Sustainable City Development & Asian Urban Railways

Toshiji Takatsu

Introduction

Unfortunately, many parts of Asia have long suffered from economic poverty coupled with severe traffic congestion. However, despite the 1997 Asian Financial Crisis, Asia saw a massive explosion of prolonged economic growth for most of the 1990s. These economic developments changed the industrial landscape of the region with increasing urbanization resulting from rising income levels and population growth. Many of the newly industrializing countries suffer from inadequate public infrastructure such as subways and high-speed urban railways, which created increasingly serious problems with traffic jams, air pollution, etc., as private car ownership grew exponentially.

Furthermore, there have been increasing calls by the international community to cut emissions of greenhouse gases such as CO_2, which is a primary cause of global warming and climate change. In comparison to automobiles, trains with high passenger levels can carry more people faster and in greater safety than cars while causing much less environmental damage. As a consequence and to ensure sustainable development, many cities in Europe are now being developed based on the concept of public transport systems centred on urban railway systems. Recently, even Asian cities outside Japan and S. Korea, such as Hong Kong, Singapore, Bangkok, Manila, Jakarta, etc., are pushing ahead with railway-based urban mass transport systems.

This article outlines how Asian economic growth, urbanization, and the current state and problems with urban transport systems have affected the development of Asian urban railways; it examines the importance of railways in hot topics such as environment and energy in sustainable city development.

First, there are many definitions of what constitutes 'Asia,' but in this article, we mean everything eastward from Iran (including Turkey) and the Pacific islands as defined by the United Nations, Economic and Social Commission for Asia and the Pacific (UNESCAP). Additionally, we define urban railway transport systems to include mainly wheel-and-rail based subways and urban high-speed railways as well as light rail systems such as monorails, automated guideway transit (AGT) systems and light rail transit (LRT) systems.

Asian Miracle

Asia is a vast and very diverse region, covering areas with very different climates, geography, peoples, history, religions and cultures. The political systems across Asia range from socialist to liberal democratic and the economies range from developed to newly industrializing and underdeveloped. Following the Asian Financial Crisis of 1997, the Newly Industrialized Economies (NIEs) of formerly low-income agricultural economies like S. Korea, Taiwan, Hong Kong, Singapore, etc., as well as the other ASEAN members of Malaysia, Thailand, the Philippines, Indonesia, Viet Nam, Cambodia, Laos and Myanmar have managed to show good economic growth. Moreover, the People's Republic of China (PRC) is continuing to show sustained high economic growth since the country joined the World Trade

Table 1 Selected Economies of ESCAP Region: Rate of Economic Growth, 2000–04

	Real GDP				
	2000	2001[a]	2002[b]	2003[b]	2004[b]
Developing economies of ESCAP region	7.0	3.1	4.2	5.4	5.9
South and south-west Asia	4.5	4.6	5.5	6.0	6.6
Bangladesh	5.9	6.0	4.3	–	–
India	4.0	5.4	6.0	6.3	7.0
Iran	5.9	5.5	6.5	6.5	6.1
Nepal	6.4	5.9	5.0	6.0	6.5
Pakistan	3.9	2.6	4.0	4.7	5.2
Sri Lanka	6.0	0.9	3.3	5.5	5.9
Turkey	7.1	-8.4	2.0	4.4	4.1
South-east Asia	6.5	1.8	3.2	4.4	4.6
Cambodia	5.4	5.3	4.5	6.3	6.0
Indonesia	4.8	3.3	3.8	4.9	4.6
Laos	5.7	6.4	5.0	–	–
Malaysia	8.3	0.4	3.2	5.1	6.1
Myanmar	13.6	5.0	5.1	5.9	–
Philippines	4.0	3.4	4.0	3.4	4.0
Singapore	9.9	-2.0	2.0	5.8	5.7
Thailand	4.4	1.5	2.5	2.5	3.5
Viet Nam	6.8	6.8	6.1	6.8	7.3
East and north-east Asia	8.0	3.2	4.3	5.7	6.2
PRC	8.0	7.3	7.0	7.5	7.6
Hong Kong, PRC	10.5	-0.2	1.0	6.0	6.3
Mongolia	1.1	1.4	4.0	5.0	6.0
S. Korea	8.8	3.0	3.9	4.6	5.0
Taiwan	5.9	-2.2	1.7	4.0	5.4
Developed economies of ESCAP region	2.5	-0.2	-0.9	1.6	1.5
Australia	3.8	4.1	3.0	4.1	3.6
Japan	2.4	-0.5	-1.2	1.4	1.4
New Zealand	3.8	2.6	1.9	3.3	2.0

Source: UNESCAP, *Economic and Social Survey of Asia and the Pacific 2002*, UN, New York, 2002.
a Estimate.
b Forecast/target.

Organization (WTO) in 2001, and now enjoys an economy of comparable size to Italy. English-speaking nations like India with a good standard of education have seen huge and expanding growth in fields like information technology (IT) such as software development. From 1996 to 2000, the average growth in world GDP was +2.6% but the economies of many Asian nations grew at a much higher rate than the world average; the future is expected to see continued higher economic growth and development than the rest of the world due to adoption of innovative technologies, increasing industrialization, and inward investment from overseas (Table 1).

On the other hand, despite having formed relatively few trade agreements until now, there has been recent and increasing regional cooperation, such as the start of the ASEAN Free Trade Area (AFTA), the Japan–Singapore Economic Partnership Agreement (JSEPA), etc. The PRC is aiming to complete creation of a free trade area (FTA) with ASEAN by 2010 starting with a reduction in some agricultural tariffs from 2004. In the future, it is likely that the globalized economies of the Asian region will need to become more interlinked to cooperate in dealing with problems concerning the environment, energy, urbanization, etc.

Exploding Populations and Increasing Urbanization

According to UN statistics, the world population in 1960 was 3 billion people. By 2000, this had doubled to 6 billion. This increase is expected to continue centred on developing countries, reaching 7.8 billion people by 2025. The population of Asia in 2000 was 3.7 billion (62% of the world total) with some of the most populous nations including the PRC (1.27 billion), India (1 billion), Indonesia (210 million), and Japan (120 million). According to UN statistics, the population of Asia in 2025 is forecast to have increased by 1 billion to reach 4.7 billion based on growth in India, Pakistan, PRC, etc. This is a 27% increase over 2000 and will still comprise 60% of the world total. In addition to forming a large manufacturing bloc and market, Asia's huge population will also be a large consumer of energy and will be required to play a major role in countering the resultant problems of global warming and environmental pollution.

