2

Infrastructure and Urban Development: Evidence from Chinese Cities

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Infrastructure services—including power, transportation, telecommunications, provision of water and sanitation, and safe disposal of wastes—are central to economic production and urban growth. It is commonly agreed that infrastructure plays an important role in stimulating urban land development and private economic activity (Démurger 2001; Gramlich 1994). The adequacy of infrastructure—which can contribute to diversifying production, expanding trade, coping with population growth, reducing poverty, or improving environmental conditions—helps determine a country's success (World Bank 2004) by accommodating economic and urban growth (Calderon and Serven 2004).

Infrastructure has been used as a tool to stimulate the growth of human settlements in many urban areas. Policy makers and planners have used infrastructure systems to attract private investments for housing and economic development. Despite this, the link between infrastructure and urban growth remains understudied, and infrastructure research has developed in isolation from the large literature on urban growth.

This chapter discusses the links between infrastructure provision and urban expansion, the relationship between levels of infrastructure and land prices, and the mechanisms used to finance infrastructure. Data and case studies from developed and developing cities in China provide empirical evidence about the extent to which the provision of infrastructure affects urban development and shapes development patterns.

China was chosen as the case study for this chapter because it provides sufficient dynamics and variation to enable the investigation of these research questions. In three decades of market-oriented reforms, China has been one of the world's fastest-growing economies, with per capita real incomes more than quadrupling since 1978. During this period, China has made substantial investments in infrastructure and has improved access to services such as safe water, sanitation, electric power, telecommunications, and transportation (J. Zhang 2011). Today, China is set to accelerate the construction of urban public infrastructure by investing as much as 7 trillion yuan (US$1.03 trillion) during its 12th Five-Year Plan from 2011 to 2015.

The scale of infrastructure investment and the extent to which infrastructure has transformed the urban landscape in China might seem remarkable. However, problems persist in the form of insufficient provision of infrastructure, discrepancies in the level of infrastructure across regions, deficiencies in cost recovery, inadequate sources of financing, and the lack of incorporation of sustainable principles in shaping urban growth. This chapter describes these challenges in infrastructure provision in China and explores the causes of some of the existing problems.

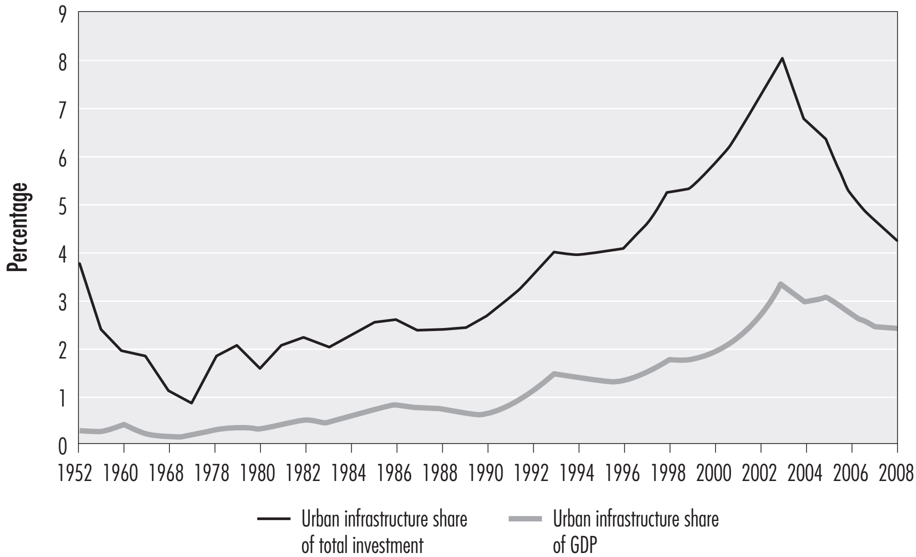
An Overview of Infrastructure Development in China

THE SCOPE OF INFRASTRUCTURE INVESTMENT IN CHINESE CITIES

Since implementing economic reform with the adoption of its opening-up policy in 1978, China has made substantial investments in infrastructure, improving access to services such as clean water, sanitation, electricity, telecommunications, and transportation (Economic Research Institute for ASEAN and East Asia 2007). Urban infrastructure investment in China has grown exponentially in the last several decades. From 1978 to 2008, urban infrastructure investment as a percentage of gross domestic product (GDP) fluctuated between 0.33 and 3.29 percent, while urban infrastructure investment as a percentage of total investment ranged between 1.79 and 8.02 percent (figure 2.1). Despite this marked increase, infrastructure investment in China relative to both GDP and total investment was lower than it was in other developing countries, as reported in a World Bank survey, and it was below the levels recommended by the United Nations (World Bank 2004), as shown in table 2.1. Although China spends about 50 percent of its GDP on fixed investment (compared to the world average of less than 20 percent or the U.S. figure of 15 percent), only a small percentage is spent on urban infrastructure.

As shown in figure 2.1, China's investment in infrastructure in recent years has increased, relieving economic and social development pressures caused by limited infrastructure. This investment has been driven by the high demand for infrastructure services, which has been fueled by steady economic growth. Increased public expenditures in infrastructure are also related, in part, to the proactive fiscal policy adopted by the government to minimize the impact of the financial crisis (Liu 2010). Many problems still exist with the current practice of infrastructure development. Inadequate infrastructure is evident in some regions,

Figure 2.1
Urban Infrastructure Investment: Share of Total Investment and Share of GDP, 1952–2008



Sources: Ministry of Housing and Urban-Rural Development of China (2000–2011); National Bureau of Statistics of China (1996–2011).

Table 2.1
Infrastructure Investment Share in Developed Countries, 1950–1990

	USA (1950–1983)	Japan (1960–1980)	Germany (1976–1980)	Developing Countries Percentage Recommended by UN	Developing Countries Percentage Surveyed by World Bank (1980–1990)
Infrastructure investment as a percentage of GDP	1.2–1.8	2.1–4.2	1.7–1.9	3.0–5.0	2.0–8.0
Infrastructure investment as a percentage of fixed assets investment	6.0–10.2	6.4–12.9	7.3–9.0	>10.0	20.0

Source: World Bank (2004).

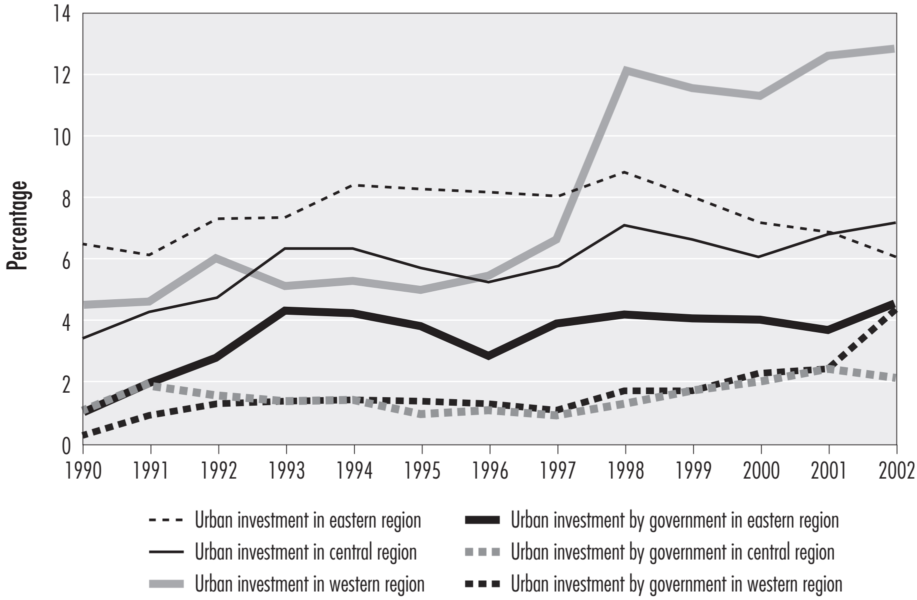
especially the western region, despite the recent increase in investment. In addition, insufficient investment in infrastructure could hinder urban and economic growth (Economic Research Institute for ASEAN and East Asia 2007).

REGIONAL DISCREPANCIES IN URBAN INFRASTRUCTURE INVESTMENT

To analyze regional discrepancies in urban infrastructure investment, data are agglomerated for three urban regions—east, central, and west—to compare levels of infrastructure investment. For the purposes of comparison, the eastern area includes the cities of Beijing, Shanghai, Tianjin, Guangzhou, Nanjing, Shenyang, Qingdao, Jinan, Shenzhen, Xiamen, Dalian, Hangzhou, and Ningbo; the central area includes Wuhan, Changchun, and Ha'erbin; and the western area includes Chongqing, Chengdu, and Xi'an.

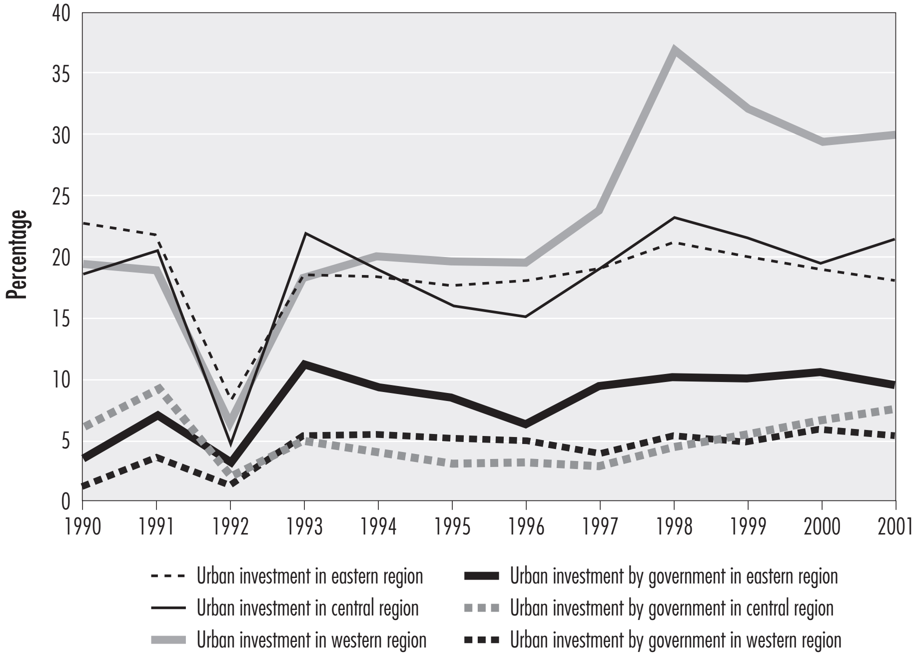
Figures 2.2 and 2.3 reveal several regional patterns of infrastructure investment. First, as the more industrialized and developed part of the country, eastern cities entered an advanced stage of economic development with a relatively stable or slightly declining ratio of urban infrastructure investment to GDP. Around 1998, infrastructure investment in eastern cities started to drop after having risen

Figure 2.2
Urban Infrastructure Investment: Share of GDP by Region, 1990–2002



Sources: Ministry of Housing and Urban-Rural Development of China (2000–2011); National Bureau of Statistics of China (1996–2011).

