

# Engineering Singapore's Land Transport System

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**Abstract.** There is a wide array of public transportation in Singapore. Travelling from one part of Singapore to another is a breeze thanks to a highly penetrative public transport system. The three main modes of public transport in Singapore are the Mass Rapid Transit (MRT), buses and taxis. Buses are, by far, the most common form of public transportation in Singapore, followed by the MRT and taxis respectively. Public buses serve almost every part of Singapore, making it the most extensive form of public transportation, while the MRT provides speed and efficiency, especially during peak hours.

This case examines the public transportation of Singapore from a large scale system engineering perspective and aim to help the reader to understand the complexities of such a system: its mission, vision and goals, boundaries, and promoting public transport through a systems approach.

## Formulation of Goals

In any large scale system, the formulation of goals is very important for various reasons: goals give the system a target to aim for; goals help the system to allocate resources and concentrate its time and effort; goals provide the motivation for the stakeholders to preserve; goals help the system to establish priorities. Very often, systems forget or ignore their goals, moving aimlessly in circles. Goals are usually derived from the system's mission and vision.

**Mission.** Mission or purpose is the reason for the system's existence. The mission statement help the organization make decisions that are in alignment with its core purpose. The Land Transport Authority (LTA) is a statutory board under the Ministry of Transport that spearheads land transport developments in Singapore. It plans the long-term transport needs of Singapore, taking care of those who drive as well as those who take public transport. LTA's mission is to "**Connecting people and places, enhancing travel experience**" (Land Transport Authority, 2014)

**Vision.** Vision is a clear image of your desired future. Vision answers the question, what is the final result we want? It is a picture of the future the system seeks to create. It gives shape and direction to the organization's future and helps people set goals and prioritize strategies for moving the organization closer to its desired results. Once one is clear on the vision, one can then focus on one's strategies that are in alignment with the results one wants to achieve. LTA's vision is "a people-centered land transport system." (Land Transport Authority, 2014)

**Goals.** From the mission and vision, the following goals/objectives are derived (Public Transport@SG, 2014):

- a. To deliver a land transport network that is integrated, efficient, cost-effective and sustainable to meet the nation's needs.

- b. To plan, develop and manage Singapore's land transport system to support a quality environment while making optimal use of our transport measures and safeguarding the well-being of the travelling public.
- c. To develop and implement policies to encourage commuters to choose the most appropriate transportation mode.

LTA's strategy to provide an attractive public transport system includes (Land Transport Authority, 1996)

- a. managing demand for private transport through ownership and usage restraint to ensure sustainable mobility into the long term,
- b. integrating transport planning with land use planning for a sustainable outcome due to land scarce Singapore,
- c. keeping roads safe and the air clean together with the Ministry of the Environment and Water Resources (MEWR)
- d. reviewing vehicle standards regularly, public education and enforcement programmes together with the Traffic Police.

In the 2008's Land Transport Masterplan, the vision is to work towards a more people-centred land transport system that will meet the diverse needs of an inclusive, liveable and vibrant global city. Three key strategic thrusts were identified (Land Transport Authority, 2008):

- a. Making public transport a choice mode
- b. Managing road usage
- c. Meeting the diverse needs of the people

We will see how these goals were translated into strategic thrusts and how they permeated everything that LTA does to achieve the system's goals. Last year, another Land Transport Master Plan 2013 was laid out to address the changing expectations of commuters and to achieve greater integration in common spaces.

### **Boundaries, Complexities and Integration**

A boundary for a system is a periphery or a temporary limit at which some noticeable change in the application behaviour happens. It is a line or plane indicating the limit or extent of something. Some of these boundaries create conditions that are due to the system's intended behaviour or specifications, or business rules (e.g. "for getting a driver license, the applicant must be at least 18 years old"). Some are "implicitly" created e.g. importing foreign talents create new social and cultural boundaries. Hence it is very important to know what the boundaries and their conditions are in a large scale system so that the planner chooses how to deal with them. For example, in the past, one boundary condition was not to build housing in industrial estates due to pollution and possible health problems. This resulted in workers spending time transporting from their homes to their workplace. With better pollution control as well as building more gardens around industrial areas, it is possible to remove this boundary condition especially in a land scarce country (which is another boundary) like Singapore.

