CHAPTER 7

Issues in transportation planning – the Singapore experience

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Abstract

Singapore can be considered as one of the few Asian cities to be successful in urban transport planning and management. It has introduced several far-reaching vehicle-restraint policies, such as the vehicle quota system, the electronic road pricing scheme and a high vehicle tax structure, all of which have been effective in relieving traffic congestion on the roads. Recognizing that these restraint policies must be complemented by a good public transport and transportation management system, the Singapore Government has, in the past two decades, embarked on several ambitious programs to introduce intelligent systems into its transportation operations as well as to develop an efficient urban rail network. These decisions are in line with Singapore’s long-term transportation plan to integrate land use and transportation planning, to develop a comprehensive road network, to manage car population and road usage, and to provide quality public transport for its people. This chapter discusses the issues related to urban transportation planning in Singapore, with the intention of drawing out the lessons learned from its experience.

1 Introduction

1.1 Background

Singapore, an island city-state of 685km$^2$ and a population of 4.1 million in 2002, is one of the highest densely populated countries in the world (see fig. 1). Located 137km north of the equator at the southern tip of the Malaysian Peninsula, it faces a severe constraint of land scarcity.

Evolved from a small fishing village of 150 inhabitants to a British regional trading post in 1819, Singapore attained self-government in 1959, joined
Malaysia in 1963 and became an independent city-state in 1965. Since then, Singapore has witnessed significant changes in the development of its economy. It is today a major Asian metropolitan centre and one of the newly industrialized economies in Asia. Currently, there are over 5000 foreign companies located in Singapore, and many of these multinational corporations have established regional headquarters and manufacturing bases on the island. The World Bank had reported that Singapore's 1997 GNP per capita of US$32,940 was the sixth highest in the world [1].

Transportation has always played an important role in the economic and physical development of modern Singapore. From the days of Sir Stamford Raffles when he founded modern Singapore to the present day, the aspiration for an efficient transport system is evident as a governance principle among its political leaders.

1.2 Towards an efficient transport system

An efficient transport system is one that is able to move, as many commuters as possible to their desired destinations, in the shortest possible time. Such was not the experience in the 1960s when the city was plagued with chronic congestion problems in the city centre, poor traffic management of its facilities and inefficient public transport operations. Singapore had recognized that the lack of an efficient transport system could have a damaging effect on the economic growth and development of the country.
A multi-pronged and integrated approach involving several issues has been adopted by the Singapore government and the Land Transport Authority (LTA), in pursuing an efficient system that meets the needs of the country. The concerns taken into consideration in the transport planning process may be summarized in the following four issues:

1. Land use and transport planning;
2. Travel demand management;
3. Traffic engineering and control; and
4. Public transport operations.

The first two relate to the demand for travel, while the other two are associated with the supply of transport services. They interact with each other in the sense that any attempt to deal with the issues of how one group will affect the other. For example, improvements in public transport operations are often planned together with a travel demand management scheme.

The first issue stems from the need to maximize land-use utilization, which is particularly important in land-scarce Singapore. Of the 640km² of total land area, 12% are dedicated for roads and other facilities to support the road infrastructure. This is a sizeable proportion since only 13% of land is taken up for housing. This percentage is also comparable to major developed cities like Paris, Tokyo and Munich [2]. This may imply, therefore, that the limit of land utilization for transport development may have been reached. Since land use is one of the prime determinants of movement and the propensity of trip-making, it makes sense to integrate the planning of transport systems with the land use system such as to minimise travel demand and the need for more transport infrastructure.

Secondly, the phenomenal social and economic growth in the early years of nationhood had resulted in a high demand for transportation, especially private vehicular travel. From the viewpoint of most people, driving in private vehicles is the most attractive solution in meeting individual transport needs. The country’s ratio of motor vehicles per km of road has increased nearly threefold in the last forty years (see table 1). Despite the investment in road expansion programs, given the land constraints, it is impossible for road development to keep pace with the growth in car population. Hence, the success of any efficient transport system will depend upon the effective application of travel demand management.

Thirdly, public transport operations are regarded to be instrumental in the government’s attempt in restricting the use and ownership of private motor vehicles. The imposed demand management measures meant that there will be a heavy reliance on the public transport system. Currently, more than 50% of the 7.0 million daily passenger trips are made on public transport modes, with buses carrying the major proportion (see table 2). With affluence, the population has increased their expectation of an efficient and comfortable public transport system. There is also an implicit need to ensure that the public transport services remain an attractive alternative to the private car.
Table 1: Vehicle population in Singapore.

<table>
<thead>
<tr>
<th>Year</th>
<th>Private cars</th>
<th>Other vehicles</th>
<th>Vehicles per km of road</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961</td>
<td>70,108</td>
<td>47,828</td>
<td>82.1</td>
</tr>
<tr>
<td>1970</td>
<td>142,568</td>
<td>147,855</td>
<td>149.9</td>
</tr>
<tr>
<td>1980</td>
<td>152,574</td>
<td>218,767</td>
<td>157.6</td>
</tr>
<tr>
<td>1990</td>
<td>271,174</td>
<td>271,178</td>
<td>188.2</td>
</tr>
<tr>
<td>2001</td>
<td>398,787</td>
<td>309,583</td>
<td>227.1</td>
</tr>
</tbody>
</table>

Source: Singapore Department of Statistics [3]

Table 2: Daily Passenger Trips.

<table>
<thead>
<tr>
<th>Public transport modes</th>
<th>Trips per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRT</td>
<td>1,339,000</td>
</tr>
<tr>
<td>Buses</td>
<td>3,001,595</td>
</tr>
<tr>
<td>Taxis</td>
<td>588,632</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4,929,227</strong></td>
</tr>
</tbody>
</table>

Source: Singapore Department of Statistics [3], Land Transport Authority [4]

Lastly, in the short term, there is always a need to maximize the road capacity through various means, such as traffic engineering measures and traffic control schemes.

In tracing Singapore’s experience in planning its transportation system, these four issues will be examined in turn. The lessons learnt from the last 40 years of transportation planning will be discussed in the last section along with the challenges that Singapore would face in planning for the future.

2 Land use and transport planning

Land use and transportation have always played an important role in the economic and physical development of modern Singapore. The vision of its founder Raffles, to transform the small fishing village to a great commercial hub and a free port was manifested in his Town Plan, where the residential areas were separated from the commercial zone near the river bank to facilitate trading. With careful planning and great foresight of the founder, the island soon became one of the major transportation and distribution centres that attracted both people and goods from nearby regions. This section discusses the practice of urban transport planning in Singapore in three periods of development. The era prior to the 1960s may be considered to be one when there was little or no systematic transport planning. From the 1960s to the 1980s, which roughly coincided with the early period of nation building, transport planning was mainly problem-driven. In the 1990s and early 21st century, transport planning has become vision-driven.
2.1 No systematic planning

Singapore in the 19th century was experiencing unprecedented prosperity derived from its importance as a trading post. Trade expanded eightfold between 1873 and 1913, and the prosperity attracted immigrants from areas around the region. By 1860, the population had grown to 80,792. Despite the rapid growth, transport planning in the years leading to the 1960s, if any, was relatively simple and insignificant.

The first formal transport study was reported in 1938 when the Traffic Conditions Committee was formed to consider the traffic conditions in the town centre and to make recommendations for improvements. It reasoned that there was more than sufficient traffic capacity on the roads as ‘most of the roads in Singapore were planned when less than half the volume of traffic now using them was in existence’ [5]. Apparently, the Committee was more concerned with facilitating motor car movements than meeting transport needs of the populace as seen from their recommendations, such as extensive removal of road obstacles (including street vendors), segregation of pedestrians and cyclists from the motor traffic, provision of better road signs and markings as well as the creation of more parking space.

