Urban Transportation Characteristics and Urban Mass Transit Introduction in the Cities of Developing Countries

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Abstract: JICA has been conducting urban transportation master plan studies in more than 50 cities in developing countries, which established comprehensive traffic database including person trip, traffic volume, and users' stated preference. This paper analyzes the relationship between urban socio-economic indicators and traffic patterns particularly in the cities of developing countries and identifies their urban transportation characteristics based on the above traffic database. Special attention is paid on the "two-wheeler cities" in Asia which have different trend from global tendencies. The criteria to introduce urban mass transit system are also identified in conjunction with level of socio-economic development of cities.

Keywords: Urban Density, Socio-economic Development Phase, Car Ownership, Modal Share, Urban Mass Transit, Developing Countries

1. INTRODUCTION

Rapid urbanization have posed several problems on developing countries, especially in the transportation sector, which include traffic congestion, inconvenient mobility, deteriorated traffic safety, serious air pollution and social injustice/inequity.

In order to tackle such problems, a comprehensive urban transport strategy is essential, which comprises a set of long-term policy objectives and policy measures in both physical infrastructure and institutional improvement. The strategy should also include a description of how to implement and manage the proposals, based on which necessary actions should be taken on a timely basis.

There are two important factors to formulate an urban transport strategy. Socio-economic development phase of the target city is one of the key factors to be considered since introducing mass transit system especially MRT (Mass Rapid Transit) takes huge cost and long period from planning to inauguration. Traffic pattern of a city such as car ownership and modal share should also be well analyzed and reflected to the strategy.

There were some previous studies such as Newman *et al.* (1999), Suzuki *et al*. (2007), etc discussing relationships among socio-economic indicators, car ownership and traffic patterns. However, there are few studies that focus on the cities of the worldwide developing countries due mainly to the limit of data collection.

Japan International Cooperation Agency (JICA) conducted a research study, the Research on Practical Approach for Urban Transport Planning (JICA, 2011). It undertakes (i) the collection and typological analysis of basic data on current urban situations and traffic patterns of urban agglomerations or cities in the world and (ii) the examination of the development needs in urban transport infrastructure and the related institutional capacity building vis-à-vis phases of socio-economic development and proposals on urban transport strategy formulation.

This paper (hereinafter called "the Study") introduces two practical implications extracted from JICA (2011) for an urban transport strategy formulation in the cities of developing countries. Firstly the Study analyzes the relationships between the urban socio-economic indicators and urban traffic patterns. These indicators are urban density, GDP (gross domestic product) per capita, the modal share of public transport, and the passenger car ownership based on the comprehensive traffic database in more than 50 cities of the worldwide developing countries. Secondly the Study quantitatively examines the criteria to introduce urban mass transit system in conjunction with level of socio-economic development of cities, based on which an appropriate timing for introducing of urban mass transit is identified.

Following the research framework in Chapter 2, Chapter 3 describes the relationships between the urban socio-economic indicators and the urban traffic patterns, where two wheeler cities are analyzed separately. Timing of introduction of mass transit system in association with phases of socio-economic development is provided in Chapter 4. Finally Chapter 5 describes conclusion and issues for future considerations.

2. RESEARCH FRAMEWORK

2.1 Research Method

In Chapter 3, two steps are taken to find correlative relationships among the four indicators in the cities of worldwide developing countries: namely urban density, GDP per capita, passenger car ownership, and modal share of public transport. First, target cities are grouped in terms of population size, GDP per capita, or regional distribution and plotted by above four indicators. Then the relationships are examined in order to identify their urban transportation characteristics. Either linear or non-linear regression analysis, whichever has higher coefficient of determination (R^2), is applied on all of the plotted data. The same regression analysis is applied on the each grouped data in order to compare the strength of the association among the groups.

In Chapter 4, the development phases of the cities are graphically illustrated with longitudinal data of urban population and GDP per capita. The timing to start operating urban mass transit system in each city is plotted on the above development curve in order to analyze an appropriate timing to introduce urban mass transit system in association with the development phases of the cities.

2.2 Data Source

The Study utilizes the existing available database to prepare basic urban profiles including urban population, urban density, and GDP per capita. It includes Demographia (Wendell Cox, 2010), World Urbanization Prospect of United Nations (UN, 2010), and World Development Indicators of World Bank (WB, 2008). Detailed information on urban transport such as car ownership and modal share are extracted from the Millennium Cities Database for Sustainable Transport of UITP (UITP, 2000) and the final reports of the JICA urban transport master plan studies (JICA MP), which cover 53 cities listed in the Table 1. In principle car ownership is the number of passenger cars per thousand people, while that of some cities may include different kinds of vehicles, such as trucks, due to the data availability. Modal share of public transport is the percentage share of total person trips (excluding walking trips) that use public transport mode, which include bus, BRT, tram, metro, suburban and rail. Semi-public transport such as taxi and para-transit are also included in the public transport, if it is segregated. Website information is referred to particularly for the history of mass transit system in each city.

2.3 Selection of the Cities for the Study

The Study adopts a step-wise approach to the selection of cities. First step analysis is done for UITP-100-cities. It include 15 cities in East/Southeast Asia, 3 in South Asia, 10 in Latin America, 6 in Middle East, 20 in North America and Oceania, 5 in Africa and 41 in Europe, of which year is 1995. All data required for the first step analysis are extracted from the UITP database.

Since the UITP 100 cities cover fewer cities in developing countries, the second step analysis is focused on the cities in developing countries. 53 cities are selected from cities which were studied by JICA for urban transport master plan formulation in the past. Other 12 cities are added to the selection as follows. Countries such as Singapore and Korea are no longer developing countries, but the two cities of Singapore and Seoul are included in the selection because their presence is informative of the relationship between the takeoff process and urban transportation. Kolkata is the only JICA-studied city in India, but four more cities (Delhi, Mumbai, Hyderabad and Pune) are added to the selection. In all, 65 cities (hereinafter called JICA-studied Cities) are selected as listed in Table 1, of which 25 cities are overlapped with the UITP-cities.

As for 53 cities with JICA MP, required data are basically extracted from the JICA reports. In case the data is not available in the report, the available database is utilized. Population, urban density, and traffic-related indicators are extracted from UN (2010), Demographia (Wendell Cox, 2010), and UITP (2000), which are also applied for additional 12 cities without JICA MP. GDP per capita is taken from World Development Indicators (WB, 2008) for all 65 cities, since GDP per capita on individual cities are not available or not suitable for comparative analysis.

There are two notes to be cared. First one is definition of a city. In the Study, cities are analyzed not as administrative units but as urban agglomerations, which are spatially continuously built up land mass of urban development above a certain level of urban density as defined in the UN (2010) and Demographia (Wendell Cox, 2010).

The second one is disparity of current situations from the available compiled database. The Study deals with city-level statistics and transport indices of developing countries. Since it is hardly possible to use the same database uniformly for the entire selected cities, the Study uses nationally aggregated statistics or estimates the necessary data from the available growth rate. There are cases that the obtained data, particularly for UITP (2000) for the year of 1995 is outdated. For instance, in China, car ownership in the cities have rapidly increased in the past decade. In Jakarta, household motorcycle ownership has increased significantly, from 34% in 2002 to 72% in 2010 and modal share of commuting trips of passenger car and motorcycle have increased accordingly. However, this research intends to identify the general relationship between urban socio-economic indicators and traffic patterns and not to examine the historical change or the latest transport situations of the specific cities. Therefore the present trend of some cities does not reflect our findings.

