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ORIGINAL PAPER

Singapore motorisation restraint and its implications on travel behaviour and urban sustainability

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Abstract The example of Singapore shows that rapid urban and economic growth does not have to bring traffic congestion and pollution. Singapore has chosen to restrain car traffic demand due to its limited land supply. Transport policy based on balanced development of road and transit infrastructure and restraint of traffic has been consistently implemented for the past 30 years. Combined with land use planning, it resulted in a modern transport system, which is free from major congestion and provides users with different travel alternatives. As the economic growth caused a substantial increase in demand for cars, several pricing policies were introduced with the aim of restraining car ownership and usage. Growth of the vehicle population is now controlled and potentially congested roads are subject to road pricing. These measures help to keep the roads free from major congestion, maintain car share of work trips below 25% and keep the transport energy usage low. Although Singapore conditions are in many aspects unique, its travel demand experience can provide useful lessons for other rapidly growing cities in Asia.

Keywords Singapore motorisation · Traffic restraint · Travel demand management · Modal split · Road pricing · Vehicle Quota System

Introduction

Rapid pace of urbanisation and economic development in Asia leads to accelerated motorisation and produces the unwelcome effects of urban traffic congestion and major environmental problems. It is estimated that in the last decade of the 20th century the number of city dwellers in East and South Asia increased by 300 million (41%) and the number of motor vehicles by 20 million (35%) (World Bank 2006).

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Many governments have not been able to handle such a massive growth and as a result the quality of life in some cities is actually deteriorating. In comparison, Singapore's industrialisation and economic growth have not led to serious traffic congestion and pollution problems because of its successful approach to transportation system development and travel demand management.

Singapore is a fully urbanised island state with a population of 4.35 million and a land area of just under 700 km^2. With a per capita GDP of US$25,800[1] in 2005, it is classified as a Newly Industrialised Economy (NIE). As evident from Table 1, over the last three decades, the real Gross Domestic Product (GDP) has been increasing at an average annual rate of around 7%. Such sustained growth has increased the demand for both passenger and freight transport as well as car ownership aspirations of the population. However, with a population density of 6,222 persons per km^2 and about 12% of its scarce land already being used for road infrastructure, Singapore has very limited scope for road expansion. This situation resulted in the government having to adopt tough demand management policies to restrain the growth of car ownership and usage to reasonable levels. These fiscal measures have generated substantial revenue, which is partly used for financing new road and public transport projects.

Singapore's innovative transportation policies have been closely studied by transport economists and researchers, as evidenced by a large body of literature on the subject (e.g. Cochrane et al. 1986; Behbehani et al. 1988; Spencer and Madhavan 1989; Olszewski and Turner 1993; Phang 1993; Willoughby 2001; May 2004). The objectives of this paper are: to briefly review the development of vehicle restraint methods over the last 30 years; to investigate the effect of these measures on travel behaviour, motor vehicle fleet and transport energy consumption and finally to suggest how the Singapore experience could be useful for other cities. The paper is organised as follows: Sect. 2 introduces the Singapore transportation system; Sects. 3 and 4 outline the car ownership and usage restraint policies; Sects. 5 and 6 present some evidence on the effects of these policies and finally Sects. 7 and 8 discuss the relevance of restraint to other cities and provide conclusions.

Singapore transportation system

Emergence of a planned city

Before achieving self-rule in 1959, Singapore like many Asian cities was characterised by overcrowding, poor housing conditions, high levels of unemployment and poverty. After independence in 1965, the government embarked on an ambitious programme of industrialisation and construction of public housing. A strict urban planning and development control system was put in place by means of Planning Act legislation. Recognizing the need to safeguard land for public housing and infrastructure development, in 1966 the government enacted the Land Acquisition Act, by which extensive areas of land have been acquired from private owners (Dale 1999).

In 1971 the first concept plan for long-term urban development was drawn up. The 25-year development strategy incorporated a comprehensive land use and

[1] As of December 2006 US$1 = $1.55 Singapore dollars.

Table 1 Socioeconomic and transport indicators

		1970	1975	1980	1985	1990	1995	2000	2005
Area	km^2	586.4	596.8	617.8	620.5	633	647.5	682.7	699.4
Population	('000)	2074.5	2262.6	2413.9	2736	3047.1	3525.6	4017.7	4351.4
GDP (current prices)	S$ million	5805	13373	25091	38923	66175	119470	159840	194360
GDP (2000 prices)[a]	S$ million	16230	25565	38844	52439	77158	117745	159840	193453
GDP annual growth[b]	%	n.a.	9.51%	8.37%	6.19%	8.03%	8.82%	6.30%	3.89%
GDP per capita[a]	S$	7823	11299	16092	19166	25322	33397	39784	44458
	US$	4548	6569	9356	11143	14722	19417	23130	25847
Cars		106900	142045	152574	221279	271174	342245	386780	432827
Motorcycles		78900	83145	118345	127564	122525	129587	131937	139434
Goods vehicles		25600	41363	78020	107146	115536	137913	134756	139098
Other vehicles		6400	13825	22402	30771	33117	32384	39334	43633
Total vehicles		217800	280378	371341	486760	542352	642129	692807	754992
Car ownership	Per 1000	51.5	62.8	63.2	80.9	89.0	97.1	96.3	99.5
Road length	km	1938	2167	2356	2645	2882	2972	3100	3234
Veh. per km of road	Veh/km	112.4	129.4	157.6	184.0	188.2	216.1	223.5	233.5

