

HANDBOOK ON HIGH-SPEED RAIL AND QUALITY OF LIFE

Edited by Yoshitsugu Hayashi, KE Seetha Ram,
and Shreyas Bharule

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and Shreyas Bharule

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Preface

In the last 5 decades, evolution in rail transport has given birth to high-speed rail (HSR), marking the “second age of rail.” During this time, HSR networks have grown rapidly, reducing the travel time between cities in East Asia and Central Asia while connecting countries in Europe and shrinking the time-space geography of the continents. As a form of infrastructure, HSR is inevitably tied to an intricate web that overlaps urban–regional functions and the geographic expanses of human life. These overlaps induce complexity but, if developed as an integrated system, can achieve significant outcomes for the overall betterment of life. Several countries are planning to develop HSR networks, and there is a need to introduce a new point of view on the impact of transport infrastructure on quality of life. *Handbook on High-Speed Rail and Quality of Life* aims to discuss the complex implications of transport infrastructure, such as the direct transport system impacts on travel demand and mode, the development and financial impacts, the wider economic impacts, and the collective impacts on quality of life.

The chapters in this handbook are a collation of research and studies presented at Asian Development Bank Institute (ADBI) knowledge events. To better comprehend the complex impacts of investment in transport infrastructure, ADBI held a series of knowledge-sharing events in Tokyo between February 2018 and May 2019. The events comprised conferences and seminars covering the broader aspects of the planning, operation, and implementation of HSR infrastructure. Additionally, five special sessions and a high-level panel discussion on “Messages for Policy Makers for Developing and Operating Transportation Infrastructure” were organized at the World Conference on Transport Research at the Indian Institute of Technology Bombay, Mumbai, in May 2019.

The participants of these events ranged from policy makers to analysts, researchers, and specialists in the field of transport. Several of the participants were first-time authors and have contributed their experiences based on empirical evidence from existing ex-post evaluation studies. This handbook condenses and organizes the perspectives discussed during several discussions into four parts. Part I compiles emerging quantitative studies on modeling the effects of HSR on quality of life. Next, Part II discusses the impacts of transportation on urban and regional scale. Part III brings together specific cases that highlight the complexities involved in drawing messages for policy makers. Finally, Part IV discusses the institutional needs for HSR

development. This compilation illustrates the complex impacts of HSR infrastructure, informs about the effects, highlights the impacts, and presents a debate with a special focus on emerging economies that is curated to draw policy lessons for the future.

The policy messages from the 25 chapters in this handbook indicate that emerging economies and their populations have much to gain from transport modes that provide high-speed mobility with reliability and safety. The world has become interconnected on many levels, and an essential lesson from the case studies in this handbook is the consideration of the complexity involved in the successful design, construction, and operation of an HSR project. We hope this handbook will be a useful resource for policy makers planning to adopt HSR in their countries and that readers in the policy, development, and research communities will find this compilation insightful.

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The cases, concepts, and ideas presented in the chapters of this handbook were discussed and refined during the conference and seminar series held at the Asian Development Bank Institute (ADBI) in Tokyo and five special sessions held during the 15th World Conference on Transport Research at the Indian Institute of Technology Bombay in Mumbai. These events enabled the contributors to present their findings and exchange their world views with other academicians, consultants, development leaders, government officials, managers of high-speed rail systems, and metro, rail, and subway operators.

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Abbreviations

ACO	ant colony optimization
BCR	benefit–cost ratio
BKC	Bandra Kurla Complex (India)
CAGR	compound annual growth rate
CAREC	Central Asia Regional Economic Cooperation
CBA	cost–benefit analysis
CBD	central business district
CGE	computable general equilibrium model
CIDCO	City and Industry Development Corporation (India)
CNC	core network corridor
DID	difference-in-difference
DMIC	Delhi–Mumbai Industrial Corridor
EIB	European Investment Bank
ERTMS	European Rail Traffic Management System
EU	European Union
FAR	floor area ratio
G20	Group of 20
GDP	gross domestic product
GVA	gross value added
h	hour
HAC	heteroscedasticity- and autocorrelation-consistent
HHI	Herfindahl–Hirschman Index
HSR	high-speed rail
IAM	integrated assessment method
ICE	InterCity Express (Germany)
ICT	information and communication technology
IIT Kanpur	Indian Institute of Technology Kanpur (India)
IT	information technology
JIC	Japan International Consultants for Transportation, Co. Ltd
JICA	Japan International Cooperation Agency
JNR	Japanese National Railways
JR East	East Japan Railway Company
km	kilometer
km/h	kilometer per hour
KORAIL	Korea Railroad Corporation
KTX	KORAIL Express
LVC	land value capture

MAHSR	Mumbai–Ahmedabad High-Speed Rail
MCDCA	multi-criteria decision analysis
METI	Ministry of Economy, Trade and Industry (Japan)
MMR	Mumbai Metropolitan Region (India)
MSRDC	Maharashtra State Road Development Corporation
NAINA	Navi Mumbai International Airport Influence Notified Area
NEG	New Economic Geography
NHSRCL	National High Speed Rail Corporation Limited (India)
O&M	operation and maintenance
PEIT	Spanish Strategic Plan of Infrastructures and Transport
PIP	Principles for the Infrastructure Project Preparation Phase
PPP	public–private partnership
PRC	People’s Republic of China
QOL	quality of life
QP	Quality Principle
SAD	station area development
SCBA	social cost benefit analysis
SCEA	social cost effectiveness analysis
SCGE	spatial computable general equilibrium model
SDG	Sustainable Development Goal
SDM	system dynamics model
SPA	special planning authority
T20	Think20
TDR	transfer of development rights
TEN	Trans-European Network
TEN-T	Trans-European Network for Transport (European Commission)
TGV	Train à Grande Vitesse (France)
TOD	transit-oriented development
UIC	International Union of Railways
URSD	Urban Renaissance Special District (Japan)
VAR	vector autoregression
VCF	value capture financing
WEI	wider economic impact

Introduction

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Defining High-Speed Rail

Since the origin of the railways in the United Kingdom in the early 19th century, “high-speed” has been a time-relative concept. The 56-kilometer (km) Liverpool–Manchester Railway was the world’s first commercial passenger railway developed for intercity transport. The 50 km per hour (km/h) speed record achieved by the steam-powered “Rocket” locomotive in 1830 represented a truly high speed for its time. Soon, with the changes in technology, passenger rail travel would see tremendous upgrades in speed. The German diesel trains achieved 215 km/h in 1939 and the French electric-powered *Train à Grande Vitesse* (TGV) holds the current record on steel rails at 574 km/h (set in 2007). More recently, in April 2015, the magnetic levitation Chuo *Shinkansen* line achieved 603 km/h on a test track in Central Japan.

In rail transport, trains that use specialized rolling stock and operate at more than 250 km/h on new dedicated lines and 200 km/h or 220 km/h on upgraded lines are accepted as high-speed rail (HSR), as per the International Union of Railways (UIC 2008), although there is no single standard definition of HSR. In order to provide a non-speed related definition, Campos and de Rus (2009) reviewed the technical and economic characteristics of 166 HSR lines in 20 countries. Examining various lines—based on the infrastructure, development costs, operation costs, and forecast demand—the authors distinguish four HSR network types: the exclusive exploitation type, the mixed-speed type, the conventional mixed type, and the thoroughly mixed type. The description makes it clear that HSR is a combination of various infrastructure elements, which together form a single, integrated system and should be observed as a complete system.

High-Speed Rail and Its Effects

Since the early 1900s, Japan has been a pioneer in rail-integrated land development (De Souza, Ochi, and Hosono 2018). A consistent

incremental improvement in integrated land development practices has resulted in the economic development of the cities served by the *Shinkansen* corridors, suggesting an interdependence of the implementation and planning processes. Over time, the services and industries agglomerated along the first *Shinkansen* corridor have established nodes with connecting transit facilities in cities like Tokyo, Nagoya, and Osaka, which have emerged as prominent hubs (RIDA and OECF 1995).

The Republic of Korea has followed the Japanese integrated model of development but has required additional efforts in integrating regional public transport with the Korea Railroad Corporation (KORAIL) Express (KTX) corridors and stations to enhance revenue. With the fast mobility of KTX, a new form of the national economy was born. International conferences can now be held at places other than Seoul. The added accessibility attracts almost 100,000 people to connected cities from the Seoul capital area (KOTI 2015). This population shift was unprecedented in the country's history. The integration of public transit with KTX is underway around hub stations (Lee et al. 2014).

The case of the high-speed rail corporation in Taipei, China is unique. After becoming almost bankrupt, the company has resurrected itself in the past 10 years by making meticulous efforts to streamline the operations and sustainability of HSR. Reorganizing the company's operations management, improving stakeholder relationships, and establishing station-to-city center bus services has increased ridership and resulted in steady revenue growth (Chen 2018). This economy-wide discourse makes it clear that it takes more than a decade to establish a thriving HSR corridor. However, the methods to achieve success can be different.

HSR ushers in a paradigm shift for interregional mobility, boosting national economies. HSR systems reinforce accessibility and strengthen interregional as well as intraregional relations. Empirical data analysis of HSR's impact in Japan and other countries shows the direct impacts of salient features of HSR, like savings in travel time, improved safety, comfort, punctuality, and frequency of trains, which are significant in terms of increased business activity and productivity (Hayashi et al. 2017). With the increased accessibility to better markets, it is possible for businesses located in one region to explore national and international opportunities, which would previously have been accessible only to businesses located in capital cities. Such movement of businesses not only intensifies intercity economic links but, over time, creates an urban–regional development ecosystem along the HSR corridor region (Bharule 2019). Thus, the length of the HSR corridor,

the choice of the HSR station location, and its seamless integration with the existing urban transport infrastructure are critical.

HSR is the preferred mode of travel over automobiles and planes for distances of 400–700 km (Hayashi et al. 2015). Since the inauguration of the first *Shinkansen* line, the intercity travel time has reduced by over 50% in Japan. Technological innovations have helped in upgrading top-speed and train car safety, assuring increased frequency and improving the ride quality (KOTI 2015). HSR competes with roads and airlines, not just because of the change in modal share but also the total travel time, including access and egress, with added comfort and travel safety. In addition to this, global challenges, such as environmental impacts and climate change, are significantly reduced because HSR generates a far smaller carbon footprint compared with other forms of high-capacity transport (Hayashi et al. 2015, 2017). HSR connects and creates important hubs in the cities through which it travels. Yoshino and Abidhadjaev (2016) analyzed the effects of linking cities with HSR in the case of the Kyushu *Shinkansen* line's in Japan. The *Shinkansen* line construction started in 1991. It was partly operational until 2004, and in 2011 it became fully operational. During construction, land prices and property tax revenues increased in municipalities around the HSR stations.

Nakamura et. al. (1981) conducted interview surveys in cities along the Sanyo *Shinkansen* line, which started service between Osaka and Fukuoka in 1972. Using a system dynamic model, they analyzed the impacts of the extension of the *Shinkansen* line on interregional industrial relations. The study found that the *Shinkansen* had impacted the internal organizational system of firms, causing them to close branches in lower-ranked cities. The closed branches were merged the firms' headquarters located in Osaka. The accumulation of these services demonstrated a transformation in the regional economy; this change in the regional trend was also observed during the initial reconnaissance of the research. The research highlights the impacts of HSR on organizations, which can result in internal restructuring for the efficient management of resources and time. The local impacts of HSR infrastructure are not limited to one sector but pinpoint individual businesses, giving them the opportunity to improvise internally and expand geographic coverage.

HSR has been in operation for over 50 years in many countries. In Asia itself, during the past 2 decades, several corridors have been developed in the PRC, India, Viet Nam, Thailand, and other countries are also planning and constructing HSR. Studies on the impacts of transport infrastructure have argued that the effects of transport infrastructure investments at the respective locations are subject to externalities.

Economy-Specific Experiences in Developing High-Speed Rail Infrastructure

Japan

Japan is the pioneer in introducing HSR to the world. The first HSR link in the Japanese rail network came into commercial service in 1964, connecting Tokyo to Osaka. Known as the *Shinkansen* (新幹線), meaning “new trunk line,” the 515.4-km Tokaido line corridor was built in a linear geographical setting that was apt for rail travel, with the primary goal of expanding the capacity of the overcrowded Tokaido route between Tokyo and Osaka. Takatsu (2007) points out that the design of the Tokaido *Shinkansen* line alignment attempted to use existing railway stations on the conventional railway line connecting Tokyo and Osaka. However, some cities and towns on the Tokaido *Shinkansen* line were served by new stations located away from the existing stations on conventional railway lines. The Japanese *Shinkansen* trains began operations at a speed of 210 km/h, which reduced the travel time to 3 hours and 10 minutes, making Tokyo–Osaka day trips feasible. A speed upgrade to 270 km/h in 1992, further reduced the travel time to 2 hours and 30 minutes.

Republic of Korea

The Republic of Korea’s Seoul–Busan axis is the primary passenger and freight traffic corridor. The national rail operator introduced the KTX HSR service in 2004. The KTX service has shrunk the intercity travel time to less than 3 hours. This has not only changed commuting habits and lifestyles but it has also had significant social, economic, and cultural impacts (Terabe et al., n.d.). Since the introduction of the KTX, the number of rail passengers has increased alongside a significant decrease in the number of passengers opting for private cars, express buses, and aircraft to travel along the same route. The national government aims to expand the KTX network and reduce road use to the extent that it is possible to reach any part of the country within 1 hour and 30 minutes (Chosun Ilbo 2010).

People’s Republic of China

The People’s Republic of China (PRC) leads the world in terms of HSR line length. The Mid-to Long-term Railway Network Plan, laid out for the horizon year 2020 and adopted by the government in 2004, was

updated in 2008. Under this plan, the Beijing–Tianjin HSR, the first of a new generation of HSR, opened in August 2008 with a maximum speed of 350 km/h and is known as *Gaotie* (高铁). High-density corridors, like Beijing–Shanghai and Beijing–Guangzhou, have a design speed of 350 km/h, one of the highest in the world, while several other corridors with more modest passenger volumes have a maximum design speed of 250 km/h. Generally, both these types of HSR projects in the PRC are passenger-dedicated lines and greenfield projects (UIC 2008). At the end of December 2013, most of the metropolitan regions in the PRC were either connected, or in the process of being connected, to lines with a maximum speed of 200 km/h or higher (Ollivier, Sondhi, and Zhou 2014).

The PRC's HSR network is expected to span 30,000 km by 2020. This expansion will help in connecting 80% of the PRC's cities by creating eight corridors, each from north to south and east to west. This network configuration is envisioned to revitalize many economically challenged cities in western and central parts of the PRC because of the hub effect created by the HSR system, especially at junctions offering a new means of travel and also regenerating and redistributing economic activities by encouraging population mobility (Li et al. 2016). With increasing passenger flow and accessibility, cities on HSR lines are becoming strategically important targets for industries such as the hotel, catering, logistics, and real estate industries. While regional economic differences are not rare in a global economy, the PRC's regional differences are by far the most disparate of any in the world (Amos, Bullock, and Sondhi 2010; Ollivier, Sondhi, and Zhou 2014).

Taipei, China

Plans for the first HSR corridor in Taipei, China came to light in 1989. The plan aimed to tackle the growing issues in managing the congestion between Taipei, China's two largest cities. The high-speed rail corporation operates 345 km of HSR between north and Kaohsiung in the south. Valued at \$13 billion at the time of implementation, the project was one of the world's largest privately funded railway construction projects. Under the Station Zone Development Agreement, the government granted the rail corporation a 50-year concession to develop the land surrounding the stations for commercial, residential, and recreational purposes (Terabe et al., n.d.). Although the project started without much delay, the ridership count was lower than expected. The government revived the debt-ridden corporation and introduced a new operations and management structure. The government is a major stakeholder in the corporation,

but the company operations are privately managed (Chen 2018). The operator expects an increase in ridership after the opening of more stations on the line soon after an expansion scheduled in 2020.

Europe

The first HSR lines in Europe were built around the 1980s. By connecting important cities, they improved the travel time on intranational corridors. Private operators operate almost all lines in the European Union (EU), and they receive EU funding. The EU Council Directive of 1996 specifically aimed to achieve interoperability of high-speed trains (EU Law 2008). This cross-border infrastructure promotion was part of the larger Trans-European Transport Networks (TEN-T), which are a part of the wider Trans-European Networks (TEN) that were envisioned by the EU in 1990. The wider system of TENs includes transportation, telecommunications, and a proposed energy network spread across the EU.

France

France was the first European country to start HSR services in 1981. The TGV service between Paris and Lyon, with a duration of 2 hours and a length of 450 km, is part of a strategy to decongest the overly congested conventional routes. A dedicated HSR line was constructed, and the terminals were integrated with the existing stations. While converging all the lines toward Paris, the French government strategically developed more profitable lines first. In recent years, the observed regional development in terms of social returns has been higher than expected (The Local 2018). Such an initiative has encouraged the government to contribute to the construction costs and further expand the network (O'Sullivan 2018).

Spain

The first Spanish *Alta Velocidad Española* (AVE) line opened between Madrid and Seville in 1992. As in the case of Japan, the incompatible Spanish rail gauge made it necessary to overlay a new standard gauge line (Givoni 2006). The first line was progressively extended and connected to Barcelona. As a part of an EU Commission plan to develop an extended TEN, the Spanish network was connected to the French railway network in 2012 (Railway Gazette 2011). In 2010, Spain developed the largest HSR network in Europe. With the

population concentrated around the coast and Madrid in the center of the country, Spain developed a radial railway network. Currently, with over 3200 km of HSR lines, Spain's network is second to the PRC's HSR network.

Germany

Deutsche Bahn, the German railway company, started its first railway service, the InterCity Express (ICE), in 1991. The ICE network is designed to connect major cities and hubs within Germany and in the neighboring countries of France, the Netherlands, Switzerland, Denmark, Belgium, and Austria (Sands 1993). German ICE services are used for short-to-medium distances between the cities, and trains operate at speeds of 200 km/h and 250 km/h (UIC 2008).

Italy

Italy partially began its first dedicated HSR in 1978, with the construction of a 254 km *direttissima* line connecting Rome and Florence. The line was completed in 1992. With the introduction of *direttissima* lines, the travel time between the main Italian cities has been progressively reduced (Desmaris 2016). Infrastructure in Italy follows the country's geography, and the HSR lines are oriented in a north–south perspective, with the greatest density in the north. Italian HSR is an exception in Europe, as the distance between the cities is shorter compared to other countries, and Italian HSR lines operate at different speeds.

Countries Currently Developing High-Speed Rail Infrastructure

India

In early 2010, India's Ministry of Railways announced—in its Vision 2020—seven HSR lines connecting several cities in distinct parts of the country. A 508-km HSR line connecting Mumbai and Ahmedabad in western India will be the first to be developed. In 2015, India and Japan entered a Memorandum of Cooperation on High-Speed Railways. Under the agreement, the Mumbai–Ahmedabad HSR will adopt Japanese *Shinkansen* technology. Adopting a dedicated track configuration, the line is envisioned to decongest India's busiest passenger railway corridor. The project is estimated to be operational by late December

2023 and to cost \$16 billion, funded by official development aid from the Japan International Cooperation Agency.

Indonesia

The Java HSR project is planned to connect the densely populated region between the national capital, Jakarta, and the second-largest city, Surabaya, which are located 730 km apart on the Indonesian island of Java. As part of the PRC's One Belt One Road initiative, a 150-km initial phase of the rail link is envisioned to be operational by early 2021. After several rounds of proposals and bidding since 2008, the project was finally awarded to the PRC in 2015, and it is being developed at an estimated cost of \$5.5 billion for the first phase connecting Jakarta to Kertajati International Airport, the second largest airport in Indonesia, near Bandung city.