Table 1. Cities Selected for In-depth Analysis (1/2)

	City	Country	Population(000), 2010*	JICA M/P year
	Asia			
1	Hangzhou	China	5,305	1994
2	Chongqing	China	5,460	1994
3	Dalian	China	3,255	1996
4	Chengdu	China	4,785	2001
5	Ulaanbaatar	Mongolia	885	2009
6	Jakarta	Indonesia	22,000	1987, 1990, 2004
7	Surabaya	Indonesia	2,885	1983, 1997
8	Medan	Indonesia	2,340	1980
9	Makassar (Ujung Pandang)	Indonesia	1,405	1989
10	Bangkok	Thailand	8,250	1979, 1988, 1990
11	Manila	Philippines	20,795	1973, 1985, 1999
12	Davao	Philippines	1,335	1981
13	Ha Noi	Vietnam	2,355	1997, 2007
14	Ho Chi Minh City	Vietnam	7,785	2004
15	Kuala Lumpur	Malaysia	5,835	1999
16	Johore Bharu	Malaysia	860	1984
17	Vientiane	Laos	575	2008
18	Phnom Penh	Cambodia	1,560	2001
19	Kolkata (Calcutta)	India	15,535	1992
20	Dhaka	Bangladesh	10,135	2010
21	Seoul	Korea	19,910	1970
22	Singapore	Singapore	4,635	1988
23	Colombo	Sri Lanka	2,080	1984, 2006
24	Kathmandu	Nepal	1,280	1993
25	Lahore	Pakistan	7,110	1991, drawing up
26	Karachi	Pakistan	13,085	drawing up
27	Baku	Azerbaijan	1,650	2002
28	Kabul	Afghanistan	3,370	2009
	Middle East			
29	Cairo	Egypt	17,290	1966,2002、2008
30	Baghdad	Iraq	5,850	1988
31	Tehran	Iran	8,170	1977
32	Damascus	Syria	2,370	1999, 2008
	Latin America			
33	Caracas	Venezuela	2,675	1965
34	Guayaquil	Ecuador	2,690	1983
35	Guatemala City	Guatemala	1,810	1992
36	Barranquilla	Colombia	1,795	1985
37	Cartagena	Colombia	935	1992
38	Bogotá	Colombia	7,845	1996
39	Santiago	Chile	5,805	1967
40	Managua	Nicaragua	895	1999
41	Panama City	Panama	945	1982
42	Asunción	Paraguay	2,605	1986, 1992
43	Belém	Brazil	1,610	1991, 2002
44	Lima	Peru	7,995	2005
45	Guadalajara	Mexico	4,210	1969
	Africa			
46	Kampala	Uganda	1,625	2010
47	Nairobi	Kenya	3,365	2006
48	Lusaka	Zambia	1,395	2009
49	Dar es Salaam	Tanzania	2,905	1995, 2008

Table 1. Cities Selected for In-depth Analysis (2/2)

	City	Country	Population(000), 2010*	JICA M/P year
50	Lilongwe	Malawi	575	2008
51	Monrovia	Liberia	500	2009
	Europe			
52	Istanbul	Turkey	13,135	2009
53	Bucharest	Romania	1,995	2000
	Cities which don't have JICA master plans			
54	Beijing	China	13,955	None
55	Shanghai	China	18,400	None
56	Guangzhou,	China	13,245	None
57	Mumbai (Bombay)	India	21,255	None
58	Delhi	India	20,995	None
59	Hyderabad	India	6,720	None
60	Pune	India	4,935	None
61	São Paulo	Brazil	20,180	None
62	Curitiba	Brazil	3,030	None
63	Rio de Janeiro	Brazil	11,670	None
64	Buenos Aires	Argentina	12,975	None
65	Mexico City	Mexico	18,690	None

* Demographia (Wendell Cox,2010) and refer to UN (2010) for cities not included in the Demographia

3. URBAN TRANSPORTATION AND CITY TYPES

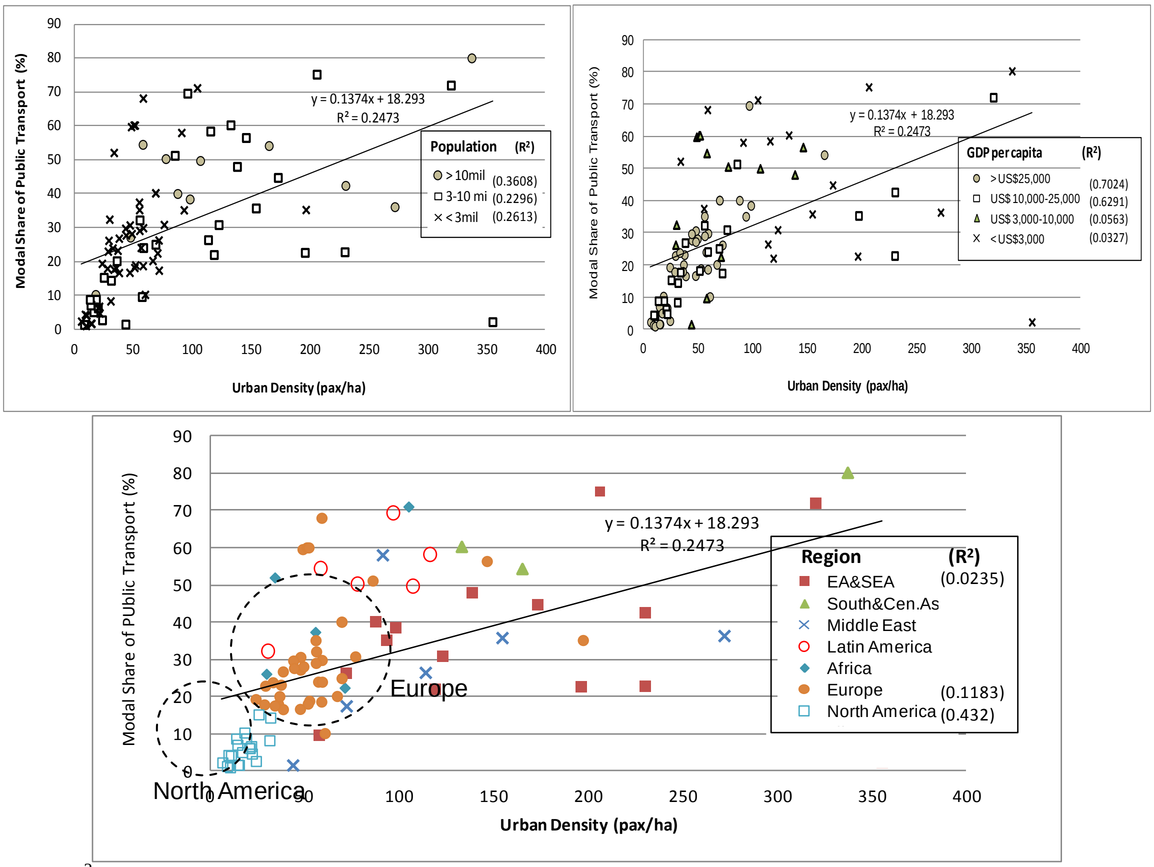
3.1 Urban Density and Modal Share

The relationships between the urban density and the modal share of public transport are plotted in Figure 1. The figure depicts the relationship showing the terms of population size, GDP per capita and region. An appreciable tendency of correlation can be found between the higher urban density and the larger share of public transport, but the correlation coefficient itself (R^2 =0.2473) of the UITP 100 cities is not sufficiently strong. The similar situation is indicated to three different classes of population size.

In terms of GDP per capita, there is a strong correlation in high-income countries between the higher urban density and the larger share of public transport. The correlation diminishes progressively from high-income countries to medium-income countries and then to low-income countries. The correlation by region is generally weak, except that the cities in Europe and North America are found concentrated in a certain range of urban density and modal share. There is no distinct correlation in Southeast Asia, Middle East and Latin America, suggesting the diversity of cities in these regions.

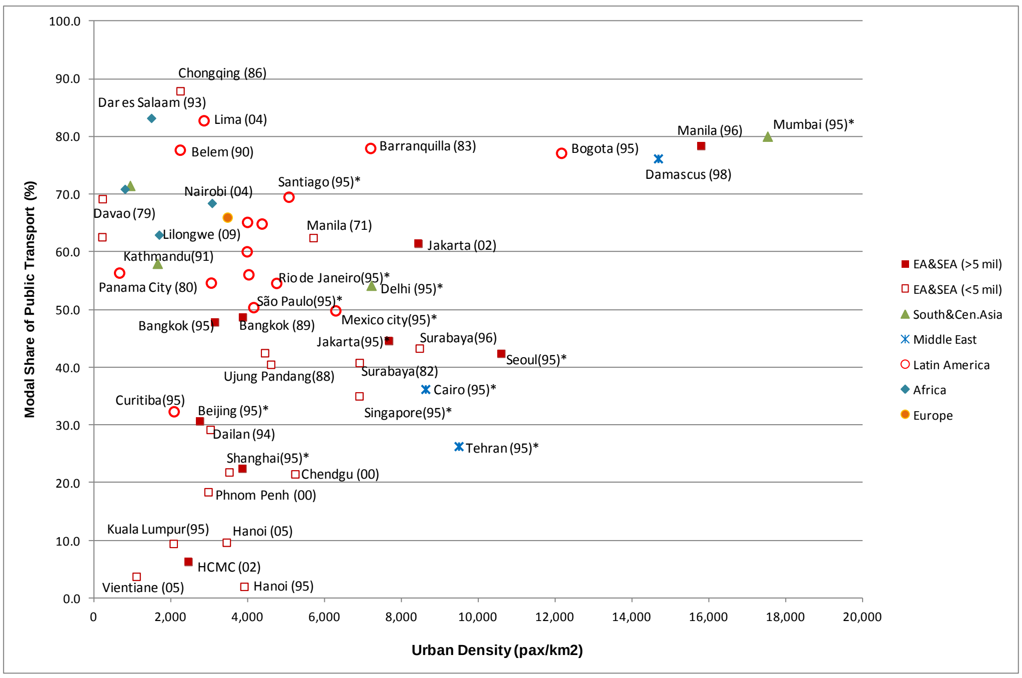
Figure 2 shows urban density and the modal share of public transport in the JICA-studied cities. There is no apparent indication of the correlation in the plotting. The JICA-studied cities are composed of mainly those of developing countries with no reflection of the correlation found in developed countries.

