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Land Transport Policy and Public Transport in Singapore

Soi Hoi Lam and Trinh Dinh Toan

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Abstract

Singapore has a sophisticated and efficient system of land transport and a growing demand for transportation to be satisfied. Constrained by a limited physical space, a comprehensive set of land transport policy has been in place to balance the growth is transport demand and the effectiveness and efficiency of the land transport system. A multi-pronged approach has been used to achieve the objective of a world-class transportations system. These include integration of urban and transport planning, expansion of road network and improvement of transport infrastructure, harnessing the latest technology in network and traffic management, managing vehicle ownership and usage, and improvement and regulations of public transport (MOT, 2002).

Singapore has been the first country in the world who introduced various new techniques, notably the Area License Scheme (ALS) in 1975 and the Vehicle Quota System (VQS) in 1990. An Electronic Road Pricing (ERP) system replaced the ALS in 1998 to take the role of congestion management, the experience of which has also drawn particular attention from many large cities in the world. In 2003, the world's first and only frilly-automatic heavy rail Mass Rapid Transit system open to the public, marking a new chapter in Singapore's effort in its, an innovative approach to solve its land transport problem. This paper studies policy adopted in Singapore in managing its land transport.

I. INTRODUCTION

With almost 4 million people living on an island of about 650 km^2, Singapore faces challenges in meeting the daily needs of commuting by its population. Land use now already covers 11% of the island, about the same percentage as residential areas. If the current trend continued, roads alone would occupy 16% of Singapore's land area by the year 2010. In 2001, an average of 7.7 million motorized trips was made in a day. The estimated number of trips may grow beyond 10 million by 2010 (MOT, 2002). Mean while, the limited land area on an island has constrained the development of road networks.

To maintain a sustainable transportation system to support the growth of economy and activities, an integrated and comprehensive approach has been taken to manage the demand and plan for the supply of transportation systems. In the area of public transport, in the white paper published by LTA (LTA, 1996), the policy was stated and the vision of a seamless and integrated multimodal public transportation system was illustrated.

About 90% of Singaporean working population needs a transport means to go to work, about 60% of them use public transport such as buses, mass rapid transport (MRT) or light rapid transit (LRT). In the year 2002, there were 3,144 kilometers of road. Eight expressways with the total length of 150 kilometers constitute the back bone of the road infrastructure in the island, the longest of which is the Pan Island Expressway (PIE) of 42 kilometers long. By the ends of the year 2002, the total motorized car population in Singapore registered was 405,797 and about 19,007 taxis (MOT, 2002)

The Mass Rapid Transit System (MRT) consists of three main lines: the East West, North East and the North South lines of total length of 111 kilometers, of which 39 km are underground. There are 65 stations (Statistic Singapore, 2002), of which 31 stations are underground, 33 stations are elevated and 1 station at ground level. The system serves more than a million passengers a day (MOT, 2002). The MRT network is a conventional, electrically driven railway system, which provides high frequent trunk services and represents the back borne of the land transport system.

The Light Rapid Transit (LRT), developed since 1999, serves as a feeder system to the MRT system. The system, 7.8 km long with 14 stations, is driverless, operating at 3 minute-interval during peak hours (Statistic Singapore, 2002), provides accessible services to residents along its route by having stations close to people's homes.

In 2002, the bus system, operated by two private companies, has a total of 261 lines served by about 3400 buses during the regular schedule (MOT, 2002). The services include trunk, feeder and express services, supplemented by "Bus Plus" scheme which provides minibus services during peak hours. Special Night buses for commuters who travel after the normal services are also available. They normally run along the MRT lines.

Singapore currently has a total taxi population of approximately 19,000 vehicles operated by 4 taxi companies: Comfort Transportation, City Cab, TIBS and the Yellow-Top. Almost all the taxis are equipped with GPS-based automated dispatching system which keeps tract, monitors and navigates the vehicles (MOT, 2002). With the total daily trips of about 580,000, taxi service in Singapore plays an important role in providing rapid, convenient and personal transport for middle and upper income groups, compatible to other high-income countries. As an important flexible means of transport, taxis bridge the gap between public and private transports.

In this paper, the land transport policy adopted by Singapore to achieve its objectives will be discussed. After that, the components that make up of the multimodal transit system in Singapore will be introduced. Next, the infrastructure and strategies to integrate the multimodal transit services will be discussed, as these strategies have profound impacts on the way the multimodal transit system in Singapore is planned and modeled. In this paper, focuses will be placed on the development of such a system and the different approaches taken by operators and authorities to model the system.

LAND TRANSPORT POLICIES IN SINGAPORE

A comprehensive land transport network, which meets people's needs and expectations, and supports economic and environmental goals, is much needed. To achieve the above objectives, a multi-pronged strategy has been adapted which comprises:

- Integrations of town and transport planning
- Expansion of road network and improvement of transport infrastructure
- Harnessing the latest technology in network and traffic management
- Managing vehicle ownership and usage
- Improvement and regulations of public transport (MOT, 2002).