Figure 2.3
Urban Infrastructure Investment: Share of Total Infrastructure Investment by Region, 1990–2001



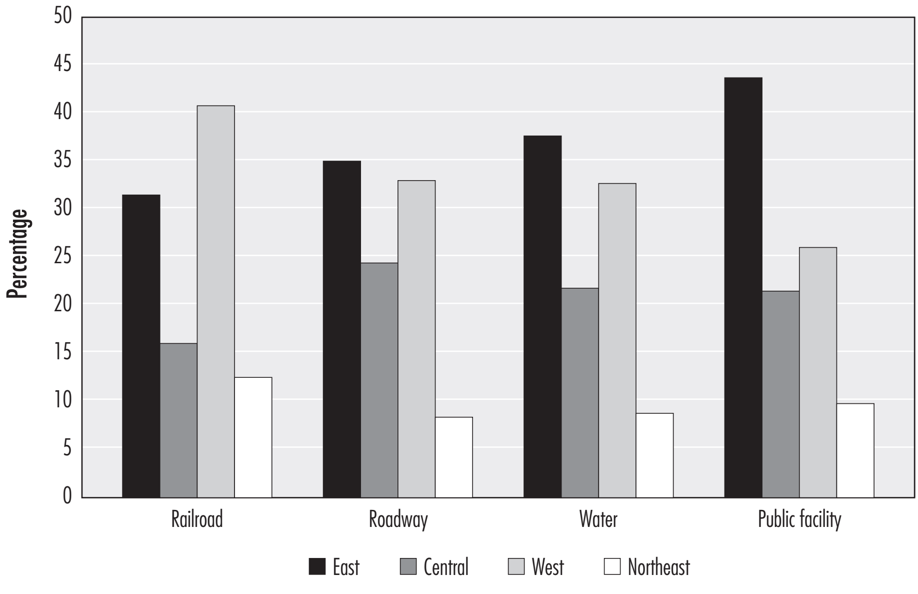
Sources: Ministry of Housing and Urban-Rural Development of China (2000–2011); National Bureau of Statistics of China (1996–2011).

continuously for years: the ratio of urban infrastructure investment both to GDP and to investment in fixed assets has dropped, falling below the levels of the central and western cities (figure 2.2). This can be attributed to a comparatively high GDP and high amounts of fixed capital, which hold the ratio investment at a relatively low level. The ratio of governmental infrastructure investment to GDP and to investment in fixed assets, however, remains relatively high (figure 2.3), consistently surpassing levels in the central and western cities. Second, from 1997 to 2002, western cities had the highest ratio of investment in urban infrastructure to GDP. Driven by the national Develop the West strategy, the ratio in western cities increased rapidly after a long-term downturn and surpassed the ratio of the eastern and central cities. In addition to exhibiting the lowest ratio of investment in urban infrastructure to GDP, cities in the central region had the lowest infrastructure investment per capita (National Bureau of Statistics of China 1996–2011). Through the mid-1990s, the ratio in the central cities increased moderately but remained below that of the east.

A different classification of regions sheds light on how different types of infrastructure investments vary across China. Figure 2.4 illustrates the distribution of several types of infrastructure investments in the east, central, west, and northeast regions. Infrastructure investments in interior areas have grown significantly in recent years following several policy regimes, including Develop the West, Revitalize Old Industrial Bases in the Northeast, and Boost the Equalization of Public Services. From 2003 to 2010, on average, 40.5 percent of China's railway investment was channeled to the west. Over the same period, road investment in the west comprised 32.7 percent of the national total. This heavy investment in the western region's transportation infrastructure has decreased businesses' transportation costs and has promoted the redistribution of industry from coastal areas to the interior. The investment in public services is highest in the east, followed by the western, central, and northeastern regions. The east's higher financial capacity as compared to other regions accounts for its larger share of investment in public facilities, such as drainage systems within cities.

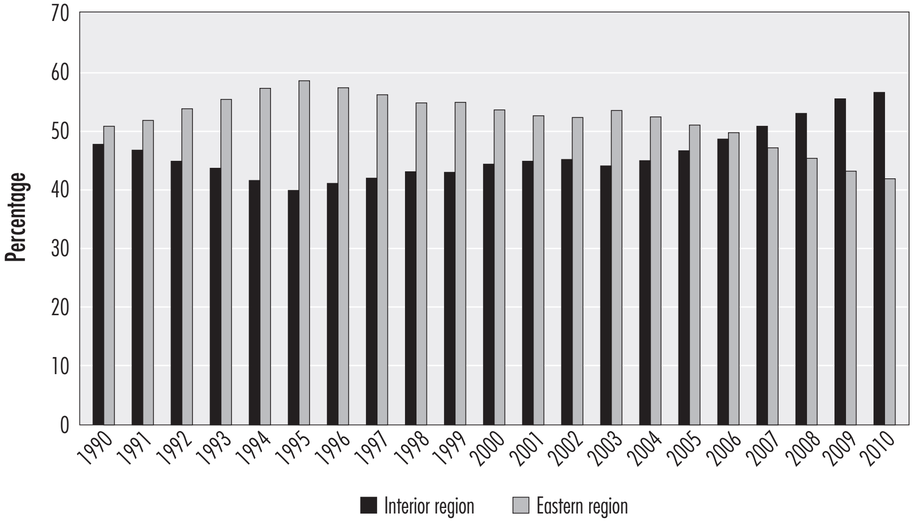
In general, infrastructure investment is shifting from more developed cities to developing cities. Figure 2.5 compares the distribution of infrastructure in-

Figure 2.4
Distribution of Infrastructure Investments by Type and Region, 2003–2010



Source: State Council Development Research Center Information Network (1980–2010).

Figure 2.5
Infrastructure Investment Shift by Region, 1990–2010



Source: National Bureau of Statistics of China (1996–2011).

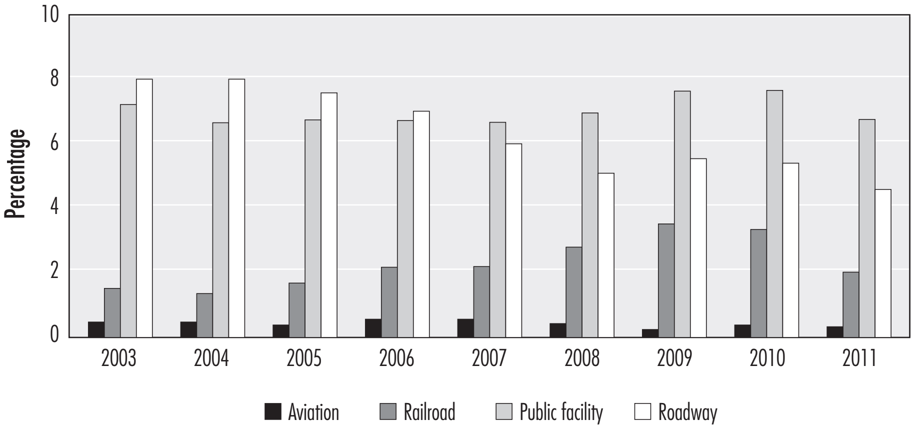
vestment in the eastern and inland regions as a whole between 1990 and 2010. Infrastructure investment in the eastern region was greater until 2007, when it was surpassed by investment in the interior.

TRANSPORTATION INFRASTRUCTURE INVESTMENT

Since the late 1980s, China's investment in major urban transportation infrastructure, including railroads, roadways, aviation, and public facilities, has increased significantly with rapid urbanization in the country (Economic Research Institute for ASEAN and East Asia 2007). Figure 2.6 demonstrates investment trends by type from 2003 to 2011. During this period, total investment in major transportation infrastructure accounted for 13.2 to 17 percent of total urban investment, or 15.7 percent on average. Contributing to the rise in government spending in 2009 was an increase in investment to address the financial crisis, resulting in a small peak in investment in railways and public facilities.

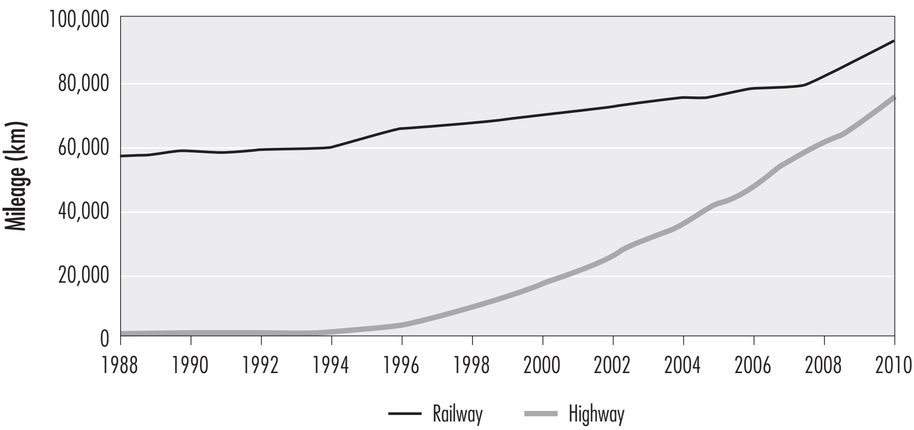
More specifically, railway mileage increased from 51,700 kilometers to 78,000 kilometers, a total increase of 50 percent and an average annual increase of 1.4 percent from 1978 to 2007 (figure 2.7). During this period, road mileage tripled, and civil aviation mileage increased 15-fold. According to the Interim and Long Term Railway Network Plan adopted by the State Council in 2004, the target is to add 120,000 kilometers of railway to the nation's existing 91,000-kilometer network by 2020, with an investment of 700 billion RMB (approximately

Figure 2.6
Ratios of Investment in Major Urban Transport Sectors to Total Urban Infrastructure Investments, 2003–2011



Source: National Bureau of Statistics of China (1996–2011).