Table 2 Major Population Parameters in Selected Economies of ESCAP Region, 1960–2025

Region	Urban population (million)		Urbanization (%)				Annual average growth of urban population	
	2000	2025	1960	1980	2000	2025	1980–2000	2000–25
South and south-west Asia	482	957	17.9	24.3	32.1	46.4	3.5	2.8
South-east Asia	193	363	17.6	24.4	37.2	53.3	4.0	2.6
East and north-east Asia	472	776	17.1	22.0	34.7	49.3	3.6	2.0
Pacific island economies	2.0	4.6	11.8	21.4	26.6	39.0	3.3	3.3
North and central Asia	147	165	50.9	63.4	67.3	72.1	0.9	0.5
Developed economies in ESCAP region	119	126	64.5	77.4	79.7	84.5	0.7	0.2
ESCAP region total	1415	2392	23.1	28.8	37.7	50.8	3.0	2.1
World	2845	4537	33.6	39.6	47.0	58.0	2.4	1.9

Source: UNESCAP, *Economic and Social Survey of Asia and the Pacific 2001*, UN, New York, 2001.

In the 1960s, Asia had relatively little urbanization and only one in five people were living in cities. However with urbanization, one in three people were city dwellers by 2000. In the future, economic development in Asia will see a change in the industrial structure from mining and agriculture towards manufacturing, commerce, and services and a movement of population from agrarian villages to increasingly larger cities. According to UN figures, about half the world's population is expected to be living in cities by 2025. From 2000 to 2025, the population of Asia is expected to grow by 966 million but the population of cities will increase by 977 million. In other words, the future population increase will be absorbed by cities (Table 2).

In particular, in 1950, New York was the only megacity of 10 million or more people but there were 19 megacities by 2000 and there are expected to be 23 by 2025. There were 10 megacities in Asia in 2000 and this number will have risen to 15 by 2025. In other words, 65% of the world's megacities will be in Asia in 2025. These Asian cities will not just be the national centres, they are also likely to be networked to offer international-level financial and information functions.

The exploding population growth and progress of urbanization are going to cause increasing urban density, along with a whole range of big-city problems such as housing and transport problems, environmental pollution, noise pollution, etc. In particular, the population density in the bigger megacities of the more developed Asian nations is very high, ranging from 150 to 300 km^2—many people are moving in from farming regions, and poor-quality slum housing is sprouting up in many places, creating wide-ranging problems of poverty and deprivation. As a consequence, construction of basic city infrastructure such as housing, transport, power, drinking water and sewers is an important subject of discussion. One of the most important is establishment of urban transport facilities and there is no doubt that efficient management of effective urban transport is an important precondition for the economic development of many Asian nations.

Current Conditions of Urban Transport in Asia

Increasing automobile usage

Automobile ownership in Asia is still relatively low level compared to countries like Europe and the USA but it has been growing very rapidly in recent years. The ownership rate for private vehicles per 1000 people varies widely between different countries is just something around 1:100 in countries like India and the PRC, which is a relatively low ratio compared to Japan (Fig. 1). In the future, these large countries with huge populations can expect massive increases in car ownership due to rising levels of disposable income and changes in industrial structure. This will have a very serious impact on the region.

The numbers of cars in Asian cities is rising rapidly. For example, according to a UN report, the number of cars in Bangkok increased sevenfold in the 20 years between 1970 and 1990. In Beijing, the number of automobiles increased threefold from 540,000 to 1.57 million between 1991 and 2000. Jakarta, Kuala Lumpur and some Indian cities are all in the same situation.

Moreover, a special feature of public transport in Asian cities is the large number of bicycles, motor bikes, and three-wheeled transport such as the Thai *tuk-tuk*. Half of the vehicles in Thailand, Malaysia, Indonesia, etc., are two- and three-wheeled, and Bangkok alone has 2 million bicycles and motor bikes. In Ho Chi Minh City, Viet Nam, and Penang, Malaysia, there are about 300 bicycles per 1000 people. As income levels rise, many of these people will transit from bicycles and walking to other forms of motor transport and it is likely that the PRC, Viet Nam, India, etc., will see massive increases in motor transport.

Traffic congestion

These rapid and large increases in the number of motor vehicles are causing increased urban sprawl as residential areas spread outwards. On the other hand, insufficient rail-based transport systems to carry commuters into and out of cities means that more people are using the already inadequate roads, creating serious traffic congestion and jams. The centres of cities like Bangkok, Delhi, Jakarta, Singapore, Manila, etc., are already suffering from severe and worsening congestion.

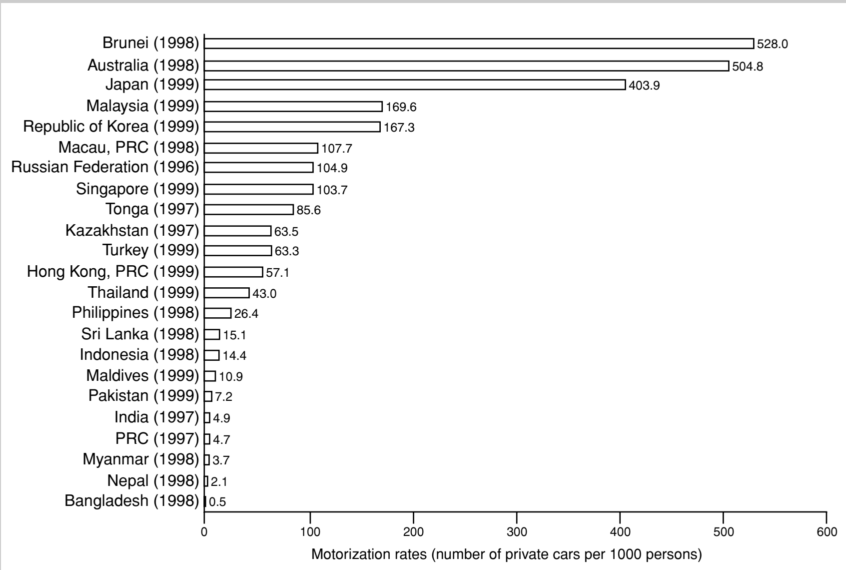
As part of my work for UNESCAP, I lived with my family for 2 years in Bangkok where the average traffic speed is the same as that of pedestrians because there are so many dead-end roads, resulting in awful traffic jams. As a result, businesses and citizens experience huge problems going about their daily lives and it is necessary to check the traffic conditions every day to be sure of allowing enough time to reach business meetings, personal appointments, etc. Bangkok traffic is characterized by jams and delays, but when the new school term starts or a VIP motorcade is travelling through town, traffic comes to a standstill. There are also endless numbers of traffic accidents each day. Clearly, Bangkok's roads are at saturation point. Congestion eased slightly following the 1997 Asian Financial Crisis only to worsen again as the economy recovered.