INTEGRATIONS OF TOWN AND TRANSPORT PLANNING

Trip making pattern and traffic volume are functions of spatial distribution and land uses. Transport planning and land use planning need to be integrated effectively so as to reduce the need for travel. In other words, transport planning must become an integral component of town planning. Similarly, long-term transportation planning should embrace short term traffic management in controlling travel demand.

In Singapore, the planning practice shows that there is a careful consideration of integration of transport planning into the master plan, called Development Guide Plan (URA, 2003). Physical provision of transport infrastructure is made in such a manner that the system delivers maximum service for the population. Large complexes of developments outside of the CBD, including residential, industrial and social infrastructures are normally clustered proximally, within a walking distance to MRT to encourage greater commuting via public transport and ride sharing. It is planned that in the next 10 to 15 years, commuter facilities and housing development will be fully integrated to create a "seamless" transport system. Building more homes near work places and more work places in residential areas is one of the key directives in Singapore to moderate demand for transport.

Singapore has long time pursued a decentralization process, adapted to the CBD. From 1970 to 1996, in the city central area, the population has tremendously reduced, from 241,300 to 100,000. As compared to the whole country the employment in the CBD has slightly reduced to below 25% while the retail shopping area has dramatically been cut down from 68% to 47% (Willoughby, 2000). The city centre is now allocated more for offices and shopping areas.

Not only is the transport system closely integrated into land-use planning, it also represents convenient physical and institutional integration among transport modes. While the MRT provides high-frequency, rapid and comfortable mobility for the long distance and heavy traffic corridors, the LRT system serves as feeders to the MRT network, and the bus network remains as the basic mode of public transport (LTA, 1996), serving less heavy corridors to supplement the MRT and LRT networks. This physical integration actually aims to reduce unnecessary trips, enhance convenience and comfort, maximize the network efficiency, and therefore reduce the congestion potential.

EXPANSION OF ROAD NETWORK AND IMPROVEMENT OF TRANSPORT INFRASTRUCTURE

Among various supply-side tactics for reducing congestion, building more roads or expanding existing infrastructures is vital to accommodate vehicles in a city that has experienced rapid growth (Downs, 1992) as Singapore. The whole island is integrated and connected by a comprehensive system of streets and highways. Although the country already has devoted about 15% of its extremely scarce land for road and road related infrastructures (Willoughby, 2000) construction of new expressways of small scale is still considered to provide better connectivity as a seamless transport for all citizens, sustain economic activities, and to relieve congestion. Though allowing a reasonable increase in the car usage, the system will employ the ERP to moderate traffic volume and to regulate congestion problem.

HARNESSING THE LATEST TECHNOLOGY IN NETWORK AND TRAFFIC MANAGEMENT

An important objective of congestion management is the enhancement of traffic management system so as to improve carrying capacity and to smooth traffic flow. In Singapore, the road network in the island is fully signalized and highly coordinated in arterials streets to minimize delay. The Green Link Determining (GLIDE) system, implemented since 1988 to regulate traffic signals outside the city center, has been expanded to cover almost all of 1600 road intersections of the entire island. This computerized-coordinated traffic light system will create "green waves" to increase the capacity of junctions and reduce delays. There is also a "Junction Eye traffic monitoring" system for several critical intersections.

The LTA deployed Intelligent Transportation System (ITS) to enhance the traveling condition in Singapore. Traffic.smart is a system that provides one-stop comprehensive real-time traffic information. Several ITS components contribute data automatically to traffic.smart. Information on the incidents, updated for every 5 minutes, and travel time - every 2 minutes is available on the Web and accessible by the public in a 24/7 manner. However, users can choose to manually update the map information by clicking on the "Update" button in the map interface.

A variety of advanced techniques is heavily utilized, including the Advanced Traveler Information System (ATIS), Advanced Traffic Management System (ATMS). An important application of those systems is in the area of incident management, a system developed to deal with non-recurrent congestion. Through the Internet the information on traffic situation, estimated travel time and advice from dynamic route guidance system are also available to assist travelers to decide the route of travel, the time of departure and the mode of travel they are willing to ride. Video streaming images of selected expressway locations are occasionally released to reflect traffic situation to assist decision-making process. LTA will further extend the system to provide traffic information and navigational services to commuters through radios, telephone hotlines or variable message signs. In the distant future, satellite-based traffic monitoring systems will be developed.

TRAVEL DEMAND MANAGEMENT – MANAGING VEHICLE OWNERSHIP AND USAGE

Congestion alleviating strategies

In order to relieve traffic congestion, various approaches can be considered. In general, those techniques belong to either supply-side or demand-side strategies (Downs, 1992). It is universally recognized that while the supply-side strategies attempt so provide maximum capacity based on available resources, the demand-side strategies seek to regulate demand for travel, particularly trips made during peak hours. For such an island that has limited land as Singapore, the latter proves an essential and feasible approach.

