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Understanding the factors affecting the urban transport energy in Asian cities – pathways of urban transport indicators from 1995 to 2009

Abstract

Through developing urban transport indicators – comprised of road indicator and offset indicator, the paper tries to identify the key factors that contributed to both increase and decrease in passenger vehicle gasoline consumption as well as CO_2 emissions growth. Creating the urban transport indicators for the three time periods of 1995, 2005, and 2009, the paper tries to understand the changing factors affecting passenger transport in the urban areas of Asia. The paper found that ensuring access to mass transit systems, such as rails and subways, is a key to offset the growth in vehicle dependence in the urban areas of Asia. Cities such as Bangkok, Beijing, and Jakarta are developing mass transit systems – as the alternative to passenger vehicles, however, the size of mass transit network is not yet sufficient to cover the urban land area, and this leads to continued heavy dependence on road transport. In contrast, road dependence has been reduced or maintained at relatively low levels in Hong Kong, Seoul, Shanghai, Singapore, and Tokyo as a result of ensured access to rails and subways. Importantly, in these five cities, holistic approach is taken to develop and implement policies related to regulate vehicle usage through vehicle registration, parking regulation, and fuel prices taxes, aside from the infrastructure development. This provides a good lesson to the cities of early stage of development for the need to plan development of mass transit systems, and consider requirements for developing city-specific energy, environment and transport policies.

Keywords: urbanization, motorization, mass transit systems, energy security, and sustainable development.
JEL Classification: Q41, Q58, R42, R48.

Introduction

Road transport is responsible for significant share of the world CO_2 emissions. In 2008, CO_2 emissions from the road sector accounted for 20% of the world CO_2 emissions (IEA, 2010a). In terms of growth trends, CO_2 emissions from the road sector grew at a faster pace (2.3% per year) than that of total world CO_2 emissions (1.8% per year) during the time period between 1990 and 2008. In addition, the world's road transport is almost entirely dependent on oil products, accounting for 96% in 2008 (IEA, 2010b), which are rendering energy security concerns at some countries because of rising prices, and increasing imports. In future, Asia and the Pacific region's transport sector CO_2 emissions – mainly from road – is projected to increase at 2.8% per year, the fastest pace by sector from 2005 to 2030 (Asian Development Bank, 2009)[1]. Therefore, how to slow the growth trends in CO_2 emissions as well as oil products demand from road transport is an important policy agenda across the world for the purpose of enhancing sustainable development and energy security.

Concentration of wealth in the urban areas of Asia has driven the motorization trend over the past two decades, which lead to increases in oil imports and CO_2 emissions within the region. Particularly, in those urban cities that are rapidly developing, while making relative slow progress in building infrastructure necessary to facilitate the use of mass transits (such as rails and subways), their income growth has spurred the passenger vehicle ownership. For example, Bangkok's vehicle ownership expanded from 169 per 1,000 population in 1995 to 384 per 1,000 population in 2009. Also, Beijing's vehicle ownership per 1,000 population rapidly increased from 28 in 1995 to 171 in 2009. Meanwhile, some urban areas in Asia have recently expanded mass transit infrastructure, and this facilitates shift away from heavy dependence on vehicle use. In Shanghai, for example, length of subway/rail infrastructure has expanded to reach 355 km in 2009 from zero in 1995, and the number of vehicle ownership per 1,000 population is lower compared with the other cities, increasing from 8 in 1995 to 50 in 2009.

Urban population will increase in future through structural transformation of rural areas and migration of rural populations into urban areas. According to the United Nations (2007), urban population in Asia is projected to increase by 36 million annually from 2005 to 2030, and this accounts for about 50% of the world incremental growth in urban population during the same time period. The continued dependence on vehicles in these areas will drive the growth in oil demand, which in turn will raise the energy security concerns amid slow growth in oil production within the region, in addition to CO_2 emissions increases. Besides, in many of the urban cities of

[1] Asian Development Bank (2009) shows that the transport sector CO_2 emissions in Asia and the Pacific is projected to increase at the fastest annual rate of 2.8%, followed by the power sector at 2.6%, the residential/commercial sectors at 2.4%, and the industry sector at 1.5% between 2005 and 2030.

Asia, heavy traffic congestion has been causing economic losses. For example, the average travel speed of passenger vehicles at the urban core area of Bangkok represents 12 km per hour, and that of Jakarta reached 15 km per hour.

Mass transit may serve well to shift heavy dependence on passenger vehicles, and facilitate efficient mobility of urban areas in terms of time. A study by Cullinate (2002), which conducted survey of 389 persons in Hong Kong, suggests that good public transport deter car ownership.

Mass transit (subways and rails) can also assist to save energy and CO_2 emissions per passenger in urban areas if enough infrastructures are in place to increase passengers' access to the subway/rail system, and the subway/rail's occupancy rate. In Tokyo, with dwellers of high dependence on public transport, subways' energy requirements per passenger km represent less than one-third of that of passenger vehicles (Ministry of Economy, Trade and Industry, 2010; Tokyo Metropolitan Government, 2009). Likewise, mass transit's CO_2 emissions per passenger km in Asian cities (Tokyo, Manila, Hong Kong, and Taipei) are lower than that of the average passenger vehicle. Meanwhile, it should be noted that CO_2 emissions per passenger km of mass transit is determined by occupancy rate of mass transit, and choice of energy type to generate electricity; therefore, great diversity is observed among the Asian cities (Tokyo's mass transit CO_2 emissions per passenger km represents less than 20% of that of passenger vehicles, while Taipei's case offers about 50% of passenger vehicle (Fedor and Aponte, 2007).

This paper tries to identify key factors affecting the passenger transport energy consumption in the urban areas of Asia, and evaluate their urban transport systems. The cities chosen for this paper involve diverse economic development and resources endowment, including Bangkok, Beijing, Hong Kong, Jakarta, Seoul, Shanghai, Singapore, and Tokyo. To evaluate this relationship in urban areas, the paper develops two indicators: road indicator, and offset indicator, which are combined to be called "urban transport indicators". The framework is based on the author's work (Doi, 2007), meanwhile this paper updates data in order to capture the recent trend, make revisions on historical data, and gain new insights into the performance of urban transport in the major cities of Asia. Using the indicators on different time periods, an evolution of urban transport system can be presented. Also, both contributing and offsetting factors to the dependence on road transport can be identified through these indicators to consider the city-specific requirements for the purpose of energy security enhancement and sustainable development.