Traffic congestion also has a huge social cost—a recent World Bank report estimated that a 10% reduction in peak traffic in Bangkok would produce annual direct cost savings of around US$400 million. In addition, traffic jams lower the speed of public transport such as buses, causing inconvenience and economic losses for users.

Environmental problems

Many cities are suffering from severe environmental problems caused such as air pollution that damages the health of citizens. This is because there are few vehicle inspections or controls on auto emissions and many vehicles are old and

Figure 1 Motorization Rates in Selected Countries of ESCAP Region 1997–99



Source: UNESCAP Review of Transport in the ESCAP Region 1996–2001

Bangkok road congestion (G. Sakai)

Tricycle taxi rank in Manila (Author)

produce high levels of emissions. In particular, two- and three-wheeled vehicles like motorbikes and tuk-tuks produce more exhaust emissions than ordinary cars because they burn poor-quality fuels. Vehicles such as Manila's famous jeepneys and Bangkok's tuk-tuks carrying up to 10 passengers are a popular and cheap form of public transport. For example, it is reported that Dakar's 70,000 *bajaj* three-wheelers produce the same amount of exhaust emissions as 30 times that number of ordinary vehicles.

In addition to harmful suspended particulate matter (SPM), etc., exhaust emissions also contain nitrogen oxides (NOx) that cause air pollution and carbon dioxide (CO_2), which is a greenhouse gas and major cause of global warming. For this reason, the air quality in many of Asia's largest cities exceeds the WHO guidelines for SPM levels, resulting in health problems such as respiratory illnesses and other damage such as photochemical smog. A World Bank report notes that health-related losses caused by auto emissions in Bangkok, Jakarta and Kuala Lumpur alone amount to US$5 billion annually. In Japan, the amount of CO_2 emitted by an automobile per standard transport unit is 9 times greater than that produced by railways.

CO_2 emissions are a major cause of global warming—not only are emissions causing local health and environmental problems, they are also causing severe global damage.

Furthermore, rising numbers of autos result in high negative social costs due the increased numbers of traffic accidents, high noise levels, road congestion, illegal parking and interference with the flow of public transport such as buses.

The megacities are experiencing even more urban sprawl as car ownership rises and the damage to the environment caused by road congestion is rising too.

Sustainable urban transport

Long-term forecasts by the International Energy Agency (IEA) predict the world total energy demand in 2030 will be 1.7 times today's level—or the equivalent of 15.3 billion tonnes of oil. In Asia (excluding Japan), energy consumption was 1.8 billion tonnes of oil, and is expected to increase to 3 billion tonnes in 2010 and 4.1 billion tonnes in 2020. Coal reserves are finite, and will run out one day. Additionally, burning coal produces large amounts of CO_2, creating global-scale problems such as global warming.

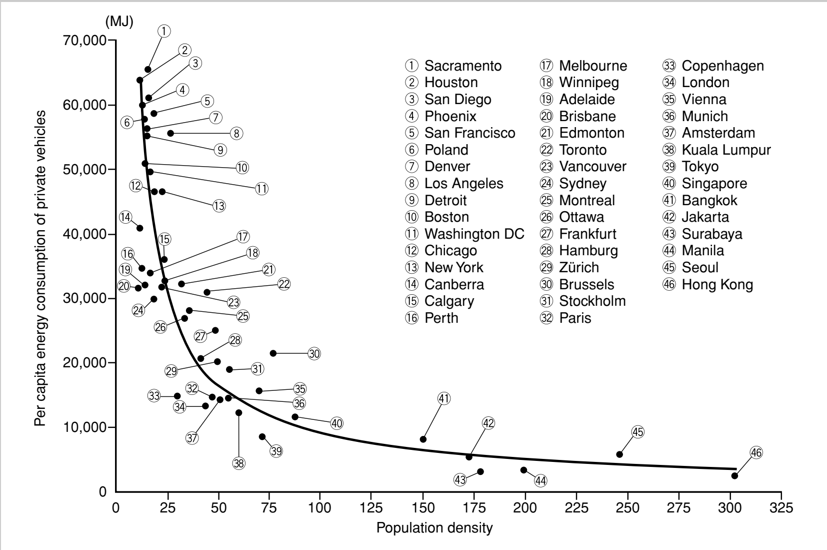
Sustainable development was a major theme of the 1992 Earth Summit in Rio de Janeiro that discussed sustainable use of resources and protection of the environment for future generations. In terms of transport, the World Bank said 'Economic and financial sustainability requires effective use of resources as well as appropriate use of assets. A sustainable environment and ecosystem requires sufficient consideration of the external costs of transport whether or not future development will be publicly or privately financed. Socially sustainable development requires acceptance of improved transport services by all levels of society.'

Figure 2 shows the per capita personal energy consumption estimated from fuel consumption. In the populous cities of Asia, per capita energy consumption still remains low. However, the future large and rapid population growth in Asia coupled with urbanization is expected to change this situation. Large differences will emerge in the future, depending on whether Asian cities choose to build American-style road infrastructure or public transport systems, such as urban high-speed railways.

Sustainable economic growth that gives consideration to limiting factors such as world energy and environmental problems is becoming a global problem. Sustainable cities have been a popular topic since the early 1990s and so-called Transit Oriented Development (TOD) has been proposed as a solution for achieving compact cities with the appropriate population and traffic densities.

The Third Conference of the Parties (COP-3) held by the United Nations Framework Convention on Climate Change (UNFCCC) in December 1997 adopted the Kyoto Protocol for limiting emissions of greenhouse gases such as CO_2 after 2000. The total world emissions of CO_2 in 1998 were estimated at 6.6 billion tonnes. The world leader in CO_2 emissions was the USA followed by the PRC (12.8%) with Japan

Figure 2 Population Density and Per Capita Energy Consumption of Private Vehicles



Source: K. Williams et al, *Achieving Sustainable Urban Form*, E&FN SPON, 2000.

