De-coupling of urban mobility need from environmental degradation in Singapore

Dr. Shobhakar Dhakal

Institute for Global Environmental Strategies
Kitakyushu Office, 3-9-30 Asano, Kokurakita-ku, Kitakyushu 802 0001, Japan
Tel: +81 93 651 3711, Fax: +81 93 513 3712, E-mail: dhakal@iges.or.jp

Introduction

1. Energy use from fossil fuel is the fundamental cause of environmental emissions from urban transportation. Cities around the world have tried several measures that ranges from end-of-pipe interventions to more upstream measures such as containing travel demand in many forms by command and control to market based approaches. Energy demand itself is a 'derived demand'; the real demand is for the goods and services. In case of urban transportation, it is the demand for travel that fulfils urban dweller's need for mobility. Cities and economies often have limitations to contain growing travel demand for its possible negative effect on economic growth. The thrust is therefore on how to reduce travel demand without hampering economic development and how to organise travel demand into better modal structure. These require manipulation of urban planning and land use policies together with transportation and environmental planning. Many cities and regions in the world suffer from serious vehicle pollution and traffic congestion that manifests into several social, economic and human health costs. In general, modal share of private transportation and their contribution to pollutant concentration are of serious concerns among policy makers. End-of-pipe approaches such as setting emissions standards, fuel quality improvements, vehicle technology interventions and improving traffic management have a limitation over which environment and congestion cannot be improved as number of vehicles and their use increases. Such end-of-pipe measures are *necessary but not sufficient* for a long-term solution to the environmental and congestion problem from urban transportation in dense Asian mega-polies. An integrated measure is the most.

Vital statistics

1. Area:
   581.5 km^2 (1967) , 647.8 km^2 (1997), 682.3 km^2 (2001)
2. Population:
   3.1 million (1991), 4.13 million (2001)
3. Population density: 6,050 person per sq m
4. City central area population:
   241300 (1970), 100000 (1996)
5. Land use:
   Built up area 49.7% (1997)
6. Per capita GDP (current market price)
   1306 (1960), 21812 (1990), 37145 (2001)
7. Car population:
   26 per 100 households (1980), 31 per 100 households (1990)
8. Road length:
   (1965) 1761 km (1993) 2989 km, 11% of land use,
   (1997) 3101 km 13.1% of land use
9. Average speed during rush hours:
   City roads (20-30 kph), Expressways (45-65 kph)
10. Modal split of journey to work:
    Private 19.1%, Public 56.8%, Other 4.6%, non motorised 19.5% (1980)
    Private 25.1%, Public 54.3%, Other 7.8%, non motorised 12.8% (1995)

Sources:
Willoughby (2000)
http://www.singstat.gov.sg/keystats/annual/yos/yos18.pdf
http://www.singstat.gov.sg/keystats/hist/gdp.html
http://www.sustainabledevelopment.org/blp/learning/casebooks/uncrd/ All accessed 25th November 2002

2. Since it independence, policy makers in Singapore have been serious about integrated urban, land-use and transportation planning. The fundamental motivation for Singapore was not environment but economic prospects, which envisioned being a prominent manufacturing, commercial and trading centre by utilising its unique geographical location. Singapore has been successful in meeting unprecedented travel demand while controlling congestion and environmental pollution to the acceptable limit (within WHO and EPA-USA level) while its economy grew from 7.5 billion S$ in 1965 to 138 billion S$ in 2001 (at 1990 market price)[1]. Singapore employs a mixed approach of command-and-control and market-based-instruments to manage traffic demand and related

[1] Singapore Department of Statistical (http://www.singstat.gov.sg/keystats/hist/gdp1.html accessed 25th November, 2002)

environmental problems. Our analyses will discuss on several policies and instruments with special attention to three key instruments, congestion pricing, parking regulations, and vehicle ownership restrictions. Theoretically speaking, congestion pricing has potentials to fully internalise the marginal social cost of private motor vehicle travel by including it into the cost of the individual's travel itself. Our focus in on the achievements, i.e. a clear demonstration of the achievement, and instruments that were used to make these achievement. The analyses on underlying condition for these instruments to work in the places other than Singapore are important in order to supplement other cities' quest for congestion-less and pollution-less urban system through these instruments. Therefore, this paper examines success story of Singapore addressing following question.

- How successful was it?
- What was the underlying situation under which the city-state opted for such aggressive policies?
- What kind of policies and policy instruments were implemented? What were the prevailing situations that led to the successful implementation of policy instruments? Why did it worked?
- Are there prospects for replicating one or more aspects of Singapore's experience elsewhere? Under what situation?

Success story of Singapore: Challenges and strategies

3. Singapore's experience should be viewed in a holistic approach, i.e. from the integrated perspective not only from environment. This encompasses urban planning, land use, transportation planning and environmental planning.

Key dates:

1968: Ministry of Communications established
30% import duty on Cars
1970: Bus service reform begins
1972: Import duty and ARF increases
1973: Singapore bus service unifies
1974: ARF raised to 55%
1975: ALS scheme initiated, ARF raised to 100%, Preferential ARF started
1978: ARF raised to 125%
1980: ARF raised to 150%
1987: MRT begins
1989: ALS extended to other vehicles
1990: Vehicle Quota System begins
1994: ALS implemented whole day
1995: Road Pricing System on expressway
1998: Electronic road pricing begins
1999: ERP extended to highways

4. Singapore separated from Malaysia and became an independent city-state in 1965; at the time, housing shortage and unemployment was a major problem in the city. Singapore was more sort of densely packed settlement surrounded by shantytowns in the coastal area. Average density of the city's core 400 hectare exceeded 1,200 person per hectare in 1959 (Willoughby, 2000). In 1965, nearly 70% of the Singapore population of 1.8 million was concentrated within 5-km radius from port of Singapore, then city centre (Humphery, 1985). Newly elected People's Action Party prioritised housing and employment as a major government focus. The landmark Land Acquisition Act that was passed in 1966 gave government sweeping hands to acquire any land, which was indeed a land-reform legislation. An aggressive pursuit for urban planning, housing development and industrial estate development went ahead by Urban Redevelopment Authority and Housing and Development Board (HDB) under Ministry of National Development. Strategic location and economic liberalisation attracted huge manufacturing investment after 1965 and Singapore maintained double digit economic growth till first oil shock in 1973. In late 60s, Singapore also attracted attention from financial and commercial sector investors apart from manufacturing sectors. In the 1960s and 70s, per capita car ownership in Singapore was much higher relative to its per capita income. In 1960s alone, car population doubled and motorcycle tripled, income was constantly rising while public transportation system was slow and unreliable. Traffic congestion was in peak in 1975 with 19 km/hour average vehicular speeds during peak hours (Phang and Toh, 1997).

