Imagining the Future of Mobility in Singapore

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SUMMARY

Singapore's current transport system faces three major challenges: a growing population that places pressure on the transport network, infrastructural limitations that manifest themselves in infrastructural breakdowns and inadequate crisis management, and higher expectations from Singaporean residents regarding the convenience, reliability and comprehensiveness of the public transport system. As such, we outline a framework for the integration of infrastructure and information within a 'smart' transport network. Our framework combines a tripartite system incorporating alternative vehicular technologies and modalities, such as electric cars and ride-sharing, with a decentralized, dense IoT network that provides publicly available data analysis and visualisation. This will help to improve mobility for all Singaporeans in three ways. Firstly, it better manages vehicular traffic, overcoming unpredictable demand-supply imbalances in public transport, and enhancing sustainable and affordable transport. Secondly, the insights gained from data collection and analysis will help to improve journey planning and multimodal transport options for both public transport users and commuters on the road, as well as streamline road traffic conditions on the road in real-time. Finally, this network enhances predictive maintenance and condition assessment for transport asset owners, increasing the service life of critical infrastructure and enabling a smoothly-running transport network in the long run.

1. Introduction

For decades, Singapore's transport system has been a crucial backbone of our nation, reliably serving the mobility needs of citizens and residents. However, as Singaporeans become increasingly affluent and globalized and as our infrastructure ages, our transport system faces a raft of challenges, from demographic changes to rising commuter expectations for convenient and affordable transport, that we need to overcome. We focus on two separate, yet deeply intertwined trends, which can be leveraged upon. The first is that of emerging vehicular technologies and modalities, such as electric cars and ride-sharing, which constitute a key pillar of future urban transport networks. The second is that of an Internet-of-Things enabled transport information system, which will combine data-mining insights with real-time information to provide timely and relevant insights to all commuters and road-users. Our thesis hence focuses on integrating infrastructure with information to enhance mobility for all.

2. Limitations and Challenges

Demographic Changes: A transportation system serves the travel demands of a region's demographics. Singapore's resident population has increased significantly since 1990s, and is expected to rise to 6.9 million by 2030.[i] With a greater predicted population density of 13,700 residents/km^2 by 2030[ii], there will be increasing expectations for greater public transport infrastructure capacity.[1] Singapore's demographic issues are further compounded by an ageing population: the number of senior citizens doubled to 440,000 since 2000, and is expected to rise to 900,000 by 2030.[iii]

Transport Infrastructure Limitations: However, Singapore's public transport network appears increasingly ill-prepared to meet increasing demand. Frequent railway breakdowns due to ageing infrastructure are exacerbated by inadequate crisis preparation.[2] Furthermore, railway delays can lead to network paralysis due to the lack of transport alternatives. The old policy of scrapping bus routes running parallel with newly-built railway lines to minimize resource duplication[iv] encouraged overdependence on a central network backbone. Yet, this low network redundancy becomes catastrophic when these crucial lines fail, as seen in the massive 2015 North-South and East-West Line breakdowns which railway operator SMRT could not cope with, even after mobilizing all its assets.[v] Poor crisis management such as poor public communication, inefficient and infrequent backup shuttle services worsened the problem.[vi] Train upgrading programmes have been implemented, but railway infrastructural improvements may take up to 2019 to be completed.[vii] In addition, there remains little space for new road infrastructure: Singapore already has the 5th highest road density globally, occupying 4.8km of road/km^2 of land.[viii] Therefore, besides focusing on capacity optimization, policies to strengthen

[1] Singapore's public transport mode share is expected to rise to 70% by 2020 as a larger proportion of higher-income commuters rely on public transport.
Information from LTA UITP Singapore International Transport Congress Exhibition. Ministry of Transport, 07 October 2013.

[2] Since 2011, annual MRT service delays have ranged between 320 and 400 incidents. *Information from: "MRT Incident Statistics." Land Transport Authority, 11 March 2015.*

our transport framework must emphasize alternatives that encourage long-run sustainability compatible with increasing demand.