Table 3 CO_2 Emissions

	Per capita CO_2 emissions (Tonne)	Percentage of world	Percentage of world population
USA	5.43	22.5	4.7
PRC	0.68	12.8	21.1
EU	–	12.7	6.2
Russia	2.66	5.9	2.4
Japan	2.45	4.7	2.0
India	0.29	4.4	16.5

Source: Oak Ridge National Laboratory

(4.7%) and India (4.4%) in the fifth and sixth places, respectively. The PRC is already producing about the same amount of CO_2 as all 15 EC Member States together. India's CO_2 emissions are only slightly less than Japan's but larger than Germany's.

The principle problem is the completely different amounts of CO_2 emitted by different countries at different stages of development. Per capita CO_2 emissions in the USA are currently eight times that of the PRC and 19 times that of India (Table 3). Given the 1.2 billion population of the PRC and the 1 billion population of India, in the future, there is a high chance that per capita CO_2 emissions from these countries will increase dramatically due to the synergistic effect of gross population, concentration of population in cities and rising car ownership. Since the combined populations of the PRC and India now make up one-third of the world total population, even if per capita CO_2 emissions rise by only a small amount, it will have a dramatic impact on world total emissions. If the number of vehicles in the PRC increases in line western Europe, it is calculated that not only would the total oil reserves of Saudi Arabia be consumed but also CO_2 emissions would rise to 2 billion tonnes, or about one-third of the 1998 world total.

The Kyoto Protocol set targets for reduction of emissions by the world's advanced economies but not for developing countries. Due to future rapid urbanization and the spread of automobile ownership in Asia, it is very unlikely that world targets for CO_2 emission reductions will be achieved. Clearly, a move towards sustainable city transport systems with a low environmental burden, such as rail-based urban mass transit, is inescapable for Asia and the world.

Current Condition of Asian Urban Railways

Characteristics of urban systems

Typical urban transport systems include high-speed railways, monorails, AGTs, tramways, LRTs, buses, private motor vehicles, bicycles, etc., each with its own characteristic advantages and disadvantages. Introduction of a city transport system requires careful analysis of the transport and technical characteristics along with the scale of the city, the transport objective, the transport demand, etc., to ensure that the best system is selected.

High-speed urban rail systems such as subways can satisfy large transport demand amounting to several tens of thousands of people per hour in each direction and are a key transport infrastructure that can carry people at high speeds over either long or short distances. On the other hand, automobiles offer the high convenience of door-to-door travel but the transport efficiency is low due to limits on the number of passengers per vehicle; the hourly transport volume is also poor.

Intermediate modes using new technologies such as monorails, AGTs and trams running on dedicated guideways are appearing too. Furthermore, unlike rail-based transport systems, there are also new bus-based systems using relatively simple technologies such as dedicated bus lanes and buses running along guided paths.

Japanese urban railways

In addition to Japan's three major cities of Tokyo, Osaka and Nagoya, 15 other regional cities are served by rail-based transit systems such as monorails, subways and AGTs (Fig. 3). The JR Group's railway operators and other private railway companies are heavily involved in suburban housing and station developments as well as in intercity transport, making them major players in the transport systems of many Japanese cities.

Recently, long-distance commuting on shinkansen by office workers and students has become commonplace as free time has become more valuable and commuting distances have increased.

Subways

Public urban high-speed railways, especially public systems in city centres play an important role in city life. Subways are railways built under cities with a high density of above-ground infrastructure—but most subways emerge above ground as soon as they leave the densely occupied city centre. In Japan, cities with only a road system and a population exceeding 1 million usually suffer from road congestion and high-speed large-volume public transport systems, such as subways are essential infrastructure.

Subway construction is usually very expensive depending on the construction method and takes a long time, so it is important to confirm the likely profitability and minimize the construction costs.

As a consequence, linear motor subways requiring a smaller tunnel than conventional subways and costing much less to construct have recently been built in Tokyo, Osaka, Yokohama and Kobe.

The world's first subway was the Metropolitan Railway opened from Paddington (Bishop's Road) to Farringdon Street in the City of London on 10 January 1863. The first subway in Asia was opened in Tokyo between Ueno and

Figure 3 Urban Transit Systems in Japan

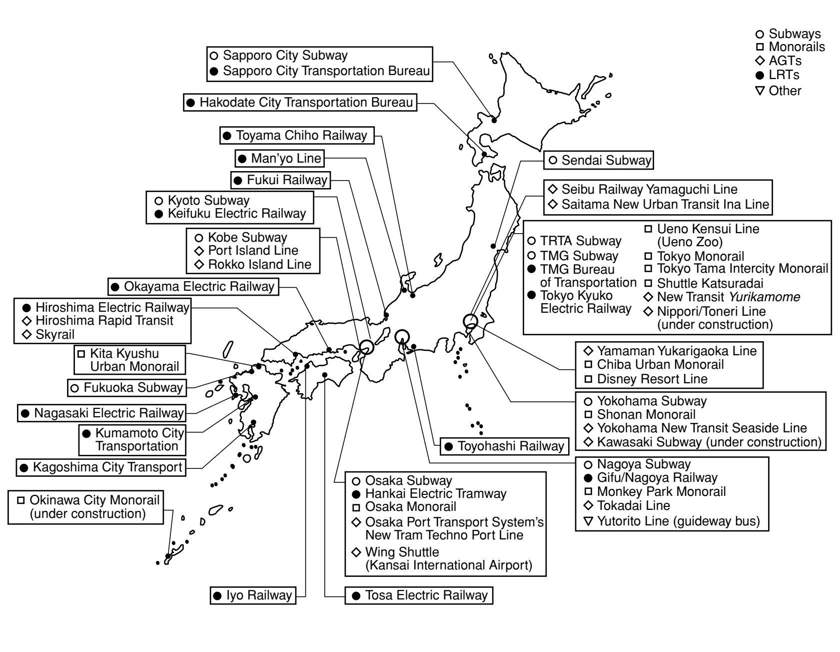


Figure 4 Delhi Metro Plan (Phase 1)