Figure 2.7
Railway and Highway Mileages, 1988–2010

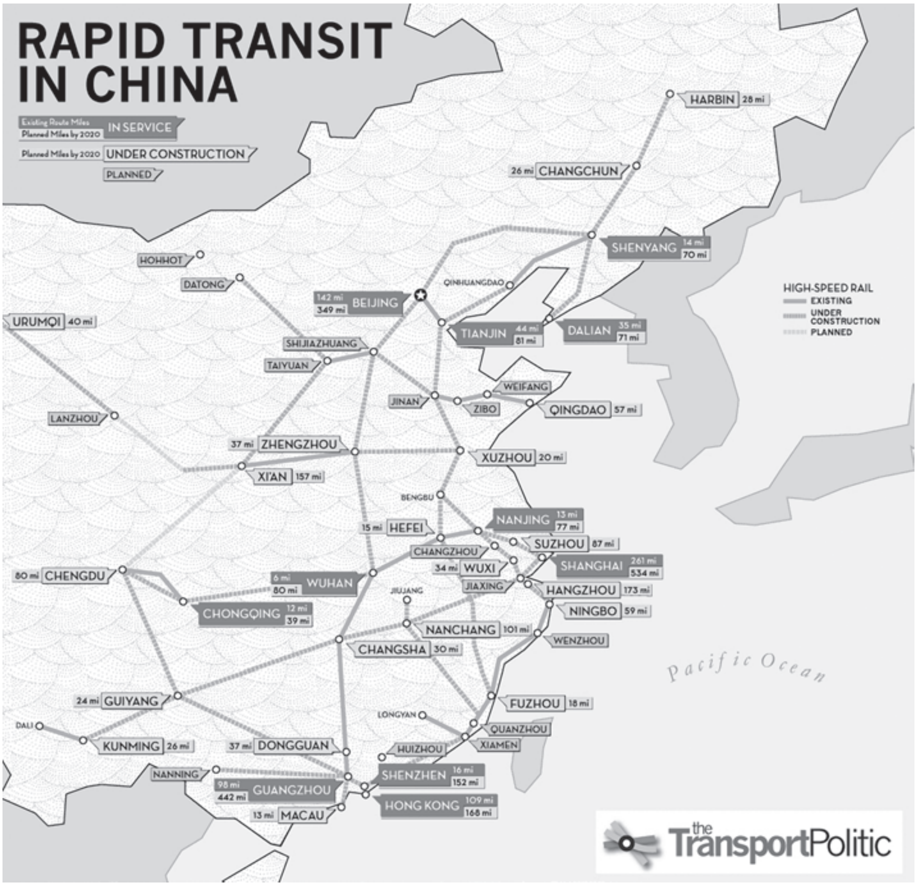


Source: National Bureau of Statistics of China (1996–2011).

US$113 billion) in the 12th Five-Year Plan period between 2011 and 2015. The objective set in the 12th Five-Year Plan is to construct an additional 120,000 kilometers of railway before 2015, 45,000 kilometers of which would be high-speed railway. China currently has 13,000 kilometers of high-speed railway. A high proportion of these planned infrastructure projects will connect cities in the western region, such as from Xining to Lanzhou, or will connect cities in the west to those in the central or eastern regions.

Intra-urban railway transportation infrastructure is also developing at an accelerated rate. In Shanghai, for example, the State Development Reform Commission has approved a plan to increase subway mileage to 850 kilometers by the end of 2015, which would far exceed the total subway mileage in New York or London. Spatially, these new intra-urban railways are concentrated; as shown in figure 2.8, 95 percent of urban railway transportation is concentrated in 11 provinces and cities in the east and is developing at an exceptionally rapid pace in the Yangtze River Delta.

Figure 2.8
Distribution of Rapid Transit in China



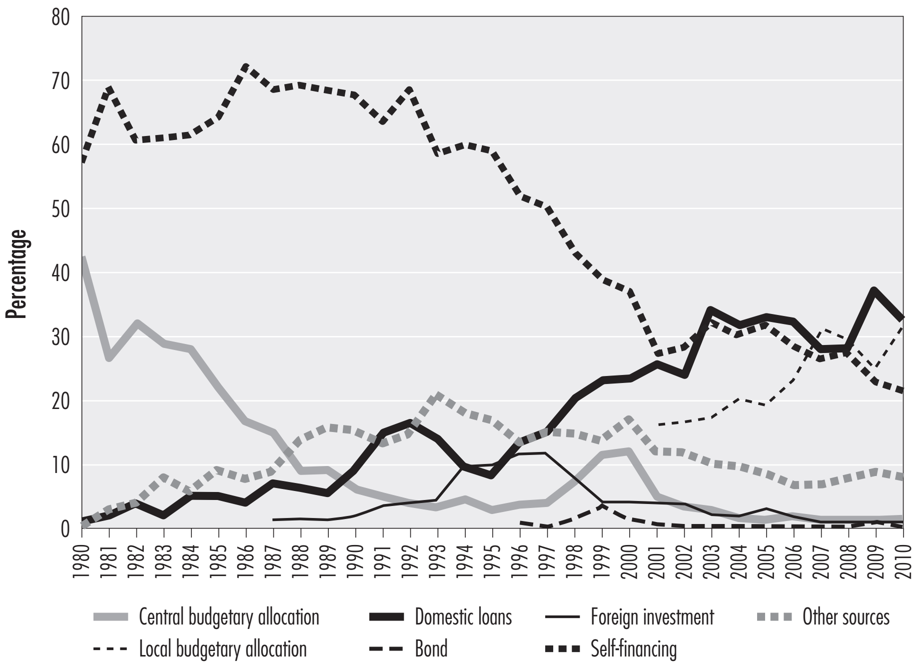
Source: Freemark (2010). Reproduced with permission.

THE FINANCING MECHANISMS OF URBAN INFRASTRUCTURE IN CHINA

Funding for urban infrastructure in China comes from seven sources: central budgetary allocation, local budgetary allocation, domestic loans, bonds, foreign investment, self-financing, and other funds. The funding sources have become much more diversified since the beginning of China's economic reform in the early 1980s. New financing channels for urban infrastructure construction emerged with the introduction of foreign capital in 1985, bond financing in 1996, and local budgetary allocation in 2001.

Figure 2.9 shows the evolution of China's different funding sources as a proportion of total urban infrastructure investment since 1980. Central budgetary allocation gradually decreased as a percentage of total investment, dipping below 10 percent in 1988 and remaining there, except for 1999 and 2000, when the government increased investment in infrastructure to cope with the impacts of Asian financial turmoil. In these two years, central budgetary allocation reached 11.96 percent and 12.75 percent of total funding, respectively. Nonetheless, the

Figure 2.9
Changes in Funding Sources for Urban Infrastructure Investment, 1980–2010



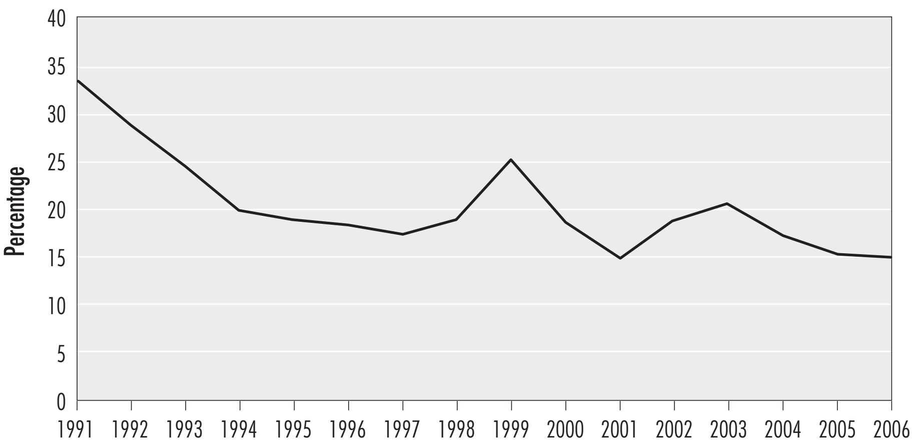
Source: Statistics from State Council Development Research Center Information Network (1980–2010).

central government has not been a major source of funding for urban infrastructure since the 1980s. Figure 2.9 also shows that urban infrastructure funding has gradually evolved. Self-financing and domestic loans are now the primary sources of funding, supplemented by a wide range of additional sources, including central government investment, foreign investment, and bond projects. The extent of private and foreign investment in infrastructure development has been very small, with the foreign direct investment (FDI) accounting for less than 2 percent (Sahoo, Dash, and Nataraj 2010).

The proportion of the central budget in financing urban infrastructure has been decreasing rapidly in recent years, largely due to the implementation of a tax-sharing policy in 1994. At the same time, the increased availability of local financing through bank loans has enabled local governments to invest more in urban public facilities. Figure 2.10 shows that infrastructure investment as a share of central government spending has shown a downward trend, dropping to just 15 percent in 2006 from 34 percent in 1991. The same trend can be observed for state-owned investment as a share of total urban investment, which fell from 64.3 percent in 2003 to just 35.6 percent in 2011.