[a] In constant year 2000 prices

[b] During the previous 5-year period

Sources: Department of Statistics, Singapore (1974–2006) transport plan that envisaged construction of a system of expressways, complemented by a network of arterial roads. In addition to building a string of high-density housing estates (called New Towns), the plan proposed a Mass Rapid Transit system to connect the New Towns with the central area and industrial estates. In order to reduce demand for travel, all the New Towns were planned with industrial zones and several regional commercial centres were proposed to reduce job concentration in the CBD. While the concept plan has been revised and updated in 1991 and 2001, the urban development vision of the early 1970s has been largely realised and in many aspects exceeded. In today's modern garden city some 86% of the population lives in public housing apartments, 90% of which are owned by their occupants (Yuen 2004).[2]

The present road network comprising 150 km of expressways, 594 km of major arterial roads and 2,490 km of other roads serves all forms of transport including an efficient network of bus services. A 109-km Mass Rapid Transit (MRT) system of three radial lines was built over the last 20 years and is being extended. Three Light Rapid Transit (LRT) lines serve as feeders to the MRT. There are continuous efforts to improve the public transport system by integrating the MRT lines with feeder modes and providing better accessibility (May 2004; Luk and Olszewski 2003).

As shown in Table 1, the present car ownership is still under 100 cars/1,000 people, which is very low for an industrialised country. In fact, it is lower than in countries with one third of Singapore's per capita income (Willoughby 2001). Figure 1 shows the growth of population, GDP and vehicle fleet, relative to 1975. While in the last 30 years the real GDP has increased about 7.5 times, the car population has only tripled and its present growth rate is barely keeping up with the population growth.

Transport policy

By the early 1970s, the motor vehicle population was near 300,000 and traffic congestion was becoming a serious problem in the city. The first comprehensive transport study warned that congestion would soon lead to urban strangulation. Thus, an integrated Land Transportation Strategy was adopted in mid 1970s, with the following aims:

(1) Integrating land use and transport planning,
(2) Increasing road capacity as far as practicable,
(3) Managing demand for travel, especially that of the private car, and
(4) Providing an efficient public transport system.

The above strategy has been consistently pursued over the last three decades. In 1996 Land Transport Authority (LTA) was established with a mission to create a world-class transport system to serve the Singapore population (LTA 1996). LTA is in charge of both roads and public transport planning as well as traffic management and safety, which gives it a clear institutional advantage in dealing with potentially conflicting priorities.

The rapid economic growth in Singapore has naturally increased people's desire to own a car. As shown in Table 1, around 755,000 motor vehicles are currently

[2] Discussion of Singapore urban planning and development control is beyond the scope of this paper. Interested readers are referred to: Dale (1999) and Yuen (2004).

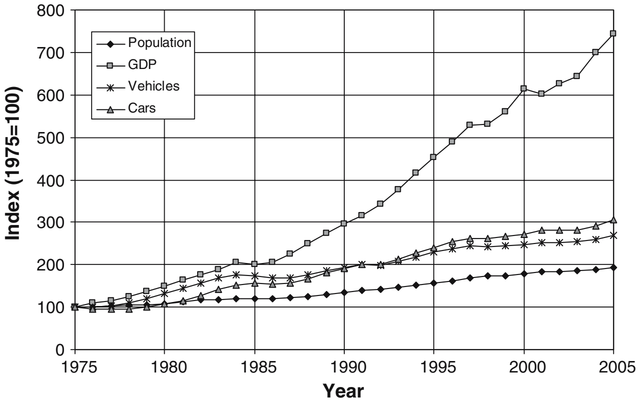

Fig. 1 Growth in Singapore's population, real GDP and the vehicle population. *Sources*: Department of Statistics, Singapore (1975–2006)

registered resulting in a ''statistical'' density of 233 vehicles per km of road. With about 12% of its land area devoted to road transport uses, there is little scope for major increases in road capacity. Therefore, some control on vehicle ownership and usage was deemed necessary to prevent traffic gridlock. Over the years several fiscal, administrative and traffic management measures have been introduced. Ownership restraints include a variety of taxes and registration fees as well as a direct quota imposed on the number of new vehicle registrations. Usage restraints include high gasoline taxes and parking fees, an Off-Peak Car Scheme and road pricing. These measures will be discussed briefly in the following sections.