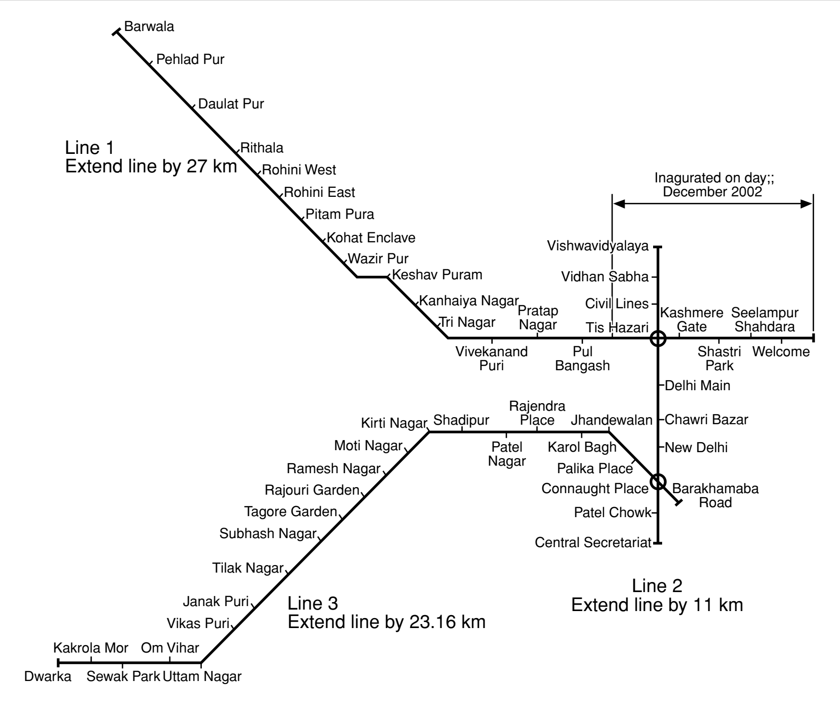


Table 4 Asian Subways

Couttries	Cities		Population (1000)	Year	Route-km	Lines	Stations	Employees	Fare system	Passengers (1000)	Track gauge (mm)	Electrical system	Current collecting system	Operations	Time interval	Rolling stock
Japan	Tokyo	TRTA subways	8,050	1927	171.5	8	159	10,106	Section	2,084,900	1,435, 1,067	DC600, DC1500	Third rail, overhead line	ATC, ATO	1 min 50 s	2,431
		TMG subways		1960	77.2	4	77	3,764	Section	575,110	1,435, 1,372, 1,067	DC1500	Overhead line	ATC, ATO, ATS	2 min 30 s	736
	Osaka		2,590	1933	115.6	7	111	6,506	Section	931,800	1,435	DC750, DC1500	Third rail, overhead line	ATC	2 min	1,200
	Nagoya		2,160	1957	76.5	5	74	3,122	Section	411,200	1,435, 1,067	DC600, DC1500	Third rail, overhead line	ATS, ATC	2 min	724
	Sapporo		1,810	1971	48.0	3	49	1,162	Section	206,210	2,150	DC750, DC1500	Third rail, overhead line	ATC	3 min 30 s	404
	Yokohama		3,390	1972	40.4	2	32	1,259	Section	125,690	1,435	DC750	Third rail	ATC	4 min 30 s	228
	Kobe		1,480	1977	22.7	1	16	697	Section	97,940	1,435	DC1500	Overhead line	ATC, ATO	3 min	168
	Fukuoka		1,300	1981	17.8	2	20	637	Section	114,300	1,067	DC1500	Overhead line	ATC, ATO	3 min	144
	Kyoto		1,460	1981	26.4	2	27	738	Section	110,400	1,435	DC1500	Overhead line	ATC, ATO	3 min 30 s	204
	Sendai		1,000	1987	14.8	1	17	321	Section	5,963	1,067	DC1500	Overhead line	ATC	3 min	84
	Hiroshima		1,120	1994	18.4	1	21	221	Section	1,884	1,700	DC750	Rigid double track	ATC	2 min 30 s	144
S. Korea	Seoul	Seoul Metropolitan Subway	10,230	1974	134.9	4	115	11,492	Zone	1,306,000	1,435	DC1500	Overhead line	ATS, ATC	2 min 30 s	1,944
		Seoul Metropolitan Rapid Transit		1995	89.0	3	86	4,951	Zone	410,000	1,435	DC1500	Overhead line	ATC, ATO	2 min 30 s	834
	Pusan		3,810	1985	54.9	2	55	2,630	Section	224,000	1,435	DC1500	Overhead line	ATC, ATO	3 min 30 s	528
	Daegu		2,440	1997	24.9	1	29	1,317	Section	44,000	1,435	DC1500	Overhead line	ATC, ATO	5 min	216
	Inchon		2,300	1999	21.9	1	22	954	Section	133/day	1,435	DC1500	Overhead line	ATC, ATO	4 min	200
N. Korea	Pyongyang		2,000	1973	22.5	2	17		Flat	35,000	1,435	DC825	Third rail	Automatic door	2 min	168
China	Beijing		6,270	1969	54.0	2	40	10,000	Flat	463,000	1,435	DC750	Third rail	Automatic door	3 min	652
	Tianjin		4,750	1980	7.4	1	10		Flat	15,000	1,435	DC750	Third rail	Automatic door	12 min	24
	Guangzhou		3,220	1997	18.5	1	16	2,200	Section	134,000	1,435	DC1500	Overhead line	ATC, ATP, ATO	5 min	162
	Hong Kong		6,000	1979	77.2	5	44	7,675	Zone	798,000	1,435	DC1500	Overhead line	ATS, ATP, ATO	1 min 52 s	923
Taiwan	Taipei		2,600	1997	56.5	5	54	2,300	Section	235,000	1,435	DC750	Third rail	ATC, ATP, ATO	5 min	450
Malaysia	Kuala Lumpur		1,140	1998	29.0	1	24	600	Section	10/day	1,435	DC750	Two side tracks	ATO, no driver	1 min 30 s	70
Singapore	Singapore		304	1987	83.0	2	48	28,300	Section	315,000	1,435	DC750	Third rail	ATO, ATP	2 min	510
India	Calcutta		11,000	1984	16.5	1	17	3,136	Section	62,000	1,676	DC750	Third rail	ATP	10 min	144
	Dehli		13,000	2002	8.3	1	6	800	Section	20/day	1,676	AC25000	Overhead line	ATP, ATO	8 min	24
Turkey	Ankara		2,890	1996	23.1	2	22	10,000	Flat	107,500	1,435	DC750	Third rail	ATC, ATO	3 min	141
	Istanbul	Light Metro	11,000	1989	17.8	1	16	625	Flat	127,000	1,435	DC750	Overhead line		5 min	105
		Cable Car		1875	0.6	1	2	20	Flat	7,800	1,510	DC440	Overhead line	ATO, Abt system	3 min	4

