A STUDY ON ASIA'S INFRASTRUCTURE NEEDS
ESTIMATING URBAN RAIL INFRASTRUCTURE NEEDS

Final Report

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CONTENTS

CHAPTER 1 INTRODUCTION

1.1 Background

There have been a few published demand forecasts of infrastructures in Asia. Among them, Infrastructure for a Seamless Asia (2009) published by ADB and ADB Institute is the most frequently referred study up to now. This study estimated the infrastructure demand (from year 2010 to 2020) in Asia is estimated would be around 8 trillion USD. Asian Development Bank (hereinafter referred to as "ADB") reviewed the study and published another report titled "Meeting Asia's Infrastructure Needs", in February 2017. In this report, the demand for four economic sectors (power, communication, transportation, and water sanitation sectors) from 2016 to 2030 is estimated. This report also estimated that the developing countries/areas in Asia need to invest a total amount of 26.2 trillion USD (in 2015 prices) from 2016 to 2030, 1.7 trillion USD annually (including costs for climate change measures) to keep up the current economic growth. Without costs for climate change, 22.6 trillion USD in total and 1.5 trillion USD annually are required. JICA and ADB have had a discussion on the studies and they agreed to conduct a joint research to review the above demand forecast of infrastructures until 2030 in Asia.

Other than the four economic sectors that ADB has already estimated for, there are many other social sectors such as education, health and disaster prevention sectors. In order to estimate accurately the total amount that Asian counties need to invest, it is desirable to forecast the demands for these social sectors too.

Based on the above discussions, JICA has launched the research project titled "The Research on the Infrastructure Demand Forecast in Asia," for macro level estimation and micro level data collection targeting the social and disaster prevention sector as well as urban railways.

1.2 Objectives of the Study

The objective of the study is to collect basic information and data on mass rapid transit (MRT) analyze them and forecast the future needs of MRT as a part of "The Research on the Infrastructure Demand Forecast in Asia."

1.3 Flow of the Study

The study forecasts the total MRT length needed by 2030 and the investments in MRT development expected between 2016 and 2030.

1.4 Target Countries

Table 1-1 below shows the countries targeted by this study which are twenty four in total. It has to be noted that this study does not include China.

Table 1-1 List of Target Countries

Area	Country	No.
West & Central Asia	Afghanistan, Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Pakistan, Tajikistan, Turkmenistan, Uzbekistan	10
East Asia	Mongolia	1
South Asia	Bangladesh, Bhutan, India, Nepal, Sri Lanka	5
Southeast Asia	Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippine, Thailand, Vietnam	8
Total		**24**

CHAPTER 2 ASSESSMENT OF MRT NEEDS

2.1 Introduction

Figure 2-1 summarizes the flow of the study for determining the MRT needs and estimating the cost. The first section reviews the literatures on MRT development, and it is followed by analysis on identifying the MRT operation timing. Then the socioeconomic data of the target countries are analyzed and cities with the prospect of MRT development are identified. The last two sections estimate the MRT length and cost needed, respectively.

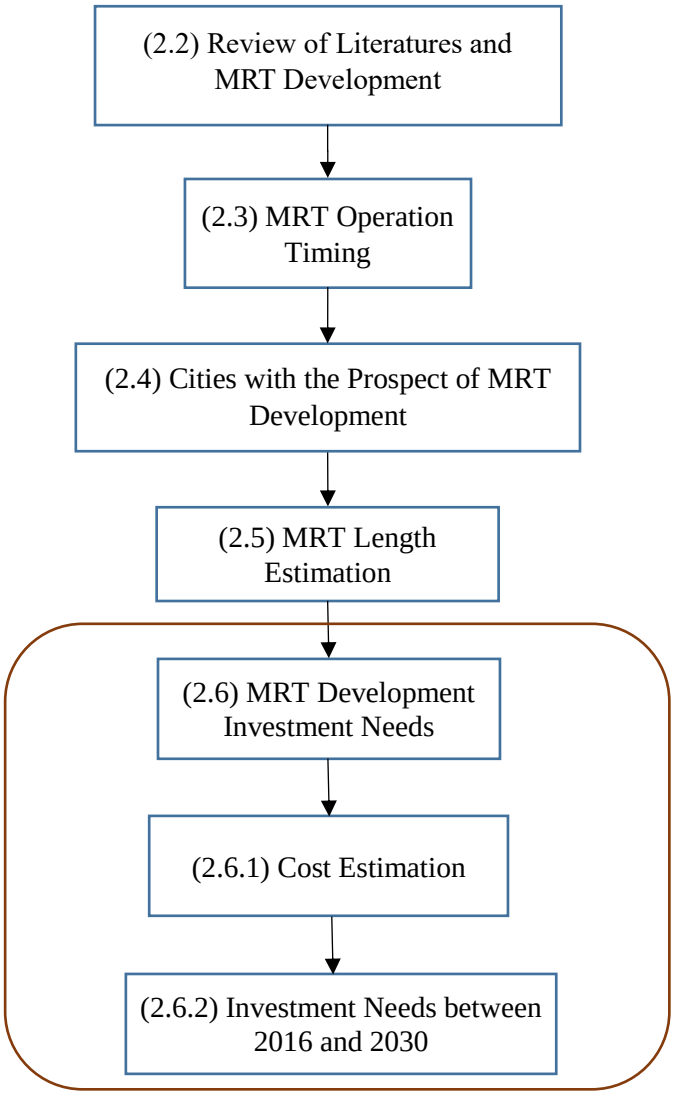


Figure 2-1 Study Flow for Estimating MRT Infrastructure Needs

2.2 Review of Literatures and MRT Development

Different studies have been conducted to estimate the infrastructure demand. Fay and Yapes (2003) estimated infrastructure demand based on socioeconomic variables. They estimated the global demand based on data across countries and for different sectors including road and rail sectors. Bhattacharyay (2010) used similar approach, but to estimate infrastructure demand in Asia and the Pacific between 2010 and 2020.

Asian Development Bank (ADB) and Asian Development Bank Institute (ADBI) jointly projected

infrastructure needs for developing Asia in 2009, and the projection was updated in 2017 by the ADB. In 2009, ADB and ADBI estimated the infrastructure needs from 2010 to 2020 of 32 developing member countries in its report titled "Infrastructure for a Seamless Asia". The study which covered four infrastructure sectors, including the transport sector, projected that the investment needs would be slightly above 8.22 trillion USD (in 2008 prices). In 2017, the ADB updated the above investment needs in its report titled "Meeting Asia's Infrastructure Needs". Unlike the 2009 study, this one covered all 45 developing countries, and the fifteen years between 2016 and 2030, and it estimated that developing Asia would need to invest 26 trillion USD (in 2008 prices).

Unlike the above studies which covers various sectors, the Japan International Cooperation Agency (JICA) conducted studies focusing on the transport sector. In 2011, JICA published a report on a research on urban transport planning titled "The Research on Practical Approach for Urban Transport Planning". This research, which is very much related to this study, reviews the existing urban transport system developments. It relates the urban transport system developments with the urban socio-economic conditions for the formulation of medium- and long-term development strategies according to urban socio-economic development. The study mainly divides the urban transport into two: mass rapid transit (MRT) and bus rapid transit (BRT) system. Light rail transit (LRT) and monorails are covered under the MRT, and the study assesses the prospect of MRT as well as BRT system development and timing.

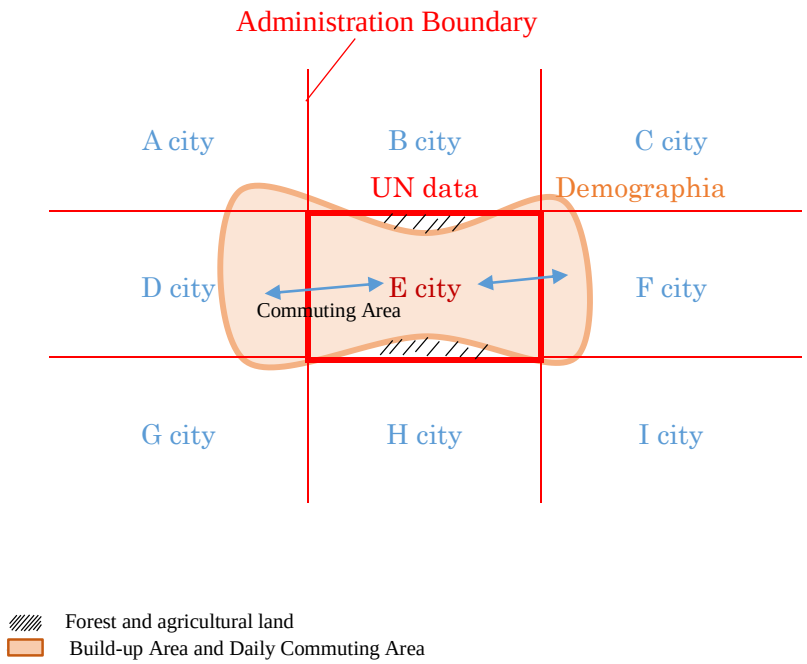
This study fundamentally updates the above JICA study, but only limited to the MRT part. Unlike the 2011 JICA study, the MRT here does not cover monorails or LRT as they have different transport characteristics and their unit costs may significantly vary. Moreover, this study revises the future MRT needs and establish more reliable relationships between the urban socio-economic changes and the length of the MRT needed.

2.3 MRT Operation Timing

The JICA (2011) study identified the city GDP level at which a city is likely to operate by analyzing historical socioeconomic status of the cities with MRT. The study found that most of the cities started their first MRT operation when their GDP was between 3 billion USD and 30 billion USD (in 2000 prices). It should be noted that the city GDP here is estimated as the product of the national GDP per capita published by the World Bank and the urban population the United Nation (World Urbanization Prospect).

