% for the same period. LTA, SLA and other government agencies coordinate among themselves for issues relating logistics and transport [72]. Road Traffic Acts are periodically reviewed to streamline and enhance road freight logistics. The introduction of online portal 'LTA.PROMPT' has increased the efficiency of application process for movement of special vehicles [72]. Congestion effect has been found to be a crucial issue in the efficiency of commercial goods vehicles as it often carries sensitive goods and timely and predictable delivery is highly important [8].

VI.3(f). Promotion of green vehicles: Green vehicles using alternative fuels and propulsion technologies emit less pollution than conventional petrol and diesel vehicles. These vehicles are often powered by compressed natural gas (CNG), electricity, hydrogen or hybrid (combination of conventional and green fuel) technologies. The usage of alternative fuels in road transport of Singapore is still at the initial stage. Recently, only 0.3% of buses are CNG-driven; about 1% of cars use alternative fuels (petrol-electric and petrol-CNG). However about 10% of taxis are now driven by bi-fuel CNG [22]. To encourage more green vehicles, Singapore has introduced Green Vehicle Rebate (GVR) scheme in 2001 which offers an offset on their registration fee of about 40% and 10% of open market values, respectively, for cars and motorcycles [73]. The new initiatives in the Electric vehicle (EV) test-bedding program involves examination of infrastructure requirements, new business models arising from EVs and to identify industry development opportunities [52].

VI.3(g). Promotion of car sharing practices: Car sharing is beneficial from congestion, pollution as well as social and economic perspectives therefore regarded as a sustainable means of transport. For a city state country like Singapore, a good public transport coupled with effective car sharing practices can be a long-term sustainable move for urban transport [2]. Car sharing is practiced in Singapore and is becoming popular as the ownership of car is rapidly moving beyond the capacity of citizens [74]. Currently three car sharing companies are operating in Singapore. To users, car sharing provides the services of a car without few most common problems: high cost of owning, parking problems, insurance, repairs, etc. The cars from these companies are available in few housing estates. In addition to this, many organizations have their own cars for shared transportation purpose of their employees. Some mass traffic generators, e.g., shopping malls, commercial complexes, schools etc. also have their own shuttle services to be used for shared transportation purpose of clients and students. There is a need to further enhance the culture of car sharing practices through government planning, initiatives and subsidization [36]. HOV lanes need to be introduced which can also potentially encourage car sharing practice in Singapore.

VI.4. Deployment of Smart Technology

VI.4(a). Vehicle emission standard: Singapore employs stringent emission standards for registration of vehicles in order to reduce the emission level thus curbing local air pollution and global warming effect [75]. From January 2001, the previously adopted Euro I emission standard was replaced by the more stringent Euro II emission standard for all petrol and diesel vehicles in Singapore. In addition, in order to reduce $PM_{2.5}$, all new diesel vehicles are required to comply with the Euro IV emission standard with effect from October 2006 [76]. From July 2003, all new motorcycles and scooters had to comply with CO and hydrocarbon (HC) emission standards. To measure the emission levels and energy efficiency of vehicles the Vehicle Emission Test Laboratory (VETL) is in operation since 2009. Singapore government looks for even more stringent emission policies. All taxi fleets will be Euro IV compliant by 2014. Compliance of buses to Euro IV is in progress and all buses will be Euro IV compliant by 2020 [24]. However, due to dimensional inconvenience, the usage of catalytic converters on motorcycles is limited which needs to be addressed to reduce emission from this mode [2].

VI.4(b). Fuel standard: The two major pollutants in petrol and diesel fuels are lead and sulphur. To reduce the emission from burning of these fuels, Singapore has phased out lead from all fuels in July, 1998. For petrol fuels the current maximum sulphur content is 0.05% which has been planned to reduce to 0.005% by end 2012 [75]. For diesel fuels, Singapore has already set the maximum sulphur content at stringent 0.005% since December 2005 [75]. However there are still some old vehicles on Singapore roads which are not stringent Euro IV compliant thus contributes more to particulate emissions. In order to address this government has initiated a trial in 2010 on the use of Diesel Particulate Filter (DPF) on those pre-Euro IV diesel vehicles.

VI.4(c). Electronic fare collection: Smart fare collection increases the efficiency and accuracy of transport transactions and enhances commuter travel experience. The revenue collection system in Singapore is equipped with smart technologies. These technologies include not only public transportation on-board and off-board fare payment, but also parking charge payments [34]. The contactless tap-and-go fare card named 'EZ-link' facilitates smart payment of fares in all public transport modes including buses, MRT and LRT. The recent upgrade named 'Symphony for e-Payment (SeP)' of that smart card handles payment for other usages like ERP, parking and payment at many other retail outlets.