Recently there is little effort undertaken to capture the nexus between the overall trend in road dependence and mass transit infrastructure in Asia. Groundbreaking work by Kenworthy and Laube (2001) established a database on 100 world cities covering the various indicators related to transport, energy and environment for the year of 1995, nevertheless the data updates for the Asian cities have not been undertaken. Dakal (2004) made a comprehensive analysis of urbanization and energy use for the selected cities in Asia (Beijing, Shanghai, Seoul, and Tokyo), and the study focused on the policy aspects. Ng, Schipper, and Chen (2011) studied the nexus between land use change and motorization trends, and developed three scenarios to analyze the impact of land use change, transport energy demand, and CO_2 emissions arising from the various policy and economic assumptions, meanwhile this study focused on the major cities in China.

The data updates are important because of the changing environment surrounding the transport sector in Asia and the world. First, the international oil prices recently have fluctuated substantially from around $54/barrel in 2005. It climbed sharply to $98/barrel in 2008, and then declined to $62/barrel in 2009 (BP, 2010). In addition, some countries in Asia which provided oil products subsidy, gradually remove it to reduce government's fiscal deficit. Thailand eliminated subsidy to gasoline in 2004 and diesel in 2005. Indonesia removed subsidy for premium gasoline in 2005, which subsequently increased the price by 70% in 2008 from 2005. RON88 gasoline is still subsidized although its price increased by 30% from 2005 to 2008 (Embassy of the USA, Jakarta, 2008). The rises in the international oil prices and oil products prices of some countries in Asia have affected the gasoline consumptions trends.

Second, to promote shift toward fuel-efficient and/or low-carbon emitting vehicles, a number of countries in Asia have recently established systems to promote "Eco-cars". In 2007, Thailand's board of investment (BOI) announced provisions of incentives for manufacturing low-cost, fuel efficient vehicles as a means to promote domestic automobile industry (Board of Investment, Thailand 2007). As an economic stimulus measure after the economic crisis in the summer of 2008, Japan provided temporary tax break and subsidy to Eco-cars, including electric, hybrid, and clean diesel vehicles. Similarly, since 2001 Singapore has been providing green vehicle rebate to those who purchased low-emission vehicles, including electric, hybrid, CNG or Petro-CNG vehicles, and the scheme is extended to include imported used low emission vehicles in 2010 (National Environment Agency, Singapore).

Third, in some Asian cities such as Shanghai and Singapore, the mass transit network has been expanded recently and it is useful to understand how the infrastructure expansion may have impact on the passengers' modal choice within a city.

This paper is organized in a following way. In Section 1, general trends in vehicle ownership and gasoline consumption of the major Asian cities are presented to understand the trends and difference among analyzed city. Section 2 explains the analysis framework to clarify the underlying considerations for the choice of indicators in this analysis. Section 3 presents the results based on the indicators' analysis, and explanation on those results are made. The last Section presents conclusions to consider necessary measures in order to develop sustainable transport system within Asian cities, and to enhance energy security.

1. Trends in passenger vehicle ownership and gasoline consumption in Asian cities

In this section, general trends in Asian cities' passenger vehicle ownership and gasoline consumption are presented. Firstly, passenger vehicle stocks per 1,000 population of the Asian cities are compared with that of country average. This would enhance understanding over different levels and trends in vehicle ownership in cities. As Figure 1 shows, dif-

ferences can be observed between the city's per 1,000 population passenger vehicle stocks and that of country average[1].

For example, China's average passenger vehicle stocks per 1,000 population reached 29 in 2008, while that of Beijing was 147 in the same year – five times bigger than the country average level. The Beijing's substantial difference from the country average results from the high income level. In 2008, Beijing's per capita Gross Regional Product (expressed in purchasing power parity (PPP) at 2005 price) was $15,800, nearly four times bigger than country's per capita GDP at $4,129[2]. By contrast, Shanghai's per capita GRP represented even higher level than that of Beijing at $15,800 in 2008, while its passenger vehicle stocks per 1,000 population was 44 in the same year, accounting for less than one-third of that of Beijing. The relatively low vehicle ownership level of Shanghai results from the city's policy to implement license plate bidding. Those private car owners would have to bid for license plate as an official requirement, and in 2008 the cost of number plate was nearly $10,000 (in PPP or $6,300 in exchange rate). The additional cost of vehicle ownership results in relatively low vehicle ownership in Shanghai compared with its high income level.
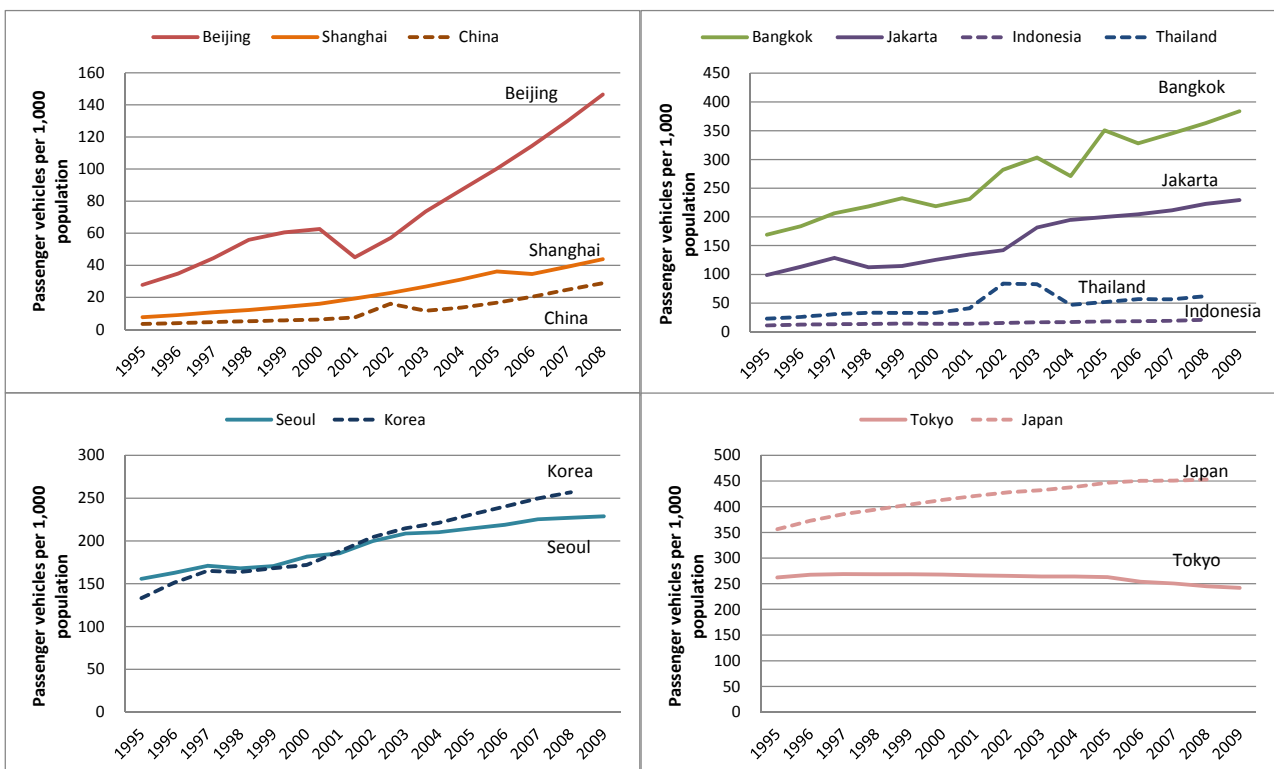

Fig. 1. Comparisons of passenger vehicles per 1,000 population between city and country average

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[1] For cities, time periods covered in this figure are between 1995 and 2009, while those of countries are between 1995 and 2008 because of data availability.
[2] Prices shown in this paper were calculated with purchasing power parity basis at 2005 prices.