5. Realising that growing economy needs sound long term city planning in land scarce Singapore, a 4-year State and City Planning (SCP) Project, a concept plan till 20 years for Singapore was commissioned and completed in 1971 with support from UNDP. It emphasised the need for planning

the city for 4 million populations rather than 2 million envisaged by earlier plans. For transportation sector, the project made important recommendations that by 1992 it would be environmentally unacceptable and physically impossible to build road infrastructure to meet prevailing private automobile growth. It suggested to ease traffic congestion within the business centre, develop rapid transit system in addition to expressways, and that bus alone would not be able to meet public travel demand by 1992 (Fwa, 2002).

6. Following recommendation from SCP, Singapore government implemented a number of measures within 1972 to 1992. These include private vehicle ownership restriction by high import duty, additional registration fee (ARF) and vehicle quota system, private vehicle use restriction in city centres by Area Licensing System (ALS), expansion of expressway systems and 67 km of rail based MRT.

7. Public transportation was being provided in Singapore principally by three groups, a large British owned bus company, eleven smaller Chinese owned companies and a herd of unlicensed taxies leading to slow, inadequate and unreliable system. Efforts to organise public transportation were made in 1970 by government forcefully and finally merging all into a single company in 1973 with its share in government hands (floated to Singapore Stocks Exchange in 1978). These measures improved the quality of public transportation, which provided a choice for private motorists to desert private cars due to its high ownership and running costs imposed by government.

8. Land use and urbanisation pattern influence travel demand through appropriate planning. Government's higher-hand over land rights allowed HDB to construct high rise affordable housing estates in planned zones of the city. The government scheme was successful to move city dwellers to these newly constructed public housings well equipped with supporting commercial and recreational establishments. As a result, 86% of the population today lives in such premises (MIA, 2001). These activities were in consistence with SCP's suggestions to adopt "Ring Concept" where high-density residential areas, industries and urban centres are to be distributed in a ring formation around the central business districts. The revised plan was introduced in 1991, which replaced ring concept to four decentralised areas in a "constellation pattern" (Lye, 2002).

9. Despite strong economic growth and 20 times increase in office space and number of employment, Singapore could maintain its environmental and transportation system under acceptable limits. By 1995, the level of motorization was slightly over 100 cars per 1000 population, which was general trend for cities with one-third-income level of Singapore. The recent data suggests that the average speeds during rush hours are 20-30 kph in city roads and 45-65 kph is expressways. Also, the level of major air pollutants in Singapore is well within acceptable limits of WHO and US Environmental Protection Agency.

Table 1 Singapore ambient air quality

Pollutant type	Average time	1982	1988	1994	1999	Standard
Carbon monoxide	8 h (roadside), ppm	1-3	1-3	1-3	1-3	9
Lead: roadside	3 months, $\mu g/m^3$	1.5	0.4	0.2	0.1	1.5
Lead: ambient	3 months, $\mu g/m^3$	0.6	0.2	0.1	0.1	1.5
Sulphur dioxide	Annual mean, $\mu g/m^3$	29	20	19	22	80
Nitrogen oxide	Annual mean, $\mu g/m^3$	18	16	29	36	100
Ozone	Max 1 h, $\mu g/m^3$	450	176	237	181	235
Ozone	1 h concentration >235 $\mu g/m^3$, days	30	0	1	0	-
PM10	$\mu g/m^3$	-	-	48	34	50
TSP	$\mu g/m^3$	70	47	55	-	75

Source: Ang and Tan (2001) citing Pollution Control Department, Ministry of Environment, Singapore
* Ozone measurements in 1982 were conducted using the Neutral Buffered Potassium Iodide Method which was subsequently replaced by the Ultra-Violet Photometric Method.

10. From environmental viewpoint, the countermeasures of Singapore for air pollution includes cleaner vehicles with controlled emission limits, cleaner fuels and controlling traffic congestion. The first and second ones are being tried with many cases of success in cities around the world while last one, controlling traffic congestion, remain a biggest problem in which Singapore's experience is a landmark success. Therefore, our attention here is focussed on these efforts of controlling traffic congestion through travel demand management (TDM). This was principally achieved through four major instruments, which limits the number of private cars as well their uses; (1) fiscal measures of car restraining (2) Vehicle Quota System (VQS) (3) Area Licensing System (ALS) which is recently upgraded to Electronic Road Pricing (ERP) system, and (4) efficient and affordable public transportation system. Singapore's end-of-the-pipe emissions management strategies i.e. vehicular emission management strategies, are described in the attached appendix in detail.

Institutional arrangement

11. In Singapore, The Ministry of Communications and Information (MCI) had the mandate to oversee all the policies of the land transportation through its departments and statutory bodies. Ministry restructuring was carried out in 1990, 1999 and 2001, and as of 2001 November, the name is changed to Ministry of Transport. The role of vehicle emission enforcement was transferred to Ministry of Environment on July 1, 1999. As of today, Ministry of Transport has mandate to look after civil aviation and air transport, maritime and ports, and land transport. Land Transport Authority (LTA), a statutory body created under Ministry of Transport in 1995 is directly responsible for all aspects of car ownership restriction, car use-restraining policies and schemes. It is also responsible for planning, implementation and management of all public and private land transportation and infrastructure policies. Urban Redevelopment Authority (URA), under Ministry of National Development is responsible for land use planning and land allocation, under which other development planning is pursued. LTA and URA jointly manage parking space and policies, while LTA and Ministry of Environment (especially newly created National Environmental Agency, 1 July 2002) co-operate for motor vehicle emissions with the help of Traffic Police. As majority of the land is with Government, Housing Development Board (HDB) is responsible for developing housing complexes and to sell to the public. All these agencies co-ordinate closely for an integrated land use, transportation and environmental planning.