VI.4(d). Electronic road pricing: Vehicle usage is controlled by electronic road pricing. The ERP scheme makes use of roadside communication system to interact with the on-board units within vehicle to deduct the relevant congestion charges [59]. Each driver is required to keep a charging device, into which a smart-card is inserted and from which charges are deducted. The ERP system is flexible enough to allow for variation of the charges by time of day, location, vehicle type and traffic condition. The ERP scheme has resulted in reduction in traffic flow at the charging points and it is assumed that this has translated to a reduction in travel demand and hence potential improvement in transport efficiency. The next generation of the ERP system named 'ERP II' will remove physical gantries and implement a distance-based congestion charging through the use of Global Positioning System (GPS) technology [34].

VI.4(e). Smart infrastructure technologies: Singapore's expressways are equipped with a smart incident management system called Expressway Monitoring and Advisory System (EMAS) [34]. In addition to this, recently intelligent road studs are installed at 17 major intersections. All MRT stations are equipped with video surveillance systems, smart ticketing systems and electronic display of real time train arrival information. Traffic signals are fully automated. Some smart traffic signal technologies include Green Link Determining (GLIDE) System, transit signal priority (i.e. B-signal) for buses, Green Man Plus (GMP) technology, countdown timers and audio signals to aid the disabled etc. Apart from these, Singapore has speed cameras at 45 road locations and red light cameras at most major intersections. About 280 advanced surveillance cameras called J-Eyes operate at major signalized intersections [34]. Singapore's parking system is also equipped with smart technologies. These technologies include smart parking guidance system in CBD, smart park gantry systems at housing estate's multi-storey car parks, Vehicle Parking Certificates etc. [66]. Currently LTA is launching a trial on the use of Closed-circuit Camera Television (CCTV) systems near potential road sides to curb street parking [77].

VI.4(f). Smart vehicle technologies: Singapore is highly advanced in its intelligent road vehicle systems. Cars, taxis and public buses are equipped with global positioning satellites, sensory technologies and mobile networks [78]. In addition, that rail system in Singapore is seen as a symbol of a high-tech 'Smart Singapore' with automated LRT and MRT vehicles. The full LRT system and part of the MRT network is fully driverless. The on-board fare collection system is fully electronic. Smart security technologies are also installed in vehicles.

VI.4(g). Advanced traveler information: Online integrated traffic and transit map systems (e.g., TransitLink, OneMap etc.) provide travelers with transit alternatives and the multi-modal journey planner portals of SBS, SMRT and LTA provides the best routes for travelers with flexibility of choices. Real-time traffic information is also available on ONE.MOTORING portal. The public transport travel advisor provides pre-board information on arrival timings. Information on bus arrival times can be available through internet, SMS and electronic display panels at selected bus stops and MRT station platforms. Currently a smarter traffic prediction tool is being developed for better predictions of arrival timings. For taxis, a smart taxi booking system is in place, where passengers can book through the use of internet, short message service (SMS), or phone. A common telephone number is also available for easy all taxi booking facilities [79]. In buses and RTS facilities, the on-board display provides real-time information on next stops and routes. While TrafficScan uses data from taxis equipped with GPS to predict average travel time along roads the EMAS and J-Eyes collects information on incidents and congestion and broadcast this information to travelers through LTA web portals, variable message signs and in-vehicle devices [34].

VI.4(h). Congestion and incident management: The ERP system acts as a congestion management tool that aims at reducing congestion through financial measures by using smart technologies. In order to predict congestion, the 'TrafficScan' uses data from taxis equipped with GPS to predict average travel time along roads. In addition, the EMAS and J-Eyes system collects information on incidents and congestion and broadcast this information to travelers through LTA web portals, variable message signs and in-vehicle devices [34]. This smart information management system helps in the fastness and efficiency of post-accident recovery works as well as decision on alternative routes to avoid congestion.

VII. LEARNING AND GROWTH PERSPECTIVE OF SINGAPORE URBAN TRANSPORT

This section reviews the learning and growth perspective of Singapore's urban land transport. The objective of the learning and growth perspective is to identify the areas the of internal process perspective that need further update, improvement and enhancement through the practice of managing user behavior, ensuring user participation and feedback and adapting with dynamic changes and needs as well as conducting cutting-edge research and innovation.