Similar to Beijing, passenger vehicle stocks per 1,000 population for Bangkok and Jakarta represented substantially higher level than that of country's average. Bangkok's this indicator in 2008 was 363, compared with the country's average at 62 – more than five times bigger than the country's average. Also, Jakarta's per 1,000 population passenger vehicle stocks was 222 in 2008, representing more than 10 times bigger than the Indonesia's average at 21 in the same year. Again, the higher income level (in terms of per capita GRP) of cities resulted in higher passenger vehicle stocks per 1,000 population. Bangkok's per capita GRP in 2008 was $22,238, which represents nearly four times bigger than Thailand's per capita GDP in the same year. Jakarta's per capita GRP in 2008 was $12,513, more than five times bigger than that of country's average at $2,191 in the same year.

Income of Seoul and Korea represented similar level respectively at $28,704, and $22,361 in 2008. About a quarter of total Korea's population is concentrated in the Seoul metropolitan area, and this fact leads to similar income levels with that of country's average. As a result, per 1,000 population passenger vehicle stocks in Seoul had been at a similar level to that of

country's average from 1995 to 2000, but it has been surpassed by country's average from 2001 onwards. In 2008, Seoul's passenger vehicle stocks per 1,000 population was 227, compared with that of country's average at 257. Higher cost of passenger vehicle ownership in Seoul along with the recent improvement in the access to the public transport in Seoul (including buses and subways) explain the changing trends.

The case of Tokyo offers different trend from the rapidly developing cities. Tokyo's passenger vehicle stocks per 1,000 population has been representing lower level than that of country average for the entire analyzed period from 1995 to 2008. Per capita GRP of Tokyo in 2008 was nearly double the level of Japan's average at $55,032 (Japan's average was $28,661 in the same year). Aside from Tokyo's good access to public transport systems (including rails and subways), high cost of vehicle ownership (resulting mainly from parking and fuel costs) have resulted in lower passenger vehicle ownership per 1,000 population. By contrast, it is observed that Japan's number of passenger vehicle stocks per 1,000 population has been moderately increasing since 2000 onwards reflecting the increased numbers of small-sized vehicles.
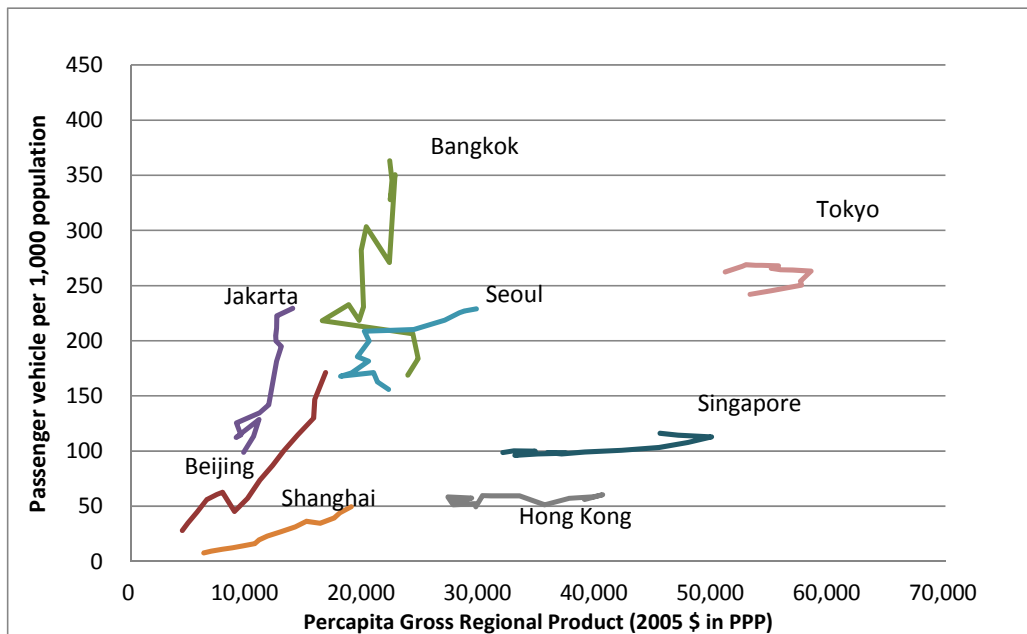

Fig. 2. Comparisons of passenger vehicle stocks per 1,000 population with per capita Gross Regional Product in Asian cities

Figure 2 compares per capita GRP of the analyzed cities, with respective passenger vehicle stocks per 1,000 population. It is interesting to observe that passenger vehicle ownership per 1,000 population has weak correlation with per capita GRP. This reflects city-specific factors such as access to public transport systems, regulation on passenger vehicle ownership, and cost of vehicle ownership. For example, despite the high income level at above

$40,000, Hong Kong's passenger vehicle stocks per 1,000 population in 2009 represented the second lowest level among the analyzed cities after Shanghai. This mainly results from good access to the public transport system as well as high cost of vehicle ownership caused by parking cost. Given a small urban land area at 335 km^2, on average Hong Kong's residents would have to pay the highest price for parking among the analyzed cities at around $5,100

(Purchasing Power Parity basis) per year. This factor, combined with a good access to the public transport system, lead to low passenger vehicle ownership per 1,000 population.

Then, what are the trends in gasoline consumption by passenger vehicles in Asian cities? To allow inter-city comparisons, gasoline consumption per 1,000 population of eight cities is presented in Figure 3. The figure shows wide variations in terms of both *levels* and *trends* of per capita gasoline consumption. In terms of the levels, gasoline consumption per 1,000 population ranged from Hong Kong's 50 tons of oil equivalent (toe) at the lowest to Bangkok's 458 toe at the highest in 2008. In terms of trends, Beijing and Shanghai's gasoline consumption per 1,000 population has been on rising trends driven by robust economic development. Meanwhile, that of Seoul has been on a declining trend due to rising fuel prices. Other cities' gasoline consumption per capita represented similar level from 2005 onwards although differences can be observed by city.