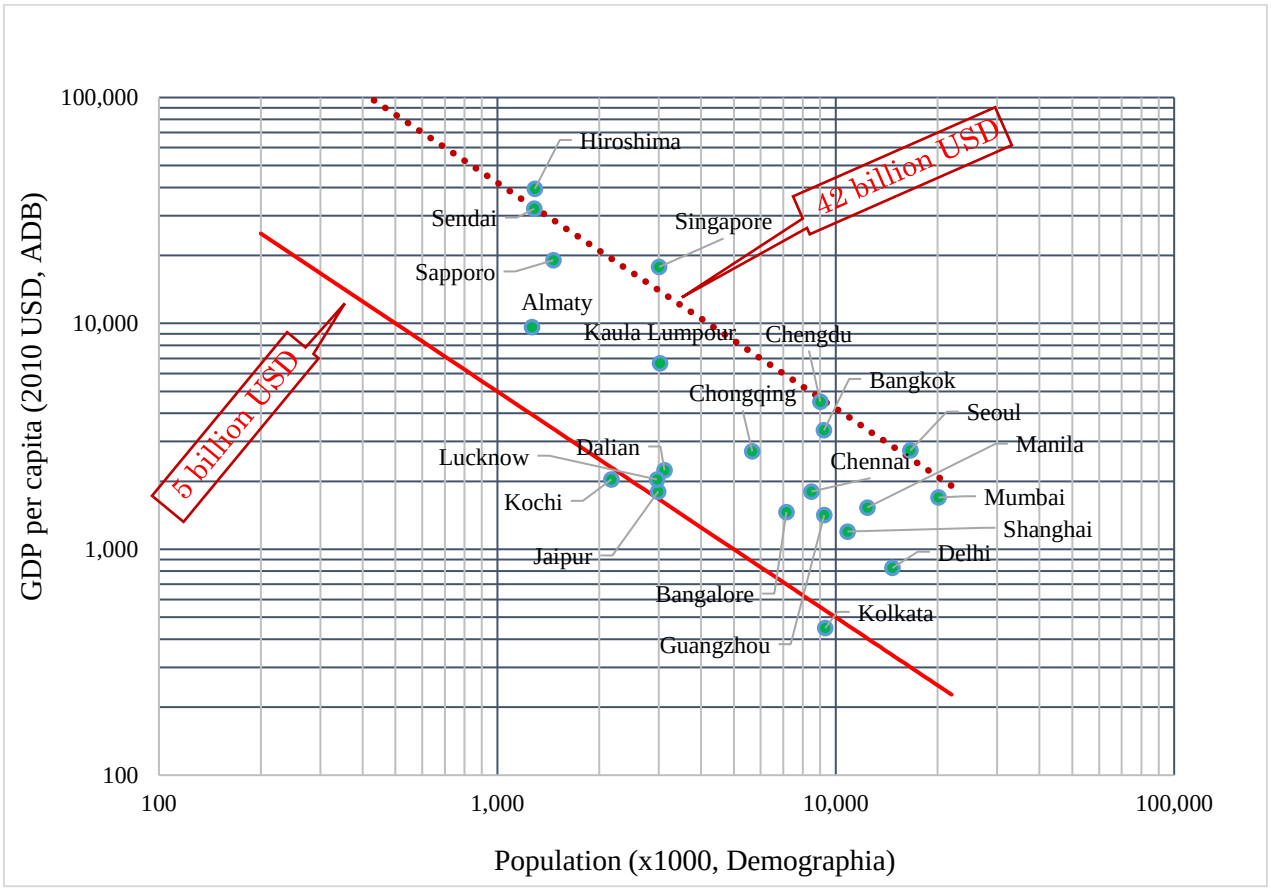
The MRT operation timing is analyzed based on similar data, but updated based on the GDP of 2010 prices. Moreover, the urban population from *Demographia* is used in combination with the urban growth rates provided by the UN for more consistency with the urban area data provided by *Demographia* used in this study. *Demographia* refers to a continuously built-up land mass within a labor market as an urban area. Therefore, it provides more consistent areas for mega cities like Bangkok, Jakarta or Delhi where different area figures are reported. While the areas of the UN data coincide with the administrative boundaries, those of *Demographia* can include the areas of the adjacent cities. The difference of the definitions on urban area between *Demographia* and the UN data is illustrated in Figure 2-2.

Figure 2-3 below shows the updated graph of the MRT operation timing. The 3 billion USD lower bound (in 2000 prices) increased to 5 billion USD (in 2010 prices), and the upper bound increased from 30 billion USD (in 2000 prices) to 42 billion USD (in 2010 prices). Although the location of some of the cities has relatively changed, the result shows a pattern similar to that of the updated JICA (2011) study which is based on the UN data. As a result, any city with GDP of 5 billion USD or more (i.e., the product of urban population and national GDP per capita in 2010 prices) may be considered to have the potential to operate MRT.



Source: JICA Study Team

Figure 2-2 Image of the Definitions of Urban Area



Source: Prepared by JICA Study Team with data of Asian Development Bank for GDP, and of *Demographia* for Population

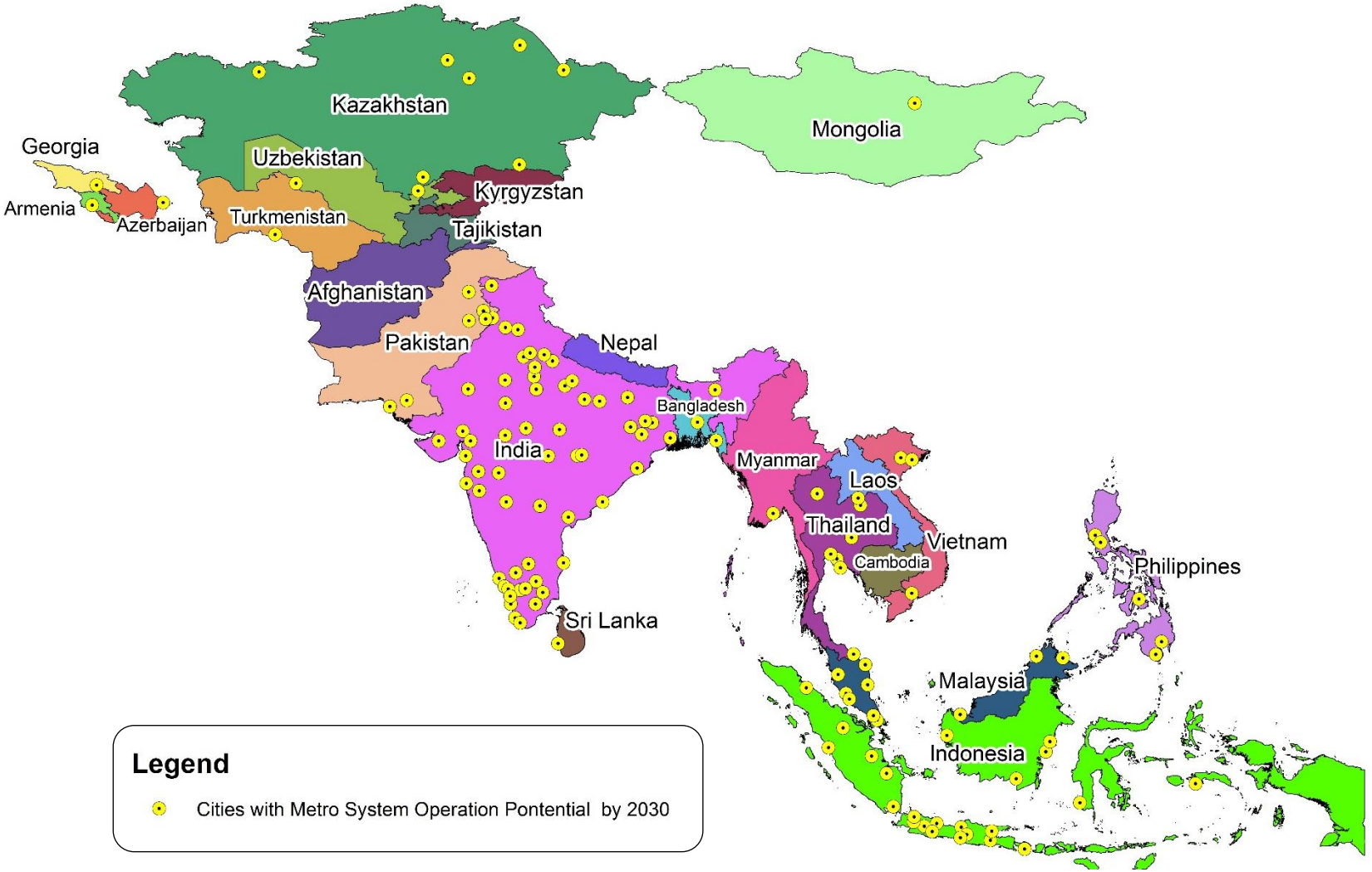
Figure 2-3 GDP per Capita and Urban Population at First MRT Operation

2.4 Cities with the Prospect of MRT Development

Considering the time needed for appraisal and development, cities which need MRT by 2030 are targeted in this study. Section 2.3 has identified that any city with GDP of 5 billion USD (in 2010 prices) or above has the potential to develop MRT. Therefore all cities with GDP of 5 billion USD or more (i.e., the product of urban population and national GDP per capita in 2010 prices) are considered to have the potential to operate MRT.

Based on the above requirement (i.e., 5 billion USD city GDP threshold), all the cities with the potential to operate MRT by 2030 are identified (refer to Appendix 2 for the list of the cities). The cities are further classified into those, which as of now, operating MRTs, those with MRT development plans, and those without plans. The classification is based on the readily available information, and reconfirmation is advised on the latest plans and status of each candidate city.

Figure 2-4 shows all the cities of the target countries with the potential of operating MRT by 2030 (i.e., those with at least 5 billion USD GDP). It includes cities with less than one million population but satisfying the GDP criteria.



Source: JICA Study Team

Figure 2-4 Cities with the Potential of Operating MRT by 2030

Figure 2-5 (a) to (r) show the MRT needs and plans of each country in detail. It shows cities which are operating MRT, those who have planned and those which have yet to plan.