Car ownership restraint policies

Fiscal measures

Since Singapore has no domestic car industry, a logical first step was to impose a high customs duty on cars. This has varied from 45% of the Open Market Value (OMV) of a vehicle[3] to the current figure of 20%. In addition to a one time registration fee (now $120), owners pay an Additional Registration Fee (ARF), which at its peak in 1980s was equal to 175% of the OMV but after the introduction of the vehicle quota system has been reduced to 110% of OMV. Annual road tax depends on engine capacity and is also substantial: for example, it now amounts to $500 for a 1,000 cc car and $3050 for a 3,000 cc car.

The above taxes on car ownership drastically reduced the growth in vehicle numbers. Between 1973 and 1982, the car population grew by 35% as compared to between 100% and 150% forecast by OECD (Behbehani et al. 1988). However, except for a brief economic slowdown in 1985–1986, the growth picked up again despite high car prices. Phang (1993) explained this phenomenon by showing that demand for cars was more income elastic than price elastic. In the late 1980s the growth far exceeded 3% per year, which was the rate estimated to be sustainable, taking into account the expansion of the road network. This necessitated the

[3] The OMV is the value declared by local distributors which includes factory and shipping cost of the vehicle.

introduction of more radical restraint measures. Following a public debate on the issue in 1989, the government decided to put a cap on all new motor vehicle registrations, in the form of a Vehicle Quota System (VQS).

Vehicle quota system

Under the VQS, prospective owners of new vehicles (other than scheduled buses and emergency vehicles) need to successfully bid for a Certificate of Entitlement (COE), a fixed number of which are auctioned to the highest bidders each month. The COE for a new vehicle is valid for 10 years. Its validity can be extended for another 5 years or 10 years by paying the ‘‘prevailing premium’’ price, calculated as the 3-month moving average.

Since its introduction in 1990, the VQS has undergone several modifications. Initially, there were four COE categories for cars, based on engine capacity: <1,000 cc, 1,001–1,600 cc, 1,601–2,000 cc and >2,000 cc as well as separate categories for motorcycles and goods vehicles. The combined monthly quota for the four car categories was 2,070 vehicles. In addition, some 470 COEs were available in the ‘‘open’’ category, which allows one to buy any type of vehicle but practically is used for car purchases. In 1999 the four car categories were combined into two: up to 1,600 cc and above 1,600 cc. Initially, the certificates were transferable, but following public concern over speculation, they were made non-transferable.

The Quota System lets market forces determine the premium prices. Figure 2 shows the changes in monthly quota and COE premiums over the last 16 years for cars under 1,600 cc. The values shown are for December of each year. For the first 8 years the premiums followed an increasing trend (with a dip in 1995) while the quota available for all the car categories combined (including the ‘‘open’’ category) remained almost constant at around 2,400 per month. The COE premium for cars under 1,600 cc reached an all-time-high of $62,200 in July 1997. Together with the other fiscal measures (ARF, customs duty) this has raised the price of a new medium-size car in Singapore to an exorbitant level of over six times its OMV.

Since their peak in 1997 the COE premiums have eased considerably (Fig. 2) and now stand at between $9,605 and $12,889, depending on the car category. This constitutes between 10% and 20% of the on-the-road price of a new car. The main reasons for the declining trend of COE prices are:

(1) The quota numbers have been increased substantially due to ‘‘recycling’’ of COEs of de-registered vehicles[4] (Fig. 2).
(2) The introduction of Internet open bidding system in 2002 made the whole bidding process more transparent. The auction now takes 4 days and bidders can monitor the current COE price on-line and revise their bids accordingly (LTA 2006).

It remains to be seen whether the current spell of relatively low car prices can be sustained. In 2005 a total of 88,076 cars were de-registered while the number of new registrations was 109,167, giving a net increase in the car population of 21,000. The huge number of de-registrations of cars purchased during the period of high COE

[4] The number of vehicles taken off the road and any unused COEs are added to the next year's quota.

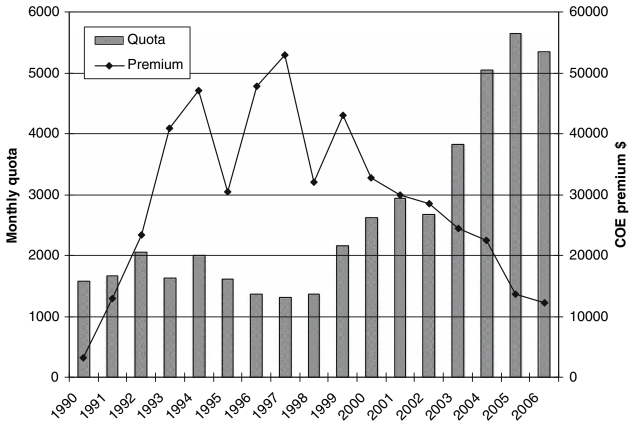

Fig. 2 Trends in monthly quota and COE premium for cars under 1,600 cc (values for December each year). *Source*: LTA (2006)

prices (1996–2000) is due to the fact that owners can get a refund for the "unused" part of the COE within the first 10 years of its validity.