In order to further reflect differences in income level among the analyzed cities, gasoline consumption per capita was normalized by each city's income (Figure 4). This indicator can offer proportional size of per capita gasoline consumption relative to the size of income level. As the figure shows, wide variations exist in the historical trends of income normalized per capita gasoline consumption among eight cities. Bangkok and Jakarta represented the highest levels of this indicator although it declined from the respective peak levels in 1998 and 2000, which suggests these cities' high dependence on passenger vehicles for mobility – relative to the size of income. By contrast, Hong Kong's indicator had the lowest level over the analyzed periods from 1995 to 2008, which suggested least dependence on passenger vehicles for meeting the mobility needs – relative to the income level. The case of Seoul offers an interesting trend that income normalized per capita gasoline consumption has been continuously declining since 1995, and the trend is accelerating in recent years from 2004. Beijing's indicator shows an increasing trend since 2001 onwards, which coincides with the timing of China's WTO accession.
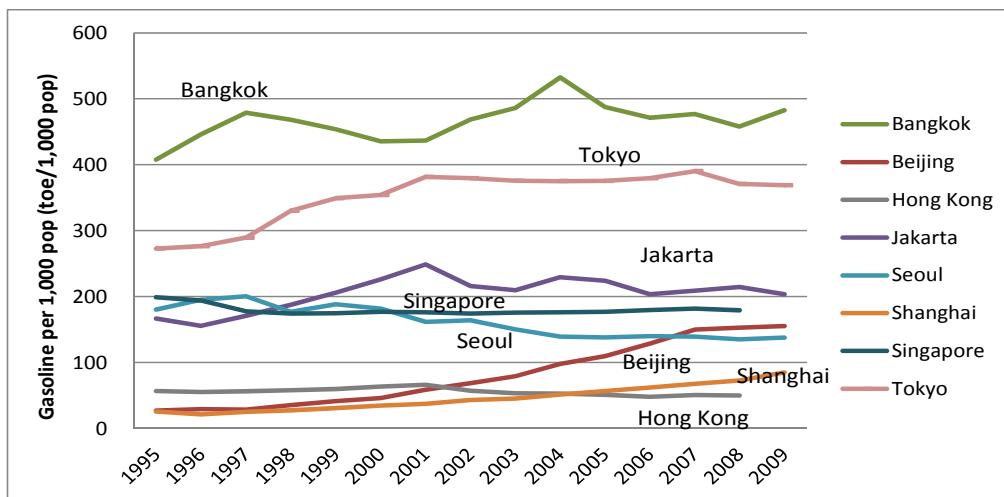

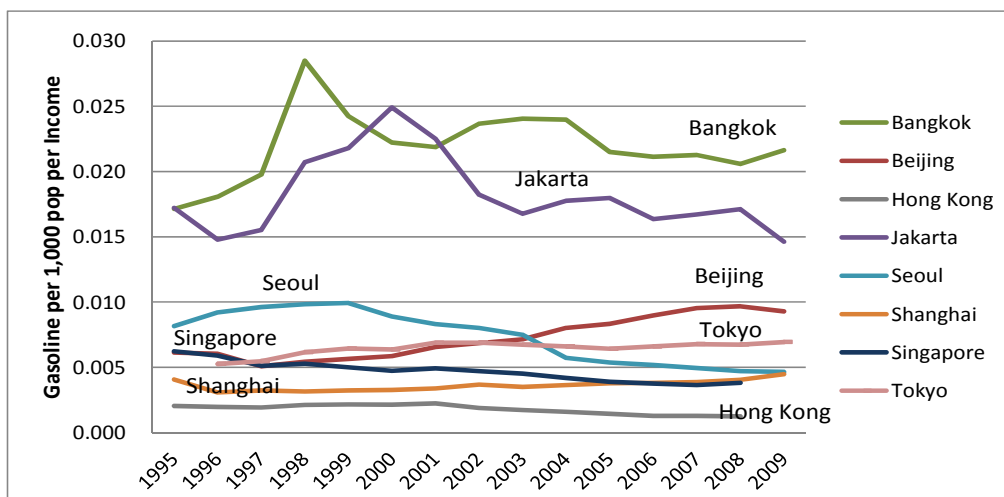**Fig. 3. Comparisons of per capita gasoline consumption in Asian cities**

Fig. 4. Comparisons of per capita gasoline consumption normalized by income in Asian cities

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2. Analysis framework

This section describes the analysis framework for the purpose of developing the urban transport indicators. In fact, various factors affect the transport energy use in the urban areas of Asia. For the passenger transport, those factors include urban form, demographic trends, and infrastructure development of urban mass transit systems. Urban form (such as sub-urbanization or re-urbanization) affects the travel distance of passengers, and demographic trends (such as population migration from rural areas into urban ones) would drive the growth in the number of passengers. The ease of access to the urban mass transit systems may reduce dependence on passenger vehicle stocks and can contribute to reduce overall energy use in the urban areas. In addition to these factors, costs of vehicle ownership (including tax, registration fee, fuel prices, parking costs, and insurance) are the main elements that constitute the vehicle ownership level, which in turn affect the passenger transport energy use in the urban areas.

To comprehensively capture both driving and offsetting factors to urban transport energy use, which leads to CO_2 emissions, the paper develops two indicators: (1) *road indicator*; and (2) *offset indicator*. These two indicators are combined to be called the *urban transport indicators*. The indicators analysis is made for 8 major cities in Asia which are at different economic development levels. These include Bangkok, Beijing, Hong Kong, Jakarta, Seoul, Singapore, Shanghai, and Tokyo. In addition, the analysis is undertaken for three time periods on 1995, 2005, and 2009.

The urban transport indicators are created to meet four purposes. First, the urban transport indicators can serve to understand city-specific driving and offsetting factors for the urban transport energy use. Second, the indicators make it possible to compare the urban transport system in each city with the others. Third, the indicators' analysis of different time periods for 1995, 2005, and 2009, can allow identification of changes in both driving and offsetting factors for the urban transport energy use. Forth, the urban transport indicators can serve as the basis to make city-specific transport, energy and environmental policies.