The Master Plan for the period 1952–1955 was the first attempt by the Government to introduce some form of transport planning which involved establishing a road plan for the country. However, the intention of the plan was to preserve and protect land parcels required for domestic transport corridors, for example, the main arterials or parkways in outer areas of Bukit Timah, Woodlands, Braddell and Thomson [6].

2.2 Problem-driven planning

In the post-war years, Singapore faced formidable problems, notably serious unemployment and acute housing shortage. In 1960, the population had already exceeded 1.6 million and by 1968, it had passed the 2-million mark. The urgent task faced by the leaders who had obtained self-rule from the colonial rulers in 1959, was to embark on a massive crash building programme to house the people as well as to set out a large-scale industrialization programme to create jobs for the populace [7]. Furthermore, to sustain the efforts of industrialization, the leaders wisely saw the need to educate the young and to train the work force. A crash programme to build new schools was therefore also launched.

Transportation was not given the priority largely because heavy commitments were already placed on housing and industrialization. Massive developments in housing, factories and schools in the 1960s and 1970s had resulted in increased travel volume and longer travel distances. The urgent need to build a substantial number of housing units within a relatively short time favoured the construction of high-rise dwellings. The high traffic generated from such buildings, made worse by their high spatial density, added additional pressures on the road system. The successful economic policies adopted by the government also meant rapid economic growth, with the Gross Domestic Product doubling within 8 years from $2016 million in 1960 to $4091 million in
Advances in City Transport: Case Studies

This raised the propensity of the people to own and operate private vehicles.

The inadequate transport supply, coupled with increasing transport demand due to growth and development, resulted in mounting traffic problems for the government. Poor traffic management and serious congestion in the city centre, inadequate and inefficiently operated public transport services, poor infrastructure maintenance, as well as poor driver discipline, ineffective enforcement and high road accident rates were the typical problems then. Perhaps one of the most serious problems was the lack of proper transport planning as whatever attention given to domestic transportation was in the form of road widening, construction and the provision of car parks. It soon became clear that unless these transport problems were tackled systematically, the overall development of Singapore would be hampered. It was only in 1968 that the Ministry of Communications was formed to oversee the planning of transport facilities when the importance of the transportation issue was formally acknowledged by the political leadership.

Since then, Singapore transport planners have adopted an integral approach in planning. By closely relating the expansion of urban transport facilities with other measures for promoting desired patterns of land use, they aimed at integrating urban development with transport planning. This integrated approach in planning was translated into a long-range, holistic, urban land-use and transportation master plan soon after the nation’s independence. The Concept Plan with a broad, strategic, long-term land use and transportation plan was updated once every 20 years to guide Singapore's physical development.

2.2.1 The 1971 Concept Plan

In 1971, with the help of the United Nations Development Programme, a long-range comprehensive master plan for the entire urban landscape was devised, known as the 1971 Concept Plan. The intention of the plan was to integrate land-use with transportation along designated corridors by the year 1992 for a population of 3.4 million. Within this concept was the Strategic Transport Plan which proposed a comprehensive island-wide network of expressways and arterial roads, as well as a Mass Rapid Transit (MRT) system to facilitate transportation between zones of high traffic generation.

At the same time, since movements within the transport system did not normally add value to purpose of the journey, it was also logical to minimize the inconvenience in travel by ensuring seamless travel from origin to destination. This involved, for example, a proposal for a proper mix of development, and concentrating high building densities around mass rapid transit stations so as to ensure maximum accessibility for commuters to key nodes of employment, housing, leisure, and other social activities.

By adopting a ‘Ring Concept’, the plan envisaged the development of a concentric ring of new high-density satellite towns of housing estates around the central water catchment area, with each town separated by green spaces and a system of parks and open spaces. The need to integrate land use and transport planning expressed itself in the motivation to minimize the number and length of
trips. With shorter trips, commuters were expected to be less dependent on cars. To enable workers to live, work and study within the same town, light industries and schools were located within housing estates. The development of transportation infrastructure was also integrated in each town by locating bus interchanges and MRT stations with commercial facilities in the town centres, so as to facilitate movement of people to the downtown area.

2.3 Vision-driven planning

By 1989, much of Singapore's infrastructure envisaged in the 1971 Concept Plan, such as new towns, expressways, the MRT system and the renewed Central Area, had already been put in place. As the economy grew, the city also had to keep up with the changing demand for a modern physical infrastructure. New Concept Plans were needed to meet the new challenges faced by Singapore as a developed country in the 21st century.

2.3.1 Revised Concept Plan 1991

The Revised Concept Plan 1991 was to guide land development that would meet the social and economic needs of the country for the ‘Year X’, when the population is expected to reach 4 million [10]. Key proposals of the Plan include better housing, a new downtown, new regional centres, technology corridors and conservation of the natural environment.

This Concept Plan adopted a ‘constellation concept’ strategy of setting up regional centres aimed at decentralizing commercial activities (see fig. 2). Decentralization is expected to result in more uniform spatial distribution of traffic as well as likely reduction in trip lengths. To relieve the activity loads in the city centre, four regional centres were planned at Tampines in the East, Seletar in the Northeast, Jurong East in the West and Woodlands in the North. Once completed, this urban hierarchy will help reduce congestion in the central area. It is to closely integrate urban development with the present planned transport system, thereby bringing jobs closer to workers' homes. This should result in a less transport-intensive, less costly, and more efficient and congenial urban environment.

An improved transport system involving various modes of transportation to serve the transport needs of the citizens was also envisaged. Public transport was to be enhanced to become an attractive alternative to the car. The strategy was to extend the mass transport system to areas of intense developments. The MRT system serving the main corridors was to be supplemented by the Light Rapid Transit (LRT) in less dense areas. A network of expressways and semi-expressways was to be developed along with the tunnel connections within the city area and bridge connections to the offshore islands.

2.3.2 The Concept Plan 2001

As the demand for land continues to increase with the rapid growth of the economy and population, there was a need for a revision of the concept plan to keep pace with changing land use needs. The Concept Plan 2001 maps out the vision of Singapore for the next 40–50 years based on a population scenario of
Advances in City Transport: Case Studies

5.5 million [11]. Key proposals presented in the plan included building new housing in established existing areas and in the CBD, expanding high-value industries, and integrating of businesses, housing and transportation. Where possible, landmarks and natural features were to be integrated as part of new towns and developments.

The Concept Plan provides for new orbital and radial rail lines; with radial lines providing direct travel into and out of the city centre (see fig. 3). The existing 93km of rail lines is to be increased to about 500km. Industries and businesses close to MRT stations are allowed higher plot ratios to maximize the use of land and to encourage more work places near MRT stations. Increased capacity on the expressways, and more flyovers and underpasses along the main arterials are planned to allow for faster and smoother rides in future.

2.3.3 Land-use integration

Land-use integration as advocated in the Concept Plan is achieved by encouraging high density developments at and around major transport nodes such as the MRT stations and bus interchanges. Such integration provides multiple benefits, not only to the commuters, but also to the developers and public transport providers.

Firstly, commuters can enjoy seamless travel from origin to destination and walk less in greater comfort and convenience. For example, between a MRT station and an office block, shopping mall or entertainment centre, commuters need only get on the MRT train for a ride that takes them practically to the
doorstep of their destination. Secondly, such integrated developments are expected to benefit from higher property values and increased consumer traffic. Thirdly, a good mix of residential, industrial and commercial developments will also benefit the public transport providers because it will result in a more uniform traffic demand and hence a more economically sustainable system. Such direct integration of developments needs to be planned early so as to avoid the costly investments if these are to be introduced after the rail lines are completed.