As mentioned, local financing through bank loans has become increasingly available. According to a National Audit Office report (2011), there are approximately 6,500 platforms for local financing and 10.7 trillion yuan (US$1.72 trillion) in outstanding debt. Local financing platform debt is much higher than total local government revenue. Some local governments bear a heavy burden of obligation for debt repayment. By the end of 2010, 78 municipal governments

Figure 2.10
Infrastructure Investment as a Share of Central Government Spending, 1991–2006



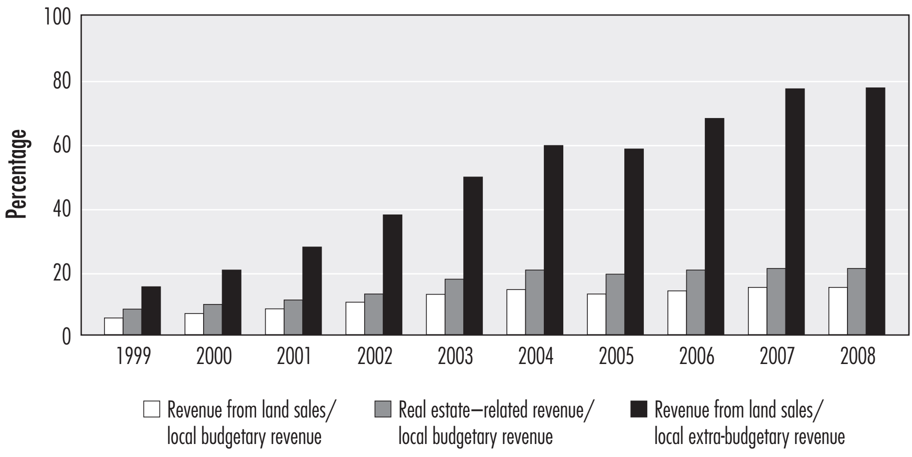
Source: National Bureau of Statistics of China (1996–2011).

(19.9 percent of all local governments) were bearing more than 100 percent of the debt ratio.

Debt repayment by local financing platforms mainly relies on local finance and land revenues, along with purpose taxes, fees, and charges from public services and asset management. In recent years, local fiscal revenue has increased rapidly, with annual growth exceeding 20 percent, a strong guarantee for the repayment of the debt by local financing platforms. In addition, local government extra-budgetary revenue has increased substantially. Revenues from land sales (also known as land transfer fees) are the largest extra-budgetary sources of income. Figure 2.11 shows that land revenue accounts for about 80 percent of the extra-budgetary revenue of local governments, making it a major funding source of debt repayment for local government financing platforms.

It is widely agreed that the local municipalities are relying too much on revenue from land sales for repayment. Revenue from land sales is not a sustainable source (Ding 2003). An alternative source of funding for local governments is levying taxes, such as property and real estate taxes. However, resistance to establishing such taxes is considerable (C. Zhang 2011). Another potential source of funding for local financing platforms is charging fees for the services that public infrastructure provides. This approach raises an important question about how to price public services in China without causing social unrest. China's current pricing mechanism for rail, urban rail transit, and other public services has evolved from past practices of the central planning system. The lack of a more

Figure 2.11
Local Government Income from Land Sales, 1999–2008



Source: Ministry of Land and Resources of China (2000–2009).

flexible pricing mechanism may increase the risk of local governments defaulting on their debts. For example, at present, Shanghai Metro fare box revenue barely covers interest payments; consequently, local government fiscal revenue is required for the repayment of principal (C. Zhang 2011). The development of other public service pricing mechanisms, such as land value capture, is important to ensure that local governments will be able to repay their loans.

Infrastructure, Urban Scale, and Urban Land Prices: A Cross-Sectional Analysis

Infrastructure development in China has affected urban expansion and land prices in various ways. Many studies have examined the driving forces of urban land expansion across Chinese cities (He, Ke, and Song 2011; Ke, Song, and He 2009; Liu, Zhan, and Deng 2005; Song and Zenou 2006) and have found that China's urban expansion exhibits a great number of spatial differences, resulting from different levels of demographic change, economic growth, and changes in land use policies and regulations (Liu, Zhan, and Deng 2005). However, few attempts have been made to investigate how infrastructure provision can affect urban expansion and urban land prices. Démurger (2001) provides empirical evidence demonstrating the links between infrastructure investment and economic growth in China using panel data from a sample of 24 Chinese provinces between 1985 and 1998. The results indicate that besides differences in terms of reforms and openness, geographical location and infrastructure endowment accounted significantly for observed differences in growth performance across space and that transportation facilities are a key differentiating factor in explaining the growth gap.

This chapter examines the links between infrastructure investment and urban growth; specifically, this section offers empirical evidence suggesting how different levels of infrastructure provision contribute to variations in urban scale and land prices across Chinese cities. This chapter applies a consolidated monocentric model that was previously developed by He, Ke, and Song (2011). The model is developed to account for both "closed" and "open" city features in a developing country, where permanent urban residents and migrants interact in the informal goods market and the land market and yield a distinctive equilibrium pattern.

The theoretical model (He, Ke, and Song 2011) is applied to an empirical analysis of urban scales and land prices across all Chinese cities for 2010. Table 2.2 describes the variables used in two regressions of urban scale and land prices. The dependent variables are urban scale and land price, respectively, in 2010. Of main interest, the analysis includes a set of variables accounting for infrastructure level in 2005: number of city buses per thousand residents (*Bus*), street length per resident (*Street*), number of express highways (*ExpHwy*), capacity of railroad center (*RRCenter*), capacity of airport (*AirPort*), and percentage of infrastructure investment compared to GDP (*Infra_GDP*). Together, these variables characterize

Table 2.2
Variables and Data Sources

Variable	Description	Units
Urban scale	Defined as $\sqrt{Built\_distr / \pi}$ where *Built_distr* is the area of the urban built district	km
Land price	Defined as land sale values divided by area[a]	¥10,000/hectare
Bus	Number of city buses per thousand residents	NA
Street	Street length per resident	km/person
ExpHwy	Number of express highways passing through the jurisdictional territory	NA
RRCenter	For cities at the prefecture level and above, *RRCenter* is 0 if total railway passenger throughput was zero in year 2000; non-zero throughput values are grouped into six quantiles, and numerical values 1–6 are assigned accordingly; for cities at the county level, *RRCenter* is assigned the value 1 if there is a railway station within 30 km from the urban center, and 0 otherwise	NA
AirPort	For cities at the prefecture level and above, *AirPort* is 0 if total airline passenger throughput was zero in year 2001; non-zero throughput values are grouped into six quantiles, and numerical values 1–6 are assigned accordingly; for cities at the county level, *AirPort* is assigned the ordinal values 0–4 if number of daily flight departures is no greater than 0, 200, 300, 500, or greater than 500 from airports within 100 km from the urban center	NA
Infra_GDP	Percentage of infrastructure investment compared to GDP	NA
UrbPop	Population of permanent residents with nonrural residence permits in the jurisdictional territory	10,000
Salary	Average annual salary income of permanent residents	¥1,000
GDP_AgriLand	Defined as $\frac{GDP\_Ag}{Urban\_area - Built\_distr}$ if $GDP\_Ag \neq 0$; otherwise as $\frac{GDP}{Urban\_area}$	¥10,000/km^2
Price_lag	Defined as *Price* in the previous year	¥10,000/hectare
Land_Supply	Available land for transactions in the market[a]	hectare
Capital	Dummy for provincial capital cities or directly governed cities (30 in total)	NA
Prefecture	Dummy for prefecture-level cities (249 in total)	NA
Resource	Dummy for resource-extraction cities (16 in total)	NA
Central	Dummy for cities in the central region, including the following provinces: Anhui, Heilongjiang, Henan, Hubei, Hunan, Inner Mongolia, Jiangxi, Jilin, and Shanxi	NA

(continued)

Table 2.2
(continued)

Variable	Description	Units
Western	Dummy for cities in the western region, including the following provinces: Chongqing, Gansu, Guizhou, Ningxia, Qinghai, Shaanxi, Sichuan, Tibet, Xinjiang, and Yunnan	NA

NA = not applicable.
[a]For details on variable construction, see He, Ke, and Song (2011).

the capacity of intracity infrastructure levels and long-range transportation infrastructure in each city. It is hypothesized that a greater level of infrastructure provision and investment corresponds to better accessibility, hence larger cities and higher land prices. There are 660 officially designated cities in China. Excluding observations with missing data on key variables, 638 observations are retained for the urban scale equation. Data on land prices are available only for cities at the prefecture level or higher. Of these, 260 of the 280 have complete data and are used in the price equation. The data are extracted from the *China City Statistical Yearbook, 2011*; *China Statistical Yearbooks for Urban Construction, 2011*; and *China Statistical Yearbooks for Land and Resources, 2010*.

The regressions include a set of control variables as suggested by previous studies (He, Ke, and Song 2011), such as population (*UrbPop*), average annual salary income of permanent residents (*Salary*), and average productivity of agricultural land (*GDP_AgriLand*) as a proxy for the price of agricultural land (Brueckner 1990). In addition, a set of dummy variables are used to define city types, such as provincial capital cities (*Capital*), prefecture-level cities (*Prefecture*), resource-extraction cities (*Resource*), and cities in different regions (*Central* or *Western*). For land price estimation, lagged land price (*Price_lag*) and land supply (*Land_Supply*) are also included. These variables all have large standard deviations relative to the means and show great dispersion, suggesting significant disparities among Chinese cities in urban scale and land prices, and the attributing factors (table 2.3).

Following He, Ke, and Song (2011), the *log-log* form is used to estimate the urban scale and land price equations. The results are shown in table 2.4.