Source: JICA Study Team

Figure 2-5 (a) Armenia

Source: JICA Study Team

Figure 2-5 (b) Azerbaijan

Source: JICA Study Team

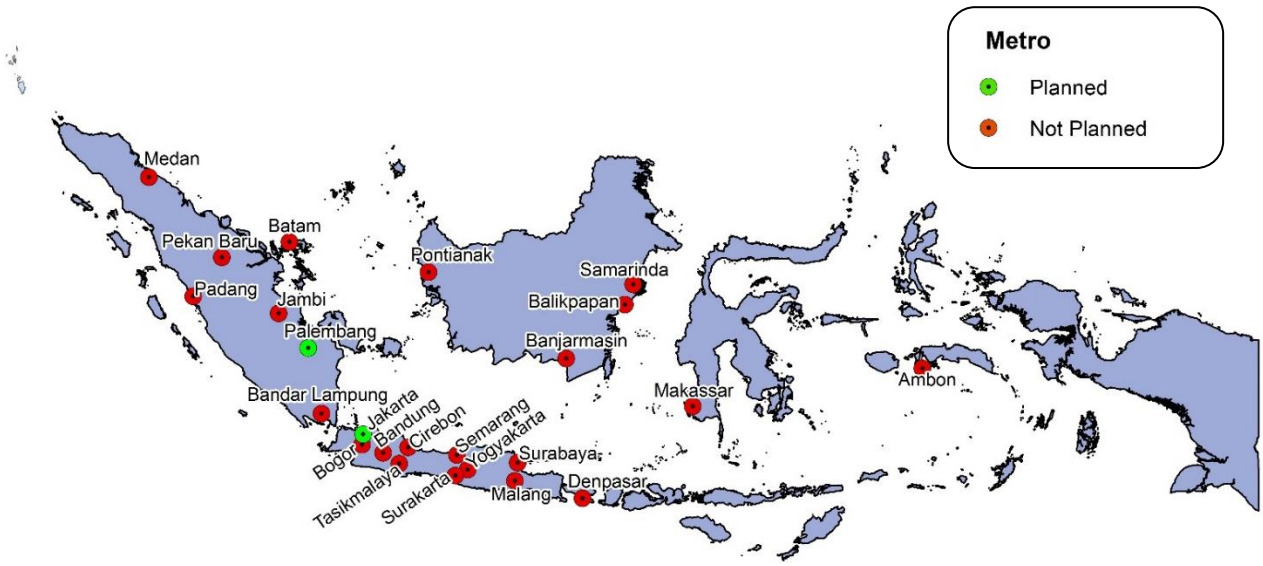
Figure 2-5 (c) Bangladesh

Source: JICA Study Team

Figure 2-5 (d) Georgia

Source: JICA Study Team

Figure 2-5 (e) India



Source: JICA Study Team

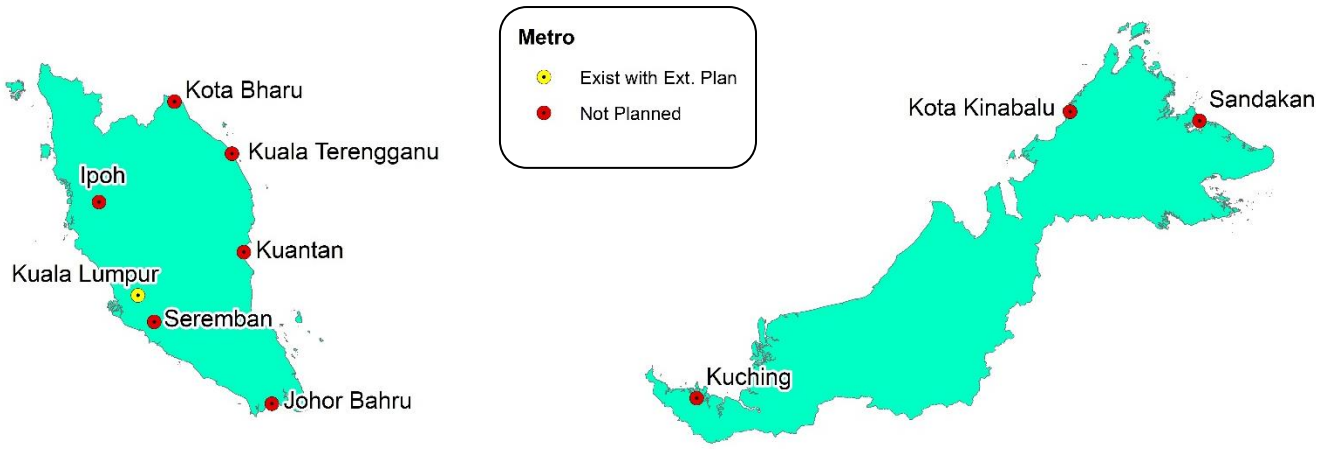
Figure 2-5 (f) Indonesia

Source: JICA Study Team

Figure 2-5 (g) Kazakhstan

Source: JICA Study Team

Figure 2-5 (h) Laos



Source: JICA Study Team

Figure 2-5 (i) Malaysia

Source: JICA Study Team

Figure 2-5 (j) Mongolia

Source: JICA Study Team

Figure 2-5 (k) Myanmar

Source: JICA Study Team

Figure 2-5 (l) Pakistan

Source: JICA Study Team

Figure 2-5 (m) Philippines

Source: JICA Study Team

Figure 2-5 (n) Sri Lanka

Source: JICA Study Team

Figure 2-5 (o) Thailand

Source: JICA Study Team

Figure 2-5 (p) Turkmenistan

Source: JICA Study Team

Figure 2-5 (q) Uzbekistan

Source: JICA Study Team

Figure 2-5 (r) Viet Nam

Figure 2-5 Cities with MRT or with the Potential of MRT Development by Country

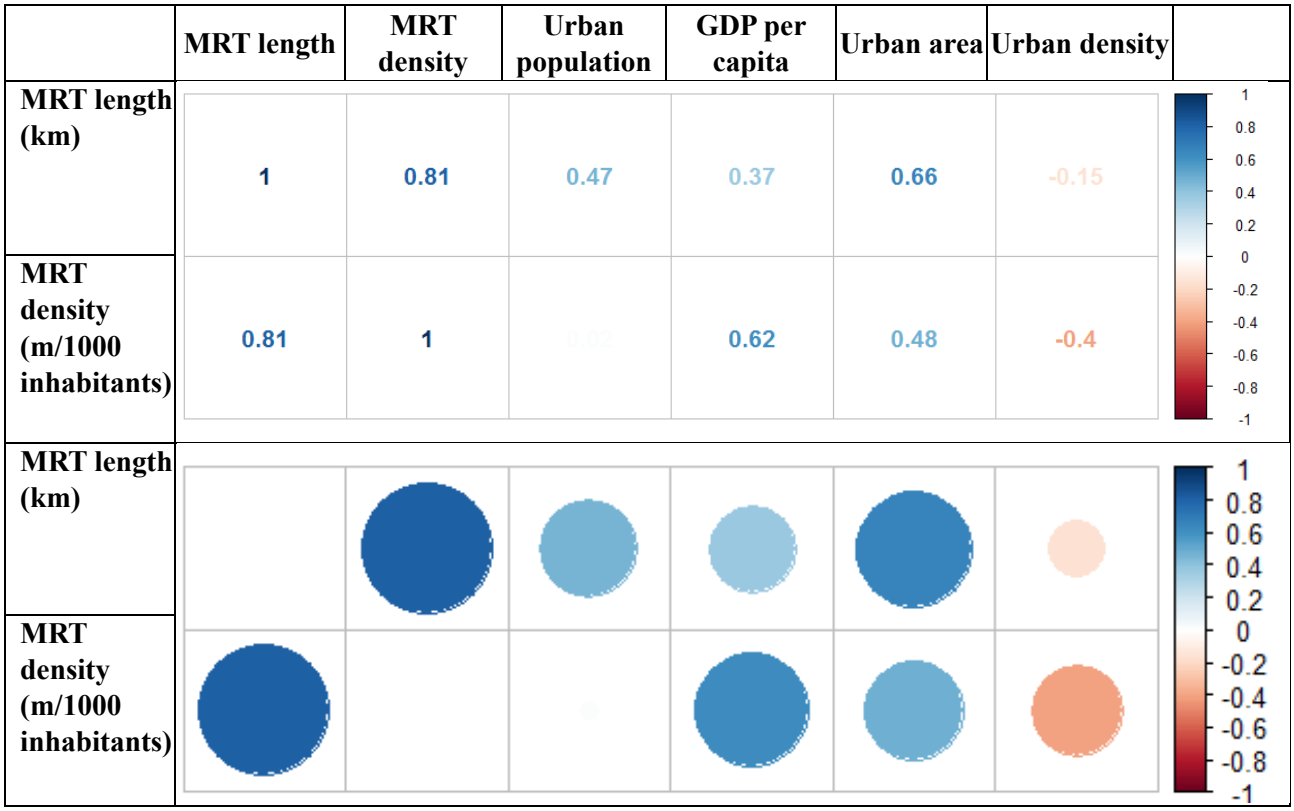
2.5 MRT Length Estimation

2.5.1 MRT Length Estimation Model

This study used a regression model to establish the relationship between the MRT length and socioeconomic status of the cities, based on the MRT development and socioeconomic data collected. The MRT development data include existing and planned MRT length of cities from candidate countries. The planned MRT development is included under the assumption that the development will be realized as planned.

The MRT length and MRT density (MRT length per 1,000 inhabitants) are considered as the dependent variables of the regression model, and their correlations with different explanatory variables (including GDP, urban population, urban density and urban area) were analyzed (refer to Appendix 3).

Figure2-6 shows a typical correlation pattern observed by the study. As the figure confirms regression models with different combinations and numbers of explanatory variables are possible, and study analyzed and compared different such regression models. Different analyses were also conducted by grouping different countries (such India, other countries) and compared the regression model results.



Source: JICA Study Team

Figure 2-6 Correlation Coefficients

Several regression models were compared using length and MRT density as dependent variables, and combinations of the remaining variables as independent variables. As the case shown in Table 2-1 demonstrates, independent variables, except the urban area, could not explain the total length significantly. In addition, it is difficult to obtain future urban area data, which makes difficult to use this model to the forecast the future MRT length. In contrast, the t-values of the GDP per capita and urban area are significant for the MRT density model, and as such the study decided to forecast the future MRT needed based on the MRT density.

Table 2-1 MRT Length Estimation Models Options

	Total length as a dependent variable		MRT density as a dependent variable	
Variables	Coefficients	*t*-value	Coefficients	*t*-value
GDP per capita (USD /person)	0.000275	0.06	0.000902	4.13
Urban area (km2)	0.055454	4.48	0.001319	2.16
Urban density (people/km2)	0.001687	0.17	0.000234	0.48
Adjusted R2	0.63		0.74	

As explained above, future MRT length needs are estimated based on a model using MRT density as a dependent variable. MRT density models with three variables (GDP per capita, urban area and urban density) as independent variables and two variables (GDP per capita, urban area) were compared (Table 2-1). As a result, it was found that adding the third variable (urban density) does not improve the model. Therefore, the following MRT model with two variables was estimated and used to forecast MRT length:

$$\text{Length/1,000 inhabitants} = \beta_1 * \text{GDP per capita} + \beta_2 * \text{Urban area}$$

Where *Length* is MRT length in meter, *GDP per capita* in 2010 USD prices, and *Urban area* in kilometer square of urban agglomeration. Table 2-2 below shows the summary of the estimation result of the model with two and three explanatory variables.