At present, many developments with high plot ratios are being constructed above or adjacent of MRT stations. A good example of such land use and transport integration is the Dhoby Ghaut MRT Interchange Station which was opened for commuter traffic together with the North–East Line in June 2003. Developed together with a 6-storey retail and 10-storey office tower blocks, it will also serve the proposed Circle Line in 2006 in addition to the North–South and North–East Line. The station will have five underground levels with covered pedestrian links to nearby buildings and will handle traffic of 22,000 people during the peak hour.

On the other hand, transport facilities are integrated into the developments in the newer housing estates. In Punggol, residential units are built within 300m walking distance of the nearest LRT stops and connected by sheltered walkways to facilitate walking in all-weather conditions. In some older housing estates such as Toa Payoh, existing transportation infrastructure is being redeveloped to integrate transport facilities with commercial activities. The purpose is to improve connectivity among the bus interchange, the MRT station, and residential and commercial developments nearby.
2.4 Future developments

Singapore has practised land use/transport planning integration, and adopted a policy of enlarging the rail’s catchment area by concentrating high-density public housing and commercial developments closer to the MRT stations. To achieve this integration, a number of schemes are used. These include public-sector land ownership, housing and infrastructure provision, establishing major developments over MRT stations and depots, and recently encouraging private sector developments.

It is envisaged that future MRT stations would likely be built underground so that land can be freed for housing and commercial developments. This not only solves the land-constraint problem, but will also enable better integration of different land use developments.

3 Travel demand management

The high demand for private transport in Singapore is in part due to its unmatched attractiveness over public transport in terms of convenience, mobility, flexibility and enjoyment of privacy in travel. Furthermore, with economic growth and rising affluence, owning a car has become an aspiration of most Singaporeans who view the car not just as a mode of transportation but also an important symbol of social status.

In 2002, there were 557,584 motor vehicles on the road, representing a 27% increase compared to a decade earlier. However, road lengths have only expanded by 9% over the same period. With about 225 motor vehicles for every km of roadway, Singapore is one the most highly densely populated in the world, in terms of vehicles per km of road. Despite heavy investment in road expansion programmes, it is impossible for road development to keep pace with the growth in vehicle population. The challenge for Singapore has always been to seek innovative ways to restrain vehicle growth and usage so as to keep vehicle population within manageable levels to contain the congestion problem.

Recognising that congestion imposes a social cost to the country, because of wasted time, unnecessary fuel spent, pollution, and lost man-hours, Singapore has always applied fiscal measures by levying a high premium for the right to own and use private vehicles. Since the late 1960s, various schemes have been implemented to manage the increase in number and usage of vehicles on the road. While earlier measures of high vehicle and road taxes have controlled vehicle growth to some extent, they have become less effective as the propensity to own cars continues to increase with rising affluence. In 1990, the government introduced the Vehicle Quota System (VQS), in which potential vehicle buyers are required to bid for the right to purchase new vehicles.

Usage restraint measures have also been implemented in tandem with ownership restraints. These include the Area Licensing Scheme (ALS) in June 1975 and later the Electronic Road Pricing (ERP) in 1998, in which motorists are charged a congestion fee for driving into the Central Business District (CBD) and along highly-traffic arterial roads during the peak periods. Other measures such as the Off-Peak Car Scheme and high parking charges in the CBD are also...
implemented to discourage the usage of cars during the peak hours. This section traces the development of these ownership and usage measures and discusses their usefulness in travel demand management.

3.1 Ownership restraint

3.1.1 Fiscal measures
The initial policy of vehicle restraint was to use fiscal control measures. In June 1968, when it was recognized that restraint measures were necessary, import duties for cars were increased drastically from 10% to 30% of the open market value (OMV). Further measures followed and in October 1972, an additional registration fee (ARF) of 25% ad valorem was imposed on new cars. At the same time, the annual road tax on vehicles, which hitherto was at a flat rate of 10 cents per cc. of the engine capacity, was revised severely to a sliding scale of between 10 and 30 cents per cc., depending on the vehicle class by engine capacity. When these measures were considered not entirely successful, further revision of road taxes and ARF were imposed in quick succession [12]. By 1983, the ARF had increased to 175% ad valorem.

With the introduction of VQS, the ARF for passenger cars was, however, reduced to 150% of the OMV in February 1991 with the intention of reducing the effect of high vehicle upfront cost to potential car owners. In addition, together with the implementation of ERP in 1998, a new vehicle tax structure was introduced to make the cost of travel more evident, as emphasis shifted from charging for ownership to charging for usage. At the same time, while retaining a sliding tax scale in favour of smaller-engine vehicles, the disparity in taxes and other fees between smaller and larger vehicles has been significantly reduced to align with the argument that contribution to congestion is not dependent on the vehicle engine capacity.

Currently, the new road tax rates (see table 3) are calculated based on the use of road space, as measured by passenger car unit (PCU) factors, as well as the contribution of road damage, in the case of heavy vehicles [13]. Thus, fixed and upfront vehicle taxes such as registration fee, ARF and road tax have been reduced for most vehicles.

3.1.2 Ownership licensing
Though the Area Licensing Scheme implemented in 1975 had been successful in curbing traffic congestion in the CBD during the peak hours, it did not slow down vehicle population growth. Price restraints in the form of taxes such as registration fees, import duties and ARF had also failed to deter increases in vehicle purchases. It was reasoned that a quantity restraint on vehicle ownership in terms of a quota system would be necessary eventually to cope with the problem of a rising vehicle population.

Under a quota system, the government can directly control vehicle population by prescribing a maximum number of new vehicles to be added, taking into account vehicles to be scrapped and hence taken out of circulation. By allowing the right of car ownership to be determined by market forces, the government would be freed from the heavy administrative burden of having to make constant adjustment to taxes [14].
Table 3: Existing tax structure for private cars

<table>
<thead>
<tr>
<th>Vehicle Tax</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Registration Fee</td>
<td>$140</td>
</tr>
<tr>
<td>Additional Registration Fee (ARF)</td>
<td>130% of OMV$^2$</td>
</tr>
<tr>
<td>Certificate of Entitlement (COE)</td>
<td>varies according to bidding process</td>
</tr>
<tr>
<td>Import Duty</td>
<td>20% of OMV</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Annual Road Tax</th>
<th>Road Tax Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Capacity (EC)</td>
<td></td>
</tr>
<tr>
<td>$\leq 600$ cc</td>
<td>$400$</td>
</tr>
<tr>
<td>$600 &lt; EC \leq 1,000$ cc</td>
<td>$400 + 0.25 \times (EC - 600)$</td>
</tr>
<tr>
<td>$1,000 &lt; EC \leq 1,600$ cc</td>
<td>$500 + 0.75 \times (EC - 1,000)$</td>
</tr>
<tr>
<td>$1,600 &lt; EC \leq 3,000$ cc</td>
<td>$950 + 1.5 \times (EC - 1,600)$</td>
</tr>
<tr>
<td>$EC &gt; 3,000$ cc</td>
<td>$3,050 + 2.0 \times (EC - 3,000)$</td>
</tr>
</tbody>
</table>

$^1$Applicable from May 2002; $^2$OMV: Open Market Value.
Source: Land Transport Authority [13]

Such a scheme, known as the Vehicle Quota System (VQS), was implemented on 1 May 1990. The number of vehicle quotas are revised annually, based on the long-term projection in vehicle population growth at a sustainable rate of 3% in tandem with growth in road capacity, but adjusted to take into account vehicle deregistration patterns. Table 4 illustrates the projected vehicle quotas in 2002 and 2003.