Thailand

The Government of Thailand approved five HSR lines in late 2010. Although the statuses of the lines vary, all of the planned 1,500-km network converges on the capital city of Bangkok. The network will be developed in several stages and it is envisioned to be complete by 2036, with the earliest operation beginning in 2021. The complete network inclusive of airport links is estimated to cost \$30 billion. The Thai HSR network is developed under official development aid projects, with two lines awarded each to Japan and the PRC, while the fifth line is still in the proposal stage. In addition to the network, a 220-km corridor of an airport link HSR is under development as part of the Thai Eastern Economic Corridor Project. Under the project, the airport link is proposed to connect three international airports between Bangkok and Pattaya. Developed under a Sino-Thai public-private partnership consortium, the project is due to open in 2024.

Despite such growth in HSR networks, the doubts of the potentials of HSR infrastructure have not been fully dispelled. While the potential effects of HSR can be long-ranging and multitudinous, challenges include building alternative resources that are required to elicit benefits from the spillovers of mega-infrastructure projects.

Handbook on High-Speed Rail and Quality of Life outlines the global experience of HSR development, construction, impacts, and planning, with a special focus on countries planning for HSR development in the coming decade. HSR infrastructure brings in considerable socioeconomic benefits that cannot be captured through econometric

modeling alone. Thus, capturing the impacts of HSR infrastructure requires analysis involving a scalar as well as a temporal lens. The studies compiled in the four parts of the handbook show that HSR may become a core infrastructure for desired urban developments and quality of life over time. Part I focuses on the emerging frontiers of modeling spillover effects of HSR for quality of life. Part II draws lessons from the relationships between HSR stations and the development ecosystems of urban and regional systems. Part III presents case studies to draw policy messages for countries planning to implement HSR infrastructure. Part IV distills the key aspects of institutional development for the successful operations and management of HSR infrastructure. The studies discussed in the handbook vary with the scale of development and the time required to achieve the expected results. This handbook emphasizes the aspects of HSR infrastructure that enhance quality of life.

HSR is beneficial both to the cities and towns along the corridors and the railway operators. For the cities and towns, HSR serves as a form of urban amenity that is crucial for accelerating their economic growth and improving quality of life. For the railways, HSR is a new medium to set the brand value of the operators, while at the same time the station areas provide an important opportunity to harness revenue through nonrailway businesses. Every HSR project affects and is affected by stakeholders with diverse needs and with varying degrees of power. However, policies can be effectively executed only with the support of strong institutions and human resources that can address the challenges, such as financial and capacity constraints, to successfully implementing and operating the project.

Careful planning and coordination are required to capture the full development effects of an HSR project, even though actualizing the benefits may take decades. The success of an HSR project relies on a harmonious relationship between multiple stakeholders by policies that accommodate their views and needs. Evidence in this handbook suggests that the introduction of transport infrastructure, such as HSR services, by itself may not drive the spillover of economic activities. There is a need for a set of policies which, along with transport infrastructure, generates implications for spatial development strategies that focus on enhancing quality of life at all.

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PART I

**Frontiers of Modeling
the Spillover Effects
of High-Speed Rail
for Quality of Life**

Key Messages

The first part of this handbook presents an overview of the new tools, methods, and processes that are necessary to quantify, visualize, and assimilate the effects of high-speed rail (HSR) development in the decision-making process of policy makers. The development journey of HSR around the world has not been steady, but full of successes and failures. The first few HSR projects in Japan, developed over 5 decades ago, enjoyed instant success among users, leading to nationwide HSR development plans. The later projects, however, did not enjoy the same level of ridership, so the development plans were either reduced or put on hold for the long term. Examples from Europe also mimicked the Japanese story. Many factors were responsible for an unenthusiastic response for the later projects. Most prominent among them was the rationale that the benefits of HSR measured in terms of time and energy savings often did not outweigh the exorbitant cost of its development.

More recently, the remarkable growth in HSR development in the People's Republic of China in the last decade has given the debate around the world renewed momentum. Academic studies on the topic have now also gathered evidence for the significant long-term socioeconomic impacts, known as the spillover effects, at the urban, regional, and national levels. Including such academic evidence in the decision-making process is thus essential to make a sound judgment about the investment. However, the challenge remains to develop practical decision-making methods and tools that can help quantify and visualize the spillover effects of such large-scale infrastructure projects. In this regard, Part I explores the frontiers of modeling the spillover effects of HSR while offering valuable lessons from cases around the world. Together, the six chapters not only provide evidence supporting the development of HSR but also offer a repository of tools that policy makers can readily use when deciding on the situation in their own country or area.

Chapter 1 provides an in-depth explanation of an innovative scheme for land acquisitions and quantifies its potential benefits for HSR. Large-scale infrastructure projects often face challenges in acquiring the necessary land. Over the years, many different approaches have been tried to convince landowners to give up their land more willingly—with limited success. Such approaches have repeatedly failed because of the complexities involved in the transfer of land rights. Thus, the

chapter explores an innovative approach using land trusts where no transfer of land is necessary. The case study on HSR in Taipei, China demonstrates the increased benefits of using a land trust mechanism for all stakeholders.

Chapter 2 discusses several possible strategies to evaluate the nine core transport network corridors in the European Union. HSR is one focal point for the proposed core network corridors. The chapter highlights that conventional cost-benefit analysis is too narrow and could lead to a patchwork of independent projects rather than an integrated network. Favored are dynamic approaches that are well-calibrated on the base of empirical observations, such as macroeconomic or system dynamics models, instead of theoretically more challenging general equilibrium models, which nevertheless remain the mainstream in the economic literature.

Chapter 3 examines the effect of HSR on the land prices of targeted regions in Taipei, China using difference-in-difference (DID) methodology on prefectural-level data. Local land prices in regions covered by HSR are compared with those in other regions not covered to estimate the impact of HSR. The findings presented in the chapter suggest a positive effect on the average land prices in HSR regions from the start of construction, with the effect becoming even larger after the beginning of the operation. This positive relationship between HSR investment and land prices in Taipei, China offers meaningful implications for potential HSR investments in other economies because increases in local land prices often lead to increased local tax revenues.

Chapter 4 examines the relationship between HSR and the agglomeration economy in the scope of specialization and diversity, using Japanese data across 17 industrial sectors at the municipality level. The analysis reveals that both specialization and diversity benefit economic productivity. Yet, a city that is not specialized and does not have a high level of industrial diversity will lose out in the economy. Further, distance to HSR services could affect a city's specialization and diversity. The chapter thus presents an important result for policy makers to consider an integrated planning framework such that HSR access positively affects a city.

Chapter 5 introduces and applies the concept of spillover effects on HSR development to formulate the economic impact on increasing regional tax revenues. The chapter extends the idea to spatiotemporal modeling and analysis by developing a model to estimate the extent of the spillover effect using data on spatiotemporal land cover, land price panels, and municipality tax revenues. The observed development trends around each station highlight the characteristics of the respective spillover effect. The study results suggest that some of the features

around stations promote the spillover effect, while others may obstruct it, thereby providing a practical tool for station area planning during HSR development.

Finally, Chapter 6 explores promising new ideas and technologies to collect spatiotemporal data that are beneficial for evaluating and visualizing the impact of infrastructure development. Collection, maintenance, and improvement of such spatiotemporal data are proven necessary as cities experience rapid growth. The new data archives discussed in the chapter demonstrate the capability of applying such well-managed data to analyze the complex interactions happening at urban and regional levels.

The logical conclusions based on the scientific studies presented in this part of the handbook thus establish, beyond doubt, that developing countries have much to gain from the development of transport modes such as HSR that provide high-speed mobility to masses of their population. The six chapters of this part of the handbook provide empirical evidence of the much-debated spillover effects of large-scale transport projects. In addition, the state-of-the-art methodologies used in the studies offer a repository of tools and data sources that policy makers can readily develop and use to make sound judgments about the potential socioeconomic impacts of HSR development in their own country.

1

Land Trust Scheme and the Spillover Effects of Infrastructure Investment

Naoyuki Yoshino, Kai Xu, and KE Seetha Ram

1.1 Background

There are huge infrastructure investment needs in Asia and the Pacific. As Table 1.1 shows, infrastructure needs are very high compared with tax revenues in many regions of Asia and the Pacific. Based on the ratio of infrastructure investment to tax revenues in the last column, it is clear that 26.3% of the total tax revenue is needed for infrastructure investment in the region as a whole. In South Asia, as shown in the third row, this is as high as 49.1%. If all the infrastructure projects are financed by tax revenues, a public budget deficit would accumulate. In

Table 1.1: Infrastructure Investment Needs in Asia and the Pacific

Region	Investment Gap (IG)	IG/GDP (%)	IG/Tax (%, as of 2015)
Central Asia	33	6.8	29.6
East Asia	919	4.5	21.4
South Asia	365	7.6	49.1
Southeast Asia	184	5.0	36.4
The Pacific	2.8	8.2	30.9
Asia and the Pacific	1,503	5.1	26.3

GDP = gross domestic product.

Note: Monetary values are in billions of United States dollars at 2015 prices.

Source: Authors' estimation based on Asian Development Bank (2017) database.

this situation, private sector investment is the key to the sustainable development of infrastructure.

In many Asian countries such as Bangladesh, India, Indonesia, and Thailand, land acquisition is one of the main issues for infrastructure development that delays the completion of projects and lowers the rate of return of private investment. For instance, Japan had a plan 30 years ago for a high-speed rail project linking Narita Airport with the city center of Tokyo (Nakamura et al. 2019). However, a few landowners who did not want to sell their land and thus opposed the project hindered the construction of the high-speed railway. Land acquisition is not only a problem for infrastructure projects; the construction of commercial buildings and apartments in Japan has always involved negotiation with landowners. Land trusts have been extensively used in Japan in the area of commercial and residential buildings. Borrowing the concept of land trusts, this chapter will discuss the potential application of the scheme to infrastructure investment.

1.2 Introduction of the Land Trust Scheme

Figure 1.1 shows the traditional method of land acquisition by purchase from landowners. The landowners sell the land to infrastructure companies, and the company pays the land price at the beginning of construction. The cost of the land is a major cost of the infrastructure. In Malaysia, for example, about 50% of the total cost of transport infrastructure investment goes toward land purchase.

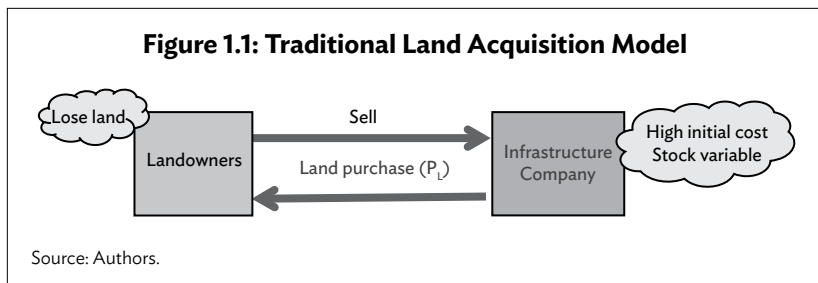
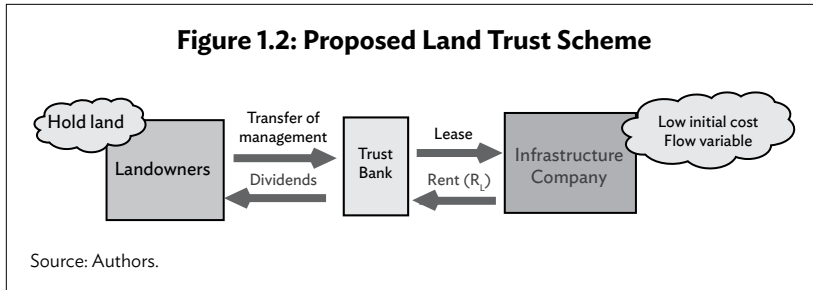


Figure 1.2 shows the proposed land trust scheme. Under this scheme, landowners retain ownership of the land but lease the land to the infrastructure company instead of selling it. Between landowners

Figure 1.2: Proposed Land Trust Scheme

and infrastructure companies, the trust bank acts as the intermediary monitoring whether the land is properly used and paying rent to landowners based on project revenues.

The situation can be represented as follows:

$$P_L = R_L + \frac{R_L}{(1+d)} + \frac{R_L}{(1+d)^2} + \dots + \frac{R_L}{(1+d)^2} + \dots = \frac{R_L}{d} \quad (1)$$

$$P_L \gg R_L \quad (2)$$

Equation (1) shows the relationship between the cost of land purchase (P_L) and land rent (R_L). P_L is the present discounted value of R_L . If the duration of rent is unlimited, P_L equals R_L divided by discount rate d . Therefore, the cost of P_L is much higher than R_L , as indicated in equation (2). If the land trust scheme is applied to infrastructure investment, the initial cost of purchasing land will be significantly reduced. Under this proposal, the infrastructure company only needs to pay the annual land rent using the company revenue received from user charges. Furthermore, if spillover tax revenues are considered, as will be discussed later, the payment of land rent to landowners would be easier.

The upper diagram in Figure 1.3 shows the current costs and benefits of infrastructure projects. These include the cost of the land purchase (P_L), construction cost, and operation and maintenance costs, while the benefits come from user charges, highway tolls, train tariffs, and so on, depending on the type of infrastructure project. Under the proposed land trust scheme, as shown in the lower diagram, the total costs of infrastructure investment will be the cost of the land rent (R_L)—replacing the land purchase (P_L) cost—the construction cost, as well as the operation and maintenance costs. The benefits are not only the user charges but also spillover tax revenues created by the infrastructure investment.

Figure 1.3: Costs and Benefits of Infrastructure Investment**a. Current Scheme**

Cost:
Land purchase cost (P_L)
Construction cost
Operation cost
Maintenance cost

Benefit:
User charge

$$\begin{aligned}
 G_t &= \text{Construction cost} \\
 &\quad + \text{Land purchase cost } (P_L) \\
 G_{t+1} &= \text{Operation cost} \\
 &\quad + \text{Maintenance cost} \\
 &\vdots \\
 G_{t+n} &= \text{Operation cost} \\
 &\quad + \text{Maintenance cost} \\
 \text{Total cost} &= G_t + G_{t+1} + \dots + G_{t+n}
 \end{aligned}$$

$$\begin{aligned}
 T_t &= 0 \\
 T_{t+1} &= (\text{User charge})_{t+1} \\
 &\vdots \\
 T_{t+n} &= (\text{User charge})_{t+n} \\
 \text{Total benefit} &= T_t + T_{t+1} + \dots + T_{t+n}
 \end{aligned}$$

b. Proposed Scheme

Cost:
Land rent cost (R_L)
Construction cost
Operation cost
Maintenance cost

Benefit:
User charge
Spillover tax revenue

$$\begin{aligned}
 G_t^* &= \text{Construction cost} \\
 &\quad + \text{Land rent cost } (R_L) \\
 G_{t+1}^* &= \text{Operation cost} \\
 &\quad + \text{Maintenance cost} \\
 &\quad + \text{Land rent cost } (R_L) \\
 &\vdots \\
 G_{t+n}^* &= \text{Operation cost} \\
 &\quad + \text{Maintenance cost} \\
 &\quad + \text{Land rent cost } (R_L) \\
 \text{Total cost} &= G_t^* + G_{t+1}^* + \dots + G_{t+n}^*
 \end{aligned}$$

$$\begin{aligned}
 T_t^* &= 0 \\
 T_{t+1}^* &= (\text{User charge})_{t+1} + \text{Spillover} \\
 &\vdots \\
 T_{t+n}^* &= (\text{User charge})_{t+n} + \text{Spillover} \\
 \text{Total benefit} &= T_t^* + T_{t+1}^* + \dots + T_{t+n}^*
 \end{aligned}$$

Source: Authors.

1.3 Introduction of Spillover Effects

Infrastructure can create regional spillover effects, such as the construction of new apartments that increase the value of property; new businesses will come into the region and create new employment, new

restaurants will open, and the services sector can be developed. This regional development will increase tax revenues from the infrastructure projects. These tax revenues include revenue from property tax, corporate tax, income tax, and sales tax.

Theoretically, the concept of spillover effect can be expressed using the following equations:

$$Y = f(K_P(K_G), L(K_G), K_G) \quad (3)$$

$$\frac{dY}{dK_G} = \frac{\partial f(K_P, L, K_G)}{\partial K_G} + \frac{\partial f(K_P, L, K_G)}{\partial K_P} \frac{\partial K_P}{\partial K_G} + \frac{\partial f(K_P, L, K_G)}{\partial L} \frac{\partial L}{\partial K_G} \quad (4)$$

The production function (3) consists of three factors: infrastructure investment (K_G), new business opportunities (K_P), and the associated new employment (L).

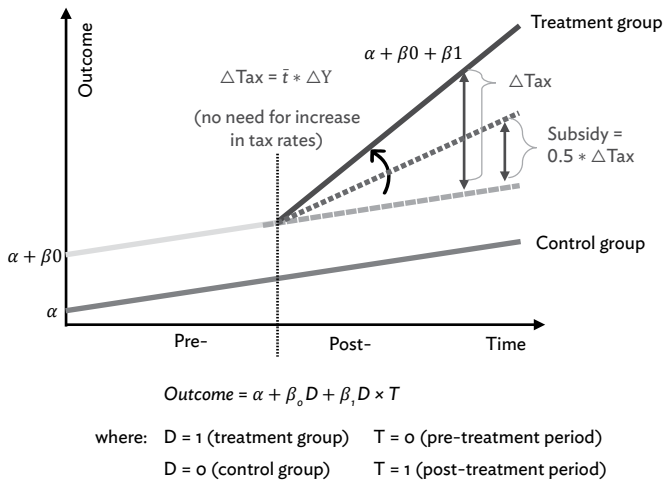
Infrastructure development has both direct and indirect impacts. Direct impacts reflect the immediate outcome of infrastructure development, such as an increase in road capacity due to the development of transport infrastructure, while indirect impacts are the short- and long-term effects of the investment, such as an improvement of capital inputs and employment from regional economic activities, which usually take time. The indirect impact is assumed to be the spillover effect.

Equations (3) and (4) show the impacts of infrastructure investment. The first component is the direct effect of infrastructure investment (K_G), which creates economic activities in the region. The second component shows that the infrastructure investment will bring private businesses into the region, which is represented by changes in K_P , increasing regional gross domestic product. The third component shows that infrastructure investment will bring employment into the region. New businesses are created, new restaurants are opened, and new employees are hired. The second and third are called external effects, or spillover effects.

All the spillover tax revenues are shown by the solid black line in Figure 1.4. Currently, this increase in spillover tax revenues is collected by the government and not returned to infrastructure investors. However, supposing 50% of these tax revenues are returned to infrastructure investors, then the infrastructure companies and investors would receive not only the user charges but also the spillover tax revenues, as shown by the gray dotted line, increasing their revenue and the rate of return of the investments.