2.1. Road indicator. Road indicator was developed to capture the dependence on passenger vehicles for meeting passenger mobility needs in the urban areas. Three variables were chosen as the key factors that drive the growth in urban passenger vehicle energy consumption, including: (1) passenger vehicle stocks; (2) road length; and (3) average vehicle travel distance. Road indicator was calculated as a weighted average of three factors (50:20:30). Data were collected from the official sources:

1. **Passenger vehicle stocks** is the key variable that contributes to gasoline consumption and CO_2 emissions, because those vehicle owners tend to rely on vehicles for their mobility once it is acquired. The number of vehicle stocks is in fact determined by diverse factors, such as income level, vehicle's unit price, and cost of vehicle ownership (for the payment of tax, registration fee, gasoline price, parking cost, and insurance fee). For example, some countries, which are growing rapidly to surpass income level at above $15,000, tend to have high vehicle ownership level because of relatively low cost of vehicle ownership resulting from relatively low gasoline price, and absence of parking regulation or insurance system. As a variable constituting the road indicator, passenger vehicle stocks per 1,000 population was normalized by income (as per capita GRP in PPP at 2005 year value) in order to allow comparison of vehicle ownership level by city with different income levels.

2. **Road length** is another important variable that supports passengers' use of vehicles, and leads to drive gasoline consumption and CO_2 emissions. Urban development takes place concurrently with the development of road. Evidence shows that road development can ease congestion in short-term, but in longer time horizon, it will assist increased use of vehicles to meet growing transport needs in urban areas (Ng et al., 2010). Therefore, in order to capture the dependence on road transport, road length was utilized as a variable. Meanwhile, in order to allow inter-city comparisons with different economic development levels, road length was normalized by income of each city.

3. **Average vehicle travel distance** is utilized as a proxy to represent vehicle usage. In some cities such as Bangkok, where access to mass transit network is limited to the urban core areas, passengers from sprawling urban areas tend to drive vehicles for relatively long distance. By contrast, city dwellers in Tokyo on average drive their vehicles relatively for short distance as most of workers utilize rails and subways for commuting, while they drive vehicles during weekends only. Therefore, average vehicle travel distance can represent city-specific differences on how passenger vehicles are utilized. In this analysis, daily average travel distance per vehicle (km) is applied.

2.2. Offset indicator. Offset indicator was created to identify city-specific factors that can reduce passenger vehicles' gasoline consumption and CO_2 emissions. Three variables were chosen to develop offset indicator: (1) passenger vehicles energy efficiency improvement; (2) accessibility to rails/subways; and

(3) governance. Similar to the road indicator, the offset indicator was calculated as a weighted average of each variable (30:40:30):

1. **Passenger vehicles energy efficiency improvement** is an important element that can reduce growth trends in passenger vehicles' gasoline consumption. Passenger vehicles energy efficiency improvement is affected by technological development, vehicle size, and vehicle utilization of urban areas. In this analysis, the variable is calculated as changes in gasoline consumption per passenger vehicle for certain time periods. For the 1995 and 2005 offset indicator analysis, a ten-year annual average growth rate of gasoline consumption per vehicle was utilized respectively, while for the 2009 analysis a four-year annual average growth rate of gasoline consumption per vehicle was utilized.

2. **Accessibility to rails/subways** is the critical factor that can facilitate people's shift away from passenger vehicles dependence. Unless good access to rails/subways is ensured, a major shift of passengers – away from vehicle dependence – does not occur. As a means to capture the difference in access to rails/subways by city, total number of rail/subway stations within the urban area is divided by urban land area to create accessibility variable. Tokyo has well developed sub-urban rails' infrastructure that can feed passengers into urban rails/subways, however, this ex-urban infrastructure was excluded from the variable calculation to provide equal conditions for comparison. In fact, rails/subways are concentrated on the urban areas in the other cities.

3. **Governance** means a process of decision-making

and its implementation. This is also an essential aspect of evaluating urban transport system as a whole. Initially, the development of infrastructure for roads, rails, subways, and buses require coordination with the urban planning. Also, the development of transport policy requires considerations for a list of issues, including infrastructure development for road/rails, automobile industry, energy pricing and taxes, energy and environment, and safety. To those different issues, inter-agency coordination is essential, and it is necessary to resolve sometimes conflicting interests by agency at both central and local levels.

To account for different level of governance among the cities analyzed, the World Bank's "Worldwide Governance Indicators" is utilized. This offers 6 dimensions of governance for the time period between 1996 and 2009, including: (1) voice and accountability; (2) political stability and absence of violence; (3) government effectiveness; (4) regulatory quality; (5) rule of law; and (6) control of corruption. For the purpose of this analysis, the average level of 3 dimensions from the governance indicators (government effectiveness, regulatory quality, and rule of law) was utilized. Although city-specific governance indicators are not produced in this report, country average is utilized as a proxy. The 1995 indicator analysis relied upon the 1996 governance indicators.

3. Results

Table 1 displays the analyzed cities' ranking for both road indicator and offset indicator in 2009. The table includes variables that constitute each indicator (road, and offset indicators respectively), and the resulting scores for each indicator.

Table 1. Ranking of the cities (2009)

	Road indicator				
	City	Vehicle stocks (Tokyo = 10)	Road length	Vehicle travel distance	Road indicator
1	Jakarta	36.0	130.2	21.0	50.4
2	Bangkok	37.7	40.2	74.0	49.1
3	Beijing	22.5	70.7	45.0	38.9
4	Seoul	16.8	25.5	49.4	28.3
5	Shanghai	7.6	59.0	40.0	27.6
6	Singapore	4.9	14.1	53.7	21.4
7	Tokyo	10.0	35.2	31.2	21.4
8	Hong Kong	3.1	7.5	56.1	19.9
	Offset indicator				
	City	Vehicle efficiency	Access to rails and subways	Governance	Offset indicator
1	Hong Kong	3.6	51.6	95.3	50.3
2	Tokyo	-1.9	45.9	85.3	43.3
3	Seoul	1.6	43.9	80.4	42.2
4	Singapore	4.4	15.2	97.2	36.6
5	Shanghai	-2.2	41.4	49.9	30.8
6	Beijing	4.8	10.6	43.9	20.6
7	Bangkok	2.5	6.1	57.5	20.4
8	Jakarta	2.3	14.4	41.3	18.8

3.1. Road indicator results. Road indicator ranking shown in Table 1 includes scores for each city, with higher value meaning higher dependence on passenger vehicles for meeting mobility needs. Jakarta was ranked number one among the analyzed cities in terms of dependence on road transport. Meanwhile, a caution needs to be paid in interpreting the result. The scores express each cities' dependence on road transport – relative to the economic development[1].

Different factors differently affect the road indicator results. For example, Jakarta and Bangkok represented a similar level of road indicator respectively at 50.4 and 49.1. Jakarta's case indicates that aside from the higher passenger vehicle ownership, longer road length – relative to its economic development – contributed greatly to the score. Bangkok's high score resulted from relatively long travel distance of passenger vehicles in addition to the high passenger vehicle ownership level – again relative to its economic development.

Comparison between Singapore and Tokyo offers another interesting insight since different factors resulted to make the same road indicator score. In the case of Singapore, two variables (vehicle stocks, and road length) were lower than that of Tokyo, but average daily travel distance is longer at 53.7 km than that of Tokyo at 31.2 km. This means that those passenger vehicle owners (of which number is smaller than Tokyo) rely more heavily on vehicles to drive longer distance.