There is a comparatively significant regional difference. The cities of Africa in the early phase of development are plotted in the area of low density and high public transport share in the chart. On the other hand, the cities in Latin America show a relatively high share of public transport regardless of the level of urban density. The cities in Asia show an appreciable tendency of correlation. The population size varies a great deal, but in the cities of over 5 million population, the higher urban density is correlated with the higher share of public transport in the similar manner found among 100 global cities.



Note: R^2 is shown only on the groups of 10 or more samples. Regression line is shown on the all plotted data.
Source: UITP (2000)

Figure 1. Urban Density and Modal Share of Public Transport (100 Cities in 1995)

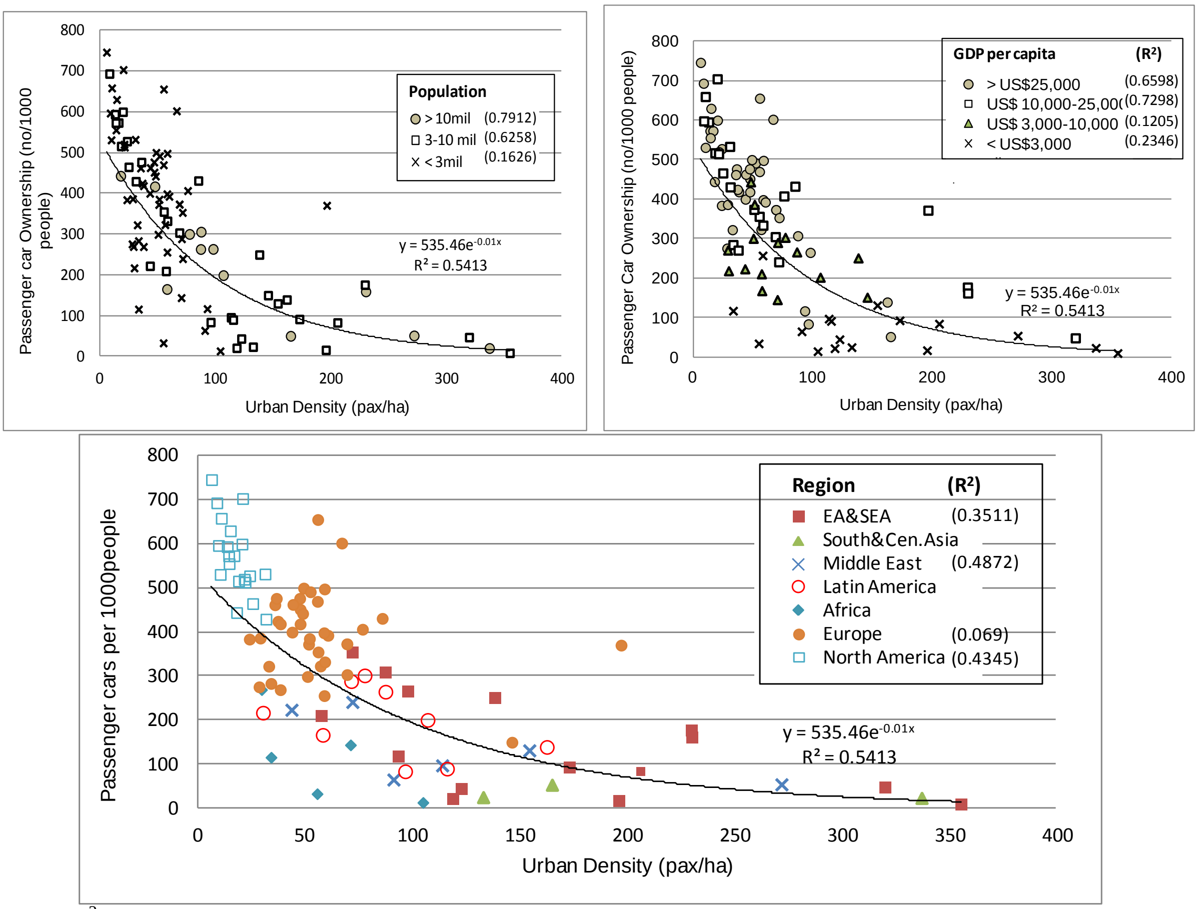


Note: The number in parentheses after each city name indicates the year of the JICA master plan study. Urban density and the modal share of public transport pertain to the year when each JICA study was conducted.
Sources: Various JICA Study Reports and UITP (2000) for cities marked with *

Figure 2. Urban Density and Modal Share of Public Transport (JICA-Studied Cities)

3.2 Urban Density and Passenger Car Ownerships

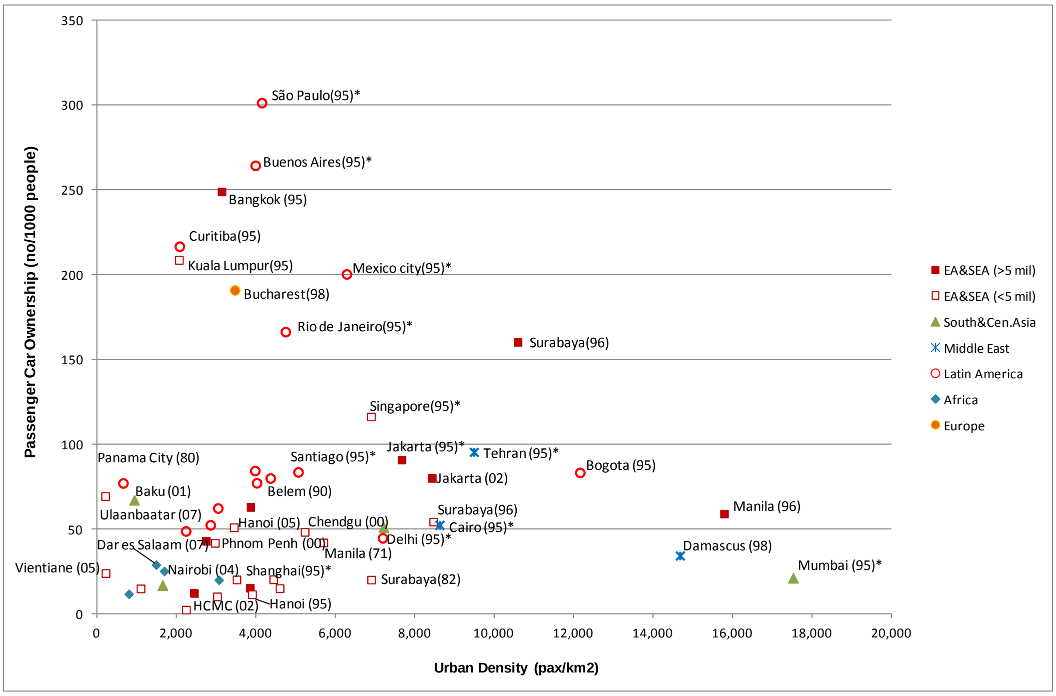
Figure 3 plots the relationships between urban density and passenger car ownership in terms of population size, per capita GDP and regional distribution. An appreciable correlation (R^2 =0.5413) exists between higher urban density and lower car ownership in relation to city population. The comparable results are shown in the past studies, such as inverse relationship between urban density and transport-originating energy consumption identified in Newman *et al.* (1999). The correlation is stronger in high-income countries but weaker in medium- to low-income countries. In terms of regional distribution, the cities of Europe and North America are found concentrated in a certain range of urban density and car ownership, although the correlation coefficient is not sufficiently high in these regions. There is no distinct correlation found in other regions.



Note: R^2 is shown only on the groups of 10 or more samples. Regression line is shown on the all plotted data.
Source: UITP (2000)

Figure 3. Urban Density and Passenger Car Ownership (100 Cities in 1995)

Among the JICA-studied cities, there is a correlation between lower density and higher car ownership as shown in Figure 4. However, many low-density cities in Africa and Latin America have a low ratio of private car ownership.