Under the VQS, a person wishing to register a vehicle must first obtain a Certificate of Entitlement (COE) through a bidding process that is conducted twice a month. For the purpose of bidding, vehicles are classified into 5 categories:

- Category A: Cars below 1600 cc
- Category B: Cars above 1601 cc
- Category C: Goods vehicles and buses
- Category D: Motorcycles
- Category E: Open category (for use in any category)

All successful bidders within each category pay the lowest successful bid price of the category. Affixed to registered vehicles, COEs are valid for a maximum period of 10 years. A vehicle deregistered before the 10th year may obtain a prorated refund based on the original COE value. Beyond the tenth year, the owner must obtain a new COE valid for another 10 years, at the prevailing bid price computed as the average of successful bid amounts over the past 3 months. Such a scheme ensures that no individual holds perpetual ownership rights to a vehicle and helps to lower the age of the vehicle population.
Table 4: Projected vehicle quotas for 2002 and 2003.

<table>
<thead>
<tr>
<th>VEHICLE CATEGORY</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars (1600cc &amp; below)</td>
<td>294,100</td>
<td>130,225</td>
<td>133,897</td>
<td>130,978</td>
<td>-</td>
<td>689,200</td>
</tr>
<tr>
<td>Cars (1601cc &amp; above)</td>
<td>391</td>
<td>3,907</td>
<td>4,017</td>
<td>3,929</td>
<td>-</td>
<td>20,676</td>
</tr>
<tr>
<td>Goods Vehicles &amp; Buses</td>
<td>14,325</td>
<td>7,125</td>
<td>6,225</td>
<td>13,200</td>
<td>13,625</td>
<td>54,500</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>12</td>
<td>17</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>38</td>
</tr>
<tr>
<td>OPEN</td>
<td>3,480</td>
<td>2,206</td>
<td>1,889</td>
<td>2,832</td>
<td>2,725</td>
<td>13,132</td>
</tr>
<tr>
<td>Total Quota For May 2002 to April 2003</td>
<td>26,640</td>
<td>13,255</td>
<td>12,134</td>
<td>19,965</td>
<td>16,352</td>
<td>88,346</td>
</tr>
<tr>
<td>Total Quota For May 2001 to April 2002</td>
<td>35,220</td>
<td>13,848</td>
<td>8,406</td>
<td>14,667</td>
<td>17,150</td>
<td>89,291</td>
</tr>
</tbody>
</table>

Source: Singapore Department of Statistics [15]

Several changes to the system have taken place since its first implementation. In October 1991, COEs were made non-transferable from one owner to another prior to the vehicle registration process. To curb excessive speculation in prices and profiteering by motor vehicle dealers, vehicle distributors were prohibited from bidding directly. As the COE prices across categories began to stabilize, the initial four vehicle categories were merged into two categories in March 1999 [16].

To further encourage a more transparent system and an informed bidding process, the Open Bidding System was implemented in April 2002. This proved to prevent large fluctuations in COE prices as evident in the earlier period before 1999 as seen in fig. 4. Such moves demonstrated the government’s desire to seek an equitable method through general consensus and resulted in increased confidence of car buyers.

The VQS system has resulted in significantly increasing the cost of owning a car, so much so that the car price per capita GDP rose from 2.7 in 1986 to 3.7 in 1991 and further to 4.7 in 1994 [17]. Because of persistent criticism of the high cost of car ownership, the government has on many occasions explained the rationale of the scheme, citing the limitation of land space and the unacceptable condition of congestion-filled roads. Despite disapproval from some quarters [18], the VQS system has been considered the most effective means of controlling vehicle growth. Other methods of limiting car growth, such as allocation of ownership rights by need, ballots, or a pay-as-you-bid system were also examined but were considered to be inappropriate [19].
3.2 Usage restraint

With the implementation of the VQS, the ownership cost comprises about 60% to 70% of the total cost of operating a car in Singapore. Having incurred a high capital cost of acquiring a car, drivers tend to use the cars more extensively because of the relatively lower cost of usage. The annual mileage of cars in Singapore in 1991 was 18,600 km. By international standards, this is very high considering the fact of its small land mass and road network. This trend is not sustainable in the long run, and usage restraints are needed to keep the roads free from congestion.

It is recognized that traffic congestion arises because the road user takes into account only his private cost and not the public cost of operating the vehicle [20]. Road pricing was considered a direct economic instrument that can control road usage. By internalizing this social cost, it will reflect the marginal congestion costs of road usage and lead to an optimal amount of congestion that is worth its costs to society.

3.2.1 Manual approach

Singapore started restraining vehicle usage in the early 1970s in response to the severity of the congestion problem in the city centre. Initially, staggered work hours and car-pooling were introduced to reduce peak traffic demands and to discourage the use of private transport into the city. However, such schemes did not work well, largely because there was a limit to allowing flexible work hours in many businesses and work [12]. Moreover, staggered work hours actually discouraged car pooling as the opportunities for forming car pools were reduced.

Figure 4: Fluctuations in COE prices of Category A and B (Category 2 and 3 prior to May 1999). Source: Singapore Department of Statistics [15]
3.2.1.1 Area Licensing Scheme  In 1975, the government introduced a vehicle restriction package that included an Area Licensing Scheme (ALS) supplemented by a Park-and-Ride System (PRS) and increased parking fees. Under the ALS, the Central Business District (CBD) was cordoned and declared a Restricted Zone (RZ) for private vehicles on weekdays from 7:30 to 9:30 am (and later extended to 10:15 am). Vehicles entering the RZ via the 27 entry points would have to purchase a supplementary licence to be displayed on the windscreens. Vehicles were manually inspected without stopping by police personnel as they entered the RZ.

To complement the ALS, 10,000 car parking spaces around the periphery of the RZ were opened for commuters, and special shuttle buses were introduced to carry them from these fringe car parks into the central area. In addition, charges for public parking were raised within the CBD areas and a charge was imposed on each privately-owned lot in the CBD.

Post-ALS data had showed that the traffic flow during the operational period fell by 45%, while the percentage of car travel fell from 56% to 46% of all trips to work [21]. The success of the ALS was attributed to several factors. Firstly, while vehicle traffic into the city was restricted during the peak hours, the accessibility to and mobility within the central area was maintained by providing efficient and reliable alternative modes of transport. This ensured that the economic vitality of the area was sustained. Secondly, the mobility of the private car was not restricted as the ALS was only applied when and where it was needed to eliminate local congestion. Thirdly, the scheme was simple, easy to understand by the motorists, and reliably enforced without a cumbersome administrative structure [22].

Changes to the licence fees, operating hours, exemption conditions and the RZ boundaries had been made over the years in order to achieve the desired results. For example, when traffic speeds within the city deteriorated, particularly during the evening peak and along the ring roads, the restricted period was extended in 1994 to cover the whole day from 7:30 am to 6:30 pm.

3.2.1.2 Road Pricing Scheme  In 1995, the government decided to implement a manual Road Pricing Scheme (RPS) on three expressways leading to the RZ when the congestion levels along these stretches began to escalate. While the ALS were based on the concept of cordon charging into the RZ, RPS was based on a linear passage and point charging that regulated traffic demand during peak hours on specific roads/highways. To complement the RPS, express bus services were introduced from the affected residential areas to the city, while Park-and-Ride parking lots were designated at some 29 car parks near MRT stations to ensure that good alternatives of travel were provided for commuters seriously affected by the charges.

The imposition of a $1 road pricing on the expressways resulted in a reduction of traffic by more than 40% within the restriction period but an increase in traffic flow of 80% half an hour before and 34% half an hour after the restriction period. Traffic flows also diverted to alternative routes. At the end of July 1997 it was found that about 16% of the motorists had stopped using the tolled expressways. Of these, some
3000 motorists had switched to alternative routes on the surface streets, while others had travelled at times outside the restricted hours or had either car pooled or shifted to public transport. An increase of 40% in ridership on the express buses was also reported [23]. The RPS may be viewed as an experiment to understand road user behaviour towards a full-scale point charging system facilitated by an electronic charging technology.