Table 5 Asian Monorails (excluding Japan)

Couttries	Operation section	Length (km)	Stations	Distance between stations	Type	Train set	Passengers	Capacity	Location	Year
Korea	Daejeong	2.4	3	800	Straddled (tyre)	8	-	-	Research complex	1993
China	Shenzhen	1.7	3	567	Straddled (tyre)	3	-	-	Over road	1993
	Shenzhen	4.4	7	629	Straddled (tyre)	3	-	-	Over road	1998
Malaysia	Kuala Lumpur	3.2	3	1,067	Straddled (tyre)	-	-	-	Over road	2000
	Kuala Lumpur	8.6	11	782	Straddled (tyre)	-	-	-	Over road	2000
Singapore	Sentosa Island	6.4	6	1,280	Straddled (tyre)	-	-	-	Park	1981
	Jurong Birdpark	1.7	2	850	Straddled (tyre)	4	-	-	Park	1991
Australia	Sydney Harbour Link	3.6	8	450	Straddled (tyre)	7	80	5,000	Over road	1988
	Broad Beach	1.3	3	650	Straddled (tyre)	2	88	1,500	Over road	1989
	Gold Coast Sea World	2	3	667	Straddled (tyre)	2	100	1,800	Park	1988

Table 6 Asian AGTs (excluding Japan)

Couttries	Operation section	Length (km)	Stations	Distance between stations	Type	Train set	Passengers	Capacity	Location	Scheduled speed	Maximum speed	Year
Taiwan	Taipei–Mucha Line	11.5	12	1,045	Rubber tyre, lateral guide rails	4	-	25,000	Over road	-	70	1996
China	Hong Kong International Airport	0.75	2	750	Rubber tyre, lateral guide rails	2	152	6,000	Airport/building	22.4	70	1998
Singapore	Changi Airport	1.3	3	650	Rubber tyre	-	-	5,000	Airport/over road	22.4	44.8	1990
	Bukit Panjang	7.8	14	600	Rubber tyre, central guide rails	19	105	40,000	-	25.0	55.0	1999

Asakusa in 1927. New subway lines followed in S. Korea, N. Korea, PRC, Taiwan, Malaysia, Singapore, India and Turkey. Amongst these in Malaysia, a completely driverless linear motor subway linking the city centre and suburbs was opened in 1998. In December 2002, Indian Prime Minister Vajpayee opened the first 8.3-km overhead section of the 198-km high-speed Delhi Metro presently under construction (Fig. 4).

A 20-km subway extension is presently being constructed in Bangkok by the build-operate-transfer (BOT) method with opening expected in April 2004. This new

Kashmere Gate Station of Delhi Metro Line 1 (N. Osawa)

Shahdara Station of Delhi Metro Line 1 (N. Osawa)

construction philosophy is being used to plan and build many Asian cities such as Beijing, Shanghai, Nanjing, etc. (Table 4).

Monorails

Monorails are a transport system in which straddled or suspended carriages run on rubber tyres along a single track. Although they have a lower transport capacity than traditional railways, monorails can be built into the densely populated centres of cities because the pillars supporting the overhead rail have a small footprint and the track can negotiate steep gradients and tight curves thereby greatly reducing land acquisition costs and facilitating relatively economic construction and operation.

Japan's first genuine commercial city monorail was the Tokyo Monorail opened in 1964 to provide access to Haneda Airport. Other monorails have been built in Osaka, Chiba and elsewhere. In addition, smaller monorails that carry 50 passengers in each car are being developed for regional cities with lower transport demand. Monorails have been introduced in the PRC, Malaysia, Singapore, etc. (Table 5).

Automated Guided Transit (AGT) systems

Generally, AGTs are a medium-capacity transport system in which driverless, lightweight-rubber-tyred vehicles run under computer control along a guideway, etc. Like monorails, AGTs are a relatively medium-capacity transport system that can be easily built in heavily built-up central city areas because the footprint of supporting pillars is small, making land acquisition costs relatively economical. The first AGTs in Japan were the Port Island Line (*Portliner*) in Kobe opened in 1981 and the Port Town Line in Osaka Bay. Subsequently, basic specifications for this new type of transport system were decided by the old Ministry of Transport and Ministry of Construction and Japan now has 10 operating AGTs.

In Asia, AGTs have been used to provide city transport systems as well as airport access in Taiwan, the PRC and Singapore (Table 6).

Light Rail Transit (LRT) systems

LRTs are really a new technically enhanced adaption of the older tramway systems abandoned by many western cities in the early postwar period. Generally, they are rail-based and share space with roads. LRTs are a medium-capacity transport system in which relatively small cars run as a short train set. Recently, LRTs have appeared in longer configurations on dedicated tracks, making them hard to define as a single unified transport group. They have been positively adopted in some parts of Europe as part of city plans to revitalize city centres, and counter air pollution from cars, etc.

Japan has 18 cities with operating LRTs and new low stepless types are also being introduced for more convenient barrier-free access for elderly and disabled people.

LRTs are being introduced in the PRC, India, N. Korea, Turkey, etc., but the numbers are relatively small compared to Europe.

Line 1 (14 km) of Manila's Metrorail was the first fully grade-separated overhead LRT opened in 1984. Since this type of system is smaller, lighter and more functional than older heavy rail systems, it is slightly different from the general definition and became known as the LRT. Line 3 (16.9 km) was fully opened in June 2000 and part of Line 2 was opened in April 2003.

A similar LRT was built in 1988 in Tunmen, a suburb of Hong Kong. It is 23-km long, and links central Hong Kong with a new town that has a planned population of 550,000 people. It was also designed to provide transport for people within the new town, which covers a relatively wide area. It runs at ground level rather than overhead, and has 41 stations.

Since December 1999, Bangkok has also opened 23.5 km of the Silom and Sukhunvit lines in the Bangkok Transit System (BTS). After 1 year of operations, 175,000 people were using these lines each day and by the end of the second year, this figure had reached 300,000, establishing the system as a popular mass transit system for Bangkok's residents. This increase in passengers was achieved by meticulous attention to detail, such as issuing passes with a 30-day validity and introduction of special tourist passes.