Note: The number in parentheses after each city name indicates the year of the JICA master plan study. Urban density and the passenger car ownership pertain to the year when each JICA study was conducted.

Sources: Various JICA Study Reports and UITP (2000) for cities marked with *

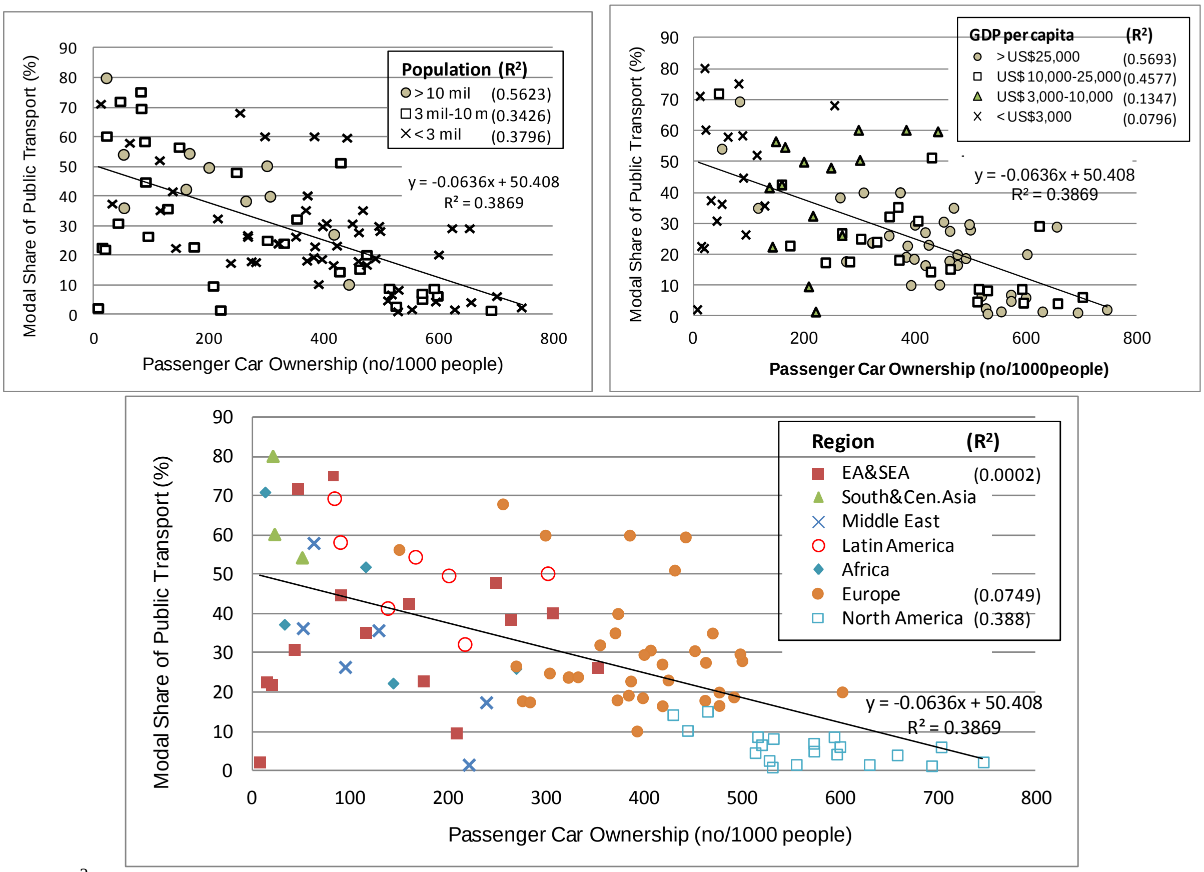
Figure 4. Urban Density and Passenger Car Ownership (JICA-studied Cities)

3.3 Passenger Car Ownerships and Modal Share of Public Transport

Figure 5 plots the relationships between passenger car ownership and the modal share of public transport in terms of population size, per capita GDP and regional distribution. A certain correlation can be read between higher car ownership and the lower share of public transport. The coefficient (R^2 =0.3869) among 100 global cities, however, is not strong enough. The correlation is strong in high-income countries but diverges from this tendency in medium- to low-income countries. As for region, the cities of Europe and North America are respectively found concentrated in a certain range of car ownership ratios and public transport shares, although the correlation coefficient is not high in these regions. There is no distinct correlation in Southeast Asia, Middle East and Latin America. This implies the diversity of cities in these regions.

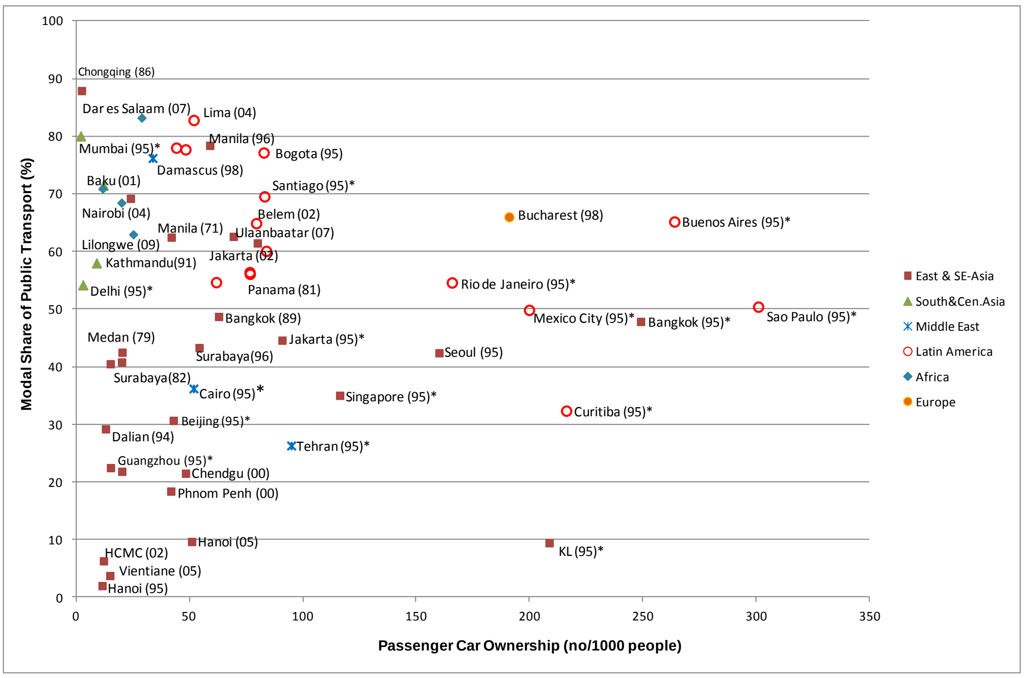
Among the JICA-studied cities in Figure 6, non-Asian cities indicate a general tendency of inverse correlation between car ownership and the share of public transport. Especially in Latin America, the cities of lower car ownership have a higher public transport share in all cases (Figure 6).

The cities in Asia show somewhat peculiar characteristics compared with those in other regions. Passenger car ownership is on the whole low in Asian cities. It is considered reflecting the low economic development level. There are cities with a high public transport share, whereas others, like Hanoi, Ho Chi Minh City, Phnom Penh and Vientiane, have a pronouncedly low share of public transport. Such a divergence from the general tendency of inverse correlation is mostly found in those cities dependent on two-wheelers.



Note: R^2 is shown only on the groups of 10 or more samples. Regression line is shown on the all plotted data.
Source: UITP (2000)

Figure 5. Passenger Car Ownership and Modal Share of Public Transport (100 Cities in 1995)



Note: The number in parentheses after each city name indicates the year of the JICA master plan study. The ratio of passenger car ownerships and the modal share of public transit pertain to the year when each JICA study was conducted.