Travel demand management in Singapore encompasses two methods: ownership control and usage control. Initially, the traffic management system aimed to impose higher costs in, owning cars such as in the Vehicle Quota System (VQS, see below). The program has for many years kept the number of vehicles at a sustainable level. Recently, the approach has shifted thee its emphasis on usage control, noticeably the Electronic Road Pricing ERP) system.

Congestion Pricing

Congestion pricing offers a potential means to influence travel behavior in congested areas. The congestion alleviating mechanism of congestion pricing is to provide a disincentive to drivers on highways by imposing fees on vehicle usage that vary depending on location, time and vehicle occupancy. By so, it encourages travelers to spread out their trips by shifting travel time to off-peak period, travel routes to less congested routes and travel modes to public transport. Besides, it makes motorists more aware of the true cost of the congestion imposed on the living environment, hence motivating them to consciously plan their trips or consider a modal shift to public transport as an alternative. Various congestion pricing measures what can be implemented include variable road pricing, vehicle-mile traveled (VMT) fees, and parking fees.

Depending on methods and scope, congestion pricing can be employed in three ways: facility pricing, regional network pricing and cordon pricing. Facility pricing is a pricing mechanism in which toll is normally levied on one or several highways such as that link major residential neighborhoods with a downtown. The method is simple to monitor and relatively political acceptable because they focus on one or some routes, therefore give rise to individual choices. Unless the highways are totally exclusive, this method tends to create congestion problem to non-priced alternative routes. Regional network pricing, on the other hand, imposes charges on a highway network of similar categories within a boundary. Cordon pricing is a pricing structure which charges vehicles on entering a designated problematic area, normally be a CBD. Prices may vary by time of day, by vehicle categories on the ground that it motivates effective use of transport facilities. During peak hours, vehicles are reluctant to enter the designated zone, by so traffic congestion in the area can be relieved. However the method may not guarantee a reduction in traffic flow on routes leading to the area. Another foreseeable common problem is that it may induce a "spilling effect" of traffic into the neighborhood areas, and create bottleneck at gantries where vehicles enter and exit the area. Singapore represents a typical example of successful implementation of the Cordon pricing method known as Area License Scheme, as introduced later.

Area License Scheme (ALS)

The Scheme was enacted in June 1975 with the objective of discourage all passenger cars carrying fewer than 4 people from entering the congested central area during the morning peak (OECD Scientific Expert Group, 1994) to alleviate traffic, to improve accessibility and mobility within the Central Business District (CBD) by requiring purchase of supplementary license to enter the area.

This Area Licensing scheme defined a Restricted Zone (RZ) in the most congested area, which is the most congested part of the city with the area of 710 ha (then expanded to 725 ha to encompass a neighborhood residential area) and is demarcated by 34 overhead gantry signs. Initially, these were monitored by traffic personnel from 7.30 to 9.30 am, and then changed to 10.15 am, Mondays to Saturdays, excluding public holidays. Only cars which display a license are allowed to enter this zone through one of the vehicular entry points. The licenses cost S$1, S$6 and S$3 a day for motorcycles, company registered cars and all other vehicles respectively, during designated peak hours (Kahaner, 1996). The monthly corresponding fees are S$20, S$120 and S$60. During less congested hours, from 9.30 am to

4.30 pm, the part-day licenses cost about 1/3, differentiated by their distinctive shapes and colors. Company cars were charged twice the resident rate for a license, while scheduled public busses, school buses, military vehicles, carpools (with four or more people) and taxis were favored and all exempted from license requirements. The Commercial vehicles were also exempted based on the grounds that the Scheme should not adversely affect the business life in the RZ. They could also move freely within the CBD without a license. The scheme was coordinated by its complementary parking policy to provide 20,000 parking spaces within the RZ with the fees increased with the parking time to discourage long time parking, seen as another instrument of traffic restraint.

In June 1989, the ALS was revised and extended to include the afternoon rush hours of 4:30 to 7:00 pm (later shortened to 6:30 pm). Furthermore, car pools, private and school busses, commercial vehicles, and motorcycles were excluded from the exempt list.

The Singapore Area License Scheme has been very successful in reducing traffic flow, therefore in relieving traffic congestion. As the most general objective, the Scheme planners set the target of a 25% to 30% decline in peak-hour traffic volume entering the RZ. Surprisingly, the Area Licensing Scheme was more successful than expected with respect to the reduced congestion during the peak hours. Traffic flow during peak hours had fallen by 45%, included a dramatic decline of 70% (Willoughby, 2000) in the number of cars in the CBD. Subsequently, the observed average speed inside the RZ during morning commuting hours was from 32 to 35 kilometers per hour, increased by 22% compared to that under the situation prior to the application of the Scheme.

