URBAN TRANSPORT ENERGY USE IN THE APEC REGION

Trends and Options

2007

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FOREWORD

We are pleased to present the report, "Urban Transport Energy Use in the APEC Region – Trends and Options". This is the first part a two-year study undertaken by the Asia Pacific Energy Research Centre.

The objective of the study is to analyse the driving factors for urban transport energy demand in both developing and developed economies of APEC. From this analysis, it also seeks to offer options to control transport energy demand in the urban areas of APEC.

The report is published by APERC as an independent study and does not necessarily reflect the views or policies of the APEC Energy Working Group or individual member economies. But, we do hope that it will serve as a useful basis for analytical discussion both within and among APEC member economies for the enhancement of energy security in APEC.

Kotaro Kimura

President

Asia Pacific Energy Research Centre

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CONTENTS

LIST OF ABBREVIATIONS

ABARE	Australian Bureau of Agriculture and Resource Economics
APEC	Asia Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
ASEAN	Association of Southeast Asian Nations
AUS	Australia
BCM	billion cubic metres
BRT	bus rapid transit
BD	Brunei Darussalam
CDA	Canada
CHL	Chile
CNG	compressed natural gas
CO_2	carbon dioxide
CO	carbon monoxide
CT	Chinese Taipei
DOE	Department of Energy (USA)
DSM	demand-side management
EDMC	Energy Data and Modelling Center (Japan)
EIA	Energy Information Administration (USA)
EWG	Energy Working Group (APEC)
FEC	final energy consumption
FED	final energy demand
GDP	gross domestic product
GHG	greenhouse gases
g/kWh	grams per kilowatt-hour (used to measure the emissions caused by the generation of one unit of electricity)
GMS	Greater Mekong Sub Region
GNP	gross national product
GRP	gross regional product
GTL	gas to liquids
GW	gigawatt
GWh	gigawatt-hour
GWP	gross world product
HC	(un-combusted) hydrocarbons
HKC	Hong Kong, China
HOV	high occupancy vehicle
IEA	International Energy Agency
IEEJ	Institute of Energy Economics, Japan
INA	Indonesia
IPCC	Intergovernmental Panel on Climate Change
JPN	Japan
kgoe	kilogram of oil equivalent
ktoe	thousand tonnes of oil equivalent
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MAS	Malaysia
mbd	million barrels per day

MCM	million cubic metres
MEX	Mexico
MMBTU	Million British Thermal Units
MOU	Memorandum of Understanding
MSW	Municipal Solid Waste
Mtoe	million tonnes of oil equivalent
NAFTA	North American Free Trade Agreement
NGV	natural gas vehicle
NRE	new and renewable energy
NOx	unspecified nitrogen oxides
NO_2	nitrogen dioxide
NZ	New Zealand
O_3	(surface) ozone
PE	Peru
PM	particulate matter of unspecified diameter (generally <10 microns)
PNG	Papua New Guinea
PPM	parts per million
PPP	purchasing power parity
PRC	People's Republic of China
R&D	research and development
ROK	Republic of Korea
RMB	Chinese Renminbi (Yuan)
RP	the Republic of the Philippines
RUS	the Russian Federation
SIN	Singapore
SO_2	sulphur dioxide
SUVs	sports utility vehicles
toe	tonnes of oil equivalent
TPED	total primary energy demand
TPES	total primary energy supply
TWh	terawatt hours
US or USA	United States of America
USD	United States dollar
WHO	World Health Organisation
WTO	World Trade Organisation
VN	Viet Nam
VOC	volatile organic compounds

GLOSSARY

On transport mode

Passenger Vehicle	A light, motor-driven, 2-axle vehicle used primarily for passenger transport on paved roadways (typically privately owned and operated on demand). Passenger vehicles include both “cars” and light trucks operated for passenger transportation.
Light Truck	A van, minivan, sport utility vehicle, or pickup truck used for both passenger and freight transport purposes (typically privately owned and operated on demand)
Heavy Truck	A vehicle with a larger chassis and more strengthened engine than a light truck, with 2 or more axles, used for freight transport
Heavy Rail	Standard intra-city rail, including most metro/subway systems (operated above or below ground), carrying its own motor but typically relying on external electricity for propulsion
Light Rail	Intra-city rail, typically with a smaller car weight, less passenger capacity, and narrower rail gauge, shorter operating distance, and slower speed than heavy rail-- including some “metro” systems (typically operated above ground at-grade), carrying its own motor but relying on external electricity for propulsion
Commuter Rail	A passenger train which may or may not share tracks with freight trains, typically operated between an urban centre and the surrounding suburban areas over longer distances and at higher speeds than heavy rail, with limited service within the urban core.
Motor Bus	A high-passenger-capacity road vehicle with 2 or more axles propelled by an on-board motor powered by on-board fuel or electricity. Motor buses may or may not operate on roads with dedicated right-of-way, and include variants such as bus rapid transit (BRT).
Trolley Bus	A high-passenger-capacity road vehicle with 2 or more axles propelled by an on-board motor powered by external electricity, typically delivered through overhead wires. Motor buses may or may not operate on roads with dedicated right-of-way.
(Urban) Mass Transit	Modes include heavy rail, light rail, commuter rail, motor bus, trolley bus, and other urban transit modes offering high passenger capacity intra-city travel service. Urban mass transit may be publicly- or privately-owned or operated and is typically run on a set schedule according to a standard fare price rather than on-demand. For this study, taxi service and inter-city mass transit (by bus, rail, plane, or ferry) is excluded from urban mass transit.

On transport measurement

Passenger-km	An indicator showing one person’s travelling for one km
Person-trip	An indicator showing one person’s travelling for one journey segment on a single mode
Tonne-km	An indicator showing one tonne of freight transport for one km

note: The terms and definitions above may vary from those found in other sources. They are offered here for clarity in this study.

Washington, D.C. Metro
http://www.flickr.com/photos/angelltsang/4336695/

EXECUTIVE SUMMARY

STUDY OBJECTIVES

Continued urbanisation poses challenges to some APEC member economies. Insufficient urban mass transit infrastructure combined with the growth in urban population income has driven motorisation trends in developing economies of APEC. Similarly, cities of some developed economies face transport challenges due to difficulties in changing lifestyle. Urban dwellers travel longer distances by heavier vehicles, leading to a steady increase in oil consumption. Together, these phenomenon drive energy security concerns because the increase in oil demand cannot be met by domestic production.

The report aims to provide policy-makers with transport options to reduce both growth in and level of urban passenger transport energy demand. The report also tries to analyse both contributing and offsetting factors affecting the urban transport energy demand in both developing and developed economies of APEC.

Subsequent chapters address the following issues:

- *Urbanisation, Motorisation and Transport Energy Use:* Exploration of the nexus between urbanisation, motorisation and transport energy use.
- *An Overview of Urban Transport Energy Use in APEC:* Characterisation of urban transport energy use in APEC.
- *Evaluation of Urban Transport Energy Use in Asia:* Evaluation of urban transport energy use in Asia through the development of indicators.
- *Energy Intensity of Urban Mass Transit in the United States:* An in-depth analysis on contributing factors to improve energy intensity of mass transit systems in the US.
- *Methods in Place to Reduce Transport Energy in APEC:* An overview of mechanisms to control growth in APEC urban transport energy use, offering cases with outcomes both successful and unintended.
- *Case Studies:* City-specific transport issues in Bangkok, Mexico City, San Francisco, Shanghai and Tokyo.

URBANISATION, MOTORISATION, AND TRANSPORT ENERGY USE

The energy demand of a number of APEC economies is growing rapidly in parallel with urbanisation. The phenomenon is particularly pronounced in Southeast Asia and China because their urban populations are currently growing rapidly and are expected to grow at a faster rate than other APEC economies. Over the past decade, the urban population of Southeast Asia and China grew at an annual rate of 3.7 percent and 3.4 percent respectively, compared with the APEC average at 2.3 percent.

At the early stage of economic development and industrialisation, urban energy consumption tends to be dominated by the energy-intensive industry sector. As economic development progresses, factors that impinge on wellbeing and living standards increasingly gain prominence, and stricter environmental regulations and higher land prices within the urban area lead to the relocation of industrial plants to the city outskirts. **Subsequently, industrial energy consumption within the urban area is gradually replaced by that of the transport, residential, and commercial sectors**.

As the city develops, city dwellers gradually move to the outskirts of the urban area to seek better environmental quality, personal safety and spacious yet affordable housing. The suburbanisation process means longer travel requirements from periphery/satellite cities to the urban core areas. **While suburbanisation progresses, business areas tend to remain located in the urban core area; therefore, commuting distance generally becomes longer with suburbanisation, driving growth in transport energy demand.**

AN OVERVIEW OF URBAN TRANSPORT ENERGY USE IN APEC

The major cities in APEC offer different characteristics in terms of their passenger transport energy consumption.

- **In terms of gasoline consumption per capita, a considerable gap exists between those cities in USA/Oceania and those in Asia/Latin America**. For example, San Francisco's gasoline consumption per capita was 1.5 toe in 2004, compared with that of Asian cities at less than 0.5 toe.
- Those cities of USA and Oceania demonstrate the relatively high number of vehicle stocks per capita, which is generally twice as high as that of cities in Asia and Latin America. This wide gap reflects differences of urban form (length of road) and cost of vehicle ownership.
- **Gasoline consumption per capita is typically inversely correlated with urban population density**. **However, for those cities in Asia, gasoline consumption per capita is only weakly correlated with urban population density** – which implies that factors other than urban population density affect the level of urban gasoline consumption.

EVALUATION OF URBAN TRANPORT ENERGY USE IN ASIA

Passenger transport energy consumption results from diverse socioeconomic factors. Such factors include income level, urban form, and demographic trends. To comprehensively capture both contributing and offsetting factors to passenger transport energy consumption in urban area, two urban transport indicators – a road indicator and an offset indicator – were created.

Analysis of these urban transport indicators suggests that ten Asian cities can be grouped into three depending on their vehicle dependencies and mass transit infrastructure development.

- **Group I** (Relative low dependence on vehicles with high ensured access to mass transit system): Hong Kong, Tokyo, Taipei, Seoul, and Singapore
- **Group II** (High dependence on vehicles with limited access to mass transit): Jakarta and Bangkok
- **Group III** (Cities at the early stage of development): Shanghai, Beijing, and Hanoi

From an analysis of indicators over time (between 1995 and 2005), the following results were obtained:

- In **Shanghai** and **Singapore**, a decrease in road indicator between 1995 and 2005 is compensated by an increase in the offset indicator during the same period.
- **Bangkok**'s road indicator substantially increased between 1995 and 2005 as city dwellers tripled vehicle ownership during a period of limited access to mass transit.
- **Seoul** and **Taipei** successfully reduced growth in their road indicators because of increased access to mass transit between 1995 and 2005.
- The urban transport indicators of **Hong Kong** and **Tokyo** did not show much change over the past ten years as their mass transit infrastructure had largely already matured by 1995.

The cases of Hong Kong, Tokyo, Seoul, Taipei and Singapore suggest that **accessibility to rail/subway is the key component that can reduce passenger vehicle dependence and improve energy intensity of the urban passenger transport sector in Asia.** In addition, **proper governance is needed to support rail infrastructure development**, as the development of rail infrastructure concerns various issues such as coordination between central and local levels, among different governmental agencies, and between the public and private sectors.

Timely investment in rail/subway infrastructure is necessary to shift people away from passenger vehicle dependence. As the case of Bangkok demonstrates, unless access to rail/subway infrastructure is ensured, a steady increase in the income of urban dwellers can drive burgeoning growth in the number of passenger vehicle stocks. In addition, it is hard to change people's lifestyle – away from vehicle dependence – once they acquire a passenger vehicle. Due to the high upfront cost, building rail/subway infrastructure faces difficulties in some Asian cities. However, **city planners, especially at the early stage of development, need to appropriately assess their future transport requirements and plan appropriate timing in investment towards rail/subway infrastructure.**

ENERGY INTENSITY OF URBAN MASS TRANSIT IN THE UNITED STATES

To answer a question on whether rail/subway is the most energy efficient option among various transport modes and, further, to identify contributing factors for transport energy intensity, an in-depth analysis on US transit systems is conducted, focusing on 83 transit systems of 60 metropolitan agencies. These are broken down into four modes, including heavy rail, light rail, commuter rail, and motor bus.

- **Energy intensity of US mass transit systems – calculated as energy requirements for annual passenger-km – is inversely correlated with the total annual passenger-km served by each system**. However, wide variation among systems is observed, with the energy intensity of systems with small transit demand representing higher variation than that of larger systems.
- In addition, **some transit modes use more energy per passenger-km than the average-occupancy US passenger vehicle does**. On average, per unit of passenger-km, US heavy rail and light rail respectively require 29 percent and 37 percent of energy compared with that of typical private automobiles. However, if energy requirements to produce electricity are taken into account, per unit of passenger-km, US heavy rail and light rail respectively consume 80 percent and 103 percent the energy of passenger vehicles.
- **Factors such as station throughput and passenger utilisation ratio display noticeable correlation with energy intensity in US heavy and light rail systems**. In contrast, many factors that are generally accepted to affect energy intensity had little correlation with transport energy intensity. Examples include service area population, population density, average trip length, and the percentage of a city's commuters that rely on urban mass transit.

Many systems, particularly larger ones, with higher passenger utilisation rates and higher station throughput have potential to save energy, however **other smaller systems might require as much as twice the energy per passenger-km as a typical automobile might**. In other words, system ridership is the key to improve energy intensities of urban mass transit systems.

Despite the difficulties in improving the energy intensity of US urban mass transit systems, **urban mass transit systems are useful tools in controlling the type of fuels used, and the way in which those fuels are used. Fuel switching through mass transit is relatively easy compared with the implementation over an urban area's entire private vehicle fleet.**

METHODS IN PLACE TO REDUCE TRANSPORT ENERGY USE IN APEC

To manage rising energy use in the transport sector, APEC region cities have tried a number of different mechanisms. These measures include (1) policy instruments such as regulation on vehicle ownership and vehicle use, land use regulations, infrastructure design, and investment, and (2) economic instruments such as energy pricing, taxation, and road pricing. In addition to these conventional measures, some newly implemented methods in APEC demonstrate potential promise:

- **Employer-based incentives**: Provision of financial incentives to employees to live within the area that they can commute by mass transit, walking, or bicycling to the office, or otherwise encourage such commute modes.
- **Pricing of parking**: Proper pricing of parking for passenger vehicles to reduce either passenger vehicle ownership or passenger vehicle use.
- **Smartcard unified payment systems**: Effective tool to encourage multi-modal transfer across urban area mass transit systems.
- **Urban mass transit privatisation**: Improvement of operational efficiency of mass transit systems through (1) sale of transit infrastructure, (2) sale of rights for expansion/upgrade of existing systems, or (3) contracting of system construction, service and operations to private entities.

Effectiveness of those measures change over time, and there could be substantial difference between short-term and long-term outcomes. In addition, the way a measure is designed can create conflict between its objectives and other policies. Therefore, **a holistic planning approach is needed to achieve the desired outcomes**.

Bangkok might benefit from the establishment of a policy that coordinates among the city's diverse transport sector policies. Reflecting on the fact that the traffic congestion in Bangkok was partly caused by lack of coordination between the city's land-use plan and transport plan, consideration of land usage will be essential when road network expansions are planned. In other words, it is necessary for each agency to work with other agencies in order to draft an integrated policy whenever multiple stakeholders are concerned.

Mexico City's effectiveness in implementing a license plate restriction programme (Hoy no Circula), and such a programme's potential application within any metropolitan area, is dependant on the programme's objectives and the degree by which it is supplement by other policies. The programme could be coupled with a fleet retirement programme, which helps to decrease the stock of less efficient passenger vehicles. It could also achieve substantial results in terms of air quality improvement and energy security if the programme is coupled with a fuel economy standard.

The San Francisco Bay Area's relative success in curbing the growth rate of gasoline consumption suggests the importance of a general populace's personal lifestyle decisions on mid- to long-term energy consumption. The effect of personal lifestyle is great enough that it should not simply be left to chance; *education* will be a central pillar of any enlightened energy policy. Of course, education cannot reduce energy consumption in a vacuum; therefore, it is essential to develop a supporting portfolio of energy consumption-targeted policies and infrastructure.

Shanghai must still resolve various challenges related to vehicle ownership and its impact on energy and the economy although the city's license plate auctioning system has achieved promising results so far. The future of license plate bidding has become uncertain because of the central government's announced plan to suspend any local policy which limits the number of passenger vehicle stocks. In addition, how to control the increasing number of passenger vehicles which are registered outside of Shanghai poses a challenge to Shanghai's policy makers. Ultimately, in order to reduce people's passenger vehicle dependence and to cope with rising transport demand, it is essential for Shanghai to expand mass transit system throughout the urban area.

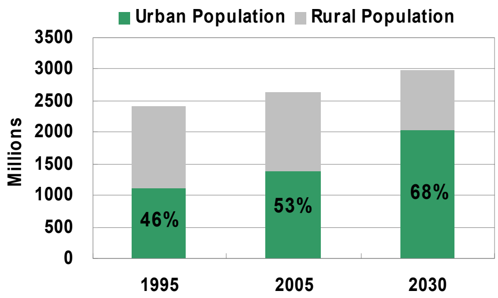
Tokyo's success in driving people to use rail and reducing passenger vehicle dependence owes largely to the city's extensive rail/subway network development. Rail/subway is an integral part of daily life for city dwellers in Tokyo. This may result from the city's early start in developing rail/subway infrastructure, which in fact has shaped city dwellers' lifestyle. This finding suggests the importance of planning appropriate timing for investment in rail/subway infrastructure and that such a plan should be implemented with the concerted efforts of both public and private sectors.

INTRODUCTION

BACKGROUND

Cities have been the engine of economic growth since the beginning of 20th century. With the structural change from agricultural-based economies to industrial and service-based ones, cities have increasingly been attracting capital, resources, and other inputs. In addition, cities' greater employment opportunities, compared with rural ones, have driven substantial gains in population.

This trend of urbanisation – migration from a rural area to an urban area or transformation of a rural area into an urban one– is particularly noticeable in the APEC region. From 1995 to 2005, urban population in APEC grew at an annual rate of 2.3 percent – outpacing the world average urbanisation rate over the same period. According to UN projections, APEC's urban population is expected to continue growing steadily at 1.5 percent per year between 2005 and 2030, expanding the share to total population from 53 percent in 2005 to 68 percent in 2030.[a]



5.1 APEC population, 1990, 2005, and 2030
APERC 2007

This continued growth in urbanisation poses challenges to some APEC member economies. Urban area challenges include the need to create basic urban services – such as a clean water supply, stable and affordable electricity/gas supply, affordable housing, and efficient mass transit infrastructure.[b] Despite such immediate needs, however, cities oftentimes cannot provide these basic services due to a shortage in financial capacity and proper governance.

Lack of sufficient urban mass transit infrastructure combined with the growth in income of urban population has driven motorisation trends in developing economies of APEC. This has in fact culminated in substantial growth in oil consumption. Likewise, some developed economy cities face challenges revolving around passenger transport energy use in urban areas. Such challenges relate to difficulties in the changing lifestyle of urban dwellers who already depend heavily on passenger vehicles for their mobility. With increasing affluence, those living in sprawling urban areas travel longer distances by heavier vehicles, which leads to a steady increase in oil consumption.

Increases in oil demand – driven largely by urban area motorisation and heavy dependence on passenger vehicles in sprawling urban areas – have not been met by increases in domestic oil production, thereby rendering greater oil supply security concerns.

[a] *United Nations (2005). World Population Projections. New York, USA.*

[b] *ADB (1999). Making Cities Work – Urban Policy and Infrastructure in the 21st Century. Manila, Philippines.*

OBJECTIVES AND SCOPE

With due consideration to both the rising concern for oil supply security and rapid or maintained growth in urban transport energy demand, this report aims to provide policy-makers with various options that may contribute to reduce both *growth in* and *level of* urban transport energy demand. The report also tries to analyse both contributing and offsetting factors to the urban transport energy demand in both *developing* and *developed* economies of APEC. By analysing factors affecting transport energy use around the region, the report assesses the current situation surrounding urban transport energy use, and it provides implications for policy-makers to plan energy efficient urban transport systems in the future.

Analysis in this report focuses on the passenger transport sector in urban areas. By transport mode, the report investigates energy use of passenger vehicles, bus, light rail, commuter rail, and subway. The report excludes analysis of the freight transport sector as well as inter-city passenger transport as these transport activities generally extend beyond functional boundaries of urban areas.

STRUCTURE OF THE REPORT

How can we reduce passenger vehicle dependence in urban life? What options do we have to improve energy efficiency in urban transport? To answer these questions, the report deals with the following key issues.

Firstly, the nexus between urbanisation and passenger transport energy consumption is explored. This will be followed by an overview of historical trends in urban transport energy use of several cities in APEC.

Secondly, factors affecting urban passenger transport energy consumption in Asia are analysed through the development of novel indicators.

Thirdly, an in-depth empirical analysis is conducted to identify key factors that can improve energy intensity of mass transit systems in US cities.

Fourthly, the measures to control growth in APEC urban transport energy use are analysed in order to capture general trends across the region and to provide lessons learned from the cases with either successful outcomes or unintended consequences.

Finally, five case studies are presented to address city-specific passenger transport issues and their implications for energy security. The five cases include Bangkok, Mexico City, San Francisco, Shanghai and Tokyo.

URBANISATION, MOTORISATION, AND TRANSPORT ENERGY USE

This chapter explores the nexus between urbanisation, motorisation and transport energy use. The key issues dealt with in this chapter are (1) the relationship between urbanisation and urban energy consumption, (2) change in urban form and its impact on transport energy use, and (3) motorisation and urbanisation.

INTRODUCTION

Urbanisation – with respect to both migration from rural to urban areas and structural transformation of rural areas into urban ones – is one of the key factors affecting energy demand growth. The greater economic potential of urban areas transfers labour and other inputs from agricultural regions to the industrial and services sectors of urban areas. This in turn leads to increases in urban energy requirements for industrial facilities and office buildings because energy is integral to support the economic activities. Along with rising incomes, urban dwellers seek greater comfort and convenience in their lives, which leads to a substantial increase in the energy requirements for households and transport.

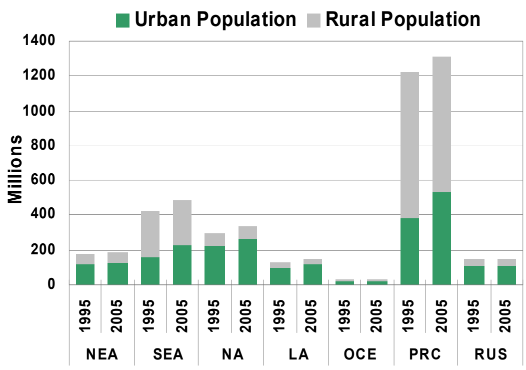
This chapter explores the nexus between urbanisation, motorisation and transport energy use. The key issues are:

- Urbanisation and energy consumption,
- Urbanisation, suburbanisation, and transport energy use, and
- Urbanisation and motorisation.

URBANISATION AND ENERGY CONSUMPTION IN ASIA

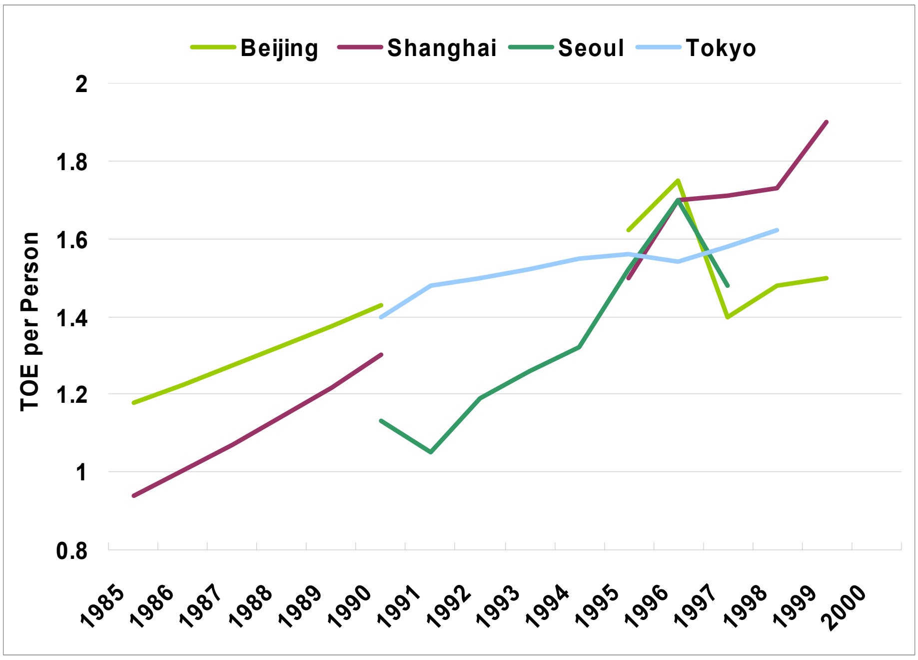
The energy demand of a number of APEC economies is growing rapidly in parallel with urbanisation. The phenomenon is particularly pronounced in Southeast Asia and China because their urban populations are currently growing rapidly, and are expected to grow at a faster rate than other APEC economies into the future. Over the past decade, the urban population of Southeast Asia and China grew at an annual rate of 3.7 percent and 3.4 percent respectively, compared with the APEC average at 2.3 percent.

With respect to the factors affecting urban energy demand growth, interesting observations are obtained from a comparison of historical trends for energy consumption in Beijing, Shanghai, Seoul and Tokyo. Historical per capita energy consumption for these cities show that of the four, the per capita energy consumption of Shanghai reached the highest level at around 1.9 toe per person in 1999 compared with that of Beijing at 1.5 toe per person, which was the lowest. For Tokyo and Seoul, the corresponding values of per capita energy consumption were Tokyo at 1.62 toe per person in 1998 and Seoul at 1.5 toe per person in 1997.[a]



7.1 Regional population in APEC, 1995 and 2005
APERC 2007, United Nations 2005

[a] *Shobhakar Dhakal (2004). Urban Energy Use and Greenhouse Gas Emissions in East Asian Mega-cities. Paper presented at the APERC's outlook workshop, 15-17 September 2004. Tokyo, Japan.*



8.1 **Comparison of urban energy consumption for Beijing, Shanghai, Seoul and Tokyo, 1985-1999**

APERC 2007, Shobhakar Dhakal (2004). Urban Energy Use and Greenhouse Gas Emissions in East Asian Mega-cities. Paper presented at the APERC's outlook workshop, 15-17 September 2004. Tokyo, Japan

The per capita energy consumption of Shanghai was the highest mainly because of the dominant share of industry within the urban area. In Shanghai, the share of the industry sector to total energy consumption was the highest at 80 percent in 1998, while the share of transport, residential and commercial sectors accounted for only a small part of total energy consumption.

By contrast, in Seoul and Tokyo, the share of industrial energy demand accounted for the smallest share at 18 percent and 11 percent respectively in 1998, with the remainder distributed within the transport, residential and commercial sectors. Despite the relatively high share of the industry sector in Beijing at 62 percent in 1998, the per capita energy consumption of Beijing was the lowest among the four cities. This is due in part to the relocation of the industrial facilities to the outside of Beijing, which in turn reduced per capita energy consumption by 14 percent in 1999 from the peak in 1996.

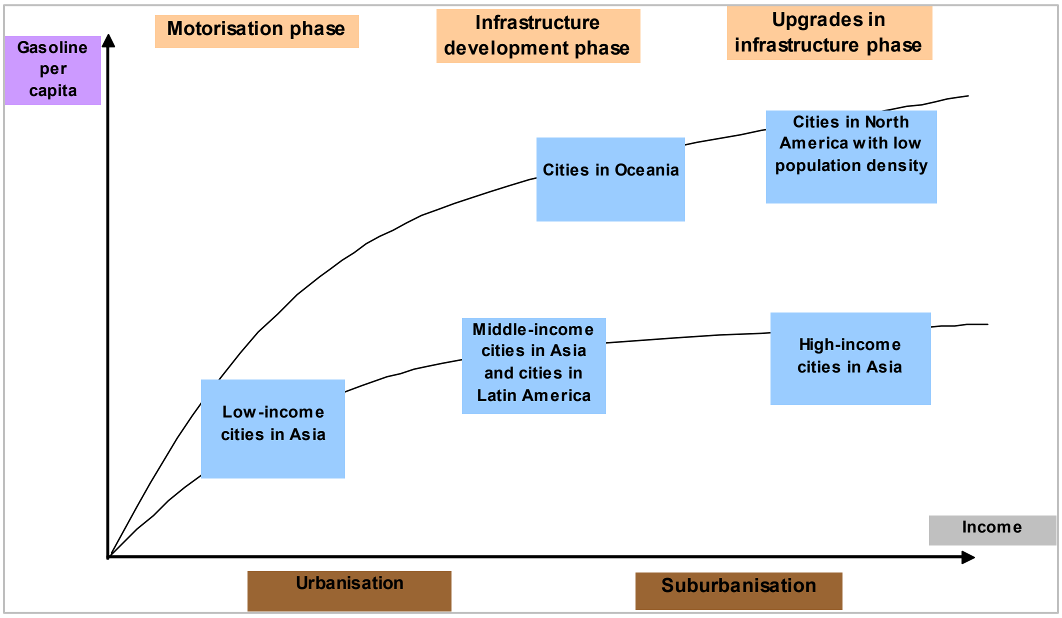
Comparison of the sectoral share of urban energy consumption in the major cities of Asia offers an interesting insight into how urban energy consumption evolves over time. At the early stage of economic development/industrialisation, urban energy consumption tends to be dominated by the energy-intensive industry sector. As economic development progresses, factors that impinge on wellbeing and living standards increasingly gain prominence, and stricter environmental regulations and higher land prices within the urban area lead to the relocation of industrial plants to the city outskirts. Subsequently, industrial energy consumption within the urban area is gradually replaced by the transport, residential and commercial sectors.

	Industry	Transport	Residential	Commercial
Beijing	62%	8%	17%	13%
Shanghai	80%	10%	7%	3%
Seoul	18%	25%	37%	20%
Tokyo	11%	37%	22%	30%

8.2 **Sectoral share of urban energy consumption, 1998**

APERC 2005 and Dhakal 2004

Urban transport energy demand results from various factors. Income is the key factor affecting the personal choice of transport mode. In addition to income, accessibility to infrastructure such as road and rail strongly affects personal choice. Urban form is another element as it determines the travel distance.



9.1 Urbanisation, motorisation, and infrastructure development
APERC 2007

9.1 portrays the nexus between income growth, urban form, transport infrastructure development, and passenger transport energy demand per capita. Two trajectories are drawn in the figure to show the general growth paths for personal transport energy use in urban areas. The higher trajectory represents the growth path of personal transport energy demand of those cities that mainly depend on passenger vehicles, while the lower trajectory offers that of those cities which mainly depend on mass transit or non-motorised transportation. Several cities in APEC are plotted in the figure to demonstrate how different factors result in different personal transport energy demand.

At an early stage of urban development (or urbanisation), energy demand for passenger transport generally grows robustly. Shifting from non-motorised transport such as walking and bicycling, city dwellers in developing economies tend to rapidly increase demand for motorised transport. In addition, due to the absence of urban mass transit, city dwellers in the early stage of urbanisation need to depend on passenger vehicles and this in turn increases energy demand.

As the city develops, city dwellers gradually move to the outskirts of the urban area to seek better environmental quality, personal safety, and spacious yet affordable housing. Rising land price in the city centre makes it increasingly difficult for them to find affordable housing in the urban core area, and it facilitates people's movement towards the city outskirts. This process, called suburbanisation, generally takes place along with the development of transport infrastructure.

[b] Especially for Asian cities, rail generally uses less energy per unit of passenger-km than passenger vehicles. In the case of Tokyo, for example, in terms of energy per unit of passenger-km, rail uses 20 times less energy than that of passenger vehicles.

[c] Some cities in APEC, especially of developed economies, have been transformed from uni-centric model into multi-centric one. Nevertheless, discussion here is focused on uni-centric city model and its relationship with transport because it is dominant in APEC as a whole.

[d] Arthur O'Sullivan 2000

[e] In future, innovations in telecommunications such as e-mail and internet may affect firms in their decisions to the location of office as these can substitute the face-to-face communication to some extent. Also, in future, telecommuting can substitute some portion of working in office firms. For further discussions, see the San Francisco case study.

For uni-centric cities, the suburbanisation process means longer travel requirements from periphery/satellite cities to the urban core areas. As suburbanisation progresses, business areas tend to remain located in the urban core area (sometimes referred to as the "central business district", or CBD); therefore, commuting distance generally becomes longer with suburbanisation, driving growth in transport energy demand.

In suburbanised areas of APEC, demand for passenger transport energy follows two different growth paths. In some cities of USA, and Oceania, suburbanisation is spurred by road infrastructure development, which in turn drives growth in passenger transport energy demand. By contrast, in the Asian cities, suburbanisation is generally supported by the development of rail infrastructure. The enhanced access to rail can reduce passenger vehicle dependence, and it can curb the robust growth trends in passenger transport energy demand.[b]

ACCESS TO EMPLOYMENT AND URBAN TRANSPORT

As the previous section described, in uni-centric cities, business area tends to be located at the business core district (CBD).[c] In order to maximise the benefits from the proximity to the functions of city centre, and to facilitate face-to-face contact, firms tend to occupy land areas close to the centre.[d] In other words, firms are not located in the suburbs so employees can minimise travelling time and cost between their office and clients.[e]

To demonstrate the concentration of office firms in the CBD, employment density of the major cities in APEC is compared. Employment density is calculated as the ratio of the number of employments in a business district by the land area. The comparison clearly shows that CBD represented the highest employment density across the cities studied.

Households' decision on where to live reflects different factors from that of firms. As the classic work of Muth suggests, households choose the location for living based on the trade-off between land costs and commuting costs.[f] In addition to this, households are more recently understood to determine housing location by optimising the costs and benefits associated with land and commuting, environmental quality, personal safety, and quality of education for children. Those different factors – from that of firms – culminate in different locations for households to reside in, and are generally available at the city outskirts.

Transport infrastructure plays a key role in integrating the activities between business areas and residential areas. In addition, what transport mode is offered determines the level of passenger transport energy consumption, as illustrated by the previous section.

An interesting illustration with respect to the relationship between residential location, employment opportunity, and transport mode in Paris and its suburbs is offered by Vivier (1999). Although the area of study is outside of the APEC region, it nevertheless provides important implications for transport infrastructure development.

The study provides a survey result regarding the number of jobs accessible in less than 30 minutes (hereafter called job accessibility) in Paris and its suburbs. The result shows that depending both on *residential locations* and *transport mode*, the number of accessible job – within 30 minutes – changes. It is interesting to note that as residential area moves towards the city outskirts, job accessibility is reduced. In

Urban Area	Business District	Employment per Square Kilo meter	Year
New York	Midtown Core	233,838	1990
	Downtown Core	170,368	1990
	South of 59 St.	85,522	1990
Hong Kong	Core CBD	171,257	1990
	Kowloon	77,508	1990
Seoul	CBD	57,951	1990
Tokyo and nearby	CBD Core	57,791	2001
	Yamanote Loop	35,506	2001
	Yokohama	11,308	2001

10.1 Employment density of the major cities in APEC

Jeffrey R. Kenworthy and Flexi Laube (1999). An International Sourcebook of Automobile Dependence in Cities: 1960-1990. University Press of Colorad, USA.
-and-
Japan Statistical Bureau 2003

	Number of jobs accessible by passenger vehicle in less than 30 minues	Number of jobs accessible by public transport in less than 30 minues
Central Paris	More than 1.5 millions	More than 1.5 millions (metro)
Buit-up inner suburbs close to central Paris	900,000	From 120,000 to 230,000 (bus)
		More than 1 million (light rail)
Inner suburbs further away from central Paris	850,000	From 100,000 to 190,000 (bus)
		From 220,000 to 420,000 (tramway)
Other suburbs	550,000	From 30,000 to 70,000 (bus)

10.2 The number of jobs accessible within 30 minutes, by residential location and transport mode

Jean Vivier (1999). Density of Urban Activity and Journey Costs. Belgium: public transport international.

addition, job accessibility is higher for commuters with passenger vehicles than that with mass transit – except for the in city centre.

The case of Paris and its suburb suggests that in sprawling urban areas, building suburban mass transit be essential to offer equal opportunity for employment. In addition, this may be of relevance to policy-makers in their efforts to reduce passenger vehicle dependence, thus to slow growth in passenger transport energy consumption.

[f] Richard Muth (1969). Cities and Housing. University of Chicago Press, Chicago, USA.

URBANISATION AND MOTORISATION IN ASIA

Along with urbanisation, the number of passenger vehicles in urban Asia has been growing robustly over the past two decades. For comparison, passenger vehicle ownership per 1,000 population for several cities and economies in Asia are shown in **11.1**.

The comparison *between economy and city* shows that with the exception for Tokyo, for the *cities* in Asia, passenger vehicle ownership per 1,000 population has reached a higher level than that of the *economy* average. This is mainly because higher income in cities drives the increase in the number of passenger vehicles. For example, in 2002 the ratio of vehicle ownership per 1,000 population for Beijing and Shanghai was four times and two times higher than that of average for China respectively. This ratio for Jakarta was nine times higher than that of Indonesia as a whole in 2002.

The comparison *among the major cities* in Asia also offers an interesting illustration in terms of the different factors affecting the number of passenger vehicles. For example, Shanghai's passenger vehicle stocks per 1,000 population was almost half that of Beijing in 2002 due to the Shanghai's higher cost of passenger vehicle ownership resulting from a mandatory requirement to purchase a license plate through an auction.[g] In Tokyo and Hong Kong, China, the ratio of passenger vehicle stocks per 1,000 population in 2002 were both low relative to their high incomes. This is because both Tokyo and Hong Kong, China have developed a rail/subway network which connects the city centre with residential suburbs.[h] In the future, due to the availability of rail/subway infrastructure and the high cost of parking, urban dwellers of these two cities will continue to be less reliant on passenger vehicles.

Economy/ City	1980	2004	1980-2004 (%)
China	2	19	10.8
Beijing	9	80	10.4
Shanghai	5	47	10.7
HKC	41	59	1.7
Indonesia	5	16	5.4
Jakarta	34	143	6.7
Japan	203	428	3.4
Tokyo	159	266	2.4
Korea	7	204	16.6
Seoul	15	205	12.6
Thailand	-	100	-
Bangkok	-	324	

11.1 Passenger vehicle ownership per 1,000 population, 1980 and 2004

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[g] To limit the number of passenger vehicles and avoid traffic congestion, the Shanghai government requires those who wish to own a vehicle to purchase a license plate through an auction. With rising demand for vehicles, at a recent number plate auction the resulting average price was US$ 4,000. See Shanghai case study in this report for details

IMPLICATIONS

The energy demand of a number of APEC economies is growing rapidly along with urbanisation. In particular, shifting from non-motorised transport such as bicycling and walking, city dwellers at early stage of urbanisation tends to increase passenger transport energy demand with relatively fast pace.

As urbanisation progresses, dwellers move to the city outskirts in order to seek for better environmental quality and affordable housing. With this suburbanisation, travel distance tends to become longer – as business areas are located in the city centre. Therefore, transport infrastructure has a key role to integrate the city centre with residential suburb. Offering mass transit in sprawling suburban areas is an important element that can lead to reduce passenger vehicle dependence and curtail growth in transport energy demand.

[h] In Tokyo, over five decades, urban area has sprawled alongside development of railway/subway corridors. Those residents of suburban areas have good access to the railway/subway for commuting, thereby successfully reducing vehicle dependence.

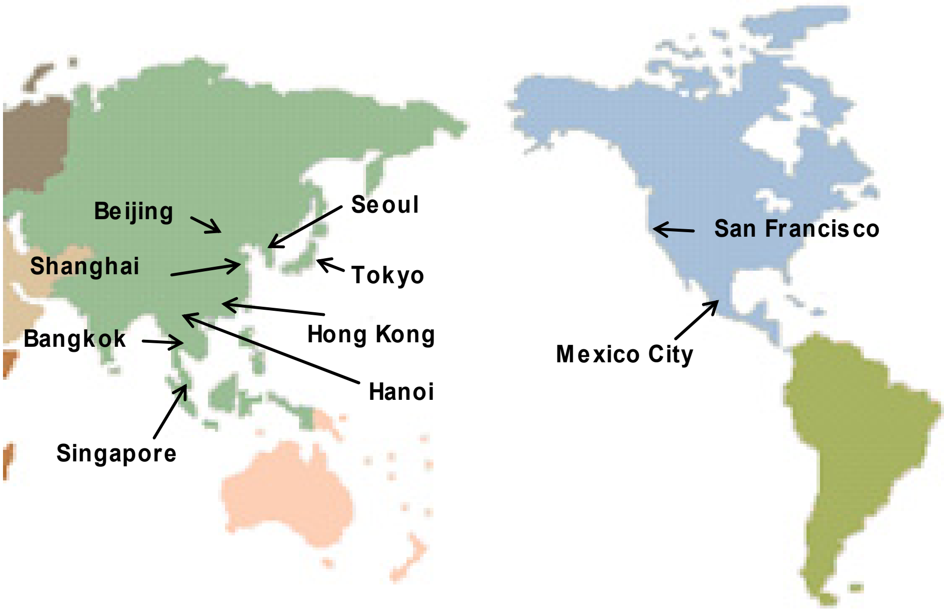
AN OVERVIEW OF URBAN TRANSPORT ENERGY USE IN APEC

INTRODUCTION

The APEC member economies offer different characteristics in terms of urban transport energy use. Even within a single economy, cities' transport energy consumption varies greatly depending on economic development, population density, and urban form.

At the outset, this chapter gives a brief summary of the cities covered in the study, offering basic information such as demography, macro economy, and transportation. Next, comparison is made between city level and economy level with regard to income, passenger vehicle stocks, and gasoline consumption per capita. This comparison demonstrates how wealth is concentrated in urban areas. Analysis on the differences among the cities being studied follows, which aims to identify their characterisation.

CITY BRIEFING



13.1 Major APEC urban areas
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BASIC INFORMATION

The cities highlighted in the following chapters include Bangkok, Beijing, Hanoi, Hong Kong, Mexico City, San Francisco, Seoul, Shanghai, Singapore, and Tokyo. Their location is shown in the map of 13.1. A brief profile for each city is provided with information on population, income (purchasing power parity (PPP), 2000 USD), and passenger vehicle stocks per 1,000 population.

14.1 provides an overview of these cities with respect to demography, economy, and transport. Population, size of land area, and population density are presented as demographic data. Next to demography, economic activity is expressed in terms of gross regional product (GRP) and personal income. A transport category contains data on car ownership expressed as the number of passenger vehicles per 1,000 population, the share of mass transit, and the numbers of buses and taxis. Subsequent sections assess how these variables are related to each other from different perspectives.

Individual case studies are carried out for Bangkok, Mexico City, San Francisco, Shanghai and Tokyo; they are each examined from the perspective of a given specific transport-related issue.

	DEMOGRAPHY			ECONOMY		TRANSPORT			
	Population	Land Area	Population Density	Gross Regional Product	Income	Car Ownership	Mass Transit	Number of Buses	Number of Taxis
	thousand	km²	pop/km²	million, US$ 2000 PPP	US$ 2000 PPP	passenger vehicles/ 1,000 pop	percent	thousand	thousan d
Bangkok	5,483	1,569	3,495	151,123	27,560	271 [a]	33[e]	224[a]	81[a]
Beijing	15,380	16,411	937	306,358	19,919	108	29.9	20	70
Hanoi	3,183	921	3,456	19,597	6,157	1	2.0 [b]	3	2
Hong Kong	6,966	1,104	6,310	234,139	34,170	59 [a]	90.0	14	18
Mexico City	19,411	4,980	3,898	175,106[a]	9,064 [a]	164 [a]	78.6 [a]	31 [b]	116 [b]
San Francisco	6,784 [d]	17,933	378	305,130[a]	43,420 [a]	645 [a]	5.5	N.A.	N.A
Seoul	10,024[a]	606[a]	16,541[a]	187,142[b]	18,689 [b]	216 [a]	62.0 [a]	204	N.A.
Shanghai	17,780	6,341	2,804	488,346	27,466	36 [a]	26.1 [a]	36	48
Singapore	4,351	699	6,222	124,681	28,653	101	55.0	13	22
Tokyo	12,170	2,187	5,564	630,651 [b]	52,197 [b]	264	63.0 [c]	14[a]	N.A.

14.1 **Overview of the cities studied, 2005**

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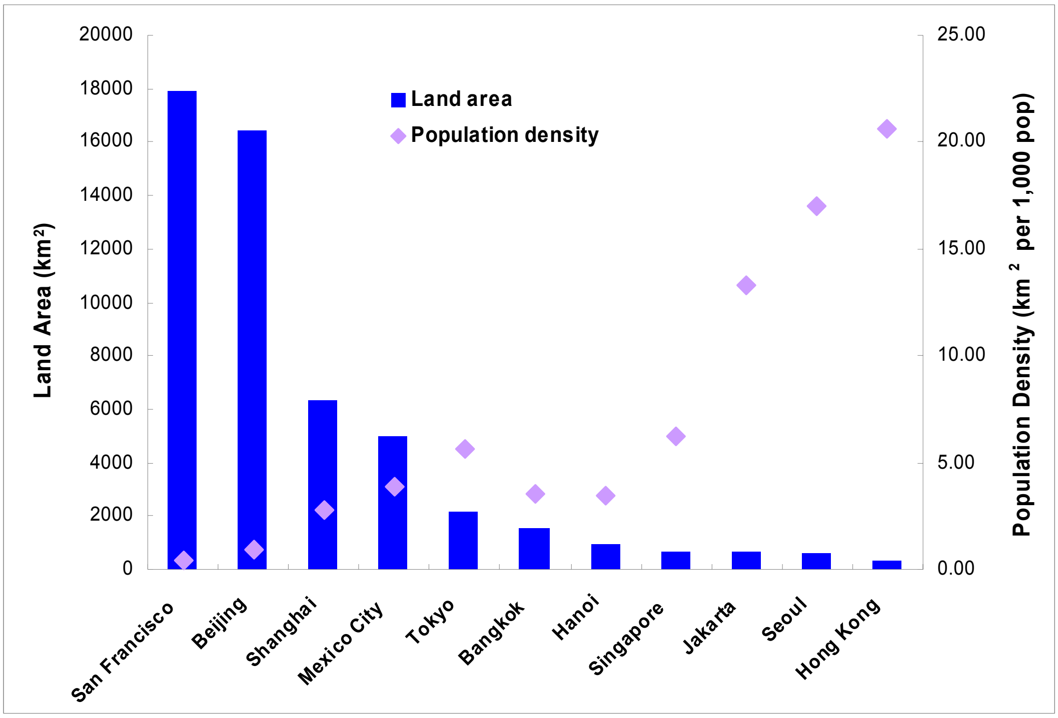
(a) 2004 data, (b) 2003 data, (c) 2001 data, (d) 2000 data, (e) 1995 data

15.1 illustrates land area and population density of the selected APEC cites. Land area is shown by descending order and includes both urban and rural areas, except for Hong Kong. In this case of Hong Kong, this study excludes some areas which are not regarded as urbanised such as woodlands, wetlands, and barren land. In general, a wide range in land areas is observed among the cities. Precisely describing an urban area boundary is quite difficult, as official jurisdictions rarely describe the true extent of the functional economic and physical movement in and around the city. Functional urban units that differ from official boundaries by their very imprecise nature, however, generally lack exclusive and non-overlapping statistical descriptions. This report, then, attempts to define the extent urban areas for analysis through a hybrid approach—accepting the tighter, jurisdiction-based boundaries where appropriate, and, in other cases, opting for broader, more functional urban area definitions for which reliable data can be compiled. Using this principle, the nine county San Francisco Bay Area registers as the largest urban area described in this report, followed by Beijing, Shanghai, Mexico City, Tokyo, Bangkok, Hanoi, Singapore Jakarta, Seoul, and Hong Kong. The difference in size between this report's definition of San Francisco and Hong Kong is approximately 17,000 km².

Along with the land area, population density is also marked in the figure. It is conventional that land area and population density are negatively correlated; the larger the land area, the smaller the population density. By and large this rule can be applied to these cities examined, except for Bangkok and Hanoi. Mexico City and Tokyo have relatively high population densities for their rather large land areas. Apart from these cases, however, a negative relationship between the land area and the population density is essentially affirmed from this figure.