The estimates show that the provision of urban infrastructure affects both urban expansion and land prices. Specifically, in the urban scale regression, of the six variables that are used to account for infrastructure level, *Street*, *ExpHwy*, *RRCenter*, and *Infra_GDP* have significant and positive parameter estimates, while *Bus* and *AirPort* are not significant determinants of urban scale. This indicates that both intracity and intercity transportation investments, including streets within cities and intercity express highways and railways connecting cities, have a positive impact on urban growth. The general measure of

Table 2.3
Descriptive Statistics of Variables Used in the Land Price Function

Variable	Descriptive Statistics			
	Mean	S.d.	Min	Max
Urban scale	3.46	2.03	0.94	21.45
Land price	698	540	28.49	3868.35
Bus	0.06	0.06	0.015	0.26
Street	8.25E-04	4.11E-04	1.67E-04	3.41E-03
ExpHwy	1.42	1.31	0	11
RRCenter	1.79	1.48	0	6
AirPort	0.84	1.76	0	5
Infra_GDP	2.69%	2.08%	1.97%	5.87%
UrbPop	55.31	110.34	2.01	1398.36
Salary	15.89	5.77	6.53	37.93
GDP_AgriLand	3.87E+04	2.99E+06	7.29	4.06E+06
Price_lag	527	457	15.78	3564.71
Land_Supply	149	201	2.44	2048.9
Capital	0.046	0.21	0	1
Prefecture	0.383	0.486	0	1
Resource	0.025	0.155	0	1
Central	0.372	0.484	0	1
Western	0.194	0.395	0	1

Note: For most variables, the statistics are calculated for the scale equation sample, which includes 638 cities. Statistics for *Land price, Price_lag*, and *Land_Supply* are reported for the price equation sample, which includes only 260 cities.

infrastructure investment as a percentage of GDP is also positive and significant, indicating infrastructure's important role in stimulating urban growth. The estimates show that a 10 percent increase in *Street* increases the urban radius by 1.39 percent, a 10 percent increase in *ExpHwy* increases the urban radius by 0.78 percent, a 10 percent increase in *RRCenter* increases the urban radius by 0.39 percent, and a 10 percent increase in *Infra_GDP* increases the urban radius by 0.05 percent.

In the land price regression, of the six variables used to account for infrastructure level, *ExpHwy*, *AirPort*, and *Infra_GDP* have significant and positive parameter estimates, while *Bus*, *Street*, and *RRCenter* are not significant determinants of urban land prices. The insignificant estimate of *Bus*, *Street*, and *RR-Center* suggests that much of the convenience provided for intracity and intercity

Table 2.4
Regressive Results in the Land Price Function

Variable	Urban Scale			Land Price		
	Estimate	*t* value	Pr(>|t|)	Estimate	*t* value	Pr(>|t|)
(Intercept)	0.867*	2.285	0.02	2.750***	3.789	0
Bus	0.009	0.781	0.31	0.008	0.972	0.34
Street	0.139***	10.973	0	0.065	0.785	0.32
ExpHwy	0.078***	9.736	0	0.058*	2.164	0.03
RRCenter	0.039***	4.573	0	0.023	1.312	0.22
AirPort	0.004	0.95	0.32	0.121**	2.711	0.01
Infra_GDP	0.005**	2.627	0.01	0.004*	2.166	0.03
UrbPop	0.313***	20.99	0	0.237*	2.291	0.02
Salary	0.174***	7.472	0	0.681***	5.882	0
GDP_AgriLand	−0.021***	−5.909	0	0.028	1.112	0.27
Price_lag				0.389***	11.381	0
Land_Supply				−0.116	−1.333	0.18
Capital	0.135***	3.695	0	0.264*	2.289	0.02
Prefecture	0.164***	5.98	0	0.497***	3.762	0
Resource	0.045	1.335	0.18	−0.035	−0.282	0.78
Central	0.051**	2.672	0.01	0.0379	1.109	0.27
Western	0.03	1.11	0.22	0.058	1.255	0.22
Adj-R2	0.816			0.606		
Wald test	24.5**			20.3**		

*p < .05
**p < .01
***p < .001

commuters by streets, public transit, and railways has not been capitalized into land prices.

The variables of *RRCenter* and *AirPort* perform differently in the urban scale and land price equations. The *RRCenter* variable is significant in explaining urban scale, while the *AirPort* variable explains more price variations. The different results can be explained by the differences between China's rural-to-urban migrants and intercity migrants. Rural-to-urban migrants, contributing to urban expansion, are more likely to use the railways than the airlines. Thus, capacity of railway infrastructure is valued more in affecting urban scale. However, intercity migrants are usually better-paid professionals. In a few highly developed Chinese cities, intercity migrants have dominated high-tech industry and financial business. Many white-collar migrants prefer air travel, and thus the capacity of the aviation infrastructure exerts a much greater influence on urban land prices (He, Ke, and Song 2011).

Most of the other variables are consistent with expectations. In the urban scale regression, urban population plays the dominant role in determining urban spatial scale. The estimated elasticity of urban scale with respect to average income (*Salary*) is 0.17 and very significant. The estimates also provide evidence that government planning is important in affecting urban scale. Estimated coefficients for *Capital* and *Prefecture* are both significant and positive, indicating that holding everything else constant, a capital city or a prefecture-level city will be larger than an otherwise comparable county-level city because of the greater number of governmental functions contained in capital and prefecture-level cities. The estimated coefficient of the regional dummy *Central* is significant, indicating that cities in central China on average use slightly more land than those in the east.

In the land price regression, results also show that land prices are very responsive to urban population and average income. Other things being equal, a 10 percent increase in average income induces a 6.8 percent increase in land prices. A 10 percent increase in nonagricultural urban population drives up land prices by 2.4 percent. *Price_lag* is significant, indicating that lagged land price induces an increase in the current price. Estimated coefficients for *Capital* and *Prefecture* are both significant and positive, indicating that holding everything else constant, a capital city or a prefecture-level city will have higher land prices than an otherwise comparable county-level city.

In summary, by examining the determinants of urban scale and land prices across Chinese cities, it is evident that when controlling for other factors, greater urban infrastructure investment contributes to a higher level of growth of human settlements and higher land prices. Because the analysis included in this section is a cross-sectional analysis, the results suggest only that earlier investment in infrastructure is correlated with more expansive urban growth and higher land prices across cities. It is also possible that earlier decisions on infrastructure investments were made because of expected urban and economic growth in selected cities (World Bank 2004). In the next section, time-series data are used to explore how earlier infrastructure shapes later land development.

Infrastructure and Urban Land Conversions: A Time-Series Case Study

Studies focusing on the links between urban infrastructure and urban spatial land development are needed. This section presents an analysis of land conversion using geographic information systems (GIS) and remote sensing data to explore the temporal and spatial characteristics of land use/cover change and urban land development from 1994 to 2005 in Shenzhen City, Guangdong Province. Then a land conversion probability analysis is used to explore whether infrastructure exerts a role in inducing land development. Shenzhen was chosen for the case study on links between infrastructure and spatial development because it is a developed and yet dynamic city that provides sufficient changes in both infrastructure level and land development. Shenzhen is the first city in China to establish a Special Economic Zone (SEZ) to attract foreign technology. Since the 1980s, comprehensive plans have been drafted and implemented to provide urban infrastructure and to construct urban development (Bruton, Bruton, and Li 2005; Sun 1991).

Figures 2.12 to 2.14 illustrate how land development occurs and how land use changes over time in three fast-growing areas in Shenzhen. As these figures show, transportation infrastructure projects are planned and implemented to attract future private investments in urban development (Sun 1991).

This section employs Shenzhen as a case, uses remote sensing data at two time periods (1994 and 2005), and constructs a land conversion model to examine the impact of infrastructure on land use conversions. Previous studies have confirmed that the decision to change the existing use is influenced by economic, social, political, and personal considerations. There are many studies of land use conversion and the factors that influence the timing and location of this phenomenon (Carrion-Flores and Irwin 2004; Irwin and Geoghegan 2001; Liu, Wang, and Long 2008; Mertens and Lambin 1997; Veldkamp and Fresco 1996; Xiao et al. 2006). This section focuses on land use changes within an urban area over time and the impact of transportation infrastructure on land developments.

The first step is to detect land use changes using remotely sensed land use/cover data. Two scenes of Landsat images are collected for analyzing land use/land cover change between 1994 and 2005. Both are Landsat 7ETM+image data, cloud free, and filtered with a 3×3 median kernel to exclude noise.[1] To detect land use changes, a number of tasks must be performed:

1. Create and prepare a training dataset to support the satellite image classification. The classification system designed to categorize the land use properties of the study area included nine classes: urban/built-up, residential, crop field, vegetable field, forest/trees, orchard, grass, water body, and barren/sandy lands. The supervised classification method Maximum Likelihood was used to detect the land cover types.

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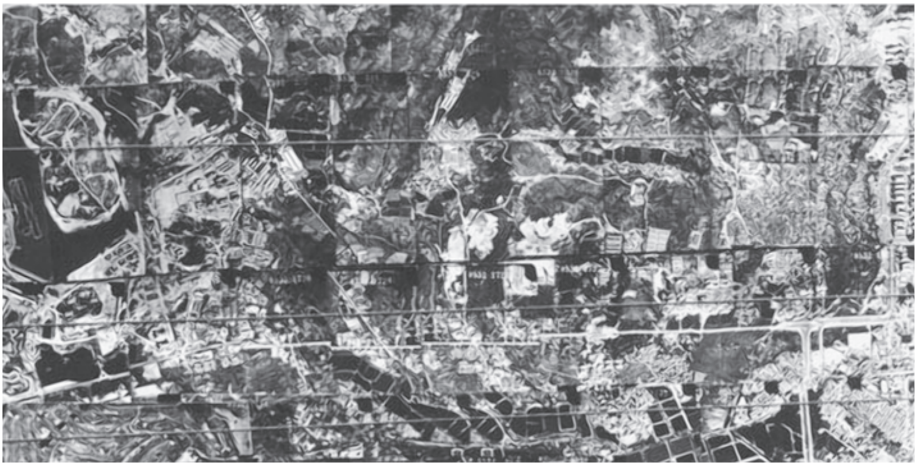
1. Orbiting satellites capture reflected electromagnetic waves in bands (ranges of wavelengths) and vary in the number of bands of data they collect, the spatial resolution at which they capture data, and the spatial scale covered. Landsat is a commonly used data source for analyzing landscape change. It has global coverage and captures data in seven bands, at a resolution of 30 meters, in scenes that are approximately 180 km^2. Landsat 5 and Landsat 7 detect blue, green, and red light in the visible spectrum as well as near-infrared, mid-infrared, and thermal-infrared radiation that human eyes cannot perceive. Landsat records this information digitally, and it is downlinked to ground stations, processed, and stored in a data archive.