Complexity arises in situations where an increasing number of independent variables begin interacting in interdependent and unpredictable ways. There are three types of complexity: system complexity

(multiple connections and ways of implementing it); behavioural complexity (goals agreement and tradeoffs and multiple stakeholders) and; dynamic complexity (boundaries change with time). In many governmental projects such as transportation, the size and the many subsystems contribute to system complexity, the many stakeholders involved contribute to behavioural complexity, and the changing environment for such long time projects contribute to dynamic complexity.

Planning, systems engineering, systems thinking and dynamics, systems architecting are some of the ways to deal with complexity and boundaries. Some of these are described below.

**System Complexity: Integration of Land Use, Town and Transport Planning.** Proper land use planning improves accessibility to goods and services and hence reduces the need for transportation. In Singapore, the majority of commercial activities is planned to be located within the city centre to create a critical mass of activities and help position Singapore as a global business hub (Sapuan, 2007). To allow people to live close to this concentration of employment opportunities, more housing is being introduced into and near the city centre. Outside the city, more employment areas are planned near suburban residential areas; for example, industrial estates and commercial hubs are situated at the fringe of housing estates to reduce commuting and lessen transport demand.

Together with other agencies, LTA integrates urban development with transport planning. Having a proper mix of developments and the highest building densities concentrated at and around MRT stations will ensure maximum accessibility, for commuters to key nodes of employment, housing, leisure and other social activities. Commuter facilities and building developments will be fully integrated. More high rise developments are being targeted near MRT stations. Radial lines will provide direct links to the city centre, while orbital lines will serve those travelling from one place to another outside the city centre. This will enhance accessibility and reduce travel times, making public transport more attractive and reducing reliance on private transport.

**Dynamic Complexity: Integration Over Time.** In 1996, a White Paper on “A World Class Land Transport System” was conceived to guide Singapore’s land transport development (Land Transport Authority, 1996). However, the environment has changed as her population has grown and become more diverse. By 2020, she expects that travel demand would increase from the current 8.9 million journeys a day to about 14.3 million journeys a day (Land Transport Authority, 2008). The public transport mode share during the morning peak hours has declined from 67% in 1997 to 63% in 2004 and 59% in 2009 (Channel News Asia, 26 Oct 2009). Fortunately, it has risen to 63% in 2012 (LTA, 2013). Singapore also has to better meet the needs of her greying population, the higher expectations of her people as well as the less privileged and lower income group. Given these constraints and limited land of just over 700 square kilometers, public transport would be the most efficient means (Land Transport Authority, 2008). With this in mind, Land Transport Authority (LTA) embarked on a comprehensive Land Transport Review in October 2006 culminating in the Land Transport Masterplan in 2008.

Hence some of the strategic thrusts from the 1996’s White paper need to be changed and the strategic thrusts in the 2008’s Land Transport Masterplan, reflects some of these changes. In 1996, the strategic thrusts were integrating transport and land use planning; expanding the road network and maximizing its capacity; managing demand of road usage and; providing quality public transport choices. In 2008, they were making public transport a choice mode; managing road usage and; meeting the diverse needs of the people. The need to manage the demand for road usage remains. But the latter emphasizes more on encouraging public transport and meeting different customers’ needs.

The environment in Singapore has changed significantly since 2008. Commuters expect to be more connected and travel faster and in comfort. More goods need to be transported. There will also be

tighter land constraints (LTA, 2013 Land Transport Master Plan). The 2013's Land Transport Masterplan was conceived to meet these challenges. In essence, it strives to connect people to more places where they work, live and play, improve travel reliability, comfort and convenience and build and the transport system with the well-being of our diverse community at heart and give more consideration to how it enhances the common living space (LTA, 2013 Land Transport Master Plan).