Major Policy Instruments

Restraining car ownership: Fiscal measures

12. Fiscal measures for restraining car ownership in Singapore include import duty that is levied through Customs and Excise Department, goods and services tax, registration fee and Additional Registration Fee (ARF) that is imposed by land Transport Authority when imported vehicle is registered, and road/fuel taxes. Singapore has relied upon very high taxes and fees to restrain car ownership initially. These measures were further successful in securing large revenues to invest in land transportation infrastructure. Import duty was 30% of open market value in 1968, which was increased to 45% after 1972 and subsequently reduced to 31% of OMV for cars, 12% for motorcycle, 7% for taxies and 31% for buses with 8 or less seats. As of 4 May 2002, import duty is 20% of OMV for cars. Goods and services tax stands 3% of cif cost plus custom duty in 2002. Additional registration fee (ARF) was originally introduced in the late 1950s but revised several times which stands 140% of open market value after 1980. As of 4 May 2002, it stands 130% of OMV. Registration fee was S$15 in 1968 and increased to S$1,000 in 1980, however after introduction of ERP in 1998 April it was reduced to S$140. A 17.5 times increase in car registration fees (total, including ARF) was made in 1972-83 period; from 10% of car price before October 1972 to 175% of car price after October 1983 (Fwa, 2002). Singapore Government has also imposed high tax on retail fuel price. Fuel taxes vary from fuel grade. Best grade gasoline is taxed at S$0.44 per litre (or 35% of pump price before 3% goods and sales tax). From late 1998 tax on diesel is lifted. The annual road tax varies from 70 cents (Singapore) to 175 cents per cubic cc for car with 1000 cubic cc engine to exceeding 3000 cubic cc engine per year (Lye, 2002). Recently, some rebate in road tax has been

offered after introduction of ERP. From September 2002, the new calculation formula for cars is given in the appendix. To lesson the implications of high registration fee on vehicle renewable/modernisation rate, Preferential ARF was launched in 1975. In this scheme, government reduced ARF rates for registration of those new vehicles that simultaneously scrap older vehicles of same class and size.

13. Growing economy and rising living standards surpassed economic disincentives to own a car. Despite such heavy financial burden to own car, Singapore saw 73% rise (average 13,000 car a year) in car population in 1977-84 followed by brief recession and again steep rise of an average 15,000 car a year in 1987-1990 (Fwa, 2002). Although this increase was much less than other similar nations, it was unacceptable for Singapore Government. Singapore Government imposed a new fiscal measure to control volume of the vehicles directly by Vehicle Quota System to maintain a 3% annual growth rate of vehicle population. In a part, Preferential ARF helped to increase vehicle population due to continued increase in ARF and the appreciation of Japanese yen which car dealers marketed with the argument of increase in "asset" if one buys a car. Indeed, in case of some class of car, older cars increased their value over time (Willoughby, 2000).

Vehicle Quota System (VQS)

14. VQS was announced in February 1990 with the intent to cap number of newly registered vehicles. VQS was easier instrument compared to ARF. ARF was a pricing instrument, and changing level of ARF was politically sensitive. In VQS government just need to fix number of allowable vehicles but not their price. Price is determined by bidding market itself. In this mechanism, prospective vehicle owner should obtain Certificate of Entitlement (COE) to allow owning a vehicle valid for 10 years through open bidding. The bidding is opened twice each month and a list of bidders in descending order is arrayed. The bid quoted by last bidder of designated quota is called "Quota Premium", and is levied on all successful bidders to own COE. So far, the demand of COE has exceeded designated quota by two times or more and quota premium for passenger car has been in a range of 30-80% of car selling price (Fwa, 2002; Willoughby, 2000). Table below lists the COE price as an illustration.

Table 2: Certificates of Entitlement (COEs) bidding of 20 November 2002

Category	Quota	Quota Premium	Total Bids Received	Number of Successful Bids	Unused Quota carried forward
Category A (Cars 1600cc and below and taxis)	1,334	$29,008	1,942	1,328	6
Category B (Cars 1601cc and above)	663	$28,001	879	597	66
Category D (Motorcycles)	835	$1	676	676	159
Category C (Goods vehicles and buses)	576	$13,789	736	567	9
Category E (Open)	1,095	$28,005	1,445	1,094	1

A, B and D are non-transferable categories
C and E are transferable category
Source: http://www.onemotoring.com.sg/main/default.asp (Accessed on November 25, 2002)

15. To allow less wealthy consumers to own a car, different sub-categories were established in the beginning. This included weekend cars, small cars, medium cars and taxis, big cars, luxury cars etc. This gave to additional complexities and consequently such sub-categorization is reduced in 1999. For cars, mainly two categories exist; below 1600 cc and equal or above 1600 cc. Public and school buses, diplomatic vehicles, ambulances and emergency vehicles are all excluded from the scheme. Beyond 10 years of COE, one should either de-register or acquire COE at the price of three-month moving average quota premium of that category. Since then many efforts were made to discourage speculation and other distortions but the basic rule remain same (Phang, Wong and Chia, 1996; Toh and Phang, 1997; Chu and Goh, 1997). For example, at the time of introduction COE was transferable which soon gave rise to speculative market. In the first two months, 20% of COEs changed ownership. Subsequently Government made COEs non-transferable with the exception of open and goods

categories in 1991 October. In face of such strict measures that were basically controlling demand rather than need, government implemented other relief measures such as Week-End Car (WEC) Scheme. WEC scheme allowed rebates in ARF, import duty, quota premium and road taxes and allowed WEC-use only during off-peak hours. For urgent uses, five day-use licenses were granted at the time of paying annual road taxes at the cost of S$ 20 a day. In essence, WEC scheme was a manual road pricing, although of a very primitive form.