### 3.2.2 Electronic approach

The manual systems of the ALS and RPS would not be efficient and effective in the long run. First, they are both labour intensive as they require many personnel for enforcement and the sale of the license. Second, the number of license types has increased to 14 as the scheme became more complicated, often leading to confusion to the users [24]. Third, the toll charges were also not responsive enough to the changing traffic demand. Further extensions of the road pricing scheme or the introduction of varying rates will add further confusion to the motorists. Finally, the use of single paper licence could not prohibit multiple crossings or entries into the controlled area and would not be effective to make the drivers pay for each usage of the road. An alternative system in the form of electronic toll collection became necessary.

In deciding the form of ERP scheme, LTA has adopted an active system over the passive system adopted elsewhere. The passive system required motorists to be billed, for example, at the end of the month. This was not ideal as a central billing bureaucracy with cumbersome billing and revenue collection procedures would have to be established. Furthermore, since motorists enjoy credit under such a system, it was feared that the congestion charging may not be as effective than when immediate payment was made. The decision then was to deduct the congestion charge at point using a stored-value card inserted into an in-vehicle unit.

The ERP system adopted in Singapore has three components: the electronic device in the vehicle called the In-vehicle Unit (IU), the charge point equipment at the roadside and a remote central computer system (see fig. 5). At each ERP charge point are two overhead gantries both equipped with antennas, vehicle detectors and enforcement cameras. When a vehicle passes the first gantry, the antennas interrogate the IU in the vehicle to verify its validity (e.g. vehicle type) and deduct the appropriate ERP charge from the stored-value card. Any vehicle without an IU or cash card, or with an insufficient balance in the cash card would constitute a violation and be photographed as it crosses the second gantry.

![Figure 5: Components of the ERP system. (Source: Menon and Chin [24])]
To squash suggestions that the ERP scheme was designed to generate revenue, the government introduced rebates on road taxes for 5 years following its introduction in April 1998 while at the same time, a higher number of vehicle quotas was released. Initially, the ERP gantries were placed at locations to mimic the earlier ALS and RPS coverage. With time, LTA has added charging points along several major roads leading to the CBD as well as along expressways that had high traffic flows. ERP charges have also been regularly adjusted to achieve optimal flow conditions on the road with vehicle speeds between 45 to 65km/h on expressways and 20 to 30km/h on arterial roads [4]. Table 5 shows the charges imposed on the various ERP locations as of 7 February 2005.

Table 5: ERP rates for cars (in S$) on selected roads as of 7 February 2005.

<table>
<thead>
<tr>
<th>Monday to Friday</th>
<th>Expressways</th>
<th>Arterial Roads</th>
<th>Restricted Zone</th>
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<tbody>
<tr>
<td></td>
<td>Ayer Rajah</td>
<td>Central East</td>
<td>Pan-Island</td>
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<tr>
<td>07:30 – 07:35</td>
<td>0.00</td>
<td>0.80</td>
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<td>07:35 – 07:55</td>
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Source: Land Transport Authority [25]
3.3 Future developments

The VQS has successfully moderated the growth of the vehicle population at a sustainable rate. With greater emphasis being placed on usage restraint measures following the introduction of ERP, the rationale for taxing vehicles has also been reviewed.

It was argued that strict tax structures and VQS are intended to control demand rather than need, and such a system had provided much inconvenience to the genuine users and curtailed the aspirations of car ownership in Singapore [26, 27]. This has not been well refuted, although the government has maintained that a balanced approach of taxing vehicle ownership and charging for usage is the correct solution. As further ERP charges are extended to other major congested points, motorists may become more conscious of the true costs of driving thus enabling them to make judicious use of the road. It is assumed that where there is better management of road resources, more COEs can be released so that the growing aspirations to own cars can be met while traffic congestion can be contained [27].

4 Public transport operations

As severe vehicle restriction measures were introduced, there was a great need for a public transport system with high quality and efficient services to satisfy the transport needs of commuters without a car. Recognising the importance of a good public transport system, the government endeavoured to provide a wide spectrum of integrated transport options that offer ‘high quality services, which are convenient, accessible, comfortable, safe, speedy and affordable to the majority of Singaporeans’ [17].

These options include bus, MRT, LRT and taxi services which are currently operated by private companies in a highly-regulated environment. The present state of operations is a far cry from the 1960s when public transport was not given much emphasis. This section charts the development of the public transport in Singapore from an unregulated to a regulated and integrated system of operation.

4.1 Unregulated public transport

Prior to the introduction of mechanized vehicles in 1896, transport needs were well met by human and animal-powered vehicles such as bullock carts, horse carriages, rickshaws and bicycles, as most trips were short [28]. With the introduction of steam trams and electric trams by the turn of the century, and trolley buses in 1925, a greater mix of public transport modes was seen on the road.

In the early years of self-rule, the government allowed the public transport services to be undertaken by private bus operators, concentrating only on controlling private vehicles. Consequently, while space was planned for car parks and road expansion, little consideration was given to waiting areas for bus
passengers and buses. The bus system then was ‘very unsatisfactory as it was common to have disruption of services due to mechanical breakdown, irregular fare and route structure, less frequent and overcrowded bus services, due to the small number of buses available’ [12]. The industry was also plagued with problems associated with operational difficulties, poor management and labour unrest.

4.2 Planned public transport

4.2.1 Bus services

With economic growth, it became evident that progress in other sectors of development would be greatly impeded by the poor public transport service. In 1970, the bus system underwent its first major reorganization. With the involvement from the government, the ten private companies of varying fleet sizes were merged to form three major bus companies with clear territorial dominance. While the reorganization did rationalize the service network and fares, there remained problems of staff management and fleet maintenance. In November 1973, the remaining three bus companies were further merged into a single, unified organisation, the Singapore Bus Service (SBS).

There were concerns that as a single operator, SBS would fall into inefficient operations as seen in many bus companies in developed countries. Thus Trans-Island Bus Services Limited (TIBS) was incorporated on 31 May 1982 as the second major public bus operator in Singapore to provide some measure of competition to SBS and ultimately improve the level of service provided by bus operators. As part of the government’s attempt to inject even greater competition into the bus service industry, the area of operation of TIBS was increased in August 1997, when 17 of the SBS routes were transferred to TIBS. Today, the two bus operators, SBS (now known as SBS Transit Ltd) and TIBS, operate a total of 261 scheduled bus routes, including trunk services, feeder services and night services.

Over the years, many special services have been introduced to meet the travel needs of different commuters. Supplementary bus services, notably the City Shuttle Service (CSS) and Scheme ‘B’ buses provided by private operators, serve the major corridors to and from the city during the peak periods. They increase the capacity of the bus network by operating on routes of the scheduled bus services.

Many improvements in the bus services have been initiated to enhance the attractiveness of travelling by bus. Bus lanes were introduced in February 1974 to ensure that buses are protected from congestion effect on the road. Buses were given exclusive use of the kerb side lanes along certain main roads from 7:30 am to 9:30 am and 4:30 pm to 7:00 pm on weekdays, and from 7:30 am to 9:30 am and 11:30 am to 2:00 pm on Saturdays. Another scheme of enhancing reliability is the introduction of dedicated traffic signals, or B-signals that allow buses to be discharged from intersections ahead of other vehicles.

Express bus services have been introduced to bring commuters from the housing estate to the CBD area in a faster and more direct way. They travel on the expressways and have fewer stops, making the bus a comparatively attractive alternative to the car. In 1998, TIBS introduced a special form of express bus service, known as the Rapid Bus Service, which incorporated an advanced bus...
priority system. These buses were fitted with transponders, which gave them priority at selected traffic light junctions.