Car usage restraint policies

Area licensing scheme

In addition to curbing car ownership, several innovative measures aimed at reducing the usage of cars were introduced. The most well known and studied of these—the coupon-based Area Licensing Scheme (ALS)—operated in the central area from 1975 until 1998 when it was transformed into an electronic scheme. It was the only example of a full-scale urban road pricing system specifically designed to reduce peak period traffic flows. Over the years the ALS has expanded in terms of types of vehicles affected, time periods and the area covered. Several studies discussed its historical development and impacts, e.g.: Holland and Watson (1978), Behbehani et al. (1988), Hau (1992), McCarthy and Tay (1993), Menon et al. (1993), Polak et al. (1994), Olszewski et al. (1996).

Under the scheme, motorists entering the Central Business District (CBD) during peak period (7:30–10:15 AM) had to buy a licence, initially priced at $3 and later at $5. The pricing levels were set and adjusted experimentally, not based on theoretical models. Although some doubts were raised about the level of charging (McCarthy and Tay 1993), the ALS was a simple and effective travel demand management scheme and showed an extremely attractive rate of return (Hau 1992).

Electronic road pricing

As the coupon system became too cumbersome (many types of coupons for different vehicles), it was upgraded to a fully automated Electronic Road Pricing (ERP) system in 1998. The planning, implementation and the initial experience with the ERP are described by Phang and Toh (1997), Luk (1999) and Menon (2000).

Under the ERP, the charge is deducted automatically from a pre-paid smart card when a vehicle passes under an ERP gantry. At present there are 48 gantries: 30 form a cordon around the CBD, 13 others are located on selected expressway segments and five on radial arterial roads. The charges at the CBD cordon apply on working days during the daytime hours: 7.30 AM–7.00 PM, but there are periods with zero charges (e.g. 10:00 AM–12:00 noon). On other roads charges apply during the morning peak period (7:30 AM–9:30 AM) and in some locations in the evening (5.30 PM–8:00 PM).

Variable pricing system

The ERP system makes it possible to vary charges by location, time of day and vehicle type, so as to relate them to the actual level of congestion. To emphasise the link between road pricing and congestion, the rates for different types of vehicles are set to be approximately proportional to their passenger car equivalent (PCE) values (Menon 2000). A method called ‘‘shoulder pricing’’ is used, which involves increasing the rate in steps every half an hour before the peak and decreasing it after the peak. For example, the current basic rates for cars on Central Expressway are:

- 7:30 AM–8:00 AM $1.50
- 8:00 AM–8:30 AM $2.00
- 8:30 AM–9:00 AM $3.00
- 9:00 AM–9:30 AM $1.00

The system is actually even more complicated because to ensure smooth traffic flow a five-minute transition rate is used whenever the rate increment is $1 or more. Thus, in the above example, $0.80 is charged from 7:30 to 7:35 and $2.50 from 8:30 to 8:35.

Rate adjustments

Traffic flow is quite sensitive to the ERP even though the charges are relatively low—the maximum rate for cars is $3.00 on expressways and $2.50 to enter the CBD, which is comparable to a one-hour parking fee in the city (Olszewski and Xie 2005). Traffic speeds are monitored by LTA and the rates are revised every 3 months to maintain speeds within bands corresponding to the desired level of service. The target speed range was defined as 45–65 km/h for expressways and 20–30 km/h for arterials and roads crossing the CBD cordon (Menon 2000). If the observed speed falls below the lower threshold, the rates will be increased, whereas if the speed exceeds the upper threshold, the rates will be reduced.

Other measures

In 1991, the ‘‘Off-Peak Car’’ scheme (originally called the ‘‘Weekend Car Scheme’’) was introduced to enable more people to own cars without contributing to congestion (Yee and Menon 1994). Newly purchased cars could be registered as off-peak cars, with an upfront saving of $17,000 on reduced registration tax fees and COE.

The off-peak car scheme has initially proved to be popular: by the end of 1991 there were 4,800 such cars but subsequently their numbers fluctuated. At present the number is 12,900—about 3% of all cars. An ‘‘off-peak car’’ is permitted to use the road network from 7:00 PM to 7:00 AM on weekdays, after 3:00 PM on Saturdays and all day on Sundays and public holidays. There are severe penalties for using an off-peak car outside these hours but daily use permits can be purchased for $20. To facilitate enforcement off-peak cars have red number plates.

Effects on travel behaviour

Traffic reduction in the central area

The immediate effect of ALS introduction in 1975 was the reduction of car traffic entering the city centre during the morning peak by over 70%. In 1992, the car volume was still at 54% of the pre-1975 level, despite the value of ALS fee expressed as a percentage of daily wage declining in the meantime by 62% (Polak et al. 1994).