Multimodal Transport: Although public transport demand is rising, Singapore's rail and bus network density greatly trail behind that of densely-populated cities like Tokyo and London. This contributes to the "first-mile, last-mile" transport gap, inconveniencing passengers and discouraging public transport use. The "gap" is partially bridged by private-hire car drivers,[ix] with 25% of Uber pick-ups/drop-offs occurring at MRT stations.[x] Nonetheless, uncertainty in the sharing economy's transport regulations remains.[xi] Response towards alternative transport initiatives has been lukewarm: NTUC Income's pilot bike-sharing programme ended in 2008 due to low ridership.[xii] However, we should continue to focus on inter-mode mobility, as it is essential to strong transport connectivity and resilience. The ease of multimodal travel may be a factor in fostering greater public transport use.[3] Boosting inter-mode travel can shift commuters from private to public transport, improve passenger satisfaction, and lower both overall and per-kilometer vehicle emissions, contributing to a sustainable transport landscape.

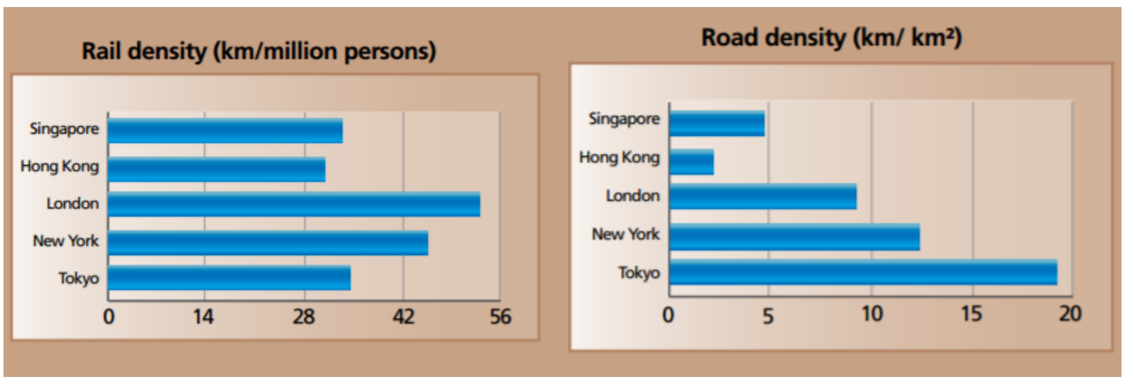

Fig. 1: Singapore's Rail & Road Densities

Source: Singapore Land Transport Authority. "Key Transport Statistics of World Cities." *Journeys*, November 2012. p69.

[3] Research has shown that Uber's presence in Singapore facilitated heavier MRT passenger use. *Information from: McSpadden, Kevin. "Three years on, how has Uber impacted Singapore?" e27.*

3.1. INFRASTRUCTURE

The traditional hub-and-spoke model of Singapore's public transport network must be further strengthened to protect against points-of-failure. To that end, Singapore must harmonise multiple transport options for both inter- and intra-regional transport. We present in Figure 3 a tripartite transport framework that forms the basis of our recommendations. These three modes are rail, bus and bike or ride-sharing modalities. The first two pillars are well-established and continually undergoing improvement, with the extension and addition of new MRT lines and the enhancement of bus fleets and bus routes. In particular, LTA is already developing Integrated Transport Hubs which provide multimodal transport options and essential amenities.[4] Such integrated towns will make each region self-sufficient, where residents can live, work and play within the same environment, and reduce the need for inter-regional travel. The bulk of our recommendations will hence focus on the third pillar – emerging modalities of transport such as autonomous and electric vehicles, and ride-sharing for both private cars and bicycles.