However the Scheme suffered from some marginal negative side effects. These include increased traffic flow before and after the restricted hours since many people shifted their travel times in the RZ to just before and after the restricted hours. Additionally, new "escape corridors" around the CBD encountered increasing traffic since commuters avoided the CBD and seek for alternative routes. To deal with the "escape corridor" situation, traffic lights were reset to accommodate the increased traffic flow. It is believed that the price was set too high so that the roads in the RZ were economically under-utilized (Watson et al., 1996). Despite these effects, the popular thinking is that these are trivial as opposed to the social and environmental benefits achieved by significant reduction in traffic congestion.

Manual Road Pricing Scheme (RPS)

Over 20 years from the start in 1975, the ALS has kept traffic in CBD free-flowing, but some expressways have become suffering from congestion, especially during morning peak hours (Kahaner, 1996). Therefore, the RPS was initiated in 1995 to relieve congestion on those expressways. A pilot project is to charge vehicles on the East Coast Parkway (ECP) and subsequently extended to the Central (CTE) and Pan Island (PIE) Expressways in May 1997. The charges were low with fees of S$0.50 for motorcycles and S$1.00 for other types of vehicles, but applicable only for the period between 7.30 to 8.30 am on working days (Kahaner, 1996). The Scheme achieved a considerable reduction in traffic volume by 40% while the average speed increased significantly, from 40 to 67 kilometers per hour. It was subsequently extended in time and scope to other expressways near downtown Singapore. However, like the ALS, it was manual labor intensive and has limited potentials to differentiate charges based on time of travel, level of congestion and actual road usage. For example, the charge of using an expressway is levied on daily basis, so repeated uses does not incur additional charges. Apart from that, it also suffered from other shortcomings, such as inconvenience and complexities, and the inability to response quickly to the level and location of incident congestion. It was therefore eventually be replaced by an electric road pricing system.

Electronic Road Pricing (ERP)

ERP is another Singapore's recent attempt on tackling traffic congestion. It came into operation in April 1998. ERP bases on a pay-per-use principle that attempts to reflect the true cost of travel. ERP covered all the areas which has been previously covered by ALS and RPS, then extended to bottlenecks on other expressways and major roads which suffer severe congestion. The system operates at 28 gantries in the previous ALS, 11 gantries at expressways, and 3 gantries at the outer ring roads (Singapore Fact Sheet Series, 2002). The operational hours are 7.30 am to 7.00 pm at the ALS on working days, and from 7.30 am to 9.30 am, Mondays to Fridays on expressways and outer ring roads. The system is flexible since charges depend on location, vehicle type and the time of day. The charges are set higher during busy periods and lower outside those periods. Large vehicles which occupy more space and thus induce more traffic congestion are also charged at higher rates.

How does the system work?

The ERP system consists of three main components: the In-vehicle Unit (IU), the gantry, and the central computer system (Keong, 2002). The IU is an electronic device installed in the vehicle that communicates with the gantry equipment that accepts a Cash Card for payment of ERP charges. The Cash Card is a stored value card for ERP advanced payment. The card must be maintained with a positive balance by motorists who can top it up from banks or cash card auto Machines near-by. This automatic type of payment allows reducing transaction costs and the need for personals at gantries to smooth traffic. The gantry is an overhead structure that records the vehicle's passages with a camera attached to it. The Central Computer System in the control room monitors the traffic network and equipment and recognizes the license on violated cars in the photographs. It can also automatically classify whether a problem under consideration belongs to errors or violations: violations include no IU installed, without a Cash Card installed, or with an insufficient balance on the Cash Card while errors are usually human errors, include incorrect insertion of Cash Card, fault Cash Card inserted or hardware faults.

When vehicles approach ERP gantries, charges are deducted automatically from prepaid-stored-value Smartcards inserted into the IU (Kahaner, 1996). A short beep is heard when the charge is deducted from the card. The system uses surveillance antennas and cameras mounted on gantries to record and monitor vehicle passage. Vehicles without IUs or Smartcards will be photographed as violators and get fines subsequently (Menon, 2002).

The system has been particularly effective. The traffic monitoring of the first two gantries shows that traffic volumes on the expressway reduced by 15% during the morning peak hours and speeds increased from 35 to 55 kilometers per hour. Violations are more or less 100 cases daily, accounting for about 0.7 % of the total daily vehicle passes. The majority of the violations were motorists without Cash Cards or with insufficient balance in their Cash Cards. The system is error-free, requires no reduction in speed when passing the system.

Apart from this system, other technologies considered for ERP include the video-imaging of all vehicles and the radio beacon-based systems are also being explored. Nowadays Singapore is looking into the future for global positioning satellite systems (Kahaner, 1996).