With many years of observations it was possible to model the relationship between car flow entering the CBD, the level of ALS charges and other explanatory variables. A time series partial-adjust model for assessing the effects of ALS was first proposed by Polak et al. (1994) and subsequently recalibrated by Olszewski and Xie (2002) for years 1974–1993. The following best-fit equation was obtained (t-values in brackets):

$$
\begin{aligned}
Ln(\mathrm{Q}_t) &\\
= {} & \underset{(5.4)}{5.142} + \underset{(2.2)}{0.294} Ln(\mathrm{Q}_{t-1}) - \underset{(-2.9)}{0.214} Ln(\mathrm{CALS}_t) - \underset{(-2.2)}{0.224} Ln(\mathrm{CP}_t) + \underset{(5.0)}{0.432} Ln(\mathrm{GDP}_t) + \varepsilon_t
\end{aligned}
$$

where: Q_t = volume of cars entering CBD during the ALS period (7:30–10:15) in year t; CALS_t = cost of the daily ALS licence for cars in year t, adjusted for inflation; CP_t = average parking cost in year t, estimated by combining parking fees at public and private car parks, adjusted for inflation; GDP_t = Singapore GDP in year t, adjusted using the national income deflator; and ε_t = a disturbance term.

Given the small sample size (n = 20), the levels of significance of the coefficients and the overall model fit (R^2 = 0.97) are satisfactory. Several other explanatory variables were tried, e.g.: parking capacity, MRT operation and overall driving cost but did not contribute to explaining the variation of traffic volume. Only car ownership had a significant effect on Q but because it was strongly correlated with GDP, it could not be used in the same equation.

The advantage of the above model is that each coefficient β has a direct interpretation as the short-term elasticity of flow with respect to explanatory variable. The long-term elasticity is obtained as: $\beta_{\mathrm{CALS}}/(1 - \beta_{\mathrm{Q}_{t-1}})$. The value of the coefficient on lagged flow indicates that there are significant delays in the response of the peak travel demand to price changes, with around 70% of the full effect of a price change becoming apparent in the first year.

The values of elasticity of flow versus ALS fee estimated from the model are:

- Short-term –0.214
- Long-term –0.303

The long-term elasticity is about 42% higher than the short-term value. The elasticity with respect to parking fees is of a similar magnitude. The sensitivity of traffic volume entering CBD to price changes is a reflection of the flexibility in trip scheduling, availability of alternative modes of travel serving the area and alternative routes for through traffic.

When ERP was started in the CBD area, it was even more effective than ALS because of its ‘‘per pass'' charging principle (as compared to a daily licence before) and time variable rate structure. The rates had to be revised down one month after the introduction because traffic in the CBD declined too much (Menon 2000). In fact LTA's revenue from road pricing decreased after the introduction of ERP, which proves that flexible systems with time-variable pricing can achieve their objective of alleviating congestion at a lower cost to users than systems with a flat toll.

Modal split

The restraint policies outlined above had a significant effect on modal split of travel in Singapore. Before the ALS was implemented in 1975, the share of private car drivers among commuters entering the CBD was 48%. This share dropped to about 29% immediately after the ALS introduction (Watson and Holland 1978) and has decreased further to 16% in 1983 (Behbehani et al. 1988).

Figure 3 shows the changes in island-wide modal shares of work trips, based on Singapore census data. The share of private car trips (including both driver and passenger) among motorised trips has increased from about 16% in 1980 to 25% in 2000. This increase is approximately proportional to the corresponding increase in car ownership from 63 to 96 cars per 1,000 population (Table 1). The latest travel surveys indicate that the overall share of private transport (i.e. including motorcycles and trucks) among motorised trips for all purposes has increased from 37% in 1997 to 42% in 2004 (LTA 2005). During that period the car ownership level practically did not change, indicating that besides motorisation the level of income also influences modal split, especially for non-work trips.

International comparisons made by Kenworthy and Laube (1999) show Singapore with one of the lowest car shares for work trips among the 46 cities studied. In 1990 lower car shares were only observed in Hong Kong and Seoul, which had even lower car ownership and much higher urban population density. On the other hand, cities like Manila and Jakarta, both with car ownership lower than Singapore, had commuter trip car shares between 1.5 and 2 times higher. This can be attributed to the high quality of Singapore public transport system, which benefits from motorisation restraint in two ways:

(1) There is a large pool of captive transit passengers, in addition to those ‘‘nudged'' out of their cars, which helps to maintain high frequency of services and to make transit operations profitable.
(2) Congestion-free roads allow buses to operate at a higher speed, which makes them more attractive.