Area Licensing System (ALS)

16. ALS is a road pricing mechanism where each car is charged for their contribution to congestion in the central business districts (CBD). This measure reduces the car-uses in CBD when import duty, ARF and other measures such as road or fuel tax cannot influence the car uses once they are on the street. Singapore's ALS Scheme was based on "cordon pricing" system and was introduced in 1975. The cordoned CBD area of 5.59 Square km (600 hectares), referred as the "Restricted Zone (RZ)" was isolated from rest of the city by constructing 22 entry point (Toh, 1977). In the scheme, the license to enter into restricted zone during morning peak hours (7.30 to 9.30) was required to be taken at the cost of S$3 (later changed to S$4) a day (S$ 60 per month, later changed to S$80) in advance. The system was paper based that verified by the observers at the entry posts. Non complying vehicles needed to pay a fine posted to their homes through letters. The restricted zone, time and the price of ALS license were changed several times later to accommodate CBD expansion, traffic and economic condition. Initially taxies and cars with more than 3 passengers excluding the driver and buses were exempted from buying entry licenses, later (since 1989) they were not exempted. At the same time, public parking charge in the restricted zone was raised and additional surcharge was levied on private parking operators to discourage car use.

17. ALS was highly successful in curbing traffic congestion in morning peak hours. By the fourth week of ALS, traffic flow during peak hours had fallen by 45.3%, number of cars in dropped by 76.2%, and percentage of commuters travelling by public transportation rose from 35.9% to 43.9% (Toh, 1977, Yap 1986). The average speed increased from 18 to 35 kph (Willioughby, 2000). The traffic reduction by 45.3% was higher than aimed 25-30%. However, this also increased traffic pressures just before or after restricted hours and to immediate-outside of restricted zone that served as an "escape corridor". Traffic management measures were implemented in those escape corridors to relieve pressures. The anticipated "mirror effect" of less traffic during evening peak hour did not happen. In order make optimal use of road space and smooth operation, several adjustments in restricted time and uses were made in later years through careful monitoring. After 27 years of ALS implementation, the inbound traffic volume in CBD in morning peak hours was still less than it used to be before ALS implementation (Fwa, 2002). Apart from congestion, the major advantage of ALS was on energy saving and air pollution reduction. Fwa and Ang (1996)'s conservative estimate of energy savings with and without ALS, based on 1990 flow and traffic speed data, suggested 1.043 GJ per day. The shift from clean vehicle to clean transportation system relieved over dependence on end-of-pipe measures for air pollution in CBD.

18. One of the major questions in ALS is whether pricing was correct given externalities to society due to congestion and environment. In 1990, a study by Public Works Department in Singapore revealed that the average speed during morning peak hours in restricted zone was higher than during non-peak periods (McCarthy and Tay, 1993). The existing price of the access license was calculated about 50% more than the optimal price. However, in the absence of time and spatially varying pricing mechanisms any such price would not be optimal. The new measures that replaced manual ALS, Electronic Road Pricing (ERP) with improved technology many pave such way for such pricing mechanism.

Electronic Road Pricing (ERP)

19. ERP was implemented in September 1998 replacing Area Licensing System (ALS). The basic idea of ERP is similar to ALS, but ERP is technologically sound so that time and spatially varying

charges is possible reflecting the true cost of vehicle uses in central business districts. In this system, all 33 ALS gantry are replaced with ERP gantry for 720 ha of core area, and each vehicle to enter into restricted zone are fitted with In-vehicle Unit (IU). IU is fitted in the lower right hand corner of windscreen in the four-wheeled vehicle and in the handle bar of motorcycle. IU unit reads stored-value cash card from which charges are deducted automatically as soon as vehicle enters into restricted zone through ERP gantry. This is done by short wave radio frequency link between ERP gantry and In-vehicle Unit. For violators, photographs of non-complying vehicle's license plates are taken automatically for further action.

20. From Institutional side, four of the departments of Land Transport Authority are involved in governing ERP. The traffic management department is responsible for setting up rules and guidelines, the computer information department maintains the hardware and software, the regulation department deals with enforcement of rules and regulation and violations, and vehicle engineering department.

21. At the moment pre-determined ERP charges varies each half-hour of a day, from S$2.50 during peak hours to 50 cents during off-peak hours depending on road sections. Charges are different for motorcycles, cars, good vehicles, taxies and buses etc; different IU units are installed in each category of vehicles. The fundamental question is what amount of charge is appropriate. Theoretically speaking, a real time pricing reflecting the cost of congestion, level of congestion and relative contribution of each vehicle category to congestion is an ideal mechanism that can internalise the externality of congestion. In reality, it's not easy to enforce such pricing although not impossible through ERP. At the moment, charges do not fluctuate depending on the traffic conditions in Singapore. ERP charges are subject to review every 3 months to suit changing traffic conditions, these charges are basically tied to prevailing speeds with the aim of maintaining traffic speeds of 45-65 kph in expressways and 20-30 kph is arterial roads (Willoughby, 2000). The successful implementation of ERP has facilitated to reduce taxes and other charges and increasing the allowable vehicle quota. The cost of IU units was less than S$300 and for new vehicles with IU units rebates are offered in road taxes as much as S$ 200. Frequent adjustments such as special reduced ERP price during school holiday when traffic reduces etc is possible and is being carried out.

Why did it work in Singapore?

22. Travel Demand Measures (TDM) have seen only a limited success in many parts of the world while supply side measures (such as building road infrastructure etc) are being actively pursued in those countries. Supply side measures are "never enough" and put greater burden environment because usually more infrastructure means more vehicles on the street. From global sustainability consideration, TDM measures facilitates energy and resources conservation at "downstream" as well as at the "upstream". The fundamental question therefore remains, why such measures worked in Singapore.