Table 2-2 MRT Length Estimation Model Results

	Two variables		*Three variables*	
Variables	Coefficients	*t*-value	Coefficients	*t*-value
GDP per capita (USD /person)	0.000912	4.24	0.000902	4.13
Urban area (km2)	0.001392	2.37	0.001319	2.16
Urban density (people/km2)	Not applicable		0.000234	0.48
Adjusted R2	0.75		0.74	

It should be noted that the sample cities of the above regression model include cities like Jakarta which planned mostly light rail transit (rather than MRT). As a result, the exclusion of Jakarta alone significantly improve the above model, which may be more appropriate for MRT oriented cities. But the cities like this still have the potential to develop MRT and reorient their current transport system development policies.

2.5.2 Estimates of Future MRT Length

The MRT length needed by a city at different socioeconomic level is estimated based on the regression model explained in Section 2.5.1 above. The lengths needed are estimated for each city at first, then tallied all for the overall MRT length need in the target cities by 2030. Input values for variables and estimation results are listed in Appendix 2 and 5 respectively. According to the result, the cities in the target countries that meet the socioeconomic requirement need 3,199 km MRT length by 2030.

2.6 MRT Development Investment Needs

2.6.1 Cost Estimation

Preliminary analysis of the cost data obtained show significant variation not only across countries but even within a country. Therefore, the samples used in the cost estimation are not country-wise but project-wise. The average cost of the MRT is affected by various factors, including the proportion that runs underground (Figure 2-7). Generally the MRT cost per km increases with the increase of the GDP per capita of a country, but the data analyses showed more complex situation as indicated in Table 2-3, in which you can see the cost per km is higher in countries like Bangladesh and Viet Nam than Malaysia. Countries like Bangladesh and Viet Nam which are introducing MRT for the first time outsource the work, and local involvement is limited. That could be one of reason behind the relatively higher cost of MRT in lower GDP countries introducing the MRT for the first time. But this trend is expected to change as the future when the capacity of the local firms develops (like India's current situation) and the firms start to undertake significant portion of the work.

India shows the lowest MRT cost on average (52 million USD/km), although significant variation of costs is observed even for the same underground proportion (Figure 2-7). But the average cost of the yen-loan projects in India is higher than the total average and it is about 76 million USD/km. The involvement of local companies in the MRT development may be the main reason behind the relatively lower average cost than other countries, but the sources of the differences between yen-loan and non-yen-loan projects are not

clear at this point.

The study considered different options of accounting the variation of the costs explained above. For example the cost is estimated separately for India and the rest of the target countries, and other options considered includes dividing the target countries by region (as dry and wet region countries). However, the representativeness of the results have become the main concern, as the samples are not only limited by unevenly distributed. The division of the samples into India and the rest of the countries, has understandably led to statically better results for Indian samples but poorer for samples from the rest of the countries.

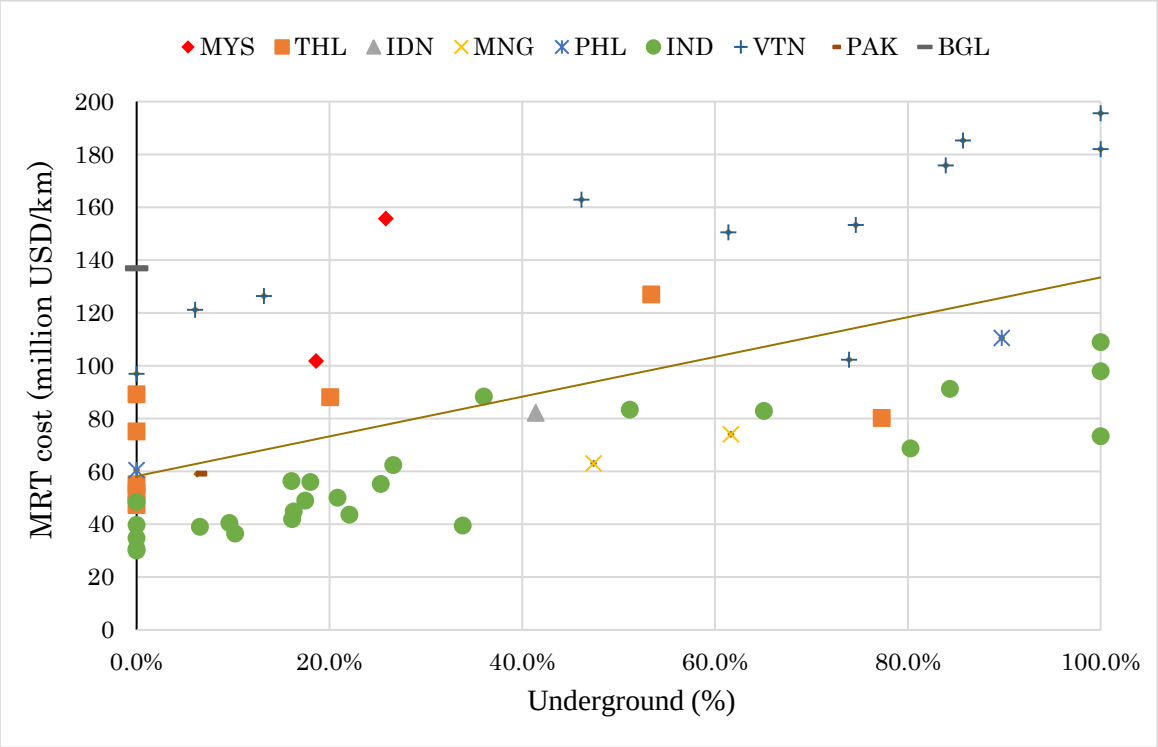


Figure 2-7 MRT Cost by Underground Proportion

Table 2-3 Distribution and Characteristics the MRT Projects

Country	Number of samples	Total length (km)	Elevated (km)	Under-ground (km)	Under-ground (%)	Cost (million USD/km)
Bangladesh	1	20.1	20.1	0	0.0%	137
Indonesia	1	15.7	9.2	6.5	41.4%	82
India	26	1070.7	774.2	296.5	27.7%	52
Mongolia	2	28.7	13.2	15.5	54.0%	68
Malaysia	2	103.2	80.2	23.0	22.3%	129
Pakistan	1	27.1	25.4	1.7	6.3%	59
Philippines	2	35	24	11	30.4%	77
Thailand	8	209.8	161.2	48.6	23.2%	76
Viet Nam	11	141.8	74.0	67.8	47.8%	140
All	54	1652	1181	470	28.5%	70

As explained above, different cost estimation options have been considered to account for the cost variation, but each option comes with its own merits and demerits. Although the variation of the cost across countries or regions is important, the objective of this study is to estimate the total cost in the target countries as a whole, and not by country or region. Therefore, the study estimated the average cost by using all samples of the target countries and establishing the relationship between the total cost and elevated length, underground length, and GDP per capita based on the projects in the study area. In addition, the study compared cost models with additional explanatory variables to the underground length and elevated length variables (which are quite related to the cost) and found the following model to explain the prevailing relationship best among the compared models:

$$\text{Total cost} = \beta_1 * \text{Elevated length} + \beta_2 * \text{Underground length} + \beta_3 * \text{GDP per capita}$$

Where *Total cost* is in million USD in 2016 prices, *Elevated length* in km, *Underground length* in km, and *GDP per capita* of 2016 in 2010 USD prices. Table 2-44 shows the estimation result of the cost model with two and three explanatory variables.

Table 2-4 MRT Cost Estimation Model Results

	Two variables		Three variables	
Variables	Coefficients	*t*-value	Coefficients	*t*-value
Elevated length (km)	43.90	7.35	26.40	5.59
Underground (km)	94.68	7.25	75.69	8.09
GDP per capita (USD /person)	***Not applicable***		0.29	7.62
Adjusted R2	0.79		0.89	

2.6.2 Investment Needs between 2016 and 2030

Total MRT length needed between 2016 and 2030 is estimated to be 3,199 km, as explained in Section 2.5.2. But only 789 km was built by the end of 2015. Therefore, the MRT length needed between 2016 and 2030 is 2,410 km (i.e., subtracting 789 km from 3,199). The investments needed are estimated using cost estimation model in Section 2.6.1. The percentage of underground length is assumed to be 28.5%, which is the average of all the sample projects from target countries shown in Table 2-53, in all target cities. The estimation results for each city are listed in Appendix 5.

The total investment needed by 2030 and investment made by 2015 are estimated at 275 billion USD and 48 billion USD in 2016 prices, respectively (using cost estimation model in Section 2.6.1). The estimate of the investment made by 2015 is based on the cost estimation model, and not on the actual investment data. As a result, the investment in MRT needed between 2016 and 2030 is 227 billion USD in 2016 prices (i.e., by subtracting investment made by 2015 from that needed by 2030). The summary of the estimation result is shown in Table 2-55. The investment needed in MRT between 2016 and 2030 is about 5 times of that made until 2015, and indicates how important it is for the economic growth of Asia.

Table 2-5 The Estimation Result of Investment Needs

	by 2015	2016–2030	Total
Estimated Length (km)	789	2,410	3,199
Estimated Investment Cost	48 billion USD	227 billion USD	275 billion USD

Trial Calculation of Gap between Need and Actual Investment

Although the total investment need between 2016 and 2030 is estimated to reach 227 billion USD, the actual investment is not expected to meet the need. The model itself is estimated based on only cities operating or planning to operate MRT, and the length estimated by applying this model does not reflect the actual MRT development of all similar cities. In another words, there are cities with socioeconomic level similar to that of the cities operating or planned to operate MRT, but have not developed MRT.