The range of bus services has also increased with time. To cater to a more exclusive and upmarket group of commuters, premium bus services operating between private housing estates and the CBD were introduced in 1994. These filled the gap between the scheduled public buses and the more expensive door-to-door taxi services.

4.2.2 Mass transit system

Two types of rail services are currently deployed to cater for public transport demand (see fig. 6). The Mass Rapid Transit (MRT) is used to serve heavy corridors of traffic, while the Light Rail Transit (LRT), being less capital-intensive, is a more practical alternative for lighter corridors. Both serve as the backbone of the country’s public transport system, which is considered to be necessary to secure acceptance of traffic restraint measures.

The need for a mass transit system to cater for future demand was always considered necessary since the first transport study in 1970. Several alternatives to the rail-based system were considered towards the end of the 1970s and these included a proposal by Hansen for an all-bus system [30]. The Comprehensive Traffic Study in 1982 later confirmed the need for an MRT system to cater for the country’s anticipated transportation needs [31]. According to the study, an all-bus system would impose severe restrictions and not provide a comparable service.

Figure 6: Singapore MRT and LRT network. Source: adapted from LTA [29]
The government finally decided to build the MRT system in May 1982 with a budget of $S5 billion. To operate the system, the Singapore Mass Rapid Transit Ltd (SMRT) was set up in August 1987 as a government-owned company. The system was finally opened in 1990 with a network of 67km track and 42 stations of which 15 were underground. It was designed to have 40% of the business and industrial areas as well as 30% of the residents within the catchment of the MRT.

Recognizing that the MRT was a massive project that required a critical mass of ridership to sustain its viability, the government made major changes to the bus routes, especially those which competed directly with the new MRT routes. The rationalization resulted in 30 bus services being abolished and 98 rerouted and 25 new services added.

Since then, Singapore has steadily expanded its MRT system. After 16 years of operation, the MRT system has now a total route length of 109km consisting of 3 lines. The original two lines were expanded with the Woodlands extension on the North–South Line and the Changi Airport extension on the East–West line completed in 1996 and 2001, respectively. The third line, known as the North–East Line, began operations in June 2003 is the world’s first fully automated underground heavy rail system. It was constructed with 13 stations, at a cost of $S2.5 billion and operated by bus operator, SBS Transit.

To complement the MRT network, a Light Rail Transit (LRT) system was planned to provide a quick and comfortable feeder service to the MRT network in housing estates or employment centres. The LRT is to serve as short-distance links to connect high activity centres as well as long-distance links and direct inter-town transit between the new towns. Although more costly to operate than the MRT, the LRT promises a comparative advantage over buses in terms of higher throughput, greater reliability and a sense of permanence [17].

The first LRT, completed in 1999, was the 8km Bukit Panjang system, which linked Bukit Panjang New Town to the Choa Chu Kang MRT Station, providing a seamless connection for commuters transferring between the two rail systems. In 2004, the Sengkang and Punggol LRT systems were built to operate as feeders to the North–East Line. These latest LRT routes are designed along with the two towns so that the lines are well integrated with town developments and the housing apartments.

4.3 Regulation of public transport

As the public transport system developed with several key operators dominating the market, the need for regulating the services became apparent. In August 1987, the government established the Public Transport Council (PTC) as the governing body to approve public transport fares and regulate bus services standards. A licence from the PTC is required for any company to operate a bus service that charges a fare. Changes in bus fares and routes also required approval of the PTC. In addition, to encourage good service levels, PTC has also stipulated stringent standards and specifications on the bus operators. These cover route planning and design, service efficiency, operational hours, affordability and service information.
To ensure standards are followed, operational audits on the level of compliance are carried out periodically by PTC.

### 4.3.1 Integration of public transport modes

The integration of the bus and MRT services saw the setting up in 1989 of Transit Link Pte Ltd to develop the integrated system for SBS, TIBS and SMRT. Four aspects of integration were identified: fare integration, information integration, physical integration and network integration.

**Fare integration** was achieved by a common ticketing system in the form of a TransitLink farecard developed for use on all three public transport systems. This arrangement allowed the introduction of transfer rebates offered to commuters transferring between the MRT and buses. The rebates were to compensate for the inconvenience in additional boarding and the non distance-based charges incurred by the transferring commuters. As part of the service improvement and to cope with an expanding rail network, a contactless Smart Card known as the Ez-link Card was introduced on 1 December 2002 to replace the magnetic Farecard. The new technology which made use of more durable cards, has allowed a higher boarding rate and faster processing time.

TransitLink has facilitated **information integration** with the annual publication of the bus-MRT printed guide providing all the travel details of the entire public transport system including transfers between modes. LTA and the bus companies have also implemented the Traveller Information Services (TIS) to provide commuters with real-time information on the public transport system at the stations and bus interchanges.

**Physical integration** is achieved by designing facilities for the different modes as a whole to enable more seamless travel. Examples of integrated facilities include various linkages between MRT stations and bus stops or taxi stands, such as covered walkways and overhead bridges. Facilities to encourage mode transfers, such as bicycle parks, are also properly located to minimize walking and allow convenient and comfortable transfers. An excellent example of physical integration between bus and rail services is the Woodlands MRT Station where transfers take place within the same building under an air-conditioned environment (see fig. 7).

The integration of the bus with the rail network reduces the amount of inefficiency and duplication in transport supply. The entire bus network with 126 bus services were reorganized in 13 phases over a 2-year period from January 1991. Fong [32] reported that the network integration had improved the productivity of the operators as well as the level of service for the commuters, reduced bus traffic into the CBD by about 20% thereby reducing city congestion, and increased profits for the operators.

**Network integration** required a fundamental evaluation of the role of MRT and buses in providing public transport services. It was decided prior to the introduction of the MRT system that the two modes would complement and not compete with each other. The authorities reasoned that buses would be more suited for shorter haul journeys while MRT for long-haul corridor travel. Even with the addition of the LRT as feeder to the MRT, buses remained an important mode to complement the rail systems.
4.3.2 Future developments

Currently, about 60% of the total trips made in Singapore are on public transport and there are plans to increase the split to 75% [17]. While buses are inexpensive, their performance is very much affected by traffic congestion on the road. Rail systems tend to offer a high degree of reliability and with its speed and comfort is well suited for mass movements, especially during the peak period. Hence it is envisaged that expansion in the rail system will be considered favourably and at the same time, efforts to improve bus operations will continue.

One issue that has come to the fore is the financing of the extended rail network. In the past, the cost of developing the rail infrastructure was borne by the government while the operating costs were borne by the operators. As the increase in patronage on additional rail lines may not be as high as the earlier stages, there were some concerns about the economic viability of the expanded rail network. Consequently, the North–East Line, which was planned for year 2010, was approved earlier based on a new financing scheme in which the government not only pays for the infrastructure costs but also helps finance the replacement assets. The costs of depreciation are to be recovered from fare revenues. This arrangement is considered fairer because the operating assets should be paid by the generation of passengers using them.

The change in financing formula paved the way for government’s approval of proposals to expand the rail system. Construction is well underway for the fourth MRT line, the Circle Line (CCL), which is to be completed in stages between 2007 and 2010, is well underway. Costing $6.7 billion, the CCL will be a fully...
underground orbital line around the city centre with interchange stations connecting the other three radial MRT lines. The CCL is expected to help commuters bypass busy central interchanges and reduce travel times.

Under the Concept Plan [11], the Rapid Transit System (RTS) is to be developed with a strategic network of high-capacity radial and orbital lines to be supplemented by a local LRT network serving regional towns. The planned RTS will have a network route length of about 500km.