23. Integrated planning of a city is the keyword in Singapore's success. All the measures are apart of a comprehensive strategy and are coordinated very closely to provide a comprehensive solution; without such strategies a single measure alone wouldn't have worked. Right to travel is basic human right, however government policies can provide various options to travelers to choose the reasonable mode of travel. Such perspectives in policies are essential and will be acceptable to citizens. When Electronic Road Pricing Mechanism was implemented in Singapore, commuters have choices to (1) pay charges and drive smoothly (2) change the time of travel to pay less charge (3) use an alternative road, (4) use public transport, and (5) use other schemes such as park-and-ride (Menon, 2002). The success of Singapore is coupled with favorable economic, social and urban conditions too. Small land and population size allowed flexibility of planning too. Being a city-state, a single tier government exists in Singapore, which eliminates all the complexities arising from layers of authorities (so easy and quick decisions) and a mismatch between local and national priorities. The economy of Singapore heavily relies on foreign investments and on transaction related to international trade, commerce and finance for which efficient transport and communication is essential. The need to fulfill this condition for economic reason has contributed to transport and environment. Unlike other countries,

improvements in environment and transport complimented economic growth in Singapore. Strong Government, stable and strong regulation and institutional frameworks for enforcement are the other reasons why it worked in Singapore. From jurisdiction point of view, roles and responsibilities of authorities responsible for urban/land use planning, land transport and environment were clearly demarcated. The land reform initiated in 1967 allowed government to acquire majority of land and subsequent development of housing estates in the city periphery and facilitated infrastructures for sound land use planning. The Housing and Development Board, which was set up in 1960 by British Colonial Government provided housing to 9% population in 1960, however, with sweeping powers under Land Acquisition Act allowed government to acquire private land for public housing or other development activities. As a result 85% of population today live at HDB housing complexes. Another reasons for success of Singapore is the periodic adjustment of policies through feedback from public and other stakeholder and learning by doing including transparency in policy formulation; policies are never perfect. For example, charges are ERP are subject to review every 3 months, charge structure and time of ALS changes several times depending on traffic and economic conditions.

24. One of the keys to these successes is infrastructure investment. Demand side management was supplemented by constructing additional road infrastructure, good maintenance of roads, improving co-ordinated traffic lighting systems, expressways and rail based MRT. The taxes and fees imposed on vehicles generated huge financial resources not only to invest on demand and supply side management but also to lessen less desirable taxes. Willoughby (2000) estimated that the annual revenue from road transportation were at least 3-4 times road expenditure.

25. There are some technology-factors that also played important role in Singapore. ERP for example, depends on sophisticated technology that allows time of day pricing reflecting traffic conditions. Its primitive version, ALS however was non-technology measure. Computerized traffic controlling system was already in place by 1986 in central business districts (Lee, 1986) which was replaced with a more advanced automated traffic signaling system called GLIDE (Green Link Determining System). GLIDE was traffic adaptive signal control monitored centrally to adjust changing traffic conditions (Lee, 1990). Efforts are being made to create Global Positioning System based coordinated public taxi calling system which dispatch taxies automatically from most nearest location although individual taxi operators are using such system. These high-technology measures provided support to non-technology measures of car ownership and use restrictions. However, high-technology measure's overall effectiveness can be questionable (Fwa, 2002).

26. Singapore is migrant's society where people moved to Singapore from many countries in and out of the region. From societal point of view, probably this facilitated Singapore in implementing policies because these migrant were economic migrants in most cases and their opposition and barriers in the form of organised resisting force to government policies was minimal.

Significance of Singapore's experience to other cities

27. The big question is therefore what are the lessons of Singapore's experience to other cities discounting the localised favourable conditions of Singapore? Being a city as well as whole nations, ease of policy implementation exists in Singapore. It is possible to control flow of goods and services in and out of the city being an "island city". In most of other cities in Asia, cities do not have clear function boundaries and have too many interactions with outside of the cities thus pose difficulties in making effective policies. In many cities, transportation sector provides employment to low-income groups through cheap travel mode such as manual tricycles (Bangladesh, India), three wheelers (many cities in South and Southeast Asia and China), Jeepney (Philippines) and others. Policies need to provide viable alternatives. The root causes of policy failures in cities of developing countries are the wrong and inadequate policies, lack of integrated policies, lack of institutional capacity to enforce existing policies, problems of jurisdiction of authorities (institutional arrangement) and lack of co-ordination, and political interests of governing parties. These are all examples of poor governance, which are often associated with lack of financial resources. Selling travel demand measures to public is not easy because it directly affects each City dweller's travel. Such measures cannot be acceptable

or popular unless it is a part of overall strategies and a good public campaign regardless of economic and social conditions of a city. At the same time acceptable alternatives need to be provided. Development of sound public transportation system is key to replicate Singapore's other successful measures.

28. Vehicle quota system in other countries needs a serious planning and would not be as simple as in Singapore. Collaboration of national government and local authorities is greatly needed. Controlling quota only at national level might produce "hot spots" due to over concentration of vehicles in few cities. National government can exercise control over total vehicle import quota and allocate registration quota to local governments based on their traffic conditions. Some form of restrictions over transit vehicles in the form of local road use charging system would compliment such policy. Hong Kong, in particular has long adopted strong vehicle ownership control measures through fiscal measures.

29. In general, strong legislative and institutional framework is prerequisite. Electronic Road Pricing may seem a little bit too far at the moment in cities of developing countries but other measures such as ALS and VQS neither need any high technology not operationally complicated. ALS, for example is a simple measure that is easy to enforce and most suitable for dense city core areas in mega-cities and medium scale cities to curtail emissions and congestion during peak hours. Local governments under Self-Governance Act, which are in force in many cities, can carry out such provision. Together with parking regulation such charging system doesn't interfere with national government and revenue generated from ALS can be used to improve roads, signal systems and to relieve pressure on escape routes around the cordoned area by the city authority. This can further relieve financial burden for maintaining road infrastructure. ALS in particular has generated lots of interest around the world. Many cities have prepared schemes to implement such cordon pricing in central city areas. Three Norwegian cities, Bergen, Trondheim and Oslo initiated such scheme in 1980 covering wider areas than Singapore. High technology options, especially ERP and Intelligent Transport System (ITS) have attracted attentions developed countries, Canada, Norway, and USA are already carrying out initial applications while Chile, Netherlands and UK are expected to do so (Willoughby, 2000). London is soon stating a system similar to that of ALS from November 2002 with 5-pound charges to enter core area. In nearby cities, especially Bangkok, Kuala Lumpur and Manila, vehicle ownership and uses restrains were proposed several times. In Manila such restrain was proposed in 1977 (Freeman and Fox, 1977 see paul's reference) however citing insufficiency in enforcement mechanism such idea was later dropped (Kirby et al., 1986 see paul's reference). Similarly, proposal was made several times in Kuala Lumpur and Bangkok for car restraining in central areas since late 70's but without any success.