Vehicle Quota Scheme (VQS) and Certificate of Entitlement (COE)

The Vehicle Quota System (VQS) was announced in Feb. and applied in May 1990. After an extensive debate in the Parliament and through the media, the Government announced its acceptance of establishing annual quota of new car licenses in order to maintain the maximum number of annual growth of vehicles of 3% (Willoughby, 2000). Anyone wishing to buy a car or motorcycle has to bid for a Certificate of Entitlement (COE). Each month, individuals can bid for a COE in one of the seven vehicle categories: cars with various engine capacities, goods vehicles and buses, motorcycles and an open category which does not restrict the type of vehicle (Kahaner, 1996). The open category allows for any change in economic conditions and also for a change in preferences. The proportion of COEs allocated to each category of vehicles is determined by historical records, except the open category which is maintained at 20%.

The bidders pay for the lowest successful bid price. The COE then stays for 10 years from the date of registration of the vehicle. Upon the due date, the owners have to pay for the current COE bid price for the vehicle if he/she wants to keep the vehicle for another five or ten year period. Certain classes of vehicles such as buses, emergency vehicles, trailers, and diplomatic vehicles are exempted from this scheme.

The working of COE Scheme lies upon the market forces to determine the acceptable prices by the public in order to make it in line with the road capacity and traffic conditions to avoid traffic congestion. An electronic bidding system has been in place since 2002. Under such a system the bidding process becomes transparent as any bidder is able to view the bids put up by other bidders.

IMPROVEMENT AND REGULATIONS OF PUBLIC TRANSPORT

Public transport is the backbone of Singapore's land transport policy. A “world class transport system”, by definition, must provide commuters with highly efficient, comfortable and convenient travel in smooth traffic. It must centre round a powerful public transport system. The public transport system in Singapore nowadays carries 55%-60% of the total commuting trips, but the LTA aims to encourage greater transit ridership to achieve 75% of the city trips by public transport in the future (LTA, 1996). The main components of the system imply MRT, LRT and buses. The functions of each component are clearly defined: MRT for heavy corridors, LRT serves as feeders to MRT, and buses serve for less heavy corridors and provide services else where, such as between residential areas. Particular attention is given to create environmentally friendly pedestrian streets in the CBD, and walkways and cycling facilities to MRT stations and bus stops. Policy on public transport system determines that the operation companies maintain full recovery of operating costs and depreciation, while the capital investment in infrastructures and replacement cost of rolling stock and equipment are carried by the government (Clarke and Wong, 1998).

Bus operations in Singapore are safe, reliable and efficient. Bus services carry 38.7% of the total journeys to work in the modal split, as compared to 20.2% that of the cars, 14.5% that of the MRT and 12.8% that of bicycles (Willoughby, 2000). Good service is a prime government policy objective. In line with the policy on public transport system, the bus service strives to maintain profitable bus services in major routes while subsidizing low profitable routes and to realize economies of scale in small market. Profits from bus services contribute towards the historical component of the replacement cost. Buses enjoy partial exemption from road tax payments on their vehicles. Bus lanes are provided in some particularly heavy demand routes and buses have priorities at traffic signals. In the future, bus operators will use satellite technology as a friendly eye in the sky to detect positions of buses (LTA, 1996) so as to provide supplementary services in case of problems. More traffic lights with B-signals will be installed to give buses an early start and late cut-off. Intelligent traffic lights will turn green automatically when there is a bus approaching.

CONCLUSIONS

Road pricing offers a good solution to deal with congestion. It also represents the best instrument to internalize the costs of externalities that motorists impose on society. With ERP, motorists will be more aware of the true cost of driving and traffic congestion will be relieved. Although the initial installation of the system is relatively costly, it would be offset by the benefits of smoothness of travel it can guarantee. Nevertheless, road pricing cannot perfectly internalize the external environmental costs. Therefore, measures such as VQS, fuel tax or imported tax are still be necessary to design an optimal price mechanism in setting the correct economic incentives to deal with traffic congestion.

To be successful, road pricing schemes should satisfy some prerequisite conditions. Firstly, prices should be varied according to the level of demand: as traffic volume increases, price increases, and when congestion level falls, so as the price. Secondly, road prices should act as a pricing mechanism to reduce congestion rather than a merely way the government raises its revenue, and the revenues collected from road pricing should stay in the transport sector (Santos, 1999) to improve the road network or public transport. Lastly, equity issues should be taken into account to keep a balance between affordability and congestion objectives: If the charge should be sufficient high to induce modal shift to public transport, it should not be too high to reduce the congestion to the lowest possible levels, but at the level that maximizes the utility of travel, including travel time and resources.

Singapore feels it important that there should be a balance between car ownership and car usage management. While ERP regulates usage of vehicles on specific roads at peak times, COE is an ownership restraint measure to regulate the growth of the vehicle population (Kahaner, 1996) to be consistent with the system capability. Other types of restraint like fuel tax, imported tax, license fee, and especially parking fee, though have limited potentials in dealing with congestion, still be necessary in couple with ERP in managing the demand, since ERP charges alone may not be adequate.