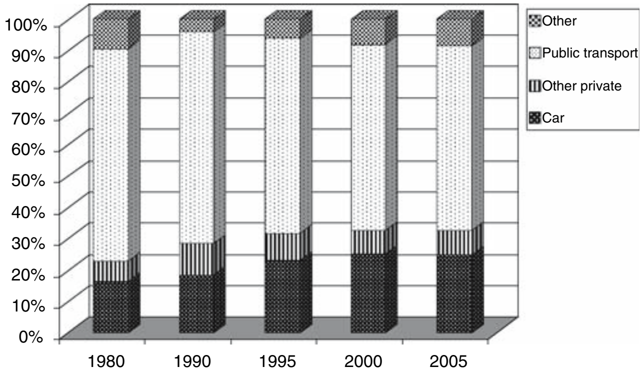

Fig. 3 Modal split for motorised trips to work based on Singapore census data. *Source*: Department of Statistics, Singapore (1990–2000)

Travel surveys (LTA 2005) reveal interesting trends in modal split. It seems that high usage of vehicles other than cars is a way of compensating for the high cost of cars, which puts them beyond reach of many families. These other vehicles are:

- *Motorcycles*—the number of motorcycles is still slowly growing (Table 1) which is unusual in a high-income country. Motorcycles provide mobility mainly for the lower income workers.
- *Taxis*—there are 870,000 taxi trips per day (11% of all trips). Taxis are efficient, relatively inexpensive and plentiful and are mostly used for non-commuting trips.
- *Chartered buses*—these provide an almost-door-to-door commuter service for people working outside the CBD. They have 8% share in work trips.
- *Goods vehicles*—pick-ups and even trucks are also used for passenger travel, not necessarily related to work.

Peak spreading

Another effect of the Area licensing scheme was to spread the morning peak of city-bound traffic, as many motorists took advantage of free-entry periods before 7:30 and after 10:15 AM. This was evident from traffic counts as mini traffic peaks appeared before and after the ALS hours. When lower-priced licences were introduced for the mid-day period in 1993, the high peak at 8:00–9:00 AM has reappeared because commuters found that it was no longer worthwhile to retime their trips (Olszewski et al. 1996).

When motorists were asked at that time how they responded to newly introduced road pricing, their first choice was to change the trip timing, followed by the change of route and then change of mode. Similar results were obtained in stated preference surveys conducted recently by LTA (2005)—84% of motorists felt that changing departure time was feasible.

When ERP was started with its time-variable "shoulder pricing" method, the peak spreading effect was even more visible from traffic observations on expressways and arterial roads. Demand elasticity with respect to ERP charges in the morning peak was estimated as –0.106 for the CBD cordon and –0.195 for expressways—almost twice as high (Olszewski and Xie 2005). This can be explained by the fact that at the expressway sites charges applied for 2 h only, so both trip postponing and bringing it forward resulted in savings whereas at the CBD cordon the only way to avoid fees was to enter before 7:30 AM.

Travel survey findings confirm that the ERP contributes to peak spreading not only locally but on an island-wide scale. Household interview surveys conducted in 1997 and 2004 show that the percentage of car trips starting between 6 AM and 7 AM has increased from 4% to 10%, while those starting between 7 AM and 8 AM decreased from 13% to 10% (LTA 2005).

Other effects

Changes in car fleet composition

The Vehicle Quota System had a profound effect on the composition of private car fleet in terms of vehicle age and engine capacity. Even before VQS there were strong incentives for scrapping cars at 10 years as part of ARF is then refunded. The annual road tax is also getting progressively higher for older cars. However, scrapping even younger cars can also be attractive because the ''unused'' part of COE is refunded. Such operations make economic sense when the COE prices are falling, as happens now (Fig. 2). Hence, over the last few years thousands of 4- to 9-year-old cars, bought when the COEs were high, have been scrapped and exchanged for new models at little or no extra cost to their owners.

Figure 4 shows the cumulative distribution of cars in Singapore by age. In 1990 the distribution between the ages 1 and 9 years was more or less uniform and the median age of a car was 6.4 years. In 2005 the median age has been reduced to just 2.2 years and only 14% of cars are more than 5 years old! Such a rejuvenation of the car fleet is of course a positive development. New cars of the same engine size are more fuel efficient, less polluting (since 2001 they have to meet Euro II emission standards) and safer to drive.

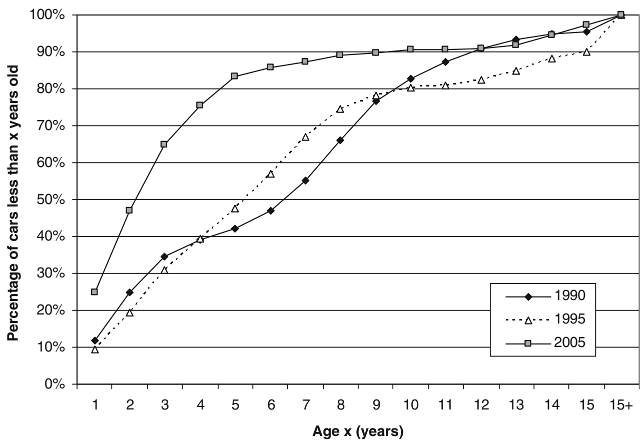

Fig. 4 Changes in cumulative age distribution of cars in Singapore. *Source*: LTA (2006)

Figure 5 shows the changes in car distribution by engine capacity. It seems that the small car category (<1,000 cc), which comprised 16.4% in 1980 has now practically disappeared. On the other hand, the share of cars with over 1,600 cc engines has grown from 19% to 39%. The fastest growing category now is cars over 2,000 cc. The main reason for these shifts is that the COE premium is now practically the same for all cars and constitutes a higher percentage of the final price of small cars than of big cars. This makes big cars relatively less expensive as compared to their OMVs. The resulting price distortion is bigger when the COE prices are high. It has been suggested that to remove this distortion, COE premium could be defined as a percentage of OMV rather than in dollar terms.