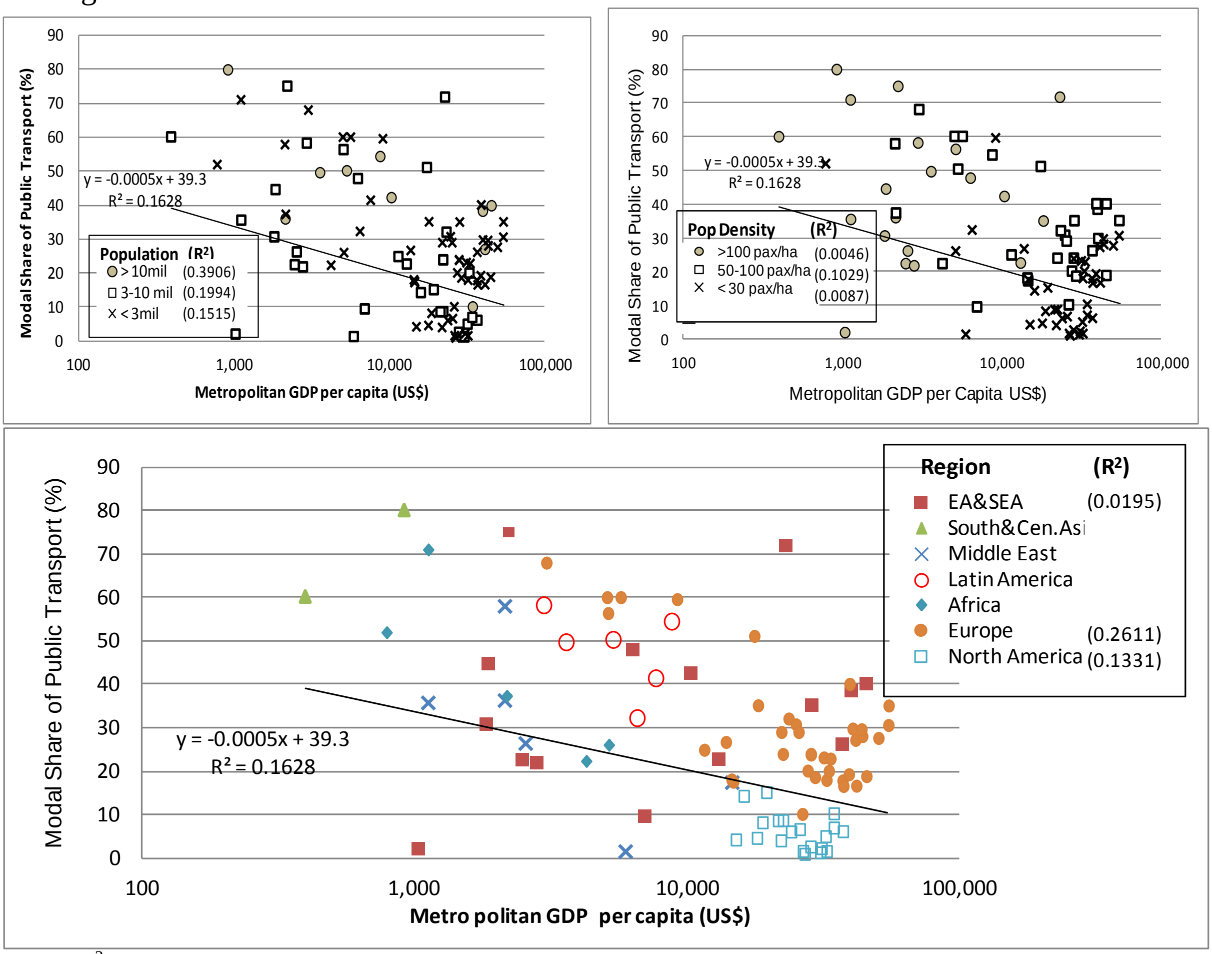
Sources: Various JICA Study Reports and UITP (2000) for cities marked with *

Figure 6. Passenger Car Ownership and Modal Share of Public Transport (JICA-Studied Cities)

3.4 Modal Share of Public Transport and Per Capita GDP

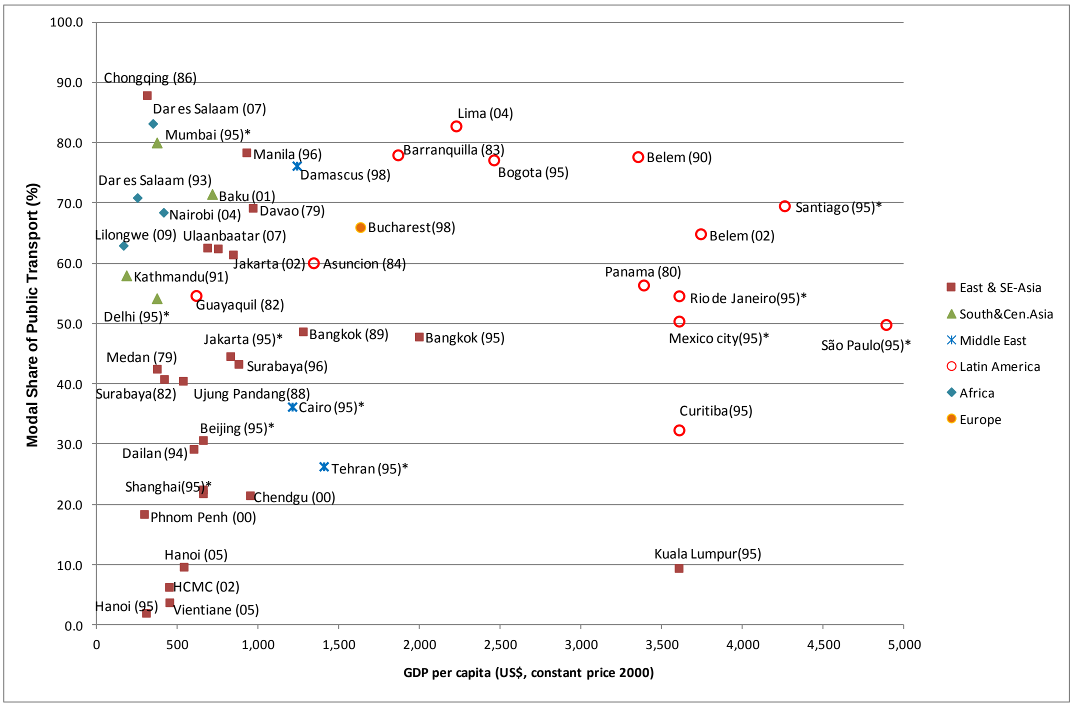
The relationship between the level of per capita GDP and the share of public transport is plotted in Figure 7 in terms of population size, urban density and regional distribution. The plotting shows a tendency of inverse correlation between the higher level of per capita income and the lower share of public transport. This general tendency is in agreement with the correlation between the higher economic level and the higher car ownership.

The analysis of the JICA-studied cities plotted in Figure 8 does not indicate a similar general tendency of inverse correlation between the higher per capita income and the lower share of public transport. The divergence is especially pronounced among the cities of East and Southeast Asia, many of which rely on two-wheelers for intra-city trips. There is no clear relationship between two indices in Latin American cities where the share of public transport ranges from 50 to 80%. Cities in South and Central Asia and Africa are very low in per capita GDP and accordingly low in passenger car ownership. Intra-city travels are done mostly on foot. If such trips on foot are excluded from the total traffic, the share of public transport rises to a high level.



Notes: R^2 is shown only on the groups of 10 or more samples. Regression line is shown on the all plotted data.
Source: UITP (2000)

Figure 7. GDP Per Capita and Modal Share of Public Transport (100 Cities in 1995)



Note: The number in parentheses after each city name indicates the year of the JICA master plan study. The ratio of passenger car ownerships and the modal share of public transit pertain to the year when each JICA study was conducted. Cities with GDP per capita more than US$ 8,000 are excluded.

Sources: Various JICA study reports and UITP (2000) for cities marked with *

Figure 8. Per Capita GDP and Modal Share of Public Transport (JICA-Studied Cities)

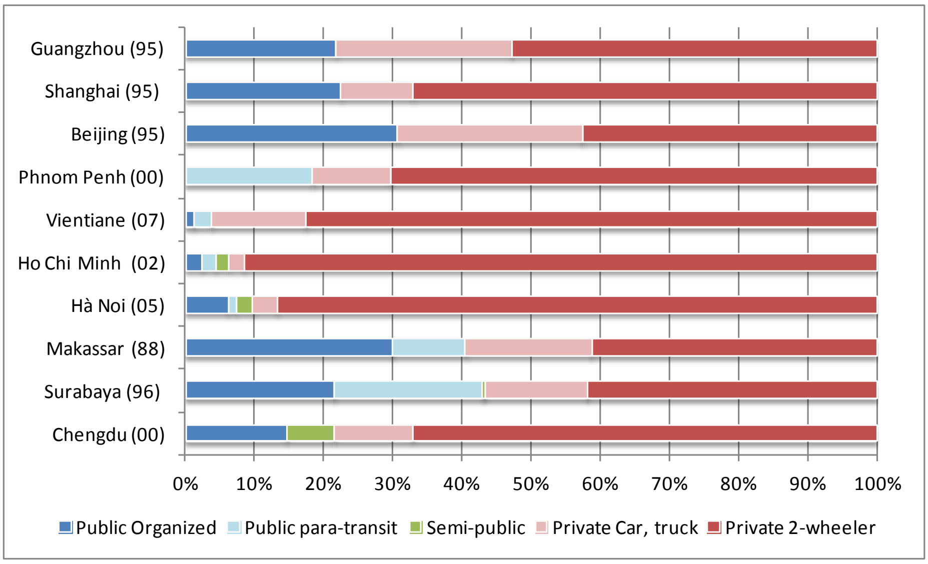
3.5 Patterns of Urban Two-wheeler Traffic

The foregoing analysis has cleared that the cities of developing countries heavily dependent on two-wheelers diverge distinctly from the general correlation found elsewhere. Separate analysis is necessary on such cities with a higher share of two-wheelers in urban traffic in terms of modal share, as shown in Figure 9.