15.1 **Land area and population density, 2005**
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CITY AND ECONOMY

In this section, historical trends between 1990 and 2005 in both city and economy levels are examined with respect to income, passenger vehicle stocks, and gasoline consumption per capita. The cities and economies are grouped into four regional definitions, that is, China (Beijing and Shanghai), Northeast Asia (Seoul-Korea, Tokyo-Japan, and Hong Kong), Southeast Asia (Bangkok-Thailand, Hanoi-Vietnam, Jakarta-Indonesia, and Singapore), and North America (San Francisco-the United States, Mexico City-Mexico). Such a comparison illustrates how an urbanised city statistically differs from the economy average.

HISTORICAL TRENDS IN INCOME

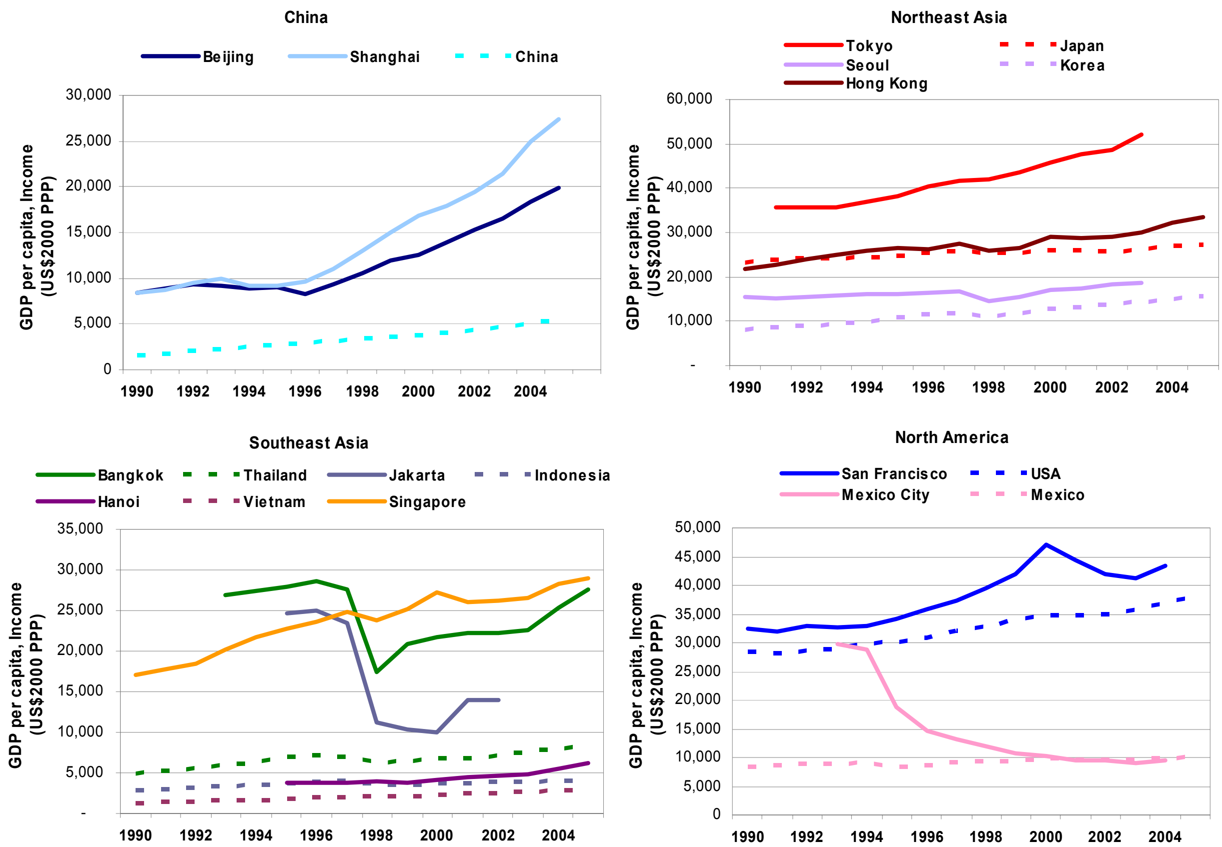
16.1,2,3,4 demonstrates historical trends in income in the four regions. City level incomes are higher than economy level incomes in all economies listed. This implies that wealth brought by economic development tends to concentrate in the city.

Income disparity between the city and economy level is quite substantial in Asia, specifically for Beijing- and Shanghai-China, and Tokyo-Japan. The most significant gap between a city and an economy is observed between Shanghai and China; Shanghai's income is five times higher than that of the national economy average level. Similarly, Beijing's income is three times higher compared to the whole economy.

This phenomenon indicates that these two cities, located along China's east coast where economic activities are concentrated, play a role in leading the national economy as a whole. In the case of Tokyo and Japan, Tokyo's income is twice that of the economy average. Unlike other Asian cities, however, a narrow gap constantly lies between Seoul and Korea. This is mainly explained by a fact that approximately 21 percent of the total population lives in Seoul, representing a large share of the economy average.

In Southeast Asia, substantially higher urban incomes relative to the national average are also seen for Bangkok-Thailand, and Jakarta-Indonesia, especially before the 1997 financial crisis. It seems, however, that the 1997 financial crisis hurt the economies of Bangkok and Jakarta more than it did the national economies, which both managed to maintain economic stability to some extent. Although Bangkok has since recovered from the crises, Jakarta's economy has remained sluggish.

In North America, decreases in income are observed in both San Francisco in 2001 and Mexico City in 1995. San Francisco's income was damaged by the bursting of the IT bubble in 2000. In Mexico, the 1994 devaluation of the peso is considered to have caused a sudden plunge in income of Mexico City.



16.1,2,3,4 Historical trends in income, 1990-2005
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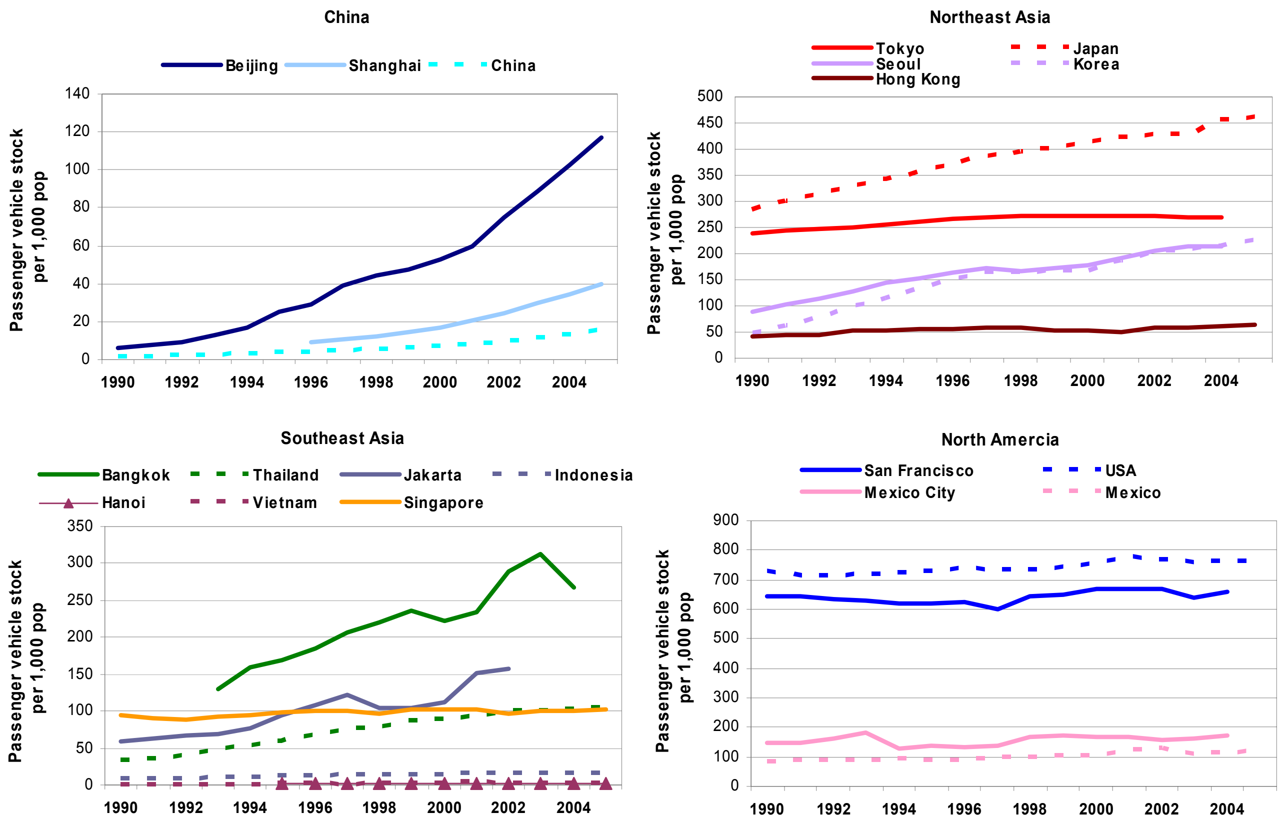
HISTORICAL TRENDS IN PASSENGER VEHICLE STOCKS

Figure 17.1,2,3,4 shows how passenger vehicle stocks increased across the four regions over the last 15 years. As a general tendency, passenger vehicle stocks are higher in cities than in whole economies except for two cases: Tokyo-Japan and San Francisco-US, where the economies have higher passenger vehicle stocks on average.

In China, Beijing and Shanghai since 1990 entered a period of rapid growth in passenger vehicle stocks. Beijing, in particular, has outpaced China in this aspect, which is indicated by an increasing gap between the city and the economy's figure.

In Northeast Asia, passenger vehicle stocks in Japan are higher than that of Tokyo and the gap between them has been widening. For the case of Seoul-Korea, passenger vehicle stocks have grown to attain the same absolute level through recent years. In Hong Kong, growth in passenger vehicle stocks has been effectively curbed.

In Southeast Asia, a wide gap between the national and the city levels is also seen between Bangkok-Thailand, and Jakarta-Indonesia. Passenger vehicle stocks in Jakarta have been increasing while those in Indonesia have remained low. In Hanoi–Vietnam, however, passenger vehicle stocks have remained low at both levels.



17.1,2,3,4 **Historical trends in passenger vehicle stocks, 1990-2005**

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The US holds a higher level of passenger vehicle stocks than the San Francisco Bay Area. This is due in part to the relative availability of alternative transport modes, such as mass transit, in the highly-developed San Francisco Bay Area as well as higher than national average land prices which disincentivise the continued ownership of "extra" passenger vehicles. Other concentrated urban areas in the US would display similar trends for similar reasons.

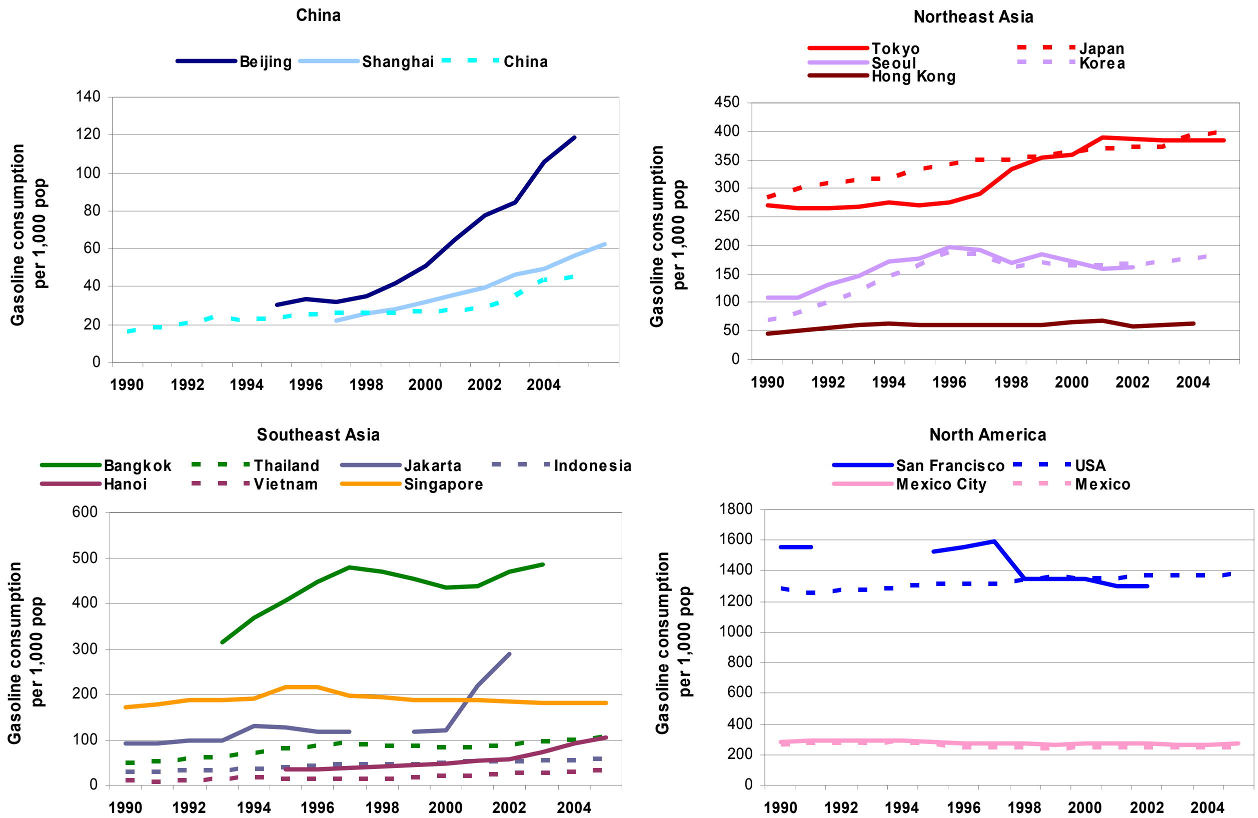
Overall, an inductive finding is that the gap in passenger vehicle ownership between a city and its economy tends to be wide in developing economies whereas it is smaller or similar in developed economies. In addition, high population density can be a restrictive factor for passenger vehicle stocks in developed economies.

HISTORICAL TRENDS IN GASOLINE CONSUMPTION

The final comparison between city and economy looks at historical trends in gasoline consumption in the four regions [18.1,2,3,4].

In China and Southeast Asia, relatively high gasoline consumption is commonly observed at the city level. Compared to the national level, gasoline consumption is extremely high in Beijing, Bangkok, and Jakarta. For Bangkok-Thailand, the difference is a remarkable 390 toe per 1,000 population. In addition, since it seems that the gap between Hanoi and Vietnam has started to get wider, Hanoi might follow the same path of other Asian cities.

The Tokyo–Japan case reveals an interesting movement. Gasoline consumption in Tokyo, once relatively small, caught up with the national level in 1999. This is partially due to a change in people's preference for vehicles; that is, consumers on the whole prefer large-sized vehicles. As a result, the gasoline consumption has been pushed upward. On the other hand, since people generally choose a compact car for a second car, energy consumption has not risen as much as might be expected in Tokyo even though the passenger vehicle stock has increased since the 1990s.



18.1,2,3,4 **Historical trends in gasoline consumption, 1990-2005**

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In the US, the absolute volume of gasoline consumption is extremely high compared to other economies - more than three times higher than second-place Japan. Opposite the previous figure showing a higher national average passenger vehicle stock compared to San Francisco, gasoline consumption in the city is in fact been higher than that of the national level. This might be explained in part by the broad geographic "functional-unit" definition used here to describe the San Francisco Bay Area. Within the city of San Francisco itself, similar to New York City, for example, per capita gasoline consumption is far below the national average; however, because the wider Bay Area also includes the cities of Oakland and San Jose, among many other smaller towns, suburban developments, and even agricultural lands but nevertheless is tightly economically and culturally integrated, personal mobility demand for frequent travel crossing the region is quite high compared to a uni-centric city urban form.

CHARACTERISATION OF CITIES IN APEC

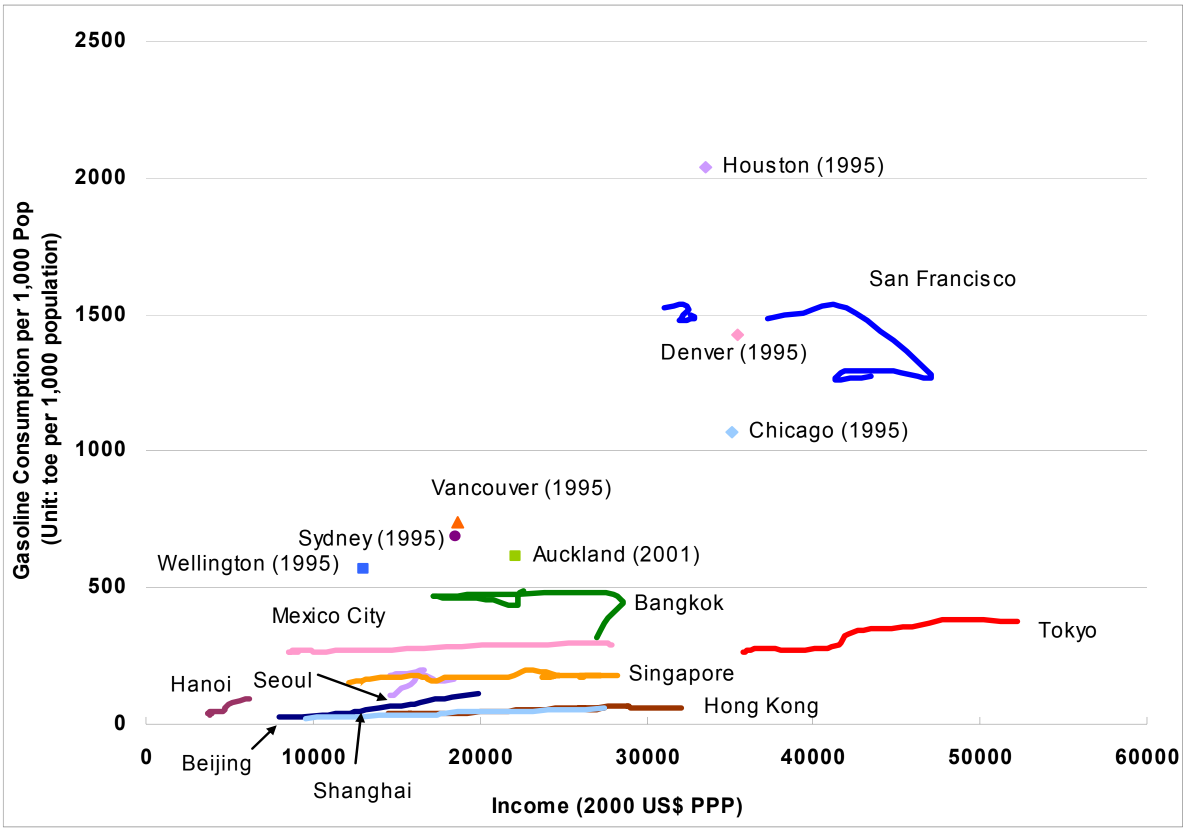
This section tries to identify characterisations of the cities that are covered in this study through analyses of the differences among them. The cities are examined in terms of income, gasoline consumption, passenger vehicle stocks, and length of road. In addition to the core group of APEC cities described above, data for other cities are included here for reference. The additional cities, named 'referential cities' for convenience hereinafter, are Vancouver in Canada, Chicago, Denver, and Houston in the United States, Sydney in Australia, and Auckland and Wellington in New Zealand. They are expected to add different views into a picture although their role is limited due to a measurement of only a single year.

INCOME AND GASOLINE CONSUMPTION

A trajectory indicating the relationship between income and gasoline consumption per 1,000 population for each city is presented in 20.1. Overall, a weak correlation between income and gasoline consumption per 1,000 population is identified. In particular, there is a wide range of income levels among economies in the group under 500 toe of gasoline consumption (per 1,000 population) from Hanoi to Tokyo. For instance, Bangkok consumes more gasoline than Tokyo and Hong Kong, although Bangkok's income level is lower than the two cities. It seems that the correlation between income level and gasoline consumption in these APEC urban areas is weaker than commonly thought.

With regard to the cities covered in the study, a considerable gap exists between San Francisco and the Asian cities (plus Mexico City). In terms of gasoline consumption, San Francisco varies from between 1,200 toe and 1,500 toe per 1,000 population while the Asian cities are all less than 500 toe per 1,000 population.

Furthermore, when the referential cities mentioned earlier are added, interesting observations are obtained. All three cities in Oceania and Vancouver are located between San Francisco and the Asian cities (plus Mexico City) as if filling in the blank space between them. The three referential cities in the US also demonstrate indicative results; that is, they end up in totally different positions in gasoline consumption regardless of their similar income levels. Chicago, where mass transit such as bus and subway relatively (for the US) widely used, is set in the lowest position at 1,066 toe as opposed to Houston, which is heavily dependent on passenger vehicles, at twice Chicago's consumption. Denver is positioned about halfway between the two cities. It is also inferred from the US cities' case that income level is trumped by other factors such as urban form, access to mass transit, and lifestyle choice in explaining gasoline consumption.



20.1 Income and gasoline consumption per 1,000 population, 1990-2005

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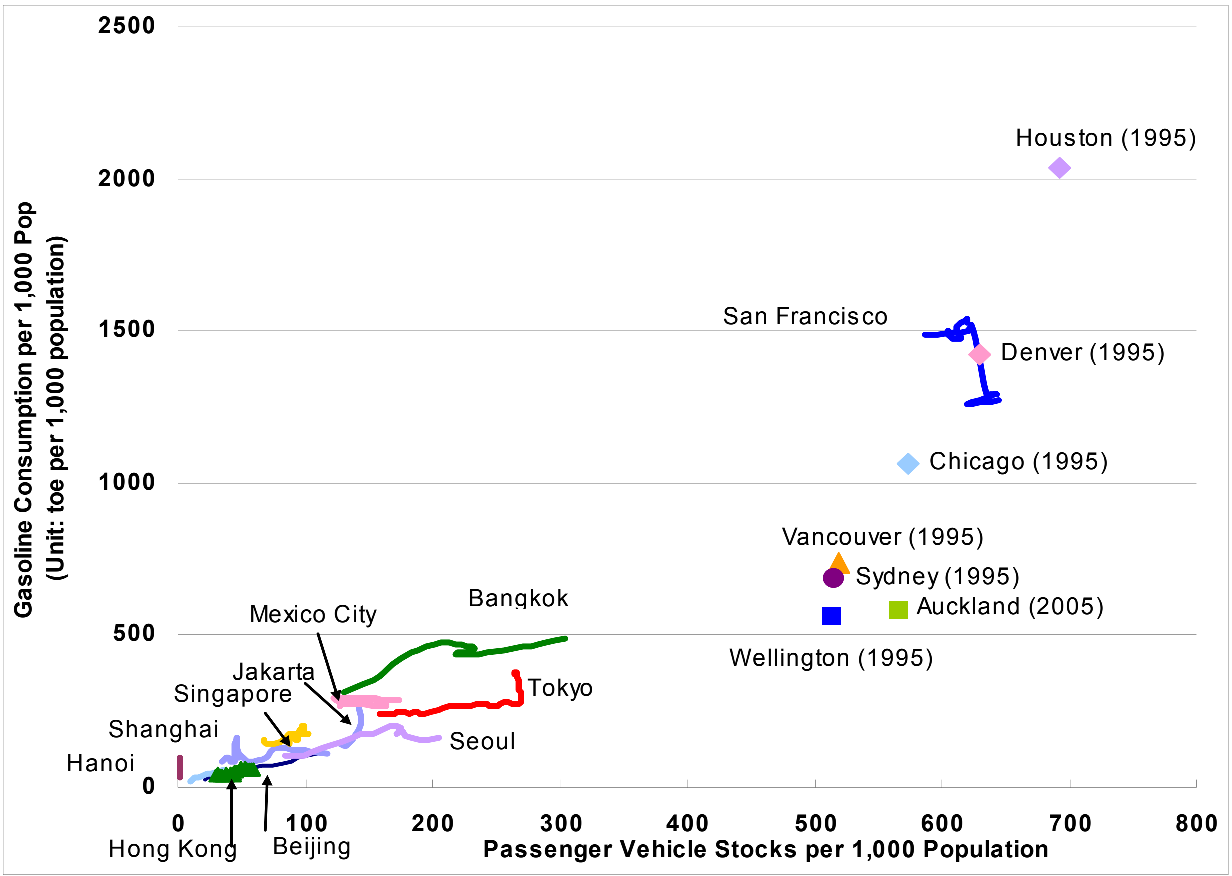
PASSENGER VEHICLES AND GASOLINE CONSUMPTION

In **21.1**, the relationship between passenger vehicle stocks and gasoline consumption per 1,000 population is examined. A fairly high correlation lies between passenger vehicle stocks per 1,000 population and gasoline consumption per 1,000 population. Here again, a wide gap is seen between San Francisco and the rest of the APEC cities in absolute level of both passenger vehicle stocks and gasoline consumption per 1,000 population, however their relationship is similar. In the group of cities along the lower left side of the figure, each city's trajectory is more or less similar when the passenger vehicle stocks are under 100 per 1,000 population, and then divergent tracks emerge above 200 vehicles per 1,000 population, such as in Bangkok and Tokyo. Interestingly the gasoline consumption in Tokyo continues to climb whereas the passenger vehicle stocks remain around 265 vehicles per 1,000 population.

Even if referential cities are included, a high correlation between the gasoline consumption and the passenger vehicle stocks still holds. Similar to the previous figure, the three cities in Oceania and Vancouver occupy positions between San Francisco and the rest. Meanwhile the three cities in the US, with their high absolute levels, demonstrate a positive relationship between the gasoline consumption and the passenger vehicle stock and reveal a striking difference among them. Interestingly, among the North American and Oceanian cities in the upper right side of the figure, the trajectory as a group is relatively steep compared to cities on the lower left side, suggesting the possibility of only extremely high upper limits, if any, on per capita urban gasoline consumption as vehicle stocks grow.



21.1 Passenger vehicles and gasoline consumption per 1,000 population, 1990-2005

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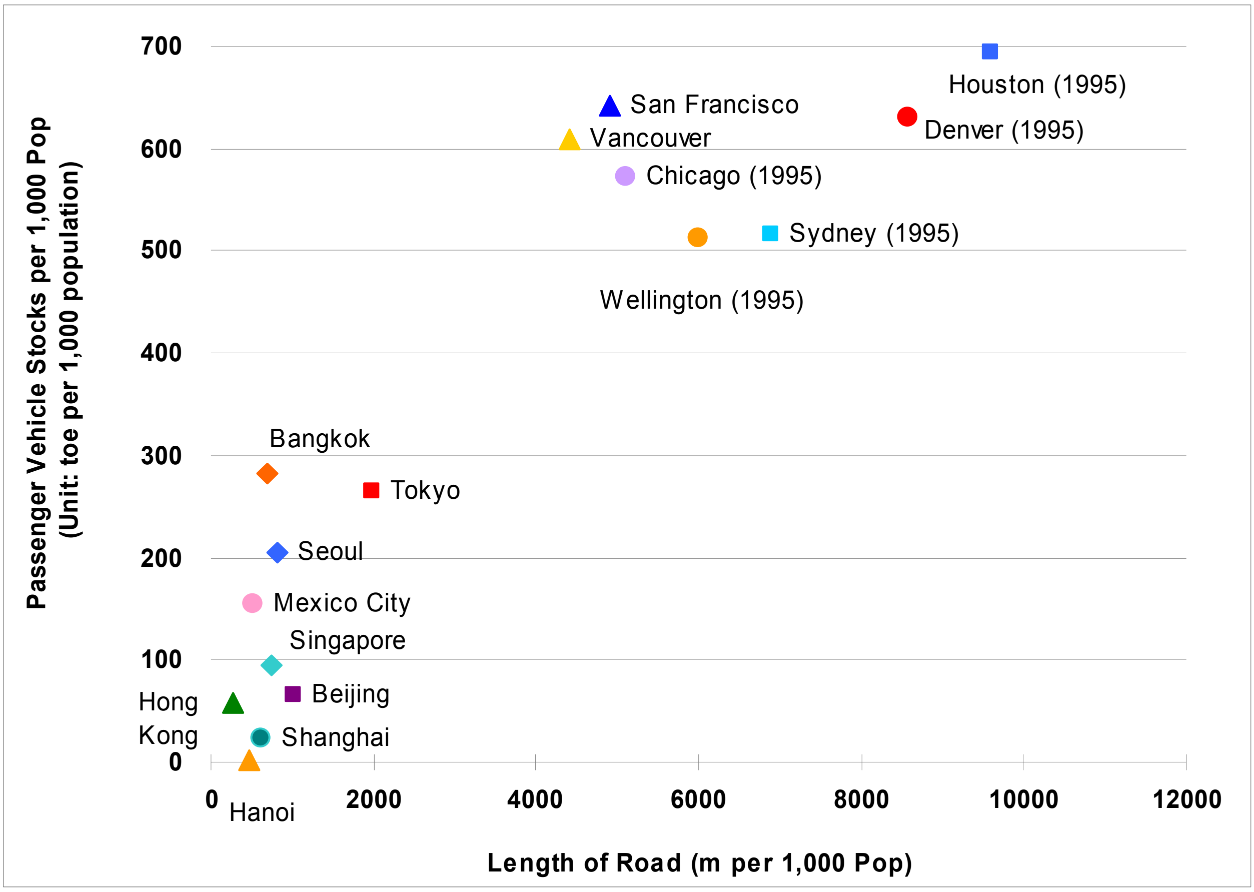
PASSENGER VEHICLES AND LENGTH OF ROAD

22.1 shows how the passenger vehicle stock per 1,000 population is related to road length per 1,000 population among the selected cities. On the whole, passenger vehicle stocks are bound by the length of road network. However, the cities are clearly bipolarised: the cities in North America (again excepting Mexico City) and Oceania versus the cities of Asia (plus Mexico City). The former group has developed long length of road network has high passenger vehicle stocks whereas the latter group is characterised with less than 2,000 m length of road per 1,000 population and relatively lower passenger vehicle stocks.

In the former group, the cities are horizontally spread; regardless of similar passenger vehicles stocks, a significant difference regarding the length of road is seen among cities, ranging from 4,400 m in Vancouver to 9,500 m in Houston. The cities in the US such as Houston and Denver are exceptionally high in the passenger vehicle stocks along with the length of road. The extensive road networks for both of these cities stand out among the sample.

On the other hand, the cities grouped together in the lower left corner are rather vertically spread out. All cities in this group except Tokyo have more or less similar length of road but the passenger vehicle stocks per 1,000 population vary from 1 in Hanoi to 282 in Bangkok. In particular, Bangkok and Seoul have more passenger vehicle stocks per 1,000 population compared to other Asian cities which have similar lengths of road network. The passenger vehicles seem to be saturated in these cities insomuch that their stocks are "limited" by available road. It is unsurprising that many of these cities are also afflicted by traffic congestion.



22.1 Passenger vehicles and length of road, 2002

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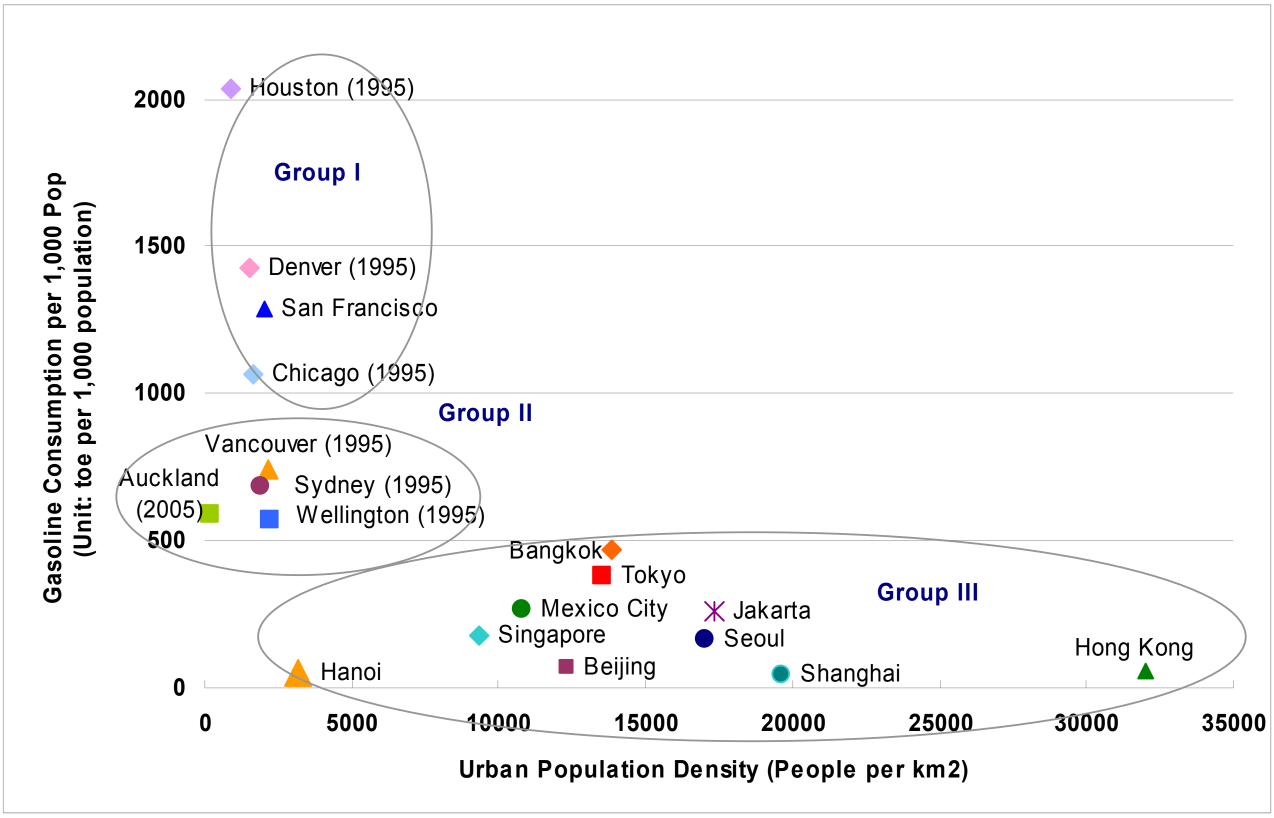
URBAN POPULATION AND GASOLINE CONSUMPTION

In 23.1, a relationship between urban population density (people per km² urban land area) and gasoline consumption per 1,000 population is illustrated. Gasoline consumption per 1,000 population is somewhat inversely correlated with the urban population density. A line explaining the relationship can be drawn in a convex curved shape.

The cities in the figure can be grouped into three. Group I represents cities with low urban population density and high gasoline consumption – all the US cities; Group II includes cities with low urban population density and moderate gasoline consumption – Vancouver and cities in Oceania; and Group III consists of cities with moderate urban population density and low gasoline consumption – the Asian cities.

Various gasoline consumption levels are observed among Group I, although population densities are quite similar. As pointed out above, Houston, at the upper bound, has a particularly high gasoline usage (2,037 toe), 971 toe higher than Chicago, at Group I's lower bound. Group II is located between the Group I and III again and shows less heterogeneity among the cities. In the Group III, where the Asian cities are scattered, a diverse range of gasoline consumption is seen regardless of the urban population density.

If only observing the cities of the Group III, it would appear that there is no correlation between gasoline consumption and urban population density. For instance, if Hanoi, Beijing, Shanghai, and Hong Kong are compared as an extreme case, the urban population density does not seem matter with regard to gasoline consumption. Moreover, compared to Tokyo, Bangkok is denser in population but consumes more gasoline. If the Group II and the Group III are compared, the gasoline consumptions of Bangkok and Tokyo get closer to that of Wellington, although the population densities of the two Asian cities are much higher than that of Wellington. Thus, the cities in the Group III considerably vary in terms of urban population density and gasoline consumption even though they are grouped in the same category.



23.1 Urban population density and gasoline consumption, 2002
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MODAL SPLIT

Modal split is measured by the share of a transport mode made by passenger vehicle, bus, subway/rail, motorcycle, taxi, bicycle, on foot, and the others for all passenger-trips. **24.1** shows the modal splits of the cities that are studied in this report. They are helpful to understand how inhabitants of each city use transport and how transport modes are different from each other. Some characterisations are drawn from this illustrative figure.

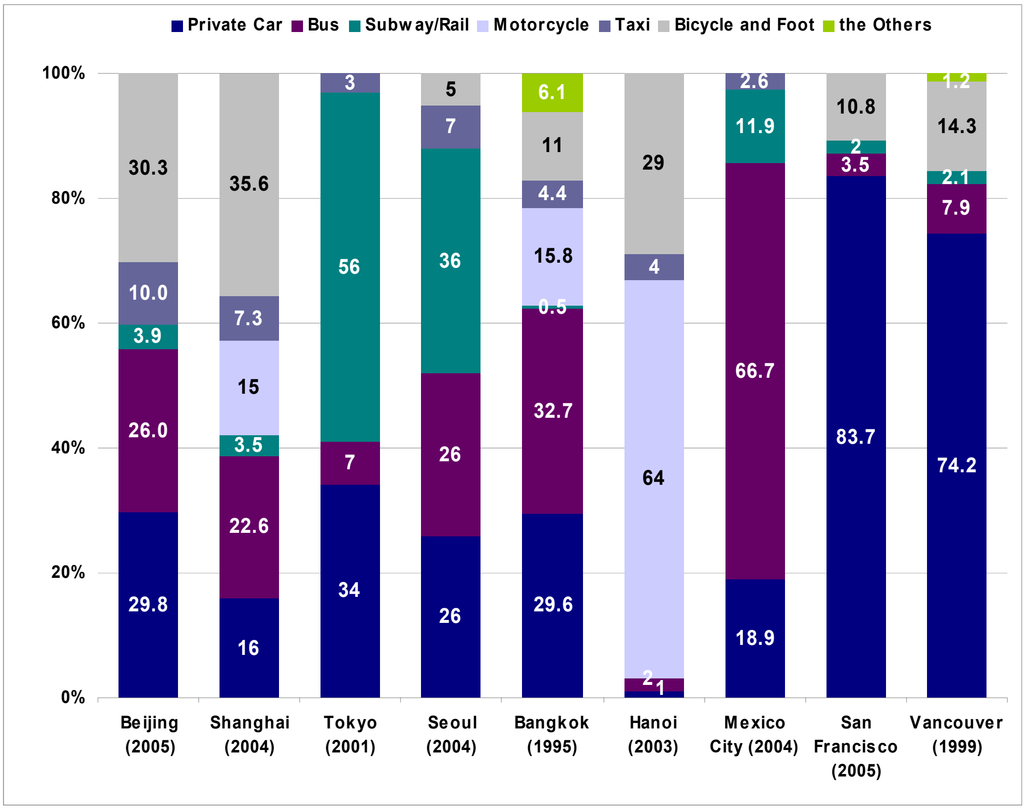
First, the extremely high share of passenger vehicles, which include both "drive alone" and "car pool", stands out in the cities of North America. Interestingly, non-motorised means such as bicycle and foot come next to passenger vehicles. The corollary is that the use of urban mass transit is considerably low.

Second, Hanoi and Mexico City are similar in that their dependence on a single mode is noticeable; motorcycles in Hanoi, and *colectivos* in Mexico City. Their shares account for more than 60 percent of all passenger-trips. However, these two cities differ from one another in that almost 30 percent of Hanoi's urban dwellers travel by bicycle or on foot and passenger vehicles account for only a negligible share. As a result, urban mass transit also plays a minor role. In Mexico City, by contrast, the use of mass transit comprises about 81 percent of all passenger trips.

Third, the share of urban mass transit including bus and subway/rail is especially high in Tokyo and Seoul, 63 percent and 62 percent, respectively. Compared to other APEC cities, expanded development of subway/rail network has helped the popularity of mass transit. One important key to these cities' success in subway/rail use has been their high accessibility; in both Tokyo and Seoul, rail transit is supported through facilitation with other transit modes. For instance, an extensive bus network makes up for otherwise inconvenient access to subway/rail in Seoul.

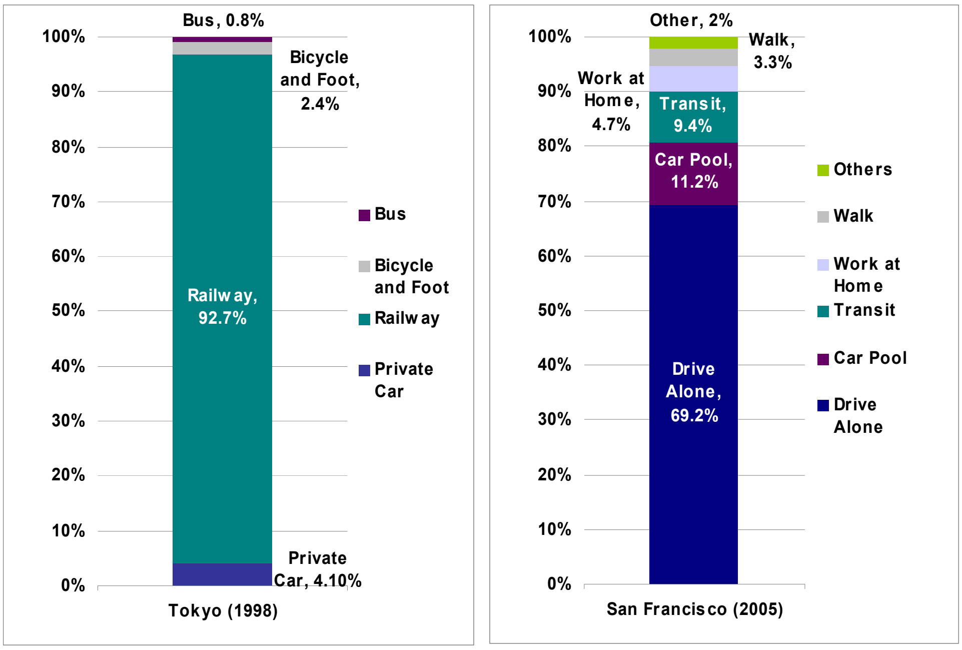
Fourth, bicycle and foot are the most used modes in Beijing and Shanghai, though dependence on passenger vehicles is looming due to increasing car ownership. Although the share of subway/rail is currently small in both Beijing and Shanghai, they are expected to increase in the future, which might put a curb on the usage of passenger vehicles in these cities.

Last, it should be mentioned that one city's modal split can vary dramatically between commuting trips versus all (averaged) trips taken. 25.1 provides a good example of this contrast in two cities, Tokyo and San Francisco. As clearly shown, most inhabitants use railways for commuting in Tokyo, which accounts for 82.7 percent of the modal share. On the other hand, in case of San Francisco, modal split between the two figures are relatively similar, indicating heavily dependence on passenger vehicles for commuting as well. For both cities, however, the general phenomenon is observed that shares of mass transit tend to increase for the relatively predictable and structured commuting demand, while they decline for more spontaneous mobility demand in other periods.



24.1 **Modal split for all passenger transport, passenger-trips**

APERC 2007



25.1 **Commuter modal split for Tokyo and SF Bay, passenger-trips**
APERC 2007

EVALUATION OF URBAN TRANSPORT ENERGY USE IN ASIA

Passenger transport energy consumption in an urban area reflects diverse socioeconomic factors. To comprehensively capture both contributing and offsetting factors to passenger transport energy consumption in urban area, urban transport indicators – road energy indicator and offset indicator – were created. The results from the indicator analysis offer that the enhanced access to rail/subway can reduce passenger vehicle dependence. The results also suggest the need for timely investment in rail/subway infrastructure..

INTRODUCTION

Concentration of wealth in some developing Asian cities has led motorisation trends in recent years. Over the past five years, for example, Beijing, one of the fastest developing cities in the world – has seen more than two-fold increase in its passenger vehicle stocks. Likewise, Shanghai's double digit economic growth over the past five years has driven near three-fold increase in its passenger vehicles. These together have exerted strong upward pressure on oil product demand, rendering supply security concerns amid dwindling domestic oil production.

This chapter identifies the key factors affecting passenger transport energy consumption in APEC Asian cities. As city dwellers in Asia are increasingly dependent on passenger vehicles for their mobility, analyses are focused on identifying factors affecting gasoline consumption – the main fuel driving passenger vehicles.[a] In order to assess both contributing and offsetting factors for gasoline consumption, two indicators – a road indicator and an offset indicator – were developed. With these indicators, the chapter also compares the contributing/offsetting factors of one city's passenger transport energy consumption to that of other cities of Asia in an attempt to evaluate the urban transport system and draw policy implications for the enhancement of energy security.

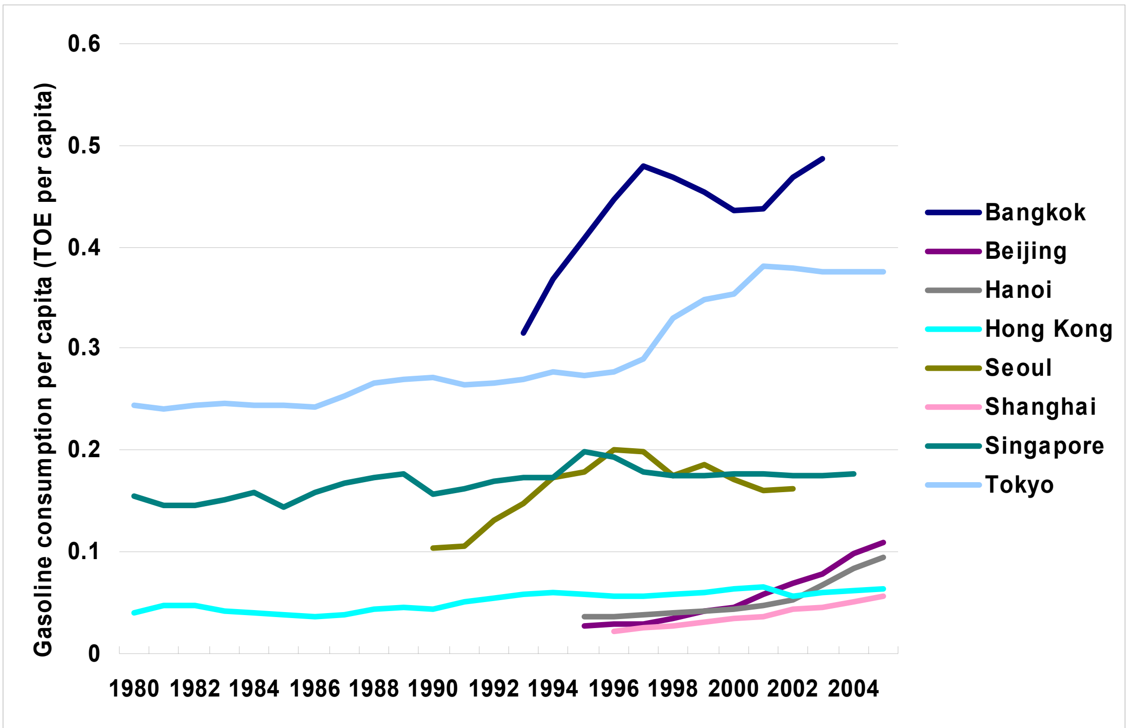
[a] *In some Asian economies, such as Thailand and the Philippines, diesel-powered vehicles are utilised for the purpose of passenger transport. However, their share of diesel to total road passenger transport is smaller than that of gasoline.*

HISTORICAL TRENDS IN URBAN GASOLINE CONSUMPTION

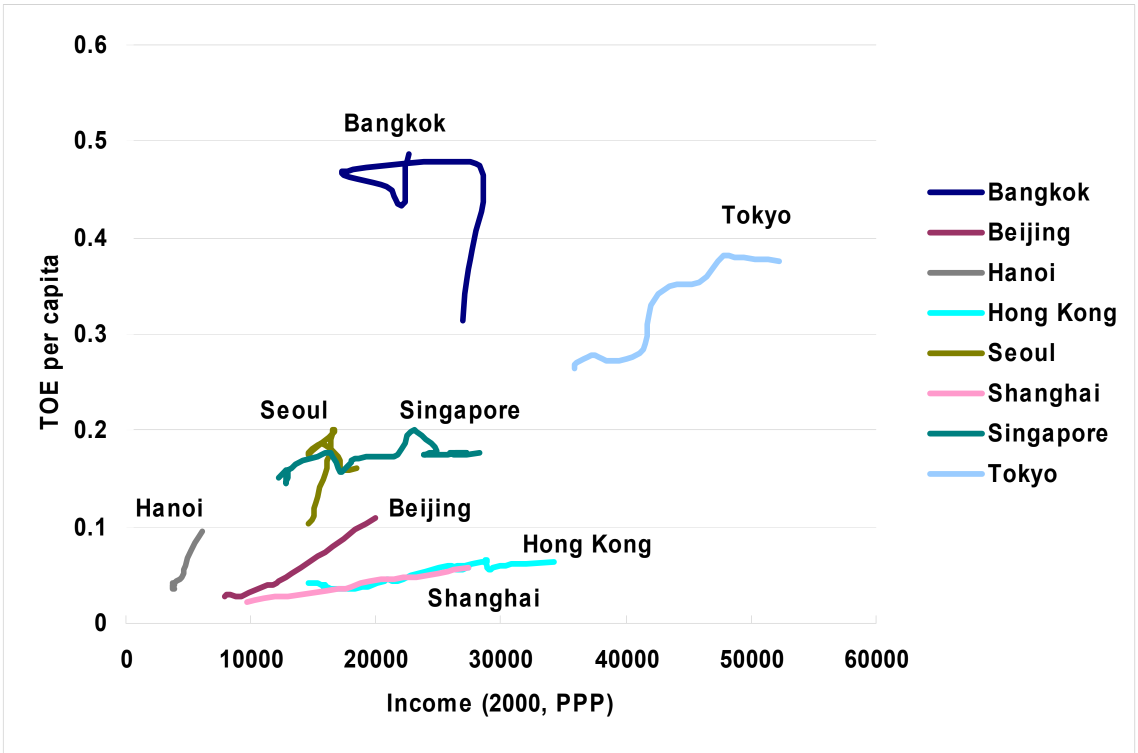
Cities' gasoline consumption varies greatly in Asia. Despite remaining at relatively low levels – compared with that of US cities – per capita gasoline consumption of Asian cities demonstrates wide variation, as shown in 28.1. For example, in 2004 Bangkok's annual gasoline consumption accounted for the highest level at above 0.5 toe per capita, nearly ten times higher than that of Shanghai at 0.06 toe per capita in the same year.