VII.1. User Behavior, Feedback and Adaptation

VII.1(a). Awareness and education: Awareness building mainly involves environment, safety and security and sustainable traffic attitudes. The necessary awareness is often deployed through web portals, information booklets, consultation and education, on-station and on-board displays etc. In order to build environmental awareness, LTA and NEA work closely with other partners to educate fleet operators and vehicle owners on causes of excessive emissions and other environmental issues [76]. To raise safety awareness, Traffic Police organizes various safety and education campaigns. Every year, Traffic Police in collaboration with other agencies develop a myriad of public education outreach programs primarily targeting vulnerable road users. Trade associations, non-government organizations, and various private companies also play a vital role in organizing safety campaign and awareness programs [5]. In raising security awareness among commuters PTSC broadcasts on-board videos regarding potential security risks in MRT services and raises commuter vigilance and security awareness [37]. Information on potential security hazards and effective reporting are also written inside public buses that attracts commuter attention. Equipped with a simulated train station, a theatre, multimedia stations and other innovative gadgets the LTA Gallery also provides awareness among commuters on sustainable traffic attitudes.

VII.1(b). Skill development and training: Skill development involves creating capabilities and skills among different groups with an aim to achieve sustainable urban transport. Especially it targets the operators and drivers, whose roles have greater impacts on an efficient, safe and secured transport system. NEA coordinates with LTA and other organizations to conduct regular trainings sessions and dialogues with fleet owners, such as the taxi and public bus companies, lorry and bus owners' associations, to update them on various environmental measures [76]. Under the Ministry of Home Affairs, SPF regulates the driving skill development and issues driving license. At present, three private driving schools are authorized by SPF to provide driving training and conduct driving tests [80]. Security officers are adequately trained before being employed. PTSC provides them necessary trainings [39]. Necessary security exercises are also conducted to test inter-agency response against multiple attacks [37]. The web site (www.safejourney.sg), run by PTSC, provides tips and help develop necessary skills among students on how they can help fight against terrorism through maintaining vigilance [81].

VII.1(c). Legislation and enforcement: In Singapore, all vehicles undergo mandatory periodic inspections at certain inspection centres to ensure that vehicles meet emission requirements [76]. In addition, visible smoke emitting is an offence in Singapore. NEA carries out daily random checks to take enforcement action against these vehicles. Smoke emitting vehicles are sent to a vehicle inspection centre for a chassis dynamometer smoke test (CDST) [75]. If the vehicle fails at CDST the owner will be fined and required to repair the vehicles before the vehicles are allowed on the roads again. To reduce the rate of accidents, safety legislations are in place. For example, for bus operators the accident rate must be less than 0.75 per 100,000 bus-km per month [29]. In addition, motorcyclists are legislated by mandatory helmet laws and day time headlight laws and taxi riders must wear seat-belts. To improve security, legislations are placed and regularly modified by PTSC [37]. However there are also evidences of violation. For example, buses do not always stop in the bus bays provided for them; instead they stop on the left lane, because they find it difficult to get back into the main traffic stream after stopping [12]. Red light cameras were installed in 1986 as a smart traffic enforcement device. Speed cameras are also placed at strategic locations to enforce against speed violations.

VII.1(d). Public participation: The government policy is to develop a people-centered land transport system [20]. In general, feedbacks are sought from the general populace on major transport policy issues. However, there has been only little involvement of public opinion in planning, design and decision making which is mainly dominated by a cult of technical expertise where the public are often seen young children by a parent and too immature to provide useful advice [36]. Regarding service effectiveness of public transportation, it is argued that, the fall in modal share in public transport is due to its failure to effectively meet a range of dispersed destination travel needs which has occurred from the government's more reliance on technical expertise rather than involving public in planning [36]. Public interest groups are also not very active as they have seen the historical success of the government and therefore often prefer to trust on government policies [36]. Nevertheless, the government is becoming aware of the willingness of people to be more vocal. Therefore community relations departments and feedback units are established and public meetings are hold to explain and advocate policy and to engage in focus group discussions. Engaging the community to transport decisions is one of the government's priorities [51].