The difference-in-difference (DID) method is utilized to capture the spillover effect. As indicated by the name, the method computes the double difference over different times, regions, or groups to estimate

Figure 1.4: Spillover Concept and Difference-in-Difference Method

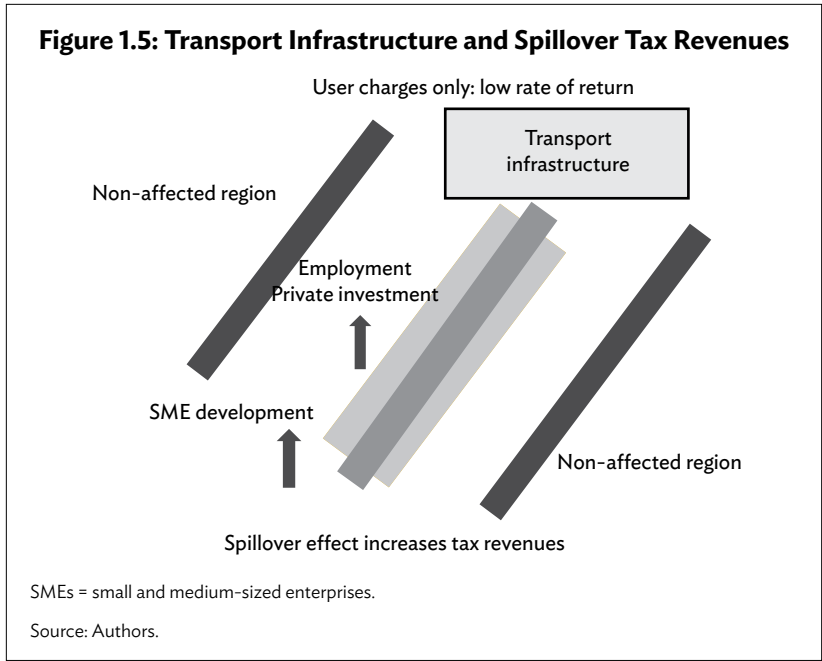


Source: Authors.

the impact of policy interventions or infrastructure projects on a certain subject.

The underlying assumption is that the changes in outcomes between groups are the same over time, and the policy or the project is the only intervention that creates a difference. To carry out a DID analysis for capturing the spillover effect, the differences between pre- and post-infrastructure investment and between treatment and control group are measured. To be specific, first, the difference in pre- and post-outcomes for both groups are obtained (the time axis). Then, for the treatment group, the difference is subtracted from the total difference to further exclude other time-varying factors (solid black line and dotted gray line). Finally, the net difference is interpreted as the spillover effect of the infrastructure project.

Figure 1.5 shows an example of spillover tax revenues. The dark gray line in the middle shows the transport infrastructure or infrastructure investment: this could be a highway or high-speed rail. The light gray regions along this infrastructure investment line represent the area into which new businesses will come, employment will be created, and small and medium-sized enterprises (SMEs) will be established. These spillover effects of the light gray region will increase the local tax revenues compared with the non-affected regions outside the solid black line.



Examples of transport infrastructure investment have been developed to investigate the spillover effects of infrastructure investment, providing a deeper understanding of such effects. The first applies the DID method to a highway project in the Philippines, and the second to a high-speed rail project in the Kyushu region in Japan. Comparing the treatment region with the control group regions reveals evidence of an increase in tax revenue along transport infrastructure projects. This increment of tax revenue is the spillover tax revenues.

Yoshino and Pontines (2015) have estimated the impact of building a highway in the Philippines. Table 1.2 shows an example of the impact of the highway on regional tax revenues.

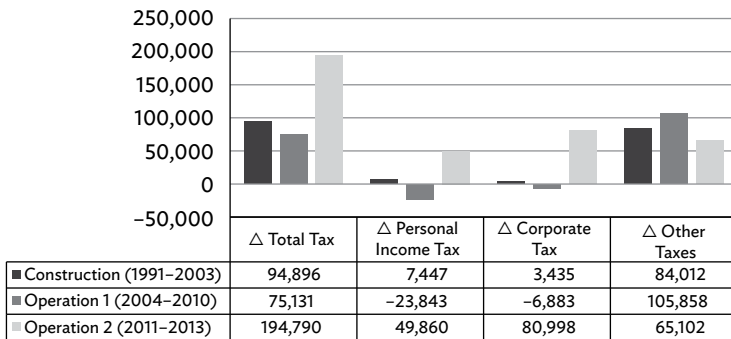
At T-2, the revenue was ₱134 million. After 4 years of operation (last column, T+4), the tax revenue of Lipa City rose to ₱371 million. This shows a significant increase in tax revenues after 4 years of operation. The same conclusion applies to tax revenues in Batangas City, which increased to ₱1,209.61 million. Compared with the period before the construction of the highway, this is about three times as much as before the construction started. Therefore, this highway project shows a big spillover effect into the region.

**Table 1.2: Tax Revenues in Three Cities
along the Highway Project in the Philippines
(₱ million)**

Region	Year						
	T-2	T-1	T	T+1	T+2	T+3	T+4
Lipa City	134.36	173.50	249.70	184.47	191.81	257.35	371.93
Ibaan	5.84	7.04	7.97	6.80	5.46	10.05	12.94
Batangas city	490.90	622.65	652.83	637.83	599.49	742.28	1,209.61

Source: Yoshino and Pontines (2015).

**Figure 1.6: Estimates of Connectivity-Increased
Tax Revenues in the Kyushu Region
(¥ million)**

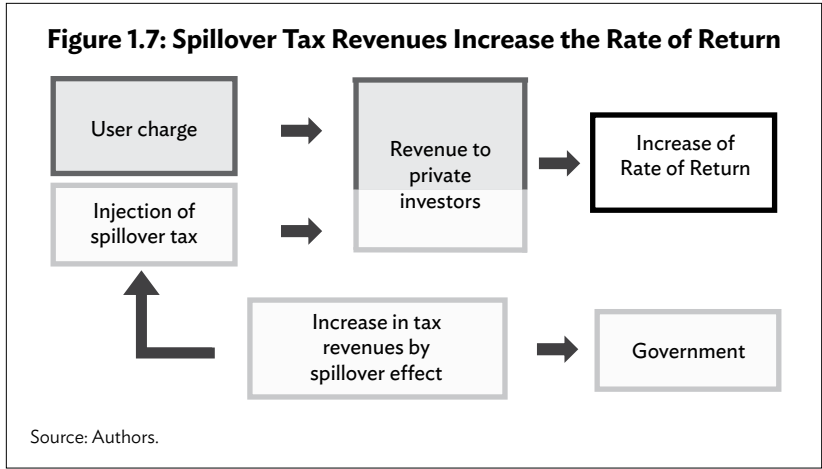


Source: Yoshino and Abidhadjaev (2016).

Yoshino and Abidhadjaev (2016) estimated the impact of the Kyushu rapid train in Japan.

In Figure 1.6, the three periods shown are the construction period, operation period without good connectivity, and the operation period with good connectivity (to Osaka and Tokyo).

Total tax revenue in the left block shows that after the connectivity was completed, tax revenue more than doubled. The personal income tax revenue shows a clear increase after connectivity. The corporate tax revenue also increased once the high-speed rail connecting large cities was completed. The last block of other tax revenues refers



mainly to property tax revenue, which is different from personal or corporate income tax. Property tax revenues started to increase during the construction period because speculators started to purchase these properties, which contributed to the increase in tax revenue. Different tax revenues illustrate different patterns of tax increments. Generally, connectivity is very important for high-speed rail in creating spillover tax revenues (Ishii, Xu, and Seetha Ram 2019).

Traditionally, all these increased tax revenues benefited government—the central government and local governments—rather than being returned to infrastructure investors. By relying on user charges only, the rate of return for infrastructure investors was very low. If 50% of these increased tax revenues were returned to infrastructure investors, the rate of return would become the solid black line in Figure 1.4 instead of the gray dotted line. The spillover tax revenues of infrastructure investment should be returned to private investors, as shown in Figure 1.7. This would increase the rate of return.

1.4 Case Study: Tsukuba Express

The Tsukuba Express (TX) is a commuter railway between Tokyo and Tsukuba City (Figure 1.8). It aims to improve accessibility between Tsukuba and Tokyo, as well as accessibility to terminal cities in the region between. The black dots represent the stations on the TX line. In this case, the treatment group and the control group are defined as follows:

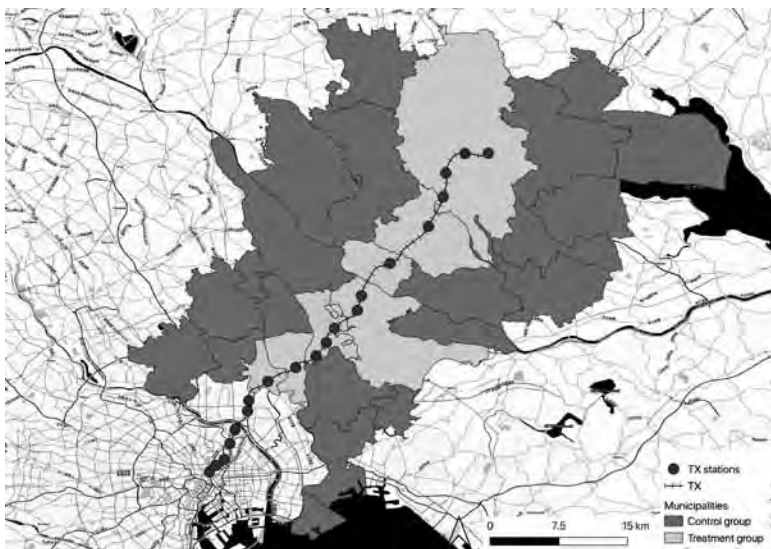
- Treatment group (light gray): municipalities with TX stations (Kashiwa, Nagareyama, Misato, Yashio, Moriya, Tsukuba-mirai, and Tsukuba cities) (n=7)
- Control group (dark gray): other municipalities in a 10-kilometer range from TX (n=20)

The Tokyo Metropolitan region and the municipalities not in a 10-kilometer range from TX are also excluded in this study because the economic impact of the railways is relatively smaller.

The construction of the railway started in 1994, and the operation of all sections started in 2005. This case study focuses on property tax revenue, using the annual reporting of property tax “settlement” revenue data from 1989 to 2017 of municipalities from e-Stat.

The settlement revenue represents the ideal value of the revenue, which excludes any delinquent or overdue payments from the previous year. Some municipalities have been merged into neighboring municipalities over the years. To aggregate the tax revenues of those merged municipalities, we used the administration boundary in 2017

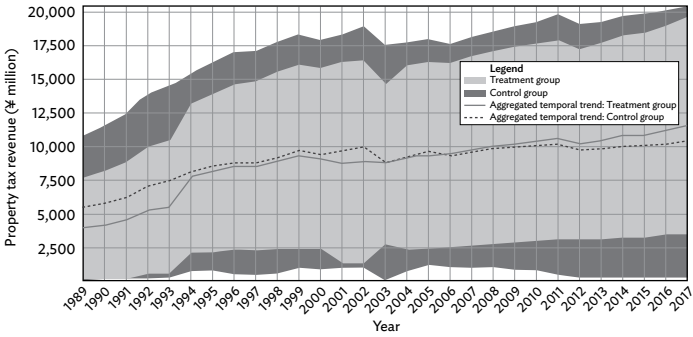
Figure 1.8: Tsukuba Express



TX = Tsukuba Express.

Sources: National Land Information Division, National Spatial Planning and Regional Policy Bureau, Ministry of Land, Infrastructure, Transport and Tourism of Japan; and OpenStreetMap contributors.

Figure 1.9: Aggregated Property Tax Revenue of Treatment and Control Group



Source: Authors; Portal Site of Official Statistics of Japan (<https://www.e-stat.go.jp/>).

and performed a spatial join to summarize the revenues of the merged municipalities.

DID was applied to compare the treatment and control groups (Miyazawa, Wetwitoo, and Seetha Ram 2019). The results are shown in Figure 1.9. The aggregated temporal trend of the property tax revenue shows that, after 1994, the property tax revenue of the treatment group clearly increased compared with the control group.

Table 1.3 shows the econometric results comparing different project phases: preconstruction, construction, and operation. Comparing the preconstruction and construction periods, there is a significant increase in time effect, meaning that the construction impact is significant. The treatment effect of the difference between the control group and the treatment group is shown, comparing the construction and operation period. After the operation started, the time effect became gradually significant as new businesses came to the region and new apartments were created. Even though the Adj. R^2 value that measures the goodness of fit is not high, the DID effect is statistically significant in both phases I and III, suggesting a clear spillover effect on property tax revenue after the construction started in 1994.

Figure 1.10 shows the spatial distribution of the property tax revenue in the target municipalities. The first map is for 1994 and the second map is for 2017. The dark gray shading of the municipalities indicates significant increases in property tax revenue. Along the TX line, many regions saw an impact on property tax revenues. The property tax revenue of a few of the municipalities in the treatment group increased

significantly, which displays the regional disparity between the control and treatment groups.

Table 1.3: Difference-in-Difference Analysis and Econometric Results

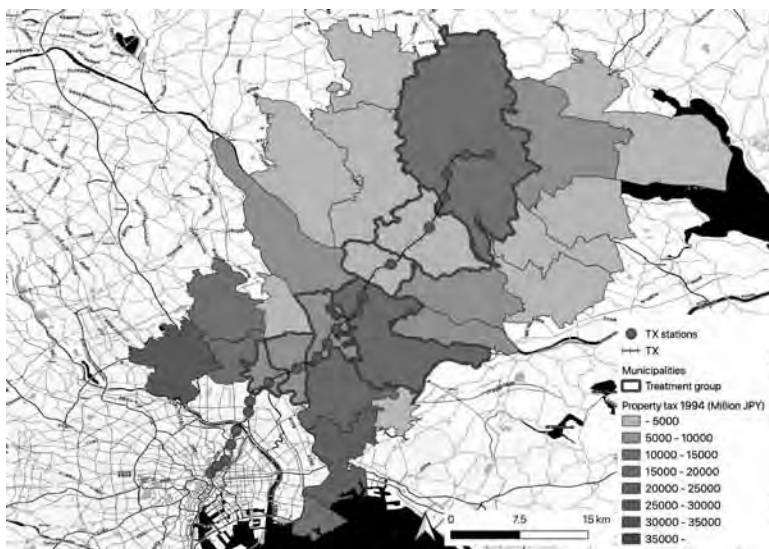
Phase	I Preconstruction vs. Construction			II Construction vs. Operation			III Preconstruction vs. Operation		
	Estimate	t-stat	sig	Estimate	t-stat	sig	Estimate	t-stat	sig
Const.	14.87	343.20	***	15.254	528.288	***	14.879	340.932	***
Treatment effect c	0.113	0.638		0.5195	4.310	***	0.1138	0.634	
Time effect t	0.375	7.193	***	0.0079	0.203		0.3837	7.502	***
DID	0.405	1.880	*	0.1530	0.940		0.5588	2.646	***
Adj. R ²		0.041			0.019			0.047	
N		1,899			2,890			2,175	

DID = difference-in-difference.

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Source: Authors.

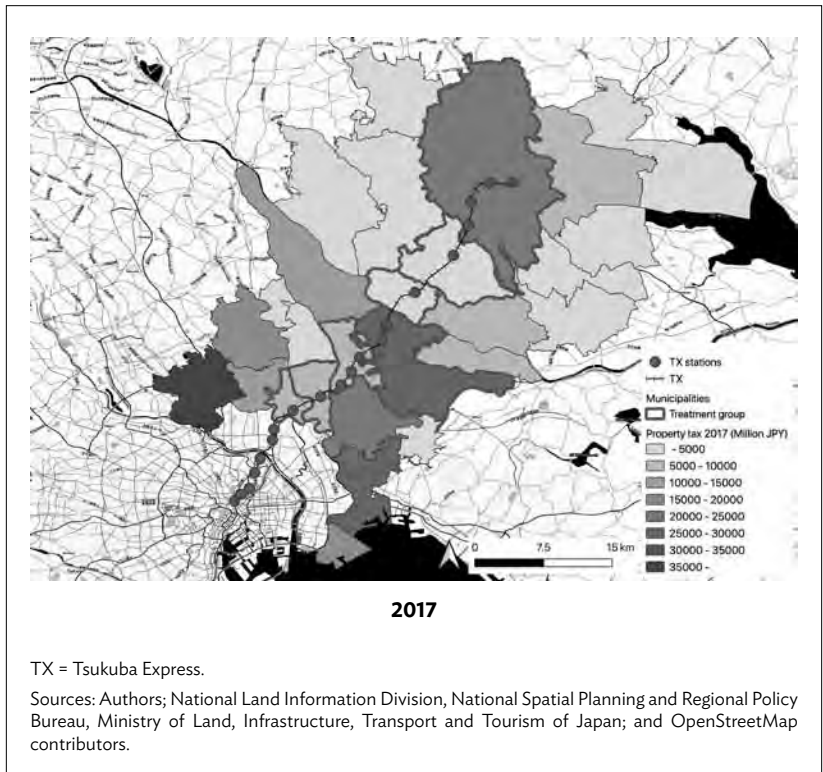
Figure 1.10: Spatial Distribution of Property Tax Revenue



1994

continued on next page

Figure 1.10 *continued*



1.5 Case Study: High-Speed Rail Project in Taipei,China

Table 1.4 shows the background of the high-speed rail project in Taipei,China. Before 1999, there was a preparation period of land acquisition before construction of the high-speed rail. The land acquisition cost was NT\$106 billion. The construction period was from 1999 to 2006, and the total construction cost was NT\$408 billion. Operation and maintenance costs from 2007 to 2033, a period of 27 years, are expected to be NT\$540 billion. In total, as shown in the cost column, NT\$1,054 billion will be spent. The generation of revenue started in 2007 when the high-speed railway began operation. User charges are expected to be NT\$1,890 billion. Therefore, the total expected revenue for this case study is NT\$1,890 billion and the total cost NT\$1,054 billion.

Table 1.4: Cost and Revenue of High-Speed Rail Project in Taipei, China

Project Phase	Year	Duration	Cost (NT\$ billion)	Revenue (NT\$ billion)		
Preparation	Before 1999	NA	Land acquisition	106	NA	
Construction	1999–2006	8 years	Construction	408	NA	
Operation	2007–2033	27 years	Operation and maintenance	540*	User charge	1,890*
Total		35 years		1,054*		1,890*

* Author estimates.

Sources: Authors; Renzhi (2019).

Further, we investigated the cost–benefit structure under the proposed land trust scheme and spillover tax revenues. Three scenarios are considered in Table 1.5. The original scenario is shown in the second column. The second row shows the net present value (NPV) of the cost. If the high-speed rail project purchases land at the beginning, then the total NPV cost, as shown in the second row, is –NT\$620 billion. If the land trust scheme is applied such that the landowners lease the land to the high-speed rail company, the initial cost is reduced and replaced by land rent cost. In this case, the NPV is reduced to –NT\$606 billion.

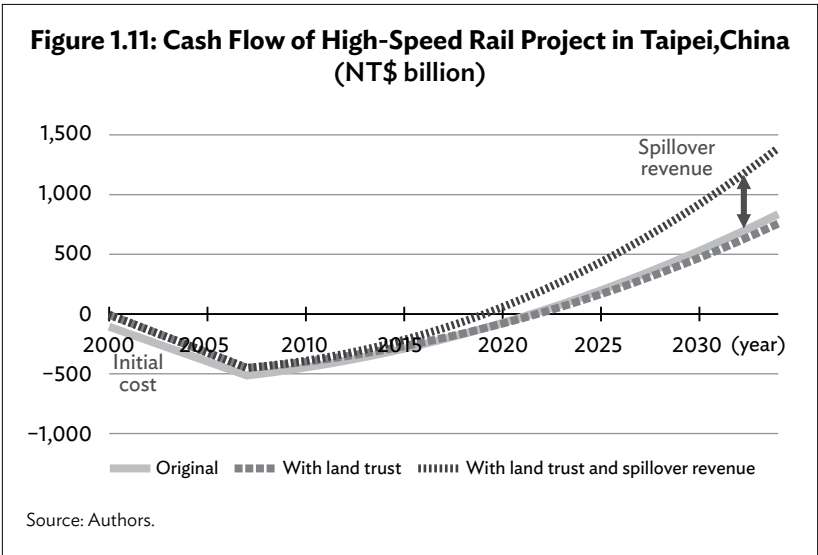
Lastly, the scenario with both the land trust scheme and spillover tax revenues is calculated in the last column. With the introduction of the return of spillover tax revenues, the NPV of the investment cost remains the same, while the total revenue increases from NT\$1,890 billion to NT\$2,524 billion. The NPV of total revenue now changes from NT\$628 billion to NT\$808 billion. Subtracting the NPV cost from the NPV revenue, the total net revenue becomes NT\$202 billion. In the original scenario without the land trust scheme and spillover tax returns, the net revenue is only NT\$8 billion. With only the land trust scheme, the net revenue is NT\$22 billion.