Aside from the wide disparities in terms of per capita gasoline consumption in Asia, it is interesting to observe the surprisingly weak correlation between income and per capita gasoline consumption of Asian cities. In 2004, Bangkok's per capita gasoline consumption was higher than that of Tokyo, while its income is less than one-third of Tokyo. In addition, Hong Kong's per capita gasoline consumption is the second lowest after Shanghai at 0.062 toe despite its high income level of USD 34,000 (2000, PPP). The cases of Bangkok and Hong Kong suggest that factors other than income determine the level of gasoline consumption per capita.

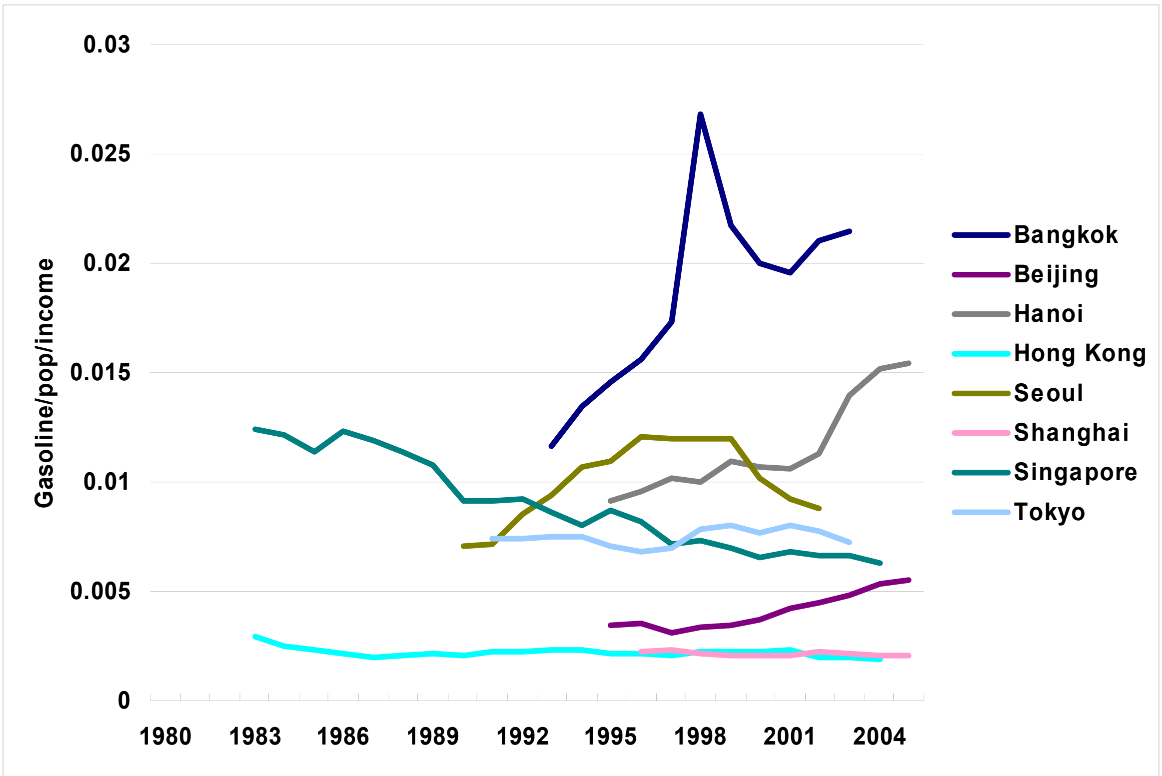
To allow comparison among cities with different economic development, per capita gasoline consumption was normalised by income [29.1]. This depiction – income-normalised gasoline consumption per capita – shows the proportional size of personal gasoline use to income level.



28.1 **Gasoline consumption per capita in cities of Asia, toe per capita**
APERC 2007



28.2 **Correlation between income and gasoline, per capita**
APERC 2007



29.1 **Income-normalised gasoline consumption per capita in the cities of Asia, toe per capita**
APERC 2007

Among the cities studied, the comparison of income-normalised gasoline consumption per capita offers substantial differences in terms of both *growth trends* and *absolute levels*. For example, Bangkok's indicator represented the highest level at above 0.02.[b] In 2004, Hanoi's indicator accounted for the second highest level among the Asian cities, suggesting the heavy dependence on road transport relative to the income level. In contrast, for Tokyo and Singapore, the indicator was on declining trend, both of which reduced by nearly half from the levels in early 1980s to recent years. Seoul's indicator shows a somewhat different trend from the other affluent cities in Asia as it was on increasing trend until 1998, and thereafter declined at a moderate rate.

In Beijing, Shanghai, and Hong Kong, the indicator shows different growth trends and levels from those cities discussed previously. Over the past decade, Beijing's indicator grew steadily at an annual rate of five percent, while that of Shanghai and Hong Kong stayed almost at the same level.

[b] *Bangkok's income-normalised gasoline consumption per capita reached the highest level in 1998 at above 25. This was caused by the substantial decline in income level – resulting from the 1998 financial crisis, while gasoline consumption was not affected by the decline in income of this year*

Diverse economic and social factors affect passenger transport energy consumption in urban areas. Major driving factors include income level, urban form, and demographic trends. Income level affects the number of vehicle stocks, while urban form affects distance travelled. Demographic trends – such as migration from rural to urban areas – drive growth in the use of motorised transport.

To comprehensively capture both contributing and offsetting factors for urban passenger transport energy consumption, two indicators were developed. One is called a "road indicator", and the other indicator is called an "offset indicator". The two indicators are combined to be called "urban transport indicators".

Ten cities/economies in Asia are selected for the purpose of this study. These are Bangkok, Beijing, Hanoi, Hong Kong, Jakarta, Seoul, Singapore, Shanghai, Taipei and Tokyo. Those cities not in Asia are excluded from the indicator analysis due to significant differences in urban form, population density, travel pattern and the passenger vehicle stock levels.

Two separate sets of urban transport indicators were created: one using data from 1995 and the other from 2005. The purpose of developing urban transport indicators for two different time periods was to demonstrate the development path of transport systems.

Through the urban indicators analysis, city-specific contributing/offsetting factors to gasoline consumption can be identified. With the two sets of indicators from 1995 and 2005, urban transport indicators also allow us to identify changes in contributing/offsetting factors to gasoline consumption. In addition, the urban transport indicators make it possible to compare a city's transport system with that of any other.

ROAD INDICATOR

The road indicator was calculated for the purpose of identifying the major driving factors of passenger vehicle energy consumption in urban areas. Among a number of factors, three key variables were selected: (1) the number of passenger vehicle stocks, (2) road length, and (3) average vehicle distance travelled. The road indicator was calculated as a weighted average of each variable. Different weights (50:20:30) were given respectively to each variable. Data was primarily collected from official sources (central or metropolitan governments).

The number of passenger vehicle stocks is the key driver for passenger vehicle energy consumption. In fact, the number of passenger vehicle stocks is determined by a wide range of factors, from income level to cost of vehicle ownership. To allow comparison among different income levels in Asia, passenger vehicle stock per 1,000 population was normalised by income.

The length of road is another critical factor affecting cities' passenger vehicle energy consumption. Urbanisation and its subsequent urban sprawl oftentimes take place concurrently with the development of road transport arteries. Dwellers in sprawling urban areas with limited access to mass transit for example, depend on passenger vehicles for mobility. Therefore, the length of road was used for the indicator analysis as a factor affecting cities' passenger vehicle dependencies.

Average distance travelled is a proxy for vehicle utilisation. In such a city as Tokyo where dwellers depend mostly on mass transit for their commuting, passengers utilise vehicles only during weekends. Therefore, average distance travelled was used for the purpose of representing cities' different patterns of vehicle utilisation.

OFFSET INDICATOR

The offset indicator was developed in order to analyse those factors that can reduce growth in urban passenger vehicle energy consumption. Three variables were chosen to calculate this indicator: (1) energy efficiency improvement for passenger vehicles, (2) accessibility to rail/subway infrastructure, and (3) governance. Again, the offset indicator was calculated as a weighted (30:40:30) average of each variable.

Passenger vehicle energy efficiency – calculated as a ten-year annual average growth rate of gasoline consumption – is an important element that can offset growth in vehicle energy consumption. Passenger vehicle energy efficiency is generally affected by technological development, vehicle size, and vehicle utilisation.

Accessibility to rail/subway is a critical component to drive people away from passenger vehicle dependence. To create a variable representing the accessibility to rail/subway systems, the total number of railway and subway stations in urban area was divided by urban land area. Higher values represent easier access to rail and subway systems. For some cities such as Hong Kong and Tokyo, rail and subway networks extend even beyond the urban area boundary. Nevertheless, this ex-urban rail infrastructure is excluded from the analysis to allow comparisons with other cities where rail and subway networks are generally developed only within the urban area.

Governance means the process of decision-making and the process by which decisions are implemented.[c] This is a particularly important indicator in evaluating the performance of the urban transport system as a whole. To initially develop a transport system and later to control the traffic system, city planners need to consider a list of issues. For example, development of road, rail, and subway infrastructure has to be coordinated with urban planning. In addition, traffic control requires coordination among various agencies at both central and local government levels. Operational schedules of bus, rail and subway have to be coordinated across companies in order for passengers to increase the accessibility to mass transit as well as to facilitate transfer from one mode to the other. City planners are also required to resolve sometimes conflicting interests and views between the public and private sectors.

[c] *UNESCAP (2006). What is good governance?*

As an indicator to analyse the quality of governance over transport system, World Bank's "worldwide governance indicator" was utilised. The report constructed indicators of six dimensions of governance: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law and control of corruption. For the purpose of this study, average level of government effectiveness, regulatory quality and rule of law was utilised. Although these indicators do not analyse governance at the city level, the governance indicator for the national economy as a whole was used as a proxy.

RANKING FOR THE URBAN TRANSPORT INDICATORS

The results from the urban transport indicators analysis are presented as below. In addition to the calculation results, the table includes those variables used to calculate the road indicator and offset indicator.

Road Indicator						Offset Indicator					
	City	Vehicle Stocks (Tokyo =10)	Road	Vehicle Mileage	Road Indicator		City	Vehicle Efficiency	Access to Rail and Subway	Governance	Offset Indicator
1	**Jakarta**	22.0	95.4	59.4	47.9	1	**Hong Kong**	0.0	45.4	94.7	46.6
2	**Bangkok**	23.2	33.1	74.0	40.4	2	**Tokyo**	-6.1	42.8	86.6	41.3
3	**Seoul**	22.1	41.7	41.9	31.9	3	**Seoul**	4.6	43.4	74.4	41.1
4	**Beijing**	10.8	62.1	45.0	31.3	4	**Taipei**	1.1	36.6	80.7	39.2
5	**Hanoi**	15.4	72.6	12.3	25.9	5	**Singapore**	1.4	13.7	98.2	35.4
6	**Singapore**	6.6	24.4	56.4	25.1	6	**Bangkok**	5.0	5.9	61.1	22.5
7	**Taipei**	15.2	32.9	26.1	22.0	7	**Shanghai**	3.7	14.4	45.8	20.6
8	**Tokyo**	10.0	37.7	31.2	21.9	8	**Beijing**	1.9	5.1	45.8	16.4
9	**Hong Kong**	3.0	8.3	57.1	20.3	9	**Hanoi**	-2.4	0.0	37.6	10.6
10	**Shanghai**	2.7	25.0	40.0	18.4	10	**Jakarta**	-6.3	5.1	31.4	9.6

32.1 Ranking for the urban transport indicators, 2005
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Caution needs to be taken in interpreting the **road indicator**. The ranking represents dependence on road transport relative to each city's economic development level. Jakarta, for example, is ranked number one regarding the road energy indicator. This means heavy dependence on the passenger vehicles for its urban dweller mobility – relative to the economic level. In order to enable comparison among cities with diverse economic levels, variables such as per capita passenger vehicle stocks and per capita length of road were normalised by income. This point should be carefully taken into consideration when interpreting the results.

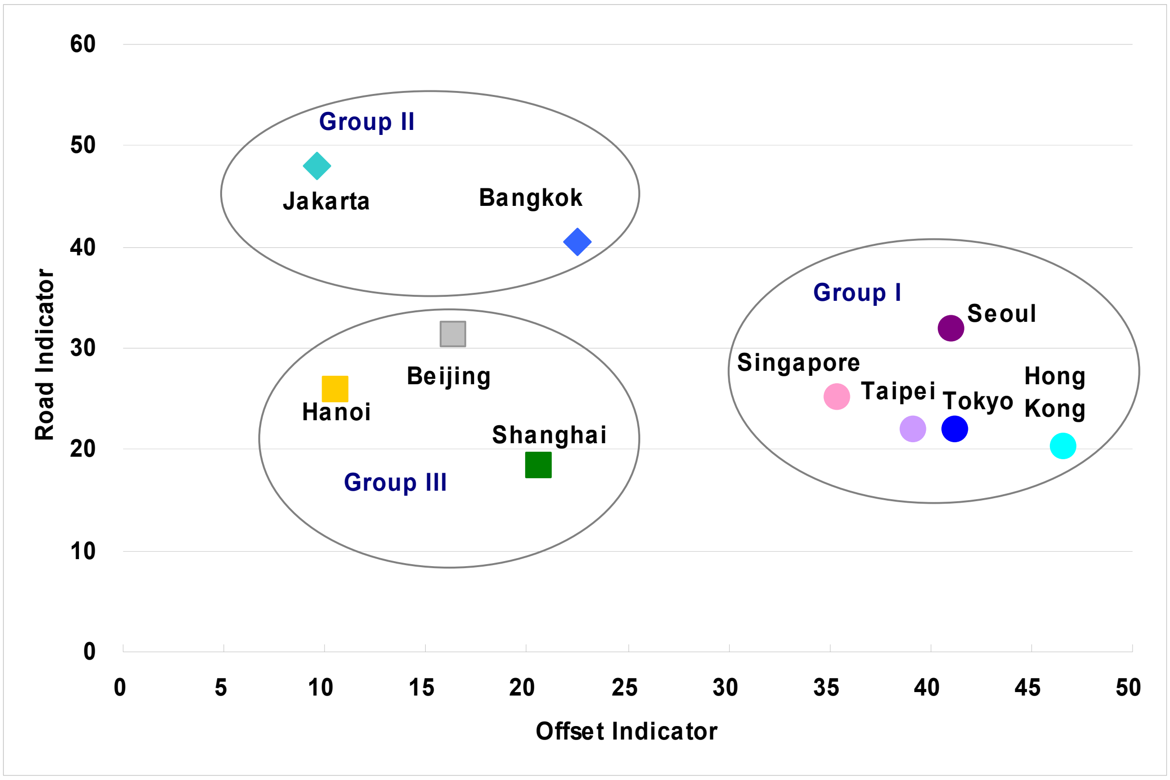
Likewise, interpretation of the **offset indicator** also demands caution. Hong Kong is ranked number one in the road energy offset indicator. This means that Hong Kong has the best alternative options to offset the increase in gasoline consumption from passenger vehicles among those cities studied.

GROUPING OF THE CITIES

The results from the indicator analysis are presented in 33.1. The x-axis represents the cities' ranking from the offset indictor, and the y-axis shows those of the road indicator. Those cities with indicator results located in the lower right-hand side of this figure are relatively highly dependent on rail and subway for their mobility. In contrast, those cities positioned to the upper left-hand side of this figure tend to rely more on road transport for their mobility.

By plotting the results from both indicators in one figure, the characteristics of urban transport in the cities of Asia become clearer.

The ten cities in Asia are grouped into three. Group I includes Hong Kong, Tokyo, Taipei, Seoul, and Singapore, and Group II includes Jakarta and Bangkok. Members of Group III include Shanghai, Beijing, and Hanoi.



33.1 Urban transport indicators, 2005

APERC 2007

Cities in **Group I** represent **the highest offset indicator**. In addition, those cities in Group I represent relatively low road indicator. The high offset indicator of this group results from the enhanced accessibility to subway and rail infrastructure. Also, proper governance, averaging at around 80 percentage points, contributes to culminate in high offset indicators above 35.

Cities in **Group II** are **highly dependent on passenger vehicles** for their mobility. Jakarta and Bangkok are ranked number one and two respectively in terms of road indicator. In addition, a wide gap with respect to road indicator is observed between this group and the other groups.

Three cities in **Group III** are relatively **at a nascent stage of transport infrastructure development**. In Beijing and Shanghai, for example, the mass transit system is not scheduled to be fully operational until around 2015. In Hanoi no mass transit system is yet in operation. Due to unavailability of an extensive mass transit system, more than half of the transport needs in Shanghai, for example, were met by such non-motorised transport as cycling and walking in 2004.[d]

[d] In 2004, more than 25 percent of Shanghai dwellers depended on bicycle, and more than 29.2 percent of those relied on walking for their passenger trips.

By comparing the indicator results, even among the same group, one can observe the gap between cities' indicator both vertically and horizontally. This poses a question: what are the factors that cause the difference in indicators among the same group?

For example, in Group I, vertical distance between cities is almost proportionally offset by the increase in the horizontal distance, excluding the case of Seoul. In fact, Seoul's offset indicator is almost at the same level with that of Tokyo at around 41, nevertheless its road indicator is about 30 percent higher than that of Tokyo.

The difference between Seoul and Tokyo in terms of road indicator is attributed to the different level of suburban rail infrastructure development. In Tokyo, more than 3 million passengers per day commute into the city from outside the Tokyo metropolitan area. Mostly, their mobility is handled by suburban rail that is directly connected to the urban subway network. By contrast, in Seoul, those commute daily from outside of the city proper depend on either passenger vehicles or buses due to the limited accessibility to the suburban rail infrastructure. To efficiently handle rising transport needs in the sprawling urban area, the case of Seoul and Tokyo provides an important implication of the need to develop suburban rail infrastructure that is connected to the urban subway network.

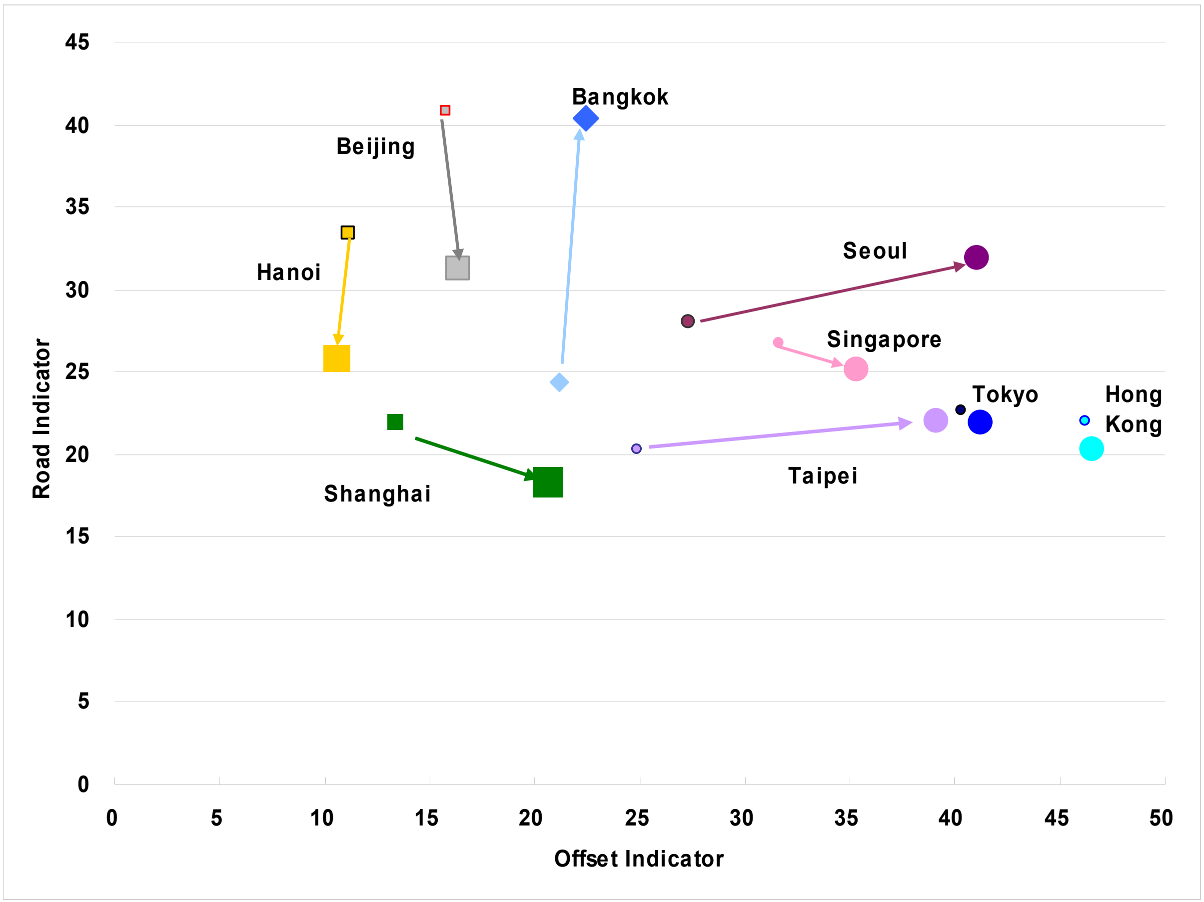
DEVELOPMENT PATH OF URBAN TRANSPORT INDICATORS IN ASIA

Development of transport infrastructure requires an arduous process of planning and coordination. In addition, the construction period of rail and subway infrastructure generally requires a few decades from the planning until the rail infrastructures can efficiently handle passenger transport requirements. Therefore, it may be of interest for policy makers to see the development path of urban transport system and to understand how the urban transport system in Asia has reached current levels.

The indicators for 1995 and 2005 are presented in **35.1**. Their evolution over time offers a glimpse at a few intriguing developments that took place over the past decade.[e]

[e] Due to availability of data, Jakarta is excluded from this. With respect to the governance indicator, 1996 and 2005 values were applied.

In **Shanghai** and **Singapore**, the decrease in road indicator between 1995 and 2005 is compensated by the increase in offset indicator during the same period, thereby moving their positions towards the right-hand side of the figure. This suggests that development or expansion of subway infrastructure contributed towards shifting people away from passenger vehicle dependence. In fact, Shanghai had no rail/subway infrastructure in 1995, but by 2005 it had already completed construction of 5 subway lines with 95 total rail/subway stations. In the case of Singapore, the number of rail/subway stations increased from 47 in 1995 to 95 in 2005, boosting rail/subway ridership.



35.1 **Urban transport indicators, 1995 and 2005**

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The cases of **Bangkok**, **Seoul** and **Taipei** offer very interesting examples with respect to the importance in developing rail/subway infrastructure to reduce passenger vehicle dependence. The road indicator for each of these three cities increased from 1995 to 2005, however the comparative size of that increase accounted for great difference in their transport system development. In fact, Bangkok's road indicator increased from 24 in 1995 to 40 in 2005 – about a 70 percent increase. By contrast, the road indicator of Seoul and Taipei rose only moderately from 27 in 1995 to 31 in 2005 and from 20 in 1995 to 21 in 2005 respectively.

The substantial difference in the increase of the road indicator between Bangkok and Seoul/Taipei is associated with the different level of rail/subway infrastructure development. As the increase in the offset indicator suggests, over the past decade, Seoul and Taipei made sizable efforts to develop subway infrastructure. The number of rail/subway stations increased in Seoul from 66 to 263 and in Taipei from 0 to 49 between 1995 and 2005, and this has curbed the growth in passenger vehicle dependence. By contrast, Bangkok's rail infrastructure development faced difficulties due to the shortage in funds resulting from the 1997 Asian financial crisis. Against the original plan to develop suburban rail system, the construction of rail infrastructure had to be suspended. Because of the limited accessibility to rail/subway combined with the relatively low cost of passenger vehicle ownership, Bangkok's number of passenger vehicle per 1,000 population more than doubled, from 169 in 1995 to 323 in 2005.

In those cities such as **Beijing** and **Hanoi**, the road indicator decreased considerably between 1995 and 2005 alongside a modest increase in the offset indicator. The substantial decrease in the road indicator is partly explained by the increase in income level – as variables such as passenger vehicle stocks and length of road were normalised by income. Over the past decade, Beijing's income more than doubled from USD 7,950 in 1995 to USD 19,919 in 2005. Likewise, Hanoi's income nearly doubled from USD 3,879 in 1995 to USD 6,157 in 2005.[f]

[f] *all income figures in year 2000 PPP terms*

Urban transport indicators of **Hong Kong** and **Tokyo** did not show much change over the past ten years as their mass transit infrastructure had already well developed in 1995. This suggests that due to enhanced accessibility, using rail/subway has become an integral part of daily life for these city dwellers. Therefore, their passenger vehicle dependence remains low – as the relative low level of road indicator demonstrates.

IMPLICATIONS

Passenger transport energy consumption results from diverse socioeconomic factors. Such factors include income level, urban form and demographic trends. To comprehensively capture both contributing and offsetting factors to passenger transport energy consumption in urban area, urban transport indicators – a road indicator and an offset indicator – were created.

The following important implications were obtained from the urban transport indicators analysis.

As the cases of Hong Kong, Tokyo, Seoul, Taipei and Singapore offer, accessibility to rail/subway is the key component that can reduce passenger vehicle dependence and improve energy intensity of the urban passenger transport sector in Asia. In addition, proper governance is needed to support rail infrastructure development, as rail infrastructure development concerns various issues such as coordination between central and local levels, among different governmental agencies, and between the public and private sectors.

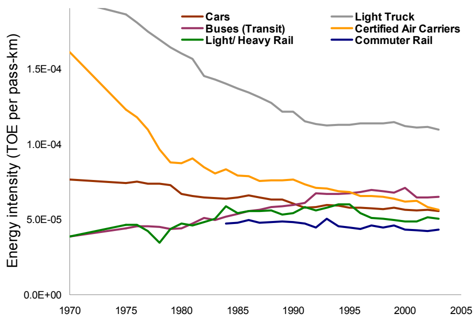
Timely investment in rail/subway infrastructure is necessary to shift people away from passenger vehicle dependence. As the case of Bangkok demonstrates, unless access to rail/subway infrastructure is ensured, a steady increase in the income of urban dwellers can drive burgeoning growth in the number of passenger vehicle stocks. In addition, it is hard to change people's life style – away from vehicle dependence – once they acquire a passenger vehicle. Due to the high upfront cost, building rail/subway infrastructure faces difficulties in some Asian cities. However, city planners, especially at the early stage of development, need to appropriately assess their future transport requirements and plan appropriate timing in investment towards rail/subway infrastructure.

ENERGY INTENSITY OF URBAN MASS TRANSIT IN THE USA

Urban mass transit in the United States has the potential to reduce transport energy demand, as well as provide other non-energy related services. However, a wide sample of US transit agencies covering multiple modes indicates that for most low ridership systems, energy savings are negligible or non existent compared to passenger vehicles. Systems with higher per station throughput and a higher load factor tend to have a lower energy intensity per passenger-km.

INTRODUCTION

One of the most striking trends in transportation energy use over the past 30 years has the been the gradual convergence across transportation modes of the average energy required to propel one passenger for one kilometre. For this fundamental measure of final transportation demand, the passenger-km, aggregate energy requirements for airplanes, trains, metro systems, light rail, buses, and even private automobiles are nearly equal. This convergence of energy intensity is depicted here on a national average level.



37.1 Convergence of passenger transport energy intensity in the US, 1970-2005

APERC 2007, United States Department of Transportation Bureau of Transportation Statistics (2005). National transportation statistics 2004. USA. http://www.bts.gov/publications/national_transportation_statistics/2004/index.html

If average energy intensity is indeed converging across modes on a national level, what are the implications for urban transit systems at the city or metropolitan level? Subway/metro (heavy rail), light rail, and commuter rail systems, in particular, are frequently regarded as providing "free-rides" to their users as far as transport energy requirements are concerned. Seeing an empty city bus, to say nothing of a subway, what energy or environmentally-conscious consumer –or policy maker—does not feel a twinge of guilt for their wasteful ways, travelling about in an energy-hungry passenger vehicle? Public campaigns, politicians, and environmental advocates often extol the theoretical energy savings inherent in such transit systems, but it is important for such claims to be supported by data. Based upon empirical NTD[a] data from roughly 60 United States metropolitan transit agencies, broken down by mode of travel, the following chapter aims to draw policy implications for the mass transit planner concerned with reducing urban transportation energy use.

As a caveat however, it is important to note that the empirical evidence and implications which follow are based purely on the experience of metropolitan areas in the United States. Using this consistent dataset ensures a minimum of consistency and precision across measurements, but it also limits the applicability of the findings with regard to APEC region Asian megacities, for example, whose special characteristics might separate them from the relatively low density, small population, high-income, and car-dependent nature of metropolitan areas in the United States. With this in mind however, the data which follows has been drawn from a stratified sample of US metropolitan areas so as to represent a wide breadth of urban characteristics—from geography to population, from land use to transit development— in the hope that concerned policy makers from anywhere in the APEC region might be able to place their own cities in the spectrum presented so as to draw useful conclusions from their own unique perspectives.

[a] United States Federal Transit Administration (2002, 2005). National transit database. USA. http://www.ntdprogram.com/ntdprogram/data.htm

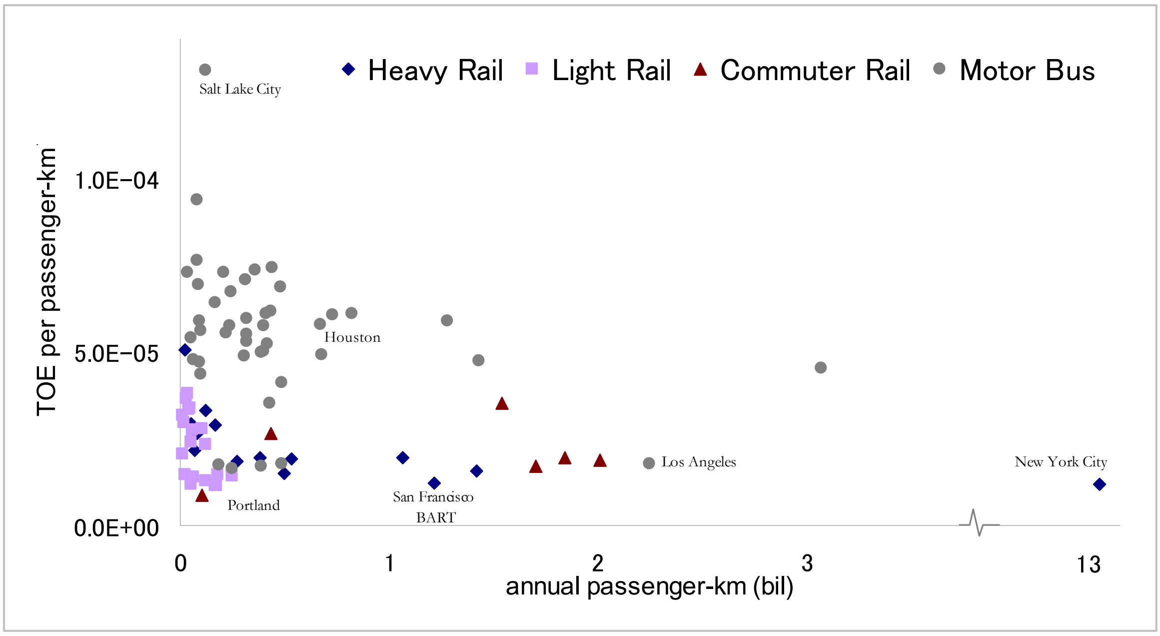
In order to both calculate system-annual-average energy intensity per passenger kilometre and then analyse this intensity against other system characteristics such as service area population density or passenger utilisation rates, 83 transit systems administered by roughly 60 transit agencies were chosen to represent a wide breadth of US urban area characteristics. This sample includes all 14 US heavy rail systems (commonly referred to as subway or metro), 19 US light rail systems (excluding only a handful of extremely small systems), 7 direct-operated commuter rail systems, and 43 city bus systems(standard, express, and BRT networks, stratified by annual passenger-km served), as defined by NTD standards. In some cases, such as the Los Angeles County Metropolitan Transit Authority (LACMTA), one agency operates multiple transit modes. In other cases, such as in New York City, multiple transit agencies and modes operate in overlapping service areas. Such incidences are not quantitatively corrected for in this analysis.

Energy intensities are calculated from aggregate annual passenger-km and fuel/electricity vehicle operational use, as reported by each agency for the NTD. As a result, non-revenue vehicle energy use is included as an energy expenditure, but non-vehicle energy requirements such as maintenance, station service, and construction are excluded. Data are averaged for the years 2002 and 2005 in the final results. NTD-reported energy use is disaggregated by fuel type (electric propulsion, electricity battery, diesel, biodiesel, gasoline, CNG, and LNG), which were converted to toe energy equivalents based upon US average conversion factors for each fuel type and aggregated within each sample. Service area population and population densities were calculated based upon US Census Bureau metropolitan and combined-metropolitan statistical areas (MSA, CMSA).[b] For perspective, the energy intensities calculated for each selected US urban area transit system are then compared to US average energy intensities of substitute modes of private transport—namely, passenger cars (the traditional private transport mode of choice in the US and other APEC member economies) and light trucks (which gained popularity for private passenger vehicle transport in the US over the past decade, but with sales which are now declining).

[b] *United States Census Bureau, Population Division (2003). Census 2000 PHC-T-29, ranking tables for population of metropolitan statistical areas, micropolitan statistical areas, combined statistical areas, New England city and town areas, and combined New England city and town areas: 1990 and 2000. USA. http://www.census.gov/population/www/cen2000/phc-t29.html*

Another important caveat to such an analysis concerns the comparison of energy intensity data across different modes or even within a single mass transit mode. Different transit systems in different areas, serving different populations, and using different technology, operate according to a wide variety of restraints and priorities. The variation is large; across different modes within a single agency, across single modes in one geographic area, and even within a single system across years. It is difficult then to make sweeping generalisations when intrinsic variation is so wide. A comparative analysis, however, is nevertheless rich with value. Moreover, by disaggregating to the system level, this variation becomes illustrative and the trends informative.

Energy intensity of United States mass transit systems is inversely correlated with the total annual passenger-km served by each system, but the variation between systems is wide. That is, for systems that serve relatively small transit demand, energy intensity is generally higher than for larger systems. More precisely, the breadth of variation in energy intensity declines towards a fairly hard minimum boundary as system service size grows. Small systems might have very low energy intensities, but they also might have the very highest. The largest systems, on the other hand, do not tend to have high energy intensities in any case. As noted above with US national averages, the energy intensity of different modes is similar on a passenger-km basis, though buses on average tend to use the most energy of all transit systems.



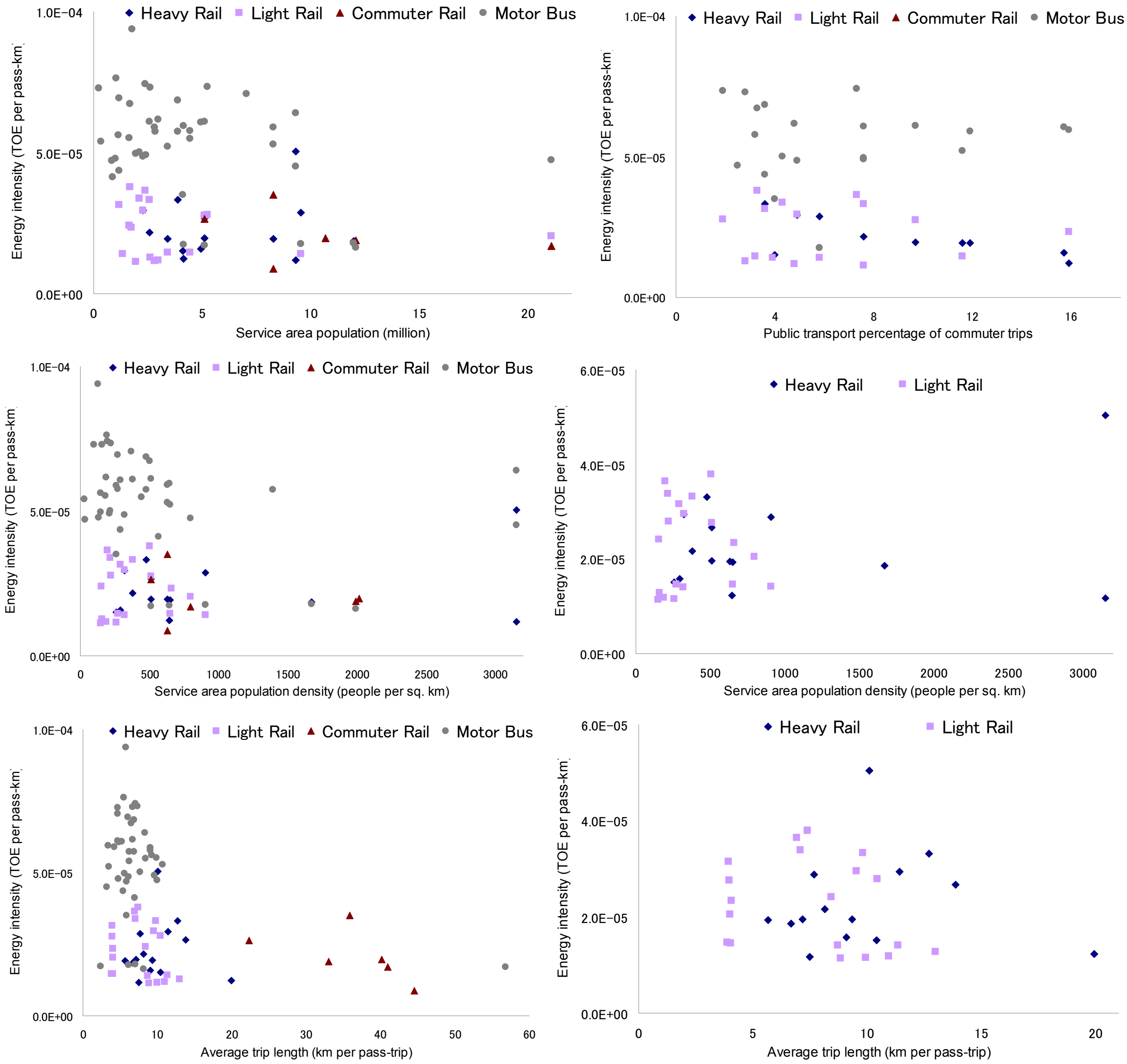
39.1 Energy intensity of 83 US urban mass transit systems vs. annual passenger-kilometres served
APERC 2007

What does this mean for the energy-conscious policy maker contemplating the initial construction or expansion of an urban transit system? The aggregate depiction above is a useful empirical foundation, but further illustration is possible through analysis of the indicators which back out the passenger-km correlation. Energy intensity is directly composed of two elements: energy use, and traveller behaviour. Energy use, in turn, can be approximated by route design and by vehicle efficiency (the aggregate of mechanical and conductor-influences). Rider behaviour is less clearly definable, but can still be described through such proximate indicators as passenger utilisation rates or passenger-trips per system station. Other logical measures might include service area population, population density, average trip length, or the percentage of a city's commuters who rely on public transit. Of the above measures, route design/land use levies what is perhaps the most complex and subtle influence on energy intensity, and so is left for future analyses. Explorations of the remaining elements, however, follows.

TRAVELLER BEHAVIOUR

In this analysis, many measures which are generally thought to affect energy intensity in fact displayed little or no discernable trend across the sample. Examples include service area population, population density, average trip length, and the percentage of a city's commuters who rely on public transit.

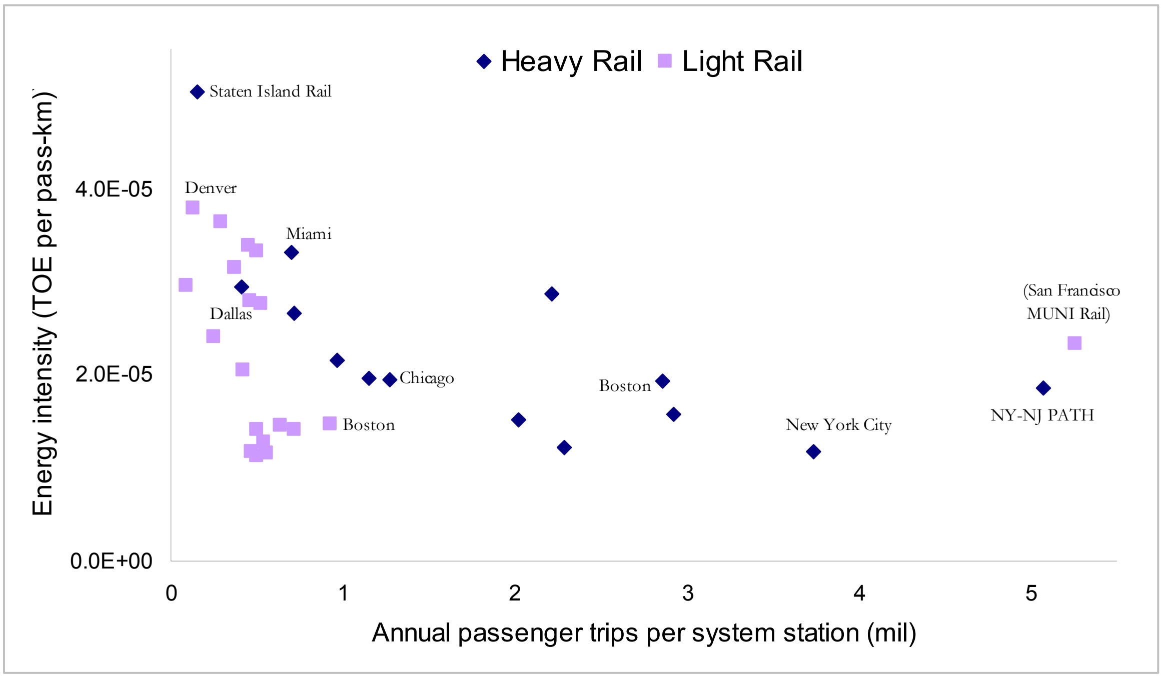
Some indicators, such as service area population density and average trip length might, do actually appear to be loosely inversely correlated with energy intensity. But, in fact, this apparent relationship is due to cross-mode differences; each of the four major public transit modes, in themselves, are actually clustered and display extremely weak correlation when isolated, as the intra-city rail transit charts depict. So, for example, while it is illustrative that motor buses tend to have both low average trip lengths and high average energy intensity when compared to commuter rail, there is no further relationship within each mode.



40.1,2,3,4,5,6 **Weak correlation of mass transit energy intensity with a number of common descriptive indicators**

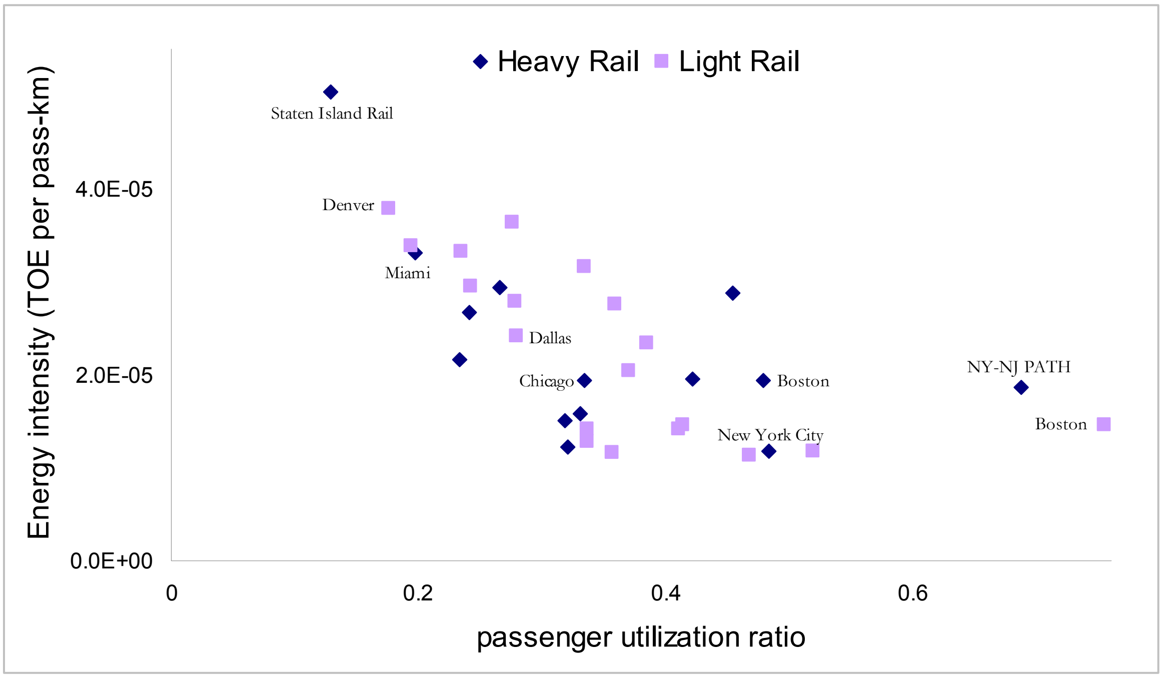
APERC 2007

One indicator that does show somewhat significant correlation with final energy intensity in US rail transit systems is station throughput—that is, calculated roughly, the number of system-wide annual passenger trips divided by the number of stations in the system. With such an indicator, mid-to-large sized rail systems, such as San Francisco Bay Area Rapid Transit (43 stations, 2.28 mil annual trips per station), are somewhat normalised against much smaller systems, such as the Los Angeles County Metropolitan Transportation Authority (LACMTA) heavy rail (16 stations, 2.21 mil annual trips per station). In this comparison, similar to that of total system service provided, above, energy intensity is inversely correlated with station throughput. In particular, with the exception of an extreme value in the SF MUNI light rail system, US light rail systems max out below 1 million trips per station, and energy intensities fall precipitously, by nearly 75 percent, as that limit is approached. Heavy rail systems have higher station throughputs than light rail, and they follow a similar path, but with a flatter slope. Neither systems, by this measure, are particularly subject to threshold discontinuities.



41.1 Correlation of mass transit energy intensity with station throughput
APERC 2007

Passenger utilisation ratios also display noticeable correlation with energy intensity in US heavy and light rail transit systems. Here, both modes are well-mixed, and show a general decline in energy intensity as the ratio of annual average passenger load to official fleet seating capacity increases. That is, fewer empty seats means less energy expended per passenger-km. Though variation is once again wide, in this data, on average, both light and heavy rail system energy intensities adhere to minimum and maximum boundaries which decline by about 50 percent as passenger utilisation ratios increase from .15 to .35. From this point, both systems are bounded by a hard energy intensity minimum of about 1.0E-5 TOE/pass-km, and an average of about 1.5E-5 TOE/pass-km, even as passenger utilisation ratios rise. Such comparisons do not establish causation between these variables, but this correlation nevertheless suggests that the most energy intensity-efficient rail transit systems in the US have passenger utilisation ratios above .3.