In Singapore, the purpose of road pricing as an important instrument to relieve traffic congestion has been made clear to the public. The responsible organization, the LTR, is empowered, experienced and persistent in carry out many of such strategic-size schemes. Historically, Singaporean Government has proved its loyalty to its people and its country, so there is a general public acceptance to government's efforts. Since the success of the country's transport schemes and policies rest on its political and administrative systems, similar policies in other countries need to be experienced with practical adjustments to their own local conditions.

THE MULTIMODAL TRANSIT SYSTEMS IN SINGAPORE

The multimodal transit systems in Singapore consist of three major systems: mass rapid transit (MRT), light rapid transit (LRT) and bus systems. Currently, out of a total of 7.7 million trips made each day, about 60% of the daily journeys are made using the multimodal transit system (MOT, 2002). The long term plan is to increase the share to 75% through expansion of the network and service (LTA, 1996). In the rail transit master plan by LTA, as shown in Figure 1, the MRT services will provide the major trunk services, while LRT and buses will function as feeder modes, in the integrated and multimodal transit system envisaged. The planning models of the rapid transit services estimate that they will serve mainly medium to long distance journeys, while LRT and buses will facilitate the short journeys of reaching people's home.

Figure 1 illustrates the existing MRT network which consists of the North South Line (NSL), the East West Line (EWL) and the Changi Airport Line (CAL) with a total length of 89 km. The North East Line (NEL) is targeted to be completed by 2003 and will add an additional 20 km to the network length. The lines radiated from the centre of the city to facilitate travel on the major corridors from all corners of the island. By 2005 the rail network will be expanded to 100 km with the completion of the phases 1 and 2 of the Circle Line, which will surround the island and intersect with all the radial lines at mid-point stations. This will greatly enhance the connectivity and accessibility of the system. In the longer term, plans exist to expand the rail system to 160km within 10 to 15 years.

The MRT system is complemented by light rapid transit (LRT) systems at various residential townships as feeder services to enhance the accessibility of the rail network. By 2006, there will be a total of three LRT lines in operation and they are: Bukit Panjang LRT, Sengkang LRT and Punggol LRT, with a total length of 27 km. A number of LRT systems are also being planned at various new residential towns.

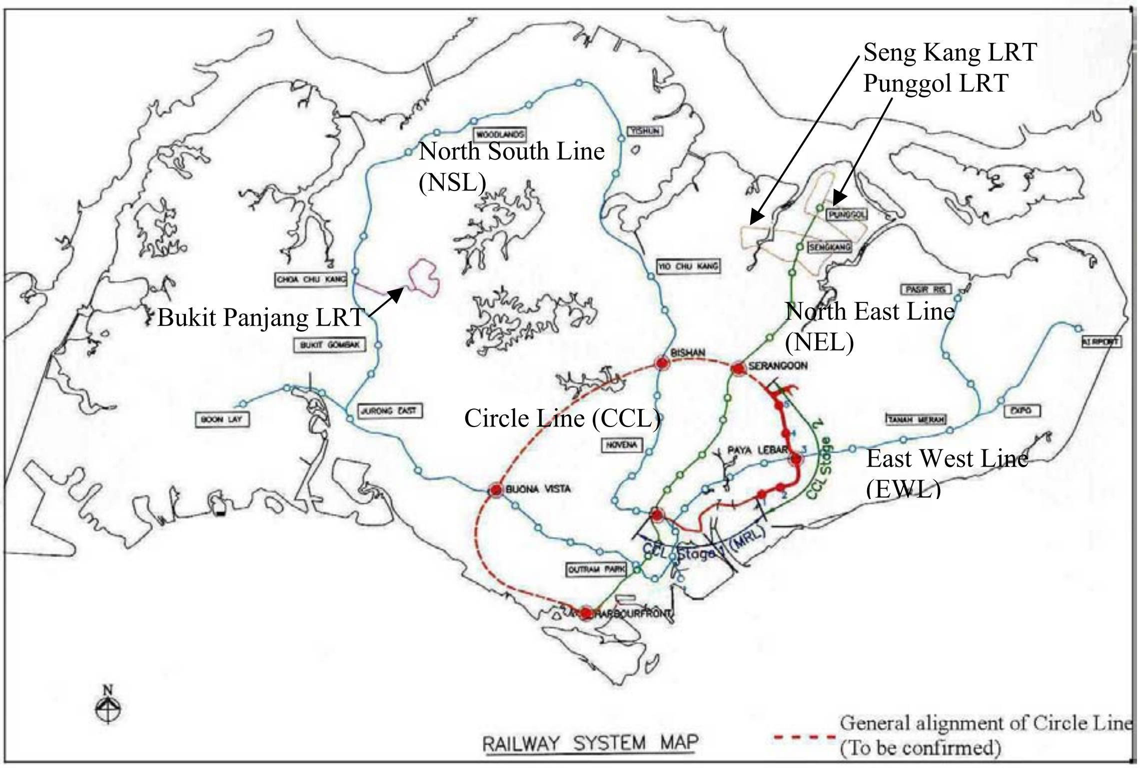

Figure 1. The backbone of the multimodal transit system in Singapore – the planned and existing MRT network (Source: LTA (2002b))