30. As mentioned earlier, the root of the integrated land use and transportation planing goes back to Land Acquisition Act of 60s allowing Government to acuire land and made land reservations for city planning. Clearly, in dense cities in Asia Government control over land does not exist with exception of few centrally administered countries. Land reform calls for setting many limits and constraints to public, and it has remained not intervened by policy makers in many countries due to their political sensitiveness. In densely built cities, some changes in land-use may be possible by providing incentives to de-populate central area, however their effectiveness could be nominal.

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Appendix I

Status of public transportation and roads in Singapore as of 2002 November
(Source: Land Transport Authority, www.lta.gov.sg on 25th November 2002)

Mass Rail Transit, MRT: Introduced in 1987, two lines covering east-west and north-south. 50 existing operating stations, 106 operational trains made up of six cars each, Daily passenger trip served 1,073,947, LRT Introduced in Nov 1999

Public buses: Two companies exist, No. of routes: Trunk 163 - Trans Island Bus Service (42), Singapore Bus Services (121), Feeder - 65 - TIBS (14), SBS (51), Total Fleet : 3,389 - TIBS (787), SBS (2,602), daily trips: SBS - 2.47 million passenger trips, Tibs - 658,127 passenger trips

Taxis: Four companies, Total fleet 19,007, Daily trips 588,632

Cars: Total population 405,797

Roads:

Total length of expressways	: 150 km
Total length of Major Arterial Roads	: 571 km
Total length of Collector Roads	: 382 km
Total length of Local Access Roads	: 2007 km
Total Road Length	: 3110 km

Motor vehicle population by type of vehicle (end of year)
(Source: http://www.gov/sg/lta/MenuFrame3.htm, accessed on 25th November 2002)

Item	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cars	285298	287612	306216	324026	345432	365558	377365	375217	382941	392961	405354
Motorcycles	121164	115339	118752	125000	128464	131260	131591	132261	133358	130964	130910
Buses	9342	9504	9541	10000	10511	10774	11008	11162	11558	12300	12624
Taxies	12705	13445	13917	14750	16517	16857	16933	17886	18029	18327	18798
Goods and other vehicles	120802	122009	125696	126836	129484	131924	133770	131453	129754	124854	127273
Tax exempted vehicles	9993	9675	10200	10999	11721	11931	12537	13102	13171	13401	13411
Cars	2113	1767	1789	1871	1957	2035	2132	2123	2195	2257	2290
Motorcycles and scooters	1246	1193	1187	1156	1123	1084	1038	1114	988	973	959
Buses	136	154	175	198	212	224	232	267	269	269	278
Goods & Others Vehicles	6498	6561	7049	7774	8429	8588	9135	9598	9719	9902	9884
Sub-Total											
Total vehicles	559304	557584	584322	611611	642129	668304	683204	681081	688811	692807	708370

Note:
New classification of goods vehicles from 1998
Tax exempted vehicle includes all categories of vehicles

Per Capita GDP at Current Market Prices
(Source: http://www.singstat.gov.sg/keystats/hist/gdp.html *accessed 25th November 2002).*

Year	1960	1965	1970	1975	1980	1985	1990	1995	2000	2001
S$	1,306	1,567	2,798	5,941	10,394	14,226	21,812	33,404	39,796	37,145
US$	427	512	914	2,505	4,854	6,466	12,034	23,567	23,085	20,732

Road tax calculation formula for cars
(Source: http://www.gov.sg/lta/MenuFrame3.htm)

Engine Capacity (EC)	Existing Road Tax Formula (per annum)	New Road Tax Formula* (per annum)
Less/equal to 600 cc	S$500 (flat rate)	S$400
Between 600 and 1,000 cc	S$500 + 0.25 x (EC - 600)	S$400 + 0.25 x (EC - 600)
Between 1,000 and 1,600 cc	S$600 + 1.0 x (EC – 1,000)	S$500 + 0.75 x (EC – 1,000)
Between 1,600 and 3,000 cc	S$1,200 + 1.8 x (EC – 1,600)	S$950 + 1.5 x (EC – 1,600)
Over 3,000 cc	S$3,720 + 2.5 x (EC – 3,000)	S$3,050 + 2.0 x (EC – 3,000)

* Effective from 1 September 2002.

Road Tax Surcharge for vehicles over 10 years

Age of Vehicle	Annual Road Tax Surcharge
Over 10 years	10%
Over 11 years	20%
Over 12 years	30%
Over 13 years	40%
Over 14 years	50%

Road Tax Surcharge for Diesel-driven cars

Diesel tax is imposed in addition to the road tax.
The diesel tax is 6 times the road tax of an equivalent petrol-driven car.

Anatomy of Singapore's vehicular emission management

Institutional and Legislative framework of pollution control

History of Vehicle emissions standards

- 1986 - UN/ECE R15.04 for petrol-driven vehicles
- 1991 - UN/ECE R 24.03 for Diesel-Driven Vehicles
- 1991 - US 40 CFR for motorcycles
- 1992 - UN/ECE R 83 or Japanese Article 31 (JIS 78) for petrol-driven vehicles
- 1994 - The Consolidated Emission Directive (91/441/EEC standard) and JIS 78 for petrol-driven vehicles.
- 1997 - The European Union (EU) Directives 93/59/EEC and 91/542/EEC stage I (Euro I) for light- and heavy-duty diesel- driven vehicles respectively.
- 2001 - Euro II (EU 96/69/EC) for cars and light duty vehicles and 91/542/EEC stage II for heavy-duty vehicles)

Source: Personal communication with Pollution Control Department, Ministry of Environment

In Singapore, the basic legislative framework for pollution control is provided by The Environmental Pollution Control Act (EPCA), which came into force on April 1, 1999. This act consolidated all the previously existing acts on air, water, noise and hazardous substances, such as Clean Air Act and others. Pollution Control Department (PCD), which was formed in 1986, is responsible for most of the issues such as ensuring environmental concerns into sectoral policies as well as air, water, noise etc. The key responsibilities of PCD are prevention, enforcement and monitoring. Under this Act, Environmental Pollution Control (Air Impurities) Regulations 2000 came into force on 1 Jan 2001. It replaced Clean Air (Standards) Regulation of 1978. From the year 2002 (July), National Environmental Agency, a statutory body under Ministry of Environment is formed (with Pollution Control Department within it as Environmental Policy and Management Division), as an executing authority, which is responsible for all aspects keeping Ministry responsible for broader policies.