5 Traffic engineering and control

The authorities have recognised early that expanding road capacity alone will not solve the problem of congestion and may even create adverse impacts on the environment. Given the land constraints, it is prudent for the government to consider ways to maximize the existing road capacity through road improvements, junction optimization and other traffic engineering measures. This section discusses some of these measures that have been introduced to maximize road capacity.

5.1 Basic measures

One of the simplest engineering measures to prevent a gridlock and hence damaging congestion was the yellow box junction. Introduced in the mid-1970s, the scheme prohibits vehicles using traffic intersections to remain in the junction area, even when the signals indicate a right-of-way of passage.

Also in the 1960s, many two-way streets within the CBD were converted to one-way pairs to form clockwise loops. The one-way street arrangements simplified junction designs and allowed better traffic signal coordination [33]. However, since they also resulted in longer travel distances for motorists and longer access distance to bus stops for passengers, some of these arrangements were reversed eventually. For example, New Bridge Road in the heart of the city was subsequently widened and converted back to a two-way street in 1998.

Since 1995, there have also been junction improvements in city areas, new towns and industrial estates. These include introduction of exclusive right- and left-turn storage lanes and exclusive left-turn slip roads. Left-turn-on-red signals were also installed in a number of sub-urban junctions to allow left-turn vehicles to bypass the signals. There were also numerous infrastructure projects to construct multi-tier road interchanges, flyovers, viaducts and elevated bypasses especially on main arterial roads upgraded to form semi-expressways.

5.2 Computer signal control

In signal control strategies, LTA has kept up with changes in signal-control technology. The older fixed-time control of signal coordination, based on TRANSYT was replaced in 1998 with the traffic-responsive system, Green Link Determining System (GLIDE) which is based on SCATS algorithm. Currently, it controls 1733 intersections across the island and this will be expanded to cover all the signalized intersections.
Other forms of signal controls have been introduced to achieve a higher throughput at signalized intersections. These include exclusive vehicle-actuated right-turn phases, overlapping signal phases, bus-priority signal and left-turn-on-red signals as well as countdown timers for pedestrians.

5.3 Intelligent transport systems

Intelligent transport systems (ITS) have been increasingly utilized to maximize transport capacity as well as to improve travel convenience and safety. This is done on the road network or public transport network by minimizing instances of operational inefficiencies, for example by dynamically adjusting transport supply to changing demand. On the other hand, ITS has also been used to provide quick and reliable information to transport users to facilitate decision-making. Safety of transport systems has also been enhanced by automated control systems as well as surveillance and early warning systems.

In 1996, an automated traffic and monitoring system, known as Expressway Monitoring and Advisory System (EMAS), was progressively installed on the entire expressway network at a cost of S$170 million. Incidents and queue formation are automatically identified from the video images received from detection cameras placed at about 500m intervals along the expressways. Once incidents are detected and verified, warning messages are transmitted via variable message signboards or broadcasting media. This allows motorists to be warned of traffic jams ahead of time so they can avoid the congested stretches.

Another scheme was the Junction Electronic Eyes (J-Eyes), which provides automatic incident detection and visual monitoring of traffic conditions at major intersections. The system is used to supplement loop data for input into the GLIDE system to facilitate fine-tuning of signal timings to cater for real-time traffic conditions.

In January 1999, LTA launched TrafficScan, a system which disseminates the traffic speeds to users through the internet, radio, television and the telephone. Computation of link speeds is done by locating some 7500 taxis on the Differential Global Positioning Systems and updated every 2 to 5 min.

5.4 Future developments

As more land is being consumed, it is increasingly difficult to find space for additional road infrastructure. LTA is planning an underground road network to increase road space. Known as the Singapore Underground Road System (SURS), it will consist of a series of underground ring roads skirting around the CBD. It will have 33 ramps at 8 major intersections when completed and will cost $3.8 billion to construct.

In addition, increasing efforts are also being made to harness technology as a means of maximizing network capacity. With separate ITS systems in operation or near completion, LTA has embarked on integrating these systems under the i_transport platform, a second generation of an integrated, interoperable, interchangeable and sustainable ITS system.
6 Conclusion

Since the nation’s independence, the planning for the Singapore transport system has revolved around four issues: land use and transport planning, travel demand management, public transport operations, and traffic engineering and control. Even though planning was somewhat piecemeal in the initial stage, and targeted only at solving specific problems, the transport plans generated did produce effective results. In some areas, the planners were not able to anticipate the outcome and this was particularly true when user response to some of the schemes was not known a priori. Despite these uncertainties, the rate at which Singapore emerged from the potential transport nightmare was impressive. Within a short span of a generation, it has developed an efficient land transport system based on an integrated transport policy of planning, demand management, public transport operations and traffic engineering.

Singapore’s boldness in implementing several drastic transport planning instruments such as the ALS, VQS and ERP, has attracted many foreign authorities to study these implementations. The chapter on Singapore’s transport planning will not be complete without insights into the lessons that can be learned from the Singapore experience. The following summarises the pertinent matters that have contributed to the success in planning of the transport system in Singapore as well as some challenges to be faced.

6.1 Lessons from the past

The changes in the population profile and characteristics as well as growth in economic conditions could have exerted tremendous traffic problems on the young nation. It appears that the measures taken by the government have alleviated Singapore’s massive problems of transportation, particularly those related to traffic congestion. Four factors are identified as the main reasons why transport planning has been successful.

6.1.1 Success-oriented planning

The determination to solve the transport problems by the government can be observed from its courage and foresight in implementing demand management instruments such as the VQS. Perhaps the initial delay in tackling transport problems during the initial stage of nation building did facilitate the policy formulation and planning process. By the time actions were needed, the problems had reached such an urgent level that quick and decisive actions were necessary. The political will to act was based on the premise that delayed actions would be even more costly both economically and politically.

Furthermore, the need to ensure that schemes would succeed had motivated planners to be thorough and sufficiently detailed in their plans, and to consciously seek ways to minimize the likely adverse impacts of the schemes. As a result, schemes were seldom implemented in isolation, but as a package of measures. For example, the implementation of ERP was supported by the introduction of express bus services to help commuters adjust their travel...
behaviour. The government did not hesitate to make necessary changes to ensure that the desired results were achieved while unexpected adverse impacts were reduced. The several modifications to the operating hours and the fees charged in the ALS and ERP over the years were good examples of how plans needed to be flexible. In some instances, fine tuning of the systems were introduced within a very short span of time to reflect changing traffic conditions.

6.1.2 Pragmatic planning
A pragmatic approach to planning is found at all levels of Singapore’s administration. Unlike in some countries where plans were buried in numerous studies and reports, Singapore enjoyed the advantage that plans were actually implemented. Realistic government expectations supported by appropriate policies and frameworks for funding were key factors contributing to the success in planning. Furthermore, the government exercised financial discipline and prudence in all their projects. For example, the MRT lines had to be clearly economical and financially viable and each line justified on its own merits based on proper cost-benefit analyses before they were built.

Practical planning also involved choosing appropriate solutions according to the needs. One observation on the transport plans adopted by Singapore was that solutions to transport problems at the early stage were generally not capital intensive. The purpose of planning then was to deal with the immediate problem of congestion and inefficient use of transport resources. They were also quick solutions, as time was the enemy. Once the basic problems of congestion were tackled, the focus in planning was on the quality of service. Inevitably, solutions became incrementally more costly as seen in the massive investment on rail and other infrastructure projects.

6.1.3 Stable government
The ability of the government to formulate transport policies which were generally accepted by the populace was in no measure due to the people’s support and confidence in the political leadership; a trust which was nurtured over many years. The government painstakingly explained policies and plans such as the ALS and the VQS to inform and persuade an increasingly educated populace, which generally understood the need for such draconian measures given the country’s land constraints.