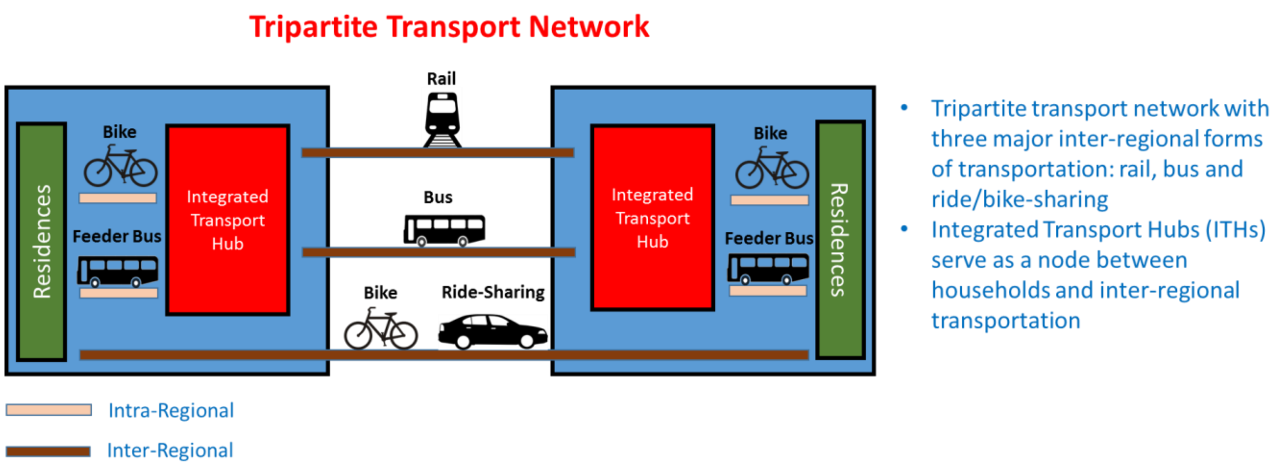

Fig. 2: Framework for a Tripartite Transport Network

3.1.1. Emerging Vehicular Technologies

Singapore must embrace emerging technologies such as electric and autonomous vehicles to improve resource sustainability and lower transport costs. Hybrid cars are becoming increasingly commonplace, with automakers like Volkswagen and BMW promising plug-in

[4] LTA has already built seven such ITHs, with three more to be built by 2019.
Information from: http://www.mot.gov.sg/News-Centre/News/2015/Fact-Sheet---Public-Transport-Improvements-and-Future-Plans/

hybrid alternatives to their current models by 2025[xiii]. This can be done through academic-industry partnerships, provisioning of test-bed environments and spaces for prototyping and development, such as the recent driverless taxi trial in one-north launched by nuTonomy and Delphi Automotive Systems[xiv]. The government must collaborate with private-sector players to develop electric car infrastructure such as an extensive charging-port network, as the relatively low marginal costs and minimal space utilization further enhance the viability of electric cars.

3.1.2. Ride- and Bike-Sharing

Although the Singapore government has been receptive to ride-sharing services like Uber and Grab that claim to free up roads, it needs to provide a transport ecosystem that enables them to act as complements and not competitors to conventional rail and bus transport. The context is key: Uber's much-touted urban benefits have been mainly restricted to US cities, where commuter public transit usage is lower than in Singapore[5]. For example, while lower carpooling fares decrease private car ownership and usage, it might encourage substitution away from rail and bus transport to ride-sharing services and incentivize the influx of carpool drivers who might otherwise not be on the road, dampening the decrease in driver-hours. Further disintermediation of the ride-sharing model, through the bypassing of platforms like Uber and Grab, might reduce the volume of private-contractor drivers on the road and thus further reduce traffic[6].

In addition, cycling can address the first-mile, last-mile problem that bedevils the Singaporean transport network. A comprehensive network of bike stations (Figure 4) would enhance cycling as a form of recreation and as a vital mode of intra-regional transport that can complement feeder buses and ride-sharing services. Worldwide trials indicate that such a system must be dense enough (about 300m between stations), contain enough capacity (of about 1-3% of the region population)[xv] and offer real-time monitoring and predictive analysis of bike availability for rebalancing purposes. While LTA is planning a comprehensive cycling path network over 700km long that will provide both inter- and intra-regional connectivity[xvi], designated cycling pavements must be introduced to enhance road safety and to make cycling viable. More comprehensive

[5] The exception is New York City, which has a commuter public transit usage of 56.7% as compared to 50.2% in Singapore. *See http://www.triplepundit.com/2015/05/new-study-commuting-30-largest-u-s-cities/ and http://www.singstat.gov.sg/docs/default-source/default-document-library/publications/publications_and_papers/cop2010/census_2010_release3/cop2010sr3.pdf.*

[6] For example, blockchain technology could be used to further decentralize the ride-sharing model, such as the Israeli startup La'Zooz that operates a real-time, peer-to-peer ride-sharing platform that uses its in-app currency to incentivize drivers.

cycling amenities like bike racks and showering facilities at key transport nodes, shopping malls and workplaces should also be implemented.