Of the JICA-studied cities where information is available on two-wheeler traffic, the 10 cities fit the condition of having a high share of two-wheelers in urban traffic. The 10 cities are listed in Table 2 with their modal shares. It should be noted that three Chinese cities, Beijing, Shanghai and Guangzhou, are not applicable to two-wheeler cities at present because of the rapid motorization since 1995 that put them wide apart from the other 7 cities. These two-wheeler cities are all found in Asian countries in the early economic development phase.

Urban and transport indices of 10 Asian cities are examined in the comparative perspective with the findings about 100 global cities as shown in Figures 10 and 11. The different data definitions do not warrant straightforward comparison. For example, the urban density cited in the UITP-compiled database on 100 cities pertains to the central area of each city, whereas the equivalent figure available in JICA studies concerns the entire administrative area of a city.

Asian cities heavily reliant on two-wheelers distinctively diverges from the strong correlations found among 100 cities between urban density and passenger car ownership and between car ownership and the modal share of public transport.



Notes: Indicates the year when each JICA study was conducted. In Guangzhou, Shanghai and Beijing, bicycles are regarded as "mechanized non-motorized mode (NMT)" and classified as two-wheelers, and thus motorbikes are not classified as two-wheelers. The available data do not distinguish "public (para-transit)" and "semi-public" modes.

Sources: Various JICA study reports, the data on Guangzhou, Shanghai and Beijing taken from UITP (2000)

Figure 9. Modal Share in Ten Two-wheeler Cities

Table 2. Summary Profiles of Ten Two-wheeler Cities

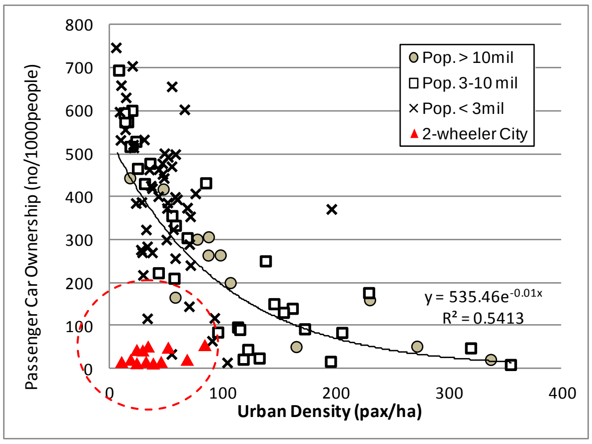
City	Year[1)]	Pop. (000)	Density (prs/km^2)[2)]	GDP Per Capita (US$)	Modal Share (%) [3)]		Car Ownership (vehicles/1000prs)
					Two-wheeler	Public Trans.	
Surabaya	1996	2,473	8,477	878	41.9	21.5	54.3
Makassar	1988	779	4,610	534	41.2	29.9	15.1
Hanoi	2005	3,183	3,456	539	86.7	6.2	51.0
Ho Chi Minh City	2002	5,285	2,461	448	91.5	2.5	12.1
Vientiane	2007	422	1,110	450	82.5	1.2	14.9
Phnom Penh	2000	1,152	2,980	293	70.2	0.0	41.8
Chengdu,	2000	3,068	5,240	949	67.1	14.7	48.3
Beijing	1995	8,164	2,457	658	42.6	30.7	42.9
Shanghai	1995	9,570	3,277	658	67.1	22.5	15.2
Guangzhou	1995	3,854	1,920	658	52.8	21.8	20.2

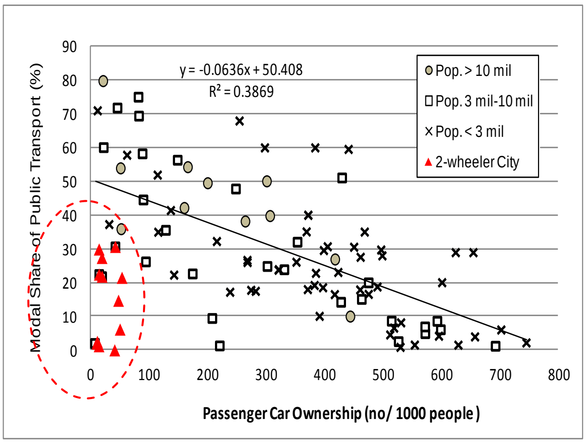
Notes: 1) Indicates the year when each JICA study was conducted

2) For Guangzhou, Shanghai and Beijing, the density is estimated on the basis of density figures in *Demographia 2010*, by using population estimates of *Demographia* and the UITP publication.

3) In Guangzhou, Shanghai and Beijing, bicycles are regarded as "mechanized non-motorized mode (NMT)" and classified as two-wheelers, and thus motorbikes are not classified as two-wheelers. The available data do not distinguish " public (para-transit) "and "semi-public" modes.

Sources: Various JICA study reports, data on Guangzhou, Shanghai and Beijing taken from UITP (2000), and per capita GDP from WB (2008)





Note: Regression line is shown on the all plotted data.
Sources: UITP (2000), various JICA Study Reports, and Wendell Cox (2010)

Figure 10. Urban Density and Passenger Car Ownership: Comparison between 100 Cities and Two-wheeler Cities

Figure 11. Passenger Car Ownership and Modal Share of Public Transport: Comparison between 100 Cities and Two-wheeler Cities

4. CONDITIONS FOR INTRODUCING URBAN MASS TRANSIT SYSTEM

It is now generally acknowledged regarding large cities in the world that it would be no longer possible to continue servicing the growing motorized traffic by constructing more and more roads. The most fundamental issue shared by global urban policymakers is how to facilitate a shift in transport demand from the private use of passenger cars to public transport means. The situation is the same in many large cities in the developing world.

Those cities, however, are poorly provided with public transport means against the increasing trend in private car ownership and use. The available public transport means would not be capable of absorbing the shift of passenger traffic. An urban transport strategy in such a context must deal with the issue of selecting the most suitable mode which will play the central role in public transport over the medium to long time span. The study clarifies the conditions for selecting the central public transport mode by examining the JICA-studied cities with regard to their different social and economic development phases, and their choices of urban mass transits.

4.1 Current Situations of Urban Mass Transit in Operation

The time of starting the operation of urban mass transit system including metro and BRT system is summarized in Table 3 based on the JICA-studied cities. In the Study, metro systems include subway, LRT and monorail systems. A metro system is defined as an urban electric passenger transport system with high capacity and high frequency of service, which is totally independent from other traffic, road or pedestrian. The terms heavy rail (mainly in North America) and heavy urban rail often have similar definitions. The term BRT is applied to a variety of public transport systems using buses to provide faster, more efficient service than conventional bus services. Often this is achieved by improving existing infrastructure, vehicles and scheduling. The goal of BRT systems is to achieve the service quality comparable to railway transits with low cost and the flexibility of bus transits.

Including those cities where a system is under construction, 11 cities chose the operation of a metro system only and 10 cities decided on a BRT system, while 17 cities chose both metro and BRT systems. Table 4 shows the shift direction between metro and BRT system.