Standards for new vehicles

For motor vehicles, various standards are in place. EURO II exhaust emissions standards are imposed from 1 January 2001 for all new gasoline and diesel vehicles. This required all the gasoline cars to be equipped with 3-way catalytic converters. Similarly, All the new motorcycles are required to comply with US 40 CFR 86.410-80 Emission Standard.

Table: European Directive 96/69/EC
(For passenger cars and light duty vehicles with maximum laden weight 3,500 kg or less)

Vehicle [1]		Limit Values		
Reference Mass (kg)	Type	CO (g/km)	HC + NOx (g/km)	PM (g/km)
Category M [2] passenger cars	Gasoline	2.2	0.5	-
	Diesel	1.0	0.7	0.08
Category N_1 Class I < 1250	Gasoline	2.2	0.5	-
	Diesel	1.0	0.7	0.08
Category N_1 Class II 1251-1700	Gasoline	4.0	0.6	-
	Diesel	1.25	1.0	0.12
Category N_1 Class III > 1700	Gasoline	5.0	0.7	-
	Diesel	1.5	1.2	0.17

Source: http://www.env.gov.sg/about/pcd/air_pollution/eu_directive_9669.htm, Accessed 26 November, 2002

1. Also applies to vehicles designed to carry more than six persons including the driver and vehicles with max. mass exceeding 2500 kg.
2. Except vehicles designed to carry more than six occupants or with maximum mass > 2.5t. These vehicles are covered by the appropriate N category.

Category M - Passenger Vehicles
Category N_1- Vehicles used for the carriage of goods and having a maximum weight not exceeding 3.5 tonnes
Category N_2- Vehicles used for the carriage of goods and having a maximum weight exceeding 3.5 tonnes.

Table: European Directive 91/542/EEC Stage II for heavy vehicles with MLW of more than 3,500 kg

Type Approval				Conformity of Production			
CO	HC g/kWhr	NOx	Pm	CO	HC g/kWhr	NOx	Pm

g/km		G/kWhr	g/kWhr	g/kWhr		g/kWhr	g/kWhr
4.0	1.1	7.0	0.15	4.0	1.1	7.0	0.15

Source: http://www.env.gov.sg/about/pcd/air_pollution/eu_directive_91542.htm, Accessed 26 November, 2002

Vehicle In-Use emission control and dis-incentives for old vehicles

In most of the cities in developing countries, the emission standards for new vehicles are well in place but the standards for existing in-use vehicles are not well enforced due to variety of complications. Prevalence of old vehicles, poor maintenance, institutional inefficiency, and strong opposition from vehicle owners are the major concerns. In case of two and three wheelers, South Asia in particular is flooded with two stroke engine vehicles making hard to meet any existing standards on street. In Singapore, the CO standard for in-use gasoline vehicle registered before 1986, 1986-1992 and after 1992 are 6%, 4.5% and 3.5% by volume respectively. Similarly, for diesel vehicles, standard for smoke is 50 HSU (Hartage Smoke Unit)[2]. Disincentives for keeping older vehicles are imposed in the form of (1) road tax surcharge (2) more frequent mandatory vehicle inspection and (3) benefits in additional registration fee. Gasoline vehicles more than 10 years old need to pay an additional surcharge of 10% of usual road tax, this increases to 50% for 14 years or older vehicles. In case of diesel cars, the surcharge is 6 times of that of equivalent gasoline cars. Government has provided provision of Preferential Additional Registration Fee for car replacements, which scrap old cars (otherwise ARF stands 130% of open market value).

Table: Preferential Additional Registration Fee (PARF) structures for cars

Age of Vehicle at De-registration	Graduated PARF Rebate (Rates before May 2002)	New PARF Rebate (For cars registered with COEs obtained from May 2002 tender)
Less than 5 years	130% of OMV	75% of ARF paid
Less than 6 years	120% of OMV	70% of ARF paid
Less than 7 years	110% of OMV	65% of ARF paid
Less than 8 years	100% of OMV	60% of ARF paid
Less than 9 years	90% of OMV	55% of ARF paid
Less than 10 years	80% of OMV	50% of ARF paid

Source: http://www.gov.sg/lta/MenuFrame3.htm, Accessed on 26th November 2002

Vehicle inspection and enforcement

All in-use vehicles must undergo mandatory inspection test supervised by National Environmental Agency and Land Transport Authority. They must pass the test of "in-use standard" to ply on the street. Cars are not required to go through such test for first 3 years, thereafter, mandatory frequency increases, as cars grow older.

Table: Frequency of mandatory inspection

Vehicle Type	Age of Vehicle	Frequency
Motorcycles & Scooters	>3 years	Once a year
Motorcars	3 - 10 years	Once in 2 years
Motorcars	>10 years	Once a year
Rental cars	3 - 10 years	Once in 2 years
Tuition cars	--	Once a year
Goods Vehicles	<10 years	Once a year
Goods Vehicles	>10 years	Twice a year
Trailers	--	Once a year
Taxis	--	Twice a year
Omnibuses	--	Twice a year
All Other Vehicles & Buses	<10 years	Once a year

[2] Personal communication at Pollution Control Department, National Environmental Agency, in November 2002.