The shift towards higher engine capacity is a cause of some concern. Bigger cars are bound to consume more fuel, which can reverse the trend towards better energy efficiency. They are also heavier and while probably safer for their occupants in an accident, they can potentially do more damage to vulnerable road users (motorcyclists, cyclists, pedestrians).

Energy use in transportation

What are the implications of the Singapore motorisation restraint on long-term transport system sustainability? One way of measuring the efficiency of a transport system is to calculate the energy input required to keep it moving. Ang and Tan (2001) showed that per capita energy consumption in road transport in Singapore is about 42% of that in France and Germany. However, such country-to-country comparisons can be misleading as in big countries most of the travel mileage occurs outside cities.

It would be more appropriate to compare Singapore with other cities. This can be done using data assembled in the invaluable international sourcebook on automobile dependence (Kenworthy and Laube 1999). The energy use can be expressed in energy per capita or per unit of the regional income and these two indicators were calculated for different cities. Figure 6 shows the comparison of energy use

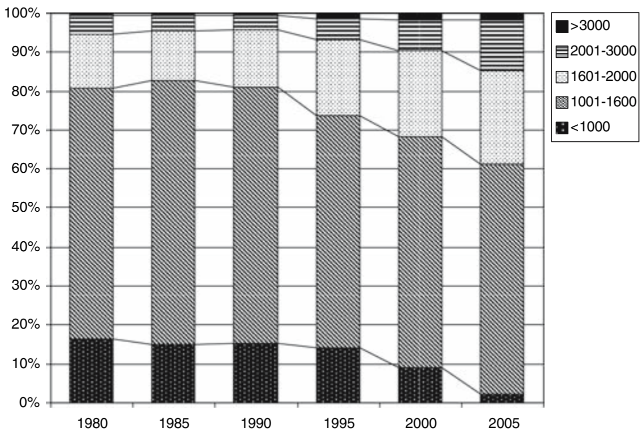

Fig. 5 Changes in the composition of car fleet by engine capacity. *Source*: LTA (2006)

indicators in 1990 for Singapore and selected cities. One can clearly distinguish four groups of cities:

(1) US cities have by far the highest rates of energy use per capita.
(2) Canadian and Australian cities have energy use about half that of US cities, with European cities doing even better.
(3) A group of developing Asian cities have relatively low energy use per capita but very high per unit income.
(4) The "wealthy" Asian cities to which Singapore belongs have the lowest transport energy use rates both on per capita and per unit income basis.

Overall, it seems that Singapore transport system is energy efficient, although even lower energy use rates are possible as shown by examples of Tokyo and Hong Kong. Compared to Singapore, both these cities have even higher urban density and better-developed mass transit systems. However, unlike Singapore, both experience congestion, which self-regulates the modal split but imposes heavy delay cost on commuters.

Road transport energy use can also be analysed based on the local petrol and diesel consumption figures published by the Customs and Excise Department (1980–1998). The volume of these fuels released each year for the local market are multiplied by their average energy equivalents and then divided by the population. Figure 7 shows the trends in road transport energy intensities calculated on per capita and per vehicle basis (this includes all types of road vehicles, as shown in Table 1). The effect of the Vehicle Quota System on energy use seems to be clear: while between 1980 and 1990 per capita energy use has increased by 32%, the increase was only 2% during the first 7 years under the VQS.

Relevance of the Singapore experience

Several authors (e.g. Willoughby 2001; May 2004) discuss the question how relevant the Singapore experience is to other countries. Some may argue that Singapore geographical and political conditions are so unique that its positive experience in

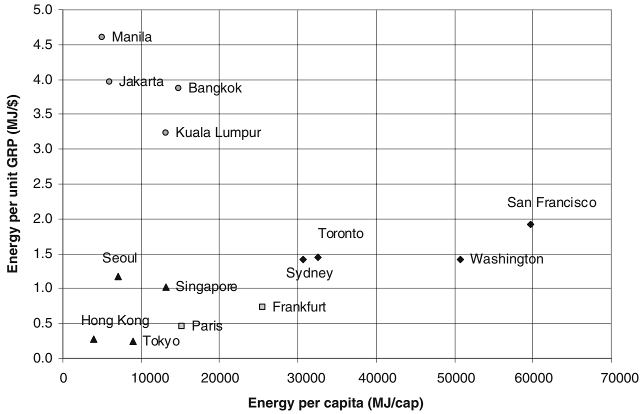

Fig. 6 Comparison of land transportation energy use for selected cities. *Source*: calculated based on Kenworthy and Laube (1999)