In terms of internal rate of return (IRR), the original case was only 5.1%. The introduction of the land trust scheme increases the IRR to 5.4%. And if we combine the land trust scheme and return of spillover tax revenues, the IRR becomes 7.7%, with which the infrastructure project can attract much more private investment compared with the original scenario.

Table 1.5: Net Present Value and Internal Rate of Return of High-Speed Rail Project in Taipei,China (NT\$ billion)

	Original	With Land Trust	With Land Trust and Spillover Revenue
Total cost	-1,054	-1,134	-1,134
Net present value (NPV) cost	-620	-606	-606
Total revenue	1,890	1,890	2,524
NPV revenue	628	628	808
Net NPV	8	22	202
Internal rate of return	5.1%	5.4%	7.7%

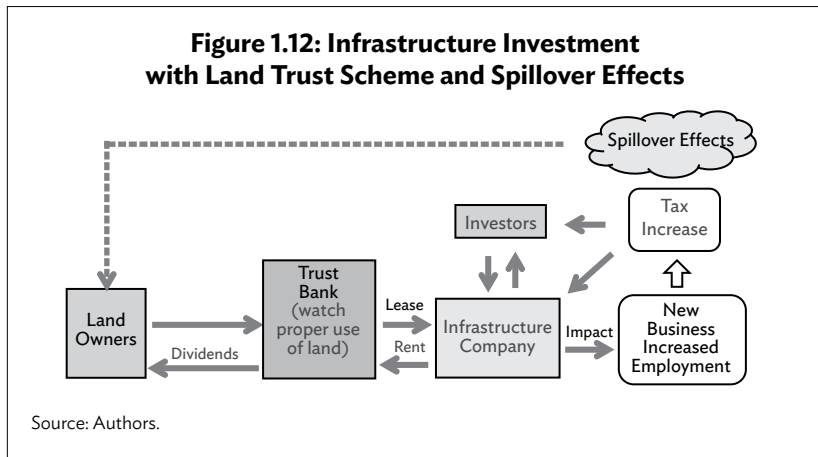
Source: Authors.



The evolution of cashflow for the above three scenarios is plotted in Figure 1.11. It is clear that spillover effects will increase the NPV of cash flows. This will continue as long as the infrastructure system is in operation. As time goes by, the spillover tax revenues will accumulate, and the gap with the original scenario will widen.

1.6 Summary

In many Asian economies, land purchase is a significant difficulty for infrastructure investment. Japan has extensively used land trust schemes for the construction of apartments and commercial buildings. This chapter sheds light on the application of a land trust scheme in the case of infrastructure construction investment. As shown in Figure 1.12, our model proposes that landowners transfer their usage rights to infrastructure companies, with a trust bank acting as the intermediary. The trust bank supervises the performance of spillover tax revenues and user charges. It also calculates the revenue that the infrastructure companies can earn, as well as the associated NPV of their revenue, which can be distributed between landowners and infrastructure companies by subtracting the corresponding costs. Furthermore, the trust bank guarantees that the dividends from the infrastructure companies are properly transferred to landowners.



Many Asian economies do not have a trust bank. In 2018, the Trust Bank Law was launched in Thailand. Trust businesses and functions can be established in ordinary banks by attaining trust bank licenses. Traditional banks can capture the trust bank function in their businesses with approval from the central banks of developing countries. This would smooth the transfer of landownership and infrastructure investment.

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2

Approaches to Measuring the Wider Economic Impacts of High-Speed Rail: Experiences from Europe

Werner Rothengatter

2.1 Introduction

Investments in high-speed rail (HSR) have a long life and generate impacts that often are not directly attributable to a specific project. Therefore, conventional cost-benefit analysis (CBA) is not sufficient to evaluate the overall impacts of HSR. Spillovers or wider economic impacts (WEIs) are identifiable on a microscale around stations, on a mesoscale for regions or corridors, and on a macroscale for the whole economy—in the case of network-wide HSR plans. Micro-based evaluations are the most difficult, because HSR stations are in many cases integrated into urban development plans, and it is almost impossible to separate the contributions of combined land use and transportation projects. On the meso- and macro-levels, it is possible to apply before-after analyses using descriptive statistics (again with problems of separating the effects) and with-without analyses using explanatory statistics, econometrics, or macro-simulation/optimization models, and to combine these with transportation, energy, and environmental modeling to prepare a quantitative base for an integrated assessment.

Section 2.2 of this chapter presents the plans of the European Commission to establish a comprehensive Trans-European Network for Transport (TEN-T) by 2050, with a core network by 2030. The heart of the core network consists of nine core network corridors (CNCs). Section 2.3 discusses the existing European HSR network and the plans for its extension within the CNCs. The investment activity for HSR varies among countries, and scientists and auditors do not regard all

HSR projects as successes. One reason for appraisal failures with HSR plans is the very narrow assessment approaches through conventional CBA, which is discussed in section 2.4. Such approaches can either lead to the rejection of beneficial projects because they do not consider the long-term strategic impacts, or they encourage promoters to predict overoptimistic figures for the short- and medium-term economic success to pass the CBA thresholds. Integrated assessment methods (IAMs), which section 2.5 presents, are intended to prepare a comprehensive picture of long-term WEIs, regional equity, and environmental and climate effects. They make clear from the beginning the extent to which decision makers can expect an HSR project or program to achieve financial returns, or the extent to which environmental sustainability or regional equity are dominant, such that the public budget has to serve as the main source of finance. The section provides examples for the application of IAMs to the evaluation of CNCs and their further development. Section 2.6 concludes by discussing the problem of determining the appropriate scope of an HSR network. This will require an opportunity cost calculus with the development and evaluation of alternative investment programs that may achieve comparable targets for efficiency, equity, and environmental protection.

2.2 Trans-European Transport Networks and Core Network Corridors

The European Union (EU) developed the idea of establishing harmonized trans-European networks for the transportation, energy, and communication sectors in the early 1990s and included it in the Maastricht Treaty of 1992.¹ It published the first concept of the TEN-T in 1996 together with guidelines for its development. It consisted of 14 major projects. In the first revision of 2004, it replaced the project-based concept with a corridor-based concept, which in particular extended the scope of the network to the “accession countries” from eastern and southeastern Europe. The second revision in 2011, modified in 2013 (European Commission 2013), foresaw a change from the corridor-based concept to a network-based concept consisting of two layers: a comprehensive network including all links of European importance, which the EU would finalize by 2050, and a core network consisting of all links of high priority, which it could finalize by 2030. These CNCs are now the focus of an implementation policy. Regarding

¹ The Maastricht Treaty founded the European Union (EU), replacing and reforming the former European Community. It established the constitutional basis of the EU and the pillar structure of its organizations.

Box 2.1: Characteristics of the Core Network Corridors of the European Union

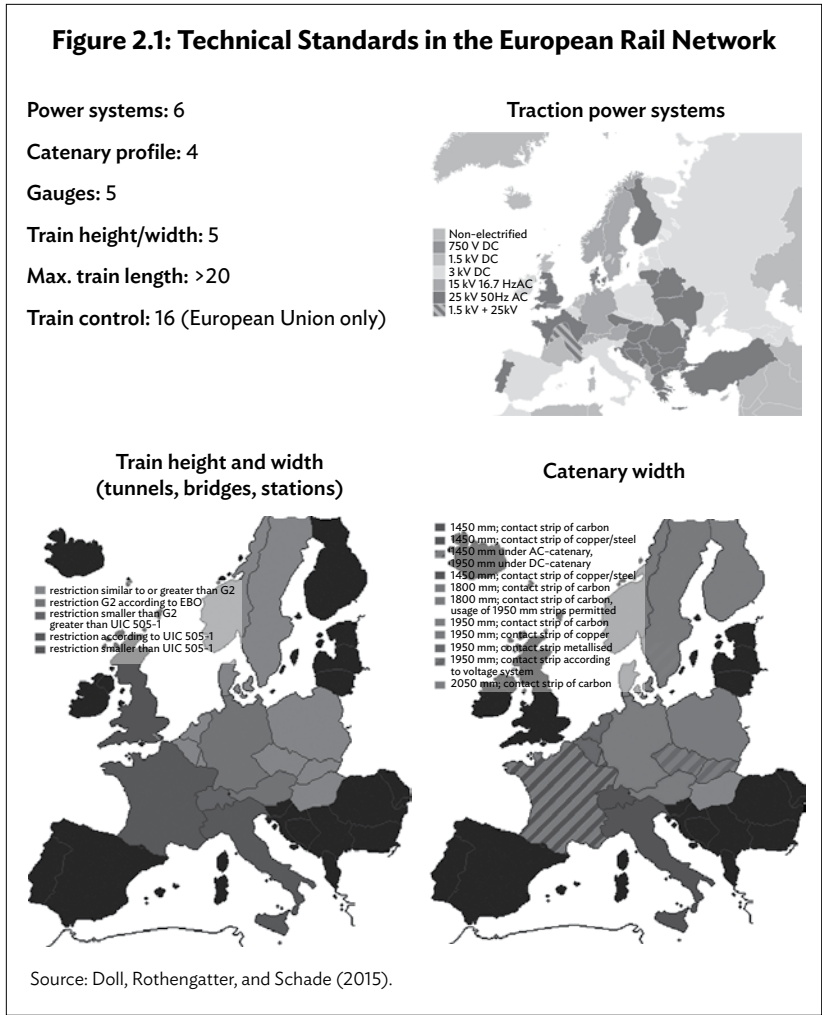
- Ten network types for modal infrastructure and related networks, e.g., motorways of the sea, networks for traffic control (ERTMS for railways, RIS for inland waterways, and SESAR for air transport)
- Nine CNC axes with 34,000, 51,000, and 16,000 kilometers of road, rail, and IWWs, respectively
- CNC connecting at least three countries
- Focus on rail and IWWs (more than two-thirds of investments)
- Ten high-level coordinators (for nine CNCs and ERMTS)
- Interoperability issues are at the core of rail investments
- High-speed rail is a substantial part of rail investments
- Evaluation focusing on EU value: EU connectivity, overcoming border resistance, and contribution to reducing CO₂ emissions (60% by 2050 according to the 2011 EU White Paper)
- Total investment costs of about €650 billion, financial support through grants (from CEF, ERDF, and EFSI funds), and loans/bonds with extended guarantees (EIB)

CEF = Connecting Europe Facility, CNC = core network corridor, CO₂ = carbon dioxide, EFSI = European Fund for Strategic Investments EIB = European Investment Bank., ERDF = European Regional Development Fund, ERTMS = European Rail Traffic Management System, EU = European Union, IWW = inland waterways, RIS = River Information System, SESAR = Single European Sky Air Traffic Management Research Program.

Source: Author.

implementation, one has to consider that the EU member states are competent in infrastructure planning and construction. This means that the EU institutions, in particular the European Commission, can motivate—but not enforce—the national institutions to follow the CNC planning. However, the European Commission has a powerful instrument to stimulate the member states to follow, which is the EU cofinance for CNC projects. A number of financial instruments for providing grants and special loans or bonds exist, which in particular support former accession countries and countries at the periphery of the EU in financing CNC projects. Box 2.1 shows some important characteristics of the CNC plans.

A main problem of the EU railway systems is their heterogeneity, stemming from different national histories. International—and in some countries even national—railway transport in the EU suffers from different track gauges, electrical power supply, axle weight and speed design, vehicle dimensions, and train control systems (presently 16 systems, see Figure 2.1). The European Commission has taken initiative for defining



so-called interoperability standards and key performance indicators (in particular for a common European Rail Traffic Management System, or ERTMS), fostering their introduction through regulations, coordination of country-specific planning procedures, and provision of cofinancing. Nine high-level coordinators for the individual CNCs and one coordinator for the ERTMS (former politicians and managers with a strong reputation) have the task of promoting the plans, removing the national barriers, and coordinating the implementation work in combination with the national authorities and the European Commission.

2.3 Planned Development of the European Union High-Speed Rail Network

2.3.1 European Union-Wide Plans and Realizations

The HSR network in the EU consisted of 8,434 kilometers (km) in 2017, including all the links on which trains can travel at 250 kilometers per hour (km/h) or faster; 1,676 km are under construction, which totals to an HSR network of about 10,100 km (see Table 2.1). The first HSR links were built in France for the TGV Paris–Lyon and the TGV Atlantique.² Germany followed in 1991 and Spain in 1992 with their first lines.

The development of the HSR network in the EU has improved the competitiveness of railways and contributed to transnational

Table 2.1: Existing High-Speed Rail Network in the European Union and Lines under Construction

a. Length of Lines at End of Year (km)

Year	BE	DE	ES	FR	IT	NL	AT	PL	UK	EU
1985	–	–	–	425	174	–	–	–	–	599
1990	–	90	–	717	194	–	–	–	–	1,001
1995	–	447	471	1,290	238	–	–	–	–	2,446
2000	72	636	471	1,290	238	–	–	–	–	2,707
2005	137	1,183	919	1,549	238	–	–	–	74	4,100
2010	209	1,272	1,866	1,912	238	120	–	–	113	6,348
2011	209	1,334	2,117	2,058	856	120	–	–	113	6,807
2012	209	1,352	2,117	2,058	856	120	–	–	113	6,825
2013	209	1,352	2,413	2,058	856	120	50	–	113	7,171
2014	209	1,352	2,413	2,058	856	120	50	–	113	7,171
2015	209	1,475	2,413	2,058	856	120	50	224	113	7,518
2016	209	1,475	2,413	2,180	896	120	50	224	113	7,680
2017	209	1,658	2,413	2,734	896	120	67	224	113	8,434

continued on next page

² The TGV (Train à Grande Vitesse) Atlantique links Paris to Tours and Le Mans.

Table 2.1 *continued***b. High-Speed Lines Currently under Construction**

	Line	Length (km)	Start of Operation
DK	Copenhagen–Ringsted	56	2018
DE	Offenburg–Riegel (Basel)	39	2029
	Stuttgart–Wendlingen	57	2021
	Buggingen–Katzenberg tunnel (Basel)	12	2021
	Wendlingen–Ulm	60	2021
	Tunnel Rastatt	17	2022
ES	Monforte del Cid–Murcia	62	2018
	Vitoria–Bilbao–San Sebastian	175	2022
	León–Asturias Variante de Pajares	50	2019
	Bobadilla–Granada	109	2018
	Plasencia–Cacere/Badajoz	193	2019
	Venta de Banos–Burgos	91	2018
	Zamora–Orense	224	2019
FR	Counterneement Nimes–Montpellier	80	2018
IT	Genoa–Milan (Tortona)	53	2020
AT	Graz–Klagenfurt (Koralmbahn)	122	2025
	Brenner Basistunnel	46	2027
UK	London–Birmingham	230	2026

AT = Austria, BE = Belgium, DE = Germany, DK = Denmark, ES = Spain, EU = European Union, FR = France, HSR = high-speed rail, IT = Italy, km = kilometer, NL = Netherlands, PL = Poland, UK = United Kingdom.

Note: Length of lines or of sections of lines on which trains can go faster than 250 kilometers per hour at some point during the journey.

Source: European Commission (2018).

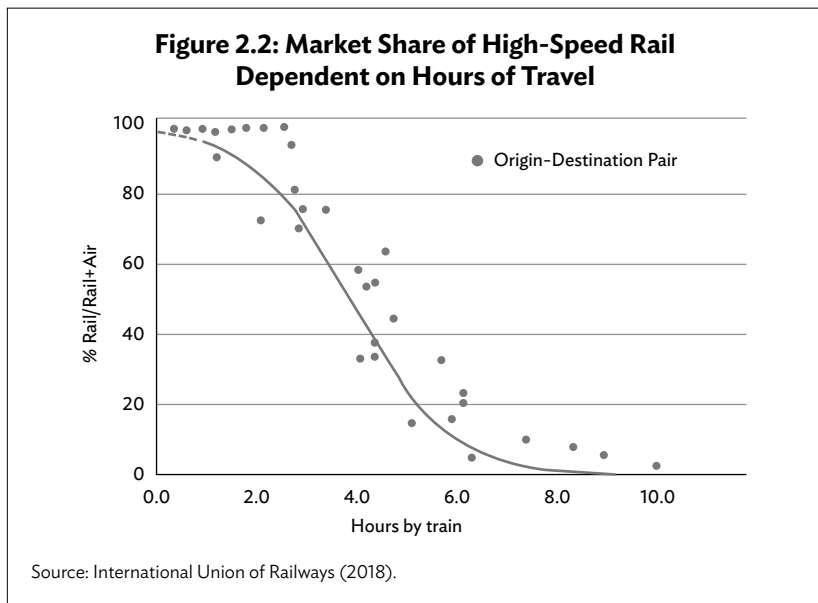
connectivity. It is a crucial part of the EU transport policy and has achieved some of the following positive effects:

- standardization of tracks, vehicles, and control systems;
- internationalization of rail services (e.g., the TGV and ICE³ for border-crossing connections between France and Germany; the ICE for connections between Germany and Switzerland; and Thalys for connections between France, Belgium, the Netherlands, and Germany);

³ The ICE is the Intercity Express in Germany.

- significant diversion of air and car traffic to rail in corridors served by HSR (e.g., Paris–Lyon–Marseille; Madrid–Barcelona; Milan–Rome; Munich–Berlin); and
- development of the regional economy in the environment of HSR stations.

The market success of HSR is strongly dependent on the duration of the trips and the performance of competitors (air for longer distances and cars for shorter distances). Rail is usually the dominant mode for travel times below 3.5 hours (Figure 2.2). However, rail travel times of 4–5 hours can also be attractive to passengers if the access/egress times to and from airports as well as the processing times at airports are high. The ICE Munich–Berlin connection, which opened in December 2017, provides an example: for the 623-km link, the travel times reduced from 6 hours to 4 hours and 25 minutes for the regular ICE and 4 hours for the sprinter ICE.⁴ Before opening, the modal split figures were 23%, 29%, and 48% for rail, road, and air, respectively, and these changed within 1 year to 46%, 24%, and 30%, respectively. The number of rail



⁴ Sprinter services between large cities have fewer stops and save travel time.

passengers has doubled on this connection. The company will extend the ICE sprinter service because it is unexpectedly well accepted. It is noticeable that the German rail service still suffers from poor reliability and punctuality, which are still worse than comparable figures in Japan, the People's Republic of China (PRC), France, or Spain. This is partly the result of many connecting stations along the lines, mixed train operations on the tracks, and, in recent years, increased repair and maintenance work. This indicates that the potential of HSR on well-connected corridors could be much greater than is presently observable.

Against the background of the positive experiences, the European Commission set ambitious goals for developing HSR and published an HSR development plan in 2010, which included 30,000 km allowing for train speeds beyond 200 km/h. However, even using a wide definition of the scope of HSR as rail speeds above 200 km/h, the reality of HSR investments is far behind the optimistic plans. The reasons for the comparatively slow progress—for comparison, the PRC has implemented around 25,000 km of HSR since 2008—are:

- long planning times with many stakeholder interventions and complex approval procedures (in particular land acquisition and environmental legacy);
- long implementation times (the average project implementation time is 16 years);⁵
- comparatively high costs of infrastructure investment (in Europe \$25 million–\$39 million per kilometer; in exceptional cases, for example, the Stuttgart–Ulm link, more than \$75 million per kilometer, compared with \$17 million–\$21 million per kilometer in the PRC);⁶
- lacking standardization of construction elements, treating every facility such as a bridge or tunnel as a unique project (contrasting the PRC construction principles);
- problems of designing guideways through densely populated areas (declining acceptance by citizens); and
- financial bottlenecks and limits to public deficit spending after the economic crisis in 2008.