3.2. Offset indicator results. Offset indicator results displayed in Table 1 offer the ranking of cities in terms of systems that can reduce passenger vehicle dependence and its gasoline consumption and CO_2 emissions growth. In other words, higher offset indicator score means more alternative options for offsetting their growth.

Hong Kong is ranked number one in the offset indicator results, to which accessibility to rails and subways contributed greatly along with the city's good governance. In fact, the top three cities (Hong Kong, Tokyo, and Seoul) ensured good access to rails and subways[2], and these cities were supported by relatively high performance of the governance level that leads to formation of energy and transport related policies (concerning registration, parking, insurance, and gasoline tax) and implementation.

By contrast, Beijing, Bangkok, and Jakarta represented the lower rankings in offset indicator results among the analyzed cities. This is mainly caused by limited access to rails and subways relative to the size of urban land area. Beijing, for example, has recently developed the subway networks, and the number of stations accounted for 145 in 2009. The coverage of Beijing's subway is concentrated on the urban core center, while the city has relatively large urban land area of 12,188 km^2. In the cases of Bangkok and Jakarta, the number of rail stations is respectively small at 43 and 76, which are respectively located at the urban land area of 700 km^2 and 528 km^2.

3.3. Urban transport indicators 2009 – grouping of the cities. The results from road indicator and offset indicator analysis are shown in Figure 5. The x-axis shows the offset indicator results, and y-axis shows the road indicator results. Those cities that are located at the lower part of right-hand side of the figure represent relatively low dependence on passenger vehicles with higher options to reduce gasoline consumption and CO_2 emissions from passenger vehicles. By contrast, those cities that are located at the higher part of left-hand side of the figure include relatively high dependence on passenger vehicles along with limited options to reduce gasoline consumption and CO_2 emissions at the point of analysis.

By plotting the results from the two indicators into one figure, city-specific passenger transport characteristics have become evident. The analyzed eight cities can be grouped into the following three:

♦ **Group I. Cities with high access to rails and subways.** Those cities in Group I represented the highest thee levels in offset indicator ranking. Three cities, namely Hong Kong, Tokyo, and Seoul, have the highest access to rails and subways – among the analyzed cities. And the transport and energy and environmental policy implementations are supported by relatively high governance. Despite these similarities, differences exist in terms of road indicator score. Particularly, Seoul and Tokyo has similar level of offset indicator respectively at 42.2, and 43.3, while Seoul's road indicator is higher at 28.3, compared with that of Tokyo at 21.4. The difference results from travel distance of each city, along with the difference in passenger vehicle stocks – relative to the size of income. In Seoul, those passenger vehicle users tend to drive longer distance than that of Tokyo.

♦ **Group II. Cities in transition toward improved access to rails and subways.** The cit-

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[1] In order to account for the differences in economic development of analyzed cities, two variables (passenger vehicle stocks per 1,000 population and road length) were normalized by each city's per capita GRP.

[2] Within a small urban land area at 335, Hong Kong has 105 MRT stations and 68 light rail stations. Within 621.5 km^2 of urban land area, Tokyo has 285 subway stations (the number of private ex-urban stations is excluded). And Seoul has 266 subway stations within 606 km^2 of urban land area.

ies in Group II – Shanghai and Singapore – are in transition toward improving access to rails and subways. Both cities have been making steady progress to offer alternative transport to passenger vehicles through developing subway systems. Meanwhile, both cities still have rooms to add more rail/subway lines, and further reduce passenger vehicle dependence. Shanghai, which has made a great stride in adding new subway lines in recent years – plan for doubling the lines to reach 22 by 2020 from current 11 lines to extend

the rails' coverage into the suburban areas as well. Singapore, which has 106 stations in 699.4 km^2 of urban land area, plans to double the MRT system by 2020 (Christopher Tan, 2008).

♦ **Group III. Cities with high dependence on passenger vehicles.** Three cities in Group III, namely Jakarta, Bangkok, and Beijing, represent high scores from the road indicator analysis. The three cities are characterized as relatively high dependence on passenger vehicles for mobility needs – relative to the income levels.
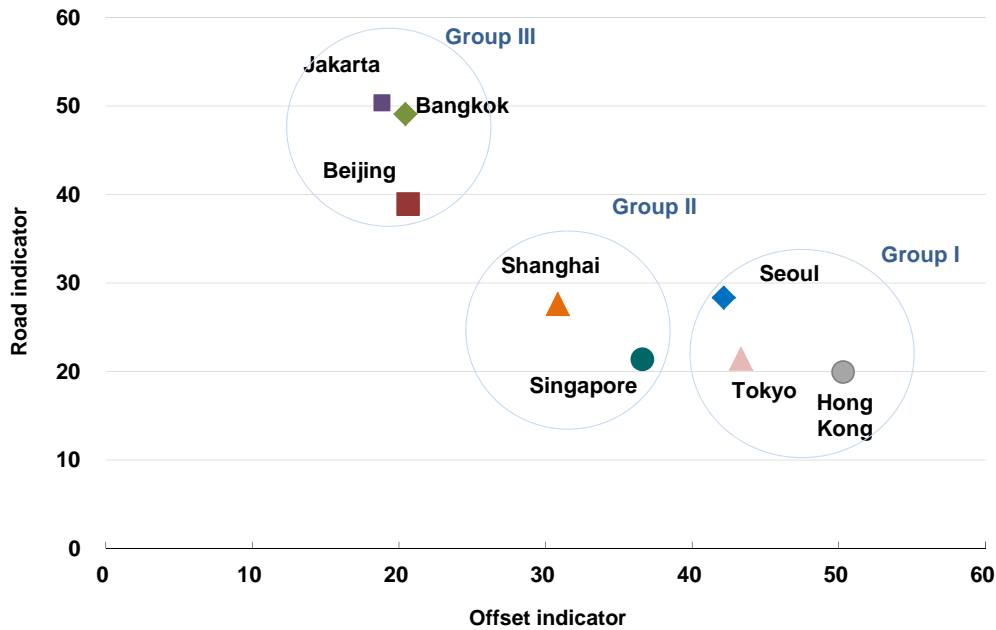

Fig. 5. Urban transport indicators (2009)

3.4. Evolutions of urban transport in Asia from 1995 to 2009. Development of transport infrastructure for road, rail and subway takes time-consuming process, including the time required to plan, design, coordinate and implement. For the purpose of drawing lessons from the transitions made by the eight analyzed cities, this section presents the urban transport indicator results for 1995 and 2009.