VII.1(e). Influence of leadership and political dynamics: Leadership and politics has a direct influence on urban transport sustainability since major decisions and strategies are adopted by the government. Singapore has been benefitted from a single-layer government system that supports effective coordination and implementation of strategies. The government is constituted by a corruption-free, highly paid and meritocratic leadership [82] that has led to the successful strategic decisions in the past years. Therefore there has been only little opposition seen in government's power to conduct technical studies and to implement the consequent policies [36]. The government adopts an approach genuinely engaged with problem-solving and in a climate of technical analysis, professional ethics and public service. Singapore is not affected by the hitches of poor, unstable and frequently changing political leadership which, in many of its neighboring countries, are often noticed to adversely impact on major transport decisions and implementation processes. However due to poor public involvement there has been seen gradual increase in opposition which is more clearly reflected in the last election.

VII.1(f). Adaptation with changing demographics and expectations: The Land Transport Master plan [20] envisions that the transportation developments are to be progressive to accommodate the new aspirations of the citizens in a sustainable manner. The demographics of Singapore are changing rapidly. Ageing population is one of the increasing concerns. In 2009, Singapore's elderly (65 years and above) population was 320,000. By 2030, elderly population is projected to triple to nearly a million (20% of residents) [67]. For elderly and physically disabled group of people, bus stops and MRT stations as well as buses and trains are being redesigned to have wheelchair accesses [22]. Recent initiative to improve the travel experience for these groups of people include audio-alert crossing facilities for hearing impaired and thickened road crossing lines for vision impaired. Green Man Plus (GMP) scheme allows elderly pedestrians more time to cross the road [83]. There are also increased user expectations [67]. Despite harsh measures to control the vehicle population growth, the demand for vehicles, especially cars, remains high. People often emphasis on personal efficiency and convenience rather than broader social benefits that influences them to use private cars instead of public modes since the latter is not direct, doesn't provide door-to-door services and there is need for transfers [36].

VII.2. Research and Innovation

VII.2(a). New innovations and practices: In order to best benefit from the technological advancement of rapidly changing world, it is imperative to innovate as well as smartly respond to new innovations. Singapore ERP is the world's first electronic congestion charging system [25]. It is the only

country in the world that has been able to control the growth rate of its vehicle fleet by imposing a heavy tax burden and purchasing permits on automobile owners [84]. In addition to its innovative approaches to problems, the ambitious country also have a good track in learning from global benchmarking practices to further improve efficiency. As smart traffic enforcement device red light cameras were installed in Singapore in 1986 following few other countries, e.g., Netherland, Israel and some European countries. Road signs in Singapore also closely follow sign regulations of UK with some local amendments. In controlling air pollution both WHO and USEPA criteria's are followed. However in order to increase the modal share of public transport more innovative measures may be needed.

VII.2(b). Research and development: The Singapore approach is to put high emphasis on research and development. Research studies are conducted at the university, college and school level under different degree programs; at the agency level (e.g., LTA, NEA, URA etc.) as well as at individual level. Currently there are two universities which offer degree programs in transport studies. Apart from these, there are also inter-disciplinary research opportunities in this area. Currently, LTA's Singapore Urban Transport Solution (STARS) focus on more innovative solutions in areas of transport systems optimization, transport telematics, integrated user experience and environment and energy [85]. The Urban Mobility Initiative (UMI) set up at National University of Singapore (NUS) seeks to find innovative solutions for a sustainable, smart and safe urban transport for future Singapore.

VIII. RESULTS AND DISCUSSION

This section discusses the results of the Balanced Scorecard for the sustainable urban transport in Singapore. The score of each sustainability indicator as obtained from review of literature, field interview and expert judgement as well as overall score for each sustainability theme has been presented in Table 2. These results have been discussed in subsections VIII.1 – VIII.4. In Fig. 3, the scores of the ten sustainability themes as obtained from review of literatures, field interview and expert judgement as well as overall theme scores are presented. From Fig. 3, it is noticeable that there are significant differences in performance among different sustainability themes. Among ten sustainability themes five have performed 'excellent' and the remaining five have performed 'good'. The 'excellent' performing sustainability themes are 'revenue and economic enhancement', 'institutional efficiency', 'built environment and land-use', 'deployment of smart technologies' and 'research and innovation'. From Fig 3, it is also noticeable that scores obtained from literature review and expert judgement are more consistent; however, out of the six themes related to user experience five were underrated by users as compared to both literature review and expert judgement. This may reflect that users are keen for even more efficient and sustainable transport system. The overall scores of perspectives are presented by different circle-sectors with varying radius where the radius denotes the overall score of that particular perspective. Among the four perspectives one has performed 'excellent' and other three has performed 'good'. The 'excellent' performing perspective is 'internal process' (score: 4.5). The 'customer', 'financial' and 'learning and growth' perspectives have scored 3.8, 4.2 and 4.4, respectively. This has resulted in an aggregated performance of sustainability of Singapore urban transport as 'good' (score: 4.2). The following sub-sections discuss important findings of this case study.