To estimate the proportion of the MRT that would be actually realized, the study estimated the MRT need in terms of length in 2015 and compared it with the actual development just for reference. The result of this analysis shows that the total MRT length built by 2015 was only 58.01% of the need. Assuming that this trend would continue in the future, it is estimated that actual investment in MRT development would reach 159 billion USD in 2016 prices by 2030 (i.e., 58.01% of the investment needed). And the actual investment in MRT between 2016 and 2030 would be 111 billion USD, which is estimated by subtracting 48 billion USD from 159 billion USD. This amount is only 48 % of the original needs (i.e.,227 billion USD). To fill the gap between the needs and the actual investment, the governments should build investment plans earlier and also secure sufficient funds for investments.

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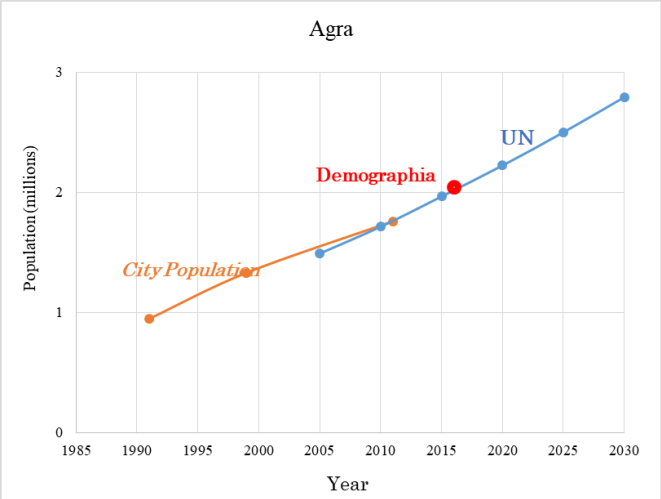
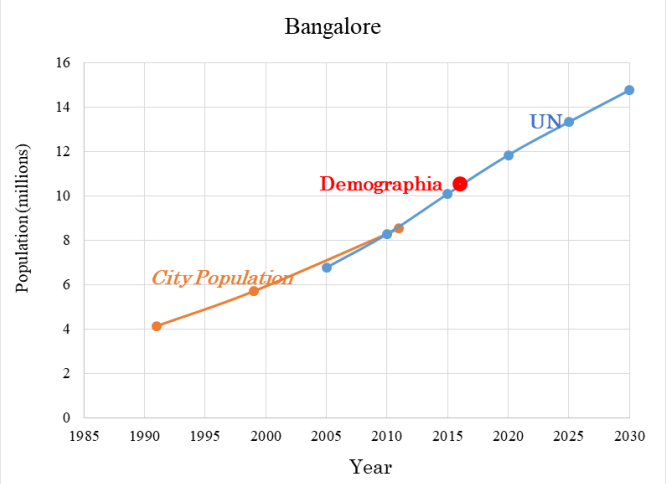
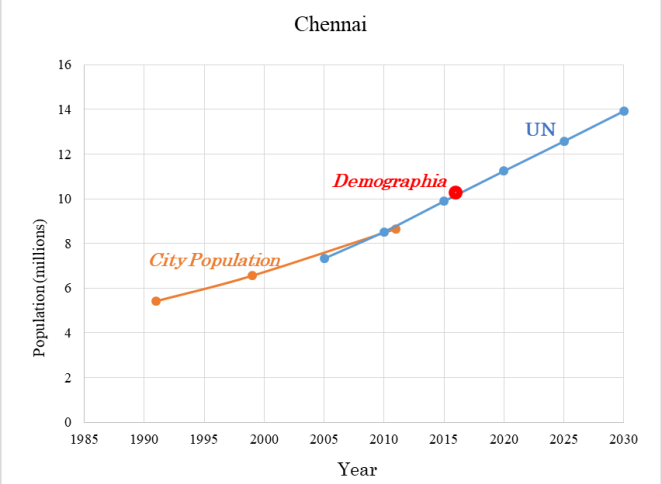
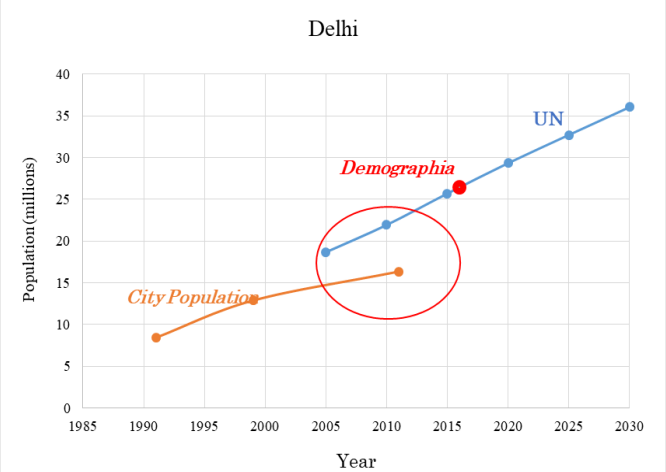
Appendix 1

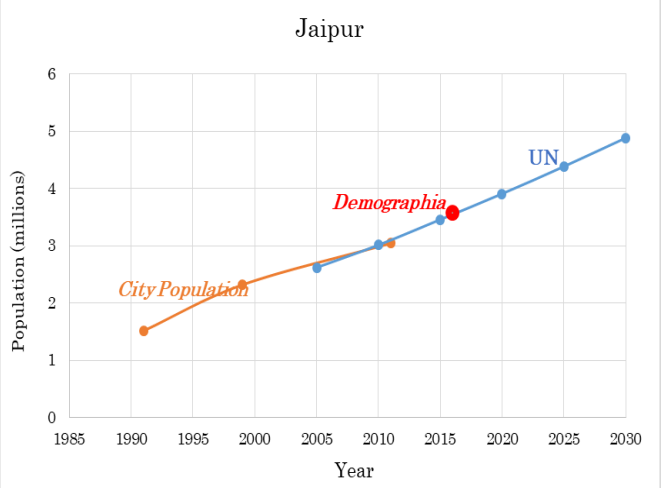
Comparison of Population Data used in the Study
(Data from *City Population*, *Demographia* and the UN)