**Behavioural Complexity.** Land transport is a matter that affects everyone. A people-centered land transport system must be planned with the community in mind. Apart from LTA and several other governmental organizations such as the Urban Redevelopment Agency, other stakeholders include transport operators, employers, commuters etc. To solicit and integrate their interests, LTA, in conceiving its masterplan, obtained contributions from a broad spectrum of people including students, workers, employers, commuters, transport operators, ordinary Singaporeans and experts; at home and abroad. In total, more than 4,500 people contributed their time, energies and ideas to the plan (Land Transport Authority, 2008). Going forward, the new Land Transport Community Partnership Division in LTA will have dedicated teams assigned to each constituency to engage the community more closely on the ground. LTA will also launch a Community Partnership Programme to invite grassroots leaders to discuss and share their views on transport policies and plans.

**Behaviour Complexity: Integration Across Organizations.** One of the greatest challenges in large scale systems engineering is the integration of the different organizations. An understanding of organizations and their ecosystems would certainly be helpful to integrate them. It would certainly not prudent to merge all the entities involved in the system, as this will result in huge bureaucracies and hierarchies, not in the least having to resolve the politics involved. However, where interfaces and interactions between different entities remain high, it makes sense to combine these entities. Hence LTA was created in September 1995 to spearhead improvements to the land transport system through integrated planning, development and management of land transport policies and infrastructure. It was formed through the merger of four public sector entities, namely: Registry of Vehicles, Mass Rapid Transit Corporation, Roads & Transportation Division of the Public Works Department and Land Transport Division of the then Ministry of Communications. The formation of the LTA allows for better integration of the functions of planning, development, implementation and management of all transport infrastructure and policies. Such integration addressed the need for a more co-coordinated approach to planning and building Singapore's land transport system.

**Sustainable Development.** Achieving sustainability is one of the most important challenges facing society. Addressing complex issues related to sustainability requires systems integration of multiple disciplines including social, economic and environmental concerns. LTA recognizes the social, environmental and economic principles of sustainable development as a strategic objective.

A world class land transport system is very costly to build and operate. Hence a framework which serves as a social contract based on partnership between the Government, the operators and commuters was devised (Land Transport Authority, 1996). This framework is based on the principles that fares have to be realistic and revised periodically to account for justifiable cost increases to maintain acceptable service level, operating costs must be recovered to make it viable, and that a need for a sustainable policy on asset replacement. This means that with the government funding the assets, operators need not have to come up with a huge investment and be able to cover operating costs. They should also use some of the revenue to provide better service. To prevent public transportation from being unaffordable, the Public Transport Council scrutinize the fares and has to balance between the need to ensure that fares remain affordable to the public and operations are commercially viable in the long term. Figure 2 illustrates the economic/ social framework for a sustainable land transport system.

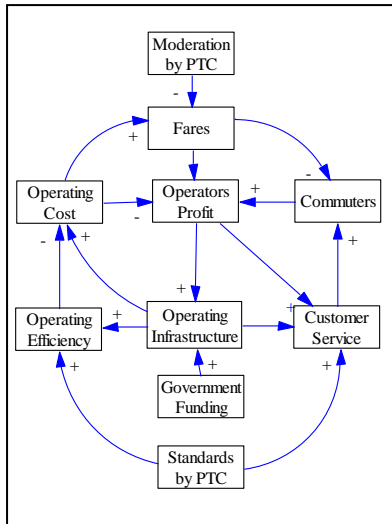


Figure 2. Economic and Social Framework for a Sustainable Land Transport System

The basic bus service market is gradually being opened up to allow competition for the bus market i.e. competitive tendering for the right to operate a package of bus services. To encourage greater efficiency and service improvements for the benefit of commuters, greater contestability in the Rapid Transit System (RTS) industry is achieved by issuing shorter operating licences for future RTS lines, compared to the 30-year licenses today.

LTA works with the Ministry of the Environment (ENV) and the Traffic Police (TP) to keep the roads safe and the air clean. Regular reviews of vehicle standards, public education and enforcement programmes are held. In addition, noise alleviating measures such as underground roads and expressway noise barricades are also implemented.