Upgrading existing railways

Many Asian cities already have national railways that provide intercity transport but they are not actively involved in urban transport. In Jakarta, Indonesia, some national railway tracks have been doubled and electrified to provide upgraded urban transport and 9 km of track has been improved by grade separation, etc.
Similar tests are under way in Kuala Lumpur where some existing suburban lines belonging to the national railways have been double-tracked and electrified.

Future Themes for Asian Urban Railway Infrastructure

City transport master plans

In the 1950s, the former Japanese Ministry of Transport established a transport planning committee to examine how Tokyo's transport system should be developed. It offered a number of findings such as a construction plan for subways, direct through operations between different operators, etc., pointing to a large expansion of the city's transport systems. The committee's recommendations did not have binding legal power but since they were based on the opinions of people related to creation of a long-term national master plan, such as municipal authorities, railway operators, academics, etc., they played a major role in important future decisions, such as through operations.
In developing counties, the local authorities are responsible for various types of city planning but there is often no central authority responsible for long-term planning, which creates problems for important city functions such as infrastructure networks. Asian megacities can sprawl out to a radius of 30–50 km, making railways a very important part of the various transport layers. In other words, it is essential to create a city transport network combining the various different transport modes such as buses, monorails, AGTs, LRTs, etc., providing relatively short-distance travel and access to medium-distance urban transport, such as subways and above-ground railways, in turn providing access to medium-to-long distance transport, such as suburban commuter high-speed railways.
A good city master plan should consider the characteristics of each transport system while also taking into account future trends in transport demand. Furthermore, important infrastructure like station buildings, plazas, etc., must consider the convenience of modal changes, such as providing car and bicycle parking. Moreover, it is important to examine links with other major transport modes, such as railway links to city airports.
Capital cities like Bangkok and Manila often have huge concentrations of population density and for reasons of balanced national development it is important to have guidelines concerning development of other regional core cities.

Cooperation between city development and urban railways

Arranging a transport network requires close coordination between city planners and city developers. In recent years, there has been a worldwide trend towards TOD aimed a freeing cities from overdependence on automobiles. The concept is rather broad but Professor Hitoshi Ieda of the University of Tokyo has proposed the following four aspects:

- Strong links between suburban housing development and public transport infrastructure
- Strengthened city centres based on public transport
- Redevelopment of city sub-centres especially railway stations and surrounding environs
- Control of land usage and overall city structure bearing in mind use of public transport

These concepts and methods are key points when considering future development of public transport in Asia.
Singapore is a typical example of an Asian city strongly in favour of TOD. It is an island state covering some 650 km^2 with a population of about 3 million people. There is a strong linkage between city policies and transport and in addition to building high-speed urban railways since 1970, there has been a lot of medium- and high-rise building development centred on railway stations. AGTs, buses and minibuses provide excellent first-mode access to railway stations and it is easy to get around the city even without a car. Furthermore, since 1995, Singapore has levied road-pricing tolls on passenger cars entering a designated central zone with the intention of alleviating road congestion. In the early days, the tolls were collected manually but an IT-based automatic payment system using an in-vehicle pre-paid cash card was introduced in 1998.
To promote use of public transport and control traffic burdens, the city authorities have implemented a comprehensive system of TDM. For example, private cars are heavily taxed, tolls are levied on passenger cars entering the central zone, and car parking fees are regularly increased. In addition park-and-ride facilities are plentiful to encourage people to leave their cars outside the city.

Using existing stock

The national railways of many Asian countries have a lot of tracks that were built during the old colonial period. They are usually single-tracked, non-electrified and very worn. Quite a few are used for intercity and freight transport but there are limits on their use for urban rail services because good links cannot be made between the fragmented local authorities.

Test run on Manila LRT Line 2 (Author)

Train on BTS in Bangkok (G. Sakai)

Many national railways operate in deficit due to government policies to keep fares low, creating problems with inadequate investment for modernizing old and worn infrastructure. Another problem is illegal squatters building housing on trackside land, which prevents track improvements. However, building new urban railways requires massive investments in both land acquisition and building infrastructure. In particular, in developing countries there is often no choice other than importing most of the high-level materials from developed countries at high prices.

In Europe, etc., there is already a widespread network running out to the suburbs permitting direct through operations of LRTs on existing railway lines; urban railways are being revitalized by upgrading low-density passenger lines and freight lines through increasing the numbers of stations and using higher-performance trains.

A few cities like Jakarta and Kuala Lumpur have used similar strategies to the previous examples and countries like Viet Nam and Myanmar, which already have relatively good existing railway networks, should build economic urban railways by using existing stock. Like Japan, for improved passenger convenience such countries could construct wide transport networks by offering through operations between new urban lines and existing suburban lines.

Cost reductions

An urban railway requires massive capital investment in infrastructure and the long repayment terms are a major problem in obtaining funds. Since there is an argument for keeping fares low in developing countries because railways are important social capital, finding ways to keep construction costs down and minimize capital tied up in rolling stock are important issues in achieving profitability after the railway opens. In other words, cost reduction is a major issue in building urban railways.

Subways are an especially good transport system because they do not interfere with roads, make efficient use of publicly owned land when built under existing roads and do not cause environmental problems, such as noise pollution. However, subway construction requires huge initial capital investment. To keep tunnelling costs down and eliminate problems of damaging existing above-ground structures, various new technologies such shield tunnelling, backfilling with excavated soil and deep tunelling are being developed.

Generally, building urban railways and subways through developed city land requires huge amounts of time and effort to acquire the necessary land and enormous construction costs due to problems with grade separation from roads, underground structures, etc. As a consequence, building an urban railway requires long-term strategies and should ideally be completed before the city is built.

Rolling stock and signalling systems are usually imported from overseas and until now many cities have built transport systems using different technical specifications. In addition, some cities even have railways operating to different technical standards, causing problems with interchangeable spares, through operations, joint ticketing, etc.

Consequently, it is important for Asian urban railways to cut costs by developing common technical standards and specifications. This would cut both design costs, and reduce manufacturing costs through economies of scale. In addition, other economies are possible through use of common spares for maintenance, etc. Another very important subject is education and training of human resources so that railway planning, design and installation can all be performed domestically.