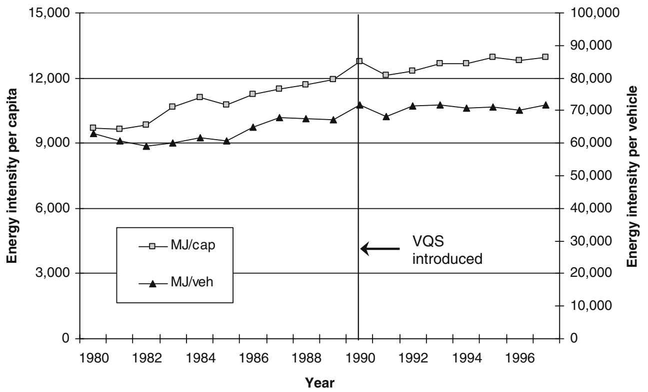

Fig. 7 Trends in road energy intensity in Singapore. *Source*: based on Customs & Excise Dept. (1980–1997)

Travel Demand Management is not transferable and of limited value to other countries. It is certainly true that Singapore is unique in being an island city, which makes it self-contained and unlike other cities, which are intertwined with wider metropolitan regions. It also has the advantage of a one-tier government, making policy setting and implementation more efficient. The government had the benefit of controlling most of the land resources, which facilitated urban planning and infrastructure construction. It also had the strong political resolve and courage to introduce restrictions on private cars for the sake of common good of containing congestion. However, even if some of these conditions are not present elsewhere, Singapore's experience with both low-technology (ALS) and high-tech (ERP) solutions can provide important lessons to other cities undergoing rapid economic development. Several elements of the Singapore transport strategy seem to be universally applicable:

- It is very important to formulate an integrated transport policy at an early stage, with clear objectives encompassing all transport modes.
- Motorists are more likely to accept restrictions on car usage if offered attractive travel alternatives, like a high standard rapid public transport and inexpensive taxis.
- Low technology cordon pricing systems like the ALS should be considered first in developing countries. They are effective, easy to implement and can generate substantial revenue. However, they require strict enforcement and may not work in cities, which do not have a well-defined CBD.
- In electronic road pricing, flexible systems with time-variable charges and "free periods" are preferable to systems with a flat toll. They can achieve the desired effect of alleviating congestion with lower overall cost to users.
- Periodic adjustments of ERP rates based on traffic speeds (or level of service) provide a self-regulating mechanism in the system. Such a goal-oriented experimental approach to demand management seems to work very well in practice.
- Restraint policies need to be closely monitored as they may have unexpected effects such as increase in car engine capacity, use of trucks for passenger transport, etc.

Besides reducing both car ownership and use, the Singapore restraint polices has been generating a substantial amount of revenue for the government. The figures published in 1993 show that the revenue collected from the motor vehicle taxes, fees and tolls amounted to over $3.12 billion (ROV 1994), which made a sizeable contribution to the consolidated revenue fund. Unlike in some other countries, the Singapore road revenues are not earmarked for transportation related expenditure. Willoughby (2001) estimated that in the years 1965–1993 the annual road revenues were at least three to four times higher than road related expenditures.

Conclusions

The example of Singapore shows how motorisation policies in each country are a product of geographical, economic and political factors. Singapore has chosen to restrain car usage and ownership mainly due to its very limited land supply. The transport policy based on balanced development of road and transit infrastructure and restraint of private car traffic has been consistently implemented for the past 30 years. Combined with land use planning, it resulted in a modern transport system, which is free from major congestion, energy efficient and provides users with different travel alternatives.

The experience with fiscal measures of restraining car ownership shows that they are effective only up to a certain point. Under conditions of rapidly rising incomes, car ownership increases quickly despite high prices. This is because demand for cars is more income elastic than price elastic. In the end, the growth of car population can only be arrested by more radical measures such as the car quota system.

However, strong economic growth and rising affluence put a constant upward pressure on car ownership and usage. While the present use of cars for commuting (25%) is low, their share of trips for other purposes is increasing. The peak spreading effect of road pricing means that the potential for congestion to occur spreads more widely both in time and space. From the point of view of energy efficiency, the gradual shift of the car fleet towards higher engine capacity is a worrying trend. Given over 30 years of experience in traffic demand management, it seems that Singapore has all the necessary system tools in place to manage these challenges efficiently.

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Biography

Dr Piotr Olszewski obtained his M.Sc. and Ph.D. degrees in highway engineering from the Warsaw University of Technology in Poland. After working in an environmental planning institute in Warsaw, in 1981 he joined the Nanyang Technological University in Singapore, where he is now Associate Professor in the School of Civil and Environmental Engineering. Dr Olszewski teaches courses in the areas of transportation engineering, urban planning and logistics. His research interests include modelling of transportation systems, travel behaviour and sustainable transport policies.