VIII.1. Customer Perspective

The overall performance of the customer perspective is 'good' (score: 3.8). However it is the worst performing among all four perspectives, which is mainly due to under performance of its sustainability theme 'environmental protection' (score: 3.5). The performances of the two sustainability themes of this perspective are discussed in the following sub-sections.

VIII.1(a). User satisfaction and social coherence: The sustainability theme 'user satisfaction and social coherence' has performed 'good' (score: 4.1). Among the indicators of this sustainability theme the 'security enhancement' has shown the highest performance 'excellent' (score: 4.8). This is mainly due to Singapore's aggressive approach towards technological advancement in a wide range of security measures as well as its proactive approach towards managing potential security hazards. All other indicators have performed 'good'. The 'employment growth' indicator has the worst performance (score: 3.5). This is mainly due to the incapability of creating adequate distant job centres other than CBD which has resulted in a spatial mismatch and at the same time has lead to increased traffic load in the CBD. Although 'accessibility, connectivity and travel time' indicator has performed 'good' (score: 4.0), the frequency and waiting time of buses is still high but accessibility and connectivity aspects are relatively better. Among other indicators the 'affordability', 'level of service and comfort', 'safety enhancement' and 'social equity and coherence' have scored 4.2, 3.7, 4.3 and 4.3, respectively.

Table 2: Scores of Indicators and Themes

Perspectives	Themes	Indicators	Scores			
			Indicator			Theme Overall
			Review of Literature	Field Interview	Expert Judgment	
Customer	User satisfaction and social coherence	Accessibility, connectivity and travel time	4.0	3.8	4.1	4.1
		Affordability	4.5	3.7	4.5	
		Level of service and comfort	3.8	3.3	3.9	
		Safety enhancement	4.4	4.1	4.4	
		Social equity and coherence	4.3	4.2	4.3	
		Security enhancement	4.8	4.7	4.8	
		Employment growth	3.5	3.4	3.6	
	Environmental protection	Impact on global environment	2.3	n.a.	2.5	3.5
		Impact on local air pollution	4.5	4.0	4.6	
		Noise control	3.8	3.3	4.0	
		Sustainable waste management	4.5	n.a.	4.6	
		Sustainable energy consumption	2.4	n.a.	2.5	
Financial	Revenue and economic enhancement	Revenue enhancement	4.6	n.a.	4.8	4.5
		Management of mobility and travel demand	4.3	n.a.	4.3	
	Effective cost management	Efficient cost distribution and cost control	4.1	n.a.	4.3	4.0
		External cost savings	3.7	n.a.	3.8	
Internal Process	Institutional efficiency	Institutional coverage and capacity	4.7	n.a.	4.7	4.8
		Integration and efficiency of institutions	4.8	n.a.	4.8	
	Built environment and land-use	Land-use and transport integration	4.2	n.a.	4.3	4.5
		Management and quality of transport infrastructure	4.7	n.a.	4.8	
		Management of parking facilities	4.6	4.4	4.7	
	Management of transport modes	Promotion of public transport	4.2	3.8	4.3	4.1
		Control over private vehicles	4.8	n.a.	4.8	
		Facilitation of non-motorized transport	3.7	3.5	3.8	
		Integration among passenger modes	4.3	4.1	4.5	
		Efficiency of commercial goods transport	4.5	n.a.	4.5	
		Promotion of green vehicles	3.9	n.a.	3.7	
		Promotion of car sharing practices	3.5	3.4	3.5	
	Deployment of smart technologies	Vehicle emission standard	4.6	n.a.	4.8	4.7
		Fuel standard	4.8	n.a.	4.8	
		Electronic fare collection	4.6	n.a.	4.6	
		Electronic road pricing	4.9	n.a.	4.9	
		Smart infrastructure technologies	4.8	n.a.	4.9	
		Smart vehicle technologies	4.7	n.a.	4.6	
		Advanced traveler information	4.6	4.5	4.7	
		Congestion and incident management	4.1	n.a.	4.2	
Learning and Growth	User behavior, feedback and adaptation	Awareness and education	4.4	4.3	4.6	4.3
		Skill development and training	4.6	n.a.	4.6	
		Legislation and enforcement	4.6	4.6	4.7	
		Public participation	2.9	2.6	3.5	
		Influence of leadership and political dynamics	4.5	n.a.	4.6	
		Adaptation with changing demographics and expectations	4.4	4.2	4.5	
	Research and innovation	New innovations and practices	4.7	n.a.	4.6	4.5
		Research and development	4.3	n.a.	4.4	