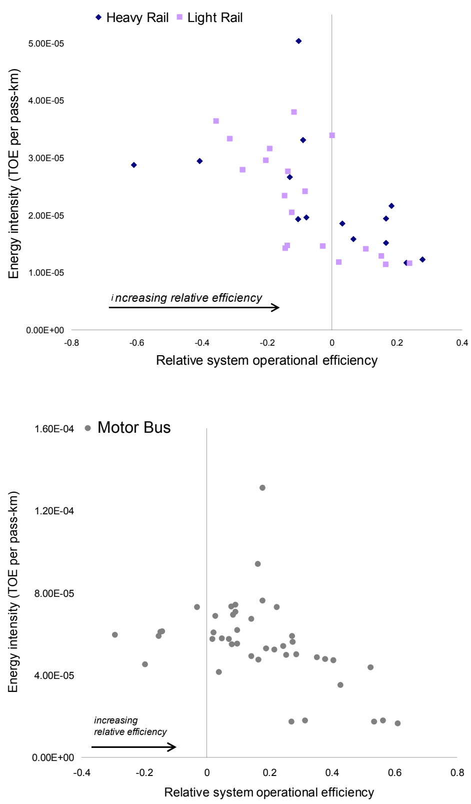


42.1 Correlation of mass transit energy intensity with load factor
APERC 2007

ENERGY USE

If seeking to reduce transit energy intensity, it is important to determine the contribution of vehicle operational efficiency, as it is ostensibly more directly controllable by the transit system manager than traveller behaviour is. The relative system operational efficiencies, depicted below for US heavy\light rail systems and bus systems compared against system energy intensities, are derived from total reported fleet annual distance travelled (both revenue and non-revenue) divided by total fleet annual fuel use. As such, this operational efficiency indicator is a combination of both vehicle mechanical efficiency and operator driving habits (and is also affected by special considerations, including route design, number of stops, or traffic speed). This calculation in itself yielded fleet annual average operational efficiencies of 2392 km per toe for light and heavy rail systems, and 1668 km per toe for bus systems, with very tight linear correlations within each mode. The chart below takes this per-mode linear correlation and compares each transit system's actual fuel use against the expected value based upon the mode average. The difference in these two values is then plotted against each system's energy intensity and normalised by total system size.

If all system-to-system variation in energy intensity could be explained by vehicle operation efficiencies alone (and discounting all ridership influences), then one would expect to find a perfectly linear inverse correlation. Instead, while an inverse correlation is discernable (that is, relatively energy efficient systems also tend to have lower overall energy intensities), the relationship is still obviously being influenced by other factors. This, of course, makes sense given the correlations between traveller behaviour and energy intensity depicted above. Ultimately then, the energy-minded decision maker need remember to address both sides of the issue—efficiency of energy use and traveller behaviour—in order to effectively reduce urban transit



42.3,4 Relative system operational efficiencies for three mass transit modes
APERC 2007

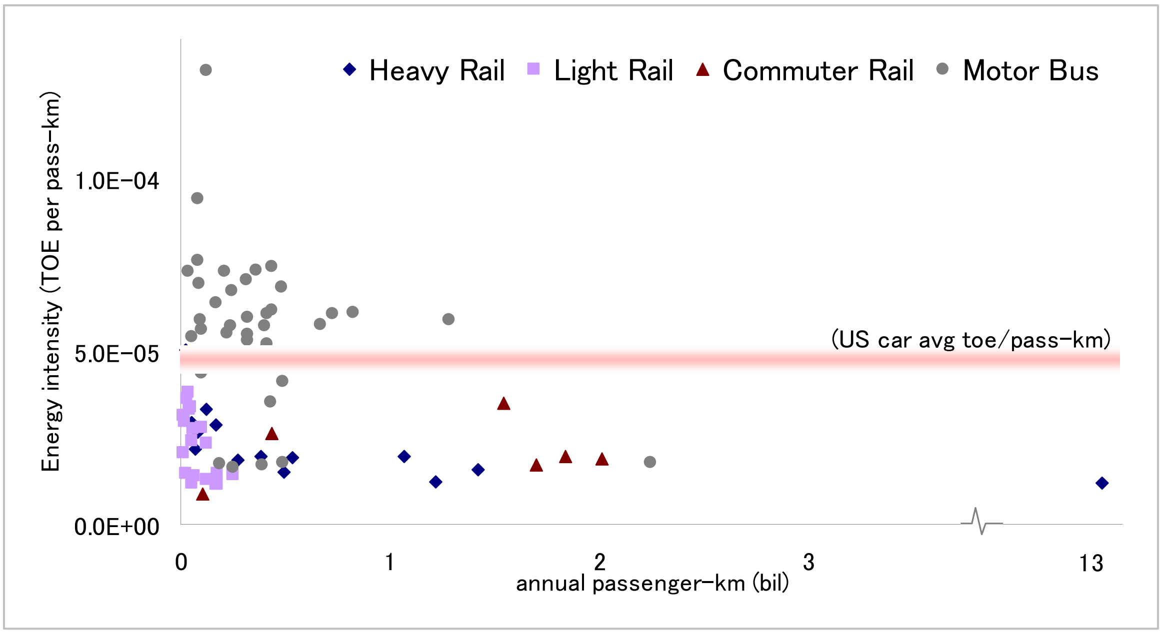
energy efficiency. From a theoretical standpoint, this conclusion is obvious; moreover, it is empirically supported.

URBAN MASS TRANSIT AND ENERGY SAVINGS

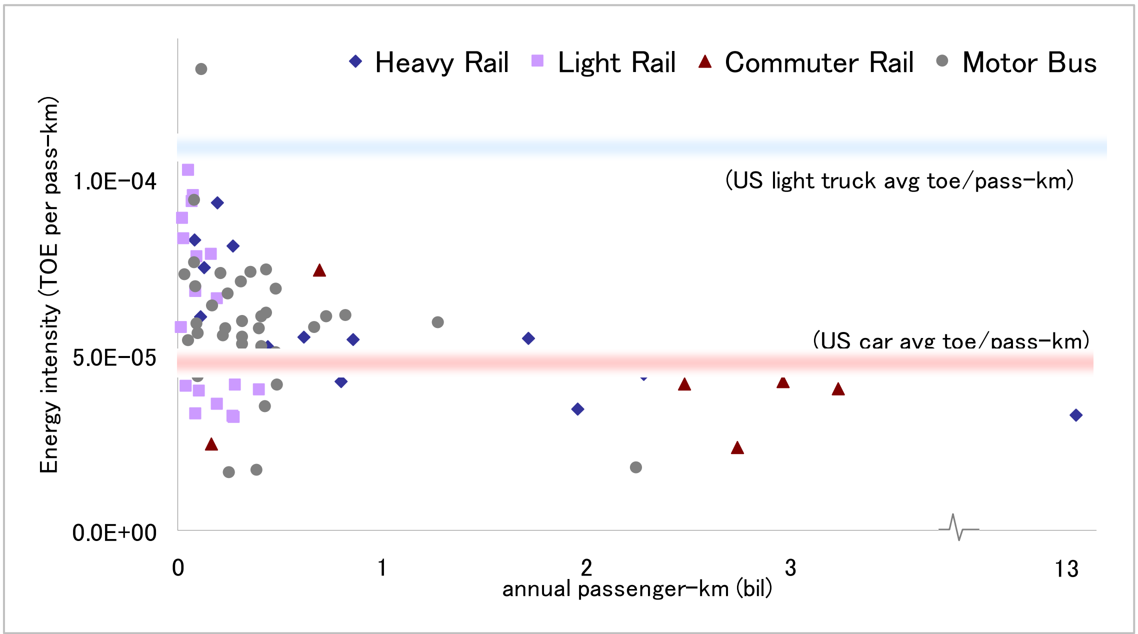
To this point, discussion of mass transit energy use and energy intensity has focused on the relative position of various US systems when compared against various energy intensity-defining factors. Knowing the patterns presented by this relationship can help decision makers place their own cities' systems along the distribution and get a sense of their energy intensity reduction options. It is equally important though to address the absolute energy intensity value itself, to determine if there is truly a need to reduce transit energy intensities. In short, the answer is yes. Urban mass transit systems, at least in the United States, use a surprisingly high amount of energy to move one passenger one kilometre. And depending on the standard used for energy bookkeeping, some modes on average (and numerous individual systems) use more energy per passenger-km than the average-occupancy private automobile does in the United States. Put another way, for some US mass transit systems (bus or rail), total metropolitan area transportation energy use could fall by taking everyone off of the subway, putting them into private automobiles, and shutting down the existing mass transit system. This finding is important, but, it is subject to several important constraints and confounding factors which ultimately still support the extremely valuable role of public transit in urban areas today. Moreover, this finding should not be taken as justification to avoid supporting urban mass transit systems—instead, it should motivate policy makers to carefully consider the local characteristics of their own urban areas in design and implementation of specially-tailored transit systems, rather than simply assuming success.

The energy intensity for a US car was based on a nation-wide average. This value may under-represent an automobile's actual urban energy intensity, since it averages both city and highway fuel economies (city fuel economy tends to be worse than highway). However, in calculating these energy intensities it was assumed that one automobile passenger kilometre was equivalent to one mass transit passenger kilometre, when in fact, due to the inherent rigidity in mass transit routes and the need for transfers, more distance might need to be travelled on a subway, for example, than would be required to reach the same final destination in a passenger vehicle. As such, these factors negate each other in the final analysis.

43.1 **Possible sources of error**



43.2 **Energy intensities of US urban mass transit compared to average energy intensity of US cars, "low" conversion factor**
APERC 2007



44.1 Energy intensities of US urban mass transit compared to average energy intensity of US cars and light trucks, "high" conversion factor
APERC 2007

A key variable in determining urban mass transit (particularly rail transit) energy use is the conversion factor used to convert a fuel like electricity to a common indicator of energy use, such as toe, so that comparisons can be made to diesel or CNG fuel use, for example. In the first chart above, which is repeated from earlier in the chapter, a fairly conservative conversion factor was used for rail electricity use. This conversion factor represents the final energy demand for the transit agency to run its trains. However, a more common conversion used in US urban mass transit literature includes the actual fuel requirements for source electricity generation so that the final electrical energy demand described above can actually be supplied. Given thermal inefficiencies inherent in US electrical generation, the average US electricity generation fuel mix profile, and average electric grid distribution inefficiencies, the actual "energy" requirements for electric-propulsion-reliant heavy and light rail systems are actually much higher.

So, whereas under the "low" conversion factor, US heavy rail systems, on average, have an energy intensity only 29 percent, and light rail systems only percent that of typical private automobile use, the "high" (and commonly used) conversion factor raises these estimates dramatically: 80 percent for heavy rail, and 103 percent for light rail systems.

Commuter rail energy intensity also rises from 71 percent to 102 percent that of private automobiles, and motor buses rise only slightly (albeit from a high starting point) from 98 percent to 101 percent.

This finding is significant. Fair arguments can be made for either conversion factor, depending on what sort of energy accounting is most relevant to a particular city or economy's situation. For the decision maker concerned with energy resource use or GHG emission, the high conversion factor is more applicable (as it goes back to the energy resource itself); for those keeping energy supply and demand balance tables, the low conversion factor should be used. This accounting choice is important though, as it changes the place of (rail) urban mass transit from a transportation energy saver to being squarely

FROM UNIT	TO TOE
kWh Electricity (includes Generation and T&D losses)	2.42E-04
kWh Electricity	8.60 E-05
Gallon CNG	6.31 E-04
Gallon LNG	1.85 E-03
Gallon LPG	1.98 E-03
Gallon Gasoline	2.80 E-03
Gallon Diesel/ Bio-diesel	3.19 E-03

44.2 "High" conversion factors
APERC 2007, International Energy Agency (2004). Energy statistics manual. Paris, France.

in line with private automobile energy requirements. It also changes the rank between different transit modes. Under the low conversion factor, heavy rail systems are clearly the least energy intensive, followed by light rail, commuter rail, and finally motor buses—the only mode clearly on par with private automobiles. With the higher factor, heavy rail systems are still the least energy intensive of the four modes, but with a much less significant margin, and the other three modes now converge at a level equally, or even slightly exceeding that of private automobiles.

An important caveat to this interpretation deals with the popularity of using light trucks for "typically" passenger automobile purposes, such as commuting, in the United States. According to the US Department of Transportation, light trucks (such as pick-ups, vans, or SUVs) accounted for 34.5 percent of total highway miles driven in 2005, compared with 57.5 percent for traditional passenger automobiles. Because, in part, such light trucks are subject to considerably less strict fuel efficiency requirements than passenger automobiles in the United States, their fleet average energy intensity is over twice as high. When compared to light trucks, therefore, or even the typical United States vehicle utilisation mix of mainly passenger automobiles but with a significant portion of light trucks as well, then the energy savings of all modes of urban mass transit, buses included, is significant. The true mix of private vehicles in use on any APEC member economy city's streets, is important to keep in mind when calculating the prospect for possible energy savings through development of urban mass transit.

LOW CONVERSION" MODE TYPE	MODE:CAR		MODE: LIGHT TRUCK		MODE: PASS. VEHICLE	
	Energy Intensity (Average)	Energy Intensity (Median)	Energy Intensity (Average)	Energy Intensity (Median)	Energy Intensity (Average)	Energy Intensity (Median)
COMMUTER RAIL	0.71	0.40	0.32	0.18	0.49	0.27
HEAVY RAIL	0.29	0.24	0.13	0.11	0.20	0.16
LIGHT RAIL	0.37	0.29	0.17	0.13	0.25	0.20
MOTOR BUS	0.98	1.0	0.44	0.45	0.68	0.69

"HIGH CONVERSION" MODE TYPE	MODE:CAR		MODE: LIGHT TRUCK		MODE: PASS. VEHICLE	
	Energy Intensity (Average)	Energy Intensity (Median)	Energy Intensity (Average)	Energy Intensity (Median)	Energy Intensity (Average)	Energy Intensity (Median)
COMMUTER RAIL	1.02	0.86	0.46	0.39	0.70	0.59
HEAVY RAIL	0.80	0.67	0.36	0.30	0.55	0.46
LIGHT RAIL	1.03	0.80	0.47	0.36	0.71	0.55
MOTOR BUS	1.01	1.0	0.45	0.45	0.69	0.69

45.1,2 **Ratio of US urban mass transit, by mode, to US average car, light truck, and mixed passenger vehicle fleet energy intensities for both "high" and "low" conversion factors**
APERC 2007

If one supports the use of the higher, fuel-based electric propulsion conversion factor (and in all cases for motor buses), then little case can be made that urban mass transit systems, as they operate on average in the United States today, significantly save transportation energy as compared to private automobiles (not light trucks, or even the typical US private vehicle mix). Many individual systems, particularly larger ones, with higher passenger utilisation rates and higher station throughput (as shown above) might save energy, but other smaller systems might actually require as much as twice the energy per passenger-km as a typical automobile might. This is important, but it does not mean that urban mass transit systems should be discounted, as transit provides many social, cultural, and environmental benefits whatever its energy intensity. Moreover, even with regard to energy use, urban transit can still be an extremely powerful management tool with regard to fleet fuel-switching.

The data above from United States urban areas suggests that larger rail-based systems with higher passenger utilisation ratios and higher per-station passenger throughput achieve lower passenger-km energy intensities. And while any individual system might not conform to such trends, these indicators are nevertheless useful. For both correlations, relative system ridership is key. For example, the system planner who is considering expansion of currently underperforming urban rail lines should carefully weigh the expected energy-intensity impact of this action against other improvements which might more directly target throughput per station or passenger utilisation ratio. Alternatives in this case might be "aesthetic" improvements such as heightening the image, comfort, and personal safety of rail systems. Other ridership-targeted alternatives might be organisational, such as offering comprehensive and user-friendly cross-system "smart" payment cards. Still other improvements might be structural in nature, such as using smaller trains in under-capacity systems (targeting passenger utilisation ratios in the short-term) while increasing frequency of service (targeting station throughput in the mid-term). This, of course, is not to say that system expansion by itself cannot help decrease energy intensity, but the fundamentals would certainly not suggest it.

In short, reducing mass urban transit energy intensity is all about getting more riders to ride more transit —and while some small and well-subscribed systems can succeed in this regard, many of them fail spectacularly. Because of this, policy makers need to carefully weigh design priorities—increasing a system's service population, for example, is noble in many regards, but it very well could be foolish from an energy perspective. For many urban areas, an energy-conscious transit system will probably be a system with a smaller footprint-- and one that targets the "low-hanging fruit" riders.

Of course, the non energy-related benefits of urban mass transit are many, and this chapter will not go into depth on such issues. Such benefits, which include increased economic access to transportation for the poor, congestion relief, improved road safety, reduction of local pollutants, "liveable" land use development, modal split diversification, and civic pride and attractiveness are both valuable and far-reaching, often creating synergistic feedbacks in a multitude of other desirable areas within a metropolitan region. In fact, because urban transportation planners in APEC cities (particularly developing cities) generally identify alleviation of these more "visible" issues (e.g.

> Asian mega-cities, in contrast to cities in the US, tend to have large populations and relatively high population density. As such, these US transport energy findings could be rather atypical and not transferable to other mega-cities. For example, analysis Tokyo's heavy rail network yields quite different energy intenisty results. The Toei Metro subway network, a heavy rail system operated by the Tokyo Metropolitan Bureau of Transportation, has an energy intensity that is about one-third that of New York City's MTA system, which has the lowest heavy rail energy intensity for the US. Of course, Tokyo's rail network itself might actually be an extreme "best case" example, since it benefits from the city's unique set of transit-oriented development patterns, high population density, and elevated ridership rates.

46.1 **US vs. Asian megacities, the case of Tokyo** congestion, road safety, and local pollution) as being of the highest priority, then urban mass transit systems are beneficial with or without reduced overall transportation energy intensity.

Secondly, it is important to remember that energy intensity is only one of many measures which directly or indirectly affect urban transportation energy use. Apart from gross energy consumption, urban mass transit systems are also useful tools in controlling the type of fuels used, and the way in which those fuels are used. When urban travellers switch from private vehicles to public transit infrastructure (or privately-controlled mass-transit), the transportation planner gains additional control over those riders' energy use—private choices become public choices. For example, an urban mass transit system gives the energy planner control over fuel quality or fuel type. Because of the nature of fleet vehicles, which are limited in number, have high turnovers, specially-train operators, and rely on specialised fuelling and maintenance facilities, they lend themselves to such initiatives as the implementation of ultra-low-sulphur diesel, or the use of hybrid drivetrains.

Fuel switching, which can be appealing from economic, risk mitigation, environmental (local and global), and public perception grounds is also relatively easy when compared with implementation over an urban area's entire private vehicle fleet. For example, if a local or national government has a policy goal of increasing the use of CNG for transportation energy demand, the biggest, cheapest, and fastest impact can be made by converting city bus fleets to CNG systems. This very technique is common in APEC urban areas today. Fuel switching is taken to its logical extreme with the development of heavy and light rail systems which effectively substitute electricity for the gasoline or diesel which might have otherwise been used in a private vehicle. This option could be extremely attractive for the decision maker concerned with local or even global environmental impacts of transportation. By eliminating local hydrocarbon combustion and shifting propulsion generation to distant power plants, local pollution (and urban health impacts) is reduced. Moreover, if electricity is generated through means, such as renewables, that minimise negative generation externalities, then the reduction of GHG emissions and consequent effect on global climate change can be significant.

Discussion of mass urban transit highlights the distinction between average and marginal energy use and energy intensity in transportation. In short, transport planners should be primarily concerned with averages (or medians), such as those presented in this chapter, while individual travellers should instead consider the margin. For private vehicles use, average and marginal energy intensity is actually the same; each new trip taken follows an average energy intensity, and, at the margin, energy equal to the average is used as a result of taking that trip (energy that would not have otherwise been consumed). In mass transit, however, the number of trips taken does not significantly affect total fuel use or service provided, and so while the statistical average energy intensity per passenger-km might be rather high, the marginal energy used as a result of an individual's decision to use mass transit is zero (or very near zero, accounting for negligible added mass, or in the case of buses, the possibility of an extra loading stop). Put another way, a subway runs whether or not a person decides to take it, but a car will either stay in the garage or be burning gasoline. Therefore, while the energy savings of mass transit are questionable from a planner's perspective (looking at averages), the savings are unequivocal for the individual traveller who will always operate at the margin. So, the question is not, "What should we take?" but rather, "What should we build?"

47.1 **Live at the margin, plan with the average**

AGENCY	LOCATION	MODE TYPE *	UNLINKED PASS-TRIPS (thousands)	PASS-KM (thousands)	AVG TRIP LENGTH (km/ pass-trip)	POPULATION (2000)	POPULATION DENSITY (persons/km2)	FUEL SOURCE **	LOW		HIGH	
									ENERGY CONSUMPTION (TOE)	ENERGY INTENSITY (TOE/ pass-km)	ENERGY CONSUMPTION (TOE)	ENERGY INTENSITY (TOE/ pass-km)
LACMTA	Los Angeles/ Long Beach	HR	35,412	271,871	7.7	9,519,338	905	E	7.8E+03	2.9E-05	2.2E+04	8.1E-05
BART	San Francisco/ Oakland	HR	98,221	1,956,839	19.9	4,123,740	644	E	2.4E+04	1.2E-05	6.7E+04	3.4E-05
WMATA	Washington, DC	HR	251,112	2,284,819	9.1	4,923,153	292	E	3.6E+04	1.6E-05	1.0E+05	4.4E-05
MDT	Miami/Fort Lauderdale	HR	15,394	195,275	12.7	3,876,380	475	E	6.5E+03	3.3E-05	1.8E+04	9.3E-05
MARTA	Atlanta	HR	76,662	797,841	10.4	4,112,198	259	E	1.2E+04	1.5E-05	3.4E+04	4.2E-05
CTA	Chicago	HR	183,580	1,715,630	9.3	8,272,768	631	E	3.3E+04	1.9E-05	9.4E+04	5.5E-05
MBTA	Boston	HR	151,639	857,492	5.7	3,406,829	651	E	1.6E+04	1.9E-05	4.7E+04	5.4E-05
MTA	Baltimore	HR	13,552	110,381	8.1	2,552,994	378	E	2.4E+03	2.2E-05	6.7E+03	6.1E-05
PATH	New York/ Newark/ Jersey City	HR	65,904	439,995	6.7	11,956,199	1669	E	8.1E+03	1.9E-05	2.3E+04	5.2E-05
PATCO	Philadelphia	HR	9,326	129,152	13.8	5,100,931	511	E	3.4E+03	2.7E-05	9.7E+03	7.5E-05
NYCT	New York	HR	1,749,030	13,090,509	7.5	9,314,235	3150	E	1.5E+05	1.2E-05	4.3E+05	3.3E-05
SIRTOA	New York	HR	3,550	35,783	10.1	9,314,235	3150	E	1.8E+03	5.0E-05	5.1E+03	1.4E-04
GCRTA	Cleveland	HR	7,330	83,528	11.4	2,250,871	321	E	2.4E+03	2.9E-05	6.9E+03	8.3E-05
SEPTA	Philadelphia	HR	86,377	618,285	7.2	5,100,931	511	E	1.2E+04	2.0E-05	3.4E+04	5.5E-05
LACMTA	Los Angeles/ Long Beach	LR	35,288	400,534	11.4	9,519,338	905	E	5.7E+03	1.4E-05	1.6E+04	4.0E-05
Sacramento RT	Sacramento	LR	10,275	86,416	8.4	1,628,197	154	E	2.1E+03	2.4E-05	5.9E+03	6.8E-05
San Diego Trolley, Inc.	San Diego	LR	27,384	272,218	9.9	2,813,833	259	E	3.1E+03	1.2E-05	8.8E+03	3.2E-05
MUNI	San Francisco	LR	47,351	192,191	4.1	1,731,183	658	E	4.5E+03	2.3E-05	1.3E+04	6.6E-05
VTA	San Jose	LR	7,285	53,870	7.4	1,682,585	503	E	2.0E+03	3.8E-05	5.7E+03	1.1E-04
RTD	Denver	LR	10,440	73,798	7.1	2,109,282	217	E	2.5E+03	3.4E-05	7.0E+03	9.5E-05
MBTA	Boston	LR	73,778	284,283	3.9	3,406,829	651	E	4.2E+03	1.5E-05	1.2E+04	4.1E-05
MTA	Baltimore	LR	6,995	68,709	9.8	2,552,994	378	E	2.1E+03	3.3E-05	6.4E+03	9.4E-05
Metro Transit	Minneapolis/ St. Paul	LR	7,902	86,468	10.9	2,968,806	189	E	1.0E+03	1.2E-05	2.9E+03	3.3E-05
METRO	St. Louis	LR	15,164	196,705	13.0	2,603,607	157	E	2.5E+03	1.3E-05	7.1E+03	3.6E-05
NJ TRANSIT	New York/ Northern New Jersey/ Philadelphia	LR	4,981	19,966	4.0	21,078,148	795	E	4.2E+02	2.0E-05	1.1E+03	5.8E-05
NFT Metro	Buffalo/ Niagara Falls	LR	5,585	21,974	3.9	1,170,111	288	E	6.9E+02	3.2E-05	2.0E+03	8.9E-05
GCRTA	Cleveland	LR	3,074	29,263	9.5	2,250,871	321	E	8.6E+02	3.0E-05	2.4E+03	8.3E-05
TriMet	Portland	LR	31,504	278,460	8.8	1,918,009	147	E	3.2E+03	1.1E-05	8.9E+03	3.2E-05
Port Authority	Pittsburgh	LR	7,265	50,310	6.9	2,358,695	197	E	1.8E+03	3.6E-05	5.2E+03	1.0E-04
SEPTA	Philadelphia	LR	23,978	95,238	4.0	5,100,931	511	E	2.6E+03	2.8E-05	7.4E+03	7.8E-05
DART	Dallas	LR	15,610	163,153	10.5	5,221,801	221	E	4.4E+03	2.8E-05	1.3E+04	7.8E-05
Metro	Houston	LR	10,234	41,144	4.0	4,427,804	271	E	6.0E+02	1.5E-05	1.7E+03	4.1E-05
UTA	Salt Lake City	LR	12,039	104,855	8.7	1,333,914	318	E	1.4E+03	1.4E-05	4.2E+03	4.0E-05
Metra	Chicago	CR	69,100	2,480,471	35.9	8,272,768	631	D, E	8.7E+04	3.5E-05	1.0E+05	4.2E-05
NICTD	Chicago	CR	3,696	164,736	44.6	8,272,768	631	E	1.4E+03	8.8E-06	4.1E+03	2.5E-05
NJ TRANSIT	New York/ Northern New Jersey/ Philadelphia	CR	66,773	2,738,847	41.0	21,078,148	795	D, E	4.6E+04	1.7E-05	6.4E+04	2.4E-05
MTA-MNCR	New Haven/ Bridgeport/ New York/ Stamford	CR	73,699	2,961,779	40.2	10,669,419	2016	D, E	5.6E+04	2.0E-05	1.3E+05	4.2E-05
MTA LIRR	New York/ Long Island	CR	98,012	3,234,622	33.0	12,068,148	1991	D, E	6.1E+04	1.9E-05	1.3E+05	4.0E-05
SEPTA	Philadelphia	CR	31,252	696,595	22.3	5,100,931	511	E	1.8E+04	2.6E-05	5.2E+04	7.4E-05

AGENCY	LOCATION	MODE TYPE *	UNLINKED PASS-TRIPS (thousands)	PASS-KM (thousands)	AVG TRIP LENGTH (km/ pass-trip)	POPULATION (2000)	POPULATION DENSITY (persons/km2)	FUEL SOURCE **	LOW		HIGH	
									ENERGY CONSUMPTION (TOE)	ENERGY INTENSITY (TOE/ pass-km)	ENERGY CONSUMPTION (TOE)	ENERGY INTENSITY (TOE/ pass-km)
LACMTA	Los Angeles/ Long Beach	MB	365,540	2,245,542	6.1	9,519,338	905	D, C	4.0E+04	1.8E-05	4.0E+04	1.8E-05
CTA	Chicago	MB	303,270	1,279,041	4.2	8,272,768	631	D	7.5E+04	5.9E-05	7.5E+04	5.9E-05
NJ TRANSIT	New York/ Northern New Jersey/ Philadelphia	MB	143,910	1,433,336	10.0	21,078,148	795	D, C	6.8E+04	4.7E-05	6.8E+04	4.7E-05
NYCT	New York	MB	964,493	3,070,229	3.2	9,314,235	3150	D, C, E	1.4E+05	4.5E-05	1.4E+05	4.5E-05
SEPTA	Philadelphia	MB	177,363	823,306	4.6	5,100,931	511	D	5.0E+04	6.1E-05	5.0E+04	6.1E-05
AC Transit	San Francisco/ Oakland/ San Jose	MB	66,634	313,788	4.7	7,039,362	369	D, G	2.2E+04	7.1E-05	2.2E+04	7.1E-05
OCTA	Orange County	MB	64,758	402,183	6.2	2,846,289	1392	D, L	2.3E+04	5.7E-05	2.3E+04	5.7E-05
MUNI	San Francisco/ Oakland	MB	93,412	319,265	3.4	4,123,740	644	D	1.9E+04	6.0E-05	1.9E+04	6.0E-05
MUNI	San Francisco/ Oakland	TB	76,857	185,376	2.4	4,123,740	644	E	3.2E+03	1.7E-05	9.0E+03	4.9E-05
VTA	San Jose	MB	37,599	244,488	6.5	1,682,585	503	D, C, O	1.6E+04	6.7E-05	1.6E+04	6.7E-05
RTD	Denver	MB	51,788	399,641	7.7	2,109,282	217	D, C	2.0E+04	5.0E-05	2.0E+04	5.0E-05
WMATA	Washington, DC	MB	150,582	727,471	4.8	4,923,153	292	D, C	4.4E+04	6.1E-05	4.4E+04	6.1E-05
BCT	Miami/ Fort Lauderdale	MB	34,604	236,036	6.8	3,876,380	475	D	1.4E+04	5.7E-05	1.4E+04	5.7E-05
LYNX	Orlando	MB	22,303	220,629	9.9	1,644,561	182	D, C	1.2E+04	5.5E-05	1.2E+04	5.5E-05
MDT	Miami/Fort Lauderdale	MB	70,061	481,074	6.9	3,876,380	475	D, G	3.3E+04	6.9E-05	3.3E+04	6.9E-05
MARTA	Atlanta	MB	73,936	430,612	5.8	4,112,198	259	D, C, O	1.5E+04	3.5E-05	1.5E+04	3.5E-05
DTS	Honolulu	MB	70,466	486,779	6.9	876,156	564	D	2.0E+04	4.1E-05	2.0E+04	4.1E-05
PACE	Chicago	MB	29,993	320,416	10.7	8,272,768	631	D	1.7E+04	5.3E-05	1.7E+04	5.3E-05
MBTA	Boston	MB	119,953	414,245	3.5	3,406,829	651	D, C	2.2E+04	5.2E-05	2.2E+04	5.2E-05
MTA	Baltimore	MB	79,452	412,093	5.2	2,552,994	378	D	2.5E+04	6.1E-05	2.5E+04	6.1E-05
DDOT	Detroit	MB	37,577	316,796	8.4	4,441,551	440	D, C	1.7E+04	5.5E-05	1.7E+04	5.5E-05
Metro Transit	Minneapolis/ St. Paul	MB	65,693	436,546	6.6	2,968,806	189	D	2.7E+04	6.2E-05	2.7E+04	6.2E-05
METRO	St. Louis	MB	31,203	209,086	6.7	2,603,607	157	D, C	1.5E+04	7.3E-05	1.5E+04	7.3E-05
Academy Lines, Inc.	Philadelphia	MB	6,795	386,055	56.8	5,100,931	511	D	6.6E+03	1.7E-05	6.6E+03	1.7E-05
PATH	New York/ Newark/ Jersey City	MB	69,169	484,867	7.0	11,956,199	1669	E	8.7E+03	1.8E-05	2.4E+04	5.0E-05
MTA Long Island Bus	New York/ Long Island	MB	30,935	250,419	8.1	12,068,148	1991	D, C	4.1E+03	1.6E-05	4.1E+03	1.6E-05
NYCDOT	New York	FB	20,034	167,658	8.4	9,314,235	3150	D	1.1E+04	6.4E-05	1.1E+04	6.4E-05
GCRTA	Cleveland	MB	49,846	307,115	6.2	2,250,871	321	D, C	1.5E+04	4.9E-05	1.5E+04	4.9E-05
TriMet	Portland	MB	69,943	389,550	5.6	1,918,009	147	D	1.9E+04	5.0E-05	1.9E+04	5.0E-05
Port Authority	Pittsburgh	MB	62,082	437,662	7.0	2,358,695	197	D, C	3.2E+04	7.4E-05	3.2E+04	7.4E-05
DART	Dallas	MB	49,101	358,309	7.3	5,221,801	221	D, L	2.6E+04	7.3E-05	2.6E+04	7.3E-05
Metro	Houston	MB	73,567	669,095	9.1	4,427,804	271	D, C	3.9E+04	5.8E-05	3.9E+04	5.8E-05
King County Metro	Seattle	MB	70,975	679,533	9.6	2,414,616	211	D	3.3E+04	4.9E-05	3.3E+04	4.9E-05
COT	Tucson	MB	15,741	91,572	5.8	843,746	35	D, C	4.3E+03	4.7E-05	4.3E+03	4.7E-05
NCTD	San Diego	MB	10,281	93,488	9.1	2,813,833	259	D, C	5.5E+03	5.9E-05	5.5E+03	5.9E-05
CTTransit	Hartford	MB	14,838	89,462	6.0	1,183,110	272	D	6.2E+03	6.9E-05	6.2E+03	6.9E-05
RTS	Gainesville	MB	7,613	35,213	4.6	217,955	96	D, E	2.6E+03	7.3E-05	2.6E+03	7.3E-05
TARC	Louisville	MB	14,771	81,171	5.5	1,025,598	191	D	6.2E+03	7.6E-05	6.2E+03	7.6E-05
KCATA	Kansas City	MB	13,962	80,052	5.7	1,776,062	127	D	7.5E+03	9.4E-05	7.5E+03	9.4E-05
NFT Metro	Buffalo/ Niagara Falls	MB	18,359	98,896	5.4	1,170,111	288	D, C	4.3E+03	4.4E-05	4.3E+03	4.4E-05
LTD	Eugene/ Springfield	MB	8,466	52,936	6.3	322,959	27	D, E	2.9E+03	5.4E-05	2.9E+03	5.4E-05
MATA	Memphis	MB	10,779	99,989	9.3	1,135,614	146	D	5.6E+03	5.6E-05	5.6E+03	5.6E-05
UTA	Salt Lake City	MB	19,956	119,217	6.0	1,333,914	318	D, C	1.6E+04	1.3E-04	1.6E+04	1.3E-04
GRTC Transit System	Richmond	MB	13,040	62,438	4.8	996,512	131	D	3.0E+03	4.8E-05	3.0E+03	4.8E-05

49.1 US urban mass transit agency operating statistics, 2002 and 2005 average

APERC 2007, USFTA-NTD 2002 and 2005

** Mode Type: (HR): Heavy Rail (LR): Light Rail (CR): Commuter Rail (MB): Motor Bus (TB): Trolley Bus (FB): Ferry Bus*

*** Fuel Source: (D): Diesel/ Bio-diesel (E): Electricity (G): Gasoline (C): Compressed Natural Gas (L): Liquefied Natural Gas (O): Other*

METHODS IN PLACE TO REDUCE TRANSPORT ENERGY USE IN APEC

There are diverse tools at the disposal of APEC region policy makers to address growing urban transport energy demand. The effectiveness and popularity of particular tools, however, varies. This section provides a brief overview of mechanisms in place within APEC economies and explores methods that have shown particular promise as well as those which have exhibited unintended results.

OVERVIEW OF METHODS IN PLACE

Transport demand within urban areas is influenced by population and economic growth, among other factors. Along with recent growth in personal income within the APEC region, these factors have contributed to further increases in travel demand (resulting from the spatial expansion of urbanised areas), passenger vehicle ownership, and passenger vehicle use. Unless coupled with effective transport system management, these factors can bring about a *transport dilemma*, which is epitomised by increased urban transport energy use. This rise in energy use is amplified by traffic congestion and, in turn, reduced attractiveness of road-based mass transit.[a]

[a] *The transport dilemma is also characterised by an increase in road–traffic related air pollution.*

To mitigate and/or manage rising energy use in the transport sector, APEC region cities have tried a number of different mechanisms. These measures fall into the following key categories:

- **Regulatory (2 types):**

  Control of vehicle ownership**,** through the use of licensing fees, insurance requirements, and ownership taxes;

  Control of vehicle use, through fuel taxes, road congestion pricing, plate restriction schemes, and other traffic demand management measures

- **Control of vehicle energy consumption,** through regulatory approaches such as fuel economy standards, or through incentive programmes such as fuel-efficient auto-use perks

- **Alternative transport promotion schemes**, which focus on mass transit and non-motorised transport encouragement, such as the development of cross-system rider planning tools and pedestrian routes, respectively

In this chapter, an exploratory look is given to a select few noteworthy measures, which either **demonstrate potential promise** or have **resulted in unintended consequences**. Three to four measures are discussed in each of these categories. As a caveat, these examples are not exclusive or exhaustive. They are only meant to highlight measures that have potential niche application within the APEC region.

In analysing any of these management policies, it is important to keep in mind that measures are fluid, which means that their effects will change over time. There could be substantial (potentially adverse) differences between short term and long term outcomes. In addition, the way in which a measure is designed can create conflict between its stated objectives and those of other policies. As such, in order to ensure a balance between policy objectives, an integrated planning approach is recommended.

Measures Which Focus on Passenger Vehicles			
Control of Auto Ownership	Control of Auto Use	Reduction of Auto Energy Use	Planning and Coordination
Automobile sales tax One-time licensing fees *-flat, graduated, or auctioned* Reoccurring registration fees *-sticker-type, smog tests, driver license* Parking fees *-residential* Minimum insurance requirements Car sharing services *–public, private short-term rental*	Road pricing *-restricted area fees, real-time congestion charges* Local fuel tax National fuel tax Parking fees *-business/ public areas* Plate restriction schemes Direct fleet use restrictions *-no drive days* Pedestrian zones *–weekend, workday* Traffic demand management	Fuel economy standards "Gas-guzzler" taxes and fees *-fuel-consumption-tied purchase fees, parking fees* Driver awareness campaigns *-driving habits, upkeep* Car maintenance requirements Auto age restrictions Fuel-efficient auto purchasing incentives *-hybrid subsidies* Fuel-efficient auto use perks *-reduced congestion charges, free HOV access*	Agency coordination Long-term planning Outside transport consultants

Measures Which Focus on Alternative Transportation		
Mass transit	Carpooling	Non-motorized transport
Bus network Bus rapid transit (BRT) network Heavy rail/ subway network Light rail network Commuter rail network Facilitation of transit connections *-feeder bus routes, park and ride service* Campaigns to improve mass transit comfort, safety, image, speed Cross-system shared ticketing schemes *-RFID/ IC-type stored value cards* Cross- system rider planning tools *-by internet, by phone*	Carpool lanes Employer benefits *-cash subsidies, provision of contingency transport options* Ride sharing services	Pedestrian routes/tunnels Bicycle routes/ lanes Bicycle parking facilities Public awareness campaigns

52.1,2 **Examples of methods in place to reduce transport energy use in APEC, by focus and theme**
APERC 2007

METHODS SHOWING PROMISE

The "up and coming" methods presented below have generally shown good results or future promise in reducing transport energy in APEC. Results, however, vary. These examples are not intended to be exclusive or exhaustive-- equally valid methods are not addressed—but instead are simply meant to be illuminative thought provokers. Readers are encouraged to envision what implementation of the following methods might look like is their own urban centres.

EMPLOYER-BASED INCENTIVES

Commuting is major component of transportation demand in urban areas, and compared to other drivers for travel demand such as entertainment or shopping, commuting journeys are largely repetitive and simple in structure. Because of these characteristics, commuting is also arguably the easiest and most effective personal transportation "sub-sector" towards which to focus efforts in reducing demand for auto use.

Efforts to reduce demand for private automobile use in commuting have traditionally come from the public sector in the form of providing mass transit infrastructure. In recent years, however, employers themselves (in fact, the true "demanders" for commuting) have made great strides in establishing their own tailor-made systems of incentives or deterrents aimed at reducing passenger vehicle commuting by their employees. Such employer-based systems are undertaken for many reasons: they may be voluntarily initiated by the employer for financial or space reasons, used as a perk to attract the best employee talent, or implemented out of a sense of moral obligation towards the environment, for example; employer-based systems can also be initiated as a result of (typically city- or neighbourhood-level) public-sector legislation aimed at reducing end-result manifestations of transportation demand such as local traffic loads, pollution, parking, or energy use—in this case, employers might be required to achieve a certain end-result with the threat of repercussions, but they are given the leeway to decide for themselves how best to implement measures to achieve that mandate. Voluntary or required, however, both motivations are attractive in that they ultimately benefit from the informational, persuasive, and financial resources of individual employers in influencing employer travel habits.

One of the most obvious ways for employers to reduce the commuting needs of their employees is by not requiring them to commute at all. Telecommuting, while it does not eliminate transportation energy demand equal to that required during commuting (see Case Study: San Francisco Bay Area in this report), does nevertheless do a good deal to reduce energy demand and has been particularly effective in various APEC region urban areas. Telecommuting, however, is naturally positioned to reduce the commuting energy needs of IT workers in comparatively developed regions, and so may not be an effective overall strategy for all urban areas.

Employers in many sectors, however, can also attempt to reduce the *distance* or preferred modes of employee commutes through financial incentives. The US-based Internet social-networking company Facebook, Inc., voluntarily offers USD 600 monthly housing subsidies to employees who live within a 1-mile radius of their Palo Alto, California headquarters.[b] This practice encourages employees to affordably live close enough to the workplace's relatively high-rent central business district (CBD) location that they can walk or bicycle to office. And because the Palo Alto CBD has multiple zonings with a number of thriving business, these employees who pay higher (but offset) rents can also take advantage of their central location to reduce the energy needs of non-commuting travel as well. It is unclear however, if Facebook's housing stipend is motivated more by a desire to reduce energy use or if it is instead seen as a perk to attract the best employees in the highly competitive Silicon Valley job market—for example, facebook also offers free parking permits for employees, which would probably *induce* commuting energy use. The exact motivation is unimportant however, in that end result is the same—painless reduction in transport energy demand.

This synergy of employee satisfaction and energy demand reduction should be extremely persuasive for transport planners who are looking to make a large impact with minimal public expenditures.

[b] *Facebook, Inc. (2007). Facebook jobs. California, USA. http://www.facebook.com/jobs.php*

And while some employers voluntarily adopt measures for commuting demand control, the prospect is far from certain. Local policy makers can encourage the practice, therefore, by offering their own monetary incentives or awards but using employers as vectors to decide the most efficient implementation (following the "wisdom of the masses")—in effect, shifting the planning and logistics away from public groups and onto employers. Alternately, policy makers can shift both the planning *and* financial burdens to employers through unfunded mandated requirements. If the action is justified (politically feasible), and the penalties for non-attainment are great enough, the optimising employer will leverage its own informational, human, and financial capital to meet the targets as efficiently as possible. Moreover, because employees can be more responsive to employer regulations or suggestions than to publicly-endorsed educational campaigns, employers implementing travel demand reduction schemes can have more direct influence and persuasive power over travellers' choices.

Stanford University, located south of San Francisco, CA in the United States, implements one such "mandated" private automobile transport reduction scheme. The University, the major employer of the area, is legally required as part of its "General Use Permit"-- negotiated with neighbouring Santa Clara County in 2000 and which governs University development, land, and water use-- to generate "no net new commute trips" over the life of the Permit.[c] If Stanford fails to comply with this requirement, it is legally bound to monetary damages to the County, including the construction of costly new road infrastructure surrounding the University.

[c] *County of Santa Clara California (2007). Stanford University general use permit. California, USA.*

The incentive, therefore, for Stanford to act in its own right to reduce commute trips is great. In response, the University has instituted a comprehensive set of measures with both penalties and incentives for employees and some students.[d] "Penalties" include: graduated (and yearly-increasing) parking permit pricing for commuting employees, and; removal of parking lots or relocation out from central campus locations. Incentives are rather more numerous, and include: bicycle lane construction, free lockers and shower facilities on campus for employees, free bicycle registration (to prevent theft), heavily subsidised bicycle helmets, and bicycling education campaigns; "guaranteed ride home" programmes that reimburse non-driving employees for emergency or unexpected travel to and from work by taxi; yearly vouchers for hourly car-rental on campus; discounted parking permits and more desirable parking locations for registered carpools of two or more passengers per vehicle; ridesharing coordination services; awards and yearly cash payouts (USD 216) to non-drivers; free or heavily subsidised passes for San Francisco Bay Area mass transit agencies; a daily, free, long-distance chartered employee "commute bus", and; an extensive free (biodiesel-fuelled) shuttle bus system, with sophisticated GPS-based real-time mapping available to riders online, to facilitate transfers from other mass transit or for other needs.

[d] *Stanford University Parking and Transportation Services (2007). Alternative transportation. California, USA. http://transportation.stanford.edu*

For its efforts, the University has received a number of awards from local and national agencies, though it still struggles to meet the "no net new commute trips" mandate. Even with the cost of the programme, however, Stanford elects to continue to pursue an expand it – in part because it is seen as generally successful and cost-effective when compared to the alternatives for non-attainment. Santa Clara County, in turn has reaped the benefits of private automobile demand reduction with minimal direct intervention.

Though the examples above focus on employer-based private automobile reduction implementations in the United States, this practice is not limited to developed areas. In fact, employer-based schemes such as these can be implemented wherever employers have the managerial flexibility, resources, and will to do so—especially in markets with strong demand for skilled labour where employers and the general public reap the "win-win" synergies of energy reduction with employee satisfaction. Moreover, employer-based schemes need not be so extensive in nature to effect change in employee habits. Even small businesses can chose or be required to implement commute reductions by, for example, offering fewer parking spaces than there are employees and offering to compensate employees who do not drive through redistribution of parking permit revenue. Again, the advantage of the employer-based system is its ability to be tailored to a specific groups needs and opportunities, so actual implementations can vary widely. All of these examples, however, offer useful roadmaps for employer-based models which can relatively painlessly be duplicated in whole or piecemeal in other APEC region urban areas.

PRICING OF PARKING

Proper pricing of parking for passenger vehicles can help reduce both passenger vehicle ownership and passenger use. Though there is some overlap to both, the pricing and limitation of "garaging" (parking for automobile storage at or near one's residence) more directly reduces demand for vehicle *ownership*, while the pricing and limitation of "parking" (in public and business areas) more directly affects modal choice and demand for vehicle *use*.

In short, cheap and overabundant garaging and parking induces passenger vehicle ownership and use while reducing quantity and/or increasing price reduces vehicle ownership and use.

Efforts directed towards limiting garaging vary widely among APEC urban areas. Generally, garaging limitations are enacted by the private sector as governments often resist measures that may directly limit passenger vehicle ownership for fear of dampening a domestic auto industry, for example. In many cities then, garaging fees are charged directly and periodically by real-estate developers, while in other areas the concept of directly charging for garaging is anathema and the only price paid is through "opportunity cost" of using one's own land to store a vehicle rather than develop it in another way.

Public measures which address garaging do, however, exist is some APEC region urban areas. In Tokyo, as well as other large Japanese urban areas, passenger vehicle purchasers are required to prove forward contracts for garaging within 5km of their residence before taking ownership. Although there is no direct cost to owners for this government registration, it does ensure that prospective vehicle buyers are fully aware of the garaging costs they will bear in future years as a result of their vehicle purchase. In Tokyo, where monthly garaging fees easily exceed USD 300 per month, this regulation helps to increase the probability of an economically efficient purchasing decision.

Parking pricing and other limitations—such as a motorist might encounter when visiting public areas or places of business-- are viewed by vehicle owners as being incidental and indirect when compared to garaging pricing. Because fees or other limitations are encountered only when actually using one's vehicle (as opposed to garaging fees, which one pays regardless of vehicle use), parking pricing can be an effective tool to limit passenger vehicle *use* without discouraging aspirations of vehicle *ownership*. Targeting vehicle use through parking fees or limitations is a more efficient way to address actual transportation energy use and is more likely to incentivise vehicle owners to shift to less-energy intensive transport modes or even reduce total travel demand. Such travel decisions, from a purely economic perspective, are made at the margin, and in the trip planner's mental calculus, parking fees are added to other incidentals such as gasoline or road pricing and help make non-passenger vehicle transport relatively more attractive than passenger vehicle transport on a case by case basis.

Many APEC urban areas engage in parking pricing, generally through "on-street" metering by the public sector and single or multi-level parking lots by the public or private sector, though rates vary dramatically among economies, or even among cities within one economy. Coordination in pricing between privately-operated parking lots and public on-street parking is a critical concern. When on-street parking is under-priced (and therefore over-demanded) and private parking lots are inconveniently placed or "over-priced" motorists will endlessly circle around their destination in search for unavailable "cheap" on-street parking instead of using an available (but "expensive") parking lot—increasing vehicle energy use.