Although the European Commission has tried to streamline the planning processes, to coordinate the planning legacy of member states and to accelerate the implementation through attractive conditions for

⁵ This is according to a report of the European Court of Auditors (2018).

⁶ See Ollivier, Jitendra, and Nanyan (2014); in Europe, meanwhile, these figures are substantially higher because of the exhausted capacities in the construction sector.

cofinancing, the progress has been modest. Furthermore, the barriers to HSR planning and implementation are growing. Several scientists have published warnings regarding the extremely high investment costs of HSR (e.g., Albalade and Bel 2010; Flyvbjerg 2014; Ansar et al. 2016). Environmental groups argue that high-speed mobility is causing high consumption of energy and CO₂ production compared with conventional rail and promote more slowness of mobility. Residents are concerned about the change in their environment and are organizing protest movements, although they may benefit from new HSR investments (e.g., the violent protests in Stuttgart, Germany, opposing the construction of a new central underground railway station and its HSR connection to Ulm/Munich).

2.3.2 High-Speed Rail Development in Some European Union Countries

The result of the different national conditions and strategies is a patchwork instead of a network for HSR in the EU (European Court of Auditors 2018). Two contrasting examples demonstrate the scope of the national investment strategies and their impact on the HSR network. First, we consider a country with a very low HSR density, the United Kingdom (UK). Until now, the UK has only one HSR link, called HS1, connecting the Channel Tunnel to London St. Pancras station (108 km). The first section opened in 2003 and the second section in 2007. The travel times between London and Paris (Brussels) reduced to 135 (111) minutes, and the HSR market shares on these connections are higher than 80%.

The UK developed early plans to extend HS1 to the north for connecting the densely populated Midlands around Birmingham, Manchester, and Leeds, and farther Edinburgh and Glasgow. These plans did not make progress because the results of the financial and cost-benefit assessment were not promising. Finding appropriate guideways in the densely populated areas north of London was the most difficult task and resulted in high cost estimates. This gave opponents arguments to attack HSR projects in the UK from different sides. High-speed enthusiasts suggested visionary alternatives (the Japanese maglev and the Hyperloop), while environmental groups were afraid of destroying biodiversity and fiscalists were concerned about the increase in public deficits. Finally, the UK Department of Transport enriched the quantitative assessment by including wider economic benefits and the prospects for strategic economic development (see the chapter by R. Vickerman in this volume) and prepared the ground for a positive public discussion and final decision.

The UK Parliament approved the HS2 “Y-project,” and the construction of phase 1 started in 2017. The plan is to complete phase 1 to Birmingham by 2026 and phase 2 to Manchester and Leeds by 2033. Unexpected constraints and barriers, together with updates to the construction design in densely populated areas, led to a drastic increase in the estimated construction costs; in the case of HS2, the early estimations of £32.7 billion (2010) rose to £56 billion at the beginning of the construction work.⁷ Even after the completion of this most expensive extension, the UK will be the European HSR country with the lowest HSR density (9.7 km per million capita).

Spain is a contrasting example. The country was among the first EU member states to introduce HSR on the link between Madrid and Seville, which was opened in 1992. The most important link, Madrid–Barcelona (625 km; 2 hours and 45 minutes), opened in 2008. In the following decade, Spain developed its HSR network rapidly to reach about 3,300 km in 2018, or 71 km per million capita. This is not only top value for Europe but even exceeds by far the HSR density figures in Japan and the PRC of about 24 km and 20 km per million capita, respectively.

After finalizing the backbone corridor of Seville–Madrid–Barcelona, the political goals of regional connectivity and modal diversion mainly drove the HSR development in Spain (from air to rail) for environmental reasons: for 90% of Spanish inhabitants to live within a maximum distance of 50 km from an HSR station and for the HSR network to connect all 47 provincial capital cities so that the maximum time needed for traveling from a province capital to the national capital Madrid does not exceed 4 hours.

To achieve such goals, the Spanish Strategic Plan of Infrastructures and Transport (PEIT) foresees an extension of the Spanish HSR network to 5,000 km by 2030. This investment contributes to adjusting the Spanish rail network to the EU standards: a change from wide gauge (1,668 mm) to standard gauge (1,435 mm) and to the ERTMS, the future standard EU rail control system. Together with the special treatment of Spain as a “cohesion” country (on the periphery of the EU), funding sources such as cohesion, regional development, or TEN-T funding could provide high financial support: Spain received about half of total EU cofinance for HSR. Economists (e.g., Albalade and Bel 2010) have criticized the HSR extension plans heavily for their weak economic foundation. In recent years, the European Commission and the EU Parliament have become increasingly skeptical and recommended tighter financial

⁷ Even higher cost estimates have been published in the media. In summer 2019, the UK government started a new revision of HS2 led by Lord Berkeley.

control of the PEIT plans (Doll, Rothengatter, and Schade 2015). Against the background of low figures for passenger volume (see Table 2.2), the Government of Spain has recently downgraded the plans partially, for instance, reducing the track designs in less densely populated areas (maximum speeds and number of tracks).⁸

**Table 2.2: High-Speed Rail Performance
in European Union Countries
(billion passenger-kilometers)**

Year	BE	CZ	DE	ES	FR	IT	NL	PL	PT	SI	FI	SE	UK	EU-28	Change (%)
1990	–	–	–	–	14.92	0.30	–	–	–	–	–	0.01	–	15.23	
1995	–	–	8.70	1.29	21.43	1.10	–	–	–	–	–	0.42	–	32.94	7.2%
2000	0.87	–	13.93	1.94	34.75	5.09	0.11	–	–	–	0.07	2.05	–	58.80	11.2%
2005	0.98	0.01	20.85	2.32	43.13	8.55	0.69	–	0.49	–	0.31	2.33	0.45	80.11	5.3%
2006	1.00	0.15	21.64	2.70	44.85	8.91	0.73	–	0.51	–	0.44	2.49	0.90	84.32	5.2%
2007	1.02	0.33	21.92	2.59	47.97	8.82	0.80	–	0.51	–	0.58	2.78	1.39	88.70	5.2%
2008	1.08	0.25	23.33	5.48	52.56	8.88	0.87	–	0.53	0.01	0.62	2.99	0.99	97.60	10.0%
2009	1.06	0.25	22.56	11.51	51.86	10.75	0.92	–	0.53	0.02	0.60	3.05	1.01	104.10	6.7%
2010	1.06	0.27	23.90	11.72	51.89	11.61	0.29	–	0.52	0.02	0.65	2.94	1.01	105.87	1.7%
2011	0.91	0.29	23.31	11.23	52.04	12.28	0.31	–	0.47	0.01	0.71	2.83	4.36	108.74	2.7%
2012	0.91	0.27	24.75	11.18	51.09	12.79	0.32	–	0.46	0.01	0.71	2.95	4.36	109.80	1.0%
2013	0.91	0.25	25.18	12.74	50.79	12.79	0.36	–	0.47	0.01	0.76	3.06	4.36	111.67	1.7%
2014	0.91	0.25	24.32	12.79	50.66	12.79	0.24	–	0.54	0.01	0.65	3.23	2.90	109.28	–2.1%
2015	1.20	0.57	25.28	14.13	49.98	12.79	1.00	0.47	0.57	0.01	0.57	3.37	2.90	112.82	3.2%
2016	1.50	0.70	27.21	15.06	50.54	12.79	0.37	1.44	0.61	0.00	0.61	3.48	2.80	117.12	3.8%

BE = Belgium, CZ = Czechia, DE = Germany, DK = Denmark, ES = Spain, EU = European Union, FI = Finland, FR = France, HSR = high-speed rail, IT = Italy, NL = Netherlands, PL = Poland, PT = Portugal, SI = Slovenia, SE = Sweden, UK = United Kingdom.

Note: In this table, high-speed rail transport covers all traffic with high-speed rolling stock (including tilting trains able to run 200 kilometers per hour).

Source: European Commission (2018).

Other European countries with significant HSR are France, Germany, and Italy. France was the first country to introduce HSR on longer distances and to achieve higher average operation speeds

⁸ See International Union of Railways (2018) for details.

than 200 km/h.⁹ The first links were Paris–Lyon (opened in 1981) and Paris–Tour/Le Mans. France was the EU country with the largest HSR network until Spain surpassed it in 2017. The French HSR system still attracts the most passengers and shows the highest passenger turnover of the EU countries (Table 2.2): three times as high as that of Spain with a similar network length. However, the passenger performance figures also show that the growth of patronage in France stopped after 2008.

This reduced the financial expectations and changed the most ambitious HSR development plans, which the Grenelle Environment Round Table sketched out in 2007.¹⁰ This meeting developed a concept for reducing the CO₂ emissions of transport, partly by shifting traffic from road and air to rail and extending the HSR network in France by another 2,000 km. After the economic crisis in 2008, on the one hand, the railway company SNCF (Société Nationale des Chemins de Fer français) increased its demand for public cofinance because of lower passenger volume expectations. On the otherhand, the public budget problems had grown and needed consolidation. In the end, the HSR extension plan suffered drastic reductions. Even transborder connections to Spain on the Atlantic and the Mediterranean coasts were suspended for financial reasons.

Only one major HSR project of the Grenelle agreement has materialized, which is the 300-km link between Tours and Bordeaux, connecting Bordeaux to Paris (540 km) in 2 hours and 4 minutes, which opened in 2017. The complex public–private partnership constructed reflects the increasing difficulties of HSR finance: a private consortium (LISEA) of nine partners under the lead of VINCI, a big construction and infrastructure operation company, received a concession for 50 years. The consortium finances €3.8 billion (49%) of the investment budget of €7.8 billion from six different sources (own capital, bank credits, and loans). The European Investment Bank (EIB) contributes €1.2 billion with a loan guarantee on TEN-T projects. The public subsidies from the French state and the EU total €3 billion (39%). The French public rail infrastructure company RFF contributes €1 billion (12%) and pays for additional investment costs of €1 billion to link the new stretch to the network and to the stations. It will also be responsible for the refinancing of the private part of the debt, which it will achieve through track charges to be paid by the rail operator SNCF. The consortium has

⁹ Italy had already introduced HSR with 250 km/h on part of the connection between Rome and Florence in 1977. The average speed was about 200 km/h.

¹⁰ This multiparty debate brought together federal and local government authorities, trade unions, and nongovernment organizations in Grenelle, a suburban location in Paris.

implemented the project on time and without cost overruns, which is a big achievement compared with other European HSR projects, which have shown high cost overruns and contributed to creating a negative image, which Flyvbjerg (2014:11) summarized as the “iron law of megaprojects: over budget, over time, over and over again.”

Germany (with about 1,700 km of HSR) will stick to its concept of constructing mixed HSR and conventional links, which will not exploit the full potential of HSR but aims at improving the connectivity of the network in a country without a main corridor (such as the Honshu corridor in Japan) or a main orientation toward a major centrality (such as the Paris agglomeration in France). Presently, the repair and maintenance works are very intense after decades of neglect, and the operator, Deutsche Bahn AG, is experiencing problems recruiting qualified personnel for driving and vehicle maintenance and servicing. As a consequence, the punctuality and reliability of the train service has dropped to a record low (about 70% punctuality in November 2018). The plans for the future are, in the first instance, oriented toward improving the reliability and punctuality, particularly at connecting stations, increasing the frequency of services on main corridors as well as reducing the energy consumption and the climate footprint through the use of renewable energy. These goals do not make it necessary to increase the maximum speeds on domestic connections with relatively short distances between stations; therefore, the new ICE 4 train generation is designed for only 250 km/h. The average speeds can be increased through sprinter services with fewer stops between bigger agglomerations.

The negative experiences with the big HSR projects under construction have reduced the appetite of policy makers and of the infrastructure manager, Deutsche Bahn, for starting further expensive projects. First, the combined HSR and regional transit Stuttgart–Ulm project is the most expensive European railway project, with estimated costs of more than €10 billion, including the construction of a heavily debated new underground station in Stuttgart, already decided in 1996. Construction started in 2010 after long processes of legal permission, coordination of public authorities, and financial negotiations with Deutsche Bahn. Furthermore, citizen protests and the following mediation processes interrupted the project's start, ending after a people's referendum in 2011 in favor of the project. The plan is to open the project for operation in 2023, that is, 27 years after making the decision. The second example is the most important international north–south Karlsruhe–Basel rail corridor link, which is showing slow progress paired with a high cost increase (costs estimated in 2015 at €7.1 billion plus at least €1 billion damage costs because of a severe breakdown

of the existing track during the underground construction of the new one). The expectation is that this major connection, which Germany designed not only for HSR but also for efficient rail freight transport (on a separate track), will not be accomplished before 2035. These examples illustrate the low planning efficiency in Germany and people's fading willingness to accept new technologies that bring changes into their living environment, a phenomenon that is often apparent in wealthier societies and that the economic literature describes through the Kuznets curve (see Uchiyama 2016).

Italy owns less than 1,000 km of HSR, which the public company, Trenitalia, a 100% subsidiary of the state-owned Ferrovie dello Stato Italiane (FS), and the private NTV Italo operate partially. Four Italian business people established NTV Italo in 2012, and it operates on four HSR connections (e.g., Turin–Milan–Naples, Rome–Florence–Venice) at maximum speeds of 300 km/h. After years of financial difficulties and major restructuring, NTV Italo is profitable, and a US equity fund¹¹ took it over early in 2018. The Italian example is interesting in two respects: it shows first that HSR services can be profitable on backbone corridors and second that competition on HSR networks is possible, beneficial for the customers, and useful for improving the quality and efficiency of the service. The European Court of Auditors (2018) therefore argued in favor of expanding the competition and fostering liberalization to push the incumbent former public national railway companies.

The following sections will focus on the further development of assessment methods to improve the decision support for European HSR projects in the planning and procurement phases.

2.4 Conventional Cost–Benefit Analysis

CBA¹² is obligatory in most EU countries for large transport investments and an element of fiscal legacy with a standardized methodology. CBA measures the direct impacts of infrastructure projects on users and on non-users. It measures the economic user benefits through consumer and producer surpluses, which it calculates with the generalized transport cost savings for existing traffic and the gained net surpluses from diverted and induced traffic.¹³ It adds environmental and safety

¹¹ Global Infrastructure Partners, a fund investing in energy, water, waste, and transport and managing infrastructure facilities such as the airport of London Gatwick (UK) or the Port of Melbourne (Australia).

¹² A brief description from Rothengatter (2018).

¹³ It measures this approximately using the “rule of the half.”

benefits to the amount, which it can measure economically through cost savings. When applying a conventional CBA, one presumes that it is sufficient to look at the transport sector only while neglecting the possible impacts on other sectors. This is theoretically only consistent if all the other markets are in equilibrium and the structural changes that a project or program induces are marginal. However, very large transport projects and network developments will generate stepwise changes for mobility and logistics, which may produce substantial feedback loops through other sectors of the economy. Therefore, conventional CBA can contribute only part of a comprehensive assessment of HSR projects.

As the CBA approach is widely standardized, it has gained broad acceptance, and its outcomes serve as a dominating criterion for project evaluation (see, e.g., European Commission 2014; Quinet 2013). If a megaproject with a low benefit–cost ratio is favored to a set of smaller projects that show a higher ratio for the same budget, then clear arguments will be necessary to support this decision. Such arguments can stem from the analysis of WEIs and/or high strategic environmental or regional equity advantages in the context of an integrated assessment, which the following sections present.

2.5 Wider Economic Impacts and Integrated Assessment Methods

2.5.1 Scope of the Methodological Approaches

Background and Terminology

The two prominent examples for the UK and Spain that section 2.3 provided characterize the wide scope of economic assessment for HSR projects in Europe, although all the cases applied standard CBA methods. Countries like the UK have followed narrow financial and economic assessment criteria for a long time and postponed promising projects with the consequence that the challenges for finance and stakeholders' acceptance have grown exponentially. Countries like Spain have focused on regional and environmental benefits and applied soft economic assessment criteria, with the consequence that a number of projects are not financially viable despite the generous EU cofinancing and now require operation in such a way that the regional and environmental advantages are diminishing. This gives rise to change in the assessment of large projects or project plans in two directions: first, restricting CBA to benefits that a project company, at least theoretically, can capture and, second, assessing all the economic impacts beyond this narrow approach through a WEI analysis. This

should include or be extended by a strategic environmental and regional equity analysis, resulting in an IAM. It is possible to carry out CBA and IAM in parallel to provide the decision maker with the necessary comprehensive decision support.

The founder of CBA, the French engineer-economist Jules Dupuit (1844), is also said to be the originator of the idea and the basic concept of WEIs. Contrasting the partial utility approach of Alfred Marshall (1920, first published in 1890), who developed the surplus concept about 40 years after Dupuit, the relevant surplus is not the reduced generalized transportation costs but rather the reduced costs (prices) on the markets influenced by new or improved transport facilities. It is the reduced payments of consumers (following cost reductions) and increased willingness to pay for goods (following higher quality of service) that increase their “relative utility” (translating the wording “*utilité relative*” of Dupuit), which Marshall later called consumer surplus in his narrow partial market approach.

Dupuit illustrated the basic idea by taking the example of the market of stone, for which it is necessary to consider the reduced price (cost) of stone as the relevant measure¹⁴ and not the reduced costs of transport of the stone from the quarry (see Ekelund and Hébert 1999, 83; illustrated in Rothengatter 2018). If a (public) company constructs a new canal to explore an unexploited quarry, then the transport costs may rise compared with the situation without investment, because the stone has to travel over a greater distance (100 instead of 4 length units;

Table 2.3: Dupuit’s Example of Comparative Costs of a Canal Investment

Route	Costs per ton of stone (Fr)
<i>Old route: a road</i>	
Extraction from the quarry	16
Transport over a short distance (e.g., 4 leagues)	4
Total former costs of production (without a canal)	20
<i>New route: a canal</i>	
Extraction from the quarry	2
Transport over a long distance (e.g., 100 leagues)	13
Total present costs of production (with a canal)	15

Fr = French franc.

Note: A league is a distance metric used in France around 1850, equivalent to about 4 kilometers.

Source: Ekelund and Hébert (1999) following Dupuit (1844).

¹⁴ Dupuit used this example to contradict strongly the suggestion of his engineer colleague Henri Navier to measure the economic advantage of a canal by the cost differential between road and waterway shipment (see Ekelund and Hébert 1999).

see Table 2.3). Therefore, it would be wrong to compare the transport costs with and without the canal and use the difference as a benefit measure. Assuming that the new quarry would be linked by a road and comparing the costs of road transport with the costs of canal transport (a fictive with–without comparison) would also be misleading, because it would hugely overestimate the benefits (for 100 length units, the costs of road transport would be 100 and the costs of canal transport 13, such that the cost difference or benefit would be 87 French francs). Comparing the total costs of *transport and production* leads to the correct measure (5 French francs) for the reduced costs of a ton of stone, which corresponds to the “relative utility” (benefit), presuming that the market price for stone will drop accordingly.

This simple example allows for a first set of conclusions:

- As soon as transport projects lead to a change in technology and organization of production, a benefit measurement based only on comparative transportation costs implies an under- or overestimation depending on the definition of the compared “with–without” constellations.
- The relevant measure is the change in the total costs of transport and production, which are presumably equivalent to a similar reduction in the market price or an increase in the willingness to pay.
- It is necessary to analyze the impacts on the total costs and market prices for all the markets that the transport facility under evaluation influences.
- Marshall’s partial approach of benefit measurement through surpluses on the transport market is restricted to the special case of a static total equilibrium on all markets except for transport and therefore only appropriate for the evaluation of small projects in an equilibrium environment.