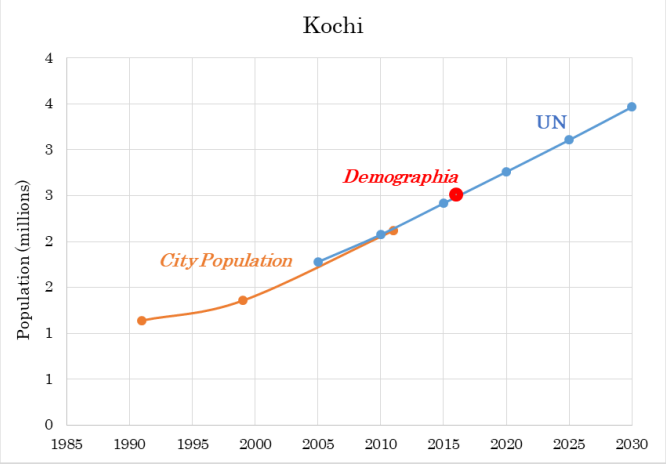


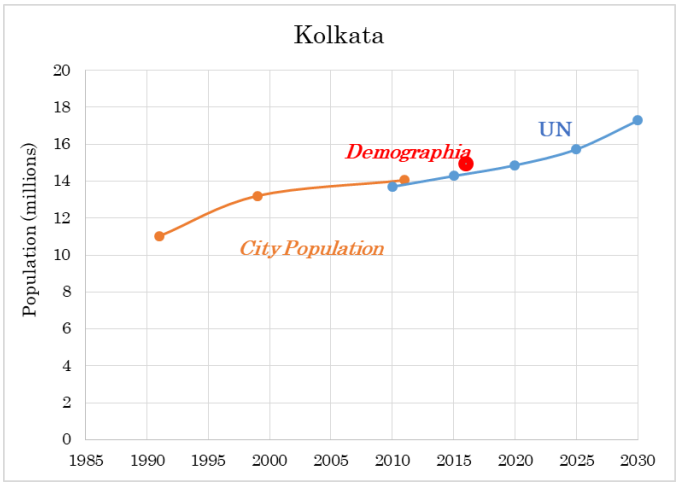


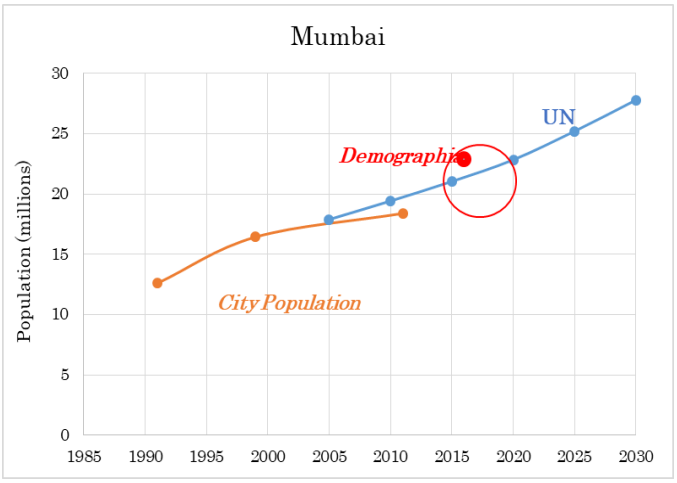


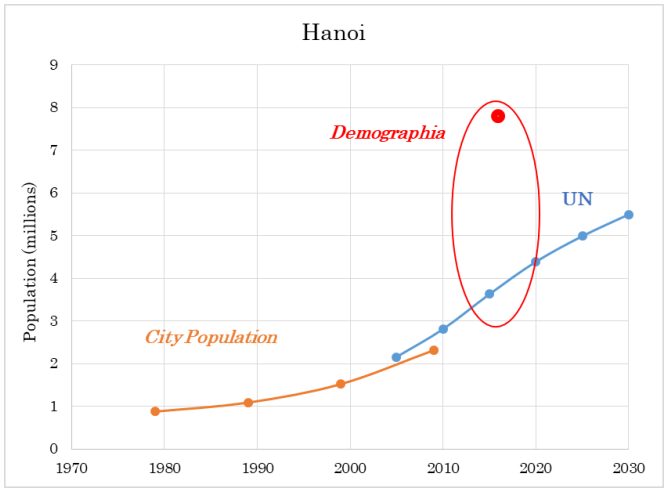


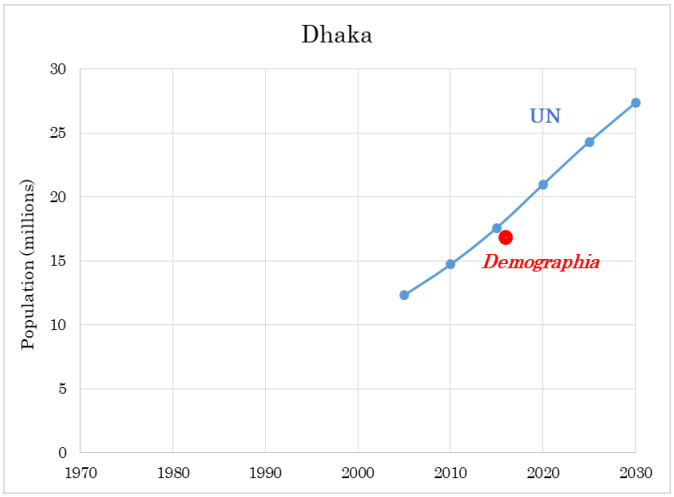





Kolkata
Population (millions)
Demographia
UN
City Population


Mumbai
Population (millions)
Demographia
UN
City Population


Hanoi
Population (millions)
Demographia
UN
City Population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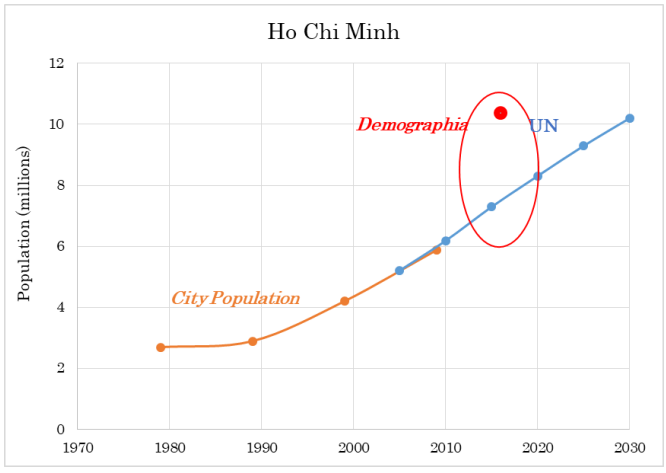
Population (millions)
UN
Demographia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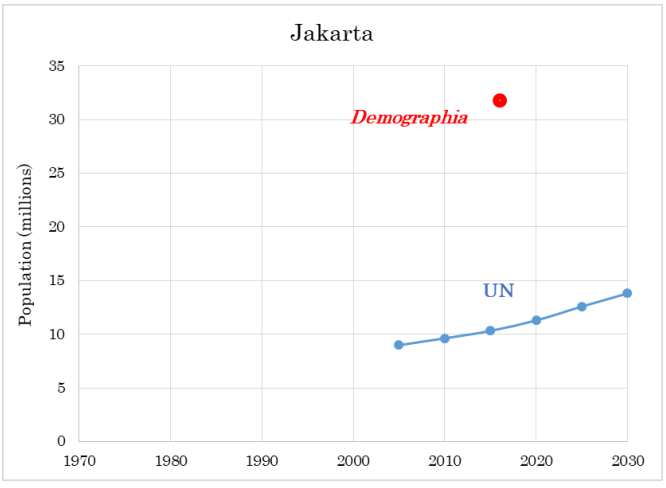
UN
City Population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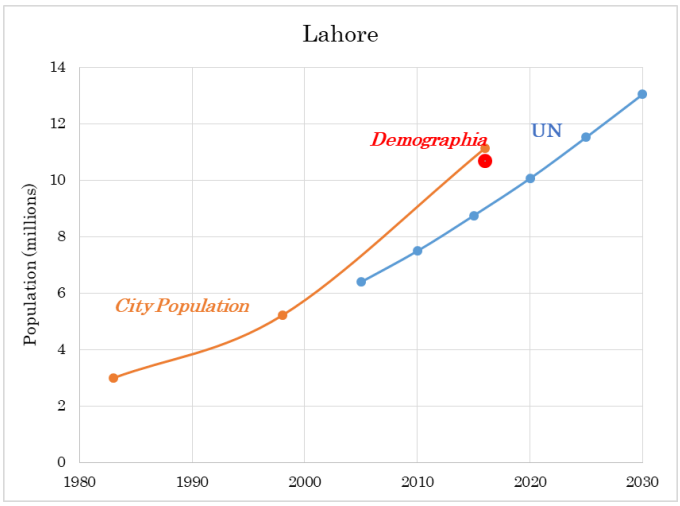
Lahore
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Demographia
UN
City Population
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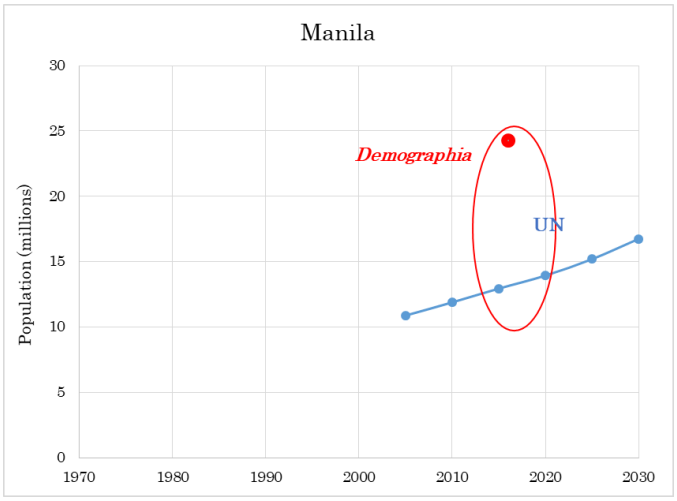
6
8
10
12
14
1980
1990
2000
2010
2020
2030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Population (millions)
Demographia
UN
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1980
1990
2000
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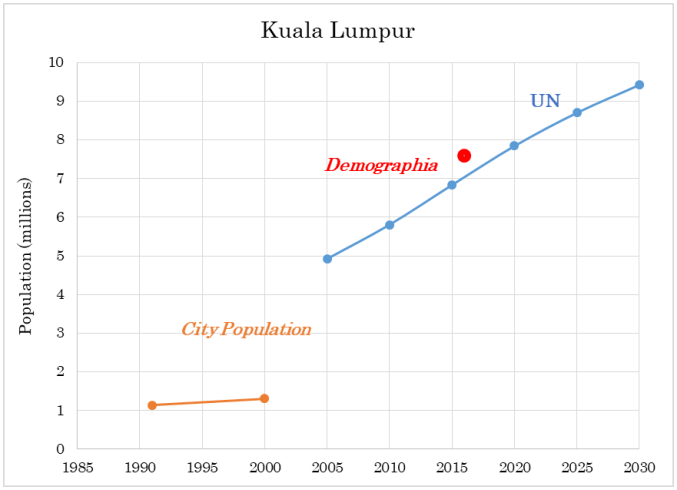
2020
2030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Population (millions)
UN
Demographia
City Population
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7
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9
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1985
1990
1995
2000
2005
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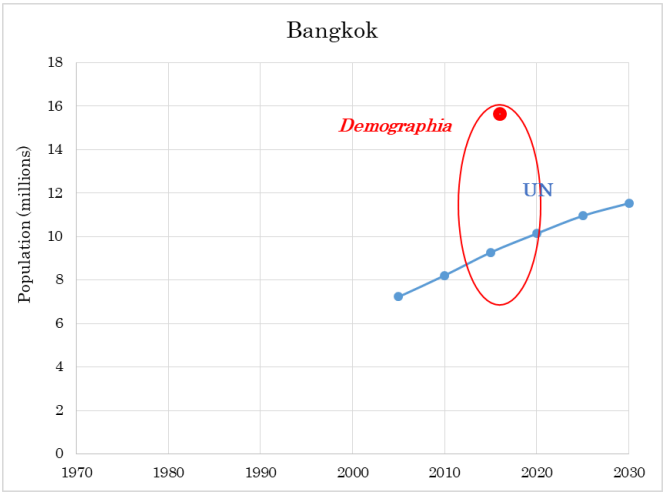
2015
2020
2025
2030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Population (millions)
Demographia
UN
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6
8
10
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14
16
18
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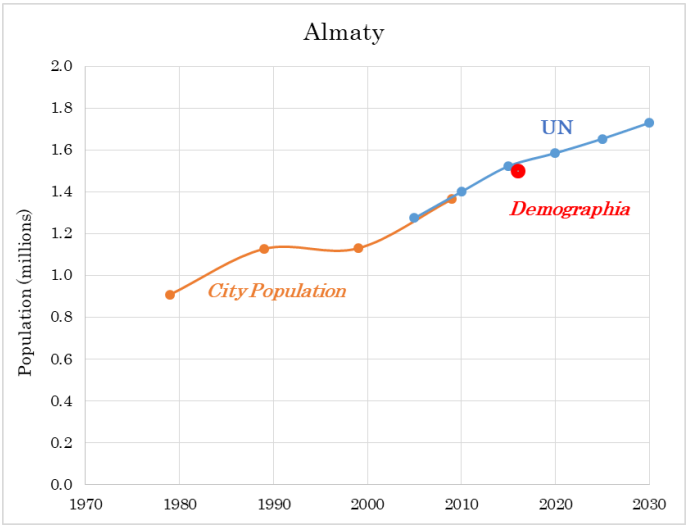
1980
1990
2000
2010
2020
2030


Almaty
Population (millions)
UN
Demographia
City Population
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1.2
1.4
1.6
1.8
2.0
1970
1980
1990
2000
2010
2020
2030

Appendix 2

List of the Urban Agglomerations with Potential of MRT Development (i.e., with GDP of 5 billion USD or more by 2030)