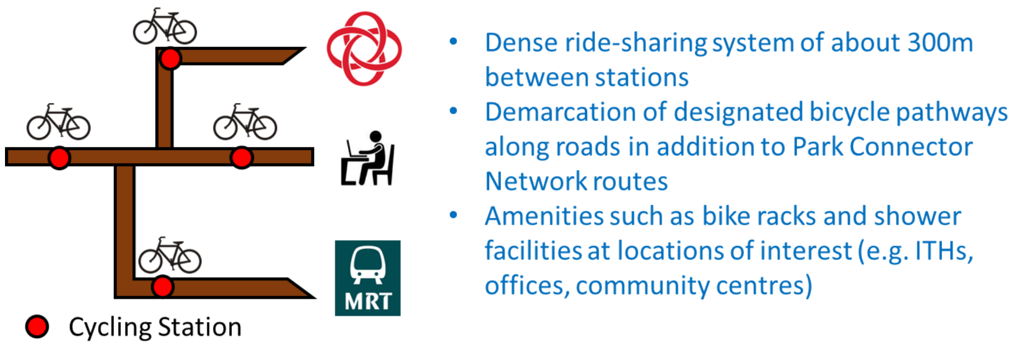

Fig. 3: Outline of Ride-Sharing Policies

3.2. INFORMATION – Towards Smart Transportation

Transport is being digitized. Every day, 5.5 million new devices become connected to the Internet-of-Things (IoT), of which vehicles represent the fastest-growing segment after smartphones and tablets.[xvii] Fine data control will create opportunities to harness data for personal and immediately actionable insights to transform the commuter journey from an infrastructure-focused to a commuter-centric experience, such as through apps that integrate real-time multichannel information with individual travel patterns to deliver customized itineraries. Data-driven insights from connected transport assets may also provide strategic directions for future development. The government must hence develop a masterplan for a cyber-physical transport system that leverages upon IoT-enabled large-scale open-source data analysis and optimization[7]. In addition, private-public collaborative policies may promote technological innovation in universities, and encourage the implementation of research into transport systems.

3.2.1. Complementing Road Infrastructure with the Transport Internet-of-Things

The IoT gathers data into a distributed network, enabling the visualization and mining of insights from global and local perspectives. (Figure 5) This could encompass anything from a vehicle,

[7] Such redevelopments include the upgrading of Mass Rapid Transit's North-South and East-West lines.

where sensors and data generate safety critical control solutions for individual assets, to a nation’s road infrastructure, connected to other decision-support systems to form a global information controlling a specific transportation network (e.g. expressways)[8] [xviii]. The decreasing cost of sensors makes Transport IoT increasingly viable, with sensor prices dropping to 60c from $1.30 in the past 10 years[xix].