Following this basic idea, one can easily conclude that the canal can induce additional businesses and activities, which today we would call secondary benefits. Dupuit recognized and partly described such effects, such as the impact on equity, but he argued that it is a matter of public policy to take account of them. This means that he made a clear distinction between the project-related (direct) utility (which already includes a substantial extension of Marshall’s consumer surplus) and the second-round effects, which the project management cannot capture or even the project users cannot enjoy (Poinso 2018). This becomes understandable against the background that Dupuit favored privatized management of the transport infrastructure—that is, the project managers should be able to finance the project by partly exploiting the willingness to pay of the users. He left the possibility

open for increasing state governance in the case of high market imperfections.¹⁵ However, it would be a matter of state governance and not of the project management to take account of secondary impacts.

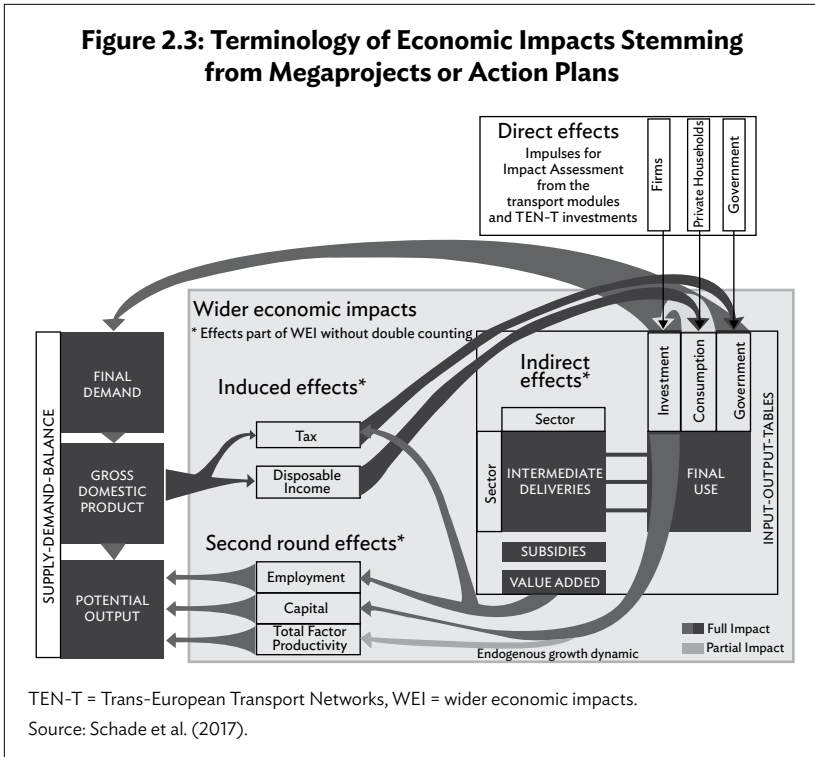
The conclusions above highlight important issues for the assessment of large transportation projects and HSR project plans.

- Long-term impacts on productivity, costs, and product/service quality through the change in technology and organization are in general likely to result from large transportation projects and HSR network plans. These require a sector-specific productivity analysis including the subsequent impacts on (endogenous) growth, industrial interchange, and trade activity.
- Market imperfections prevail in many economic sectors. On the labor market, underemployment is not an exception but the rule for many countries. Therefore, medium-term analyses of multiplier and accelerator effects are important, because they can determine the future path of economic growth.
- It is possible to regard regional and personal equity as hidden production factors, because undiscovered potential is exploitable and social conflicts avoidable. Therefore, impacts on equity (regional and personal) are not beyond a WEI assessment.
- The reaction times to changes in the transport system vary by consumer groups and industries. Therefore, a dynamic analysis is needed that can identify the time profiles of fast (e.g., output and demand adjustments) and slow (e.g., technology adjustments) feedback mechanisms and their interactions.
- The comprehensive assessment should clearly differentiate the impacts that project management can capture and the impacts that the state has to consider. This provides the base for the appropriate allocation of managerial and financial responsibilities in the procurement phase (Stillman 2018; Yoshino and Stillman 2018).

The above considerations lead to a pragmatic definition of WEIs for applied assessment work: WEI assessment includes all direct and indirect (second-round) economic effects, in particular those impacts that occur beyond the conventional benefit measurement based on the Marshallian welfare surpluses that transport cost differentials induce. This definition takes into account the fact that CBA and WEI results in general are not separable and not additive. Figure 2.3 illustrates the

¹⁵ This holds, for instance, for railways, for which some parts of Dupuit's work show a clear insight into the imperfection of this market (natural monopoly) and the need for state governance, while in other parts he showed his preference for a liberal market structure (Poinso 2012).

Figure 2.3: Terminology of Economic Impacts Stemming from Megaprojects or Action Plans



concept of WEIs (comprising all the economic impacts stemming from a project or action plan) and the different scopes for the often-used terms of direct, indirect, induced, and second-round effects.

Contrasting CBA, it is possible to base the analysis of WEIs closely on indicators of social account. This holds in particular for the macroeconomic approaches (described in section 2.5.1), which deliver data on the gross domestic product and employment as well as on the induced tax revenues of the state. The latter can provide a rationale for the state cofinance in public–private partnerships. Wider economic assessment has followed such approaches in the context of large HSR projects (e.g., the Stuttgart–Ulm/Munich project in Germany mentioned in section 2.3.2) and developed proposals for their institutionalization by “tax-kicker bonds” (Stillman 2018).

Methodologies for the Measurement of Wider Economic Impacts

The bullet points in section 2.5.1 set out a framework of issues for the measurement of WEIs beyond conventional CBA. Contrasting CBA,

there is no standard procedure or widely agreed theoretical foundation for WEI measurement. Possible approaches are the following:

- Spatial computable general equilibrium models (SCGEs), which start from a total equilibrium environment in which monopolistic competition occurs in a few sectors, leading to spatial concentration in agglomerations (Krugman's [1991] theory of economic geography). Venables (2007) and Bröcker and Mercenier (2011) developed models that aim at practical implementation.
- Elasticity models based on SCGE theory, as Graham (2006) developed and applied on behalf of the UK Department of Transport (2006), for example for the assessment of HS2 (see the chapter by R. Vickerman in this volume).
- Integrated regional land use and transport infrastructure models (see Échéniqúe et al. 1990), regional potential factor models (Biehl 1991), and regional simulation models (Vickerman 1995, 2013; Wegener 2008).
- Macroeconomic integrated models, including input-output analysis, energy, and the environment (e.g., the E3ME model of Cambridge econometrics, the E3MLAB model of the University of Athens).¹⁶
- System dynamics models (SDMs) integrating input-output analysis (e.g., the ASTRA model that the consultancies M-Five and TRT or the Fraunhofer Institute ISI, Karlsruhe, further developed).¹⁷

The following brief characterizations refer to only one model example representing each category. The description of SDM is more detailed, as an integrated CNC assessment recently applied it.

SCGEs and their simplifications through elasticity models are based on the microeconomic equilibrium and welfare philosophy. These models involve the strict assumptions of neoclassical economic theory (e.g., user- or profit-maximizing behavior, perfect foresight, convex preferences and technologies, and almost-perfect price equilibria). They assume that most markets work perfectly according to these requirements, while there are a few markets (in the model of Bröcker and Mercenier [2011] only the transport market) that show imperfections. In this case, spatial concentrations at agglomerations can

¹⁶ Descriptions of E3ME, E3MLab, and ASTRA are available online.

¹⁷ The doctoral thesis of Schade (2004) originally developed ASTRA; see also Schade (2008).

develop (the Krugman theory of economic geography) with a higher level of productivity than in low-density regions. HSR investments connect agglomerations with lower-density regions, which induces the mobility of the workforce toward regions with higher productivity and wages (migration or commuting). The elasticity approach of Graham (2006) makes this model philosophy transparent: the HSR connection of a region leads to a higher-weighted population density (population weighted with an accessibility measure), and this result is multiplied by the elasticity of productivity with respect to the weighted population density. This approach is differentiated by economic sectors such that the elasticities have to be estimated on a sector base (see the chapter by R. Vickerman in this volume).

The elasticity model of Graham is an exception to the general rule that CBA and WEIs are not separable and are not additive. The empirical application, for example in the UK and in Australia, shows an extremely high variance of estimated elasticities (Rothengatter 2017), so the degree of confidence in the results is low, a comparison is very difficult, and the transfer of results to other project areas is impossible. However, the main problem with these approaches is that the technology as such remains a constant over time so that the positive growth impact only stems from a spatial shift of production to agglomerations and not from the dynamic change in sector technology. The approach focuses on the increase in agglomeration density, which at the same time implies that the lower-density regions will lose. While this impact can be observed on some corridors served by HSR (the areas around stations benefit while the areas between stations stagnate), it appears to be too narrow to treat it as a general and always predominant effect. Furthermore, such effects may conflict with a regional policy aiming at reducing regional imbalances.

Macroeconomic computable general equilibrium models (CGEs), such as the economic module of E3MLab,¹⁸ are also based on the neoclassical assumptions, modeling the behavior of representative agents according to the *homo economicus* principles in an almost-perfect economic environment. They also generate price equilibria and their change through infrastructure investments. Contrasting the microeconomically based SCGEs, they introduce more relaxations from the neoclassical world, making it easier to model real phenomena like unemployment. CGEs are highly appropriate for applying comparative statics to quantify the impacts of exogenous changes, and macroeconomic theory has widely accepted them as the most sophisticated assessment tools. The theoretical development toward stochastic dynamic

¹⁸ See E3MLab webpage, Energy–Economy–Environment Modelling Laboratory Research and Policy Analysis at <http://www.e3mlab.eu/e3mlab/>.

equilibria is challenging, and the practical solution methods have also developed with the General Algebraic Modeling System or GAMS software. However, the heart of the method, the equilibrium approach, is also a weakness, because it prevents the model from achieving a close approximation to real observations (optimization dominates calibration) and presents difficulties in modeling technological and behavioral changes endogenously over time.

Macroeconometric models, such as E3ME (Cambridge Econometrics 2014), use long time series for testing econometric functionals and composing them into equation systems for approximating the development of macroeconomic indicators of social accounting. As in the case of E3MLab, the E3 means the integration of economy, energy, and environment into one model context, while adding transportation data exogenously. E3ME does not aim to model equilibria, which the developers argued to be an advantage; it intends to simulate real developments and not theoretical ideals. As the computational tasks are much easier to solve than in equilibrium models, the supporting submodels possess a high level of detail. For instance, the input–output submodel differentiates 69 sectors for Europe and 43 for the rest of the world as well as 53 regions. The dynamic simulations presently extend until 2050. The principal model philosophy is Keynesian; that is, the demand side is dominant, and the supply side follows the aggregate demand. Contrasting the CGEs, prices and interest rates are not results of equilibrium processes, but aggregate figures are used to estimate them, such as the gap between the aggregate demand and the potential output.

J. Forrester (1962) at MIT developed **SDM**, which consists of four basic components: cybernetics, numerical simulation, decision theory, and mental creativity (Milling 1974). Cybernetics provides the modeling principle for dynamic systems through feedback loops that link state variables (levels) for which flow variables (rates) influence or control the magnitude of changes. The mathematical representation results in a set of difference equations that can include different degrees (time lags between reactions). Numerical integration methods approximate this system of dynamic equations.¹⁹ It is possible to use the model for simulation, control, and optimization to provide decision support. Mental creativity can help fill gaps in quantitative modeling, because SDM intends to model systems comprehensively with all the endogenous components—and not just partially. With these properties, SDM is an appropriate instrument for constructing scenarios that may include visionary elements for long-term development. One of the first applications consisted of preparing the world scenarios for the Limits to Growth project of D. Meadows

¹⁹ Forrester developed the DYNAMO compiler, which is still the heart of software packages like ITHINK and STELLA.

et al. (1972). This study for the Club of Rome made SDM popular but also open to attacks from economic theorists. The reason was that the study used the “mental creativity” component extensively to model the thinking of the team of modelers and their value judgments. As a strict set of assumptions on technology and behavior, comparable to CGEs and SCGEs, does not constrain SDM, it is necessary to fill an SDM as far as possible with empirically observed, econometrically proven, and sound data. Using mental creativity in a restrictive and controllable manner, in particular making value judgments transparent or supporting them with expert ratings, can increase the confidence in the independence of the results from the modeler’s preferences.²⁰

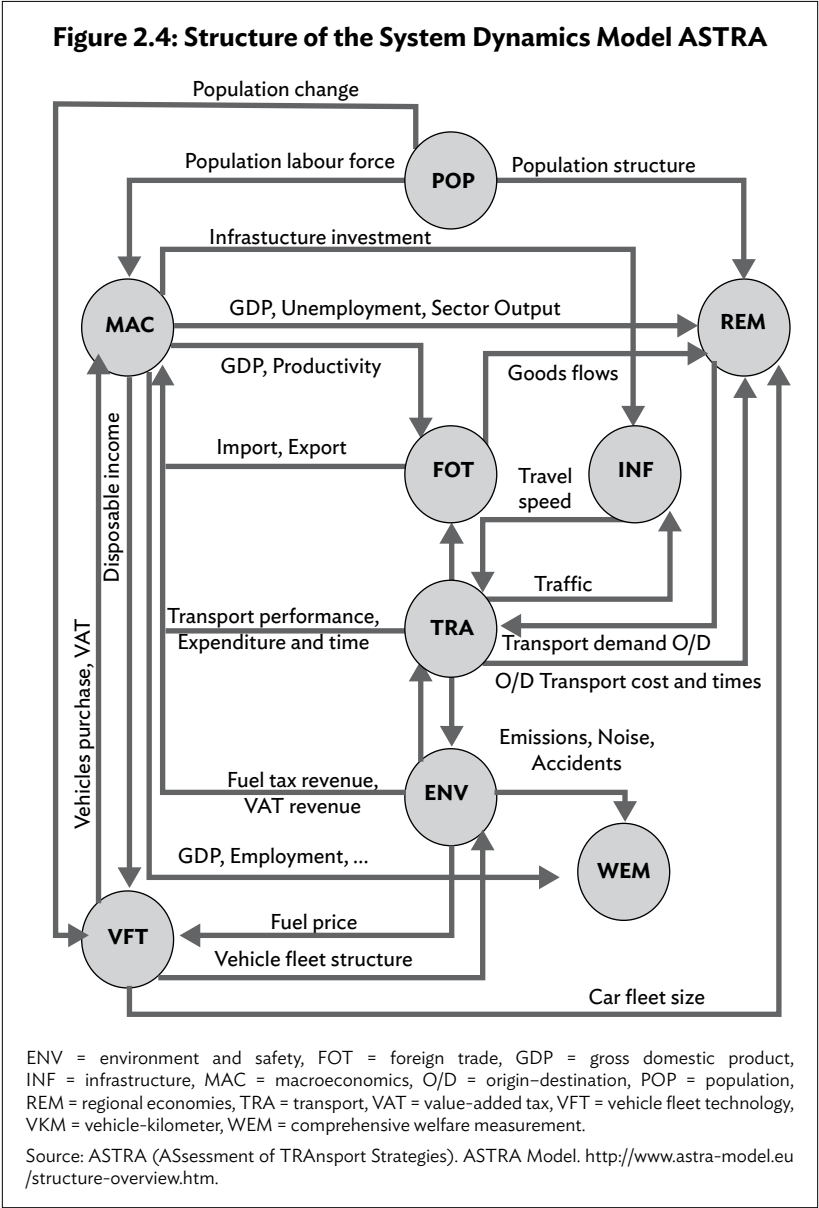
If SDM approaches are based on observed relationships and feedback mechanisms, it is possible to calibrate them at different levels: the functional level (parameters for single equations), module level (e.g., transport data for a country), and system level (EU-wide indicators). Therefore, the modeled dynamic profiles of variables can come very close to observations, even in the case of breaks of trends. The SDM ASTRA (Figure 2.4) includes modules for macroeconomics (MAC) with input–output tables for 28 countries, regional economies on the NUTS 2 level (REM),²¹ population (POP), foreign trade (FOT), infrastructure (INF), transport (TRA), vehicle fleet technology (VFT), environment and safety (ENV), and comprehensive welfare measurement (WEM). ASTRA includes a simplified transportation model (without geographical modeling of networks). Comparable to the other models for measuring WEIs, it is possible to combine it with a detailed transportation model.

The most important theory element of the macroeconomic supply side is endogenous technical progress, for which Paul Romer (1990), the recipient of the 2018 Nobel Prize in Economics, in particular developed the economic theory. Romer explained the endogenous growth dynamics by the knowledge economy as investing part of human and material resources in generating knowledge, which can then act as blueprints for innovations. This drives the total factor productivity (of labor and capital) and affects the long-term growth path of the economy. Figure 2.5 illustrates Romer’s basic idea of how the knowledge economy influences the total factor productivity in the production function. Investing part of human

²⁰ Mentioning this issue in the context of SDM does not mean that other assessment approaches are immune to manipulation risk. However, the aspiration of the early applicants to use the instrument as a quantitative representation of human thinking still influences the image of SDM. The first commercial software package including Forrester’s DYNAMO compiler was called “ITHINK.”

²¹ NUTS stands for Nomenclature of Territorial Units for Statistics, which is a regional classification: NUTS 0: country; NUTS 1: macro-region; NUTS 2: province; and NUTS 3: county level.

resources in research and development produces blueprints for inventions that creative entrepreneurs can use to develop innovations. These innovations increase the total factor productivity (productivity of capital

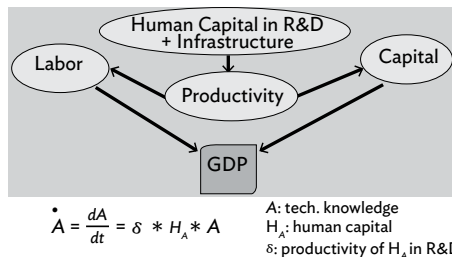


and labor, A in Figure 2.5) and push economic growth endogenously. This idea is extendable to the development of infrastructure for transport and communication networks, which—analogously to the knowledge stock—can also contribute to improving the total factor productivity over time (Rothengatter 2017). It is possible to integrate this into SDM through the production functions on the supply side such that major improvements in the transport infrastructure, which lead to a stepwise change in service quality, contribute endogenously to the long-term growth of the economy.

Yoshino and Nakahigashi (2018) presented other growth accounting and production function approaches for measuring total factor productivity impacts and quantified them for Thailand and Japan. According to the results of time series analysis, the influence of transport infrastructure on output growth is dominant in the secondary (production) sector. This means that the main productivity impacts occur through improved freight transport and trade conditions. However, the share of gross domestic product contribution of this sector is declining in highly industrialized countries. Therefore, it will be a challenge for future research to analyze the total productivity impacts on the third sector (services). Attempts to prove a positive correlation between the education level, the growth of high-tech industries, including services, and HSR have produced promising results, but researchers have not generalized them until now (e.g., the WEI assessment of the Stuttgart–Ulm/Munich project; see section 2.3.2).

The idea behind the hypothesis of such a relationship is that highly qualified people prefer working locations with good accessibility of high-speed transportation modes—for business and private travel purposes. Therefore, the improvement of accessibility through HSR can attract high-quality human capital, which induces the Romer effect that Figure 2.5 depicts.