On the road system, buses and taxis supplement the rapid transit system network and provide an alternative ways of travel. Currently, there are two major operators of the bus services, SBS Transit and Trans Island Bus Services (TIBS), with a total fleet size of about 3800 buses (SBS: 2602 buses and TIBS: 787 buses). The two companies operate a total of 282 trunk and feeder services (SBS: 172 routes and TIBS: 56 routes). Each day there are about 3.2 millions of bus riders, of which 75% of them use use SBS services. The bus services are required to satisfy the Basic Bus Service Specifications and Standards, which regulates the directness, accessibility, route length, headways, bus loading, hours of operations, affordability route information, and bus timing. In the development of a multimodal transit system, the role of the buses is set to complement the rapid transit systems. In places where there are no rapid transit, trunk bus services will fill the gap. There are about 19,000 taxis operated by two major taxi companies, which make about 600,000 trips a day (MOT, 2002).

INTEGRATION OF THE MULTIMODAL TRANSIT SYSTEMS

The multimodal transit systems are not planned and operated as individual systems. They are integrated to facilitate the convenience and efficiency in travel using multiple modes, which have become the norm for transit traveling in Singapore. The ultimate goal is to enhance the integration between different systems in a seamless manner. This can only be achieved by careful consideration of the infrastructure integration and most importantly the integration in services.

In Singapore, the forms of integration can be classified into 3 main categories: basic connectivity, establishment of transit place, and creation of a destination (Tong, 2002). To provide for basic connectivity, stations are connected with other developments and/or other forms of transit to provide shielded access in all weather conditions. The establishment of a transit place is through the integration of amenities within the premises of transit stations, for example, the Woodlands interchange with a three-level design to facilitate the transfers between MRT, buses, cars and taxis, as shown in Figure 2. For a multimodal transit station to become a destination, it needs to be integrated with the developments such that it forms an integral part of the developments, which in fact becomes a "transport-integrated" property (Tong, 2002). Example of this can be found in Novena station, as shown in Figure 3, which shows the integrated development of the stations within a commercial and office development. There are two other similar developments at Toa Payoh and Sengkang interchanges. When a transit station becomes a destination, the implication to the modeling process is that trips will be attracted to the destination, which is itself a station.

The facilities provided to facilitate the integration include bus interchanges, bus shelters, covered linkways, taxi shelters, passenger pick-up and drop-off points, pedestrian underpasses, overhead bridges, and bicycle stands.

Figure 2. The Woodlands interchange

Figure 3. The Novena station

The main strategies of achieving a multimodal transit system can be summarized as the followings (Konopatzki, 2002; Segaram, 1994, Tong, 2002):

(i) Institutional integration: It was first achieved through the formation of TransitLink, which is an inter-agency organization to facilitate the integration of services by different companies. The second major step is the formation of Land Transport Authority, which integrates all relevant areas in land transportation. The visions set out in the White Paper (1996) include the development of a highly integrated transit system for seamless travel that meets the demands of a dynamic and growing city. The third major step is the formation of multimodal transit operators, for example, the merger between the Singapore Mass Rapid Transit and Trans-island Bus Services that gave birth the first multi-modal transit operator in Singapore in 2001. The contract to maintain and operate the North East Line and Punggol and Sengkang LRT was awarded to Singapore Bus Services (SBS) as an initiative to speed up the transformation of uni-modal transporation operators into multi-modal ones to achieve the vision of seamless connection with a multi-modal network. The SBS transit (formally Singapore Bus Services) will start running the North East MRT line, as well as two new LRT lines in Singapore, by 2003. These services are all situated at the northeast corridor in Singapore, providing ample opportunities for integration of services. Therefore, the two multimodal transit operators basically have their services in different geographical areas. The operations of the MRT network by these two companies will create competition, at the same time, certain integration of their services to provide an integrated system for the public.

(ii) Physical integration: This includes providing infrastructure to facilitate the transfers between different modes of transit, for example, the vertical integration of MRT stations and bus interchanges; integration of stations with commercial and office developments, or simply by providing covered linkways.

(iii) Fare integration: Since 1986, the TransitLink fare card has been the main mode of fare payment for both MRT and bus services. Fares on multimodal trips involving both bus and MRT can receive discounts, which are given to the commuters using the fare card in the form of rebates at each transaction. In 2002, the contactless smart card: EZ Link, was launched. The EZ Link speeds up the payment of multimodal transit services when passengers board the vehicle. The convenience of using the EZ Link card has made it rapidly becoming the major mode of payment replacing the fare card.