Figure 6 presents the summary of indicators' analysis between 1995 and 2009 for the 8 cities in Asia. The directions of the arrows in the figure correspond to the evolution of results from the urban transport indicators analysis between the two time periods. As the figure offers, the evolution of indicators' results from 1995 to 2009 is substantially different by city both in terms of direction and magnitude.

The cities such as **Jakarta** and **Bangkok** moved upward, indicating the increased dependence on passenger vehicles, and the relatively small shift toward the right-hand side of the figure results from slow progresses in developing mass transit infrastructure of rails and subways.

By contrast, Beijing's case shows a downward move from 1995 to 2009, corresponding to the reduced road indicator score from 62.7 to 38.9. High road indicator score in the 1995 analysis mainly resulted from the well-developed road infrastructure – relative to the level of economic development. In 1995, Beijing's road length per 1,000 population already reached 0.94 km, compared with 1.18 km in 2009. Meanwhile, during the same time period, per capita GRP of Beijing nearly quadrupled from $4,416 to $16,738.
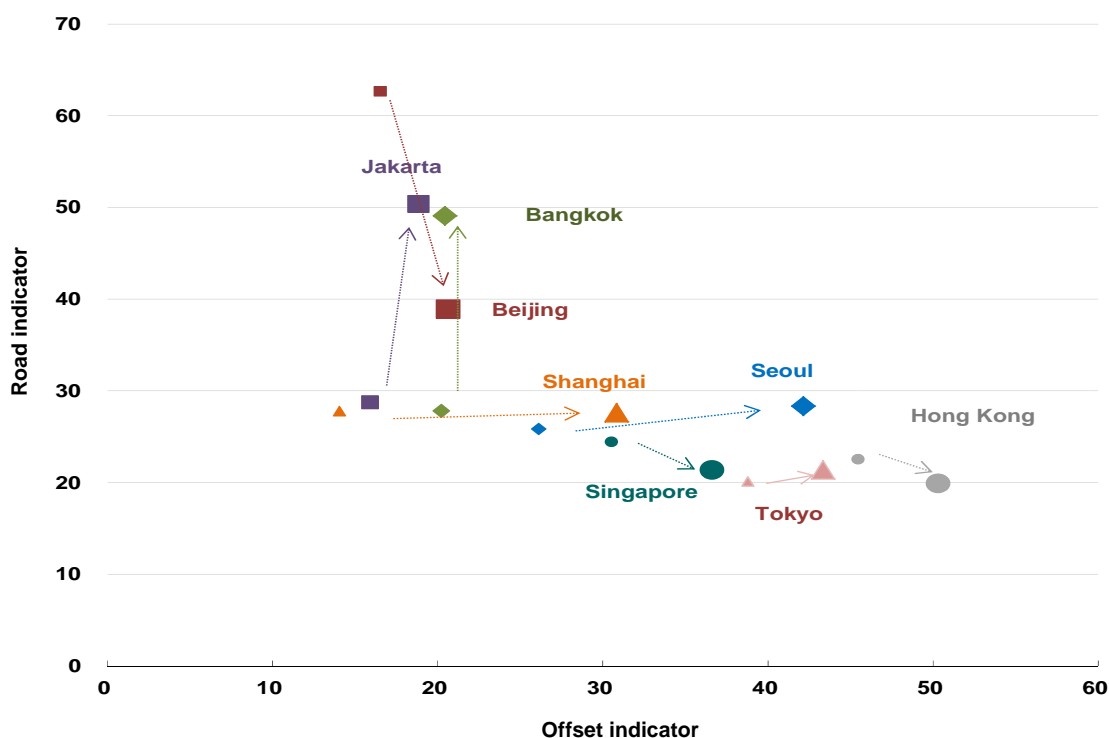
Fig. 6. Urban transport indicators (1995-2009)

Shanghai and **Seoul** moved right-ward along with the increased respective offset indicator score. This resulted from the improved access to rails/subways that took place between 1995 and 2009. In the case of Shanghai, the number of subway stations expanded from zero in 1995 to 273 in 2009, and the number of subway stations in Seoul expanded from 66 in 1995 to 266 in 2009[1]. This expanding accessibility to subways ensures passengers shift from heavy passenger vehicle dependence for the two cities.

Singapore made a progress in adding rail/subway infrastructure during the analyzed period, increasing from 47 in 1995 to 106 in 2009, while the magnitude of additions are relatively moderate compared with Shanghai and Seoul which size of urban land areas account for similar levels to Singapore. Meanwhile, Singapore's road indicator declined slightly from 24.4 in 1995 to 21.4 in 2009, resulting mainly from declining Singapore's passenger vehicle ownership per 1,000 population – relative to the size of income level[2].

The cases of **Tokyo** and **Hong Kong** show relatively small changes over the time period between 1995 and 2009. This is because those cities have already established well-developed access to rails and subways in 1995, and travel behavior of those cities did not change substantially over the analyzed period. According to the latest person-trip survey, only 11% of total population in Tokyo (urban area) relied upon passenger vehicles for meeting mobility needs (in 2008), while that of Hong Kong was about 10% in 2005.

3.5. Different pathways for 1995, 2005 and 2009. To investigate more in detail about the pathways of urban transport systems in Asia, the results from the indicators analysis for the three time periods (1995, 2005 and 2009) are summarized in the Figure 7. The cases of Tokyo and Hong Kong are excluded from this figure in order to capture the cities with more dynamic changes. Direction of arrows show the changing direction of urban transport indicators results for each analyzed time periods. By plotting the urban transport indicators' results for the three time periods, it has become more evident to understand the different pace of changes in the transport systems among the 6 cities.

Jakarta ranked number one in the 2009 road indicator, however compared with the 2005 level it has made improvements to reduce road dependence level – relative to its income, which is caused by lower length of road relative to income level. And the access to railways improved with increased number of rail stations from 27 in 2005 to 76 in 2009.

Bangkok's sharp increase in road dependence took place between 1995 and 2005 as the figure shows, and there was not major change in urban transport performance between 2005 and 2009. Besides, 2009 governance indicator result was lower at 57.5 in 2009, compared with that of 62 in 2005 and this led to lower offset indicator score in 2009.