LTA ensures that all vehicles in Singapore comply with rules, regulations and technical requirements to ensure that these are built to acceptable international standards and are safe for use on the roads. LTA also enforces exhaust emission standards for all vehicles by requiring regular inspections. The transport sector is the third largest consumer of energy after industry and building sectors and accounts for 15% of Singapore's total carbon dioxide emissions, with private cars as the chief contributor (35%) and public transportation (36%) which includes taxis, buses and MRT/ LRT (LTA, 2013 Household Interview Travel Survey 2012). It encourages energy efficiency and reduces carbon emissions by promoting the use of public transport and more energy efficient vehicles. Rebates are given to encourage the use of green vehicles by narrowing the cost difference between such vehicles and conventional vehicles. In addition, environmentally sustainable practices in the planning and development of transport infrastructure are adopted.

**Increasing Capacity Through Use of Technologies.** LTA uses technology to maximize the capacity of our roads by upgrading and installing intelligent traffic management systems. It has installed the Green Link Determining (GLIDE) intelligent traffic light system to control all traffic signals along arterial roads. As traffic flow changes, it responds by adjusting the (traffic) green time accordingly. GLIDE also links traffic signals at neighboring junctions so that motorists can travel from one junction to another with minimal stops. "Virtual slip roads" are also implemented by allowing motorists to turn left at selected traffic light junctions even though the red signal is on, similar to the American right-turn-on-red system. Adopting traffic monitoring systems like the Automatic Network Travel Time System (ANTTS) and close circuit televisions to monitor traffic conditions in real-time.

Junction Electronic Eyes System (J-Eyes) and the Expressway Monitoring Advisory System (EMAS) are also used to cover more junctions and monitor traffic conditions on arterial roads respectively. LTA further develops these systems to provide navigational and traffic information to commuters through the radio, telephone hotlines or variable message signs. These measures increase the capacity of roads and junctions and ensure smoother traffic flow.

Another system that LTA has introduced is the Electronic Road Pricing (ERP). ERP is an electronic system of road pricing based on a pay-as-you-use principle. It is designed to be a fair system as motorists are charged when they use the road during peak hours. Traffic conditions on the expressways and roads where the ERP system is in operation are reviewed quarterly and its rates adjusted where necessary to minimize congestion on the roads.

**Vehicle Growth.** To keep traffic flowing smoothly, LTA adopted a holistic approach that includes road expansion as well as managing demand for road use by controlling vehicle growth and restraining usage. One such system of restraining usage through car ownership is the Vehicle Quota System (VQS). It is a system which allows the government to control the amount of cars on the road. The quota is reviewed on a regular basis and is set per month, based on the road conditions and amount of cars permanently taken off the road in that month (by scrapping, exporting or otherwise). The VQS is controlled by the Certificate of Entitlement, or COE. Each month, the LTA will determine how many vehicles are allowed on the road according to the VQS. The LTA will then issue that amount of Certificates of Entitlement (COE) and are sold through an open bidding system.

Parking policy is another lever that will restrain car usage by reducing parking supply in the city gradually over time and increasing parking charges. Parking Guidance Systems (PGS) are also implemented to guide motorists to the nearest building with available parking to reduce circulating traffic looking for parking lots.

### **Public Transport System**

To make public transport a choice, the land transport system must be able to provide various types of public transport services, ensure that these services are customer oriented, and integrate them to ensure a seamless journey.

**Choice of Public Transport Services.** Providing an attractive public transport system is the cornerstone of Singapore's land transport strategy. One way is in providing a comprehensive range of public transport services, each being developed to the highest quality commensurate with the fares charged, and all well integrated to provide a seamless journey. The choices include:

- a. Mass Rapid Transport (MRT) to serve heavy transit corridors;
- b. Light Rail Transit (LRT) systems to serve as feeders to the MRT network;
- c. Buses to continue serving the less heavy corridors to complement MRT-LRT network;
- d. Premier bus services like BusPlus to provide higher grade of bus service; and
- e. Taxis to provide car-like services.