Figure 2.12
Changes in the New Central Business District Area Over Time

a. 1986

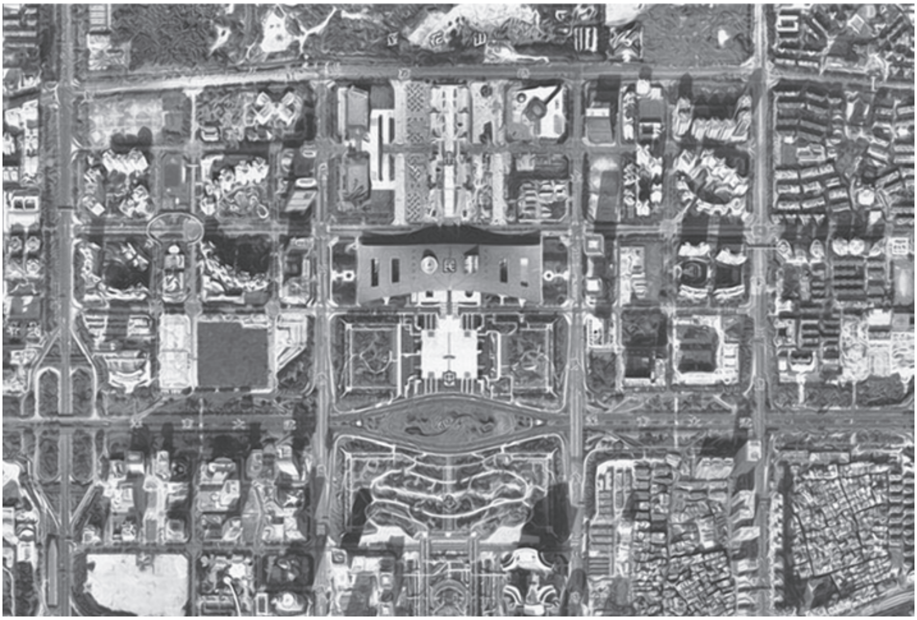


b. 1998

(continued)

Figure 2.12
(continued)

c. 2008



Source: Image from Urban Planning, Land and Resources Commission of Shenzhen Municipality (2012).

2. Derive a signature file containing spectral characteristics of land cover classes of interest.
3. Perform a supervised classification of Landsat satellite imagery.
4. Identify urban areas within the study area at two time periods (1994 and 2005).
5. Detect and quantify the observed change in urban extent between 1994 and 2005.

Figure 2.15 depicts the changes from nonurban to urban land use by each cell of 30 by 30 meters. The land use change analysis yielded a total of 8.2 percent of the cells that changed between 1994 and 2005. Figure 2.15 also shows the spatial distribution of changes, most of which occurred along the coastline and highway or arterial corridors.

Following previous studies on identifying determinants of land use changes (Bockstael 1996; Wilson and Song 2011), a discrete choice probabilistic approach was used wherein the dependent variable is the probability of observing land use change from nonurban to urban use between 1994 and 2005. The land

Figure 2.13
Changes in the Huaqiao Area Over Time

a. 1998

(continued)

use conversion model was estimated using all cells of the landscape that as of 1994 could be considered buildable in urbanized use. The dependent variable is a 0, 1 variable indicating whether the cell was actually converted between 1994 and 2005.

As shown in table 2.5, the main set of predictors is a series of variables capturing infrastructure investments. For each cell, distances to the nearest existing roads, newly added roads, and subway corridor were calculated. In addition, road density in 1995 in buffers of different sizes was included to test whether these factors affect land changes between 1994 and 2005 with the aim to test the spatial extent of the hypothesized positive effect exerted by infrastructure density. To do so, a sensitivity analysis was implemented to consider how the parameters and fit of the statistical model respond to variation on the different distance thresholds used to derive the infrastructure effect measure. A distance threshold of two miles was chosen as the upper limit for the sensitivity analysis. As a point of reference, the mean distance from all cells to the nearest infrastructure was calculated to be 0.18 miles. This value formed the basis for the lower bound of the distance radii for the sensitivity analysis. Two more distance thresholds were also selected to partition these two endpoints and lend greater detail to the sensitivity analysis: one-half mile and one mile.

Figure 2.13
(continued)

b. 2008

Source: Image from Urban Planning, Land and Resources Commission of Shenzhen Municipality (2012).

The second set of predictors was designed to capture market and neighborhood influences on land conversion. The average housing value per square foot at the beginning of the study period controls for disparities in real estate values in each cell. Distance to city center was included to account for access to aggregated economic activities by each cell. The third measure of land market conditions focuses on the supply of land and was operationalized as the proportion of total nonurbanized and buildable area in each cell at the beginning of the study period.

Table 2.6 presents regression results. Most of the explanatory variables are highly significant and of the expected sign. For the infrastructure variables, cells that are closer to the nearest existing roads, the nearest newly added roads between 1995 and 2005, and the subway corridor are more likely to be developed.

Figure 2.14
Changes in the Yantian Area Over Time

a. 1998

(continued)

Cells with denser roads nearby in 0.18 mile and one-half mile are more likely to be converted, with the one-half mile variable being the most significant among four sizes of buffers in the sensitivity analysis. The variable of road density becomes insignificant when it is measured at the one-mile or two-mile buffers. For the control variables, the higher housing values in 1995 increase the likelihood

Figure 2.14
(continued)

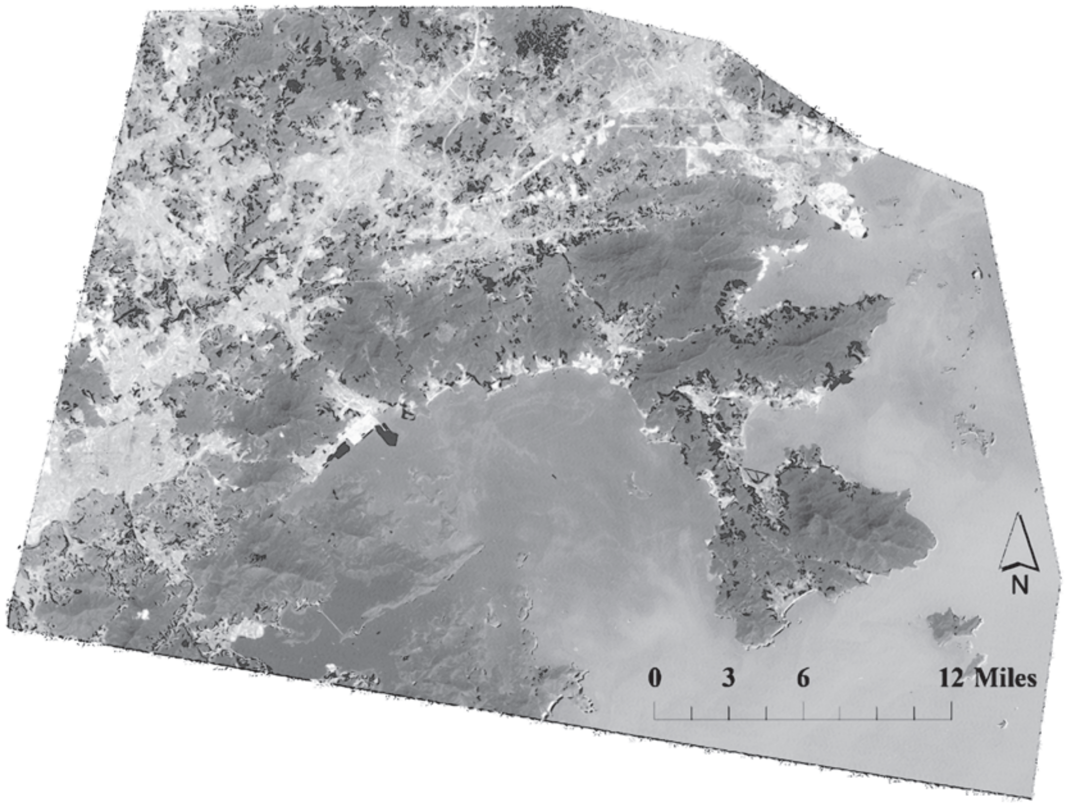
b. 2008

Source: Image from Urban Planning, Land and Resources Commission of Shenzhen Municipality (2012).

that a cell will be converted, mainly because of the expected higher return for the real estate developers (Bockstael 1996). The availability of undeveloped land in 1995 increases the likelihood of the cell being urbanized by 2005. The distance to the city center is not significant, possibly because of the uniform distribution of economic activities across the city.

In summary, through examining the determinants of urban land conversions, it is evident that when controlling for other factors, greater urban infrastructure investment increases the likelihood of land being converted for urbanized developments, indicating that access provided by streets and subway transit stimulates land conversions.

Figure 2.15
Land Use Changes in Shenzhen, 1994–2005



Source: Image from Urban Planning, Land and Resources Commission of Shenzhen Municipality (2012) and GIS calculations by the author.

Table 2.5
Independent Variables in the Conversion Model

Variables	Hypothesized Effects	Data Source
Infrastructure Level		
Distance to nearest existing roads in 1995 (miles)	+	GIS calculations
Distance to nearest newly added roads between 1995 and 2005 (miles)	+	GIS calculations
Distance to subway corridor (miles)	+	GIS calculations
Infrastructure density measured as street length in 4 different sizes of buffers in 1995 (miles)	+	GIS calculations
Market and Neighborhood Character		
Average house value in 1995 (dollars)	+	Planning bureau
Distance to city center	+	GIS calculations
Proportion nonurban uses within quarter mile in 1995	+	GIS calculations

Conclusions

Since the economic reform began in China, infrastructure investment has increased to attract private investment, accommodate economic growth (Sahoo, Dash, and Nataraj 2010), and cope with economic crisis. This chapter provides empirical evidence that infrastructure has important effects on urban expansion rates, land prices, and spatial land development. Given this set of established links, it is especially important to examine whether recent infrastructure development could help cities grow toward a sustainable future. Despite the accelerated rate of infrastructure development, there are several challenges associated with the current practice of infrastructure development in China.