Figure 2.5: Endogenous Growth Impacts



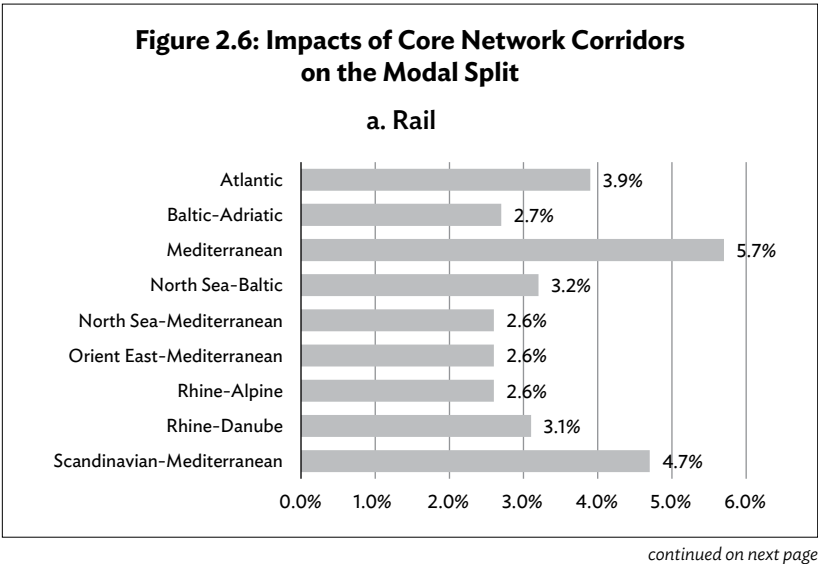
GDP = gross domestic product, R&D = research and development.

Source: Rothengatter (2017) following Romer (1990).

The model contains further interfaces between transport and the economy for the final demand. The Keynesian multiplier and accelerator impacts can stimulate the economy in the case of underemployment and foster foreign trade through a change in the terms of trade following reduced transportation costs. These demand-side effects weaken as soon as the gap between the supply (potential output) and the demand decreases. This demonstrates that an SDM can model the macroeconomic reactions according to the prevailing and expected economic regime (in the sense of Malinvaud 1977) and is not bound to a particular philosophy (neoclassical, Keynesian, or monetarist).

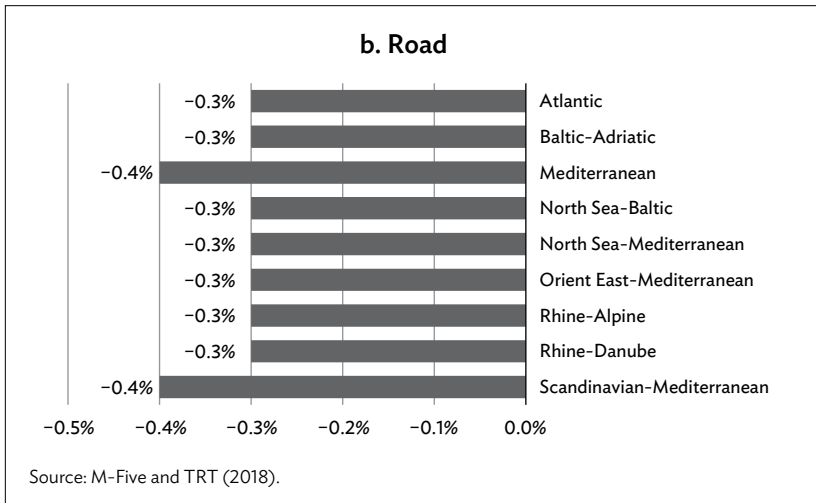
2.5.2 Application to the Assessment of the European Union Core Network Corridors

The SDM ASTRA has estimated the wider economic and environmental impacts of the CNCs (see section 2.2) until 2030 (FhG-ISI et al. 2015; M-Five and TRT 2018). ASTRA, in combination with the transport model TRUST,²² delivered the inputs for modeling the changes in



²² See TRT Trasporti e Territorio webpage, TRUST (TRansport eUropean Simulation Tool) at <http://www.trt.it/en/tools/trust/>

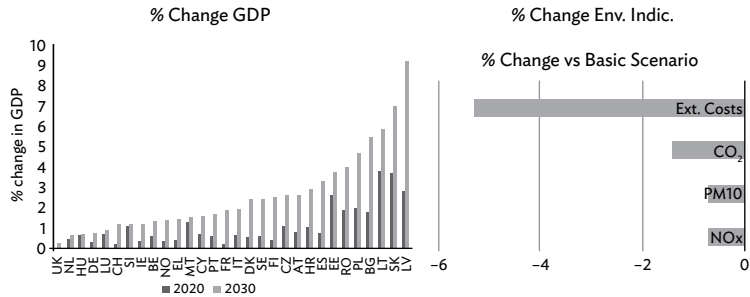
Figure 2.6 *continued*



passenger and freight transport, in particular regarding the modal split (Figure 2.6). The results underline that the influence on the modal split is in the desired direction. However, the impact of the pure infrastructure policy is limited, which means that the infrastructure policy is necessary but not sufficient and that it needs further policy measures like pricing, regulation, and improved vehicle or control technology to achieve substantial impacts on modal shift.

Figure 2.7 illustrates the impacts on the gross domestic product differentiated by EU member states and on external diseconomies (environment, climate, and safety). These impacts (as percentage changes) appear to be comparatively high in small countries, particularly in the former “accession” countries that joined the EU after 2007. Because the time horizon of the simulation is short, ending in 2030, the multiplier and accelerator effects in the initial phase are dominant (Figure 2.8). However, it is apparent that the share of the impacts of time and cost reductions or quality improvements will grow over time. In particular, the improvements of border crossings and their impacts on transnational connectivity will become evident in a later phase of CNC projects. Furthermore, the endogenous growth impacts will become apparent after the planning horizon defined for this study (i.e., after 2030).

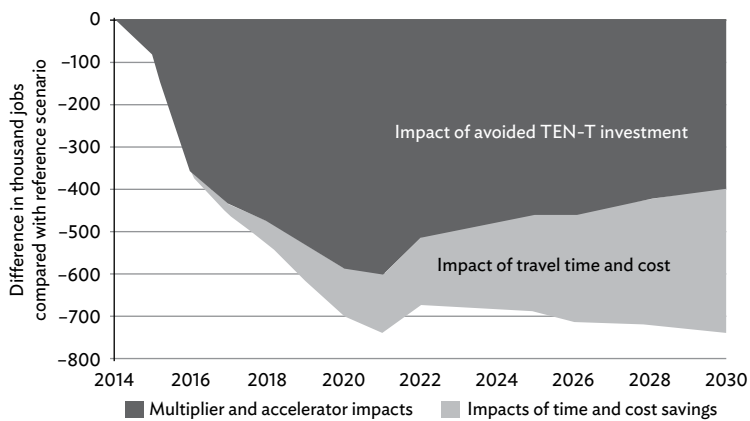
Figure 2.7: Impacts of Core Network Corridors on the Gross Domestic Product and on External Diseconomies



AT = Austria, BE = Belgium, BG = Bulgaria, CH = Switzerland, CO₂ = carbon dioxide, CY = Cyprus, CZ = Czechia, DE = Germany, DK = Denmark, EE = Estonia, EL = Greece, ES = Spain, FI = Finland, FR = France, GDP = gross domestic product, HR = Croatia, HU = Hungary, IE = Ireland, IT = Italy, LT = Lithuania, LU = Luxembourg, LV = Latvia, MT = Malta, NL = Netherlands, NO = Norway, NO_x = nitrogen oxide, PL = Poland, PM = particulate matter, PT = Portugal, RO = Romania, SI = Slovenia, SE = Sweden, SK = Slovakia, UK = United Kingdom.

Source: M-Five and TRT (2018).

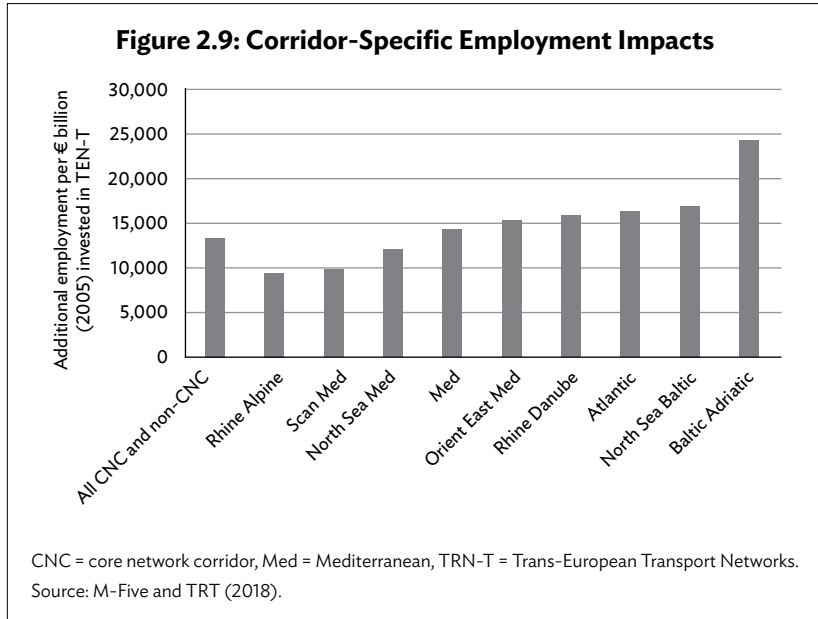
Figure 2.8: Total Employment Impacts of Core Network Corridors



TEN-T = Trans-European Transport Networks.

Source: Fraunhofer Institute for Systems and Innovation Research (FhG-ISI) et al. (2015).

The study of M-Five and TRT (2018) shows the employment impacts differentiated by the CNCs, country and industry sector (ASTRA includes input–output tables for all the EU countries, Norway, and Switzerland; Figure 2.9 presents the results).



The employment multipliers are relatively small for the corridors connecting highly industrialized regions (e.g., Rhine–Alpine and Scan–Med), while they are significantly higher in the industrially less developed corridor regions (North Sea–Baltic and Baltic–Adriatic). This indicates that considering only the agglomeration effects of HSR is not enough, as is the focus of SCGEs and their simplified elasticity approaches, because the removal of bottlenecks (geographic, political, and social) can be highly beneficial for lagging regions.

2.5.3 Ongoing Developments for Integrated Assessment Methods

Assessment methods are fully integrated if they embody modules on economics, energy, the environment, transport, and technology development. The European Commission has supported several research

and consulting projects—besides the SDM presented in section 2.5.2—in this direction. The project TRANSTOOLS²³ started by combining detailed transportation modeling with assessment tools. This approach suffered from high complexity and gave rise to the development of a simpler aggregate model called HIGH-TOOL,²⁴ which was open source and appropriate for estimating the aggregate outcomes of CNC plans. The development of TRIMODE²⁵ is presently taking place and aims at integrating differentiated transport modeling with macroeconomic, energy, and environmental modeling (in this context, it uses the CGE E³MLab; see section 2.5.1). Comparable to the models E3ME and ASTRA, these approaches integrate input–output tables with modest differentiation by sectors. They disaggregate the macroeconomic figures by shift-and-share modeling at the regional level (NUTS 3).²⁶ This provides the interface for transportation modeling that also uses this geographical classification.

The most advanced development of input–output modeling and social accounting is EXIOBASE,²⁷ which is an extended multiregional input–output model and whose development the European Commission and its Joint Research Centre in Seville (Spain) has widely supported. This open-source model is undergoing further development, and a consortium is applying it under the lead of the Norwegian University of Science and Technology. Table 2.4 gives an impression of the high degree of differentiation and the extensions by emissions and accounts for water, materials, land, and employment.

The model is appropriate, particularly if detailed information on emissions is relevant to public decision making. The model provides highly detailed supply and use tables (for 200 products and 163 industries) for 44 countries plus five regions for the rest of the world. Therefore, it is possible to analyze the sources of emissions differentiated by regions on the production side (e.g., the PRC) and the consumption side (e.g., European countries). This reveals carbon leakages and counterproductive shifts of CO₂ production from industrialized countries to emerging economies, eventually resulting in a higher total

²³ See TRANS-TOOLS (TOOLS for TRAnsport Forecasting ANd Scenario testing) website at <http://www.transportmodel.eu/>.

²⁴ See HIGH-TOOL model website at <http://www.high-tool.eu/>.

²⁵ See TRT Trasporti e Territorio webpage, TRIMODE (Transport Integrated Model for Europe) at http://www.trt.it/en/PROGETTI/trimode_project/.

²⁶ In shift and share, the regional change is usually derived here from three components: the national growth effect, industry mix effect, and local share effect. For NUTS, see footnote 21.

²⁷ See EXIOBASE webpage at <https://www.exiobase.eu/index.php/welcome-to-exiobase>.

Table 2.4: EXIOBASE—Development Stages, Differentiation, and Extensions

	EXIOBASE 1	EXIOBASE 2	EXIOBASE 3
Base year(s)	2000	2007	1995–2011
Products	129	200	200
Industries	129	163	163
Countries	43	43	44
Rest of the world regions	1	5	5
Emission types	26	40	69
Water accounts	94	344	388
Material accounts	117	117	291
Land accounts	14	15	15
Employment accounts	6	6	14

Source: EXIOBASE. <https://www.exiobase.eu/index.php/welcome-to-exiobase>.

CO₂ footprint on the consumption side. The model has proved to be applicable, for instance, in the context of the EU project LOGMAN,²⁸ which analyzed the impacts of global logistics and manufacturing on trade and transport volumes and their climate impacts.

A further preferred field of application is the analysis of detailed impacts on employment. This is the focus of the impact analysis of new technologies on the labor market. Examples are developments of automated driving and the processing of vehicles by road and rail. In this context, the United Nations Economic Commission for Europe and the International Labour Organization are using EXIOBASE for estimating the impacts of the transformation processes in vehicle manufacturing through electrification and automation (ILO 2018). As it is well known that input–output modeling is not appropriate for long-term forecasts or scenarios, it is possible to combine the model with dynamic macroeconomic and energy modeling (see Egging et al. 2017). The volume of the model (it needs 14 gigabytes of RAM for the time series from 1995 to 2011) leaves little chance to combine EXIOBASE interactively with other models like a transport model. Therefore, EXIOBASE, in the first instance, can be used to split up the impacts of changes with a high degree of differentiation that other models have quantified separately on an aggregate scale.

²⁸ See Community Research and Development Information Service (CORDIS) webpage, LOGistics & MANufacturing Trends and Sustainable Transport at <https://cordis.europa.eu/project/rcn/92918/factsheet/en>.

2.6 The Issue of Optimal Configuration of High-Speed Rail Networks

Conventional CBA concludes with a clear decision rule, at least from the theoretical point of view: the investment program should include all projects showing a positive present value or a benefit–cost ratio greater than 1. The social rate of discount implicitly represents the opportunity costs, that is, the foregone benefits of alternative spending of investment funds. Because of the deviations between CBA theory and practice in many applications (e.g., caused by appraisal biases), much higher thresholds may be necessary to adjust the transport investment program to the feasible financial resources.

Contrasting CBA, an IAM is not a separate and independent final step of final assessment. It is necessary to integrate IAM into a wider system approach for planning and decision preparation, which consists of the following steps:

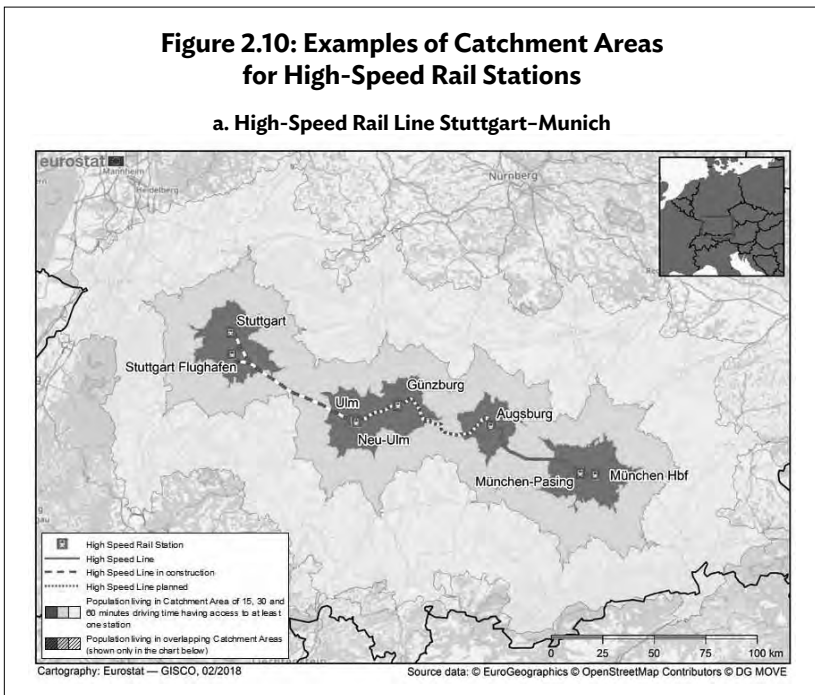
- (1) definition of the underlying goals and setting of targets,
- (2) analysis of target achievements and bottleneck removal,
- (3) development of alternative investment and action programs,
- (4) evaluation of programs and network design based on IAMs,
- (5) evaluation of projects and project design, and
- (6) life-cycle analysis of maintenance and financial needs.

In general, the underlying goals are specified and broken down starting from the Brundtland Commission (1987) definition of sustainability: economic, environmental, and social. Dependent on the societal preferences and the stage of economic development, it is possible to interpret this goal system as comprehensive social welfare or social happiness (see Hayashi et al. in this volume) and to model it as a vector maximum approach (Musso and Rothengatter 2013). If the process of decision making follows the logic above, it will be necessary to define quantitative target levels for goal achievements and constraints. In countries with decentralized decision making for infrastructure networks, this is a most difficult issue and often results in very general and not quantitatively based target descriptions. However, setting targets in a way that is too general or even fuzzy can be the starting point for planning failures, which end up with negative records for inefficiencies (see the megaproject criticism of Flyvbjerg 2014).

Clear quantitative target settings prepare the base for developing integrated concepts for target achievement and removal of identified bottlenecks. For the transport sector, these concepts include infrastructure, vehicle technology, regulation, and pricing policy. HSR

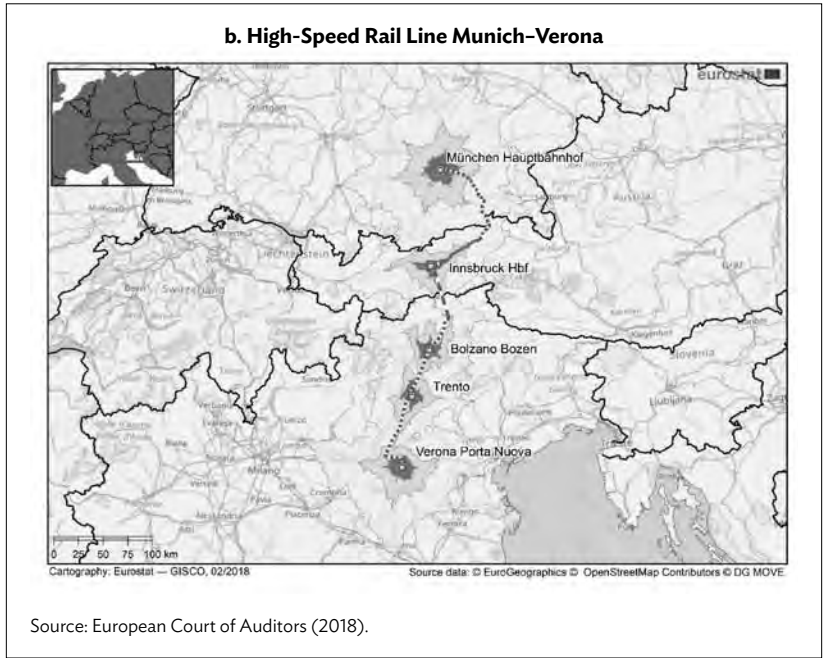
in this context can provide the backbone for long-distance passenger transport, including efficient border crossings to remove bottlenecks for interregional or international connectivity. In this case, combining HSR with the development of regional and urban networks is important to improve accessibility and avoid problems with regional equity.