Table 3.Time of Starting Operation of Metro and/or BRT Systems (1/2)

City		Time of Starting Operation	
City	Country	Metro System	BRT System
Asia			
Seoul	Korea	1974	2005
Hangzhou	China	-	2006
Chongqing	China	2005 (Monorail)	2008
Dalian	China	2003	2008
Chengdu	China	2010	-
Beijing	China	1969	2004
Shanghai	China	1995	-
Guangzhou	China	1997	2010
Ulaanbaatar	Mongolia	-	-
Manila	Philippines	1984 (LRT)	-
Davao	Philippines	-	-
Hanoi	Vietnam	Under construction	Under planning
Ho Chi Minh City	Vietnam	Under construction	-
Vientiane	Laos	-	-
Phnom Penh	Cambodia	-	-
Bangkok	Thailand	1999	2010
Kuala Lumpur	Malaysia	1996 (LRT)	-
Johore Bharu	Malaysia	-	-
Singapore	Singapore	1987	-
Jakarta	Indonesia	Under construction	2004
Surabaya	Indonesia	-	Under planning
Medan	Indonesia	-	Under planning
Makassar	Indonesia	-	-
Dhaka	Bangladesh	-	-
Kolkata (Calcutta)	India	1984	Under planning
Mumbai (Bombay)	India	Under construction	2008
Delhi	India	2002	2008
Hyderabad	India	Under planning	Under construction
Pune	India	Under construction	2008
Lahore	Pakistan	-	-
Karachi	Pakistan	-	-
Colombo	Sri Lanka	-	-
Kathmandu	Nepal	-	-
Kabul	Afghanistan	-	-
Baku	Azerbaijan	1967	-
Middle East			
Teheran	Iran	2000	2008
Baghdad	Iraq	-	-
Damascus	Syria	-	-
Cairo	Egypt	1987	2009
Latin America			
Guadalajara	Mexico	-	-
Mexico City	Mexico	1969	2005
Guatemala City	Guatemala	-	2007
Managua	Nicaragua	-	-
Panama City	Panama	-	-
Barranquilla	Colombia		2010
Cartagena	Colombia	-	Under construction
Bogota	Colombia	-	2000

Table 3. Time of Starting Operation of Metro and/or BRT Systems (2/2)

City		Time of Starting Operation	
City	Country	Metro System	BRT System
Caracas	Venezuela	1983	Under construction
Guayaquil	Ecuador	-	2006
Lima	Peru	2003	2010
Santiago	Chile	1975	2007
Belem	Brazil	-	-
Sao Paulo	Brazil	1974	2003
Rio de Janeiro	Brazil	1979	Under construction
Curitiba	Brazil	-	1972
Asuncion	Paraguay	-	-
Buenos Aires	Argentina	1923	-
Africa			
Kampala	Uganda	-	-
Nairobi	Kenya	-	-
Lusaka	Zambia	-	-
Dar es Salaam	Tanzania	-	-
Lilongwe	Malawi	-	-
Monrovia	Liberia	-	-
Europe			
Istanbul	Turkey	2000	2007
Bucharest	Romania	1979	-
For reference			
Tokyo	Japan	1927	-

Sources: Metro information from the Global List of Metro Systems, (home page of the Japan Association of Metro Companies), and BRT information from relevant sources.

Table 4. Operation or Development of Metro and BRT Systems

	Metro System Only	BRT System Only	Metro and BRT Systems	
			Order of Operation BRT➔Metro	Order of Operation Metro➔BRT
Asia	Chengdu (2010) Shanghai (1995) Manila (LRT) (1984) Ho Chi Minh City(UC) Kuala Lumpur (LRT) (1996) Singapore(1987) Baku (1967)	Hangzhou(2006)	Jakarta (2004➔UC) Mumbai (2008➔ UC) Hyderabad (UC➔ UP) Pune (2008➔UC)	Seoul (1974➔2005) Chongqing(monorail) (2005➔2008) Dalian (2003➔2008) Beijing (1969➔2004) Guangzhou (1997➔2010) Hanoi (metro UC and BRT UP) Bangkok (1999➔2010) Delhi (2002➔2008) Kolkata/Calcutta(1984➔UP）
Middle East	—	—	—	Tehran (2000➔2008) Cairo (1987➔2009)
Latin America	Buenos Aires (1913)	Guatemala City (2007) Barranquilla (2010) Cartagena (UC) Bogotá (2000) Guayaquil(2006) Curitiba (1972)	—	Mexico City (1969➔2005) Caracas(1983➔UC) Lima (2003➔2010) Santiago (1975➔2007) São Paulo (1974➔2003) Rio de Janeiro(1979➔UC）
Africa	—	—	—	—
Europe	Bucharest (1979)	—	—	Istanbul (2000➔2007)

Note: UC: Under Construction, UP: Under Planning

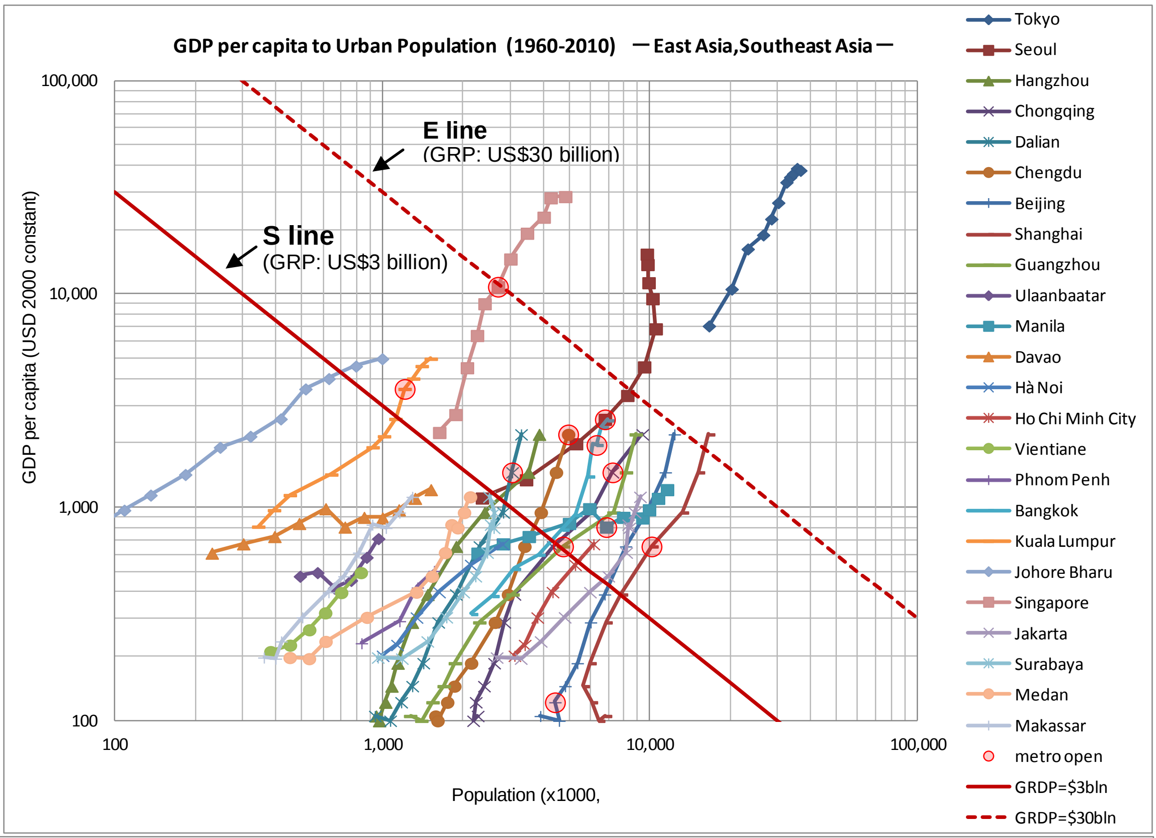
4.2 Development Phases and Timing to Start Operation of Metro Systems

Figure 12 has been prepared to show how the development phases of the cities are related to the timing to start operating their metro systems. The trends of urban population (UN, 2010) and GDP per capita (US$, constant 2000) of every 5 years during the period of 1960 -2010 (WB, 2008) are plotted in the figure. The time when each metro system was opened for operation is marked by a circle. Two parallel lines in red signify the same levels of GRDP (gross regional domestic product) among the cities. GRDP of a given city in this context is obtained as the product of the city's population and GDP per capita. The solid red line (the start line or S-line) means the GRDP level of US$3 billion, and the dotted line (the end line or E-line) shows the level of US$30 billion. The time to start the metro operation in the respective cities mostly falls between these two GRDP lines.

In East and Southeast Asia, Seoul and Singapore are plotted around the E-line. Chengdu, Bangkok and Chongqing are around the S-line, while Kuala Lumpur, Dalian, Shanghai and Manila are found between the two lines. The metro system in Beijing was officially opened in 1969, but the construction and operation as a mass transit system in the true sense of the word began in 2002. Thus, the city is almost on the E-line. Tokyo began the operation of its first metro system in 1927.

In South and Central Asia and Middle East, Teheran, Cairo and Delhi are found at midpoints between two GRDP lines, with Kolkata on the S-line. The metro system in Kolkata began its operation in 1984 over a distance of 28km and no extension has been made ever since. A plan of new extension is currently being prepared. The metro system in Delhi started operation in 2002, currently with 6 lines totaling 190km.