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[1] Higher governance indicator of Seoul results in higher offset indicator of Seoul. In 2009, the governance indicator of Seoul was 80.4, compared with that of Shanghai at 49.9.
[2] In fact, passenger vehicle stocks per 1,000 population increased slightly from 99 in 1009 to 116 in 2009 – 17% increase. Meanwhile the city's per capita GRP increased by 40% during the same time period, surpassing the growth trends of passenger vehicle stocks per 1,000 population.
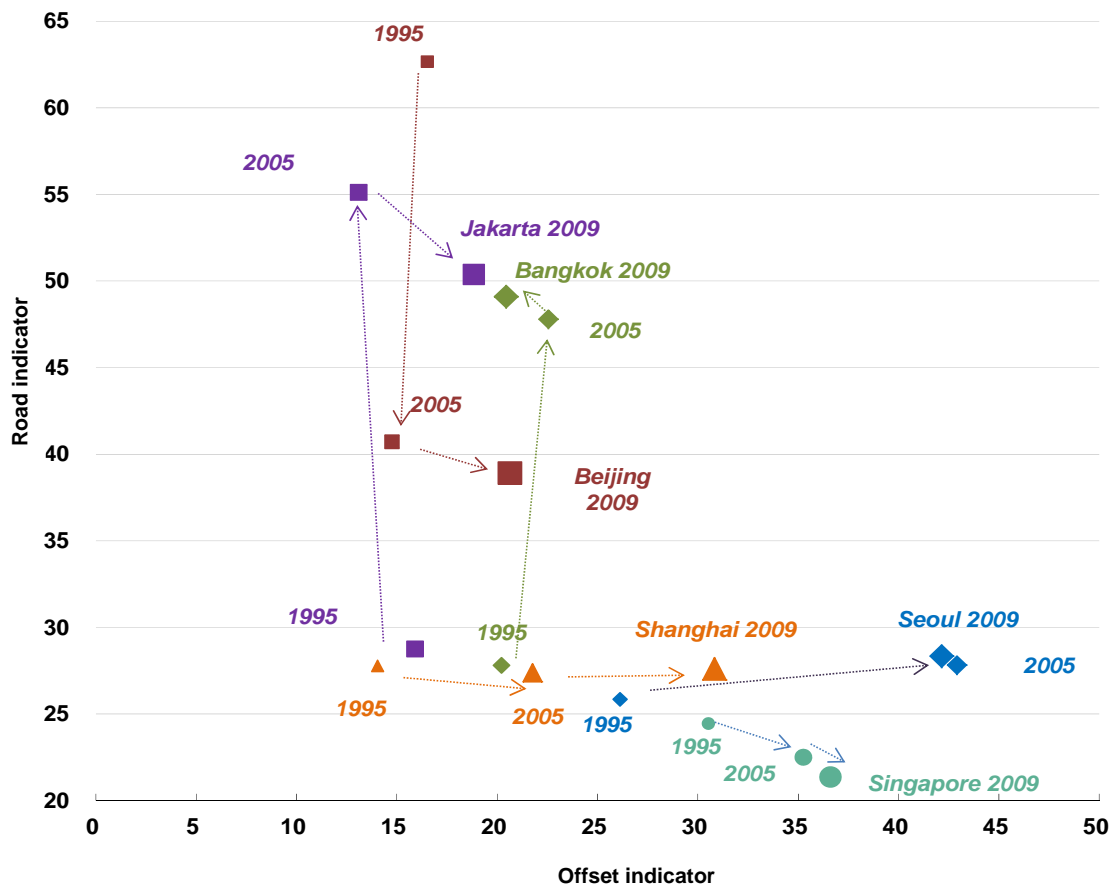
Fig. 7. Urban transport indicators (1995, 2005 and 2009)

Beijing's case show that the city's road dependence – relative to income level – became lowered from 1995 to 2005, while the changes in road indicator results from 2005 to 2009 remained relatively small compared with the previous time period. Also, it is important to note that great improvement in offset indicator took place from 2005 to 2009 as a result of opening of subway systems, of which station numbers more than doubled from 70 in 2005 to 145 in 2009 within 12,187 km^2 of urban land area.

From 1995 to 2009, both **Shanghai** and **Seoul** made a great progress in adding subway infrastructure to improve passengers' accessibility. And the efforts contributed to slow growth in road dependence of two cities. Meanwhile, the speed of improvement in subway accessibility offers difference in two cities. Seoul expanded subway system from 1995 to 2005, with increasing number of station from 66 to 263, which contributed to the substantial improvement in offset indicator (26.1 in 1995). And in 2009, the offset indicator score did stay at a similar level (42.2) compared with that of 2005 (42.9), with only additional 3 stations opened from 2005. Shanghai's offset indicator improved from 14.1 in 1995, 21.8 in 2005, and 30.8 in 2009, with expanding number of subway stations from zero in 1995, 95 in 2005, and 273 in 2009.

Singapore made gradual progress in improving the offset indicator, and lowering road indicator over the three time periods. The city has implemented the policy to control the passenger vehicle ownership through the purchase of the certificate of entitlement starting from 1990, and this contributed to relatively low road indicator even in 1995, and gradual improvements for the entire time periods. In terms of improved offset indicator, gradual progress has been made to add subway stations in Singapore, increasing from 47 in 1995, 96 in 2005, and 106 in 2009, and the high level of governance at 95-98 has been maintained during this time period.

Conclusions

Gasoline consumption from passenger vehicles in the urban areas result from a complex interaction of various factors, depending on urban form, vehicle ownership cost, availability of alternative transport mode. The results from the urban transport indicators analysis can assist us to identify the major factors affecting gasoline consumption. This in turn translates into the understanding over the factors affecting CO_2 emissions growth from passenger vehicles in urban areas. The analysis results can also offer good lessons for the cities in Asia of which income levels are growing rapidly, and transport demand is growing rapidly too.

As the cases of Bangkok, Beijing, Jakarta offered, rapid increases in income level have driven the growth in road dependence for passenger mobility purpose, and this leads to gasoline consumption as well as CO_2 emissions growth. Although these three cities are developing mass transit systems as the alternative to passenger vehicles, the coverage is either concentrated on the urban core area (Bangkok), or not yet sufficiently developed – relative to the size of urban land area – to allow easy access of dwellers (Beijing, and Jakarta), therefore, dependence on road transport represent high levels, compared with the other cities.

By contrast, cities such as Hong Kong, Seoul, Shanghai, Singapore, and Tokyo successfully developed the rails and subways infrastructure as the alternative to passenger vehicles, and this has led to slowing the growth in road dependence amid the steady growth in income levels. The important factor that has facilitated people's shift away from the vehicle dependence in these cities – is to ensure good access to subway and rail infrastructure – sufficient to cover the entire urban land area. Aside from the infrastructure development, holistic approach is taken within these cities to develop and implement policies related to regulate vehicle usage through vehicle registration, parking regulation, and fuel prices taxes.

Development of rail and subway infrastructure requires arduous process for designing, planning, and coordinating the issues among various agencies. Despite this, the cases of Shanghai and Seoul demonstrated that a major expansion of the infrastructure can be made within five to ten years, and the speed of growth in road dependence can be maintained at certain reasonable levels to each city. This can provide an important implication for those cities at the early stage of economic development, for the need to plan for mass transit systems, and consider requirements for developing city-specific energy, environment and transport policies.

Acknowledgement

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