First, the general level of infrastructure development in China is still low. Although infrastructure development has been advanced in developed cities in China, in many developing cities, the average infrastructure capacity per capita is comparatively low due to the large size of the population and the underdevelopment of infrastructure (Lin 2001). This insufficient level of infrastructure could impede efforts to accommodate both spatial and economic growth. Infrastructure must be improved, not only to facilitate economic growth (Sahoo, Dash, and Nataraj 2010), but also to overcome geographic barriers and increase western growth (Démurger et al. 2002). To address this issue, local municipalities, specifically the planning bureaus, need to design an infrastructure inventory system to accurately evaluate existing and predicted capacities. Such a system will

Table 2.6
Regression Results in the Land Conversion Function

Variables	Estimates	Significance
Infrastructure		
Distance to nearest existing roads in 1995 (miles)	0.1683	***
Distance to nearest newly added roads between 1995 and 2005 (miles)	0.5781	***
Distance to subway corridor (miles)	0.2094	*
Infrastructure density measured as street length in half mile in 1995 (miles)	0.3855	***
Market and Neighborhood Character		
Average house value in 1995 (dollars)	1.0413	***
Distance to city center	0.1588	
Proportion nonurban uses within quarter mile in 1995	–0.342	*
Model Summary		
Log-likelihood: –2834.23		
Likelihood ration test (distributed Chi square): 3490.93		

*p < .05
**p < .01
***p < .001

enable infrastructure planners to avoid wasteful investment and to more effectively expand infrastructure development to accommodate urban and economic growth.

Second, regional infrastructure development is imbalanced. Infrastructure in the eastern region of China is more developed (Loo 1999) than in the western and central regions despite the recent increase in infrastructure investment in the west. This regional imbalance is a barrier to the socioeconomic development of the hinterlands. In particular, many of these areas still have inadequate transportation infrastructure, as well as inadequate telecommunications, water supply, drainage, and electricity supply (Economic Research Institute for ASEAN and East Asia 2007; Li and Shum 2001). As regional equity is particularly important to maintaining social stability, measures need to be designed and implemented to lessen regional differences.

Finally, financing sources for infrastructure provision are still limited in China. On the one hand, increasingly decentralized central-local fiscal relations are allowing municipalities a great degree of freedom for resource mobilization through a wide range of mechanisms that greatly expand extra-budgetary revenue (Wu 1999). In other words, China has succeeded in addressing urban infrastructure backlogs by opening up new avenues for financing. But on the other hand, financing problems have emerged, prompted by debt-laden local governments in China in the aftermath of the global financial crisis (Tsui 2011). Several key institutions (the cadre evaluation system, the land management regime, and the banking sector) have created an environment that draws local governments into the trap of relying on unconventional sources, such as land transfer fees. The high levels of debt that have resulted may impede China's efforts to mitigate structural imbalances in its economy. Cities of different administrative ranks have significant variation in financial capacities. The ingenious nature of extra-budgetary and off-budgetary resource collection by local authorities has resulted in high levels of intercity and intracity inequalities, further unbalancing the distribution of infrastructure (Démurger 2001; Wang et al. 2011). Efforts have been made to diversify financing sources. Much of the money raised through foreign investment and commercial loans is used for infrastructure construction in response to insufficient public financing mechanisms. However, the repayment terms for infrastructure loans are relatively long, and banks face the risk of incurring bad debts. In some regions, commercial bank loans account for 80 percent of the total investment in transportation (Economic Research Institute for ASEAN and East Asia 2007). However, experiences with other market-oriented financing tools and taxes (such as land value capture or property taxes) are still very limited and need to be expanded. The evidence on the link between infrastructure and land prices suggests that a more efficient land value capture tool can be designed to finance public infrastructure projects.

Using infrastructure projects to guide sustainable spatial development is challenging in most cities. The priorities set by many cities on infrastructure investment focus on promoting economic growth and attracting private investment. Nevertheless, evidence shows that infrastructure does have an impact on urban scale and urban development patterns. However, when infrastructure development neglects other goals, such as efficient urban form and sustainable communities, an unsustainable form of urban land development could result. Two examples illustrate this issue.

- Many transportation infrastructure projects allocate land uses according to arbitrarily planned geometries such as axes, cores, and circles. Legacies from past central planning schemes have granted more power to the governments to determine where to locate infrastructure in China. City image projects exemplify institutional interference in the process of city growth. The layout design for Zhengzhou's new central business district (CBD) is an example of emphasizing city image and neglecting principles of sustainable design and planning. Figure 2.16 shows that in the center of the newly constructed CBD is a circular highway system, along which an international convention center, a culture and arts center, and office and residential buildings are sparsely located. This layout of infrastructure falls short in promoting walkability, accessibility, and dense developments endorsed by smart growth principles.

Figure 2.16
Zhengzhou Eastern New CBD

- The current infrastructure planning system does not ensure effective mechanisms for guiding the timing, location, and intensity of urban developments. For example, Huilongguan, a bedroom community in Beijing, was planned and constructed outside the fifth ring road and about 15 kilometers from downtown Beijing. Huilongguan is characterized by its enormous residential capacity, housing about 300,000 residents. However, there is no infrastructure concurrency requirement in terms of transportation infrastructure connecting the community to the city core. With a rapid increase in the number of private passenger cars, the current level of access roads and services is insufficient for 300,000 people. An additional concern with this suburban neighborhood is the lack of land use and transportation integration. More than 60 percent of residents in Huilongguan commute to downtown or other areas in Beijing for work. The community generates more commuting and non-commuting trips (especially external trips during peak hours), which worsens the existing transportation system not only for the lower-occupancy passenger cars, but also for the higher-occupancy bus transit. Current land use design does not consider the provision of more efficient modes of public transportation.

The failure to incorporate sustainable principles in infrastructure development has caught the attention of China's planners and policy makers. The Ministry of Housing and Urban and Rural Development is calling for more efficient and green infrastructure development in the next era of urban growth. Existing infrastructure systems and land development in many local cities have been evaluated to identify unsustainable planning practices. Advanced planning techniques are being explored and developed to improve and transform current infrastructure provision practices into a more integrative, sustainable, and inclusive public policy-making process.

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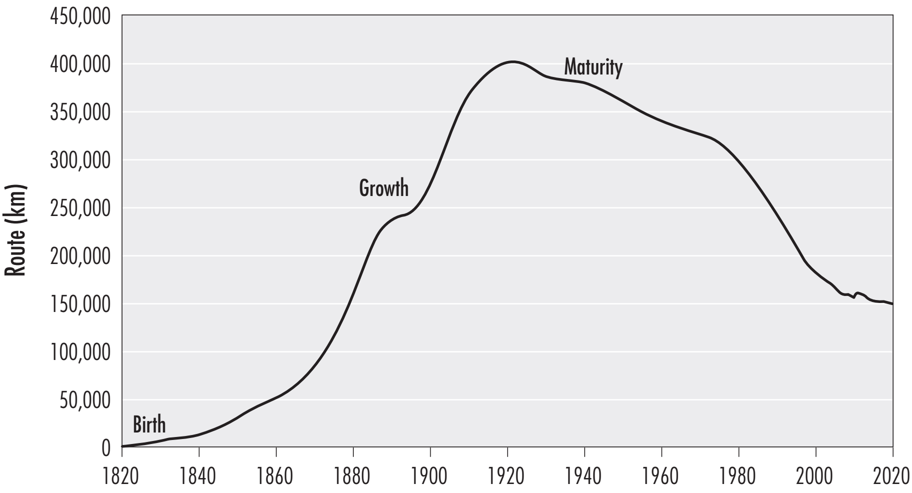
COMMENTARY
David M. Levinson

History doesn't repeat itself, but it rhymes.
—ATTRIBUTED TO MARK TWAIN

The growth of infrastructure in China is the investment story of the early twenty-first century. Yan Song's chapter documents much of what is happening. The plot underlying this story has played out previously in other developing countries, including the United States in the nineteenth and twentieth centuries and the United Kingdom in the eighteenth and nineteenth centuries. Rapid growth occurred in the railroads during the nineteenth century, following a familiar life-cycle pattern, as illustrated in figure C2.1. One of the key features of many life-cycle processes is overshoot. Shortly after peaking in 1920, U.S. railway mileage began a long inexorable decline, a process to date repeated with all technologies after they mature and when some better technology comes along.

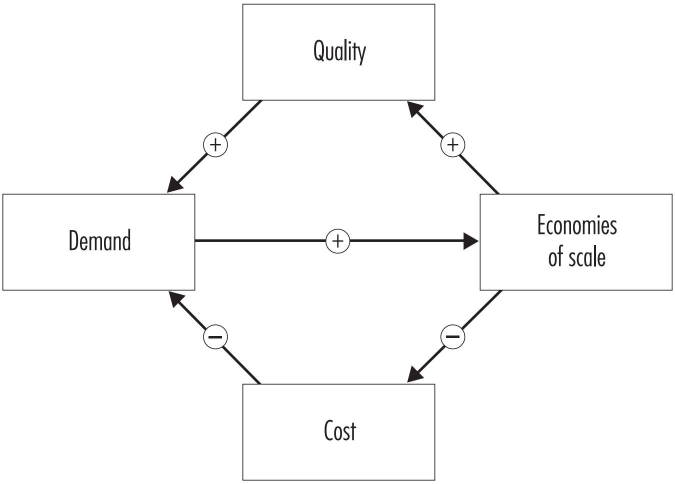
China is in the midst of riding what we call the Magic Bullet (Garrison and Levinson 2006). The Magic Bullet (figure C2.2) describes the feedback between economies of scale, service quality, demand, and cost that drives the growth of systems.