VIII.1(b). Environmental protection: Overall performance of this sustainability theme is 'good' (score: 3.5) and it shows the worst performance among all ten sustainability themes. This has been mainly due the 'poor' and 'moderate' performance of 'impact on global environment' (score: 2.4) and 'sustainable energy consumption' (score: 2.5) indicators, respectively. The CO_2 emission per capita in Singapore is 9.2 ton, which is excessively high compared to the global standard making Singapore top fourth carbon emitting country in the world (per capita calculation) and transport sector is the second largest carbon emitting sector of this city-state. The energy consumption per capita in Singapore is also consistently high compared to other global mega cities. The indicator 'sustainable waste management' has performed 'excellent' (score: 4.6). Regarding the indicator 'noise control' (score: 3.9) there is a need to reduce the noise level near road-sides and MRT stations. The best performing indicator under this sustainability theme is the 'impact on local air pollution' which has performed 'excellent' (score: 4.7). This indicates that Singapore has a very good level of local air quality.

VIII.2. Financial Perspective

The overall performance of this perspective is 'good' (score: 4.2) and it has obtained third position in performance among four perspectives. The performances of the two sustainability themes of this perspective are discussed in the following sub-sections.

VIII.2(a). Revenue and economic enhancement: The sustainability theme 'revenue and economic enhancement' has performed 'excellent' (score: 4.5). Among the indicators the 'revenue enhancement' has performed 'excellent' (score: 4.7) while 'management of mobility and travel demand' has performed 'good' (score: 4.3). Key notable points regarding indication of results of this theme are that, the travel demand is increasing and congestion exists during peak hours. The public transport modal share has also slightly fallen.

VIII.2(b). Effective cost management: The overall performance of this theme is 'good' (score: 4.0). The indicator 'efficient cost distribution and cost control' has performed 'good' (score: 4.2). Important points to highlight regarding this indicator are that, public transport, especially buses, may need to be subsidized to improve its level of service, frequency and also to serve less dense areas with more desirable level of frequency. The indicator 'external cost savings' has performed 'good' (score: 3.8). The congestion and excessive travel time during peak hours has contributed to high economic costs.

VIII.3. Internal Process Perspective

The overall performance of this perspective is 'excellent' (score: 4.5) and it is the best performing among all four perspectives. The performances of the four themes of this perspective are discussed in the following sub-sections.

VIII.3(a). Institutional efficiency: The sustainability theme 'institutional efficiency' has performed 'excellent' (score: 4.8) and it is the best performing among all of the ten themes of the Balanced Scorecard. Both of the indicators 'institutional coverage and capacity' and 'integration and efficiency of institutions' have performed 'excellent', scoring 4.7 and 4.8, respectively. This has been mainly due to an excellent level of institutional capacity and integration in the urban transport sector of Singapore.

VIII.3(b). Built environment and land-use: The overall performance of this sustainability theme is 'excellent' (score: 4.5). Among indicators the best performing is the 'management and quality of transport infrastructure' which has performed 'excellent' (score: 4.8), which denotes that Singapore has an excellent level of land transport infrastructure equipped with smart technologies. The 'management of parking facilities' has also performed 'excellent' (score: 4.6). The 'land-use and transport integration' has scored 'good' (score: 4.3). The key notable points regarding this indicator are that, more distant business centres need to be developed through the connection of more integrated MRT networks and facilitating more improved and dispersed bus transport facilities. There is also a need to reduce the transfer time among passenger modes through more improved and integrated land-use planning.

VIII.3(c). Management of transport modes: This sustainability theme has performed 'good' (score: 4.1). Among indicators of this theme the best performing is the 'control over private vehicles' which has performed 'excellent' (score: 4.8). This is due to city state's innovative and aggressive approaches in restricting car population; most notable of such approaches are VQS and ERP. 'Promotion of public transport' has scored 'good' (score: 4.1). The areas need to be improved about this indicator are the service quality of public buses, improving waiting time and to deliver more dispersed services.