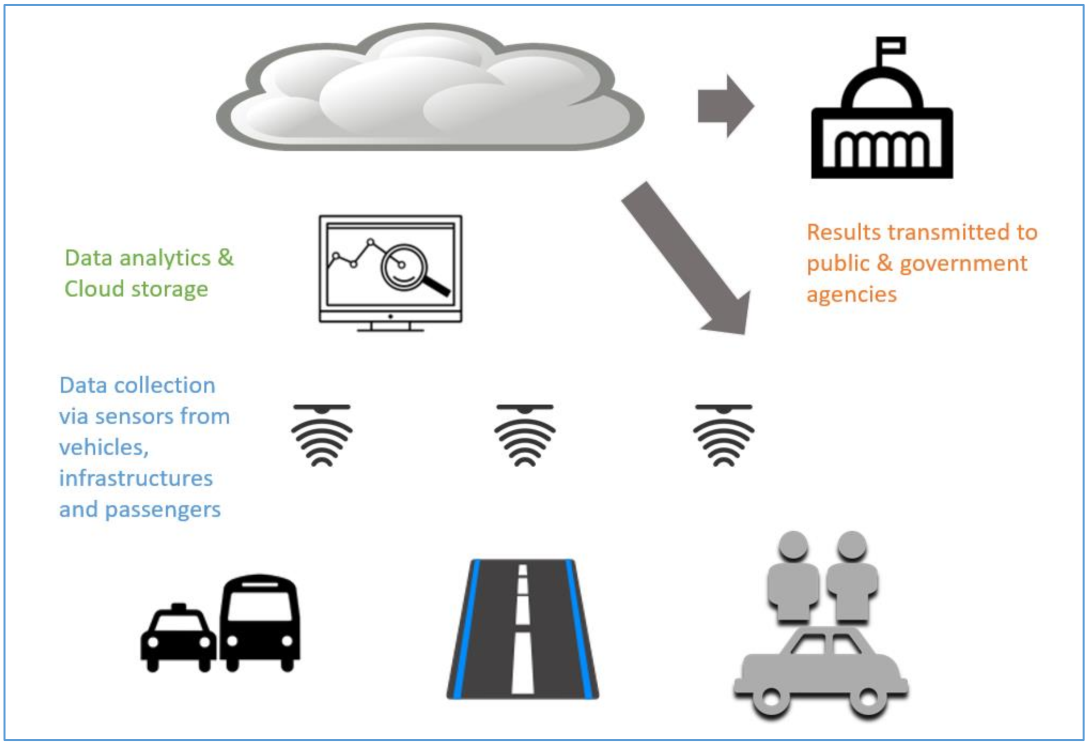

Fig. 4: Connectivity of People, Infrastructure & Data

While existing transport networks already collect and analyse sensor information such as through video and audio feeds from roadside cameras,[9] [xx] Singapore’s future transport information systems must consist of “smarter” IoT sensors that afford greater data granularity. Public transport agencies and private stakeholder firms should work together with engineering research institutes to create a decentralized network of intelligent devices for computational and analytics functions.[xxi] Machine-learning will allow devices to adaptively improve and handle

[8] For example, South Korea’s expressways are fitted with 2500 km of fiber-optic lines that form the backbone of its Intelligent Transportation System.
Information from: Jungyun, Kwon. "Leading the way, Korea's IT transportation innovations." Korea.net, 01 June 2012.

[9] Currently, video and audio feeds from roadside cameras are sent to a centralized Response Management System relying on human oversight and action.

fluctuating transport environments, detecting changes and automatically reacting by distributing real-time instructions to an array of smartphones, gantries, radios and vehicles.[xxii] Vehicles and infrastructure can transmit information and take pre-emptive measures via smart V2V/V2I communications.[xxiii] (Figure 6) A connected IoT system enhances transport management by allowing proactive responses to transport demand and supply changes, and enabling smoother intermodal transport.