Country or area	Urban Agglomeration	Population (thousand)	GDP per cap (USD)	City GDP (billion USD)	Area (km2)
		2030	2030	2030	
Armenia	Yerevan	1372	5861	8.0	376
Azerbaijan	Baku	2821	7395	20.9	1127
Bangladesh	Chittagong	4187	2074	8.7	181
Bangladesh	Dhaka	20440	2074	42.4	368
Georgia	Tbilisi	1074	6011	6.5	246
India	Agra	2421	4127	10.0	168
India	Ahmadabad	8857	4127	36.6	350
India	Aligarh	1284	4127	5.3	93
India	Allahabad	1623	4127	6.7	124
India	Amritsar	1586	4127	6.5	153
India	Asansol	1648	4127	6.8	65
India	Aurangabad	1661	4127	6.9	93
India	Bangalore	12053	4127	49.7	1166
India	Bareilly	1375	4127	5.7	83
India	Bhopal	2591	4127	10.7	181
India	Bhubaneswar	1238	4127	5.1	140
India	Chandigarh	1412	4127	5.8	259
India	Chennai (Madras)	11935	4127	49.3	1036
India	Coimbatore	3093	4127	12.8	285
India	Delhi	30410	4127	125.5	2202
India	Dhanbad	1578	4127	6.5	101
India	Durg-Bhilainagar	1552	4127	6.4	130
India	Guwahati (Gauhati)	1306	4127	5.4	194
India	Gwalior	1517	4127	6.3	101
India	Hyderabad	3683	4127	15.2	117
India	Indore	2998	4127	12.4	272
India	Jabalpur	1678	4127	6.9	119
India	Jaipur	4217	4127	17.4	505
India	Jamshedpur	1808	4127	7.5	153
India	Jodhpur	1588	4127	6.6	233
India	Kannur	2561	4127	10.6	570
India	Kanpur	3774	4127	15.6	207
India	Kochi (Cochin)	2960	4127	12.2	440
India	Kolkata (Calcutta)	17927	4127	74.0	1347
India	Kollam	1696	4127	7.0	181
India	Kota	1286	4127	5.3	130

Country or area	Urban Agglomeration	Population (thousand)	GDP per cap (USD)	City GDP (billion USD)	Area (km2)
		2030	2030	2030	
India	Kozhikode (Calicut)	2987	4127	12.3	518
India	Lucknow	3958	4127	16.3	363
India	Ludhiana	2143	4127	8.8	207
India	Madurai	1981	4127	8.2	150
India	Malappuram	2636	4127	10.9	324
India	Meerut	1929	4127	8.0	161
India	Moradabad	1263	4127	5.2	52
India	Mumbai (Bombay)	26970	4127	111.3	881
India	Mysore	1354	4127	5.6	148
India	Nagpur	3321	4127	13.7	272
India	Nashik	2188	4127	9.0	135
India	Patna	2744	4127	11.3	142
India	Pune (Poona)	6958	4127	28.7	583
India	Raipur	1668	4127	6.9	142
India	Rajkot	1963	4127	8.1	101
India	Ranchi	1564	4127	6.5	140
India	Salem	1253	4127	5.2	106
India	Solapur	1246	4127	5.1	65
India	Srinagar	1766	4127	7.3	174
India	Surat	6738	4127	27.8	233
India	Thiruvananthapuram	2401	4127	9.9	311
India	Thrissur	2793	4127	11.5	363
India	Tiruchirappalli	1383	4127	5.7	85
India	Tiruppur	1481	4127	6.1	104
India	Vadodara	2451	4127	10.1	186
India	Varanasi (Benares)	1924	4127	7.9	168
India	Vijayawada	2147	4127	8.9	80
India	Visakhapatnam	2207	4127	9.1	313
Indonesia	Ambon	679	7441	5.1	299
Indonesia	Balikpapan	720	7441	5.4	57
Indonesia	Bandar Lampung	1130	7441	8.4	106
Indonesia	Bandung	7034	7441	52.3	466
Indonesia	Banjarmasin	823	7441	6.1	65
Indonesia	Batam	1348	7441	10.0	233
Indonesia	Bogor	1541	7441	11.5	119
Indonesia	Cirebon	1449	7441	10.8	106
Indonesia	Denpasar	1406	7441	10.5	179
Indonesia	Jakarta	39791	7441	296.1	3302
Indonesia	Jambi	705	7441	5.2	78
Indonesia	Makassar (Ujung Pandang)	1830	7441	13.6	179

Country or area	Urban Agglomeration	Population (thousand)	GDP per cap (USD)	City GDP (billion USD)	Area (km2)
		2030	2030	2030	
Indonesia	Malang	1396	7441	10.4	246
Indonesia	Medan	4885	7441	36.3	479
Indonesia	Padang	1089	7441	8.1	101
Indonesia	Palembang	1799	7441	13.4	220
Indonesia	Pekan Baru	1637	7441	12.2	238
Indonesia	Pontianak	823	7441	6.1	62
Indonesia	Samarinda	940	7441	7.0	52
Indonesia	Semarang	2155	7441	16.0	272
Indonesia	Surabaya	6048	7441	45.0	738
Indonesia	Surakarta	1670	7441	12.4	207
Indonesia	Tasikmalaya	949	7441	7.1	62
Indonesia	Yogyakarta	2336	7441	17.4	233
Kazakhstan	Aktyubinsk	508	13213	6.7	400
Kazakhstan	Almaty	1533	13213	20.3	531
Kazakhstan	Astana	735	13213	9.7	181
Kazakhstan	Karaganda	564	13213	7.5	293
Kazakhstan	Pavlodar	416	13213	5.5	400
Kazakhstan	Semipalatinsk	396	13213	5.2	210
Kazakhstan	Shimkent	873	13213	11.5	135
Lao People's Democratic Republic	Vientiane	1664	3183	5.3	130
Malaysia	Ipoh	969	18752	18.2	259
Malaysia	Johor Bahru	2009	18752	37.7	816
Malaysia	Kota Bharu	433	18752	8.1	116
Malaysia	Kota Kinabalu	673	18752	12.6	351
Malaysia	Kuala Lumpur	8249	18752	154.7	2124
Malaysia	Kuala Terengganu	476	18752	8.9	605
Malaysia	Kuantan	617	18752	11.6	324
Malaysia	Kuching	859	18752	16.1	181
Malaysia	Sandakan	467	18752	8.8	2266
Malaysia	Seremban	677	18752	12.7	155
Mongolia	Ulaanbaatar	1372	7561	10.4	311
Myanmar	Yangon	6837	2404	16.4	596
Pakistan	Faisalabad	5252	1621	8.5	311
Pakistan	Gujranwala	3170	1621	5.1	148
Pakistan	Hyderabad	3683	1621	6.0	117
Pakistan	Karachi	28368	1621	46.0	1010
Pakistan	Lahore	12585	1621	20.4	842
Pakistan	Rawalpindi-Islamabad	3707	1621	6.0	427
Philippines	Angeles City	1080	5151	5.6	186

Country or area	Urban Agglomeration	Population (thousand)	GDP per cap (USD)	City GDP (billion USD)	Area (km2)
		2030	2030	2030	
Philippines	Cebu City	3075	5151	15.8	207
Philippines	Davao City	2935	5151	15.1	130
Philippines	General Santos City	1912	5151	9.8	75
Philippines	Manila	29909	5151	154.1	1787
Sri Lanka	Colombo	4812	8381	40.3	777
Thailand	Chon Buri	734	10558	7.8	166
Thailand	Krung Thep (Bangkok)	16493	10558	174.1	3043
Thailand	Lampang	576	10558	6.1	22
Thailand	Nakhon Ratchasima	505	10558	5.3	40
Thailand	Rayong	527	10558	5.6	17
Thailand	Udon Thani	734	10558	7.8	73
Turkmenistan	Ashgabat	921	13065	12.0	122
Turkmenistan	Tashauz	420	13065	5.5	60
Uzbekistan	Tashkent	2810	3187	9.0	1075
Viet Nam	Hà Noi	7954	3516	28.0	868
Viet Nam	Hai Phòng	1522	3516	5.4	570
Viet Nam	Thành Pho Ho Chí Minh (Ho Chi Minh City)	11172	3516	39.3	1580

Note:

- *Demographia* (2017) population data are used and extended 2030 using by growth rates by the UN data
- GDP is from ADB and in 2010 prices
- City GDP here is estimated as the products of the city population and GDP per capita

Appendix 3

Data for MRT Length Estimation Model

Country	City	MRT Operation Year	Model Length (km)	MRT Density (m/1000 people)	GDP per Capita (USD, 2010 price)	Urban Area (km2, *Demographia* 2017)	City Density (people/ km2)	GDP (USD, 2010 price)	Population (Operation year)
Indonesia	Jakarta	2018	15.7	0.5	4342	3302	990	4342	32688
Indonesia	Jakarta	2020	23.8	0.7	4735	3302	1020	4735	33665
Philippines	Manila	2020	39.7	1.5	3278	1787	1458	3278	26055
Azerbaijan	Baku	2016	36.6	13.1	5922	1127	248	5922	2797
Bangladesh	Dhaka	2019	20.1	1.1	1213	368	5146	1213	18937
Kazakhstan	Almaty	2015	10.3	7.0	10597	531	278	10597	1475
Malaysia	Kuala Lumpur	2017	59.6	7.6	11522	2124	370	11522	7863
Malaysia	Kuala Lumpur	2020	111.8	12.7	12839	2124	413	12839	8780
Pakistan	Lahore	2019	27.1	2.3	1247	842	1402	1247	11807
Thailand	Bangkok	2017	122.7	7.6	6140	3043	528	6140	16052
Thailand	Bangkok	2018	149.5	9.1	6362	3043	541	6362	16471
Thailand	Bangkok	2019	191.0	11.3	6611	3043	556	6611	16912
Thailand	Bangkok	2020	225.5	13.0	6884	3043	571	6884	17378
Thailand	Bangkok	2021	247.3	13.8	7181	3043	587	7181	17870
Thailand	Bangkok	2022	310.5	16.9	7498	3043	604	7498	18391
Thailand	Bangkok	2023	311.4	16.4	7832	3043	623	7832	18943
Vietnam	Ho Chi Minh	2017	11.3	1.1	1840	1580	681	1840	10758
Vietnam	Ho Chi Minh	2020	31.0	2.6	2124	1580	761	2124	12031
Vietnam	Hanoi	2018	21.0	2.4	1930	868	1008	1930	8748
Vietnam	Hanoi	2019	32.5	3.5	2024	868	1073	2024	9310
India	Agra	2022	14.0	5.7	2711	168	1463	2711	2457
India	Ahmadabad	2022	18.5	1.9	2711	350	2761	2711	9665
India	Bangalore	2017	42.4	3.9	2037	1166	944	2037	11005
India	Bangalore	2024	114.5	7.3	3023	1166	1350	3023	15746
India	Bhopal	2021	15.0	6.0	2565	181	1385	2565	2508
India	Chennai	2017	47.4	4.5	2037	1036	1023	2037	10599
India	Delhi	2011	190.0	8.3	1460	2202	1035	1460	22791
India	Delhi	2018	365.6	12.9	2161	2202	1289	2161	28380
India	Jaipur	2015	9.6	2.8	1802	505	689	1802	3479
India	Jaipur	2018	11.9	3.2	2161	505	751	2161	3792