Beijing, China faces this very problem-- parking lots are roughly 2.5 times the price of on-street parking, which has led to a certain unwillingness to use them. To address this situation, the Beijing government proposed stronger coordination among parking facilities in 2005.[e] In this case (and in most APEC urban areas), on-street fees should probably be increased to become commiserate to lot fees—average parking fees in Beijing in 2002 were nearly 10 times lower than in Guangzhou.[f]

Guangzhou, in turn, has struggled with another parking fee coordination issue—geography. In the past, parking lots throughout the city were priced the same. While this did provide a uniform price signal in discouraging all forms of passenger vehicle use, it also ignored the reality of certain parking areas being more desirable than others. From a parking perspective therefore, a driver living on the outskirts of town would face the same parking price signal driving only a short distance from his home as she would going all the way downtown. In part because of this situation, the Guangzhou government instituted a series of parking zones with graduated pricing in 2004.[g]

An entrenched problem encountered, however, when limiting people's demand for parking through price instruments is misalignment of the incentives that surround parking. Most notably, store owners understandably resist any measures to limit parking availability that might reduce consumer traffic fearing that they might lose business. For them, cheap and available parking can have positive externalities. Similarly, real estate developers, hoping to attract tenants, might depend on cheap garaging as an added perk—particularly in overheated housing markets. For the general public, however, net externalities due to (excessive) cheap parking are generally negative and extend far beyond transport energy use and into all other negative aspects of passenger vehicle use-- including pollution, congestion, and mortality—as well as the "direct" land use externalities of the parking space itself. Private parking providers, for their part, aim for operational profits and so price their offerings to maximise lot revenues—achieving this equilibrium of price and quantity depends on local conditions, but one could generally assume that private lot operators would support increased parking fees. Such concerns are often a primary obstacle to

[e] *China Daily (2005). Parking fees to be launched in Beijing. Li Jing. Beijing, China.*

[f] *china.org.cn (2002). Traffic congestion in Beijing: what to do? Zhang Yan. China. http://www.china.org.cn/english/2002/Mar/28866.htm*

[g] *China Daily (2004). Cars outstrip parking supply in Guangzhou. Liang Qiwen. Beijing, China.*

achieving harmonious parking pricing policy, and the needs of these stakeholders should be incorporated into the parking pricing planning process.

"SMARTCARD" UNIFIED PAYMENT SYSTEMS

Urban mass transit, if designed effectively, can help reduce the reliance on passenger vehicles. Thus far, however, urban mass transit has been plagued by deficiencies in customer convenience and flexibility between different operating modes, which has impeded some ridership potential. The extent and significance of multi-modal travel in the APEC region is continuously rising, with an increasing amount of passengers using two or more transport modes within a single journey. As such, the lack of integration amongst modal systems is detrimental to transport expediency. The adoption of a seamless regional fare collection system, a "smartcard", can help reduce these inefficiencies and help facilitate the use of urban mass transit.

Among the APEC member economies, over 30 urban areas have adopted a smart card system, which links their rail and bus networks. Within the United States alone, the Federal Transit Administration reports that there are 18 major transit agencies that have completed or are in the midst of implementing a smart card system.[h] The most noteworthy motivations for system installation include: to increase convenience for riders in order to potentially increase ridership rates; to reduce congestion during peak transit periods; to gather ridership data that can help in future route planning, and; to streamline transit operations so as to reduce cash handling and increase operational efficiency. According to a United States public authority, the fundamental motivation for implementing a smartcard system is to "encourage the use of public transportation and facilitate its use. To make it as easy as if you're driving one automobile, using one ticket".

[h] *Accenture (2005). Ticket to the future: smart card technology in public transportation.*

City	Card	Provider	Commencement
Atlanta	Breeze Card	Metropolitan Atlanta Rapid Transit Authority	2005
Beijing	Yikatong card	Beijing Municipal Administration & Communications Card Co., Ltd. and China CITIC Bank	2003
Boston	Charlie Card	Massachusetts Bay Transportation Authority	2006
Busan	Hanaro Card	Busan Hanaro Card Company	1997
Busan	Mybi	Mybi	2000
Chicago	Chicago Card	Chicago Transit Authority	2002
Greater Tokyo Area	PASMO	PASMO Corporation, associated with various private operators	March 2007
Greater Tokyo Area, Sendai and Niigata	Suica	JR East, JR Bus Kanto, Saitama New Urban Transit, Sendai Airport Transit, Tokyo Monorail, and Tokyo Waterfront Area Rapid Transit	2001
Guangzhou	Yang Cheng Tong	Yang Cheng Tong Corporation	2001
Hong Kong	Octopus	Octopus Cards Limited	1997
Kuala Lumpur	Touch 'n Go	Teras Teknologi Sdn Bhd	1997
Mexico City	Metrobús Card	Mexico City Metrobús	2005
Osaka-Kobe-Kyoto, Okayama and Shizuoka	PiTaPa	Surutto Kansai Association (various private operators for rail and bus)	2005
San Francisco Bay Area	TransLink card	Metropolitan Transportation Commission	Testing since 2002
Santiago	Multivía/Bip	Metro de Santiago de Chile/Transantiago	2003 to 2007/ Since 2007
Seoul Metropolitan Area	T-Money	Korea Smart Card Co. Ltd.	2004
Seoul Metropolitan Area	Upass	Seoul Metropolitan Bus Operater Association	1996
Shanghai	Shanghai Public Transportation Card		1999
Shenzhen	Shenzhen TransCard	Shenzhen TransCard Corporation	204
Singapore	EZ-Link	EZ-Link Pte Ltd	2001
Taipei	EasyCard	Taipei Smart Card Corporation	2000
Toronto	GTA Farecard	GO Transit	2007
Washington, D.C.	SmarTrip	Cubic Transportation Systems	1999

57.1 APEC region transit "smartcard" implementations
APERC 2007

The most notable implementation of a smart-card system has occurred in Hong Kong, China. The Octopus smartcard has become a widely used payment system, so much so that 95 percent of the population uses the card for its mass transit needs in Hong Kong.[i] The effectiveness of the card results from the system getting the full backing of all transport operators in the metropolitan area, including ones that serve passenger vehicles; as such, the Octopus card truly integrated all transport modes. The card's success in dissemination is attributed to the system's initial implementation scheme, where the major mass transport corporations within Hong Kong forced a compulsory migration to the smart card by making previous common stored value tickets obsolete after a few months of the new system's adoption. In addition, reduced pricing schemes were developed, so that same trip would cost less using the card than using a single ticket. Because of the lack of effective substitutes to the Octopus card, passengers quickly switched over to the card system.

[i] *Octopus Statistics (2006). Hong Kong, China. http://www.octopuscards.com/corporate/why/statistics/en/index.jsp*

High ridership is vital to enabling mass transit to accrue energy efficiencies over private vehicles. As such, it is strategically essential that passengers can conveniently access, board, and use these systems. The benefits of establishing a smart card system, as shown by current implementations, are that it improves the speed of boarding, reduces queuing at kiosks, and generally makes access more efficient. These systems have also had unexpected benefits. According to a smart-card study performed in 2006 by Accenture consulting, smart card projects have served as a catalyst for change, promoting a climate of innovation in an otherwise stagnant industry; moreover, they have spurred urban renewal developments, since improvements in urban mass transit can revitalise inner city centres.

In addition to ridership, it is also important that mass transport becomes profitable, in the sense that it can continue to operate without creating additional financial burden on the urban area. Without this, the transit system's lack of financial sustainability can lead to decreases in infrastructure modernisation and upkeep, reducing comfort and creating a deteriorated transport network that the public will not use. Previously, transit agencies focused on basic cost recovery, since most mass transit systems operate at a loss. Today, however, the climate has changed to one of net revenue and profit generation. Many modern mass transit agencies face pressure to increase profits and decrease costs, while still improving customer satisfaction, emphasising employee capacity building, and enhancing security of their transit systems. To this end, a smart card can facilitate profit-seeking activity through the provision of value added services, which can expand the card's ability to be used for other applications beyond the initial transit application. Collaborations between financial institutions and transit agencies are an appealing and profitable prospect. The expansion of these transit smart cards for multi-purposes, such as to enable retail payments, can enhance the cards' dissemination and prove to be beneficial to all stakeholders.

Although smart cards can be effective tools to improve and streamline mass transit operations, it is important to acknowledge that their implementation is quite complex and requires extensive planning. All links in the operation chain should well-coordinated and well-trained so that there will be as few technical errors as possible. In order to reduce potential inefficiencies, it is critical to integrate technologies and processes across all transit systems involved, so as to enhance the usability of the system. This is especially important in the initial stages of the system, since failures can drive passengers away, to the extent that most will refuse to accept the system after these bugs have been fixed. In addition to these basic technical aspects, marketing and customer education campaigns are vital to the success of the system. In the end, without customer acceptance, the programme will never succeed.

Ultimately, the adoption of unified payment systems has the potential to make urban mass transit more attractive to passengers who once found it difficult to utilise. The extent to which these systems can help increase ridership, as such decreasing passenger vehicle use, is debatable. Certainly, however, these systems can at least make the mass transit experience more comfortable for current riders, and in turn, decrease the negative aspects that might detract them from continuing to use mass transit as their mode of choice. In addition, it can help make current transit systems achieve financial stability, which is essential for future prosperity and success.

URBAN MASS TRANSIT PRIVATISATION

"Privatisation" of urban mass transit is commonly offered as an broad solution to the problems faced by public-dominated transit systems. Generally, the key motivator to privatisation schemes is the idea that the introduction of various forms of competition (and, hence, profit-seeking activity) can improve efficiencies in mass transit just as it has in other sectors once dominated by public ownership and operation in parts of the APEC region, such as manufacturing.[j] And much like the unified payment systems described above, a more successful urban mass transit system can ultimately contribute to transportation energy savings.

The term "privatisation" however, means many things to many people; generally, it can be thought of as any reduction in public influence over a good or service, and an increase in private sector participation.[h] But even just in the context of mass transit, such a broad definition includes three common manifestations: 1) partial or complete sale or marketisation of existing transit infrastructure and operations; 2) sale of rights or obligation to private parties for expansion or upgrade of existing systems, or; 3) contracting of system construction, service, and operations to private entities, with or without persistent operation regulations from a public entity.[l] And despite the motivation for competition, not all such manifestations necessarily induce efficiency improvement (private monopolies are just as common as public monopolies) or deliver more satisfying mass transit results than public operation and ownership might.

The final characterisation described above, however, a type of "public-private partnership"[m] (PPP or P3), is currently gaining popularity as a hybrid form of privatisation.[n] Results do vary, but this particular form of privatisation, whereby transit operation and services are contracted out to private entities while ownership remains in public hands (also known as "outsourcing"), or where non-public entities share financing, construction, and ownership with public bodies, has shown promise in improving finances, logistics, and level of service in various APEC region implementations.[o] Moreover, experience indicates that a balance of public and private oversight of operations along with creation of a non-exploitative incentive structure for private operators can effectively improve mass transit services within an urban area while simultaneously reducing the public sector's day-to-day transit burdens.

The most common mass transit PPP arrangement in the APEC region today involves non-public participation in planning or financing

[j] *Kenneth A. Small, edited by Richard Arnott (1992). Urban transportation economics. Harwood Academic Publishers. Tokyo, Japan.*

[k] *ES Savas (2006). Privatization and public-private partnerships.*

[l] *José A Gómez-Ibáñez, William B Tye, and Clifford Winston (1993). Essays in transportation economics and policy: a handbook in honor of John R. Meyer. Brookings Institution Press. Washington, DC. USA.*

[m] *ES Savas (2006). Privatization and public-private partnerships.*

[n] *Nancy Nicosia (2001). Competitive contracting in the mass transit industry: causes and consequences. University of California,Berkeley. California, USA.*

[o] *see ITDP 2006 for APEC region examples of PPP financing: Institution for Transportation and Development Policy (2006). Options for financing bus rapid transit in China. Walter Hook, Karl Fjellstrom, and Oscar Edmundo Diaz*

of new infrastructure. In recent decades in APEC, Asia Development Bank and World Bank have often assisted host member economies in planning and development of mass transit systems and infrastructure, in particular, and such participation can be seen as a form of non-public collaboration. More recently— and slightly more radically— however, private, semi-private, and even civil-society entities have become more directly involved in project planning and financing.

From the planning side, WRI's EMBARQ programme, to name one group among many, has been active through recent years in consulting with interested urban governments and stakeholders to help policymakers prioritise, plan, and implement individually-tailored and sustainability-minded urban mass transit systems in APEC cities including Shanghai, Xi'an, Mexico City, and Hanoi.[p] PPP-based financing structures are also gaining popularity. In 2006 in China, the Beijing MTR Corporation joined with two "semi-private" venture partners (both, however, wholly owned by the Beijing Municipal Government) in what was hailed as mainland China's first such PPP.[q] Under the 30-year cost-sharing agreement, the Beijing Municipal government will be responsible for land acquisition and civil construction while the PPP joint venture will handle purchase rolling-stock, operation, and management of the Beijing Metro's new "Line 4". The three PPP joint venture partners, in turn, will share costs and ownership of the company. Though the degree of privatisation in this arrangement is fairly "conservative" with respect to other APEC examples of mass transit privatisation, such as those found in Hong Kong, Tokyo, or Singapore, it could nevertheless be seen as a first step towards public divestment in urban mass transit for developing China.

[p] *Lee Schipper (2007). World Resources Institute, EMBARQ. Personal communication. Tokyo, Japan.*

[q] *Beijing MTR Corporation (2006). Press release. concession agreement for Beijing Metro line 4 projec signed. Beijing, China..*

Outsourcing is another common form of public-private partnership in APEC mass transit whereby some or all transit operations are contracted to one or multiple private entities who attempt to make a profit from running the transit service, generally without being responsible for infrastructure construction. Arrangements vary, and outsourcing can be as limited as allowing private newspaper concession stands or advertisement in transit stations or as extensive as competitively contracting full operation management, rolling stock maintenance, fee collection, and providing transit security. For any implementation of outsourcing, one important distinction is the level of decision-making prerogative granted to the private outsourcing entity. For example, in the interest of ensuring a minimum level of geographic and economic access, public urban mass transit-governing agencies commonly set fare prices and mandate which routes must be run, within certain bounds, but then allow private operators leeway with respect to frequency of service, bus/rolling stock selection, or employee compensation. Of course, any "service floor" mandated by a public agency can be argued to ultimately induce dead weight loss and reduce efficiency, but such safety-valves are quite valuable in assuaging fear that private operators will exploit a system by only running the most profitable routes, for example. Ultimately, if private entities feel that the balance of requirements versus opportunities is in their favour (i.e., satisfactorily profitable), they can be expected to participate.

The ability of private transit entities to operate so that revenues exceed costs, however, is dependent on the particular characteristics of the city of operation, and also the transit mode. For example, a common barrier to achieving positive net revenues in an urban mass transit system is the financing of capital infrastructure and real estate acquisition—such as subway line and station construction or right-of-way for bus rapid transit lanes. Even in privatised transit systems, such enormous upfront costs are generally subsidised by city, state/prefecture, and national governments in part through various preferential financial instruments or in whole. Such vertical separation of costs allows public bodies to fund transit infrastructure (much in the same way they fund road infrastructure) while allowing private entities varying degrees of autonomy in provision of services based on that public infrastructure.

Actual implementation of such financing schemes varies. For example, the Hong Kong MTR Corporation Limited was formed in 2000 during the privatisation of the Hong Kong MTR subway system and subject to and operating agreement with the Hong Kong government.[r] As part of this agreement, the MTR Corporation was issued long-term (~50 year) leases on subway capital infrastructure and guaranteed rates of return from 1-3 percent above the estimated weighted average cost of capital of the company. In addition, the Hong Kong government subsidises new line construction by the MTR Corporation (with new routes suggested by the Hong Kong government) through reduced cash payouts to the Corporation's government shareholders (who still owned approx 70 percent of shares as of 2003) and non-recourse loans, among other financial instruments. In operation, the MTR Corporation is free to set fares (following public consultation) and is given development and management rights to valuable commercial real estate properties tied to subway assets. In return, the MTR Corporation is obliged to provide a level of customer service and satisfaction deemed acceptable by the Hong Kong government.

[r] for operating agreement details, see: EDGAROnline (2004). MTR Corp Ltd: item 4, information on the company.

Hong Kong is in many ways a special case with regard to urban mass transit; with particularly high incomes and population density along with extremely high reliance on imports for gasoline, it is naturally quite suited to reliance on rail infrastructure for personal mobility needs. Acknowledging all this, however, privatisation does seem to be yet another valuable contributor to the long-term feasibility of the system. It is not surprising then that the Hong Kong MTR is one of only two profitable subways in the world—a distinction it shares with The Tokyo Metro, yet another recently privatised subway system.[s]

[s] Chris Betros (2006). Subways keep Tokyo on the move. Japan Today. Tokyo, Japan.

In many ways, the Tokyo subway system is as predispositioned to profitability as the Hong Kong MTR. However, it is insightful to note that while the recently privatized (2004) Tokyo Metro Co Ltd is profitable, the government-owned Tokyo Metropolitan Bureau of Transportation "Toei" Subway, which operates different lines that cover similar service areas to the Tokyo Metro, is not profitable.

METHODS SHOWING UNINTENDED RESULTS

The methods presented below, although potentially effective at curbing transport energy use, have frequently generated unintended results that sidetrack their progress. Nevertheless, results have varied. These examples are only meant to illuminate potential quandaries that might arise during the actual implementation process.

LICENSE PLATE RESTRICTION SCHEMES

Traffic control, in terms of congestion and vehicle emissions on urban roads, has been a major concern for transportation planners. As a result of the stop-and-go traffic caused by congestion, many vehicular fuel economies are much lower inside urban areas. Congestion is such a problem that many cities have considered demand management by regulatory control. One such method is the establishment of license plate restrictions to ration car use and ease traffic problems. Licence plate schemes restrict the use of certain sectors of the passenger vehicle fleet, usually based on the last digits of license plate numbers, during different days of the week.

Ideally, this method can control congestion and in so doing, reduce fuel consumption and alleviate air pollution. In fact, many schemes are not specifically aimed at reducing traffic congestion, but rather they are specifically aimed first at reducing vehicle emissions of local air pollutants, a top priority for many cities in the APEC region, and second to reduce energy consumption. Although these restrictions can be effective, in the short term, there are observable risks that have the potential to negate the positive impacts of the scheme.

Restriction schemes have either been implemented or proposed within the following APEC metropolitan areas: Beijing (proposed for the upcoming 2008 Olympic Games), Manila, Mexico City, Santiago, Seoul, and Shanghai. For some of the above cities, these restrictions were implemented only during days when air pollution reached critical levels (such as in Santiago and Mexico City) or during periods of extreme congestion (Seoul during the Olympic Games).[t] These schemes restricted plates to enter the "target zone" which was either applied to the entire CBD or to a specific area of the city.

[t] *John A Cracknell. (2000). Experience in Urban traffic Management and Demand Management in Developing Countries. World Bank Urban Transport Strategy Review.*

These schemes, if only temporary, can quite successful. They usually encounter public acceptance, since the programme displays the city government's commitment to reduce congestion and alleviate air quality problems. In the short term, these programmes also have the potential to aid road-based mass transit, as a result of improvements in vehicular traffic flow.

However, if employed for extended periods, license plate restriction programmes can quickly reach an impasse. These schemes run the risk of potentially increasing a city's vehicle stock, as citizens purchase vehicles to avoid the enforcement of this system. Such results were witnessed in Mexico City, where drivers initially purchased a second vehicle (a often a less energy-efficient one) in order to evade the restrictions set out by "Hoy No Circula" (please refer to Mexico City case study in the report for a detailed explanation of this programme).[u] Another potential risk is that the programme might stimulate additional trips for permitted vehicles, in order to compensate for the days without access.

[u] *Universidad Autonoma Metropolitana Azcapotzalco (1994). Research on effectiveness of "Hoy No Circula". Mexico.*

The most important aspect of these restriction programmes are their initial design. If the goal of the programme is to reduce congestion or air pollution, vehicle exemptions cannot be allowed. These exemptions can unintentionally impede success. In fact, exemptions can bolster the original problem by facilitating access to vehicles that are of inferior quality than the rest of the vehicle stock. For example, in the original inception of "Hoy No Circula", taxis and *colectivos* (mini-buses that have similar travel patterns as taxis) were exempt from the restrictions. This led to an increase in the utilisation of these vehicles, which were even less energy-efficient and created more emissions than other passenger vehicles. As a result, in the programme's subsequent updates, taxis were added to the list of vehicles that were prohibited.

Another major problem concerning plate restriction programmes surrounds the issue of equity. In many cities, lower income communities rely on passenger vehicles as a means to commute to work, rather than for leisure purposes. As such, restricting vehicular use can also unintentionally limit employment opportunities. Thus, restriction programmes should be accompanied by increased development in urban mass transit infrastructure as a means to provide a viable alternative for commuters and other segments of the urban population.

In general, although a plate restriction programme can create unintentional circumstances, the measure is not inherently defective. In certain cases, this measure has proved highly effective in curbing congestion. In Seoul, specifically, the "Sippujae" programme was put into operation during periods of extreme congestion. The resulting outcome was a reduction in total traffic by 7 percent, while vehicle speeds increased by 14 percent. In this case, the success of the programme was attributed to the fact that the restrictions applied to all drivers, which helped with enforcement.

Ultimately, one of this measure's main assets is that it can be utilised as a springboard for drivers to embrace alternative modes of transport within the metropolitan zone. In so doing, it can help reduce road congestion and reduce energy expenditures resulting from these delays. Nevertheless, based on current trends, license plate restrictions seem not to be a long term solution, since they are essentially subverted by the growth of vehicle ownership over time. Nevertheless, they can be effective in the short term or on a temporary basis. The deciding factor is the final design of the programme and whether or not all facets of its implementation are aligned with achieving the programme's final goal.

"STAIR STEP" FUEL EFFICIENCY REQUIREMENTS

Fuel economy standards have proven to be one of the most effective measures to reduce automotive energy use. Since the transport sector contributes significantly to many APEC economies' primary energy demands, these standards can directly impact an economy's energy security in terms of total fuel usage and in terms of vehicle fuelling costs, especially during periods of high oil and gasoline price. These standards are constructive because they can directly curve oil demand in transportation, by setting clear-cut efficiency targets that must be met by vehicle manufacturers. However, these standards can also lead to unintended consequences as a result of loopholes in the design of these regulations.

Many APEC member economies—Australia, Canada, China, Chinese Taipei, Japan, Korea, and the United States, to name a few--have implemented or proposed some sort of fuel economy standard. Several economies employ different standards based on different definitions of vehicle categories and weight classes, and at different levels of stringency. Some standards are based on weight or engine size. Some are applied to the overall light duty fleet, while other standards vary between cars and light trucks. To add another level of complication, some standards are voluntary and others are mandatory.

The design of these standards can play a significant role in effecting the average fuel efficiency of vehicles within an economy. Currently, many standards are designed using a multi-tiered approach based on either vehicle engine size, such as in Chinese Taipei and Korea; weight, such as in China and Japan; or vehicle type, such as in the United States.

In Korea, car manufacturers can earn credits if they exceed requirements in one engine size. The credits earned are transferred to help meet the standard within another engine size. As a result of the policy, many car manufacturers improve the fuel efficiency within the lowest tiers which belong to the smallest engines, in order to minimise the reductions that are necessary for larger vehicle engines. In a sense, this has the potential to lower the average fuel economy of all vehicles in the market, since the larger vehicles are the ones who already have poor fuel efficiency. According to a 2004 report on passenger vehicle fuel economy conducted by the World Resources Institute, this policy also creates an unfair playing field amongst car manufacturers, since foreign manufacturers do not manufacture vehicles in the smaller vehicle engine brackets.

Another case, probably the most glaring, where tiered fuel economy standards have had unintended consequences has been in the United States. The US passenger vehicle fuel economy rules, known as the Corporate Average Fuel Economy (CAFE) standards, are designed as a two tiered system with different standards for cars and light duty vehicles classified as trucks (truck standards are less stringent, 25 percent lower than the car standard[v]).[w] During the initial design of the CAFE programme in the 1970s, light trucks composed a relatively small share of the vehicle market and most of these vehicles consisted of pickups used for business and not personal transport purposes. Due to their relative small market share, light trucks did not significantly impact the average level of vehicle fuel efficiency. This changed during the mid 1980's, specifically after the introduction of cross-over vehicles (having both car and truck features) into the passenger vehicle market. As a result of loopholes in the standards, these vehicles qualified under the light truck standards even though they were used as personal transport vehicles.[x]

Consequently, this fuzzy interchange between tiers created a loophole that resulted in a 7 percent decrease in overall light duty fleet fuel economy between 1988 through the mid 1990's. This lower fleet fuel economy has since remained relatively constant. According to a US Environmental Protection Agency (EPA) report on light-duty fuel economy trends, as of 2006, sales of light trucks are projected to account for 55 percent of the US passenger vehicle market (twice 1985 market share). The trend towards re-classification of vehicles into light trucks was epitomised when Subaru modified its Outback Sedan and Wagon to meet the specifications of a light truck, as a means to avoid the more daunting fuel economy standards that apply to cars.[y]

As a result of a slew of controversy, in 2006, CAFE standards related to light trucks were changed (with changes to be gradually phased in over the 2008-2011 model years). The new rules create another tiered system, specific to light trucks, which divides vehicles into different categories based on the vehicle footprint[z], each with its own fuel economy standard (larger footprints have lower targets)[aa]. This new system, similar to the previous, has the potential to create further loopholes, however only time will reveal.

In the end, these multi-tiered fuel economy standards, have proven quite challenging to the US' efforts to improve overall light duty fleet fuel economy. The US National Academy of Sciences (NAS) committee declared in its report to evaluate the CAFE standards that the distinction between cars and light trucks "has been stretched well beyond its original purpose".[bb] This sheds light on the difficulties of implementing an effective fuel economy standard and how tiered systems can lead to unfortunate consequences that might not have been initially considered.

Another quite different example of a multi-tiered fuel economy has been implemented in China. This system is vehicle weight based, similar to the Japanese system, and is more stringent for heavier vehicles than lighter. In this system, SUV's share the same standards as passenger cars. In terms of the manufacturing of vehicles, the Chinese standards create the complete opposite incentive structure to that of

Country	Vehicle Types	Implementation
Australia	Overall Light Duty Fleet	Voluntary
Canada	Cars + Light Trucks	Voluntary
China	Weight-based	Mandatory
Chinese Taipei	Engine Size	Mandatory
Japan	Weight-based	Mandatory
Korea	Engine Size	Mandatory
United States	Cars + Light Trucks	Mandatory

64.1 **Types of fuel economy standards in APEC**

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[v] *Robert M Heavenrich (2005). Light-duty automotive technology and fuel economy trends: 1975 through 2005. Office of Transportation and Air quality, US Environmental Protection Agency. USA*

[w] *Light duty vehicles consist of sport utility vehicles (SUVs), vans, and pickup trucks with less than 8,500 pounds gross (3,856 kg) vehicle weight ratings.*

[x] *Another loophole to the tiered system is that vehicles that exceed 8,500 pounds, for example GM's Hummer H2 and Ford's Excursion, are exempt from all fuel efficiency standards.*

[y] *Danny Hakim (2004). To avoid fuel limits, Subaru is turning a sedan into a truck. New York Times. USA.*

[z] *National Highway Traffic Safety Administration, NHTSA (2007a). USA. http://www.nhtsa.dot.gov/*

[aa] *Starting in 2011, these new rules will also apply to SUVs and vans, which were formally exempt, that weigh between 8,500 and 10,000 pounds (3,856 and 4,536 kg).*

[bb] *National Research Council (2002). Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards. Committee on the Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards, Board on Energy and Environmental Systems, Transportation Research Board. National Academy Press. Washington, D.C., USA.*

the US system. It encourages the creation of lighter vehicles, which are usually more fuel efficient, than that of larger, heavier vehicles.

On the whole, multi-tired fuel economies can create quite different outcomes. The differences in the above cases emphasise the potential snags that can be encountered. In the end, the standards should be designed to accomplish the final goal of reducing energy consumption in the transport sector. The tiered system has to be designed quite carefully, preferably with a progressive approach, where the inherently least fuel efficient vehicles are pushed the hardest to meet efficiency standards. In doing so, the final outcome might actually result in increasing the overall light duty fleet fuel economy.

CASE STUDIES

BANGKOK

Passengers in Bangkok mainly depend on the road transport for commuting and other purposes due to the urban sprawl along with the main road transport and the slow progress in developing a comprehensive mass transit system. Such passenger vehicle dependence coupled with limited road infrastructure development has led in recent years to severe traffic congestion problems in the urban core. Policy coordination is necessary for Bangkok to improve transport systems and to efficiently handle growing transport demands.

Total Pop.	Land Area	Pop. Density	GRP	PCI	Gasoline Use	Pas. Vehicles
5.48 million	1,568 km^2	3,495 p/km^2	151 billion	27,560	2,842 ktoe*	1.5 million**

*APERC 2007, indicators for 2005, year 2000 USD PPP, *2003 data, **2004 data*

INTRODUCTION

Bangkok, Thailand is known as the "Venice of the East" due to the many waterways running throughout the city. With a total land area of 1,568 square km, and consisting of 50 districts and 154 sub-districts, the city's 2005 population was 5.5 million. The more broadly-defined Bangkok Metropolitan Region (BMR), which includes the Bangkok Metropolitan Area (BMA) as well as five surrounding provinces, registered a 2005 population of 9.8 million; that is, approximately 16 percent of Thailand's total population live in the region.[a] Moreover, Bangkok is dense; ranked 68th out of Thailand's 76 provinces in terms of land size, Bangkok easily has the largest population in Thailand.

Bangkok is commonly described as a "primate" city for Thailand; that is, it is the overwhelming centre of culture, population, and economic development for the whole economy. Between 1998 and 2005, the city's gross regional product (GRP) grew at an annual rate of 8.8 percent – faster than that of Thailand's 6.0 percent. In 2004, income in Bangkok was approximately 3.4 times higher than that of the economy as a whole, reaching USD 25,376 (2000 PPP).

The city's history of urbanisation dates back to the early 1960s when the Thai government released its 1st National Economic Development Plan. As the Plan delineated, the economy's government aimed at achieving development through transforming the Thai economic structure from one of agriculture to one of manufacturing. To meet the target, Bangkok played the central role, attracting capital investment for the manufacturing industry. This, as a result, has increased employment opportunities and encouraged migration from other rural areas within Thailand.

Contemporaneous to the Thai Development Plan, Bangkok formulated its first land use plan in 1960. Despite the relative early formation of land use plan, however, little action followed to turn the plan into reality. It was only in 1992 – more than three decades after the plan's formation – that the city government issued its first statutory land use plan.[b] Because of the lack of effective mechanisms to control urban development, Greater Bangkok has sprawled out towards the east, north south, and more recently towards west as well. This urban sprawl took place primarily along the main roads.

Because of this urban sprawl along main transportation arteries and the slow progress in developing a comprehensive mass transit system, passengers in Bangkok mainly depend on the road transport for

68.1 Bangkok's location in Thailand and Southeast Asia
Source: Bangkok Metropolitan Administration

[a] *The five surrounding provinces include Samut Prakarn, Nonthaburi, Pathumthani, Nakhon Pathom, and Samut Sakhorn.*

[b] *World Bank (2000). Study on urban transport development. Washington D.C., USA*

[c] *In Bangkok, roads occupy only about 11 percent of the inner city, compared with that of London, Paris and New York at around 20-25 percent.*

commuting and other purposes. Such passenger vehicle dependence coupled with limited road infrastructure development has led in recent years to severe traffic congestion problems in the urban core.[c]

ENERGY CONSUMPTION FOR ROAD TRANSPORT

	Absolute Level (Unit: ktoe)					Annual Growth Rate (%)				
	1986	1990	1995	2000	2003	1986-1990	1990-1995	1995-2000	2000-2003	1986-2003
Gasoline	868	1,399	2,271	2,475	2,842	12.7	10.2	1.7	4.7	7.2
Diesel	1,732	3,131	4,313	4,054	6,247	16.0	6.6	-1.2	15.5	7.8

69.1 Gasoline and diesel consumption in Bangkok, 1986, 1990, 1995, 2000, and 2003
APERC 2007

HISTORICAL TRENDS FOR GASOLINE/DIESEL CONSUMPTION

This section describes historical trends in gasoline and diesel consumptions in Bangkok [69.1]. To better understand the unique characteristics of Bangkok's gasoline/diesel consumption, comparison was made with Seoul, Korea [70.1,2].[d] Seoul was chosen due to similar income level with Bangkok.

[d] Each economy's per capita income (2000 PPP) in 2002 is USD 22,289 in Bangkok and USD 18,471 in Seoul.

Bangkok's gasoline consumption grew robustly at an annual rate of 7.2 percent from 1986 to 2003. Though the growth rate of gasoline consumption slowed down in the late 1990s during the 1997 financial crisis, economic recovery after 2000 has nevertheless led to increased gasoline consumption, with record consumption levels of 2,842 ktoe in 2003. Compared to Seoul, Bangkok represents the higher per capita gasoline consumption as well as the higher number of passenger vehicle stocks per 1,000 population. In addition, the annual growth rate of gasoline consumption per capita in Bangkok accounts for the faster rate than in Seoul.

Diesel consumption grew at a robust rate of 7.8 percent per year between 1986 and 2003. Because of the economic slow-down caused by the 1997 financial crisis, in the period 1995-2000, diesel consumption declined at an annual rate of 1.2 percent. Nevertheless, it bounced back to 15.5 percent growth between 2000 and 2003. Truck stocks per capita in Bangkok are smaller than in Seoul. However, Bangkok's diesel consumption per capita is larger than Seoul's figure. In addition, diesel consumption per capita in Bangkok grew at 4.3 percent per year between 1990 and 2002, while that of Seoul decreased at 2.3 percent. These results suggest that diesel is consumed more intensively in Bangkok than Seoul.

Somewhat surprisingly, Bangkok's road transport sector actually consumes more diesel than gasoline. This higher level of diesel consumption is partially attributed to the Thai policy of promoting that economy's automotive industry. This policy puts priority on local production of pick-up trucks and offers favourable conditions to consumers for the purchase of such pick-up trucks. For instance, the excise tax imposed on a standard pick-up truck is merely 3 percent whereas the same tax on passenger automobiles is between 30 and 50 percent.

	Gasoline Consumption Per Capita (toe/capita)				Annual Growth Rate (%)	Passenger Vehicle Stocks per 1,000 Population			Annual Growth Rate (%)
City	**1990**	**1995**	**2000**	**2002**	**1990-2002**	**1995**	**2000**	**2002**	**1995-2002**
Bangkok	0.25	0.41	0.44	0.47	5.3	180	232	293	7.2
Seoul	0.10	0.18	0.17	0.16	3.82	154	178	205	4.1

	Diesel Consumption Per Capita (toe/capita)				Annual Growth Rate (%)	Truck Stocks per 1,000 Population			Annual Growth Rate (%)
City	**1990**	**1995**	**2000**	**2002**	**1990-2002**	**1995**	**2000**	**2002**	**1995-2002**
Bangkok	0.57	0.77	0.71	0.94	4.3	16	21	22	4.0
Seoul	0.08	0.15	0.11	0.06	-2.3	30	35	39	3.8

70.1,2 Gasoline and diesel consumption per capita and passenger vehicle stocks per 1,000 population in Bangkok, Shanghai, and Seoul
APERC 2007

Passenger vehicles stocks include passenger vehicles and taxis, and exclude pick-up trucks because the pick-up trucks are almost all diesel engine powered

Truck stocks include heavy duty trucks.

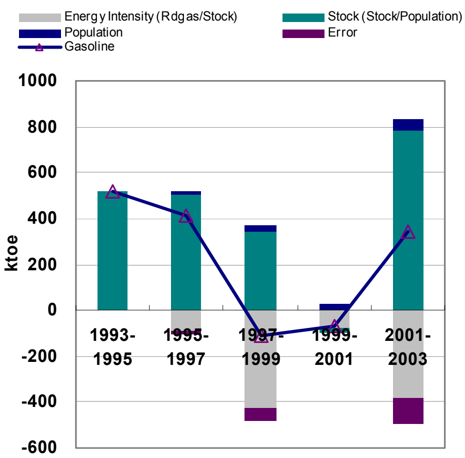
FACTORS AFFECTING GASOLINE/DIESEL CONSUMPTION

The previous section identified the increasing trends in both gasoline and diesel consumption in Bangkok. This section aims to analyse contributing factors to these growth trends by using decomposition analysis [70.3 and 71.1].

Decomposition analysis of gasoline consumption indicates that the passenger vehicle stocks per capita (hereon, stock) substantially contributed to an increase in gasoline consumption from 1993 to 1999 and from 2001 to 2003 whereas between 1999 and 2001 the contribution was negligible. On the other hand, gasoline consumption per passenger vehicle (hereon, energy intensity) negatively contributed to the growth in gasoline consumption between 1995 and 2003. The population factor marginally contributed to the increase in gasoline consumption from 1995 to 2003.

From this decomposition analysis, it becomes clear that the increase in the number of passenger vehicle stocks has substantially contributed to the growth in gasoline consumption. Due to a rapid rise in income, Bangkok's number of passenger vehicles per 1,000 population more than doubled from 130 in 1993 to 271 in 2004. In addition, the development of the automobile manufacturing industry within Thailand contributed to an increase in the number of passenger vehicle stocks as higher domestic vehicle production offered passenger vehicles lower prices than imported passenger vehicles.

This analysis also offers interesting results with respect to vehicle energy intensity. Energy intensity – gasoline consumption per passenger vehicle – negatively contributed to the growth in gasoline consumption from 1993 to 2003. In particular, energy intensity showed the most improvement between two time periods; 1997 and 1999, and 2001 and 2003. The improvement in energy intensity during these time periods reflects two separate issues: (1) between 1997 and 1999, economic recession suspended passengers from utilising their vehicles, and (2) between 2001 and 2003, consumer preference was increasingly shifting to more efficient small-sized vehicles from large-sized vehicles.[e]

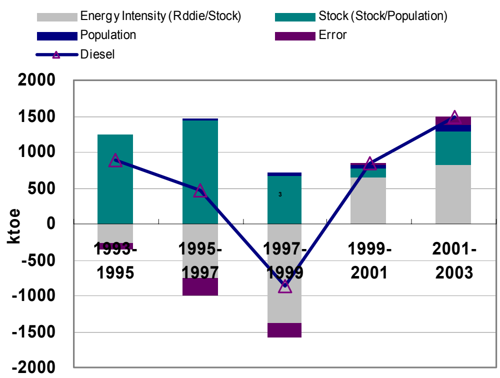


70.3 Decomposition analysis: gasoline consumption in Bangkok, 1993-2003
APERC 2007

Decomposition analysis is based on the following calculation.
*E = Rdgas/Stock * Stock/Population * Population*
(E: Gasoline consumption, Rdgas: Gasoline consumption on road, Stock: Passenger vehicle stock, Population: Population in Bangkok)
*△E = △(Rdgas/Stock) * Stock/Population * Population*
*+ Rdgas/Stock * △(Stock/Population) * Population*
*+ Rdgas/Stock * Stock/Population * △(Population)*
+ Error

[e] The small-sized vehicles quickly become popular in recent years.

With respect to diesel consumption, the decomposition analysis demonstrates another interesting result. The stock of freight trucks per capita, referred to here stock, made a positive contribution to the rise in diesel consumption throughout the period examined, particularly up until 1999. After 1999, however, the stock's contribution became smaller due to the economic recession that restrained freight truck owners from adding new stocks.



71.1 Decomposition analysis: diesel consumption in Bangkok, 1993-2003

APERC 2007

Decomposition analysis is based on the following calculation.
*E = Rddie/Stock * Stock/Population * Population*
(E: Diesel consumption, Rddie: Diesel consumption on road, Stock: Truck stock, Population: Population in Bangkok)
*△E = △(Rddie/Stock) * Stock/Population * Population*
*+ Rddie/Stock * △(Stock/Population) * Population*
*+ Rddie/Stock * Stock/Population * △(Population)*
+ Error

ISSUES

NEED FOR POLICY COORDINATION

TRAFFIC SITUATION IN BANGKOK

While the development of economic prosperity in Bangkok brought tremendous benefits, the city also had to pay the costs that came along with urbanisation and motorisation. Specifically, the city suffers from severe traffic congestion. Inadequate road networks, and lack of efficient mass transit and effective traffic control contribute to dependence on passenger vehicles, which, subsequently, cause heavily congested traffic in Bangkok.[f] The average traffic speed in BMR is around 10 km/hour.[g] The estimated peak-hour travel speed in the central business district even falls as low as 5.9 km/hour.[h]

Such intense traffic congestion inflicts external costs on the city. In a 2005 assessment, Bangkok's traffic congestion alone was estimated to result in annual economic damages of 116 billion baht (USD 2.6 billion) from passengers' excessive travel time and 27 billion baht (USD 608 million) in extra vehicle operating expenses.[i] **71.2** presents an estimate of external costs of road transport at national and regional levels in Thailand and other select APEC economies. In the worst-case scenario, Bangkok's traffic congestion costs as much as 6 percent of regional GDP, which is much higher than other APEC city estimates. Moreover, from an environmental perspective, high levels of low-atmospheric carbon monoxide (CO), which is mostly emitted by the transport sector, are a great concern in Bangkok. Therefore, traffic congestion is a serious issue socially, economically, and environmentally.

	Bangkok (1995)	Mexico City (1993)	Santiago (1994)
Cost of Congestion	1.00-6.00	2.56	1.38

71.2 Estimates of external cost of congestion in the APEC region, % of GRP

World Bank (2002). Cities on the move – a World Bank urban transport strategy review. http://www.worldbank.org/transport/urbtrans/cities_on_the_move.pdf

Congestion costs are calculated in comparison with either a free-flow speed or an "acceptable" traffic performance, and not with a calculated "optimum" level of congestion.

[f] On average, 500 additional cars enter into the network every day: Mushtaq Ahmed Memon (2003). Integrated urban air quality management (UAQM) in Bangkok. http://enviroscope.iges.or.jp/modules/envirolib/upload/60/attach/UE2_3046.pdf

[g] Krongkaew 1997, Rojopakarn 1999, Morikawa et al 2001, and Memon 2003. World Bank 2002 estimates that downtown weekday traffic speed is 10 km/hour or less in Bangkok, Manila (Philippines), Mexico City (Mexico), and Shanghai (China); 15 km/hour or less in Kuala Lumpur (Malaysia).

[h] T Morikawa, T Yamamoto, D Dissanayake, N Sanko, S Kurauchi, H Maesoba, S Ohashi, N Tiglao, C Rubite, and M Rivera (2001). Travel behavior analysis and its implication to urban transport planning for Asian cities: case studies of Bangkok, Kuala Lumpur, Manila, and Nagoya. ICRA Project Report. http://www.easts.info/activities/icra/2001/ICRA-TravelBehaviorAnalysis.pdf

PASSENGER VEHICLES VS. MASS TRANSIT

Preference for passenger vehicle travel is critically related to the traffic congestion. The share of passenger vehicle trips in the modal split had changed as follows: 46 percent in 1995, 54 percent in 1997, and 51 percent in 2001.[j] For 2006, the passenger vehicle share was estimated to have increased further still to 61 percent.[k] As **72.1** shows, the share of passenger vehicle trips in Bangkok is lower than that of

Kuala Lumpur but higher than those of other two cities in Southeast Asia. Based on these figures, it is likely that passenger vehicle transportation will maintain its popularity in Bangkok for the foreseeable future.

Understanding what lies behind the unpopularity of mass transit would help explain why people still prefer to use passenger vehicles. Bus transport is the most used mode among all types of mass transit in spite of its unsatisfactory level of service provided. Due to a lack of investment and labour force, the bus service has not kept pace with Bangkok's economic and population growth. As a result, buses are overcrowded and quite a few buses are not equipped with air-conditioning, which exacerbates uncomfortable situations. According to data published by the Bangkok Mass Transit Authority (BMTA), there is a declining trend on the number of bus passengers per day; from 1992 to 2005, the number of daily riders decreased in each year (except in 1997 during the financial crisis) from 4.1 million in 1992 to 2.0 million in 2005.

In addition to poor bus services, people in general find it inconvenient to change from one transit mode to another, or even between two buses.[l] Modal split for railway is remarkably low as railways are designed for intercity rather than urban transportation, and the fare is quite high when compared to other forms of mass transit.[m] Unless the operation of mass transit is improved, the lack of alternative transport choices will result in putting more private vehicles on road and using more fuel. To address this, the introduction of the electricity-powered "Skytrain" in 1999 and subway in 2004 was supposed to induce modal shifts from passenger vehicles.

Facing economic and social harms caused by traffic congestion, the Thai central government took measures to deal with the problem. For instance, budgets for transport were raised beginning with the 7th Plan (1992-1996) in which a trend in favour of mass transit projects emerged [72.2]. So, not only was the total amount for transport system increased from USD 1.458 billion in 6th Plan (1987-1991) to USD 8.306 billion in 7th Plan but also the share that was invested for the mass transit increased remarkably from 1 percent to 36 percent. Subsequently, feasible rail-based mass transit systems finally started to operate in Bangkok: the Skytrain, running 12 meters above street level with 23.5 km of route length and 23 stations in 1999, and the subway, with 19.7 km in length and 18 stations in 2004. Contrary to expectations, however, it seems that both the Skytrain and the subway have not yet proved to be an effective way to reduce traffic congestion. For the Skytrain, daily ridership is currently 400,000 passengers per day, one-third lower than the target figure of 600,000 riders per day needed to break even.[n] With regard to the Bangkok subway, ridership is also quite low when compared to similar urban Asian systems in Singapore, Hiroshima, Incheon, and Shenzhen, which all have similar route lengths and station numbers [72.3].

CONFLICTS IN DIFFERENT POLICIES

Despite measures taken by government, the traffic congestion has persisted in Bangkok. Moreover, poor coordination among different policies and agencies is considered to have exacerbated the problem. At the administrative level, there are more than ten transport planning, policy, or management-related organisations operating in many agencies under different ministries [74.1]. One example of conflict is that the mass transit systems are under control of different agencies; i.e., BMA for the Skytrain, and the Metropolitan Rapid Transit Authority (MRTA)

	Bangkok	Kuala Lumpur	Jakarta	Manila
Pas. Veh Transport	45.8%	68.8%	28.1%	19.6%
Mass Transit	42.7%	7.2%	25.5%	59.0%
Non-motorised Transport	11.5%	24.0%	46.4%	21.4%

72.1 Modal split of all trips in major Southeast Asian cities, 1995

J Kenworthy and F Laube (2001). The millennium cities database for sustainable transport. International Association of Public Transport.

	6th Plan (1987-1991)		7th Plan (1992-1996)	
Transport System	investment (USD million, nominal)	%	investment (USD million, nominal)	%
Road/ Expressway	1,407	96	5,181	61
Public Transport	16	1	2,888	36
Others	35	3	237	3
Total	1,458		8,306	

72.2 Actual transport investment in BMR, 6th and 7th plan

Wiroj Rujopakarn (1999). Study on transport investment in Bangkok Metropolitan Region during the 8th national economic and social development plan (1997-2001). http://citeseer.ist.psu.edu/569723.html

City	First section opened	Route length (km)	Number of Stations	Yearly Ridership (million)
Bangkok	2004.7	19.7	18	3.65
Singapore (SBS Transit, North East Line)	2003.6	20.0	16	65.00
Hiroshima, Japan	1994.8	18.4	21	17.82
Incheon, Korea	1999.10	21.9	22	74.30
Shenzhen, China	2004.12	22.0	19	189.8

72.3 Subway comparison in Asian cities

Japan Subway Association (2006). Japan. http://www.jametro.or.jp

[i] *A Fukuda, T Fukuda, S Narupiti, and A Phoowarawuthipanich (2005). Investigating travel behavior associated with the introduction of a car-sharing system in Bangkok. Journal of the Eastern Asia Society for Transportation Studies, 6:1929-1942.*

[j] *Since there is no consistent data that explains the modal split in Bangkok for a certain period of time, this study relies on information reported in studies by Rujopakarn 1999, Kenworthy and Laube 2001, and Sayeg 2002.*

[k] *Wiroj Rujopakarn (1999). Study on transport investment in Bangkok Metropolitan Region during the 8th national economic and social development plan (1997-2001). http://citeseer.ist.psu.edu/569723.html*

under the Office of the Prime Minister for the subway. Having multiple agencies in one area causes an overlapping of responsibilities and redundancies in work.[o] This could result in inefficient use of resources. In short, such poor coordination actually hinders the improvement of the traffic situation.