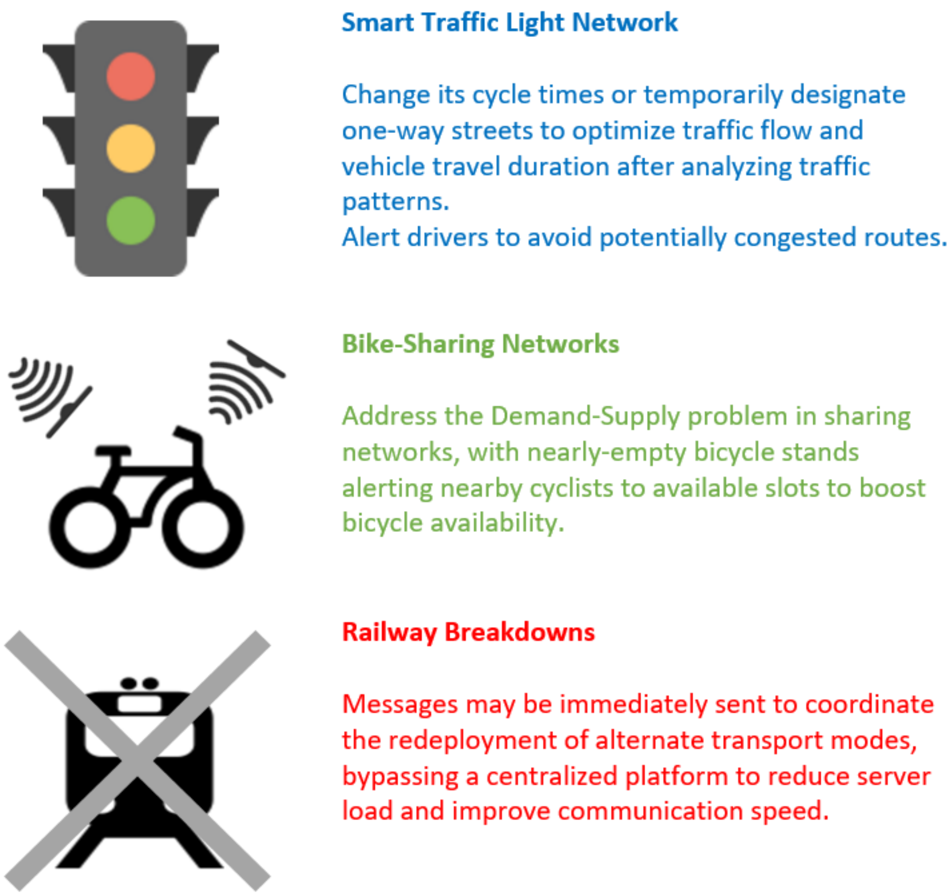

Fig. 5: Benefits of Vehicle-to-Vehicle (V2V) / Vehicle-to-Infrastructure (V2I) Communications

Sources (Information): Richard, Michael G. "Networked Traffic Lights Could Save Time, Fuel, and Lives." Treehugger, 18 March 2010.
"Smart Mobility 2030: ITS Strategic Plan for Singapore." Land Transport Authority.

3.2.2. An Integrated Platform for Information & Collaboration

The potential of big data must be realized through public collaboration. Making real-time data streams freely available on a one-stop platform can encourage citizen-centric innovation.

Ideally, this platform would aggregate data, segregate them into specific indices, and deploy them on multiple levels, such as individuals, transport modes and regions[xxiv]. Singapore must nurture an open-source marketplace where any party with real-time transport data can share or download it. This may encourage the development of crowdsourced consumer applications to complement ITHs. Real-time data can be used in visualizations of urban transport metrics[xxv] and in urban-planning simulation models, informing scenarios for future town and transport design planning.

3.2.3. Benefits of a Smart Transport System

Increased Convenience for Passengers: Integrated platforms ensure interoperability across modes and technologies, providing access to transport insights to all commuters. Consumer-based transport apps will allow passengers to see the entire transport network as a unified platform. They can plan multimodal itineraries that follow individual criteria, and which adapt to changing traffic conditions, transiting from node to node to reach their final location effortlessly.[xxvi] A smart system will also better cater to commuters of varying profiles, such as the elderly or disabled.