(iv) Network integration: The first stage of network integration is achieved through the integration of MRT-bus network, due to the duplication of services offered to public since the operation of MRT in end 1980's. The second stage of integration follows the formation of the two multimodal transit operators, integration between rail lines, bus routes and rail lines, becomes a reality. This allows the transit system integration to be expanded into the integration of services. Already, the merged SMRT and TIBS are in the process of integrating their services. Although the North East Line will not be in operation until mid-2003, the SBS Transit is also in the process of planning for the service integration in their service areas in the northeast corridor of Singapore.

CONCLUSIONS

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Land Transport Authority

LTA (2002) reported the development of a Road and Rapid Transit System Master Plans, as part of the concept plan for the development plan of Singapore, to cater to the transport needs of population in 2045. With the vision to develop an integrated land and transport infrastructure, where people can commute seamlessly from one place to another, LTA works closely with the Urban Redevelopment Authority (URA) to develop Singapore's transport infrastructure plans. The land transport strategy is geared towards providing an integrated and efficient public transport system that offers commuters fast and efficient services (LTA, 2002a). The Rapid Transit System (RTS) would be the backbone through the provision of seamless and multimodal transit services. Strategic radial and orbital lines are being planned. At the same time, the Bus Concept Plan examines the changing role of bus services and develops plan to guide the routing of the bus systems as the RTS expands. It has been envisaged that commuters would travel more on the RTS for medium to long distance journeys, while buses would provide the needed accessibility for shorter or feeder trips (LTA, 2002a). Buses as trunk services would be provided to serve areas not reachable by RTS. These are analyzed with the use of a strategic transport model, in which data such as concept plan, network inventory, housing, employment, car ownership, travel surveys and traffic data, are integrated with various model parameters to be used in a wide range of studies, such as rapid transit studies, strategic planning studies, …etc. There is also an emme/2 model for the Singapore's network which consists of more than 900 zones to facilitate the study of strategies related to the planning of the multimodal transit network (Zhou et al, 1998).

Singapore Mass Rapid Transit (SMRT)

The new Circle Line will be operated by the SMRT. The CCL crosses the East West, North South and North East lines and has an orbital alignment encircling the central city area. The new line will overlap with many existing trunk and feeder services, which are operated to complement the lack of MRT services in this area. There will be plenty opportunities to explore the possibilities of bus-rail, rail-bus and rail-rail integration. This is in addition to the planned merger with the bus operator TIBS. Therefore, a multimodal planning scheme incorporating three separate models is being developed (Konopatzki, 2002). The three models are the cost model, supply model and demand model. Economic Value Added (EVA) analysis is used as the major part of the cost model, which is used to evaluate and value the economic profit from a particular multimodal scenario. The multimodal network configuration and various operation regime can be simulated and evaluated with the use of the supply model, which is developed using the ptv Vision system. The supply model is also integrated with a digitized land data of Singapore. Strategic planning of multimodal transit systems is achieved through the use of the demand model, which is based on land use and transportation system data to generate forecasts of travel patterns and passenger demands. The demand model is developed using emme/2, therefore it is capable of integrated with a similar model developed at the Land Transport Authority.

CONCLUSIONS

The components and the development of the multimodal transit system in Singapore were discussed in this paper. The strategies of the development of a seamless and multimodal transit system were also reported. To achieve the stated objective of developing such a system, the various ways to integrate the infrastructure and services were reviewed. These have profound impacts on the way the multimodal transit system is modeled in Singapore. Due to the differences in objective, the focus in the multimodal transit modeling varies between different organizations. The different modeling approaches were discussed. It can be concluded that the further development of the multimodal transit system in Singapore will require the further enhancement of the existing models used by different agencies, and eventually there may be a need to integrate the various models to provide an integrated platform for the analysis of Singapore's multimodal transit system.

The *Land Transport Authority* (LTA) is a statutory board under the Ministry of Communications and was established in September 1995. It is responsible for planning, developing and managing the land transport system to support a quality of environment while maintaining optimal sustainable use of transport resources to meet the public travel demand. The LTA was formed as a result of a merger between four administrative bodies, namely the Registry of Vehicles Division, the Mass Rapid Transit Corporation, the Roads and Transportation Division, and the Land Transport Division under the Ministry of Communications. This has brought the activities of the various organizations involved in the planning, development and management of land transport policies and infrastructures into one solid centralized, integrated and empowered body.

The *objectives* of the LTA include:

- To deliver a land transport network that is integrated, efficient, cost-effective and sustainable to meet the nation's needs.
- To plan, develop and manage Singapore's land transport system to support a quality environment while making optimal use of transport measures and safeguarding the welling-being of the traveling public.
- To develop and implement policies to encourage commuters to choose the most appropriate transportation mode.

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