Country	City	MRT Operation Year	Model Length (km)	MRT Density (m/1000 people)	GDP per Capita (USD, 2010 price)	Urban Area (km2, *Demographia* 2017)	City Density (people/ km2)	GDP (USD, 2010 price)	Population (Operation year)
India	Kochi	2017	18.0	6.9	2037	440	591	2037	2599
India	Kolkata	1984	27.2	2.3	448	1347	883	448	11889
India	Kolkata	2018	41.9	2.8	2161	1347	1128	2161	15196
India	Kozhikode	2021	13.3	3.9	2565	518	662	2565	3430
India	Lucknow	2017	8.5	2.5	2037	363	943	2037	3422
India	Mumbai	2020	56.1	2.3	2425	881	2779	2425	24486
India	Mumbai	2023	128.1	5.0	2864	881	2933	2864	25837
India	Pune	2018	31.3	4.9	2161	583	1086	2161	6330
India	Thiruvananthapuram	2022	21.8	8.3	2711	311	845	2711	2627

Appendix 4

Data for MRT Cost Estimation Model

Country	City	Total cost (million USD)	Elevated+ At Grade	Under-ground	GDP per Capita in 2016 (USD, 2010 price)	Total (km)	Under-ground (%)	Unit Cost (million USD/km)	Density (people/ km2)
MNG	Ulaanbaatar	970	8.1	7.3	3,883	15.4	47.4%	63	4200
MNG	Ulaanbaatar	985	5.1	8.2	3,883	13.3	61.7%	74	4200
PAK	Lahore	1600	25.4	1.7	1,165	27.1	6.3%	59	12700
BGL	Dhaka	2748	20.1	0.0	1026	20.1	0.0%	137	45700
IDN	Jakarta	1290	9.2	6.5	3988	15.7	41.4%	82	9600
MYS	Kuala Lumpur	5194	41.5	9.5	11179	51	18.6%	102	3600
MYS	Kuala Lumpur	8130	38.7	13.5	11179	52.2	25.9%	156	3600
PHL	Manila	1293	1.2	10.5	2,751	11.7	89.7%	111	13600
PHL	Manila	1380	22.8	0.0	2,751	22.8	0.0%	61	13600
THL	Bangkok	2371	21.5	5.4	5,946	26.9	20.1%	88	5100
THL	Bangkok	1727	23.0	0	5,946	23	0.0%	75	5100
THL	Bangkok	2996	11.0	12.6	5,946	23.6	53.4%	127	5100
THL	Bangkok	3175	9.0	30.6	5,946	39.6	77.3%	80	5100
THL	Bangkok	707	12.8	0	5,946	12.8	0.0%	55	5100
THL	Bangkok	1694	19.0	0	5,946	19	0.0%	89	5100
THL	Bangkok	1633	34.5	0	5,946	34.5	0.0%	47	5100
THL	Bangkok	1576	30.4	0	5,946	30.4	0.0%	52	5100
VTN	HCMC	2490	17.1	2.6	1,746	19.7	13.2%	126	6,600
VTN	HCMC	2075	1.6	9.6	1,746	11.2	85.7%	185	6,600
VTN	HCMC	1482	4.9	4.2	1,746	9.1	46.2%	163	6,600
VTN	HCMC	2714	28	0	1,746	28	0.0%	97	6,600
VTN	HCMC	1563	1.43	7.46	1,746	8.89	83.9%	176	6,600
VTN	HCMC	2183	5.6	8.9	1,746	14.5	61.4%	151	6,600
VTN	HCMC	1820	0	10	1,746	10	100.0%	182	6,600
VTN	HCMC	1200	9.3	0.6	1,746	9.9	6.1%	121	6,600
VTN	HCMC	1870	3.1	9.1	1,746	12.2	74.6%	153	6,600
VTN	HCMC	1330	0	6.8	1,746	6.8	100.0%	196	6,600
VTN	Hanoi	1177	3.0	8.5	1,746	11.5	73.9%	102	9000

Appendix 5

Estimated Results of MRT Length and Cost

Country or area	Urban Agglomeration	Estimated Length Needed (km)	Estimated Cost (million USD)
Armenia	Yerevan	8.05	1450
Azerbaijan	Baku	23.44	2674
Bangladesh	Chittagong	8.97	662
Bangladesh	Dhaka	49.12	2286
Georgia	Tbilisi	6.25	1359
India	Agra	9.67	948
India	Ahmadabad	37.64	2079
India	Aligarh	4.99	759
India	Allahabad	6.39	815
India	Amritsar	6.30	812
India	Asansol	6.35	814
India	Aurangabad	6.46	818
India	Bangalore	64.90	3182
India	Bareilly	5.33	773
India	Bhopal	10.40	978
India	Bhubaneswar	4.90	755
India	Chandigarh	5.82	792
India	Chennai (Madras)	62.11	3069
India	Coimbatore	12.86	1077
India	Delhi	207.60	8954
India	Dhanbad	6.16	806
India	Durg-Bhilainagar	6.12	805
India	Guwahati (Gauhati)	5.27	770
India	Gwalior	5.92	797
India	Hyderabad	14.45	1142
India	Indore	12.41	1059
India	Jabalpur	6.59	824
India	Jaipur	18.83	1319
India	Jamshedpur	7.19	848
India	Jodhpur	6.49	820
India	Kannur	11.66	1029
India	Kanpur	15.29	1175
India	Kochi (Cochin)	12.95	1081
India	Kolkata (Calcutta)	101.05	4644
India	Kollam	6.81	832
India	Kota	5.07	762
India	Kozhikode (Calicut)	13.39	1099
India	Lucknow	16.89	1240
India	Ludhiana	8.68	908
India	Madurai	7.87	875
India	Malappuram	11.11	1006
India	Meerut	7.69	868
India	Moradabad	4.84	753

Country or area	Urban Agglomeration	Estimated Length Needed (km)	Estimated Cost (million USD)
India	Mumbai (Bombay)	134.53	5999
India	Mysore	5.37	774
India	Nagpur	13.75	1113
India	Nashik	8.64	907
India	Patna	10.87	997
India	Pune (Poona)	31.82	1844
India	Raipur	6.60	824
India	Rajkot	7.66	867
India	Ranchi	6.19	807
India	Salem	4.90	755
India	Solapur	4.80	751
India	Srinagar	7.07	843
India	Surat	27.53	1671
India	Thiruvananthapuram	10.07	964
India	Thrissur	11.92	1039
India	Tiruchirappalli	5.37	774
India	Tiruppur	5.78	791
India	Vadodara	9.86	956
India	Varanasi (Benares)	7.69	868
India	Vijayawada	8.31	893
India	Visakhapatnam	9.27	932
Indonesia	Ambon	4.89	1360
Indonesia	Balikpapan	4.94	1362
Indonesia	Bandar Lampung	7.83	1479
Indonesia	Bandung	52.27	3276
Indonesia	Banjarmasin	5.66	1391
Indonesia	Batam	9.58	1549
Indonesia	Bogor	10.71	1595
Indonesia	Cirebon	10.04	1568
Indonesia	Denpasar	9.89	1562
Indonesia	Jakarta	452.76	19476
Indonesia	Jambi	4.86	1358
Indonesia	Makassar (Ujung Pandang)	12.87	1682
Indonesia	Malang	9.95	1564
Indonesia	Medan	36.39	2634
Indonesia	Padang	7.54	1467
Indonesia	Palembang	12.75	1678
Indonesia	Pekan Baru	11.65	1633
Indonesia	Pontianak	5.65	1391
Indonesia	Samarinda	6.45	1423
Indonesia	Semarang	15.44	1786
Indonesia	Surabaya	47.23	3072
Indonesia	Surakarta	11.81	1640
Indonesia	Tasikmalaya	6.52	1426
Indonesia	Yogyakarta	16.60	1833
Kazakhstan	Aktyubinsk	6.40	3328

Country or area	Urban Agglomeration	Estimated Length Needed (km)	Estimated Cost (million USD)
Kazakhstan	Almaty	19.60	3862
Kazakhstan	Astana	9.03	3435
Kazakhstan	Karaganda	7.02	3353
Kazakhstan	Pavlodar	5.24	3281
Kazakhstan	Semipalatinsk	4.89	3267
Kazakhstan	Shimkent	10.68	3501
Laos	Vientiane	5.13	677
Malaysia	Ipoh	16.91	3941
Malaysia	Johor Bahru	36.62	4739
Malaysia	Kota Bharu	7.47	3560
Malaysia	Kota Kinabalu	11.83	3736
Malaysia	Kuala Lumpur	165.39	9947
Malaysia	Kuala Terengganu	8.55	3603
Malaysia	Kuantan	10.83	3695
Malaysia	Kuching	14.91	3860
Malaysia	Sandakan	9.46	3640
Malaysia	Seremban	11.72	3731
Mongolia	Ulaanbaatar	10.05	1538
Myanmar	Yangon	20.65	1171
Pakistan	Faisalabad	10.03	745
Pakistan	Gujranwala	5.34	555
Pakistan	Hyderabad	6.04	584
Pakistan	Karachi	81.79	3648
Pakistan	Lahore	33.34	1688
Pakistan	Rawalpindi-Islamabad	7.68	650
Philippines	Angeles City	5.35	1018
Philippines	Cebu City	15.32	1421
Philippines	Davao City	14.31	1380
Philippines	General Santos City	9.18	1173
Philippines	Manila	214.80	9490
Sri Lanka	Colombo	41.96	2817
Thailand	Chon Buri	7.24	2025
Thailand	Krung Thep (Bangkok)	228.57	10978
Thailand	Lampang	5.56	1957
Thailand	Nakhon Ratchasima	4.89	1930
Thailand	Rayong	5.08	1938
Thailand	Udon Thani	7.14	2021
Turkmenistan	Ashgabat	11.12	2535
Turkmenistan	Tashauz	5.03	2288
Uzbekistan	Tashkent	12.37	1098
Viet Nam	Hà Noi	35.10	1928
Viet Nam	Hai Phòng	6.09	755
Viet Nam	Ho Chi Minh City	60.37	2950
Total		**3,199**	**274,535**