From a policy perspective, the promotion of the automobile industry in Thailand exemplifies the addition of undesirable impacts to policies dealing with traffic congestion. The Thai government has taken a protectionist approach to encourage the automobile industry's development sine the 1960s, including local content requirements and imposition of high import tariffs.[p] Furthermore, the number of models and series of vehicles were limited so that auto-parts firms and vehicle manufactures would be able to achieve economies of scale.[q] In part owing to this favourable policy for the automobile industry, Thailand has achieved a current ranking of 16th in world auto production and the economy has set a target to become the 9th largest auto producer with production volume of 1.8 million vehicles by 2010. In addition, the government also influenced the location decision of automobile assemblers and parts suppliers by providing well-established infrastructures and incentives for investment, which resulted in a concentration of auto-parts suppliers in Bangkok and its vicinity.[r] Therefore, it is inferred that the automobile industry which increases production of cars in the market helps the number of vehicles swell up in the city as well.

MEASURES TO OVERCOME TRAFFIC CONGESTION CAUSED BY POOR COORDINATION

To redress the overlapping responsibilities among transportation agencies, one attempt made was an establishment of the Office of the Commission for the Management of Land Traffic (OCMLT) which is now responsible for overseeing the integration of various mass transit systems in Bangkok, including road- and rail-based transit.[s] However, it is reported that its effectiveness is severely limited by institutional constraints because OCMLT is unable to put effective fiscal constraints on the activities of executing agencies due to a weak relationship between its coordination of plans and budgetary processes.[t]

Furthermore, OCMLT's authority is far from complete. For example, the Metropolitan Rapid Transit Authority (MRTA), which was renamed Mass Rapid Transit Authority of Thailand in 2000, was founded under the Office of the Prime Minister in order to take responsibility for the implementation of mass transit system projects. MRTA is currently in charge of extension and new line projects for 91 kilometres of the subway in Bangkok.

[l] *United Nations Economic and Social Commission for Asia and the Pacific, UNESCAP (2001). Traffic and transportation for sustainable environment, mobility and access – application of a comprehensive and integrated approach to policy development in the Rattanakosin area of Bangkok. http://www1001.unescap.org/ttdw/Publications/TPTS_pubs/pub_2171/rattanakosin_fulltext.pdf*

[m] *Modal splits are bus (41 percent), car (23 percent), motorcycle (14 percent), taxi (5 percent), and railway and ferry (2 percent) (UNESCAP, 2001). Fares of public transports are as follows; 10 – 40 baht for the Skytrain, 14 – 36 baht for the subway; 7 baht for regular bus and 11 – 19 baht for air-conditioned bus.*

[n] *Bangkok Mass Transit System Public Company Limited (2006). Thailand. http://www.bts.co.th/en/index.asp*

[o] *There were two elevated rail projects in the late 1980s; Hopewell/BERTS project by the Ministry of Transport and Communications (MOTC) and the State Railway of Thailand (SRT) and the Tanayong (Skytrain) project by BMA. While the BMA had eventually put it into practice as the first urban rail system in the economy so-called Skytrain, the project that the MOTC and the SRT had initiated was stalled due to various problems, in which only 12 percent of the project was completed by the time of its termination. (World Bank. 2000)*

[p] *Local content requirements were abolished in 2000: Thai Auto-Parts Manufacturers Association (2006). New excise tax to support Thailand's goal of becoming "Detroit of Asia." Thailand. http://www.thaiautoparts.or.th/fileupload/New%20Excise20Tax.doc*

[q,r] *Somsupa Nopprach (2006). Supplier selection in the Thai automotive industry. Institute of Economic Research, discussion paper series no186. Hitotsubashi University. Japan. http://21coe.ier.hit-u.ac.jp/english/research/discussion/2006/186.html*

[s,t] *World Bank (2000). Study on urban transport development. Washington D.C.,*

Agency	Responsibility
Bangkok Metropolitan Administration (BMA)	- City planning (1999 Bangkok Land-Use Plan) - Provision and maintenance of roads, waterways and drainage system as well as construction and maintenance of roads, and drainage system connecting between local authorities. - Traffic engineering. - Provision of transportation services and mass transportation systems. - Provision of infrastructure.
Department of Traffic and Transportation, BMA	Responsible for traffic management and provision of transportation modes and network in the city of Bangkok.
Department of Highways, Ministry of Transport and Communications (MOTC)	Responsible for construction, repair and maintenance of all highways. (Road Development Plan)
Department of Land Transport, Ministry of Transport and Communications (MOTC)	Responsible for bus routes between economies, such as from Bangkok to Vientiane in Laos, and a Thailand-Malaysia-Singapore route.
Office of the Commission for the Management of Land Traffic (OCMLT), Prime Minister Office	State organization that advises and makes plans concerning traffic problems and patterns
Office of Transport and Traffic Policy and Planning (OTP), Ministry of Transport and Communications	Responsible for recommending policies and formulating transport, traffic and transport safety plans in line with master plans for policy integration purposes. http://www.otp.go.th/English/keyfunctions.asp
Bangkok Mass Transit Authority (BMTA)	State enterprise that runs the Bangkok public bus service and provides bus service to communities in six provinces, i.e. Bankok, Nonthaburi, Nakhon Pathom, Pahum Thani, Samut Sakhon and Samut Prakan.
The Expressway and Rapid Transit Authority (ETA), under the Ministry of Interior	State organization that is responsible for the construction, maintenance, and management of expressways and public transportation infrastructures, as well as other efforts related to expressways. http://www.eta.co.th/eng/about/index.php?ID=60
State Railway of Thailand (SRT)	State enterprise that operates railways.
Metropolitan Rapid Transit Authority (MRTA) (1992) under the Office of the Prime Minister → Mass Rapid Transit Authority of Thailand (2000)	State enterprise that is overseeing the subway construction. Bangkok Metro Co. Ltd. (BMCL) is authorized to operate the subway.
Bangkok Mass Transit System Public Company Ltd (BTS)	To operate Skytrain (Thanayong Electric Train) http://www.bts.co.th/en/index.asp

74.1 **Transportation-related government agencies in Bangkok**
APERC 2007

These are just a few of the agencies that are identified regarding the transport and traffic issues in Bangkok. World Bank (2000) reports that there are at least 27 agencies related to urban transport.

This case study indicates that it is crucial to have a policy that is coordinated among different plans so that the effectiveness of each policy is not diminished. Reflecting on the fact that the traffic congestion in Bangkok was partly caused by lack of coordination between the land-use plan and the transport plan, consideration of land usage will be essential when road network expansions are planned. Most importantly, however, this cannot be possible without the cooperation of different agencies related to transport issues. Additionally, coordination in policies would help these agencies to plan in a long-term perspective because they could better anticipate what their partner agencies are doing. To be certain, a long-term approach is needed for a complex plan such as the development of road networks. Therefore, it is necessary for each agency to work with other agencies in order to draft an integrated policy whenever multiple parties are concerned.

Next, a mass transit system which expedites people's travel is critically important to curb the use of passenger vehicles. Accessibility to transits plays an especially vital role-- not only in terms of physical access to a station/bus stop but also the convenience of transfers between two modes influences people's transport choices. Easing the traffic congestion in Bangkok will depend on the extension of existing lines and the construction of new lines in the Skytrain and subway systems to improve accessibility. Furthermore, the Bangkok case suggests the importance of actual implementation of mass transit development plans. In fact, development of urban rail systems in Bangkok was recommended as early as the mid-1970s, yet the Skytrain did not start operation until more than twenty years later due to administrative and financial reasons.[u] It is fundamental, therefore, to hold conditions such as political stability and financial capability so that such plans can actually be implemented.

Of course, there can be no quick remedy for Bangkok traffic congestion. However, if the traffic situation was to improve, it would be beneficial to society both economically and environmentally. A policy that takes a holistic approach is needed to tackle this persisting problem.

[u] There are possibly two reasons for the delay on the project; first, the Expressway and Rapid Transit Authority (ETA) which is responsible for building expressways and urban railways put more emphasis on expressway network development; and second, private stakeholders hesitated to invest in the project due to mistrust against the government agencies, but private investment was critical financial resources to implement the project (World Bank, 2000)

MEXICO CITY

The transportation sector is the largest source of energy consumption within the Metropolitan Area of the City of Mexico. Correspondingly, vehicle emissions tend to be the primary source of air pollution. Over the past three decades, several air quality management policies and emissions control programmes have been introduced in order to reduce pollution. "Hoy no Circula", a license plate restriction programme, is one measure that has been employed with both positive and negative results.

Total Pop.	Land Area	Pop. Density	GRP	PCI	Gasoline Use	Pas. Vehicles
19.4 million[α]	4,980 km^2	3898/km^2	175 billion [β]	9,064[β]	5.1 Mtoe[γ]	3.28 million[δ]

APERC 2007, α 2005 βYear 2000 USD PPP γ 2000 δ includes cars, light trucks, and motorcycle

INTRODUCTION

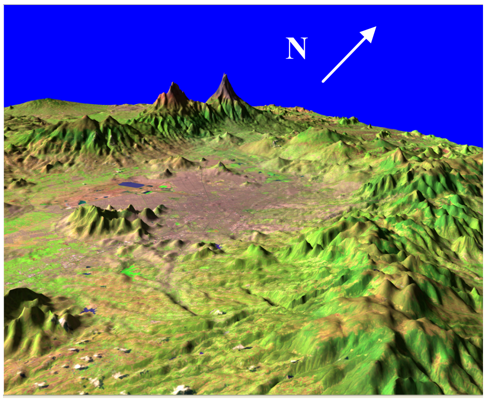
The Metropolitan Area of the City of Mexico, known as la Zona Metropolitana de la Ciudad de México (ZMCM), is located in the south central portion of Mexico. It lies in a high altitude basin, about 2240 meters above mean sea level, at the southern edge of the Mexican central plateau. This basin is bordered on the east and west by a series of mountain ranges, which rise more than 1000 metres above the valley floor, and low points to the north and south.

The ZMCM covers 4980 square kilometres, of which 36 percent are urban, and encompasses the larger metropolitan area of Mexico City. This larger area is comprised of the sixteen delegations of the Federal District, 40 conurbation municipalities of the State of Mexico and one municipality of the State of Hidalgo. The population of the metropolitan area has grown to approximately 19.411 million (as of 2005); about 19 percent[a] of Mexico's entire population resides within its boundaries, creating an average population density of about 3,898 persons per square kilometre.

Although the metropolitan area's population continues expanding, currently at an annual growth rate of 1.28 percent, the pace of this increase has declined from an average historical annual growth rate of 1.66 percent.[b]

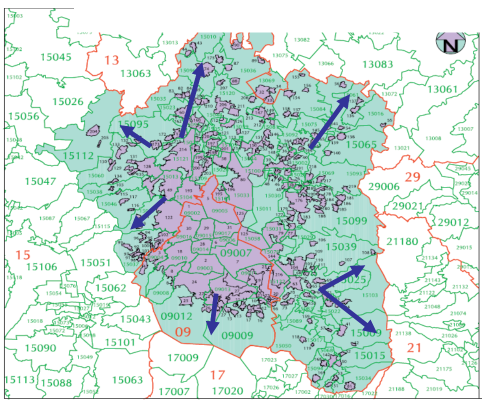
Coupled to this population growth is an expansion in the metropolitan area's spatial boundaries. The map above shows the expansion trends of the ZMCM; specifically, the green shaded area outlines the current boundaries of the ZMCM (2004). The current urbanised zones (light purple) are continuously expanding outwards, as is delineated by the purple arrows. Although these arrows only reflect potential expansion zones and directions, they exemplify the fact that the urban surface area growth rate is expanding at even a faster rate than the population growth rate. Because of Mexico City's uni-centric geospatial layout, the patterns of mobility will steadily intensify in the future, creating longer travel distances for commuters, hence making it more difficult for individuals to rely on mass transit versus passenger vehicles.

The ZMCM, in addition to being the most populated metropolitan region in Mexico, also contributes significantly to Mexico's gross domestic product. The Federal District itself contributes 22 percent of the national gross domestic product. In terms of financial development, the District has an annual metropolitan gross product (MGP) per capita



76.1 Topographic view of the ZMCM with exaggerated vertical relief

NASA/Goddard Space Flight Center Scientific Visualization Studio



76.2 Growth patterns of the Metropolitan Area of the Valley of Mexico

APERC 2007, derived from INEGI data. Map courtesy of INEGI.

This map demonstrates the expansion trends of the ZMCM. The green shaded area outlines the current boundaries of the ZMCM (2004). The light purple zones reflect urbanised areas. The purple arrows delineate potential expansion zones and directions growth rate of 16.21 percent.[c] As an indicator to its financial prosperity, the ZMCM had an annual MGP per capita in 2004 of USD 20,079, which is more than 2.5 times the national gross domestic product per capita of USD 7,766 (2000 PPP).

This spatial expansion, coupled with economic growth, has led to an increase in both intra- and inter-regional mobility demand. To meet this additional demand, the region has continued to develop its paved road network, currently at 10, 182 km, or 8.3 percent of Mexico's total. The region's transportation infrastructure also includes a metro/light rail system within the Federal District (27 km), a trolley bus network (489 km), a bus route network (4463 km), and a collective mass transit network -known as *colectivos*- (201 km). As a result of this transportation infrastructure development and the increase in travel distances, road transport energy consumption has likewise increased.

[a] *Instituto Nacional de Estadística, Geografía e Informática de Mexico, INEGI (1995). Conteo de poblacion y vivienda 1995. Mexico.*

[b] *Historical growth rate is based on 1990-2000.*

[c] *This growth rate is for the Federal District from 1995-2004. It takes into account real pesos.*

	Population Growth Rate [Percentage]				Urban Surface Area Growth Rate [Percentage]	
	1980-1990	1990-2000	2000-2005	1980-2005	1980-1990	1990-2000
DF	-0.70	0.44	0.27	-0.05	--	--
Mexico Municipalities	3.47	2.95	2.18	3.01	--	--
ZMCM	0.98	1.66	1.28	1.31	1.39	1.80

77.1 Growth patterns of the Metropolitan Area of the Valley of Mexico, 1980-2000
APERC 2007

ENERGY CONSUMPTION FOR ROAD TRANSPORT

Mobility demand, as mentioned above, in turn translates into increased transportation infrastructure requirements that impact the amount of energy consumed for road transport. Transportation fuel energy within the ZMCM is supplied by gasoline, diesel, liquefied petroleum gas (LPG), and compressed natural gas (CNG).

Overall, the ZMCM consumes more energy per capita (Toe per 1000 people) in the transport sector than Mexico's average. Not surprisingly then, the ZMCM also consumes more gasoline per capita than the country's average. This statistic might reflect the fact that the metropolitan area has a higher passenger vehicle stock (passenger vehicles per capita in 2004 were 28.1 percent greater than Mexico's average), which consists of about 95 percent gasoline vehicles [78.1].

		Percentage of Vehicles by Fuel Type				% of Vehicle Fleet (By Type)
		Gasoline	Diesel	LPG	CNG	Total
Vehicle Use	Type of Vehicle					
Private Use						**83.1**
	Personal Autos	99.8	0.01	0.14	0.03	75.6
	Pick Up	99.9	0.005	0.07	0.01	4.9
	Motorcycles	100	N/A	N/A	N/A	2.6
Passenger Transport						**5.5**
	Taxis	99.99	N/A	0.002	N/A	3.2
	Combis	100	N/A	N/A	N/A	0.5
	Microbuses	74.7	0.6	21.9	2.8	0.9
	Autobuses	0.8	99.1	0.1	N/A	0.9
% of Vehicle Fleet (By Fuel)		**95.3**	**3.8**	**0.8**	**0.07**	

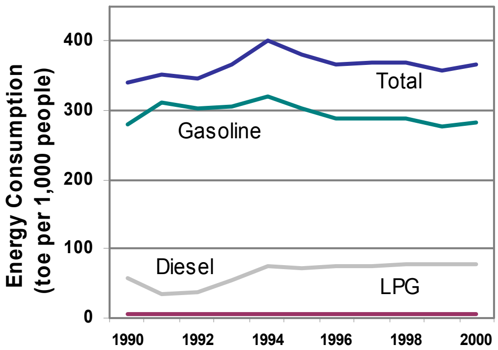
78.1 **Vehicle fleet fuel breakdown, 2002**
APERC 2007

This data reflects only vehicles used for passenger transport and personal use.

HISTORICAL TRENDS FOR GASOLINE/DIESEL/LPG CONSUMPTION

The transportation sector consumes the greatest share of energy in the ZMCM (44 percent), using more energy than the industrial sector (38 percent) and the residential sector (18 percent).

In terms of consumption share, transportation fuel is predominately supplied by gasoline (a little more than three quarters). Transport gasoline consumption in the ZMCM from 1990-2000 has grown slowly, at an annual rate of 1.78 percent. Similarly, Mexico's transport gasoline consumption as a whole grew at an annual rate of 1.76 percent, only slightly lower than the ZMCM's annual growth rate. However, if population growth is taken into account, Mexico's per capita gasoline consumption has slightly decreased on average at 0.08 percent yearly. The ZMCM's per capita consumption, on the other hand, has actually slightly increased by 0.11 percent per year, though the difference, once again, is quite small.



78.2 **Per capita transport energy consumption**
APERC 2007

	Toe per Capita [2000] ZMCM/Mex		Annual Growth Rate [Toe per Capita]		Annual Growth Rate [Toe]	
Fuel		Mexico	ZMCM	Mexico	ZMCM	Mexico
Gasoline	283.19	244.33	0.11%	-0.08%	1.78%	1.76%
Diesel	77.34	91.44	3.20%	0.57%	4.92%	2.42%
LPG	5.35	11.15	1.89%	9.57%	3.59%	11.59%
Total	365.88	346.91	0.71%	0.29	2.39%	2.13%

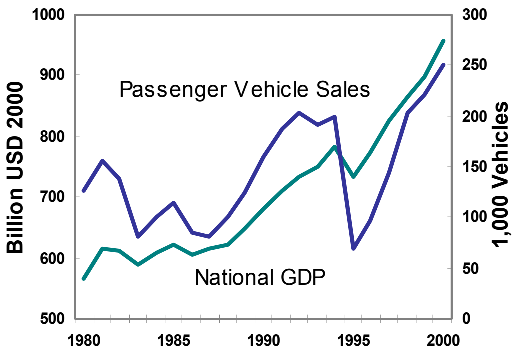
78.3 **Transport energy consumption annual growth rate, 1990-2000**
APERC 2007

This data reflects the energy consumption of (private) passenger vehicles, urban mass transit (including rail, bus, taxis, microbuses), and cargo transport vehicles.

Diesel fuel provides about one fifth of the transport energy fuel consumed within the metropolitan region. Its consumption has had an average annual growth rate of 4.92 percent within the ZMCM, more than twice that of Mexico (2.42 percent per year), which may be attributed to cargo/freight transport associated with industrial development (the ZMCM produces 30 percent of the country's industrial output). Diesel's annual per capita growth rate is the highest of all the transport fuels used in the ZMCM (3.2 percent). In contrast, Mexico's consumption only slightly grew by 0.57 percent annually during this same period.

LPG/CNG, though rising in importance, still plays a minor role in transportation energy consumption (less than 2 percent). During the 1990s, LPG/CNG use grew an average of 3.59 percent per year, in stark contrast to Mexico's growth of 11.59 percent that outpaced both gasoline and diesel growth for the country (though starting from a much smaller absolute level). In the future, the ZMCM might see similar growth rates as a result of vehicle stock changes associated with air quality issues.

During periods of economic crisis, the ZMCM's passenger vehicle sales tend to decrease as a result of exchange rate instability and high inflation and interest rates. The graph displays a downturn in passenger vehicle sales during the major economic downturns in the 1980's and 1990's. During the early 1990's, the Mexican economy went through a brief recession. As a result, passenger vehicle sales declined during the first half of the decade and then steadily increased until the end of the decade. After this rapid increase, the rise in passenger vehicle sales stabilised, increasing at a much slower pace [79.1]. A reduction in passenger vehicle purchases might have contributed to the slow rise in gasoline consumption patterns



79.1 **Trend of GDP and passenger vehicle purchases in the ZMCM**
APERC 2007

	1990	1995	2000	2004	1990-1995 (%)	1995-2000 (%)	1990-2000 (%)	2000-2004 (%)
ZMCM	152.6	132.4	167.2	169.6	-2.8	4.8	0.92	0.4
Mexico	83.7	83.4	107.4	132.4	-0.09	2.6	2.5	5.4

79.2 **Passenger vehicles per 1,000 persons, 1990-2004**
APERC 2007

	1990	1994	1995	2000	1990-1994 (%)	1994-2000 (%)	1990-2000 (%)
ZMCM	280.01	319.03	303.71	283.19	3.31%	-1.39%	-0.08%

79.3 **Gasoline consumption, toe per 1,000 population, 1990-2000**
APERC 2007

In the ZMCM, private passenger vehicles account for 83.1 percent of the entire vehicle fleet and more than 99 percent of these vehicles are gas powered. Thus, this reduction in passenger vehicle ownership reduced gasoline fuel consumption.

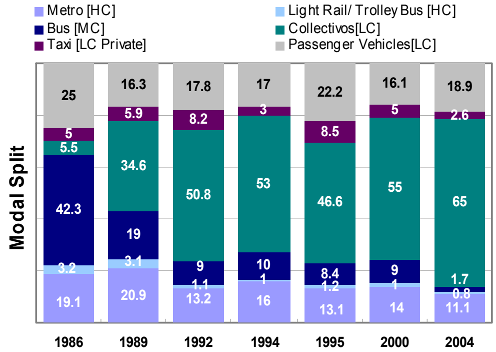
FACTORS AFFECTING GASOLINE/DIESEL/NATURAL GAS CONSUMPTION

In the ZMCM, mass transit[d] (both high and low capacity) accounts for 81 percent of passenger trips (passenger vehicles still account for 71 percent of the registered vehicle fleet on the roads).[e] In 2004, 65 percent of the person-trips taken within the ZMCM were made by *colectivos* (privately run franchised or concessioned transport that consist of low capacity microbuses that run a set route in or between towns), 18.9 percent by passenger vehicles (autos/light trucks), 11.1 percent by metro, 2.6 percent by taxi, 1.7 percent by bus, and 0.8 percent by light rail/ trolley bus.

The relative shares of mass transit transport mode for trips have significantly changed since the 1980's, from high capacity to low capacity vehicles. This shift from a high capacity bus fleet (predominately diesel) to the use of low capacity minibuses (mostly gasoline operated, however some larger ones run on diesel and others have been converted to LPG) has decreased overall fuel efficiency and increased pollution levels (most of the *colectivos* were built before 1994 and have no pollution controls) within the region.

Although mass transit contributes significantly to the transport of passengers in terms of its percentage of person-trips, urban mass transit vehicles only accounts for 5.5 percent of the vehicular fleet on the road. On the other hand, passenger vehicles account for 83.1 percent of the vehicles on the road, as such contributing significantly to both congestion on the roads and overall fuel consumption.

The difference in distribution between the percentage of passenger trips and the vehicular fleet size may be reflective of income inequality within the region. Within the Federal District, the Gini index[f], which reflects income inequality (in this case specifically monetary), was calculated to be 49.04 (2004).[g] The top 20 percent of income earners account for 56.3 percent of the District's income and within the greater ZMCM, about 13 percent of income earners make less than the official minimum wage. Since this inequitable income distribution may influence the selection of transport mode, measures aimed at reducing fuel consumption should further consider the impacts of this inequality.



80.1 Passenger modal split, all passenger transport

APERC 2007, GDF

HC refers to high capacity, MC refers to medium capacity, and LC refers to low capacity. These modal share statistics exclude trips by foot or bike, since the objective of the referenced study was to establish "demand corridors" for public transport and roads as a means to possibly justify investment in infrastructure.

[d] *Mass transit includes metro, light-rail, buses, colectivos, and taxis.*

[e] *APERC analysis based on data acquired from SETRAVI and SMA.*

[f] *The Gini index measures inequality over the entire distribution of income or consumption. A value of zero reflects perfect equality and a value of 100 is perfect inequality.*

[g] *Survey based on income. Reference: Mexico's Gini index in 2005 was 51, USA 45, Chile 54, and China 44.*

ISSUES

AIR QUALITY PROBLEMS FROM THE ROAD TRANSPORT SECTOR

As previously discussed, most of the ZMCM's energy demand is associated with urban transportation. Correspondingly, vehicle emissions tend to be the primary source of air pollution in Mexico City. An emissions inventory study conducted by the Federal District identified the internal combustion engine as the main source of most pollutants (75 percent), followed by natural sources (12 percent), services (10 percent) and industries (3 percent).[h]

The main pollutants derived from transport emissions are carbon monoxide (CO), nitrogen oxides (NOx), and hydrocarbons (HC) which originate from the incomplete combustion of fossil fuels. According to the aforementioned 2002 study, vehicles are responsible for 99 percent of the carbon monoxide, 83 percent of the nitrogen oxides, and 58 percent[i] of the sulphur dioxide in Mexico City's atmosphere. In recent years, there has been a reduction in pollutant emissions in the ZMCM,

	PM10	SO_2	NOx	CO
Private Cars	3.12	29.82	28.10	41.98
Pick- Ups	0.42	3.63	5.86	7.02
Motorcycles	0.10	0.74	0.15	1.54
Taxis	0.68	6.34	7.93	9.51
Colectivos	0.35	2.89	7.27	13.22
Buses	2.70	2.33	5.01	0.58
Trucks*	11.51	11.93	28.71	19.23

80.2 Transport contribution to total emissions, percentage by vehicle type, 2002

APERC 2007, SMA

Trucks category includes vehicles≥ 3tons and tractocamiones however, there are still approximately 2.1 million tons (includes CO, NOx, and SO_2) per year emitted by mobile sources (2002 data).

In terms of the transportation sector, an important source of air pollution is gas exhaust from private vehicles. Freight trucks contribute the largest share of PM10 and NOx emissions, however they are not responsible for passenger transport. Passenger vehicles supply the largest transport contribution (from the personal mobility road transport sub-sector) to total emissions.

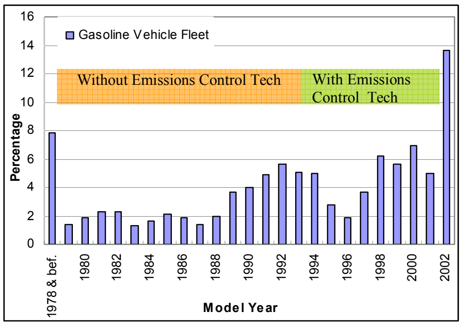
As of 2002, 34 percent of the metropolitan area's gasoline vehicle fleet and 41 percent of its diesel fleet consisted of cars from the 1980's. In addition, more than a third of the vehicle fleet did not have up-to-date electronic ignition and fuel injection systems (most vehicles are carburetted, unlike the US where fuel injection systems are standard on autos) and barely 30 percent had catalytic converters (devised to reduce the amount of hazardous gasses from the vehicle exhaust). In the metropolitan area, carburetted vehicles release more emissions per vehicle than fuel injected vehicles.

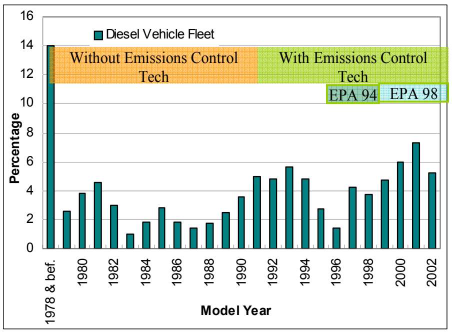
In addition to having a higher transport contribution to total emissions, private vehicles also have a higher index of pollutant contribution per passenger mode share. Although *colectivos*, which account for 65 percent of all passenger transport trips, are neither energy-efficient nor environmentally clean, they exhibit a low index of pollution per passenger trip share because they operate at high occupancy rates. Private vehicles, on the other hand, have a higher relative pollution index, resulting from their lower occupancy rates.

Overall, these emissions have contributed to making air quality a dire crisis within the ZMCM. The levels of NOx and O_3, for instance, have routinely exceeded maximum exposure limits established by both the Mexican Government and the World Health Organization (WHO) During the period between 1990-2005, WHO's ozone maximum exposure level (the point where ozone starts to threaten human health) was exceeded in Mexico City for 92 percent of all days. The consequences of this air pollution are aggravated by the metropolis' meteorological and topographical location. Due to its high altitude (the average atmospheric pressure is roughly 25 percent lower than at sea level), fuel combustion is far from ideal and results in the release of primary pollutants into the atmosphere. Additionally, since the ZMCM is located within a valley, the surrounding mountains can create air stagnation, which enhances air pollution when there are thermal inversions (warmer air passing over the valley and trapping cooler ground air beneath it). Likewise, natural dispersion of pollutants is prevented when there are insufficient ground-level prevailing winds that can blow away the contamination generated within the metropolitan area elsewhere and dilute overall concentrations.

MEASURES TO IMPROVE AIR QUALITY

Over the past three decades, several air quality management policies and emissions control programmes have been introduced in order to reduce pollution within the metropolitan area [83.1 and 84.1]. The main areas that the ZMCM has shown the most progress in regards to transportation pollution have been vehicle technology adoption, inspection and maintenance programme, and fuel improvements. Since 1994, reductions in roadside emission of CO and volatile organic compounds (VOCs) have been attributed to the deployment of emission control technologies.[j] For example, the Vehicle Emissions Verification Programme (initiated in 1982) was specifically





81.1,2 Vehicle stock ages, 1980-2002

APERC 2007, GDF 2002

The use of diesel emissions control technology and gasoline control technology began in 1990 and 1993, respectively. Gasoline vehicle models after 1993 have catalytic converters. Diesel vehicle models between 1994-1998 (~ 13%) comply with US EPA94 standards. Diesel vehicle models starting from 1998 (~ 27%) comply with

Vehicle Technology	NOx	CO
Without Catalytic Converter	3.41	20.8
With Catalytic Converter	0.32	1.74

81.3 Polluting emissions, g/km

The Union Oil Company of California 1991

	PM10	SO2	NOx	CO
Passenger Vehicles	0.19	1.77	1.80	2.59
Taxi	0.26	2.44	3.05	3.66
Colectivos	0.01	0.04	0.11	0.20
Bus	1.59	1.37	2.95	0.34

81.4 Index of pollutant contribution per passenger modal share

APERC 2007, SMA, STV

[h] *Gobierno del Distrito Federal, GDF (2002). Programa integral de transporte y vialidad 2001-2006. Gaceta Oficial del Distrito Federal. Mexico.*

[i] *In 1994, mobile emissions only contributed 24% to total sulfur emissions. Its share of emissions has grown as the share of fixed sources has decreased over time. Nevertheless, the actual emissions have decreased between 1994-2002 by 6.7% per year.*

proposed to reduce vehicular air pollution emissions by ensuring that those vehicles with high emission levels are correctly repaired to meet national pollution standards (These standards were often meet through the deployment of new emission control technologies).

During the past decade, fuel improvements have also become a fundamental component of air quality management measures and programmes[k]. The shift to unleaded gasoline (1989), the adoption of catalytic converters for the gasoline fleet (1991), and the adoption of U.S. Tier I light duty vehicle emission standards (1999) are just a few of the important strides. Additionally, the ZMCM has promoted the modernisation of the urban mass transit vehicular fleet as part of the *Programa para Mejorar la Calidad del Aire en el Valle de México*, PROAIRE (1995). Some measures derived from this programme worth mentioning include the modernisation and update of the Hoy No Circula programme; the renewal of low-capacity urban mass transit (UMT) vehicles (*colectivos,* specifically taxis)[l], the substitution of medium-capacity UMT vehicles (microbuses) with higher-capacity models[m], and the promotion of alternative fuel use within the UMT sector[n]. This diversified combination of emission control measures, although not empirically proven, has likely contributed to a decrease in the level of the ZMCM's vehicle emissions.

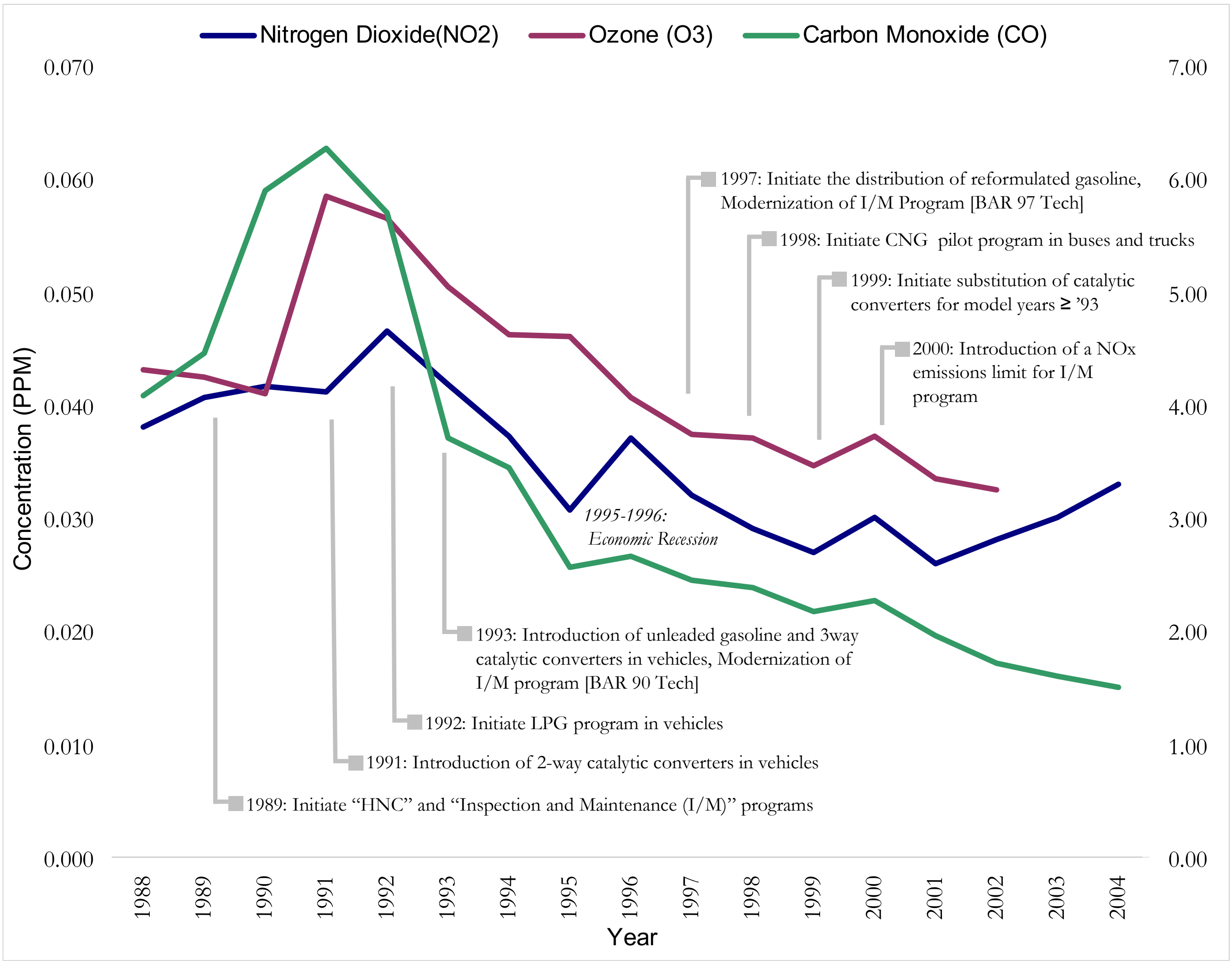
[j] *J West et al. (2000). Modeling ozone chemistry and sensitivity to emissions of VOCs and NOx in Mexico City.*

[k] *L Schipper and A Golub (2003). Transportation and environment in Mexico City: reviving a bus system or giving in to the auto?*

[l] *Measure provides financial support to public transport grants holders for the renewal of 10,000 taxis. Five-passenger colectivos are replaced with high capacity vehicles using unleaded gasoline. These replaced taxis are completely destroyed. Program is accomplished without significantly increasing the number of franchised vehicles.*

[m] *Measure was initiated with a budget of 8 million USD for the acquisition of 800 diesel buses. At present, 500 units have been replaced.*

[n] *Measure enabled UMT bus fleet renewal, which consisted of replacing old diesel buses with low-emission diesel buses (projected to be 881). At present, 506 old diesel buses have been decommissioned.*



82.1 **Pollutant trends in the ZMCM, ppm, 1990-2004**
APERC 2007

Year	Programmes		Introduction of Emissions Control Technology	Fuel Measures
	Inspection and Maintenance Programmes	**Ban on Automobile Operations**		
1981			Computerized ignition	
1982	Capital City government initiates a voluntary inspection program, "Vehicle Emissions Verification Program [VEVP], which measured HC and CO.			
1985			Fuel injection	
1988	▪ [VEVP]: Obligatory annual emissions inspection for car models ≥ 1982 with BAR '84 procedures. ▪ Test & repair centers licensed.			
1989		Hoy no Circula [HNC] program is introduced. (prohibits gasoline vehicles to run once a week on the roads in the ZMCM).		Unleaded gasoline introduced
1990	First fundamental program targeting atmospheric pollution in the ZMCM is introducted. (*Programa Integral Contra la Contaminación Atmosférica en la ZMCM* [PICCA])			
1991			Catalytic converters; They are also made obligatory in all new cars [PICCA]	Improvements in gasoline by PEMEX (on-going) [PICCA]
1992	[VEVP]: Obligatory annual emissions inspection with BAR '90 procedures (static test) for all vehicles.			
1993	Test only centers operated by MC are closed. Substituted by multi-lane, privately owned, macro-centers. Dynanometer test introduced for intensive usage vehicles.		3-way catalytic converters introduced	
1994	▪ Stricter emissions controls on all new vehicles [PICCA] ▪ Frequency of obligatory vehicle emissions testing increased to every 6 months. [PICCA]			

83.1 **Air pollution control programmes and measures, 1981-1994**

J Rogers (1996). Vehicle emissions programs in Mexico
- and-
A Villegas Lopez (2001). Metropolitan Mexico City: transportation Policies and Economic development.

[VEVP]: measures arising from VEVP programme; [HNC]: measures arising from HNC program; [PICCA]: measures arising from PICCA programme

	Programmes	
Year	**Inspection and Maintenance Programmes**	**Ban on Automobile Operations**
1996	▪ Test & repair centers closed. New verification centers authorized. Actions taken to improve quality of emissions tests: dynamometer test for all light-duty fleet, centralized operation, electronic security, gas calibration audits, oversight video-cameras and stringent recording and reporting rules. ▪ "Programme to Improve Air Quality in the Mexico Valley 1995-2000" (*Programa para Mejorar la Calidad del Aire en el Valle de México*, PROAIRE) is introduced.	▪ [PROAIRE/ HNC]: Stricter emissions-testing, HCN changes in order to foster fleet turnover and cleaner cars. Two different kinds of restrictions are introduced (identified by sticker number). Each restriction targets a diff segment of the vehicle fleet. "0": no restriction. Model years older than 1993. "1": Banned to run one day/week. Model-years 1989-92. "2": Banned to run two days/week during declared environmental emergency. Model-years 1989 and older.
1997	▪ More "Verificenters" are authorized; vehicles can be tested at any MCMA's station regardless of the origin of the car's registration plate. ▪ Emissions testing using Hybrid Test protocol CAM97 is started. (ASMT Test Procedure).	
1998	Programme to Reinforce Actions to Improve Air Quality in the Mexico Valley (*Programa para Fortalecer las Acciones de Mejoramiento de la Calidad del Aire en el Valle de México*)[is introduced. Program creates: ▪ Stricter vehicle emissions standards (<300 ppm Hydrocarbons and <3 per cent CO) →aimed at eliminating pre-1985 models (constitute 50 percent of vehicles in circulation but contribute 80 percent of the pollution). ▪ A 2 year exemption from the biannual emissions-testing for 1999 models which fulfill <0.25 grams NO compounds/km traveled.	
1999	▪ CAM Test Procedure fully adopted. ▪ Obligatory catalytic converter replacement for 1993 model year vehicles. ▪ U.S. Tier I light duty vehicle emissions standards are adopted.	▪ [HCN] New restriction stickers introduced: "00": No restriction and biannual inspection for the first time; 1999 model-year vehicles and newer.. "1": vehicle model-years 1993-95, full-injection engines and older catalytic converters. "2": vehicles older than 1993, high emitters, conventional carburetor & no catalytic converter or older one.
2000	▪ Mandatory catalytic converter replacement for 94 and 95 model-year vehicles.	▪ [HNC]: Sticker "0" for diesel vehicles passing EPA-94.
2001	[VEVP]: Capital City Government rules that vehicles with its license-plates must be tested in *Verificentros* within the same jurisdiction.	

84.1 **Air pollution control programmes and measures, 1996-2001**

J Rogers (1996). Vehicle emissions programmes in Mexico
- and-
A Villegas Lopez (2001). Metropolitan Mexico City: transportation Policies and Economic development.

[VEVP]: measures arising from VEVP program; [HNC]: measures arising from HNC programme; [PICCA]: measures arising from PICCA programme

HOY NO CIRCULA

Hoy No Circula (HNC), a policy initiative first implemented in 1989[o], is a programme restricting the use of certain sectors of the passenger vehicle fleet during different days of the week.[p] These passenger vehicle restrictions are reflected in the last digit of license plates, as such making it easier for law enforcement officials to detect vehicles violating that day's restriction.[q] At its outset, this no-driving day programme was aimed towards reducing congestion, pollution and fuel consumption by reducing vehicle kilometres travelled (VKT). Over time, however, the principal objective of HNC has changed from a circulation ban to a fleet turnover incentive.

The effectiveness of the HNC programme at achieving its overarching goals has been scrutinised since its commencement. Analysts criticise the ban's regressive nature and its generation of

[o] Programme was originally imposed as part of a short-term "emergency program" deployed for winter months in Mexico City.

[p] Hoy No Circula was a major component of the first major air pollution control plan (PICCA)..

[q] Mexican law stipulates that vehicles that violate the ban are to be impounded for 48 hours and their owners are to pay a fine equivalent to USD 200. These penalties have convinced most drivers to not drive on the days that their license plate restricts.

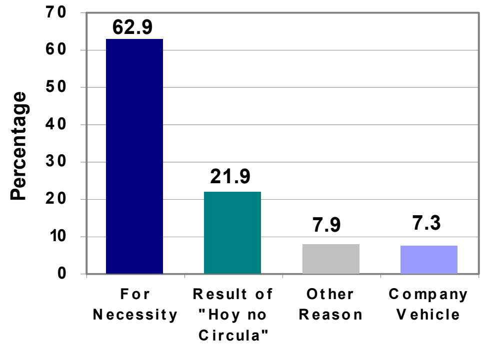
unintended consequences, specifically an increase in the procurement of additional vehicles. A study conducted by UAM Azcapotzalco in 1994 reported that 46 percent of drivers own more than one vehicle, specifically an older vehicle model.[r] The report goes on to show that out of this 46 percent, 22 percent purchased an additional vehicle as a result of Hoy no Circula. As such, 10 percent of ZMCM drivers obtained an additional vehicle as a response to the adoption of HNC during that year.

Furthermore, the empirical analysis of a 1997 study by Eskeland and Feyzioglu revealed that since the HNC's implementation, the ZMCM has turned from a net exporter of used vehicles (avg. of 74,000/year from 1983- 1989) to a net importer (85,000/year from 1990-1993).[s] The ZMCM's transformation from "a net exporter of vehicles to a net importer is consistent with households buying additional vehicles [often older and more polluting models] and delaying the scrappage of vehicles in order to be able to drive during all days of the week". Thus, the circulation restrictions seem to disproportionately impact the underprivileged, who could not afford the procurement of an additional vehicle. In addition, there is a notion that the availability of additional household vehicles might have actually stimulated additional travel. As such, this acquisition of additional vehicles poses a potential problem to not only the city's air quality goals, but also reduces its potential to reduce its energy consumption since Mexico does not have any passenger vehicle fuel economy standards.

Overall, the impact of HNC on air quality in the ZMCM is unclear because of a lack in empirical analysis on its success or failure at reducing pollution rates. One study that attempted to address this issue was conducted in 2006 at the University of Michigan in the United States. In this study, air quality measurements within the ZMCM were compared both pre and post- restrictions (1986 to 1993). The study concluded that the circulation ban had resulted in "a relative increase in air pollution during weekends and hours of the day when the restrictions are not in place," and "across pollutants and specifications there is no evidence that the [HNC] programme has improved air quality".[t]

As a result of these initial setbacks, subsequent reauthorisations attempted to address the problems with HNC.

Over the years, the HNC circulation ban and closely related policies have undergone a number of transformations. Early anti-pollution legislation required passenger vehicle owners to keep their vehicles well- tuned and serviced. As a means to foster fleet turnover and cleaner cars, (modifications to the programme in 1997 and 2004 raised the emissions standards on new vehicle models) certain newer low-emissions vehicles were exempted from the restrictions and restrictions were implemented for some taxis and buses.[u,v] During the 17 years of its implementation, the number of passenger vehicles banned on each weekday has decreased from 20 percent to about 13 percent.[w] This change in policy tactic has created a radically different outcome, where certain parts of the community bear a disproportionate share of the burden, solely as a result of their income level. As a result, these policy changes can be considered counterproductive in managing travel demand and reducing congestion within the ZMCM.



85.1 Old vehicle acquisition vs. Hoy no Circula

APERC 2007, Universidad Autonoma Metropolitana (UAM) Azcapotzalco 1994

	Before HNC	After HNC	Difference and Standard Error	
Weekends Relative to Weekdays				
Average *	(.105)	(.067)	(.037)	.014
Night-time Relative to Daytime				
Average *	(.334)	(.273)	(.061)	.007

85.2 Evidence of inter-temporal substitution

LW Davis (2006). The effects of driving restrictions on air quality in Mexico City. University of Michigan. USA

**refers to the average of carbon monoxide, nitrogen dioxide, ozone, nitrogen oxides, and sulfur dioxide emission levels. This table presents data on the average pollution levels for non-peak periods relative to peak periods. Prior to HNC, average weekend emission levels were 10.5 percent lower than average weekday levels. Differences and standard errors indicate change in relative pollution levels after HNC. Negative differences indicate relative increases in non-peak periods. Night-time is 11pm to 4am and daytime is 5am to 10pm.*

[r] *Universidad Autonoma Metropolitana Azcapotzalco 1994. Research on effectiveness of Hoy no Circula.*

[s] *G S Eskeland and T Feyzioglu (1997). Rationing can backfire: the day without a car in Mexico City. The World Bank Economic Review, 11(3): 383-408.*

[t] *For further information on the details of this study and the analytical work, please refer to LW Davis (2006). The effects of driving restrictions on air quality in Mexico City. University of Michigan. USA.*

[u] *Gobierno del Distrito Federal, GDF, Secretaria del Medio Ambiente (2004b). Actualizacion del programa Hoy No Circula. Mexico.*

[v] *Specifically, older models are restricted for 1-2 weekdays as well as some weekends. Vehicles with catalytic converters and tighter emission standards (93 and later) are exempt completely.*

[w] *C Zegras et al. (2000). Metropolitan Mexico City mobility & air Quality; white paper for the MIT integrated program on urban, regional, and global air pollution.*

IMPLICATIONS

The key transportation focus in Mexico City over the past two decades in terms of air quality management programmes has been on establishing stricter emissions controls on all new vehicles and establishing fuel measures to improve fuel quality. Analysis of air quality measurements show that though the number of days with extreme pollution has decreased, overall air quality still remains poor. In terms of the transportation sector's contribution to local air pollutant emissions, various factors that contribute to poor air quality remain to be addressed. Although the number of new vehicles with stricter emissions controls has increased, older vehicle models continue to make up a significant share of both the gasoline and diesel vehicles on the road. In terms of mass transit, the shift from larger capacity buses to smaller *colectivos* has increased the number of vehicles on the road and the pollution per passenger-kilometre provided by road transport. Additionally, current urban development expansion trends involving the growth of so-called "edge cities" in the southern and western part of the ZMCM and remote areas in the southern part of the State of Mexico have increased travel distances between the central city and the greater metropolitan area.

The current viewpoint among ZMCM authorities is that more fundamental changes must occur within the transportation sector and the policies used to address the above trends. To certain city officials, it is increasingly important to increase vehicle size in the mass transit sector, essentially transferring ridership out of low-capacity *colectivos* and back to larger capacity buses. Although this might help reduce the energy intensity and emissions per vehicle in the mass transit sector, it does not address the impact from passenger vehicles in these same categories. The trend in passenger vehicle usage needs to be addressed, since such vehicles, although comprising a smaller percentage of passenger kilometres travelled, make up a more significant portion of congestion and pollution on the roads.

In order to assess Hoy no Circula and its potential role in the ZMCM's passenger vehicle transportation transformation scheme (as well as its potential applications in other metropolitan areas), analysis of the programme's initial goals and its success at achieving these goals must be revisited. Although the programme might be an effective facet of a policy tool for fleet renewal, it has not yet been effective at accomplishing its initial intended goals of reducing congestion, pollution and fuel consumption by reducing vehicle kilometres travelled. Currently, both congestion and pollution still remain serious problems within the region.