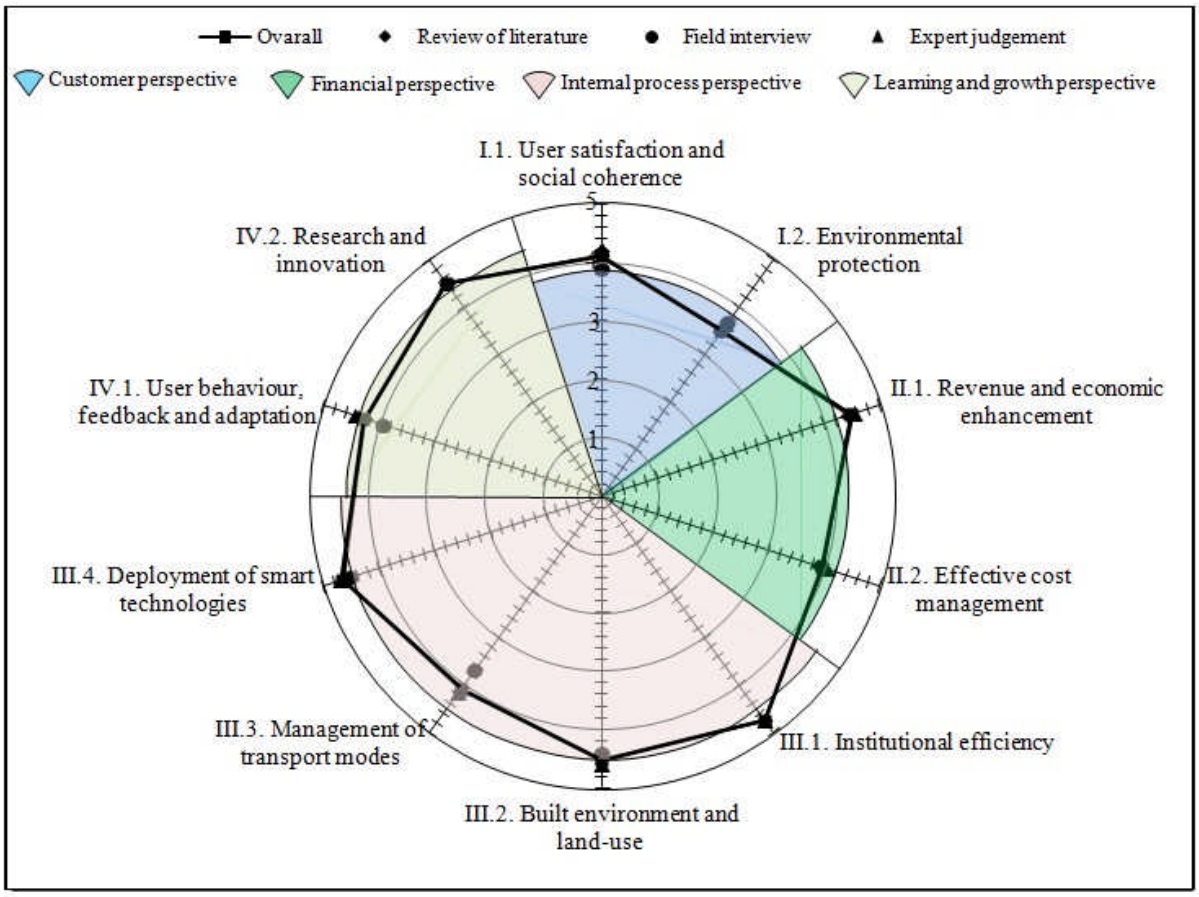

Figure 3: Scores of Sustainability Themes and Perspectives

All other indicators 'facilitation of non-motorized transport', 'integration among passenger modes', 'efficiency of commercial goods transport', 'promotion of green vehicles' and 'promotion of car sharing practices' have performed 'good', scoring 3.7, 4.3, 4.5, 3.8 and 3.5, respectively. In 'facilitation of non-motorized transport' there is still lack of smooth bikeways and connectivity for this mode to be considered as an alternative mode of transport to commuters. The lack of dedicated bike lanes is also notable. Regarding 'integration among passenger modes' high transfer and waiting time for non-first boarding(s) are areas that need to be improved. Regarding 'promotion of green vehicles' it is notable that, although there are a variety of initiatives undertaken to promote green vehicles the population of these vehicles in Singapore is still low. Finally, the 'promotion of car sharing practices' needs to be more widely practiced and there is lack of HOV lanes.