Figure C2.1
Life Cycle of U.S. Railroads



Source: Garrison and Levinson (2006).

Figure C2.2
The Magic Bullet



Source: Garrison and Levinson (2006).

Economies of scale, the property that average cost decreases as throughput (satisfied demand) increases, are found in systems like railways in their growth stage. While some of the economies may be kept as profits, in general, during the growth phase, the economies are reinvested and returned to users as either price reductions or service quality improvements, as investors seek future profits. On a passenger rail link, for example, the greater the traffic, the less the cost of movement (due to more frequent services and thus less schedule delay) and the better the service, at least until congestion sets in.

While the early railroads in the nineteenth century had to discover this process, China is in a position of not having to invent the railroad, but instead can intelligently emulate it, deploying a well-understood technology across an underdeveloped landscape. This spatial diffusion process should be expected to follow the traditional S-shaped life-cycle curve, as the best links are built first, and links continue to be added as long as the benefits outweigh the costs. By developing later, China has the advantage of being able to deploy better technologies (e.g., high-speed rail), which the United States missed in its first round of deployment and is only now thinking about building.

Interestingly, the last decade has seen a lower share of self-financing and more money coming from government budgets and borrowing than in previous years. Self-financing was used primarily for the U.S. interstate highway system (via the motor fuel tax), but borrowing was de rigueur for railways, which at first didn't have enough revenue to pay for themselves. Later, some investors were paid back (though many others were not, as most U.S. railways went through bankruptcy at one point or another, wiping out investors).

The deployment of infrastructure mirrors and reinforces the growth of Chinese cities. Rapid urbanization, enabled by economic expansion and the differential rewards for urban living, is resulting in the transformation of cities and the nearby countryside into modern developments. Clearly, there is some concern about spatial equity in China, as the chapter reports significant investments in rural areas despite the greater growth rates in urban areas.

Song documents the fascinating explosion of Chinese cities. We have seen rapid urbanization before. As places in the United States became connected to the national and global system of cities and new areas could be developed, growth was profound. Figures C2.3 to C2.6 show the transformation of growth in Minneapolis, Minnesota, from 1865 to 1891. The Minneapolis-St. Paul metropolitan area peaked at ninth largest in the United States in the 1890 census. (The city of Minneapolis was the 15th largest in the United States at its 1930 peak.) The scale of course differs in China, with Shanghai (at 13.5 million in 2009) much larger than greater Minneapolis (at 305,000 in 1890 and 3.2 million today). Shanghai is building a subway network to serve its core, like large cities before it. Although this chapter corroborates that infrastructure drives development, it is not clear from this analysis whether development also leads infrastructure, though one suspects it is true. Minneapolis and St. Paul saw land growth driven by streetcars in the late nineteenth century (Xie and Levinson 2010). In the case of the Twin Cities, streetcars led land development, but elsewhere, like London, there was mutual causation (Levinson 2008), and in New York, the subway tended to chase population (King 2011).

The life-cycle discussion is central in any international comparisons. The United States, Japan, and European nations are mature and well developed, and so they do not demand the same level of investment as fast-growing countries like China, which have proportionally less infrastructure. That China is investing rapidly, and presumably sees returns, does not imply that the United States or European nations should do likewise. China would do well to heed the experiences of the nations that went before and learn from them.

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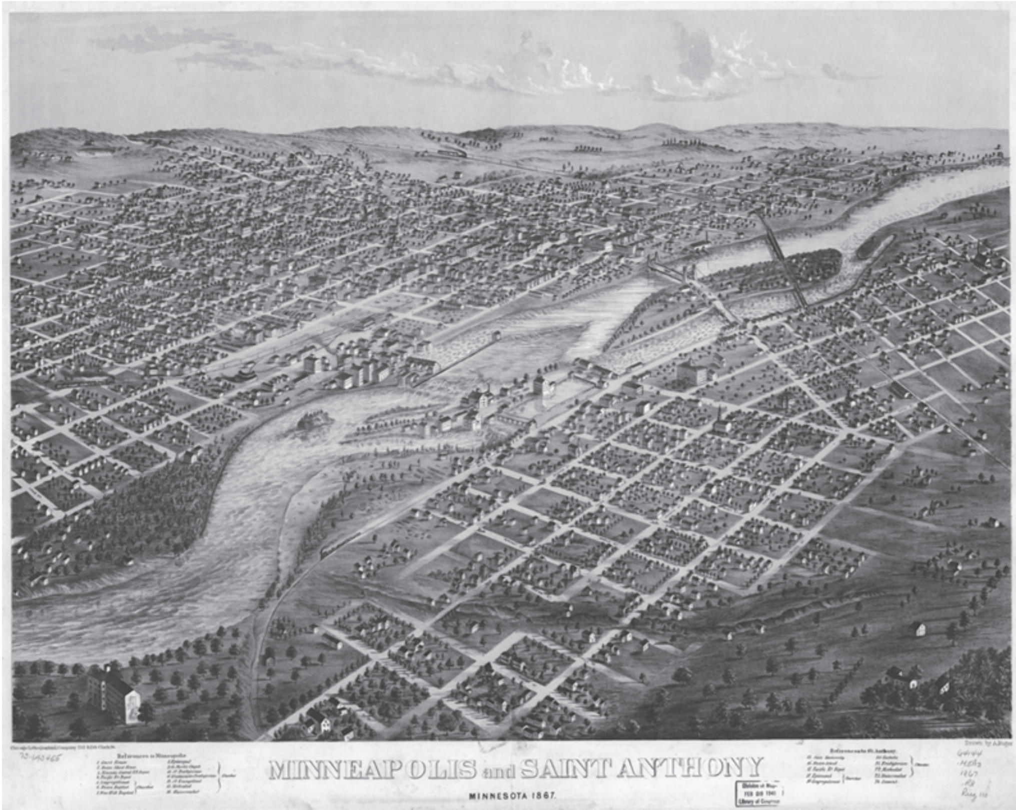
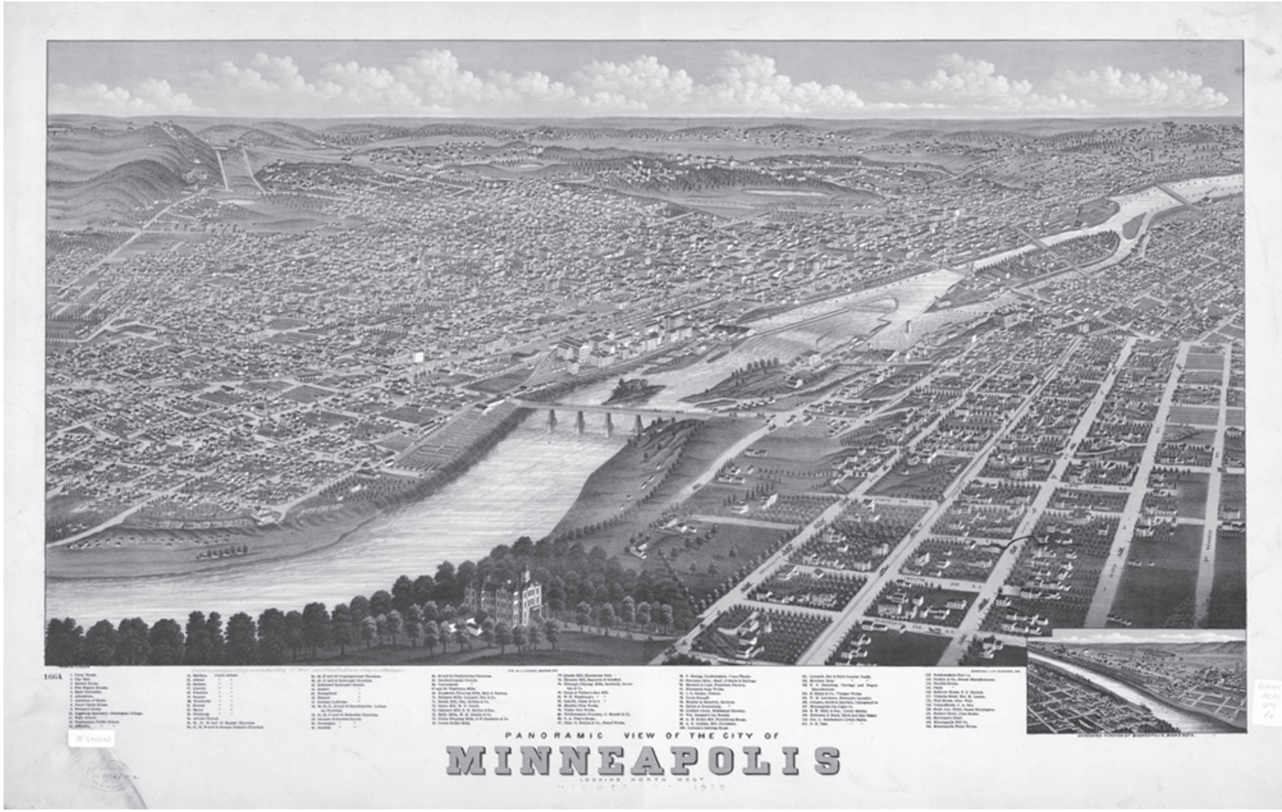
Figure C2.3
Bird's-Eye View of Minneapolis, 1865



Source: Library of Congress Geography and Map Division, Washington, DC 20540-4650 dcu, http://hdl.loc.gov/loc.gmd/g4144m.pm003930.

Figure C2.4
Bird's-Eye View of Minneapolis, 1879



Source: Library of Congress Geography and Map Division, Washington, DC 20540-4650 dcu, http://hdl.loc.gov/loc.gmd/g4144m.pm003950.

Figure C2.5
Bird's-Eye View of Minneapolis, 1885

Source: Library of Congress Geography and Map Division, Washington, DC 20540-4650 dcu, www.loc.gov/item/75694644.

Figure C2.6
Bird's-Eye View of Minneapolis, 1891

Source: Library of Congress Geography and Map Division, Washington, DC 20540-4650 dcu, http://hdl.loc.gov/loc.gmd/g4144m.pm003970.