In general, HNC might be seen as just one piece of a comprehensive and effective fleet renewal programme. Since it exempts new vehicles from the circulation ban, it may incentivise drivers to purchase newer more efficient vehicles. However, for this fleet renewal programme to be completely effective, it has to be coupled with a fleet retirement programme, which helps decrease the less efficient car stock. If not, as statistics reflect within the ZMCM, the programme might actually increase the number of vehicles on the road, instead of reducing or maintaining current vehicle stock levels. Moreover, this might affect local pollution as well, countering emission alleviation benefits accumulated from the new "less-polluting" vehicle purchases.

Alternatively, the programme can be remodelled by coupling it with some sort of vehicle licensing restriction (potentially based on a per family standard), as a means to restrict additional vehicle (those not used as a replacement to older less efficient models) stock purchases. However, when considering HNC as a potential policy course, the metropolitan area has to consider the programme's effect on different economic sectors of the population and weigh it against the potential benefits of the programme. As is, the programme can disproportionately impact social classes that do not have convenient physical access to mass transit or cannot afford a new vehicle purchase.

In terms of HNC's effectiveness at reducing congestion and energy consumption, as an alternative objective, the current implementation structure may actually hinder it from accomplishing these reductions. Currently, the vehicle exemptions defy the programme's initial objective of reducing vehicle kilometres travelled. In order for the programme to be effective, vehicles cannot be exempt from the ban based on air quality benchmarks, since these standards are irrelevant in terms of congestion and fuel use. In order to achieve these objectives, the programme needs to be redesigned or paired up with additional measures, potentially a fuel economy standard. Combining the HNC programme with some sort of fuel economy standard could help reduce both the energy consumed by road transport vehicles and their GHG emissions.

Overall, the effectiveness of this programme and its potential application within a metropolitan area is completely dependant on the programme's objectives and the course by which it is supplement by other policies.

SAN FRANCISCO BAY AREA

The San Francisco Bay Area, much like other United States metropolitan areas, relies heavily upon passenger vehicles for personal mobility. However, the growth rate in gasoline consumption in the Bay Area has remained approximately one-half that of the United States average over the past two decades, even declining on a per capita basis, in the face of rapid economic and population growth. An important factor in minimising increases in gasoline use has been conservation-oriented attitudes of that area's general public.

Total Pop.	Land Area	Pop. Density	Total Income	PCI	Gasoline Use	Pas. Vehicles
7.0 million	17,933 km^2	392 p/km^2	305 billion*	43,450*	10.1 Mtoe	4.5 million

*APERC 2007, indicators for 2004, *year 2000 USD PPP*

INTRODUCTION

Located along the Northern Californian Pacific coast of the United States, the San Francisco Bay Area functions as a cohesive metropolitan unit while maintaining broad geographic and demographic diversity. Its combined population of 7.03 million (2004) extends across the nine counties which border San Francisco Bay, encompassing several urban, suburban, and even rural areas, with a total land area of 17,933 km^2. An average population density of 392 persons per sq km obscures the polycentric and lumpy heterogeneity of the area, which ranges from the cultural city centres of San Francisco, Oakland, and San Jose (San Francisco county: 6088 p/km^2), to the rapidly expanding suburbs of the East Bay (Alameda County: 758 p/km^2), to the high-tech jobs of Silicon Valley (Santa Clara County: 508 p/km^2), and the world-famous wine growing regions of the northern coastal ranges (Napa Valley: 68 p/km^2).[a]

Such diversity, combined with population and total personal income growth of 1.31 percent and 3.49 percent yearly since 1980, makes the Bay Area a point of interest for investigation of transportation energy consumption. In this relatively wealthy (year 2000 USD PPP per capita personal income of 43,450 in 2004) and highly developed area (the fifth largest consolidated metropolitan area in the United States), personal mobility is key to quality of life.[b] To fulfil this, Bay Area transportation infrastructure includes nearly 35,000 km of roads and highways, 7 major bridges, and 548 lane-km of HOV lanes as well as extensive mass transit systems operated by numerous and sometimes overlapping agencies, including 5 major urban/suburban bus and ferry networks, 3 light rail/metro systems (255 centreline-km), and 2 heavy/commuter rail lines (262 centreline-km).[c] Typical of United States metropolitan areas, however, the primary mode of transportation in the Bay Area is by passenger vehicle.

HISTORICAL DEVELOPMENT

European American settlement of the City of San Francisco began following the California gold rush of the mid-1850s and spread around the San Francisco Bay as the region quickly established itself as a centre for trade, finance and culture. Completion of the First Transcontinental Railroad in 1869, with its terminus in the East Bay city of Oakland, along with continued immigration from Asia and the Eastern United States helped sustain annual population growth of roughly 3 percent through modern day[d] and earn San Francisco the title of "Gateway to

88.1 True-colour composite satellite image of the SF Bay Area
USGS 2006

[a] *United States Census Bureau (2006). State and county quickfacts. USA.*

[b] *United States Bureau of Economic Analysis (2006). Table CA1-3. Regional Economic Information System. USA.*

[c] *APERC 2007*

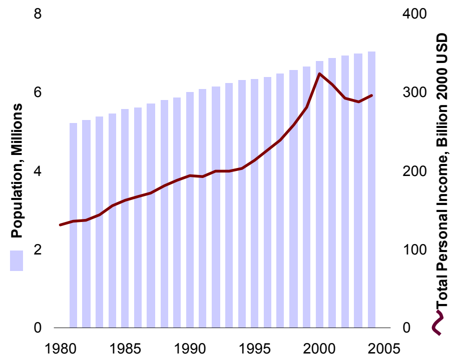
[d] *Association of Bay Area Governments (1997). Bay Area population 1920 and earlier. Compiled from United States Census Bureau, Richard L. Forstall, 1996. California, USA.*

the Pacific". Most of the City of San Francisco was destroyed during the Great 1906 Earthquake and Fire, and though the city was quickly rebuilt, subsequent growth diverted out from the city.

In the 1950s, the City of San Jose began rapid growth and suburbanisation which, along with higher education centres such as Stanford University, fuelled the initial technological and economic development of what is now referred to as "Silicon Valley" in the San Francisco Peninsula and South Bay-- first as a centre for military technology and later, with the creation of the semiconductor, into a world focal point for computers, the Internet, venture capital, and the IT industry. Rapid sustained growth of Silicon Valley through the 1980s and 1990s led to increases in income and property values in the Bay Area and resulted in San Jose's population overtaking that of San Francisco. More recently, the area experienced a short recession following the post-2000 bursting of the "dot-com bubble", but has now recovered to rates of growth commiserate with the past two decades. Today, the San Francisco Bay Area is one of the wealthiest areas in the United States, with a median household income of 61,100 year 2000 USD PPP, the highest of any United States Metropolitan Statistical Area (CMSA/SMA).[e]

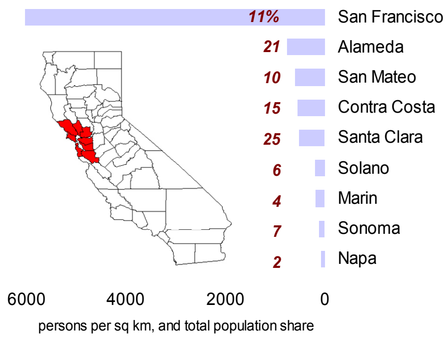
With the development of the string of adjacent towns in Silicon Valley through the 1960s, 70s, and 80s, a uniformly dense corridor of commerce and residence formed between the geographically-confined dense urban centre of San Francisco and the comparatively sprawling San Jose to the south. Early in this period, as was happening across the United States, a network of national interstate highways was built around the Bay Area, cementing the personal automobile as mode of choice for commutes and other transportation needs. However, San Francisco is noted for its public outcry against freeway construction through the Peninsula and city during the "Freeway Revolt" of the 1960s and 1970s, and many planned freeways were never built, or were even deconstructed.[f] Motivations for this outcry included the strong environmental movement for which San Francisco was noted at the time, as well as public concerns over energy use and the prospect for irrevocably changing the character of the city. The City of San Francisco is noted today for lacking major interstate crossings through its urban core, instead forcing drivers to cross the city on stoplight-controlled local boulevards, uncommon for a large city in the United States.

The "Freeway Revolt", however, did not leave the Bay Area without extensive public and private transportation infrastructure. In addition to what interstate highways were built in the 1960s, the Bay Area traveller today is confronted with a network of bridges, highways, bus, and commuter-, heavy-, and light-rail transit systems (notable rail systems include the San Francisco MUNI rail, BART, and Caltrain services) crossing and encircling the Bay. It is quite common, then, today for commuters to live, for example, in the relatively affordable and rapidly westward-expanding suburbs of the East Bay and commute by car to Oakland and San Francisco, or for young professionals to live in San Francisco for its cultural attractions but travel daily by rail to the South Bay for work—and such infrastructure, where different transport modes often parallel and overlap one another, offers the traveller a wealth of choice and flexibility to exercise personal preference.



89.1 **Population and personal income of the SF Bay Area, 1990-2005**

APERC 2007, California State Department of Finance, US Bureau of Economic Analysis, US Census Bureau



89.2 **SF Bay Area nine county area with population density and share, 2005**

APERC 2007, US Census Bureau

[e] *United States Census Bureau (2006). State and county quickfacts. USA.*

[f] *Daniel P Faigin (2004). California highways: the history of San Francisco Bay Area freeway development. http://www.cahighways.org/maps-sf-fwy.html*

HISTORICAL TRENDS FOR GASOLINE/DIESEL CONSUMPTION

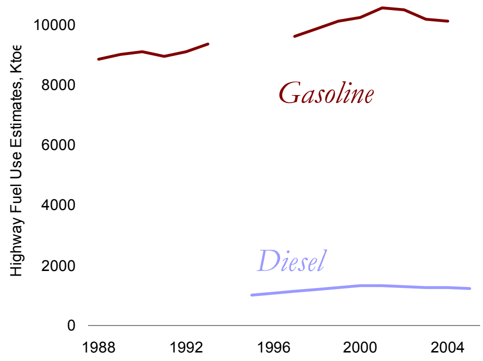
Total gasoline consumption in the Bay Area has grown only very slowly since 1988. This is particularly striking for a United States metropolitan area whose economic growth has outpaced that member economy's average over the same period; while United States gasoline consumption grew at 1.78 percent yearly from the period 1988-2003, the San Francisco Bay Area's consumption grew by only 0.95 percent per year on average, climbing slightly through the area's tech-boom of the late 1990s before slowing again in the first years of the millennium.[g] Moreover, per capita gasoline consumption in the Bay Area has actually fallen slightly, by an average 0.26 percent annually over the same period. The forces behind such an anomalous trend are not immediately obvious, but begin to reveal themselves through other Bay Area transportation data.

Diesel fuel, though rising in importance, still plays a minor role in Bay Area transportation energy demand. Through the late 1990s and early 2000s, total diesel use was only 10-15 percent that of gasoline, but it grew an average of 2.1 percent per year over that period, outpacing gasoline.[h] With California's particularly strict state air quality standards, no currently marketed diesel-powered passenger automobiles are approved for sale in the state. The California Environmental Protection Agency estimated in 2000 that only 4 percent of all California vehicles used diesel fuel (mostly trucks), and even this "California diesel" is subject to fuel quality and sulphur content regulations more strict than United States federal standards.[i] It is possible, however, that near-term technological improvements in catalytic converters from Japanese and European auto manufacturers might allow for diesel automobiles to pass these standards and gradually expand diesel demand in the Bay Area.

FACTORS AFFECTING GASOLINE/DIESEL CONSUMPTION

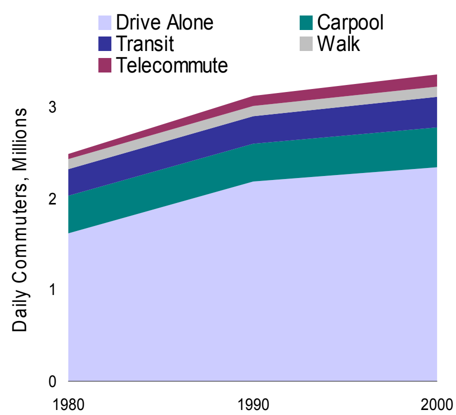
Transportation demand in the San Francisco Bay Area is met primarily by passenger vehicles. In 2005, 83.5 percent of all Bay Area person-trips were made by passenger vehicle, 9.3 percent by walking, and only 5.5 percent by mass transit. However, over half of all person-trips made, 50.5 percent, were in a carpool of some sort.[j] Modal split patterns for commuters also favour passenger vehicles. 69.2 percent of trips to work in 2005 were made by driving alone, while only 11.2 percent of workers carpooled and 9.4 percent used mass transit. The relative shares of each transport mode for both commuting and total trips have remained essentially unchanged since 1990 with the exception of workers who telecommute or work at home, which reached 4.7 percent in 2005, up from only 1.9 percent in 1980, having surpassed walking in popularity.[k] Despite the speed of its growth (3.79 percent per year since 1980), however, telecommuting in the Bay Area is still small in its relative share of total trips.

The relatively flat gasoline trend cannot be explained by a downturn in passenger vehicle purchases, either. Though slightly slower than the United States average, passenger vehicle ownership in the Bay Area nevertheless grew by 1.61 percent per year between 1980 and 2003.[l] Additionally, Bay Area total vehicle kilometres travelled (VKT) increased over the period as well, also by 1.61 percent per year.[m] This rate, however, is actually quite low compared to the US average of 2.47



90.1 SF Bay Area annual gasoline and diesel use, 1988-2004

APERC 2007, California Department of Transportation, Caltrans Office of Transportation Economics



90.2 SF Bay Area commute modal split, 1980-2005

APERC 2007, US Department of Transportation Federal Highway Administration, US Bureau of the Census

[g,h] *Caltrans (1997-2004). Office of Transportation Economics, Division of Transportation Planning. California, USA.*

[i] *California Environmental Protection Agency (2000). California diesel fuel fact sheet. Air Resources Board. California, USA.*

[j] *San Francisco Bay Area Metropolitan Transportation Commission (2005). Travel forecasts for the San Francisco Bay Area, 1990-2030. Planning Section. California, USA.*

[k] *United States Census Bureau (1980, 1990, 2000). Decennial censuses; summary tape file 3A (1980-1990) and demographic profile. USA. http://www.mtc.ca.gov/maps_and_data/datamart/census/dp234/Means19802000.htm*

[l] *San Francisco Bay Area Metropolitan Transportation Commission (1997). Auto ownership in the San Francisco Bay Area: 1930-2010. Charles L. Purvis, Planning Section. California, USA.*

percent growth in VKT per year[n], and is significant in that it means annual km travelled per vehicle were flat over the period 1990-2003.

Thus, while drivers continued to purchase more automobiles, even on a per capita basis, the amount that each new car was driven remained constant. Combining this fact with annual average fuel efficiency improvements of .42 percent in the Bay Area through the 1990s (as measured by kilometres per litre of gasoline) led to relatively slow 0.95 percent annual growth rate in total gasoline used per passenger vehicle and a 0.26 percent annual *decline* in per capita gasoline consumption.[o] It is significant that improvement in San Francisco Bay Area *fleet average* fuel economy was able to offset the increase in vehicle kilometres travelled through the 1990s. And while engine enhancements certainly deserve credit for much of this trend, technology alone does not fully explain Bay Area transportation energy use.

% person-trips, 2005	All Trips	Commute Only
Drive Alone	33.2	69.2
Carpool	50.5	11.2
Transit	5.5	9.4
Walk	9.3	3.3
Bike\Other	1.5	2
Telecomm.	-	4.7

91.1 SF Bay Area modal split, 2005
APERC 2007

[m] Caltrans (1997-2004). Office of Transportation Economics, Division of Transportation Planning. California, USA.

[n] United States Department of Transportation (2003). Journey to work trends in the United States and its major metropolitan areas, 1960-2000. Federal Highway Administration, Office of Planning, CTPP 2000. USA.

[o] APERC 2007

Yearly Change (%)						
Demographics	**SF Bay**	**US Tot**		**SF Bay**	**US Tot**	
Population	1.31	1.08	*1980-2003*	1.14	1.19	*1990-2003*
Pers. Income (SFB), GDP (US)	3.49	3.05	*1980-2003*	3.10	2.89	*1990-2003*
Per Capita PI, GDP	2.16	1.95	*1980-2003*	1.94	1.68	*1990-2003*
Passenger Vehicle Stats	**SF Bay**	**US Tot**				
Ownership	1.61	1.73	*1980-2003*			
Vehicle Kilometres Traveled	1.61	2.47	*1990-2000*			
Gasoline Consumption	0.95	1.78	*1988-2003*			
Kilometres per Vehicle	(0.03)	0.88	*1990-2000*			
Gasoline per Vehicle	(0.31)	0.26	*1988-2003*			
Fuel Efficiency (KPL)	0.42	1.86	*1990-2000*			
Modal Split- Relative	**SF Bay**	**US Tot**				
Auto (all trips)	0.07	(0.07)	*1990-2000/1*			
Transit (all trips)	(1.33)	(2.01)	*1990-2000/1*			
Walk (all trips)	(0.11)	1.63	*1990-2000/1*			
Bike (all trips)	2.26	2.31	*1990-2000/1*			
Telecommute (commute)	3.79	1.82	*1980-2000*			
Modal Split- Relative	**SF Bay**	**US Metro**		**SF Bay**	**US Metro**	
Drive Alone (commute)	0.40	0.76	*1980-2000*	(0.03)	0.25	*1990-2000*
Carpool (commute)	(1.16)	(2.61)	*1980-2000*	(0.08)	(1.01)	*1990-2000*
Transit (commute)	(0.80)	(2.26)	*1980-2000*	0.21	(0.81)	*1990-2000*
Walk (commute)	(1.58)	(3.08)	*1980-2000*	(1.17)	(2.94)	*1990-2000*
Modal Split- Absolute	**SF Bay+**	**US Metro**		**SF**	**US Metro**	
Drive Alone (commute)	1.87	2.66	*1980-2000*	0.67	1.70	*1990-2000*
Carpool (commute)	0.26	(0.77)	*1980-2000*	0.62	0.42	*1990-2000*
Transit (commute)	0.64	(0.41)	*1980-2000*	1.13	0.63	*1990-2000*
Walk (commute)	0.02	(1.25)	*1980-2000*	(0.17)	(1.54)	*1990-2000*

91.2 Yearly percent change, San Francisco Bay Area vs. United States and US metropolitan area averages
APERC 2007

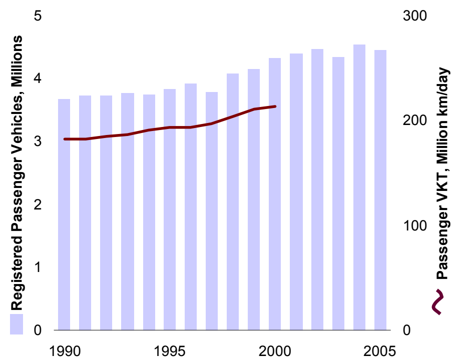
PUBLIC AWARENESS FOR SUSTAINABLE DEVELOPMENT

The San Francisco Bay Area is often characterised by a populace that embraces progressive ideals and so-called lifestyles of health and sustainability (LOHAS). Public concern towards environmental issues is particularly strong in the Bay Area. A 2003 San Francisco Magazine/Binder and Associates poll of Californians reported that 82 percent of Bay Area residents agreed with the statement "I consider myself an environmentalist", compared with 71 percent in the rest of California.[p] Only 45 percent of all United States residents agreed with that statement in a similar 2006 SRIC-BI/ecoAmerica poll. In 2004, 61 percent of Bay Area residents polled felt that the US Federal government was not doing enough to protect the environment of the United States, and 50 percent said they would, "seriously consider purchasing or leasing a vehicle powered by a hybrid gas and electric engine" even if it were more costly. Statewide, 55 percent of Californians felt that "environmental growth should be given priority" in governmental policies, compared with only 29 percent who favoured economic growth. 81 percent of Californians supported state legislation to require automakers to reduce greenhouse gas emissions from new passenger vehicles in 2009, and 66 percent thought it a good idea to enact legislation adding USD 6 to vehicle licensing fees to pay for cleaner engines in older diesel vehicles.[q] Individuals' lifestyle choices and personal beliefs, such as those pro-environmental attitudes expressed above, can have great influence over matters generally thought to be governed by economics or politics alone. It is of interest, then, to explore the importance of Bay Area consumer personal choice (or, economically speaking, preference) in shaping the patterns of such a complex matter as urban transportation.

FUEL CONSUMPTION AND AUTOMOBILE PURCHASE PREFERENCE

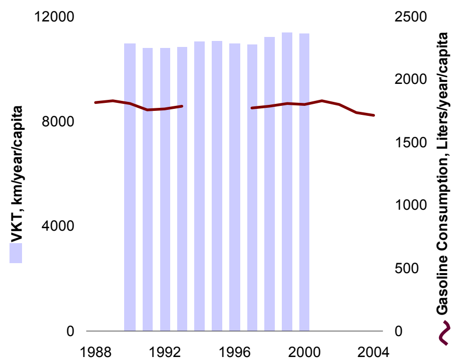
Hybrid car sales offer one useful perspective on such matters of personal choice. With high brand awareness in the United States, hybrid drivetrain passenger vehicles are believed by the general pubic to be beneficial to the natural global environment owing to their superior fuel efficiency, but more expensive than a less efficient but otherwise comparable automobile.[r] From this, it follows that the purchaser of a hybrid passenger vehicle has preferences such that she is willing to pay for external environmental costs. The San Francisco Bay Area has one of the highest per capita purchase rates of hybrid passenger vehicles in the United States, and ranked second in 2005 year total vehicle registrations, behind only Los Angeles (the Bay Area had 31 percent fewer total registrations, but with a population 47 percent smaller than that of Los Angeles). In fact, Bay Area residents purchased 8 percent of all hybrid vehicles sold in the United States in 2005.[s]

Such a high number of hybrid passenger vehicle purchases in the Bay Area can be attributed to a number of factors. Higher than United States average per capita incomes in the Bay Area make purchasing a hybrid, with a sticker price exceeding that of its conventional-powered counterpart, more affordable. High average gasoline prices (USD 2.15 per gallon/ USD 0.58 per litre in the Bay Area vs. USD 1.46 per gallon or USD 0.38 per litre for the United States, in nominal prices averaged over the span 1995-2005)[t] make fuel-efficient vehicles more financially attractive and offer quicker payoffs. Additionally, California State policy



92.1 SF Bay Area passenger vehicle stock and daily vehicle kilometers traveled, 1990-2005

APERC 2007, California Metropolitan Transportation Commission, California Department of Transportation



92.2 SF Bay Area per capita vehicle kilometers traveled and yearly gasoline consumption, 1988-2004

APERC 2007, California Department of Transportation, Caltrans Office of Transportation Economics, California State Department of Finance

[p] *Kevin Berger (2003). What it really means to be green. San Francisco Magazine, June.*

[q] *Public Policy Institute of California (2004). PPIC statewide survey: special survey on Californians and the environment. Mark Baldassare. California, USA.*

[r] *R. L. Polk & Co. (2005). Consumers taking a 'wait and see' attitude in their adoption of hybrid vehicles. http://usa.polk.com/news/latestnews/news_071105_01.htm*

[s] *R. L. Polk & Co. (2006). Hybrid vehicle registrations more than double in 2005. http://usa.polk.com/news/latestnews/2006_0504_hybrids.htm*

which gives hybrid owners (with fuel efficiency exceeding 45MPG/ 19.1 KPL, among other restrictions)[u] free access to high-occupancy vehicle (HOV) carpool lanes when driving alone is a powerful incentive for commuters to avoid traffic by purchasing such a passenger vehicle (a policy whose very formation was heavily influenced by pro-hybrid public opinion—67 percent of Californians supported this legislation).[v] These factors alone, however, cannot fully describe the purchasing phenomenon, where potential buyers are willing to wait months on dealer waiting lists for delivery of their hybrid vehicles. Another element, that of personal choice and lifestyle preference, is also instrumental in driving up hybrid car sales in the Bay Area. More generally, such a public mentality has contributed to San Francisco Bay Area's 1.22 percent average annual reduction in per capita gasoline consumption between 1988 and 2003.

MODAL SPLIT, VKT, AND TELECOMMUTING

And while the effect of personal choice on the San Francisco Bay Area total transportation system may not be overwhelming, it is nevertheless strong. As described above, the relative shares of various transportation modes in the Bay Area have remained essentially flat over the past twenty years. However, when compared to average rates of change in modal split for other United States metropolitan areas, the Bay Area trends do become noteworthy. In metropolitan areas across the United States, the overwhelming transportation trend between 1980 and 2000 was the growing reliance on single-occupant passenger vehicles for daily commuting. On average, every other major mode—including carpooling, transit, and walking-- declined in relative and even absolute terms while the popularity of single-occupant passenger vehicles swelled. Despite United States metropolitan area population and job growth, fewer total people in metro areas in 2000 used these "alternate" forms of transportation than in 1980, while the total number of commuters who drive alone grew, on average, by 2.66 percent annually.[w]

In the San Francisco Bay Area as well, the absolute number of commuters driving alone increased since 1980. However, over the same period, the number of commuters increased for every other "alternate" mode as well—in carpooling, and, more notably, in transit. These survey results are supported by data recording gains in ridership from the Bay Area's major transit agencies, particularly through the 1990s. So even though modal split shares are essentially flat, the Bay Area is actually outperforming the United States metropolitan average in terms of the absolute number of riders using "alternative" commute modes. And although per capita VKT did rise through 1990-2000, it was held to only .35 percent yearly.

Moreover, just as personal choice in passenger vehicle purchase may have contributed to reductions in Bay Area per capita gasoline use, LOHAS lifestyle decisions may have also been influential in capping the growth of VKT in San Francisco Bay. One example of this is the popularity of telecommuting, which underwent rapid growth as daily commute mode choice since 1980, totalling 4.7 percent of Bay Area commute modal share in 2005—a particularly high share when compared to other APEC economy cities. Of course, the decision to telecommute or work from home can be made for a number of reasons, such as stress or commute time reduction—and is not necessarily a matter of a personal preference for environmental sustainability (though Bay Area survey evidence from Ory and Mokhtarian 2005 suggests the correlation does in fact exist)—but whatever the motivation, the effect of this choice is still felt in the aggregate

[t] San Francisco Bay Area Metropolitan Transportation Commission (2006B). San Francisco Bay Area gas prices, 1986-present. Charles L. Purvis, Planning Section. Compiled from the State of California Department of Finance, Demographic Research Unit. California, USA.
-and-
United States Department of Energy (2007). Historical US weekly retail gasoline prices. Energy Information Administration. USA.

[u] California Air Resources Board (2006). AB2626 eligible vehicles: single occupant carpool lane use stickers. http://www.arb.ca.gov/msprog/carpool/carpool.htm

[v] Public Policy Institute of California (2004). PPIC statewide survey: special survey on Californians and the environment. Mark Baldassare. California, USA.

[w] United States Department of Transportation (2003). Journey to work trends in the United States and its major metropolitan areas, 1960-2000. Federal Highway Administration, Office of Planning, CTPP 2000. USA.

Telecommuting and working from home are lauded by public planners and private corporations alike for reducing costs while simultaneously relieving congestion, pollution, and commuter stress. However, such benefits arise only insomuch that telecommuting actually does systematically reduce total vehicle distance travelled— itself a commonly debated point. Mokhtarian (2004), Choo et al (2005), and Moos et al (2006), among others, point out that while telecommuters do logically reduce the distance they travel to and from work on days that they telecommute, much of these reductions can be lost in the aggregate due to the equilibrium effects of telecommuting on other aspects of one's life, which in turn generate new vehicle travel demand. For example, occasional telecommuters relieved of daily commuting requirements might choose to live farther from their place of work, thereby increasing vehicle distance travelled on days that they do physically travel to work. Moreover, travel diaries suggest that telecommuters tend to make more trips for non-work purposes during the day than office workers, and that these trips are more likely to be taken in a private automobile.

In addition, the United States Department of Energy (1994) has estimated that removing vehicles from the road during commute hours can actually induce latent road use demand, drawing formerly non-commuters onto relatively less congested road networks.

[continued on next page]

transportation system. Here, then, a useful lesson that applies to passenger vehicle use, in both directions: a population's personal lifestyle choices can dramatically alter the dynamics of a transportation system, even if such a change was not the primary intent of the decision maker.

TRAVEL STRATEGIES AND PERSONAL ATTITUDE

More generally, the strength of personal preference in determining travel mode has been determined by Bay Area sociological surveys to overpower other influencing factors, such as urban layout, density, or job availability. Cervero and Duncan[x] determined through travel surveys and geographic analysis that preferences in San Francisco for walking, for example, vary dramatically among races and genders, with African American males most likely to favour walking. Moreover, Cao and Mokhtarian[y] found that Bay Area residents' travel strategies are heavily influenced by "attitudes, personality, and lifestyle". In particular, they determined that travellers with "pro-environmental solutions attitudes" were more likely to purchase fuel-efficient vehicles, reduce single occupant passenger vehicle use, and commute by bus, rail, or walking.[z] As incomes increased, younger residents were also more likely to accept and personally adopt travel-reduction public policies, presumably because of the increased travel choice and flexibility afforded to higher income young families. Finally, Kitamura et al[aa], Bagely and Mokhtarian[bb], and Schwanen and Mokhtarian[cc] reconfirm the importance of attitude and lifestyle choice over neighbourhood design and composition in influencing San Francisco Bay Area travel strategies, but more so in relatively urban areas where multiple travel options exist.

This last point is an extremely important caveat when considering the place of attitude, preference, and lifestyle choice in affecting a metropolitan transportation system. For travel strategy choice to even exist, a metropolitan area must possess at least a certain threshold infrastructure and design which allows multiple transportation options, be they walking, riding a bus, or simply electing to fulfil transport demand without actually travelling. It's obvious to state, but if there is no bus system, one cannot ride a bus, however strong one's desire. Similarly, a steel worker cannot telecommute. In this sense, from a policy perspective, it is important that citizens of a metropolitan area are offered an *enabling environment* to exercise personal choice in travel strategies. This helps to explain why the San Francisco Bay Area is an interesting focus area to examine matters of personal choice in the transportation system—individual preferences aside, it is the area's foundational enabling environment allows those preferences to be expressed and to affect measurable change.

Despite such rebound effects, however, telecommuting does seem to reduce total vehicle distance travelled in the United States, but by no more than 1 percent in the aggregate. Considering though that all mass transit (which is subject to rebound effects of its own) was estimated to reduce vehicle distance travelled in the United States by only 1.8 percent, with yearly non sunk-cost expenditures of USD 28 trillion, then the value of cheap telecommuting actually seems quite good (Choo et al 2005).

Even if telecommuting can be agreed to reduce vehicle travel distance, albeit only slightly, the systematic effect of telecommuting on final energy demand is even more complicated still. Studies in both the United Kingdom (Hopkinson et al 2002) and the United States (Kitou and Horvath 2003) have explored the possibility that home workers might simply be translating gasoline fuel reductions into increased electricity or heating demand. Here again, though, total energy and emission offsets generally outweigh the rebound effects, but that this can vary according to local climate, electricity generation mix, and employer office space management.

94.1 Telecommuting and energy use

[x] *Robert Cervero and Michael Duncan (2003). Walking, bicycling, and urban landscapes: Evidence from the San Francisco Bay Area. American Journal of Public Health, 9:1478-1483.*

[y] *Xinyu Cao and Pactricia L Mokhtarian (2005). How do individuals adapt their personal travel? Objective and subjective influences on the consideration of travel-related strategies for San Francisco Bay Area commuters. Transport Policy, 12:291-302.*

[z] *David T Ory and Patricia L Mokhtarian (2005B). When getting there is half the fun? Modeling the liking for travel. Transportation Research, 39A:97-123.*

[aa] *Ryuichi Kitamura, Patricia L Mokhtarian, and Laura Laidet (1997). A micro-analysis of land use and travel in five neighborhoods in the San Francisco Bay Area. Transportation, 24:125-158.*

[bb] *Michael N Bagley and Patricia L Mokhtarian (2002). The impact of residential neighborhood type on travel behavior: A structural equations modeling approach. The Annals of Regional Science, 36:279-297.*

[cc] *Tim Schwanen and Patricia L Mokhtarian (2005). What affects commute mode choice: neighborhood physical structure or preferences toward neighborhoods? Journal of Transport Geography, 13:83-99.*

The San Francisco Bay Area's relative success in curbing the growth rate of gasoline consumption suggests the importance of a general populace's personal lifestyle decisions on mid- to long-term energy consumption. In some urban areas, such lifestyles might arise organically over time and be self-sustaining. However, the effect of personal lifestyle is great enough that it should not simply be left to chance; *education* will be a central pillar of any enlightened energy policy. Just as decision makers strive to encourage new energy efficient technologies or use various instruments to control energy consumption, much success might be found in addressing the background growth in energy *demand* itself by speaking directly to the people. When each urban inhabitant becomes conscious of the impacts of her own energy consumption, it can help to "grease the wheels" in reaching the goals of any other more direct energy consumption-targeted programme —be it increasing urban mass transit ridership, improving vehicle fleet fuel efficiencies, or encouraging telecommuting.

Of course, education cannot reduce energy consumption in a vacuum—it depends on a supporting portfolio of energy consumption-targeted policies and infrastructure. And it is not omnipotent—the San Francisco Bay Area, whatever its personal attitudes towards transportation, has per capita road energy consumption levels far above the APEC urban area average. However, with such complimentary initiatives in place– that is, the enabling environment—the returns on investment in public education, awareness, and attitude could be far greater than constructing an equivalent extra few meters of subway track, for example.

Because of the requirement for this established enabling environment, however, and the need for energy consumers to have the relative luxury be able to freely exercise their own personal choice in a matter such as transportation, investments in energy awareness education might be more attractive in the APEC region's mature, developed, and high-income urban areas. Here, extremely high land values deter further investment in urban mass transit infrastructure, for example, personal vehicle ownership levels are generally quite high, and road networks are both convenient and extensive. Each individual is more likely to have the physical and economic freedom, then, to change both her own and her family's transportation energy demand, and, in turn, their collective impact on the Earth. And while the choice is theirs to make, it can be inspired.

SHANGHAI

Though the implementation of a passenger vehicle license plate bidding system in Shanghai has shown some success, the otherwise limited accessibility and comfort of the existing urban mass transit system has failed to restrict overall growth in passenger vehicle stocks, particularly for privately-owned passenger vehicles.

Until recently, Shanghai's passenger vehicle stock was quite low compared with its average income level while the size and utilisation ratio of passenger vehicles was higher than other large Chinese cities such as Beijing. As Shanghai's passenger vehicle development enters a period of rapid growth, a key issue is how to decrease gasoline consumption without limiting vehicle ownership

Total Pop.	Land Area	Pop. Density	GRP*	PCI*	Gasoline Use	Pas. Vehicles
17.8 million	6,341 km^2	2,804 p/km^2	488 billion	27,470	1.0 Mtoe	0.64 million

*APERC 2007, Shanghai Statistic Yearbook, indicators for 2004, *year 2000 USD PPP*

INTRODUCTION

Shanghai, one of China's four pseudo-autonomous municipalities, sits at the mouth of the Yangtze River's delta with the East China Sea. It is the largest city in the People's Republic of China in terms of economic size, and it is still growing rapidly. Shanghai is among the most important industrial, commercial, financial, trade, and cultural centres of China. In addition, Shanghai today is the busiest shipping port in the world.

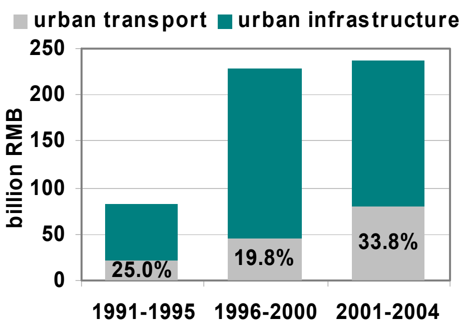
The city of Shanghai has a total land area of 6,341 square kilometres, representing 0.06 percent of China's total territory. Shanghai extends about 120 km from north to south and nearly 100 km from east to west. The city is comprised of 18 districts covering a total area of 5,300 square kilometres and one county, Chongming County, which includes three islands covering an area of 1,041 sq. km.

From 1992, Shanghai began to develop the new Pudong District, accelerating total economic development to an unprecedented pace. Since 1992, Shanghai has maintained a double-digit GRP growth rate for 14 consecutive years, driven primarily by the growing manufacturing sector. In 2005, the city's GRP reached USD 488.3 billion, and per capita GRP reached USD 27,466 (in year 2000 USD PPP terms), a 4.3-fold increase from 1992.

While maintaining such rapid economic growth, Shanghai has also achieved a big increase in its financial revenues. The city has been investing huge sums in road and rail infrastructure to develop urban transport. In recent years (2001-2004), 33.8 percent of the city's investment in infrastructure was invested in the urban transport sector. As a result of such sustained development, urban road transport infrastructure in Shanghai gained momentum. In 2005, the total length of road reached 12,227 km, with 4,020 km of that in the city centre. Thus, road length per capita increased remarkably from 1.3 metres per capita 1991 9.0 metres per capita in 2005.

In the recent years, the Shanghai government has increasingly turned to rail transit as one of the solutions to its traffic problems. The total length of rail transit lines was 148 km in 2005, 133 km longer than in 1996. Rail transit is playing an increasingly important role in

96.1 Map of Shanghai districts
en:User:Ran, 2007, GNU free documentation license 1.2



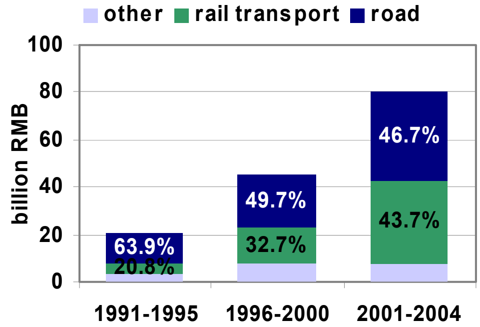
96.2 Shanghai urban infrastructure investment, 1991-2004
APERC 2007, Shanghai Transportation Planning Net (2006). China vehicle industry statistical yearbook. Shanghai, China. http://www.scctpi.gov.cn/

Shanghai's mass transit system as a means to cope with rising transport demand in the urban area, as well as mitigating air pollution from the transport sector.

With high economic growth, Shanghai has been experiencing an extremely rapid urbanisation process. Due to a constant inflow of people from other Chinese provinces, Shanghai's population has been steadily growing. By the end of 2005, Shanghai's population reached 17.78 million, increasing from 11.47 million in 1980. The ratio of Shanghai's urban population to total population increased from 61 percent in 1980 to 84 percent in 2005.

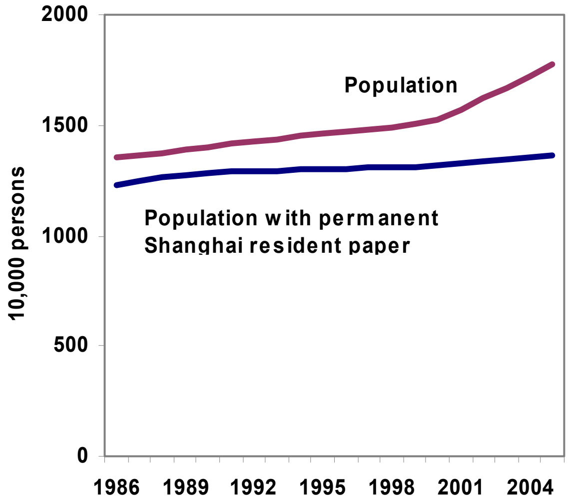
Shanghai's urban core has expanded as well, from 289 square kilometres in the 1990s to 750 square kilometres today. However, as the number of people moving from within the city centre to the periphery increases, the ratio of population living in the urban core actually decreased from 32.0 percent in 1995 to 23.8 percent in 2003. This decentralisation combined with substantial income growth has led to increased demand for motorised transport, shifting away from non-motorised transport such as walking and bicycling.

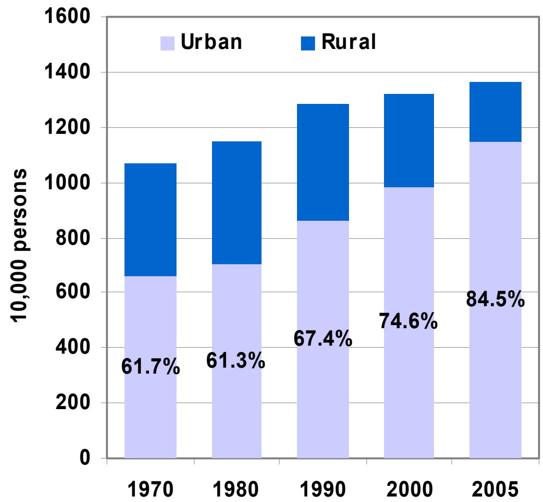
Passenger vehicle stocks[a] increased rapidly from 134,100 in 1996 to 644,300 in 2005 at an annual average growth rate of 19.2 percent. In 2005, passenger vehicle stocks per 1,000 population reached 36.2 – a big increase from 9.1 per 1,000 population in 1996. This increase, in turn, has led to traffic congestion problems.



97.1 **Shanghai urban transport infrastructure investment, 1991-2004**
APERC 2007, Shanghai Transportation Planning Net (2006). China vehicle industry statistical yearbook. Shanghai, China. http://www.scctpi.gov.cn/

[a] *In this section, the definition of passenger vehicle means small cars and mini-cars, excluding taxis, as specified by China's statistical standards for passenger vehicle data. Vehicle stocks are passenger vehicles registered in Shanghai.*





97.2,3 **Shanghai population trends, 1986-2004 and 1970-2005**
APERC 2007, Shanghai Statistical Bureau (multiyear). Shanghai statistical yearbook, series year. Shanghai, China.

ENERGY CONSUMPTION FOR ROAD TRANSPORT

HISTORICAL TRENDS FOR GASOLINE/DIESEL/NATURAL GAS CONSUMPTION

Along with the rapid economic development, Shanghai's transport energy consumption has been growing rapidly at an annual rate of 15.4 percent between 1995 and 2005. This is substantially higher than that of the Shanghai's total energy consumption, which grew at an annual rate of just 6.1 percent between 1995 and 2005.

With such fast growth, the share of transport sector energy consumption to total energy consumption also increased rapidly. In 2005, the transport sector accounted for 20 percent of Shanghai's total energy consumption, increasing from 9 percent in 1995.

By transport sub-sector, the water sub-sector accounts for the biggest share in total transport energy consumption (due to Shanghai's importance as a global maritime shipping port). In 2005, for example, the water sub-sector stood at 50 percent of transportation energy consumption, followed by the road sub-sector at 34 percent.

Along with the rapid growth of passenger vehicle ownership, gasoline consumption – the main fuel for road transport - has been grown rapidly. Between 1996 and 2005, gasoline consumption grew at an annual growth rate of 12.5 percent. In 2005, gasoline consumption of the road transport sector reached 2,484 ktoe, of which passenger vehicle use accounted for 42 percent, followed by small trucks and buses at 29 percent, taxis at 21 percent, and motorcycles at 8 percent.

Since the late of 1990's, Shanghai's taxis and city buses began transitioning to LPG and CNG fuels. By 2005, Shanghai's passenger transportation sector consumed 150 kton LPG and 6 million cubic metres of natural gas.

	Absolute Level				Annual growth rate (%)		
	1985	1996	2000	2005	1985-1996	1996-2000	2000-2005
Gasoline consumption (ktoe)	299.7	855.2	1362.7	2484.4	10.00	12.35	12.76
Gasoline consumption per 1000 person (toe)	22.1	58.1	89.5	139.8	9.15	11.42	9.31
Passenger vehicle stock per 1000 person		9.4	16.5	37.3		15.18	17.72
Per passenger vehicle gasoline consumption (toe)		2.4	2.3	1.6		-1.76	-6.26

98.1 Increasing trend of Shanghai's passenger vehicle stock and gasoline consumption, 1985-2005

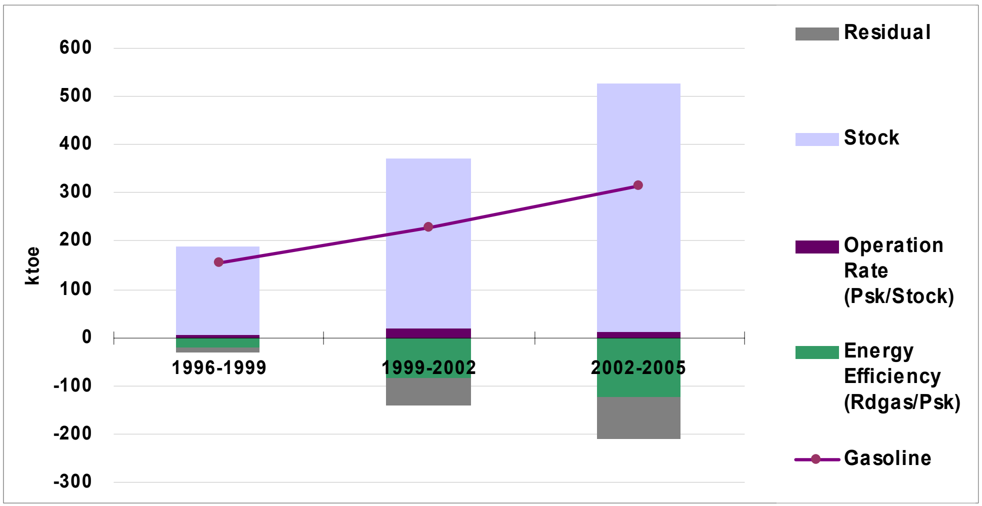
APERC 2007, Shanghai Statistical Bureau (multiyear). Shanghai statistical yearbook, series year. Shanghai, China.

FACTORS AFFECTING GASOLINE/DIESEL CONSUMPTION

To analyse drivers for the recent robust growth in gasoline consumption, decomposition analysis was conducted. The following three factors are identified as the key elements contributing to the growth in passenger vehicle gasoline consumption:

- Energy intensity (energy requirements per passenger km)
- Operational rate (passenger km per vehicle)
- The number of passenger vehicle stocks

The analysis shows that between 1996 and 2005, the number of passenger vehicle stocks – shown as stock – contributed greatly to the growth in gasoline consumption [99.1]. It is interesting to observe that the contribution by the increase in the number of passenger vehicle stocks to the growth in gasoline consumption has been expanding in the recent years. By contrast, energy requirements per unit of passenger km – shown as efficiency – negatively contributed to the growth in gasoline consumption. In addition, contribution by passenger km per unit of vehicle remained modest during the given time period.



99.1 Decomposition analysis: gasoline consumption in Shanghai, 1996-2005

APERC 2007

Decomposition analysis is based on the following calculation.

$$E = E/Psk * Psk/Carstock * Carstock$$

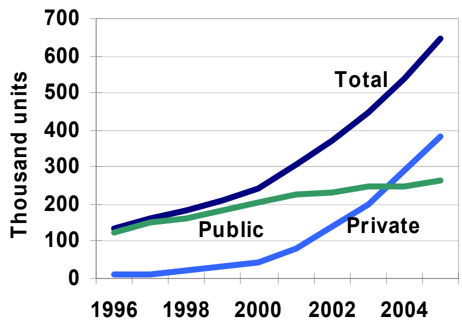
(E: Gasoline, Psk: Passenger km, Carstock: Passenger vehicle stocks)

$$\triangle E = \triangle(E/Psk) * Psk/Carstock * Carstock$$
$$+ E/Psk * \triangle(Psk/Carstock) * Carstock$$
$$+ E/Psk * Psk/Carstock * \triangle(Carstock)$$
$$+ Residual$$

As the decomposition analysis result indicates, over the past decade, growth in gasoline consumption was lead by the burgeoning growth in the number of passenger vehicle stocks. Between 1996 and 2005, the number of passenger vehicle stocks increased at an annual rate of 16 percent [99.2]. In recent years, the growth in the number of passenger vehicle stocks has even accelerated, growing at an annual rate of 21 percent between 2000 and 2005, driven mainly by the rapid increase in ownership of private (individual or business), as opposed to public (government agency), passenger vehicles.

The noticeable increase in the private passenger vehicle stocks is supported by the government's decision in 1984 to allow the use of private vehicles, which had been prohibited previously.[b] Despite the central government decision to allow private passenger vehicle ownership, however, the 1996 share of private to total passenger vehicle stocks was as small as 6 percent compared with that of public at 94 percent. This was primarily because of the cost of vehicle ownership, which was quite high relative to income levels. Yet, in 2005, driven by income growth, the private share of passenger vehicle ownership reached 60 percent, exceeding that of public at 40 percent.