Confirming resources

Urban railways are part of the basic social capital of cities. In addition, they are also a long-term asset with fixed costs such as renewal of wooden and earth structures, stations, tracks, etc., and they also have external costs on the economy, society and environment. In addition, urban

Morning rush hour at Mangala Station, Jakarta (I. Tsuruda)

railways have long conception periods involving a great number of risks such as extended period of time to acquire land for tracks, large funding needs, cooperation with many related bodies, demand forecasting, fare setting (keeping fares low as social policy), etc. As a consequence, public bodies such as the national government and local authorities must play a principal role, especially in funding. Many urban railways in Europe benefit from public subsidies to assist with infrastructure costs. In addition, operations may also be subsidized to cover deficits resulting from operating loss-making 'social' services or to keep fares low.

Urban railways require huge capital, making them a difficult priority when choosing which basic social infrastructure projects to fund but they form important social capital in a city's structure, and should be given first priority in budget allocations. In addition, it is essential to obtain effective funding from multiple sources such as taxes levied on car users and investment from developed nations and international organizations.

In recent years, some Asian urban railways have been funded by private capital using BOT, build-transfer-operate (BTO) and build-lease-and-transfer (BLT) methods. Various other public–private partnerships (PPP) and private finance initiative (PFI) methods are also being investigated. In addition, vertical division methods such as separation of infrastructure and operations are being adopted. These techniques offer ways of building infrastructure without government investment but there are risk management issues. The Bangkok Hopewell Project was intended to build a joint overhead rail and road network on government land using the BOT method. Construction started but delays and the Asian Financial Crisis in 1997 prevented Hopewell Corporation from obtaining the necessary funds and the company finally broke the contract and abandoned the project. The partly finished infrastructure, such as the overhead structures, remains rotting in the tropical rain. Clearly, developing countries require sufficient pre-consideration of legal implications and risk management as well as clarification of responsibilities before undertaking major infrastructure projects.

Moreover, it might be useful to consider alternative sources of funding such as new types of environment funds. With increasingly severe environmental problems, in recent years, international rules have been established to limit emissions of greenhouse gases. Since the aim is to cut global emissions, a system has been established to cut factory emissions, plant trees, etc., funded by international trading of national emission rights. Japan plans to establish an environmental fund for trading emission rights centred on the Japan Bank of International Cooperation, etc., by September this year. A switch to urban railways from cars is one solution to help cut CO_2 emissions and solve energy problems. Consequently, we propose a system of funding urban railway construction using financial resources created by trading emission rights. Since cities in some less-developed Asian countries have very large populations, these countries offer the attraction of having very large emission rights that could be traded with advanced countries to raise capital for railway construction.

International cooperation and action

So far, we have described some ongoing measures for improving Asian cities. The types of railways that are in use vary according to complex factors such as the city geography, history, culture, etc., presenting great difficulties in arriving at a universal standard for railways, unlike the car. Like in the Japanese example, it is difficult to apply the experience of one city to all other cities in Asia but there is some benefit in considering the lessons learned by the various cities. For example, private railways play a major transport role in large Japanese cities and they have business groups responsible for developing housing along their lines as well as commercial businesses like department stores and hotels near their station terminals, which produce internal profits for the group. Maybe some Asian

Manila LRT Line 3 running on centre divide of road (Author)

Alabag Station on Philippine National Railways (Author)

cities could copy this business strategy. Asia nations are gradually embracing free trade and their economies are becoming more globalized. Although city transport problems are local, they also have a global component through their impact on the environment and energy resources; solving these major global problems certainly requires international cooperation. It is not enough to just strengthen the organizations and systems of each country and city—they also require networking via the Internet to facilitate information sharing, etc. Since development and construction of sustainable city transport systems are major international subjects, there is an undoubted need for an international database where the current conditions, problems, and experiences of each city can be accessed by all. The aim of building sustainable cities will require strengthened international cooperation between governments, industry and academia in a variety of fields, including education of the workforce, establishment of common specifications, technical cooperation, financial cooperation, etc.

To build shinkansen and urban railways economically, quickly and to the highest technical standards in Japan, the Japan Railway Construction Public Corporation (JRCC) performs a variety of roles including investigation, planning, design, construction supervision, materials procurement, etc., based on its wealth of technical experience. JRCC has a great deal of expertise in assisting with construction of urban railways such as subways, elevated lines, airport lines, etc., both in Japan and overseas in countries like Thailand and Indonesia. It provides technical exchanges with overseas railways both through accepting foreign trainees and researchers at its facilities in Japan, dispatch of staff overseas for short- and long-term periods, cooperation with R&D, etc. JRCC staff are using their long experience of domestic urban railways and technologies to help solve transport problems in Asian cities and hope that their work will make an international contribution to solving the world's environmental and energy problems. ■

Further Reading

Toshi-kotsu Kenkyukai, *Korekara no toshi-kotsu* (Future Urban Transport), Sankaido, 2002.

H. Ieda and N. Oka, *Toshi saisei—Kotsu-gaku kara no kaito* (City Rebirth—Answers from Transportation Studies), Gakugei Shuppan-sha, 2002.

K. Takeuchi and Y. Hayashi, *Chikyu kankyo to kyodai toshi* (Global Environment and Megacities), *Iwanami Koza Chikyu kankyo-gaku* (Iwanami Lectures on Global Environment), Vol. 8, Iwanami Shoten, 1998.

Y. Akiyama, *Sekai no tetsudo jijo—Asia hen* (World Railway Situation—Asia), Yoshii Shoten, 1998.

H. Ieda, *Ajia no kotsu—Do miru ka, soshite Nihon ni yakuwari wa?* (Asia's Transport—How Do We See It and What is Japan's Role?), *Un'yu to Keizai*, November 1998.

K. Ota, *Jizoku kano na toshi kotsu ni mukete* (Aiming for Sustainable Urban Transport), *Un'yu to Keizai*, January 2001.

UNESCAP, Review of Transport in the ESCAP Region 1996–2001.

Toshiji Takatsu

Mr Takatsu is the Deputy Director of the Tokyo Regional Bureau of the JRCC. After obtaining a degree in civil engineering from Hokkaido University, he joined JNR in 1972. When JNR was privatized in 1987 he transferred to JRCC. He worked for UNESCAP from 1990–92 as transport specialist. He is a joint author of *Korekara no toshi-kotsu* (Future Urban Transport) published in Japanese by Sankaido, 2002.