All Other Vehicles & Buses	>10 years	Twice a year

Three companies with about 6-7 stations are currently carrying out vehicle inspection. This is a comprehensive vehicle inspection including emissions approved by Land Transport Authority.
Source: http://www.onemotoring.com.sg/vehMaintain/maintain_insp.asp, Accessed 26th November 2002

For enforcement, Clause 19 of the Environmental Pollution Control Act (Vehicular Emissions) states that no any person can use any smoky vehicle on the road. The enforcement system in Singapore is strong. Smoky vehicles are monitored by inspectors on the street with the help of digital video cameras, as a proof. A team of inspectors who are not involved in capturing video images verifies these standards breach, then owner is identified from registration database and fine is imposed. Non complying drivers are sent to traffic court subsequently. The amounts of penalties vary from number of offences in the period of two years. The vehicles then go through emission testing at authorised centre and must pass it before plying on the street. Surveys carried out Pollution Control Department have shown that rate of smoky Singapor-registered vehicle decreased from 8% in 1990 to 2% in 2001. In the year 2001, 11,070 vehicles and 17,299 motorcycles were booked and fined for violating smoke emission standard[3]. The emission testing for Malaysian or third country vehicles are carried out at border checkpoint. Foreign vehicles must pay 30 S$ per day as fee to remain in Singapore.

Table: Penalties for smoky vehicles

Offence	Emission of visible smoke from vehicle	Failure to pay the composition fine
1st Offence.	Composition fine of $150. ($70)	Charged in Court:
2nd Offence within 2-year period.	Composition fine of $300. ($100)	Maximum fine of $2,000 upon conviction.
3rd & subsequent offences within 2-year period of 1st offence.	Composition fine of $500. ($150)	Maximum fine of $5,000 for second or subsequent conviction.

Amount in brackets applies to motorcycles and scooters.
Source: Personal communication at Pollution Control Department, National Environmental Agency in November 2002.

In order to test emissions, Chassis Dynamometer Smoke Test is introduced from September 2000. Hong Kong is using such testing for a quite some time. In this test, as opposed to free acceleration smoke test, testing is done simulating urban driving conditions and loading. This test provides an exact replication of emissions during actual driving on road.

Scheme on Certification of Motor Workshops

Since many of the vehicle maintenance workshops many not have enough skills and knowledge to for proper maintenance, National Environmental Agency closely collaborated with other stakeholders in a scheme *called Scheme on Certification of Motor Workshops* since 1999. The stakeholders are Lorry Owners Association, Vehicle Inspection Centres, Motor Traders, Land Transport Authority, Motor Shop Association and others in this scheme. Private sector-led *Motor Industry Certification Board* administers this scheme which begun since September 2000. Under this scheme, certificates are awarded to motor workshops, which has enough knowledge, equipment and expertise to properly maintain the diesel vehicles. This system aim to increase technical expertise on parts of workshops; some government funding under Singapore Productivity and Standard Board is provided to get technical consultant's support. As of September 2002, more than 22 motor workshops have been certified, though it is not mandatory.

Fuel economy labelling

Eco-labelling has been popular as a market based instrument, especially it is mandatory (Several EC directives are issued) in Europe. Voluntary energy labelling scheme was started in Singapore for energy intensive household appliances such as refrigerators and air-conditioners from April 2002. As

[3] 2001 Pollution Control Report, Published by Environmental Policy and Management Division, Ministry of Environment, Singapore, ISSN: 0218-8643.

of September 2002, over 14 manufactures have already joined this scheme[4]. As a continuation of such initiative, fuel economy labelling programs are planned for motor vehicles from may 2003 which will contain (a) vehicle description such as maker, model, and engine capacity (b) fuel economy under city driving conditions in km/litre, and (c) fuel economy range of vehicles with comparable engine capacities[5].

Fuel quality interventions

In terms of fuel quality, the major concerns in Singapore has been lead content of gasoline and sulphur content of diesel. For lead, Singapore reduced its level in gasoline progressively from 0.84 g/litre before 1981 to 0.15 g/litre in 1987. Unleaded gasoline was introduced in 1991 and subsequently leaded gasoline was phased out by July 1998. Before 1996 sulphur content in diesel was 0.5% by weight, this was reduced to 0.3%. Low sulphur content diesel was introduced since 1999, which replaced diesel with sulphur content of 0.3% (by weight) to one with 0.05%. Such reduction has led to reduction of lead level in ambient air drastically as well as contributed to controlling level of SOx and particulate in air. Low sulphur also allowed implementing EURO II standards.[6]

Promotion of alternative fuel vehicles

There are few mechanisms to promote alternative fuel vehicles in Singapore. Natural gas vehicles (CNG), hybrid vehicles and electric vehicles are classified as Green Vehicles in Singapore. LPG vehicles are not promoted under these mechanisms citing their fire and explosion hazards, despite the fact that LPG taxies and common in Japan and other parts of the world. Tax rebates are offered to lower the cost of clean vehicles. However, CNG vehicle are just running on trial basis that includes 12 CNG buses by Singapore Bus Services and few taxies[7].

Table: Tax rebates for clean vehicles in Singapore as of January 2001.

Type of vehicle	Registration fee rebate	Road tax rebate
Electric vehicles	Equivalent to 20% of open market value	20%
Hybrid vehicles	Equivalent to 20% of open market value	10%
Natural gas vehicles	Equivalent to 20% of open market value	20%

Source: Personal communication, Ministry of Environment, Singapore on November 14-20, 2002.

No rebates have been offered to clean vehicles for license to own vehicles (Certificate of Entitlement, COE) and to use road (Electronic Road Pricing, ERP). From institutional perspective, policies and procedures for COE and ERP are responsibilities of Land Transport Authority and the rationale behind no rebate has been that clean vehicle do not contribute towards reducing congestion.

[4] Source: http://app10.internet.gov.sg/scripts/nea/cms/htdocs/article.asp?pid=1448, As of 28 November 2002.
[5] Personal communication at National Environmental Agency, Ministry of Environment, Singapore in 14-20 November 2002.
[6] Personal communications; 2001 Pollution Control Report, Published by Environmental Policy and Management Division, Ministry of Environment, Singapore, ISSN: 0218-8643.
[7] 2001 Pollution Control Report, Published by Environmental Policy and Management Division, Ministry of Environment, Singapore, ISSN: 0218-8643.