Furthermore, the good and stable relationships among the transport users, service providers, unions and the authority also helped the implementation of such policies. The government’s action to set up committees and agencies to plan and manage transport operations as well as to gather feedback and deliberate on transport issues had developed a sense of responsibility among the various parties.

6.1.4 Consistent policies
Having identified the causes of the problems, i.e. the limitation of land resources and the many aspirations resulting from healthy economic growth, the government had consistently pursued a transport policy of traffic restraint and vehicle population control while allowing reasonable expansion in road capacity. The
reason that such policies can be maintained consistently is, to a large extent, because the ruling political party has been in government since 1959. The stability in the political leadership has enabled transport policies to be formulated with a long-term perspective. Moreover, continuity in leadership also ensured that the formulated policies can be effectively translated into actual plans which were eventually implemented, evaluated and refined to the changing circumstances.

The lessons are perhaps best summarized by Liew [23], 'For the transport policies to be effective, it is necessary to maintain a long-term perspective, anticipate change, understand the forces driving demand and supply and adopt a holistic approach when responding to the challenges. In addition, policies have to take into account changing aspirations, new lifestyles and the psyche of the society. Not only must transport planning and policy formulation be rigorous, the process of reaching consensus or at least broad agreement should be widely settled through some debate and continual explanation of the rationale of even proven policies'.

6.2 Challenges for the future

Singapore has made great strides to overcome the transport problems faced by growing cities, and has done well in its course of realising a world-class transport system. While transport planning in Singapore has long focused on providing an efficient transport system, i.e. reducing congestion and achieving acceptable traffic speeds, there is now a need to look into other challenges, and anticipate the next phase of development. This section looks into some of the possible future issues.

6.2.1 Land constraints

Land constraints have always been one of the key challenges facing Singapore since the 1950s. In the Concept Plan 2001, the projected land available when the population reaches 5.5 million is 76,000ha, taking into account future reclaimed land. However, the demand projections by URA for each land use have indicated a shortfall of 4000ha [34]. As roads currently account for 12.4 per cent of the total land space in Singapore, the challenge is to reduce significantly the demand for road space. There is a need to look into improving accessibility by integrating land use and bringing home and work together. Proposals, such as using smart space-saving car parking systems, building more basement car parks and future underground MRT and LRT lines could be the approach to reducing land space for transport infrastructure.

6.2.2 Transport for the mobility-impaired

An emerging concern is the transport needs of the elderly and other mobility-impaired. As the population aged, the transport system which has hitherto supported a fast-pace populace may no longer be suitable. Along with this is the need to increase the accessibility of the mobility-impaired. There may be a need not only to introduce special facilities, such as ramps and lifts as well as specially-designed vehicles, but also changing signages and information which may be suitable for these groups of transport users.
6.2.3 Freight movements

Most of the policies and plans have been targeted at the movement of people. An efficient transport system is necessary to support the distribution process of goods. This is all the more important in view of the contribution of manufacturing to GDP and the dependence of the economy on trade. For Singapore to function as a global city, coupled with the need for sustainable economic growth, there is an urgent need for planning with respect to land freight transport.

While the demand for vehicular transport of people can be checked through effective measures, the demand for transport arising from the need to move goods cannot be easily curtailed because of its economic value and the desire to increase the cargo handled by Singapore’s ports. Even though a large portion of cargoes handled through the port are transhipment, the need to handle valued-added goods bound for re-export cannot be ignored. There is some evidence [35], that logistics operators in Singapore are locating their facilities away from the port to avoid high land prices near the port vis-à-vis modest transport operating costs. This phenomenon creates a higher but unnecessary level of traffic on the road network and to some extent is a result of the efficient transport infrastructure provided.

6.2.4 Multi-modal transport integration

As integration in the transport system develops, there will be a greater need to integrate travel between various modes to further enhance seamless travel. With growing affluence and standards of living, commuters would become increasingly more time-sensitive and would demand a ‘seamless’ public transport service, which is comfortable and convenient.

It is insufficient just to integrate land transport modes. Links to air travel and sea travel will have to be more seamless. Coupled with the rise in recreational trips, there may be more air and sea trips to local as well as regional resorts. To facilitate multi-modal operations in both passenger and freight transportations, the integration of information for all modes of travel in land, air or sea will be necessary.

6.2.5 Transport safety

As the nation becomes more affluent, a higher premium will be placed on safety. Recent rise in transport accidents worldwide, particularly in air and sea travel, has generated increasing awareness of the inadequacy in safety regulations and management. Domestic transport mishaps will not only cripple the transport network but also result in high economic losses [36].

Transport safety will be of greatest concern to the transport system designer and provider as well as the transport authority. First, as human control is gradually replaced by the intelligent machine, the burden will be on the system designer to ensure designs that are safe under a wide variety of, if not all the possible, conditions. Also, if public transport is to be encouraged, the transport system provider will have to assume a greater responsibility to ensure safe operation. On the other hand, the transport authority will have to take up the responsibility to ensure safety standards are drawn up and adhered to during operation.
6.2.6 Charging for the cause of congestion

The motorists, being the direct users of the road system, have been required to pay for their contribution to congestion on the roads. Vehicle ownership costs have also been imposed as traffic generation can be attributed to vehicle ownership. Other contributors to congestion may have to pay for the cause of congestion and privilege of usage.

One group that may be subjected to further charges is the developers. Although developers pay development charges, there may be a need for them to pay for congestion alleviation schemes. This will ensure that developers will act responsibly to minimize the traffic impact on the road network adjacent to the developments. Traffic impact fees may not be limited to congestion costs but may be associated with environmental costs including safety costs.

6.2.7 Sustainable transportation

The concept of sustainable developments has been promoted in many countries since the early 1980s. The move towards sustainable transportation will mean a greater use of greener modes such as walking, cycling and green vehicles. In the past, due to insufficient infrastructure, these modes have not been considered suitable for all weather conditions. However, the development of the network of park connectors initiated in the early 1990s has encouraged more people in adopting walking and cycling as alternative modes of transport. These could be further promoted through better planning of a denser network, coupled with covered walkways, and bicycle parks and lanes. Already, new towns are developed to have pedestrian-oriented streets with traffic calming schemes, to discourage use of motorized vehicles especially for shorter trips. Furthermore, ‘blue corridors’ or waterways should also be linked or combined with green corridors.

The use of green motor vehicles that contribute less to pollution, and save on energy and non-renewable resources does seem like an attractive option towards sustainable transportation. Vehicles such as compressed natural gas (CNG) buses and hybrid cars that are currently running on the roads should be promoted through lower taxes and more refuelling stations.

Opportunities for sharing of transport facilities such as public cycles and cars for specific segments of the journey may be explored. Sharing of personal cars is being tried but given the high capital outlay, owners are unlikely to rent out the cars for public use. A more viable alternative would be to have agencies such as car rental companies undertake the scheme. However, more importantly, the sharing of less environmentally polluted modes such as cycles and personal rail transit should be explored.

To attain sustainable transportation, environmental impacts are likely to become important considerations in the future. As traffic increases on Singapore roads, concerns over noise pollution and deterioration in air quality will need to be addressed. Transport providers as well as planners will have to offer transport modes and schemes that will be less environmentally damaging.

6.2.8 Closing remarks

The challenges ahead are many but given the astute leadership of the government with the continued support of the people, as well as the prudent practice of
comprehensive land use, transport planning and sound traffic management policies, Singapore is well poised to achieve its vision of a quality land transport system as it develops into a tropical city of excellence.

References


[29] Land Transport Authority (LTA), *Rail Map (including lines under construction)*, Land Transport Authority: Singapore, 2005.