Another important factor supporting the growth in the passenger vehicle stocks is the development of automobile industry in China. Recognising the importance of automobile industry as a primary industry for developing manufacturing, iron and steel, and electronics industries, among others, both the Shanghai and central Chinese governments decided to strengthen the domestic automobile industry in 1990s. Through forming joint ventures with the major foreign automobile companies, Chinese automobile manufactures expanded production from 2.1 millions units in 2000 to 5.7 millions units in 2005.[c] This increased production has spurred the competition among producers to lower sales prices of passenger vehicles across China, including Shanghai.



99.2 Shanghai passenger vehicle stocks, 1996-2005

APERC 2007, Shanghai Academy of Environmental Sciences (2005). Transportation situation and traffic air pollution status in Shanghai. Shanghai, China
-and-
Shanghai Statistical Bureau (multiyear). Shanghai statistical yearbook, series year. Shanghai, China.

[b] *APERC (2004). Energy in China: transportation, electric power and fuel markets. Tokyo, Japan*

[c] *Shanghai Transportation Planning Net (2006). China vehicle industry statistical yearbook. Shanghai, China. http://www.scctpi.gov.cn/*

Despite the burgeoning increase in the number of passenger vehicle stocks, interestingly, energy intensity in terms of energy requirements per unit of vehicle has been negatively contributing to the growth in gasoline consumption. The main reason for the improvement in energy intensity is the changing composition in terms of fleet average vehicle size and frequency of use. Government agencies, which once held the predominate share of Shanghai's passenger vehicle fleet, tend to own large-sized vehicles (above 2000 cc in terms of the engine size) and use their cars quite frequently throughout the year (with high yearly distance travelled per vehicle) while private owners tend to purchase mid- and small-sized vehicles (average engine sizes of 1600 cc and below 1400 cc, respectively). In addition, the Shanghai government recently has encouraged the private sector to purchase energy efficient small-sized vehicles. This increased engine propulsion efficiency in smaller vehicles, rather than a decrease in annual kilometres travelled per vehicle, altogether resulted in the steady improvement in energy intensity.

ISSUES

AUCTIONING FOR LISCENCE PLATE

During 1980s, traffic congestion and urban air pollution became the major obstacles constraining economic growth in Shanghai. Even with the small vehicle population, the streets in the urban core area were congested, due to the relatively low level of road infrastructure development. During 1980s, for example, Shanghai's road area per capita in the central urban area stood at 2.29 sq. m, which was among the lowest in the world.[d] In part because the roads were so crowded, with pedestrians, bicycles, and autos all jammed together, Shanghai experienced high accident rates and pervasive human exposure to poor quality air.

Traffic congestion worsened air quality in Shanghai. In 1993, for example, emissions from the transport sector was the major cause for Shanghai's urban air pollution problems, accounting for about 90 percent of carbon monoxide emissions, 92 percent of volatile organic gases, and 23 percent of nitrogen oxide emissions.

Faced with the worsening traffic congestion and air quality, Shanghai's city officials began implementing a bidding system for passenger vehicle license plate registration in 1986 in order to limit the growth in the number of passenger vehicle stocks.

During the early 1990s, Shanghai also implemented a policy measure to restrict driving days based on this license plate number. Similar in nature to Mexico City's *Hoy no Circula* plate-based driving restriction policy, the Shanghai policy allowed those drives with odd numbers in their number plate to drive only on the odd number days. Likewise, those drivers with even numbers in their number plate could drive only on the even number days. However, if drivers purchased a special number plate (with a "Z" sign) at a one-time cost between USD 12,100-36,200 (RMB 100,000-300,000, at the then nominal exchange rate of 8.28 RMB per USD), they were allowed to drive passenger vehicles freely on any day throughout the year.

Before 2000, the price of a license plate for a private vehicle was more than USD 12,100. After 2000, however, the average price fell to roughly USD 4,250. Since 2000, the total number of license plates

License plate auctions in Shanghai are held one weekend every month in the western Shanghai suburb of Anting. Approximately 5000 plates are auctioned at a time, though the exact number depends on Shanghai's monthly care sales and vehicle scrap page rates—generally, however, only about half of license bidders that participate each month will successfully acquire a plate. Regardless of the biding outcome, all auction participants must pay a deposit of roughly USD 250 in part to prevent bidders from attending multiple auctions with the hope of receiving a lower price (the Shanghai government does not set a floor-price for the licenses). Though prospective plate buyers may also participate by phone or Internet, most bid in person at the auction site.

Changes to the bidding process over the years include the merger in 2002 of the formerly separate auctions for imported and domestic passenger vehicles (which has generally resulted in higher bidding prices), and the 2004 expansion of license plate bidding to include publicly-owned passenger vehicles to prevent back-door registration of privately-owned passenger vehicles.

100.1 Implementation of license plate bidding in Shanghai

APERC 2007, Iliev, George (2005). How to get a number plate in Shanghai. Shanghai Expat. http://www.shanghaiexpat.com/modules.php?op=modload&name=News&file=article&sid=181

awarded per year in Shanghai has grown dramatically, from 32,000 in 2002 to 67,000 in 2005, for example.[e]

[d] *Xinhua News Agency (2004). Auto buyers have no brand loyalty yet: survey.*

[e] *China Daily (2006). Resident's love affair with cars continues.*

The direct effect of the license plate bidding system is to limit the number of passenger vehicles. In Shanghai, vehicle population growth is apparently lower than that of other cities with similar development conditions. Moreover, Shanghai's government gains approximately USD 250 million in income each year from these plate fees. This income has provided more financial support for government to promote the infrastructure construction of roads and other urban mass transit, which provides better conditions for citizens. The policy contributed much to the controlling of congestion and achievement of relative high-speed of vehicle travel in city centre.

CONFLICTS WITH OTHER POLICIES

Though the Shanghai plate-bidding system is believed to have been relatively successful, its future is nevertheless uncertain. In the beginning of 2004, the Chinese central government announced regulations that require suspension of any local policy limiting the purchase of private passenger vehicles. The proposed purpose of this central government policy is to promote the development of the vehicle manufacturing industry by encouraging the private purchase of passenger vehicles. As a result, a conflict between the auctioning for license plate and the regulation was seen, which may lead to the abolishment of the auctioning system for liscence plates in Shanghai.

INCREASE OF PASSENGER VEHCILES WITH OUTSIDE LISCENCE PLATES

Since the price for license plates is very high and vehicles with license plates issued in some regions outside Shanghai are also allowed to run in the city, many vehicle owners now buy license plates outside the city. This offsets the role of license plate bidding policy in reducing the number of vehicle stocks and also reduces the city's tax income from vehicle owners. Up to 20,000 Shanghai residents each year are now thought to purchase license plates from neighbouring cities in Jiangsu or Zhejiang province, where prices are up to two orders of magnitude below those of Shanghai, even though such action requires that drivers return to the place of plate purchase each year for vehicle inspections. Such practice is more common among buyers of cheaper passenger vehicles, as the plate cost for them represents a relatively larger share of total vehicle ownership cost.[f]

[f] *Iliev, George (2005). How to get a number plate in Shanghai. Shanghai Expat. http://www.shanghaiexpat.com/modules.php?op=modload&name=News&file=article&sid=181*

In part to deal with this problem, however, the Shanghai government in 2002 began limiting access to some major thoroughfares during rush hours for passenger vehicles with outside plates. Moreover, Shanghai has begun to pressure surrounding cities in the Yangtze delta to raise their own license plate prices for Shanghai residents seeking registration.

IMPLICATIONS

Shanghai's license plate bidding has been successful in terms of limiting the number of passenger vehicle stocks. Although Shanghai's income level is high at USD 27,470 (PPP), in 2005, its passenger vehicle stock per 1,000 reached 55.9 – less than half of that of Beijing at 122.4 in the same year. The license plate bidding also helped increase funding for developing road and mass transit infrastructure.

Despite this success, Shanghai nevertheless must still resolve various challenges related to vehicle ownership and its impact on energy and the economy. For example, the future of license plate bidding has become uncertain because of the central government's announced plan to suspend any local policy which limits the number of passenger vehicle stocks in order to promote the Chinese domestic automobile industry.

In addition, how to control the increasing number of passenger vehicles which are registered outside of Shanghai poses a challenge to Shanghai's policy makers. Taking advantage of the price differentials, more than 20,000 Shanghai residents are estimated to register their vehicles outside of the city every year. Immediate action needs to be taken to coordinate with the other local governments in terms of vehicle registration.

Ultimately, in order to reduce people's passenger vehicle dependence and to cope with rising transport demand, it is also essential for Shanghai to expand mass transit system throughout the urban area. Due to the expected rise in travel demand between central Shanghai, Pudong, and neighbouring cities such as those in the Yangtze River basin, it is also essential to build (rail) transport infrastructure for optimum connection.

TOKYO

The rail/subway is an integral part of daily life for those dwellers in Tokyo. This mainly results from the city's early start in developing rail/subway infrastructure, which in fact has shaped city dweller's lifestyle. This finding suggests the importance of planning appropriate timing for investing in rail/subway infrastructure, and that the plan be implemented with the concerted efforts of both public and private sectors.

Total Pop.	Land Area	Pop. Density	GRP	PCI	Gasoline Use	Pas. Vehicles
12.3 million	2,187 km^2	5,524 p/km^2	560 billion*	52,196	4.6 Mtoe	3.2 million

*APERC 2007, indicators for 2004, *year 2000 USD PPP*

INTRODUCTION

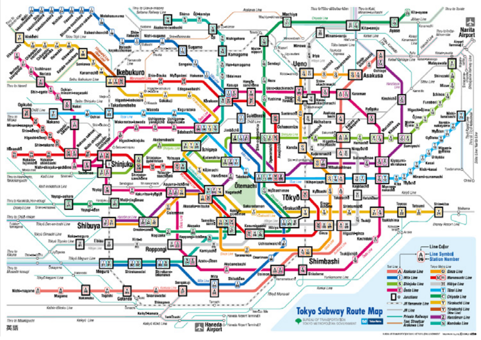
Tokyo is the capital of Japan, comprised of 23 central special ward areas as well as several suburban cities and even small islands. Recognised as a "primate city", Tokyo functions as the political, economic, financial, and cultural centre of Japan. With about 12 million people – representing 10 percent of total Japan's population – living in 2,187.08 km² of total land area, Tokyo's population density reached 19,748 per km² in 2004.[a]

Gross regional product (GRP) of Tokyo reached USD 560 billion (2000 PPP) in 2004, making it the world's largest metropolitan economy. In fact, Tokyo's GRP is comparable to the size of Australia's entire GDP (USD 550 billion in 2004). In 2004, Tokyo's GRP was large enough that if the city was counted as a national economy, it would be the 12th largest in the world.

History of Tokyo's modern urbanisation dates back to 1950 when the Japanese economy began recovery after World War II. In parallel with Japan's economic development, an increasing number of private companies relocated their bases to Tokyo from elsewhere in Japan in order to gain easier access to information, finance, and logistics. Above all, Tokyo has offered the best access to communication with the central government; at an early stage of Japan's development, direct accessibility to the central government was crucial to obtain government support for business.

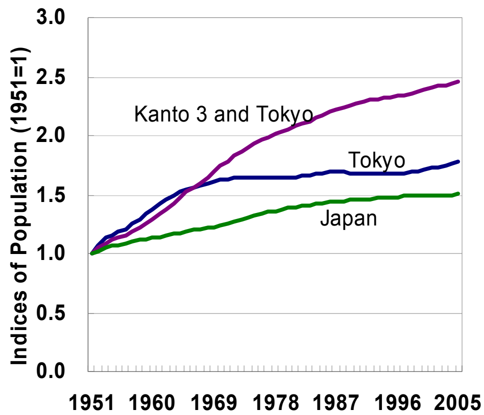
Along with economic development and increase in the number of companies, Tokyo's population grew rapidly. Economic development drove labour transfer from rural agricultural areas or other smaller cities in Japan. From the early 1950s to the mid 1960s, population in Tokyo grew at an annual rate of above 3 percent per year – a faster rate than that of Japan's total population at 1.4 percent. With this fast growth rate, population in Tokyo surpassed 10 million in 1962, accounting for 10 percent of Japan's total population, rising from 6.9 million in 1951 or 8 percent of Japan's total population.

The growth rate of population peaked in 1964 when Tokyo hosted the Summer Olympic Games. Between 1964 and 1975, Tokyo's population grew at 0.9 percent per year – a slower rate than the previous decade. Economic development had sharply increased the Tokyo's land value, driving people away from living in the Tokyo area. In addition, rail infrastructure development allowed commuters to



103.1 Tokyo subway diagram
Tokyo Metropolitan Government, Bureau of Transportation , 2006

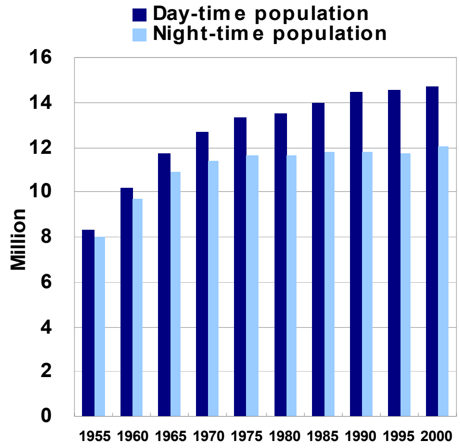
[a] Out of total 12 million population, roughly 8 million live in the 23 central wards. In the 23 central wards, population density is higher; 12,872 per km2



103.2 Indices of population for Tokyo, Kanto 3 Area and Tokyo, and Japan, 1951-2005
APERC 2007, Jumin Kihon Daicho Jinko Yoran 2005

Kanto 3 (the region surrounding Tokyo) includes the population of Chiba, Kanagawa and Saitama prefectures.

travel to the city centre from the outskirts of Tokyo such as Chiba, Kanagawa and Saitama prefectures. Tokyoites also moved to such outlying areas to seek better environmental conditions. This out-migration has led to a widening of the gap between Tokyo's day-time and night-time population.



104.1 Widening gap between day-time and night-time population in Tokyo, 1955-2000
APERC 2007, Tokyo Metropolitan Government 2005

ENERGY CONSUMPTION FOR ROAD TRANSPORT

HISTORICAL TRENDS FOR GASOLINE/DIESEL CONSUMPTION

Similar to the other world cities, Tokyo faced heavy traffic congestion at an early stage of development during the 1950s and 1960s. Motorisation and lack of road infrastructure were primary drivers of the congestion problem. Due to income growth, Tokyo's urban population more than doubled the number of passenger vehicle stocks from 623,000 in 1960 to 1.4 million in 1966, however, the length of paved road increased only by 50 percent during the same period. This relative lack of infrastructure expansion exacerbated the traffic congestion.

Because of motorisation, gasoline consumption also increased at the rapid pace. How to handle the growing number of commuters, particularly those from Tokyo's outskirts, posed a formidable challenge to policy makers and city planners at that time.

Since the 1970s Tokyo has successfully reduced its dependence on passenger vehicles through the efforts to develop rail infrastructure. By shifting commuters' transport from passenger vehicles to railways, Tokyo slowed growth trend in gasoline consumption. For example, per capita gasoline consumption of Tokyo remained low at 0.24 toe per person from 1970s through 1980s. This is in fact less than 20 percent of that of the US average [104.2].

		1980	1990	2002	1980-1990(%)	1990-2002 (%)
Tokyo	Gasoline consumption per capita (toe per capita)	0.25	0.27	0.36	0.8	2.4
	Passenger vehicle stocks per 1,000 population	159	239	266	4.2	0.9
USA	Gasoline consumption per capita (toe per capita)	1.3	1.3	1.4	0.0	0.6
	Passenger vehicle stocks per 1,000 population	656	726	766	1.0	0.4

104.2 Gasoline consumption per capita and passenger vehicle stocks per 1,000 population in Tokyo, Japan and USA
APERC 2007

FACTORS AFFECTING GASOLINE/DIESEL CONSUMPTION

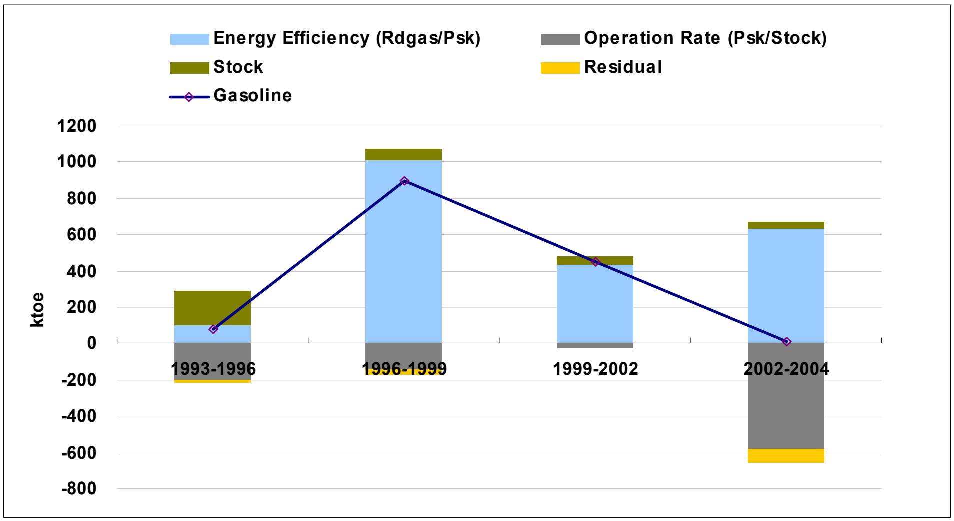
Despite remaining at an absolute low level, Tokyo's gasoline consumption is growing at a faster rate in recent years. Between 1990 and 2004, gasoline consumption in Tokyo grew at 2.7 percent per year, while it grew at 1.3 percent per year over the previous decade.

To analyse the key drivers affecting the recent faster growth in gasoline consumption, a decomposition analysis was conducted.

The analysis below shows that gasoline consumption per passenger km – denoted as energy efficiency – contributed greatly to the incremental growth of gasoline between 1993 and 2004 [105.2]. In particular, this trend is pronounced from 1996 onwards. By contrast, the number of passenger vehicle stocks – shown as stock – only marginally contributes to the growth in gasoline consumption. Moreover, operational rate – measured as the ratio of passenger km per vehicle – negatively contributed to the growth in gasoline consumption.

	Absolute Level (Unit: ktoe)			Annual Growth Rate (%)	
	1980	1990	2004	1980-1990	1990-2004
Gasoline	2,779	3,162	4,564	1.3	2.7

105.1 Gasoline consumption in Tokyo, 1980, 1990 and 2004
Tokyo Metropolitan Government 2005



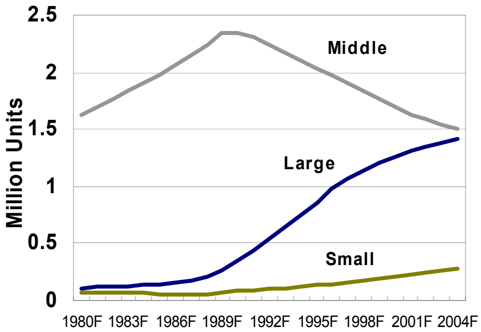
105.2 Decomposition analysis: gasoline consumption in Tokyo, 1993-2004
APERC 2007

The analysis is based on the following calculation.

*E = E/Psk * Psk/Carstock * Carstock*
(E: Gasoline, Psk: Passenger km, Carstock: Passenger vehicle stocks)
*△E = △(E/Psk) * Psk/Carstock * Carstock*
*+ E/Psk * △(Psk/Carstock) * Carstock*
*+ E/Psk * Psk/Carstock * △(Carstock)*
+ Residual

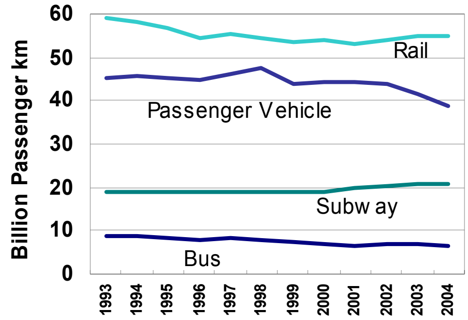
As the decomposition analysis indicates, gasoline requirements per unit of passenger km became larger in recent years. From 1993 to 2004, gasoline requirements per unit of passenger km increased by 71 percent from 0.07 toe per passenger km in 1993 to 0.12 toe per passenger km in 2004. In fact, Tokyo dwellers now prefer to own large-sized vehicles, leading to bigger energy requirements for a unit of mobility. For example, the share of large-sized vehicles in total passenger vehicle stocks increased from 22 percent in 1993 to 43 percent in 2004 [105.3].

The decomposition analysis offers another interesting illustration regarding the driving pattern for passenger vehicles. Between 1993 and 2004, operational rate of passenger vehicles was steadily declining, making negative contribution to the growth in Tokyo's gasoline consumption. This may be because drivers use passenger vehicles for short distance travel or their driving frequency is falling. As shown in



105.3 The number of passenger vehicle stocks by size, 1980-2004
APERC 2007, Tokyo Metropolitan Government 2005

106.1, passenger km of passenger vehicles has been steadily declining, while that of rail and subway has been slightly rising (in particular since 2002). In fact, 2002 marks the timing for the opening of a loop-style subway line (the Oedo line), which has further improved accessibility to subway/rail infrastructure and may have reduced the needs for passenger vehicle use.



106.1 **Annual passenger-km by mode, 1993-2004**

APERC 2007, Tokyo Metropolitan Government 2005

ISSUES

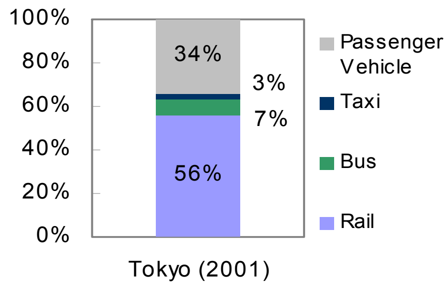
RAIL-CENTRIC CITY DEVELOPMENT

Despite the recent relative fast growth, the absolute level of personal gasoline use in Tokyo remains low compared with those of cities in USA or Oceania. This mainly results from the intensive use of rail/subway for passenger transport as an alternative to passenger vehicle. In fact, rail/subway accounted for 56 percent of total person trips, followed by passenger vehicles at 34 percent, bus at 7 percent and taxi at 3 percent in 2001. With respect to commuting, the share of rail/subway to the Tokyo's person trips is even higher, reaching 92.7 percent, followed by passenger vehicles at 4 percent and bicycle/walking at 2.4 percent.

The extensive development of a complimentary rail/subway network within the Tokyo metropolitan area supports city dwellers' mobility. The route length of total rail/subway network in Tokyo metropolitan area reached 1,003 km in 2004– by far the largest in the world. Out of the total route length, private rail accounted for 386 km, the formerly state-owned JR East 325 km, and subway 292 km.

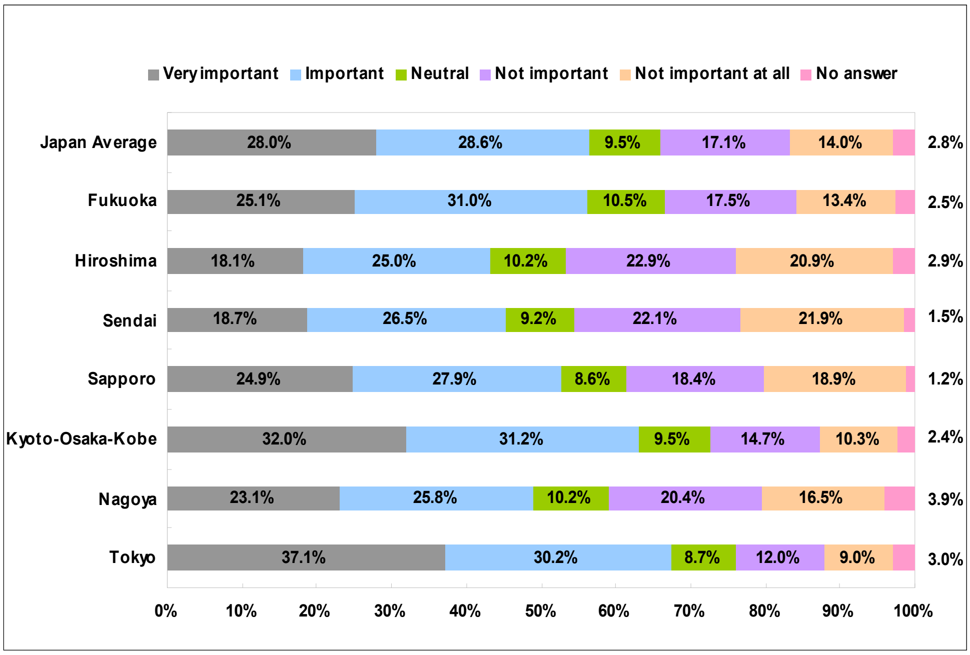
In addition to the rail/subway network within Tokyo metropolitan area, the rail network also extends to the suburbs and satellite cities, of which route length totals 2,021 km. Transfer from suburban rail to urban subway is rather smooth. Due in parts to such easy transfer, suburban rails are carrying more than 3 million passengers daily to central business area.

For Tokyo dwellers, accessibility to rail means accessibility to their work as well as their leisure. In fact, a Tokyoites' decision on where to live largely depends on accessibility to rail. According to a survey conducted by the Ministry of Land and Transport in 2005, more than 67 percent of respondents considered the accessibility to rail as an important factor affecting their decision on living location, which is higher than that of Japan's average at 56 percent. This suggests that rail is an integral part of daily life to those dwellers in Tokyo.



106.2 **Person-trips by mode, 2001**

APERC 2007, Ministry of Land and Transport 2005



107.1 **Importance of living in a home with good rail transit accessibility for Japanese city dwellers**

APERC 2007, Ministry of Transport 2005

This raises a few questions regarding the Tokyo's rail/subway development:

- What are the major contributing factors for Tokyo's rail/subway infrastructure development?
- What are the sources of financing for rail/subway infrastructure development?
- What were the hurdles for rail/subway infrastructure development, and how did rail/subway companies overcome those hurdles?

The following sub-section tries to answer these questions in order to provide lessons learned from the urbanisation and rail infrastructure development in Tokyo.

PRIVATE RAIL DEVELOPMENT

Private-led rail development is one of the main elements of Tokyo's success in shifting people away from passenger vehicle dependence. Tokyo's urban development and subsequent suburbanisation took place hand in hand with the rail infrastructure development. Private rail lines extend to the north, east, and west, and allow relative easy access from the residential suburbs to the urban core.

The key feature of private rail infrastructure development lies in those companies' strategy to diversify into business areas that compliment their core rail business. In an attempt to increase rail-based travel demand and ultimately to increase budgets for rail infrastructure investment, some rail companies own department store, sport arenas, theatres, and other amusement facilities. For example, private rail companies generally built department stores on top of the building of nodal stations such as Shinjuku, Shibuya, and Tokyo, in order to increase the customer base for both rail and retail businesses. In contrast, private rail-owned amusement parks or sport arenas are commonly developed in the areas around terminus stations; that is, they are intended to create transport demand from the city centre.

In addition, private rail companies have expanded business operations to include property development. From the early 1950s onward, private rail companies played an important role in Tokyo's suburban property development. Rapid concentration of wealth in the urban core had escalated the land price at that period, and this in fact spurred the need to develop residential suburbs.

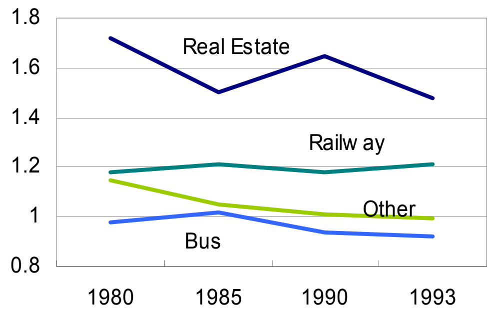
Investment in real estate provided the best return to Tokyo's railway companies—exceeding that of actual railway operation. As 108.1 shows, the financial rate of return for real estate – measured as the ratio of total revenue to total cost – for Tokyo's private rail companies ranges between 1.72 in 1980 and 1.48 in 1993. By contrast, the financial rate of return for railway business ranges between 1.18 in 1980 and 1.12 in 1993. Although rail business remains the core component for Tokyo private rail companies, accounting for more than 50 percent of combined total revenue for the rail companies and their subsidiaries, real estate business has generated the highest return among the rail companies' diversified business areas. This added revenue has in fact allowed the rail companies to expand capacity and invest in infrastructure development and upgrades.

Among the major private rail companies, Tokyu Corporation offers one of the best examples of making such real estate development as a means to increase budgets for rail infrastructure investment. A project called "Tama Denen Toshi" or Tama Garden City presents how Tokyu Corporation successfully integrated land development into the rail business operation.

The project, proposed in 1953 with construction beginning 1959, transformed 50 km² of wooded hills and farmland into a planned residential area. Currently, this vast land area encompasses four cities, with half a million residents and 30 km of rail line. Tama Garden City functions as the important satellite residential city for commuters to Tokyo and their families.

One essential mechanism used by the Tokyu Corporation to assemble the land needed to build rail infrastructure and real estate was "the land readjustment programme". Instead of purchasing all of the land required for development, Tokyu coordinated with landowners (mostly farmers) to form cooperatives. These cooperatives were responsible for consolidating properties and returning landowners smaller but fully serviced parcels with higher land values.[b] Each Tama landholder gave away between 20 and 30 percent of her land. Tokyu then transformed about one-third of those lands contributed by the landowners into roads, railways, and parks, with the remainder re-developed into housing areas for sales.

With the development led by Tokyu, the land value of Tama Garden City more than tripled from 1953 to in the mid 1960s. In fact, the profits obtained from the sale of new residential plots covered the cost of developing public areas, including rail infrastructure development. Ultimately, original landowners could enjoy the benefits incurred from the development as they could sell their properties at higher prices.



108.1 Average return on investments by rail companies, 1980-1993
APERC 2007, Cervero 1998

108.2,3 Tama Plaza in 1972 and 2004
Tama Plaza Terrace Homepage 2007

[b] *Robert Cervero (1998). The transit metropolis: a global inquiry. Island Press. California, USA*

Year	Eligible Area of Subsidy	Subsidy Rate (%)	Source of Subsidy
1967-1969	90% of capital investment in the previous year	10.5%	Central Government (100%)
1970-1972	90% of capital investment in the previous year	50%	Central Government (50%), Local Government (50%)
1973-1977	90% of capital investment in the previous year	66%	Central Government (50%), Local Government (50%)
1978-1989	90% of capital investment in the previous year	70%	Central Government (50%), Local Government (50%)
1990	80% of capital investment in the previous year	70%	Central Government (50%), Local Government (50%)
1991 -	80% of capital investment in the previous year	70%	Central Government (50%), Local Government (50%)

109.1 Subsidy-to-subway construction, 1967-present

APERC 2007, Ministry of Land and Transport 2005

SUBWAY DEVELOPMENT

Since its opening in 1927, Tokyo's subway has continuously expanded its coverage, handling capacity, and operational frequency, except for the period during World War II. Currently, two companies, Tokyo Metro and Tokyo Metropolitan Subway (*Toei Chikatetsu*), are in charge of the subway business, of which route length totalled 292 km with 266 stations in 2006. Although the total route length of Tokyo's subway is shorter than that of other world major cities such as New York (393 km), London (392 km), and Paris (312 km), it serves as the main transport mode through transferring passengers from suburban rail and moving passengers within the urban area.[c]

From the onset of major subway development in the 1950s, the Japanese central government was strongly committed to a rail-based future for Tokyo. Central authorities identified the need for early subway development in the report prepared by the committees under the Capital Construction Law of 1950 and the Metropolitan Region Development Law of 1956.[d] In addition, the Urban Transport Council under the Ministry of Transport recommended in its report published in 1956 that the subway should be linked to suburban rails in order to reduce transfer times. The strong commitment by the central government culminated in the decision to develop 5 subway lines in 1957, some of which were linked to suburban railways that were already in operation.

In addition to the central government, Tokyo metropolitan government also played an important role in subway development. In fact, the master plan and the final decision for subway development were made through coordination between central and metropolitan governments.

Though official government support was strong, Tokyo subway development nevertheless faced financial difficulties at its early stage of development due to high upfront costs. In an attempt to offer financial assistance, transport bonds and loans were issued by the Trust Fund Bureau.[e] To help support the subway companies, the central government initiated a programme to subsidise part of interest payment in 1962. In 1967, the programme was amended to provide direct subsidy for construction. As shown in **109.1**, the subsidy rate to the eligible capital investment cost increased from 10.5 percent in 1967 to the current 70 percent.[f] In addition, though the central government initially had sole responsibility for provision of the subsidy, since 1970 the Tokyo municipal government provides half of the subsidy for capital investment requirements.

[c] *Institute for Transport Policy Studies (2005). Annual report. Toshi Kotsu Nenpou (in Japanese).*

[d] *World Bank (2000). Study on urban transport development. Washington D.C., USA.*

[e] *Aoki Makoto (2002). Railway operators in Japan – Central Tokyo. Japan Railway & Transport Review 30. Tokyo, Japan.*

[f] *The increase in subsidy rate from 10.5% to 70% reflects increasing difficulties in terms of land acquisition due to rise in land price.*

ENHANCED CONNECTION BETWEEN RAIL AND SUBWAY

Guided by the recommendations of the Tokyo Urban Transport Council of 1956, a number of subway lines in Tokyo have been connected to the suburban railways. As shown in **110.1**, more than nine subway lines are directly linked with suburban rails, thereby offering through service for passengers.

Through linking suburban rail to subway, passengers can travel from Tokyo's outskirts to the urban core without transfer. In addition, the thorough/joint service between suburban rail and subway can reduce congestion at terminal stations, increasing system operating efficiencies and reducing the need for constructing large and expensive terminating rail yards in the city centre.

The benefits of enhanced connection between suburban rail and subway lines become obvious only after several issues were resolved, however. Such issues related to coordination between rail and subway companies with respect to setting time schedule, fares, technical standards for gauge/ rolling stock size, and safety standards. However, once these initial hurdles were cleared, the benefits to cooperating companies were easily worth it.

Subway	Railway	Date Started Operation
TMG Asakusa Line	Keisei line	4 Dec 1960
	Keikyu Line	21 Jun 1968
	Hokuso Kaihatsu	31 Mar 1991
TM Hibiya Line	Tobu Isezaki Line	31 May 1962
	Tokyu Toyoko Line	21 Aug 1964
TM Tozai Line	JR East Chuo Line	28 Apr 1966
	JR East Sobu Line	8 Apr 1969
TMG Mita Line	Tokyu Meguro Line	26 Sep 2000
TM Namboku Line	Tokyu Meguro Line	26 Sep 2000
	Saitama Railway	28 Mar 2001
TM Yurakucho Line	Tobu Tojo Line	25 Aug 1987
	Seibu Ikebukuro Line	1 Oct 1983
TM Chiyoda Line	JR East Joban Line	20 Apr 1971
	Odakyu Line	31 Mar 1987
TMG Shinjuku Line	Keio Line	16 Mar 1980
TM Hanzomon Line	Tokyu Denen Toshi Line	1 Apr 1981

110.1 Enhanced connection between rail and subway
APERC 2007, Ministry of Land and Transport 2005

IMPLICATIONS

Tokyo's rail-centric city development provides unique lessons to other rapidly developing cities. Despite its high income level at well above USD 50,000, and Japan's being a global automobile manufacturer, Tokyoites depend less on passenger vehicles than on rails/subways for their commuting, leisure, and other travel purposes. Thus, relative to income level, Tokyo's passenger transport energy consumption per capita represents one of the lowest among Asian cities.

The success in Tokyo's driving people to use rail and reducing vehicle dependence owes mainly to three factors: (1) strong government involvement in planning for urban development as well as rail infrastructure development, (2) private-led rail infrastructure development, and (3) enhanced connection between suburban rail and urban subway systems.

Strong government involvement in rail infrastructure development in Tokyo has been supported by close coordination and cooperation between the Tokyo municipal government and the Japanese central government. In fact, Tokyo's urban planning was jointly developed by both the central and municipal government. In addition, any disputes revolving around land acquisition for rail infrastructure development were resolved through consultations with both central government agencies and municipal government.

The efforts between central and municipal governments with respect to urban planning and development of rail infrastructure, in fact, paved the way for the private rail companies to develop suburban cities and rail infrastructure. Having initially run short of financial capacity, both levels of government worked together with the private companies for their suburban city as well as rail infrastructure development.

Private companies also coordinated with landowners in their efforts to develop planned residential areas and rail infrastructure. This has generated win-win situations for both parties, as rail companies developed infrastructure along with new sources of demand while land holder captured in the growth in land value.

As travel census results show, rail/subway is an integral part of daily life for those dwellers in Tokyo. This mainly results from the city's early start in developing rail/subway infrastructure, which in fact has shaped city dweller's lifestyle. This finding suggests the importance of planning appropriate timing for investing in rail/subway infrastructure, and that the plan be implemented with the concerted efforts of both public and private sectors.

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APPENDIX

CITY PROFILES

Macro Data

	Unit	1990	1995	2000	2005	Annual Growth Rate
Population	millions		5.57	5.68	5.48	-0.13% (1993-2005)
Population Density	person/ km^2		3,551	3,621	3,496	-0.13% (1993-2005)
Gross Regional Product	million USD 2000 PPP	119,796	156,047	123,721	151,123	1.56% (1990-2005)

The Number of Registered Vehicles

	Unit	1990	1995	2000	2005	Annual Growth Rate (1990-2005)
Passenger Vehicles	thousand	598	941	1,241	1,526[i]	6.92% (1990-2004)
Trucks	thousand	337	494	858	850	6.36%
Buses	thousand	322	346	322	224	-2.39%
Motorcycles	thousand	729	1,373	1,965	1,594	5.35%
Taxies	thousand	24	60	74	74	7.80%
Others	thousand	36	27	37	19	-4.17%

Energy Sales/ Consumption

	Unit	1990	1995	2000	2005	Annual Growth Rate
Gasoline	ktoe	1,399	2,271	2,474	2,842[ii]	4.84% (1990-2003)
Diesel	ktoe	3,131	4,313	4,053	6,246[ii]	4.71% (1990-2003)
NGV	ktoe				37	

Road and Parking

Total Length of Road Network	4,076 km (2004)
Total Length of Express Road Network	175.9 km (2004)

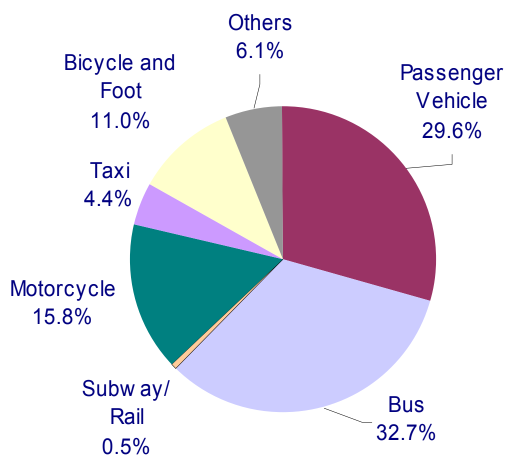
Public Transport

Total Length of Subway/Rail Lines	Skytrain: 23.5km Subway: 19.7km
Total Length of Bus Priority Route	

Air Pollutant Emissions from Motor Vehicles (tonnes) (1997)

CO	349,711
NOx	264,648
PM	20,602
HC	232,973
SO_2	9,784

Modal Split (1995)



i 2004 data *ii 2003 data*

Macro Data

	Unit	1990	1995	2000	2005	Annual Growth Rate
Population	millions	15.31	16.79	18.07	19.41	1.59% (1990-2005)
Population Density	person/ km^2	3,281	3,376	3,628	3,898	1.15% (1990-2005)
Gross Regional Product	million USD 2000 PPP		301,570	178,338	175,106[i]	-5.29% (1990-2004)

The Number of Registered Vehicles

	Unit	1990	1995	2000	2005	Annual Growth Rate (1990-2004)
Passenger Vehicles	thousand	2,292	2,178	2,944	3,160[i]	2.32%
Trucks (light truck)	thousand	16.0	13.1	17.7	30.0[i]	4.61%
Buses	thousand		30.8	25.4[iii]	30.7[ii]	-0.02% (1995-2003)
Motorcycles	thousand	29.0	33.0	60.2	85.9[i]	8.08%
Taxies	thousand		68.7	115.7[iii]	116.0[ii]	6.76% (1995-2003)
Others (microbus)	thousand		31.0	29.3[iii]	32.2[ii]	0.46% (1995-2003)

Energy Sales/ Consumption

	Unit	1990	1995	2000	2005	Annual Growth Rate
Gasoline	ktoe	4,287.3	5,099.4	5,116.1		1.78% (1990-2000)
Diesel	ktoe	864.6	1,189.5	1,397.2		4.92% (1990-2000)
NGV	ktoe					

Road and Parking

Total Length of Road	10,182 km (2004)
Total Length of Express Road Network	913 km (2004)

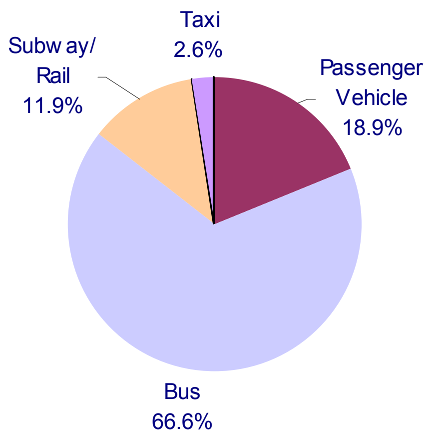
Public Transport

Total Length of Subway/Rail Lines	27 km (2004)
Total Length of Bus Priority Route	489 km (2004)

Air Pollutant Emissions from Motor Vehicles (tonnes) (2004)

CO	1,927,101
SO_2	4,929
NO_2	156,311
PM10	4,444

Modal Split (2004)



i 2004 data *ii 2003 data* *iii 2001 data*

Macro Data

	Unit	1990	1995	2000	2005	Annual Growth Rate
Population	millions	6.00	6.33	6.78	7.03[i]	1.14% (1990-2004)
Population Density	person/ km^2	334	353	378	392[i]	1.14% (1990-2004)
Gross Regional Product (Personal Income)	million USD 2000 PPP	194,939	216,197	319,273	305,130[i]	3.25% (1990-2004)

The Number of Registered Vehicles

	Unit	1990	1995	2000	2005	Annual Growth Rate
Passenger Vehicles	thousand	3,670	3,824	4,319	4,456	1.30% (1990-2005)
Trucks (commercial/van)	thousand	961	879	957	964	0.02% (1990-2005)
Buses	thousand					
Motorcycles	thousand	144	127	118	151	0.32% (1990-2005)
Taxies	thousand					
Others	thousand					

Energy Sales/ Consumption

	Unit	1990	1995	2000	2005	Annual Growth Rate
Gasoline	ktoe	9,101		10,570	10,127[i]	0.77% (1990-2004)
Diesel	ktoe		1,005	1,332	1,237	2.10% (1995-2005)
NGV	ktoe					

Road and Parking

Total Length of Road (centerline-km)	34,542 km (2004)
Total Length of Express Road Network	2,559 km (2004)

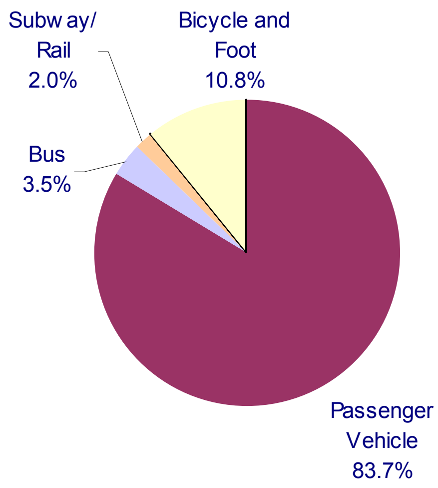
Public Transport

Total Length of Subway/ Light Rail	255 km (2005)
HOV Route Length (lane-km)	548 km (2005)

Air Pollutant Emissions from Motor Vehicles (ug/m^3) (2005)

CO	531.744
SO_2	2.615
NO_2	24.438
PM10	23.5

Modal Split (2005)



i 2004 data *ii 2003 data*

SHANGHAI

Macro Data	Unit	1990	1995	2000	2005	Annual Growth Rate
Population	millions	14.00	14.63	15.22	17.78	1.60% (1990-2005)
Population Density	person/km²	2,208	2,307	2,400	2,804	1.60% (1990-2005)
Gross Regional Product	million USD 2000 PPP	114,830	131,856	257,292	488,346	10.13% (1990-2005)

The Number of Registered Vehicles	Unit	1990	1995	2000	2005	Annual Growth Rate	
Passenger Vehicles	thousand		134[i]	244	644	19.06%	(1996-2005)
Trucks	thousand	93	137	165	192	4.93%	(1990-2005)
Buses	thousand		63[i]	83	116[ii]	7.93%	(1996-2004)
Motorcycles	thousand	64	114	551	1,266	22.02%	(1990-2005)
Taxies	thousand	11	37	43	48	10.32%	(1990-2005)
Others	thousand						

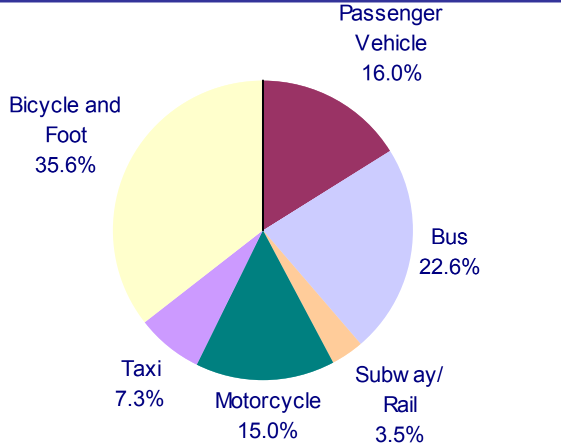
Energy Sales/ Consumption[iii]	Unit	1990	1995	2000	2005	Annual Growth Rate	
Gasoline	ktoe		312[i]	530	1,012	13.96%	(1996-2005)
Diesel	ktoe						
NGV	ktoe						

Road and Parking	
Total Length of Road	12,227 km (2005)
Total Length of Express Road Network	7,805 km (2004)

Public Transport	
Total Length of Subway/Rail Lines	Subway: 147.8 km
Total Length of Bus Priority Route	

Air Pollutant Emissions(in urban area)(ug/m3) (2005)	
CO	
SO_2	0.061
NO_2	0.061
PM10	0.088

Modal Split (2004)



i 1996 data *ii 2004 data* *iii only for passenger vehicles*

TOKYO

Macro Data

	Unit	1990	1995	2000	2005	Annual Growth Rate
Population	millions	11.63	11.54	11.82	12.27	0.36% (1990-2005)
Population Density	person/ km^2	5,318	5,278	5,404	5,612	0.36% (1990-2005)
Gross Regional Product	million USD 2000 PPP	416863.1[i]	443,647	542,457	630,651[ii]	3.51% (1991-2003)

The Number of Registered Vehicles

	Unit	1990	1995	2000	2004	Annual Growth Rate	
Passenger Vehicles[iii]	thousand	2,779	3,026	3,166	3,213	1.04%	(1990-2004)
Trucks (heavy trucks)	thousand	401	344	314	315	-1.70%	(1990-2004)
Buses	thousand	15.9	14.8	14.0	14.0	-0.90%	(1990-2004)
Motorcycles	thousand						
Taxies	thousand						
Others	thousand						

Energy Sales/Consumption

	Unit	1990	1995	2000	2005	Annual Growth Rate	
Gasoline	ktoe	3,162	3,151	4,185	4,606	2.54%	(1990-2005)
Diesel	ktoe	2,218	2,467	2,801	3,548	3.18%	(1990-2005)
NGV	ktoe						

Road and Parking

Total Length of Road Network	24,052 km (2005)
Total Length of Express Road Network	

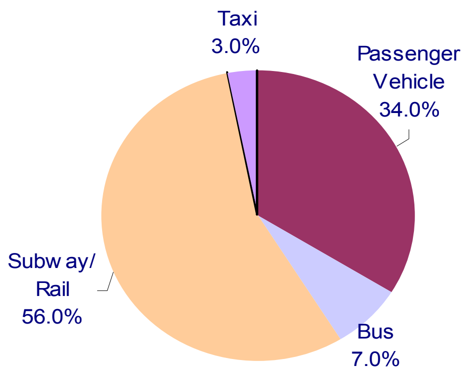
Public Transport

Total Length of Subway/Rail Lines	Subway:279.4 km (2004) Rail: 715.6 km (2004)
Total Length of Bus Priority Route	

Air Pollutant Emissions from Motor Vehicles (tonnes) (2000)

CO	0.8 (ppm)
NOx	
PM	0.033 (mg/m^3)[iv]
HC	
SO_2	1300 (tonnes)

Modal Split (2001)



i 1991 data *ii 2003 data* *iii Passenger vehicles include taxies.* *iv SPM data*