**Customer Oriented Services.** LTA also works with the operators to make public transport more customer-oriented. Examples of such measures include (Land Transport Authority, 1996):

- a. improving travel times through more bus priority schemes like priority at traffic light junctions and bus lanes. It is mandatory for motorists to give way so that buses can come out of bus bays without delay, and buses will enjoy signal priority over other vehicles at major junctions in the city.
- b. improving commuter facilities by providing bus arrival times at bus stops, over the phone or Internet;
- c. providing better bus services by refurbishing bus stops, providing more covered linkways from their flats to improve accessibility of the public transport system;
- d. encouraging higher operational efficiency through the use of Global Positioning System (GPS) to pinpoint the location of buses to significantly improve scheduling.

With these measures, commuters can expect a speedier and smoother ride on the bus. The reliability of bus travel will also improve as buses enjoy greater right of way on the roads.

The MRT network which serves heavy traffic corridors, is also being expanded the target is to have a coverage as comprehensive as the London Tube or Paris Metro. Within the Central Area, a commuter will be able to access a RTS station within five minutes walk on average. Capacity on the existing lines will also be enhanced by increasing the frequency of trains. Commuters can look forward to better connectivity and a more comfortable ride on the trains (Land Transport Authority, 1996).

Taxis offer personalized service and supplement the high end of public transport. Measures to improve this service include periodic evaluation and publication of the performance of taxi operators and incentives for the best performing fleet operator; differential pricing to address the acute shortage of taxis during peak periods; Flexibility for operators to offer a wider variety of services; and using GPS technology to improve the radiophone service to better match demand and supply.

**Integration of Public Transport Services.** To enhance the integration and efficiency of public transport services, the LTA took on the role of a central bus network planner in 2009. It plans the public transport network from the commuters' perspective, focusing on the 'total journey' experience of the commuters. LTA enhances the hub-and-spoke system, so that the bus and rail services work in partnership. There will be more frequent and direct feeder bus services so that commuters can reach the transfer hubs quickly, and enjoy seamless and efficient transfers to the MRT or trunk buses to continue with their journeys. Moreover, more fully integrated transport hubs where bus interchanges and RTS stations are co-located with retail and commercial activities are being built. To facilitate transfers, a distance-based through-fare structure was adopted by 2009 so that commuters is charged a fare based on the total distance travelled in a journey, without incurring a transfer penalty when they switch between buses or between the bus and MRT. This will encourage commuters to take the most efficient routes.

A people-centered land transport system must provide for the diverse needs of our society and contribute to a quality, liveable environment especially access to transportation for the low-income groups, the elderly, wheelchair users, families with young children, pedestrians and cyclists (Land Transport Authority, 2008).

**Ensure physical accessibility for all.** To make the transport system user-friendly and accessible for all, all new and existing MRT stations will be accessible to persons with disabilities/ impairments. The public bus fleet will progressively be replaced with low-floor wheelchair-accessible buses. Moreover, an island-wide programme was launched to ensure that pedestrian walkways, access to RTS stations, bus and taxi shelters, and all public roads are barrier-free by 2010. Some measures to be

implemented include removing obstacles or widening walkways to provide a clear passageway for wheelchair users and using higher reflectivity materials for traffic signs to improve visibility.

**Affordable public transport for lower-income Singaporeans.** To ensure that public transport remains affordable to low income families, the Government continues to provide targeted help to the needy through Government assistance such as the Workfare Income Supplement Scheme (WIS) and community help schemes such as transport vouchers.

**Facilitate cycling.** With its increasing popularity, cycling can be a non-motorized transport option to bring commuters to major transport nodes. To facilitate cycling, LTA provide better bicycle parking facilities around MRT stations and bus interchanges; allow foldable bicycles onto buses and trains on a trial basis; close short gaps between the park connectors and transport nodes to cater to commuters who cycle to the MRT stations or bus interchanges; and install appropriate road signs to alert motorists to the presence of cyclists along frequently used routes.

## **Conclusions**

In this case, we have described the large scale systems engineering framework and how the conceptualization and systems engineering of Singapore's land transport system were carried out. With the human dimension in centre stage, a people-centered land transport system is being built for all Singaporeans to enjoy an active lifestyle in a vibrant global city. However, this could not be carried out without using a systems approach, understanding the complexities of land transportation and the boundaries faced by the system and integrating them to encourage public transportation.



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