In Latin America, Buenos Aires was the first city to introduce its metro system in1913, and Mexico City, Rio de Janeiro, Sao Paulo and Lima are found around the E-line. Caracas and Santiago are found between two GRDP lines. In Africa, there is no city that operates a metro system. In Europe, Istanbul is near the E-line, whereas Bucharest is around the S-line, opening its metro system in 1979.



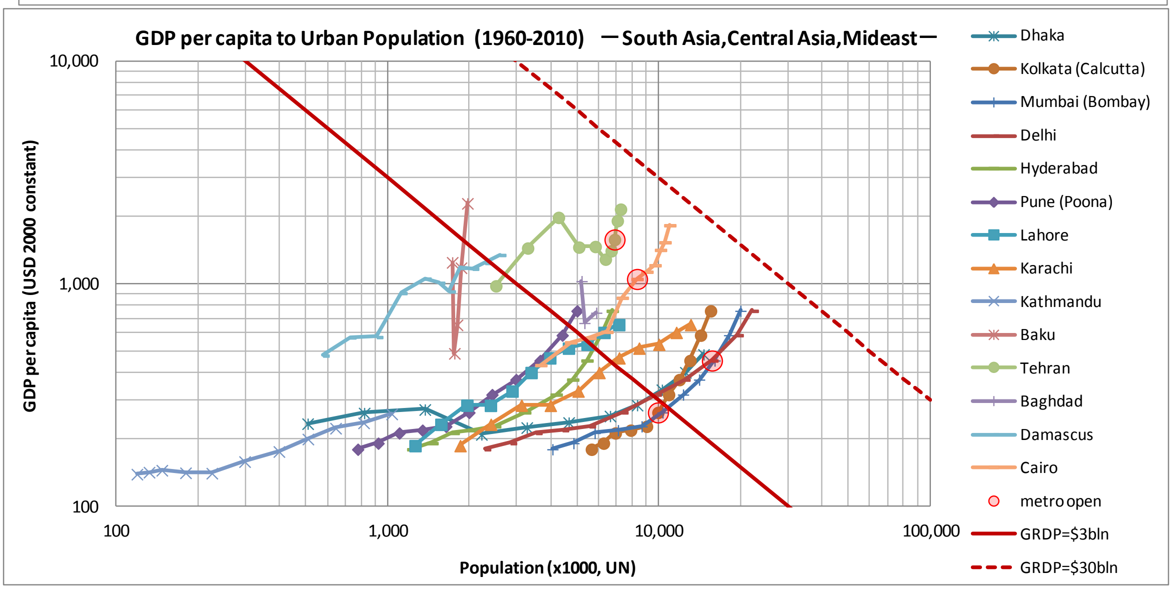
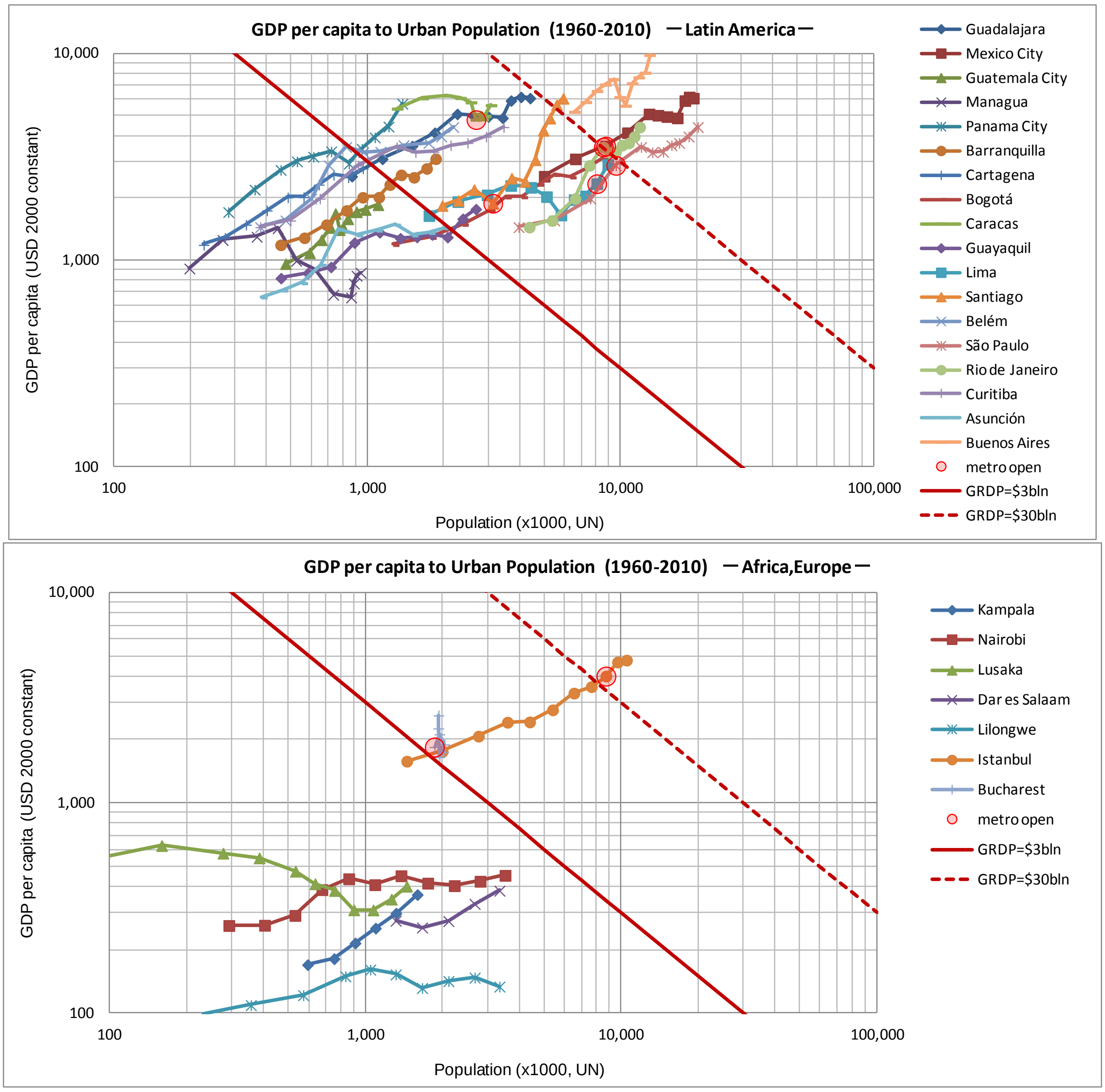


Figure 12. Metro Operation Relative to GDP per capita and Urban Population Size (1/2)



Note: The red solid line indicates the GRDP of US$3 billion and the red dotted line the GRDP of US$30 billion (constant 2000 US$). GRDP of each city is calculated by multiplying the city population by GDP per capita

Source: WB (2008), UN (2010), and Wendell Cox (2010)

Figure 12. Metro Operation Relative to GDP per capita and Urban Population Size (2/2)

5. CONCLUSION

Analysis of relationship between urban socio-economic indicators and traffic pattern shows that cities of developing countries have a different trend from global tendencies, which are identified from the UITP database. Among Asian cities, the concept of two wheeler city should be introduced. The larger their modal share of two-wheelers, the more divergent they are from the global tendencies. It is necessary to consider such traffic patterns specific to cities in developing countries, when formulating urban transport development strategies.

It is reasonable to argue that the metro operation timing is closely related to the achieved level of socio-economic development of cities. The larger their population, the more likely they are to develop a metro system, even though GDP per capita is not high enough. On the other hand, cities blessed with higher levels of GDP per capita opened their metro systems, even if their population is yet small. It is possible to presume that the achievement of a certain level of GRDP be the condition for a given city to introduce a metro system

There are some issues for future research. Firstly, while the Study did overall analysis on the relationship of urban transportation patterns and city types, and only focused on 2-wheeler cities, future study should conduct in-depth analysis focusing on specific types of cities, such as low-income cities, Islamic cities, or cities where walking has high share in the modal share. It will be useful to formulate more effective urban transport strategy. Secondly the Study focused on the limited number of urban indicators, including urban population, urban density, and GDP per capita, there are many other indicators which are closely related with urban transport pattern, including geographical conditions, road density, modal share of public transport, etc. Further research should take comprehensive analysis with wide range of urban indicators. Thirdly, since the Study only focused on the timing to start mass transit operation as a major part of urban transport strategies, the future research should analyze relationship of other important transport policies with urban typology, such as development of urban expressway and Traffic Demand Management (TDM) scheme.

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