VIII.3(d). Deployment of smart technologies: The overall performance of this sustainability theme is 'excellent' (score: 4.7) and it has obtained the second best score among all sustainability themes of the Balanced Scorecard. Out of the eight indicators under this theme seven has performed 'excellent' and one has performed 'good'. Among the 'excellent' performing indicators the 'vehicle emission standard', 'fuel standard', 'electronic fare collection', 'electronic road pricing' 'smart infrastructure technologies', 'smart vehicle technologies' and 'advanced traveller information' have scored 4.7, 4.8, 4.6, 4.9, 4.9, 4.7 and 4.6, respectively. Singapore adopts a very stringent fuel standard. Singapore is the pioneer in deployment of technology in congestion pricing, which has been successful in controlling private vehicles. In addition, Singapore is a global landmark in the deployment of world-class cutting-edge technologies in infrastructure facilities. The

indicator 'congestion and incident management' has performed 'good' (score: 4.2). The relative under score of this indicator compared to other indicators under this sustainability theme is mainly due to presence of congestion, especially in the peak hours.

VIII.4. Learning and Growth Perspective

The overall performance of the perspective 'learning and growth' is 'good' (score: 4.4) and it is the second best performing among all four perspectives. The performances of the two sustainability themes of this perspective are discussed in the following sub-sections.

VIII.4(a). User behaviour, feedback and adaptation: The sustainability theme 'user behaviour, feedback and adaptation' has performed 'good' (score: 4.3). Among six indicators three have performed 'excellent', two 'good' and one 'moderate'. The 'excellent' performing indicators are 'skill development and training', 'legislation and enforcement' and 'influence of leadership and political dynamics', all scoring 4.6. The indicators 'awareness and education' and 'adaptation with changing demographics and expectations' have performed 'good', both scoring 4.4. The indicator 'public participation' has performed 'moderate', scoring 3.0. Public interest regarding planning and decision making are increasing and there is an increasing need reflect public opinion in these processes.

VIII.4(b). Research and innovation: The overall performance of this sustainability theme is 'excellent' (score: 4.5). The indicator 'new innovation and practices' has performed 'excellent' (score: 4.7). Singapore has been best benefitted from the technological advancement through both innovating as well as learning from the global benchmarking practices. Singapore's ERP is the world's first electronic congestion charging system and the idea of VQS is also innovative and successful. The indicator 'research and development' has performed 'good' (score: 4.4) which implies a good level of research and studies are existent in the field of urban transport sustainability.

IX. CONCLUSION

In this study, an attempt was made to measure the performance of sustainable urban transport in Singapore based on the framework of Balanced Scorecard. Results show that, the Balanced Scorecard is highly desirable for strategic performance measurement and management of sustainable urban transport as it creates a holistic assessment framework of different aspects of urban transport sustainability and therefore helps identifying the major critical areas of strengths and weaknesses and therefore, preventive measures can be undertaken. As learnt from the application in the Singapore case, the overall performance of sustainability in Singapore's urban transport is good. The key areas of strength mainly which has transformed Singapore's urban transport into a global icon are an efficient institutional structure, a world-class land transport infrastructure system, strict control over ownership and usage of private vehicles, innovative approaches towards problem solving and deployment of cutting-edge technologies. On the other hand the moderate performing critical areas are the carbon emission, energy consumption and public participation. In addition, areas that are marginally good and still need further improvement include congestion management, employment facilitation through enhanced land-use transport integration, improvement of the level of service, frequency and diverse geographical service of public buses, facilitation of non-motorized modes and car sharing and promotion of green vehicles.

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ABOUT THE AUTHORS:

Md. Habibur Rahman*
B. Sc. (Civil Engineering), Bangladesh University of Engineering and Technology; currently pursuing his Ph.D. at the Department of Civil and Environmental Engineering of National University of Singapore. His major research interests include sustainable urban transport, intelligent transport systems, environmental assessment and impact analysis, strategic performance evaluation, public transportation, transportation security and transportation economics.
**Corresponding author:* Traffic Laboratory, Block EW1, #04-02B, Engineering Drive 2, National University of Singapore, Singapore-117576, Tel: +65-65162255, e-mail: habibur@nus.edu.sg

Chin Hoong Chor
B. Engg. and M. Engg. (Civil), National University of Singapore; Ph.D. (Transportation), Southampton; currently working as associate professor of Civil and Environmental Engineering at National University of Singapore. His research interests are in the areas of sustainable transport, urban sustainability, transport system modeling, traffic safety analysis, public transport operations and environmental management.