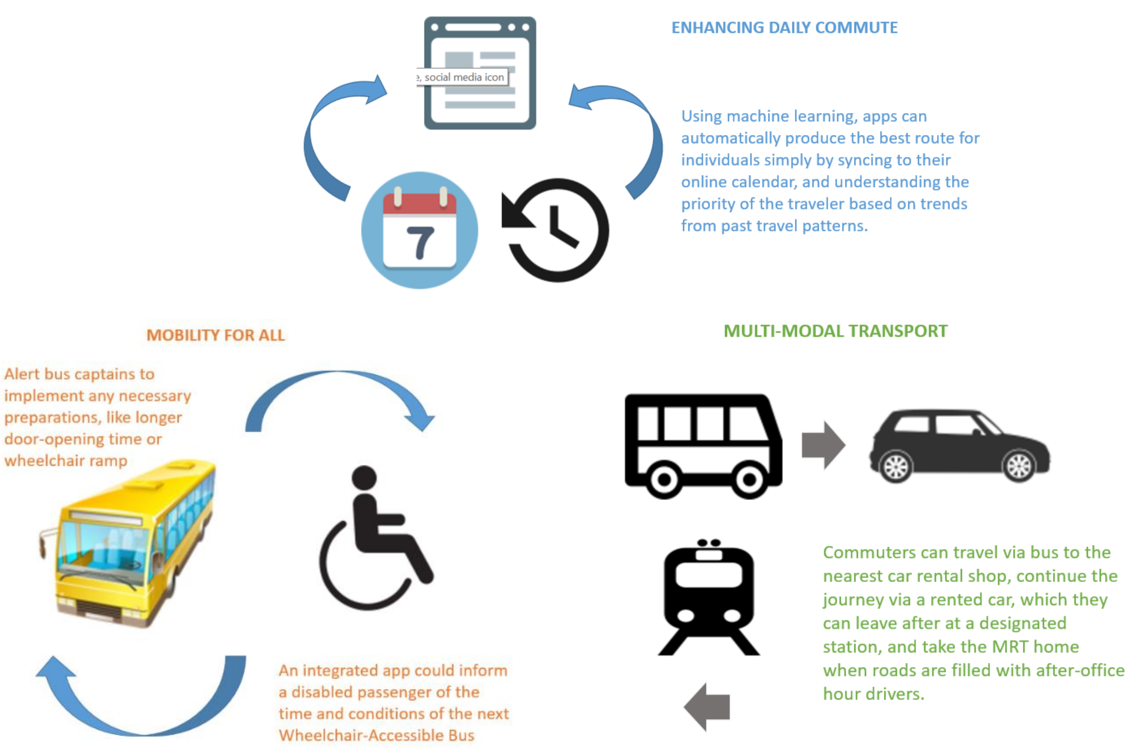

Fig. 6: Benefits of a Smart Transport System for Passengers

Fleet & Route Optimization: Real-time data assists individuals and firms in reallocating resources to better match demand. Aggregated historical information like expressway traffic volume and choke-points will help transport planners optimize traffic movements such as incentivizing more private-hire cars, rerouting public transportation lines during special occasions, or reducing trains during off-peak hours to balance demand.[10] Instead of operating on a fixed schedule, Singapore can look towards a transport system dynamically calibrated to real-time traffic flow.[11][xxvii]

Predictive Maintenance: Vehicular IoT sensors may also provide technical insights into transport infrastructure maintenance levels.[12] Railway asset owners shall then leverage upon historical information such as train capacity utilization and signaling equipment deterioration rates to identify proactive maintenance, replacement cycles and potentially forestall future breakdowns.[xxviii] Condition-based assessment models can also reduce unnecessary checks and thus save on costs.[xxix] This will contribute to better crisis planning strategies, improving crisis management and responsiveness in times of emergencies.

3.2.4 Considerations

Public-private collaboration is relevant to achieving a reliable and user-friendly transport information system. A strong public hand is essential to maneuvering private forces of innovation for the social good, and Singapore must ensure that public transport remains navigable. Even as we tap into the IoT-enabled world, we must continue to make transport infrastructure accessible even to those without smartphones and sophisticated journey planning functionalities. We should ensure real-time data through public information systems along the entire commuter journey, from billboards at transport nodes to in-vehicle information screens on buses. Additionally, the transition to smart mobility must be organically calibrated to interoperate

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[10] For example, in rush hours, expressways may change speed limits to enhance traffic flow, while cars with GPS will receive updates on faster alternate routes to bypass the delay.
Information from: Jungyun, Kwon. "Leading the way, Korea's IT transportation innovations." Korea.net, 01 June 2012.

[11] Researchers have shown that IoT-enabled traffic lights may reduce the time drivers spent at traffic junctions by more than 28% during rush hours.
Information from: Glaskin, Max. "Could smart traffic lights stop motorists fuming?" New Scientist, 12 February 2008.

[12] These include assets such as trains and buses.

with existing rail and road infrastructure. Nonetheless, this integrated platform still allows for the aggregation and presentation of a spectrum of transport information, enabling new transport solutions[xxx] that will be the hallmark of the smart transport system.

4. Conclusion

The upcoming transport challenges Singapore faces must be addressed with the synthesis of modern transport technologies with real-time, actionable information. As Singapore overhauls its infrastructure, it must leverage on smart algorithms and networks to ensure optimal capacity usage and mitigate transport problems. But the integration of infrastructure with information also serves to boost the commuter experience, and to seamlessly weave it within a smart, citizen-centric paradigm that enhances the lives of Singaporeans.

- END -

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