Figure 2.10 gives examples of the different sizes of catchment areas for HSR stations. The first example (a) illustrates the corridor between Stuttgart and Munich and shows good accessibility of HSR stations, which also allows for the exclusion of some stations from high-frequency services to increase the average speed between the main agglomerations. The second example (b), depicting the corridor between Munich (Germany) and Verona (Italy), indicates that the catchment areas of the stations between these agglomerations could increase by improving the regional transit services. These examples underline that developing the secondary networks simultaneously is necessary to feed the HSR services in a better way and to improve the location quality of regions. This would contribute to avoiding negative backwash effects for areas without a direct HSR service.



continued on next page

Figure 2.10 *continued*



When designing HSR—beyond its function as a backbone network—as an instrument for improving the environment and regional development, as section 2.3 presented for the Spanish HSR policy, it is necessary to check whether such a policy is superior to the backbone concept combined with improvements of secondary regional transit systems.

A rational algorithm for political decision making would suggest developing alternative configurations for HSR networks with different densities. This means that evaluating alternative concepts makes the opportunity cost calculus explicit. IAMs can evaluate the present outcomes for all the underlying goals and the degrees of target achievement. These outcomes will show whether a dense regional HSR network may be superior to an HSR backbone concept with respect to regional equity and environmental sustainability (e.g., CO₂ savings for climate protection). They will also confront the policy makers with the associated budget needed for equity and the environment in the life cycle of investments. Life-cycle assessment makes it transparent that public finance may be needed not only to implement an investment project but

also to provide the necessary maintenance for decades, which may limit the political appetite for constructing dense HSR networks. Conversely, positive information on long-term WEI can motivate regions and stakeholder groups that expect benefits from the HSR investments to participate in the finance of investment and future maintenance, for example according to the value capturing suggestions of Yoshino and Stillman (2018).

Having identified the best network configuration, setting up an appropriate master plan follows. The optimal design for individual projects can be determined with the support of CBA and risk analysis, followed by optimal scheduling methods that consider the synergies between HSR links when developing the network in a staged process.

The present state of HSR implementation in the EU, which the European Court of Auditors (2018) characterized as more a patchwork than a network, shows that there is high potential for improving planning and decision processes by quantifying WEIs and applying IAMs to achieve an efficient EU HSR network configuration in 2030 and beyond.

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3

How High-Speed Rail Affects Local Land Prices: Evidence from Taipei,China

Nuobu Renzhi

3.1 Introduction

Transportation infrastructure, such as high-speed rail, is widely considered a critical booster to economic development and an important contributor to technological innovation. This is one of the most engaging reasons why many economies invest significant public spending in the transportation sector.

High-speed rail, the fastest and most up-to-date railway system, has been treated as an elite symbol of national transportation development. It is also very expensive land-based transportation infrastructure. The construction cost of high-speed rail in Taipei,China (THSR) was about NT\$513 billion, which means that the cost per route kilometer is about NT\$14.9 billion. The huge expenditure required for high-speed rail projects makes it very difficult for policy makers to decide whether to adopt such investments, an issue that was faced by Taipei,China. The THSR project was at first expected to be fully funded by the government, but this idea was rejected based on the huge costs and the uncertainty of the potential project value, which led to a combination project including private investors. It is therefore vital to re-estimate the value of high-speed rail projects in a wide category that not only focuses on a project's direct value, such as ticket revenues or the investment expenditure contributing to the local economy, but also on the spillover effects, such as increases in the local land value, which may indirectly boost the economy. Doing so may avoid the problem of underestimating the project value of the THSR in the long term (Bowe and Lee 2004).

This chapter uses local land prices to examine the spillover effects of the THSR and is perhaps the first empirical work that formally evaluates

the impact of the THSR on local land prices. Land prices are widely considered an indicator of future economic performance. Liu, Wang, and Zha (2013) have shown that land prices have a positive effect on business investment. Renzhi (2018) has found that house prices (mostly determined by land prices) also have a positive impact on gross domestic product (GDP) by serving as an accelerator of unconventional monetary policy. Chen (2001) has also found that real estate prices (mostly determined by land prices) and stock prices play an important role in amplifying bank lending in Taipei, China. To provide more evidence of the important role of land prices in the economy of Taipei, China, I use a structural vector autoregression (VAR) model to estimate the effect of land price movements on the GDP. The results suggest that an increase in land prices will lead to a persistent growth in real GDP, and this positive effect may last for 5 years. All of these findings provide firm evidence to show the importance of studying the spillover effects of the THSR on local land prices.

To evaluate the impact of the THSR on local land prices, I employ a difference-in-difference (DID) approach. Specifically, I distinguish between a treated group (regions with the THSR) from a control group (regions without the THSR) and compare the land price movements of these two groups before and after three time periods related to the THSR: the construction period, the first operation period, and the second operation period. I also divide the treated group into station-located areas and route-passing areas (areas with stations or only routes, respectively). The baseline results show that the THSR contributes 17.8% to growth in local land prices in station-located areas and 19.9% in route-passing areas during the first operation period; in other time periods, the THSR also has positive effects, but these are not statistically significant. This result is verified by a robustness check.

A regional analysis determined that there appear to be heterogeneous movements of local land prices in different parts of the treated group. Specifically, I arranged the treated group into north, mid, and south to see the differences. The north region was greatly affected by the THSR, which contributed a 34.7% increase in local land prices for station-located areas during the first operation period and a 43% increase during the second operation period. For the route-passing areas in the north region, the THSR contributed 20.3% to local land price growth during the construction period, and this positive effect became even larger with a 38.4% increase in land prices in the first operation period and 42.6% growth during the second operation period. There did not appear to be any significant increase in local land prices in the mid and south regions resulting from the THSR, which is consistent with the results of Andersson, Shyr, and Fu (2010) who have pointed out the THSR only has a minor effect on house prices using data from the city of Tainan.

This finding raises concern about potential existing “straw effects” caused by the THSR with a better connection to northern developed areas.

The remainder of the chapter is organized as follows. Section 3.2 describes the role of land prices in the macroeconomy. Section 3.3 shows how high-speed rail affects land prices by detailing the estimation approach, data, and results. Finally, section 3.4 presents the conclusions.

3.2 Land Prices and the Macroeconomy: The Evidence

The dynamic connections between house prices and the macroeconomy have been studied by many researchers in recent years. Iacoviello (2005) and Iacoviello and Neri (2010) have explained the positive co-movements between house prices and consumption expenditures by assuming households with credit constraints are using houses as collateral. Davis and Heathcote (2007), however, have provided evidence that house price movements are mainly driven by fluctuations in land prices instead of other factors such as construction costs. Based on this finding, Liu, Wang, and Zha (2013), using land as firms’ collateral when getting loans from banks, have shown that land prices have a positive relationship with business investment. The transmission channel is simple: when land prices increase, they drive up the collateral values of firms, which raises firms’ borrowing capacity and makes more investment and consumption possible, leading to growth in the economy.

3.2.1 The Structural Vector Autoregression Model

In this subsection, I examine whether the above relationships of land prices and macroeconomy also exist in Taipei, China, based on a basic structural VAR model using an aggregate semiannual data series from September 1992 to March 2018.

Let X_t be a 4×1 vector of endogenous random variables at time t , which consists of real GDP (y_t), the monetary aggregate (m_t), the interest rate (i_t), and aggregate real land prices (lp_t). Then, the model can be specified as follows:

$$X_t = A_{0-1}A_1X_{t-1} + \cdots + A_{0-1}A_pX_{t-p} + \varepsilon_t, \quad (1)$$

where $X_t = (y_t, m_t, i_t, lp_t)$, $A_0 - A_1L - \cdots - A_pL^p$, is the p th-order lag polynomial, and ε_t denotes the VAR residual vector that captures each structural shock of the endogenous variables.

The identification strategy I use is based on block recursive restriction (Christiano, Eichenbaum, and Evans 1999), with macroeconomic

non-policy variables ordered first (y_t), followed by monetary policy variables (m_t and i_t), and finally monetary variables (lp_t). In this way, the structural VAR model can be identified by imposing the restriction that the monetary variables do not simultaneously affect macroeconomic variables.

3.2.2 Estimation of the Impulse Response Functions

The estimation results of the structural VAR model are presented in Figure 3.1, which shows the impulse responses to structural one-unit shocks in two standard error bands. The solid line denotes the estimated responses in levels over 10 periods (5 years) and the shaded areas enclose 95% confidence intervals calculated using Runkle's (1987) Monte Carlo simulation method.

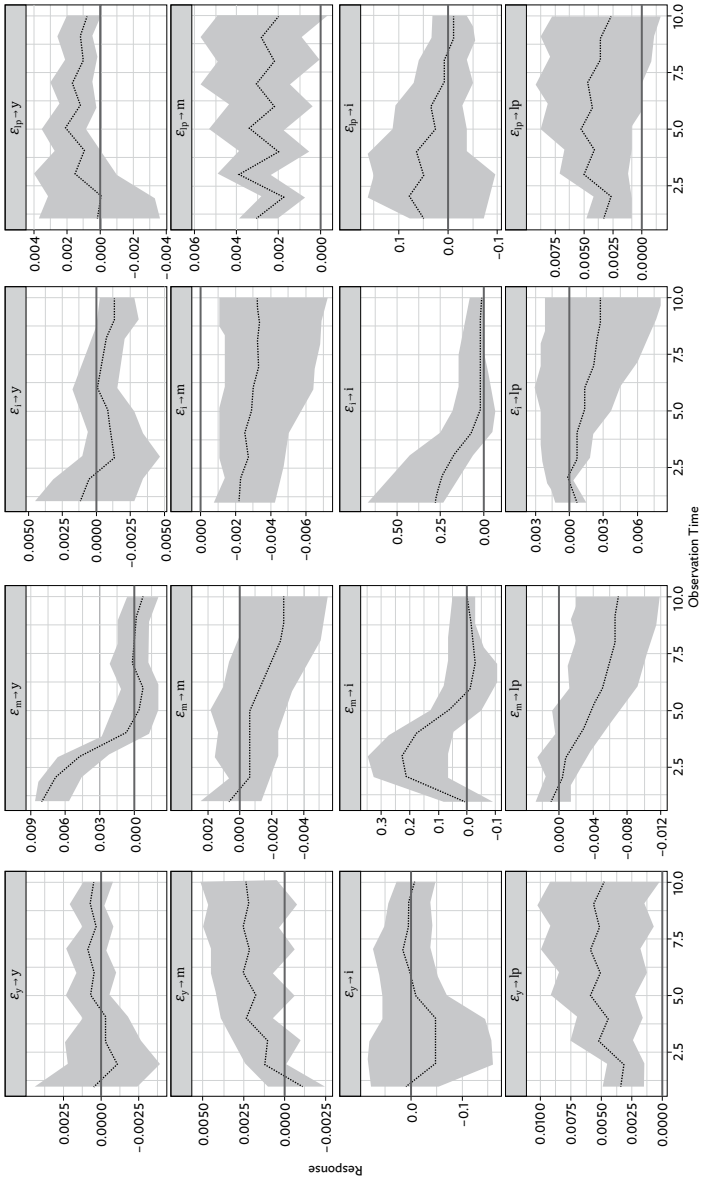
First, I looked at the impulse responses to a positive land price fluctuation as shown in the fourth column, which is the main objective of the estimation. When there is an increase in land prices, the real output shows a persistent rise, and this positive effect may last for 5 years (fourth column, top row). Because the standard error bands of estimation for the impulse responses of real output are relatively tight, the results are reasonably meaningful.

Then, I considered the impulse responses of land prices to monetary policy variables: the monetary aggregate and the interest rate. An increase in the interest rate, indicating that a tight monetary policy shock has hit the economy, led to a persistent drop in land prices (third column, bottom row). This result indicates that a higher interest rate causes a fall in land prices by increasing the costs of financing land-related investment. A restraining monetary aggregate also generated a negative effect on land prices (second column, bottom row), which again shows that a tight monetary policy will dampen land markets by decreasing money supply.

The impulse responses of land prices to real output shock (first column, bottom row) show a positive effect of real output on land prices. Combining this with the positive effect of land prices on real output from earlier may provide evidence of land prices functioning as an economic accelerator. In all, it appears that a positive shock to land prices has a persistent positive effect on real GDP. With such evidence, the meaning of estimating the effects of the THSR on local land prices is further enhanced.¹

¹ Checking the robustness of my empirical results with several alternative frameworks by replacing the weighting matrix used in the estimation, I obtained similar impulse response results compared to those in the benchmark model. One of the test results is shown in Appendix A3, while other results are omitted due to space constraints, but can be obtained on request.

Figure 3.1: Impulse Responses



Note: The shaded areas enclose 95% confidence intervals calculated using Runkle's (1987) Monte Carlo simulation method.
Source: Author's estimation.

3.3 How Does High-Speed Rail Affect Local Land Prices?

Having shown the importance of land prices in affecting economic growth, I now describe in this section my empirical strategy, data, and the results of the impact on land prices resulting from the construction and operation of the THSR.

3.3.1 Institutional Background and Research Design

The island of Taipei, China features rugged central mountainous terrain that separates the island into the west and east coast. Although the west coast covers only half of the island, nearly 90% of the population is concentrated there. With high population density and rapid economic development, the demand for north–south intercity transportation has been increasing over the years, calling for the need of an efficient high-speed mass transportation system. The THSR provides the best solution. The 349.5 kilometer THSR route connects most of the main cities located on the west coast and makes it possible to travel from Nangang in the north to Zuoying (Kaohsiung) in the south in only 2 hours, which greatly improves efficiency for intercity and regional daily commuting and business trips.

Transportation infrastructure investment has often played a key role in restructuring urban land use and land price patterns in Taipei, China (Andersson, Shyr, and Fu 2010). To determine whether the THSR has significant effects on local urban land prices, I employed an empirical strategy based on a DID approach, which allows the estimation of the THSR's effect on land prices by comparing the difference between the land price changes in regions with the THSR and those in regions without. I group the data samples into treated group (regions with the THSR) and control group (regions without the THSR) and split the time framework into pre-project and post-project.

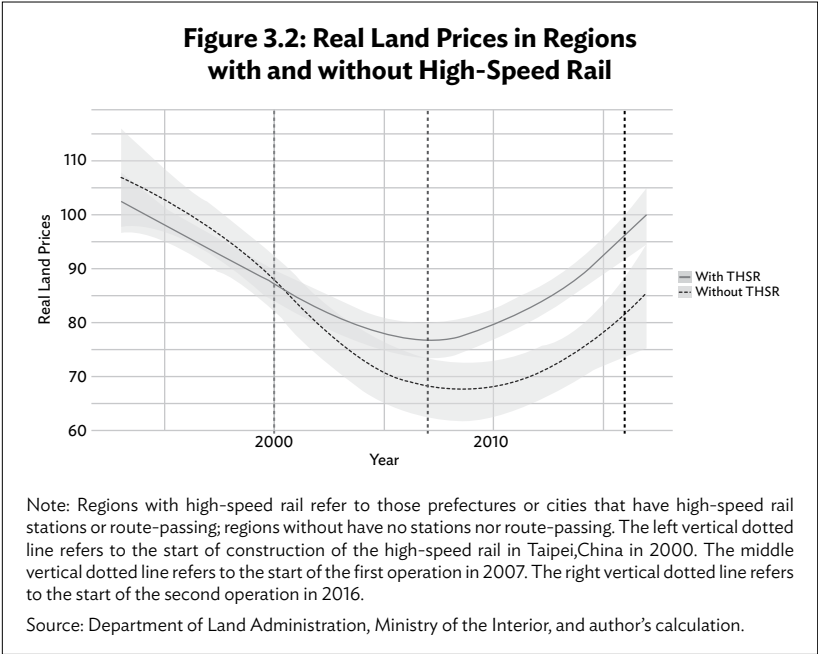
The time-based comparison is made using the following framework: pre-construction covers the years before 2000, in the absence of THSR construction or operation. The design and construction period until the first phase of THSR operation to Zuoying covers the period from 2000 to 2006. The first phase of operation constitutes the period from 2007 and 2015, and the second phase of operation, when Miaoli, Yunlin, Zhanghua, and Nangang stations were opened, includes the time period from 2016 until the present (Table 3.1).

In Figure 3.2, I compare the average real land prices in the regions with THSR routes to the regions without. The treated group comprises

Table 3.1: The Construction and Operation Timeline of the High-Speed-Rail in Taipei,China

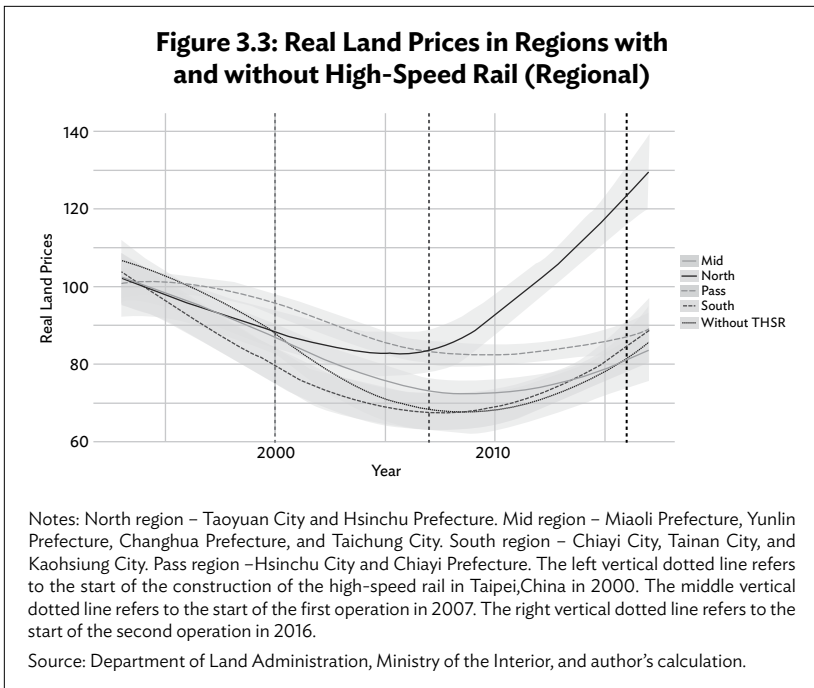
Period	Pre-construction	Construction	First Operation	Second Operation
Years	Until 2000	2000–2006	2007–2015	From 2016

Source: THSR Corporation.



the 13 prefectures and cities that have THSR stations or routes passing. The control group refers to the six prefectures and cities with no THSR stations or routes passing: Yilan Prefecture, Keelung City, Nantou Prefecture, Pingtung Prefecture, Taitung Prefecture, and Hualien Prefecture. Real land prices were calculated using the nominal urban land price index and the inflation rate (further details concerning data acquisition are covered in the data subsection).

We can see that both groups of regions experienced a downward trend in real land prices before 2007. This was largely caused by the



collapse in the real estate market in early 1990. Land prices in regions without the THSR started at a relatively higher level, but land prices in regions with the THSR recovered more quickly after 2000 and even showed a higher increasing trend after 2007. This finding seems plausible, because it indicates a positive impact from the THSR on local land prices, even during the construction period.

The land price samples may mask some heterogeneous factors behind the average number. I therefore rearranged the treated sample into four regional groups: north, mid, south, and pass. The pass region refers to those prefectures or cities that have no THSR stations but only routes passing through. Based on this new distinction, the land price movements are totally different (Figure 3.3).

Only the north region showed significantly higher land price growth after construction of the THSR began. The north region is a relatively more developed area economically, compared to the island as a whole. If most of the positive spillover effects on land prices from the THSR only happen in the north region, rather than in other regions, the potential for a “straw effect” should not be neglected. This finding shows not

only the importance of considering prefecture-specific factors in the estimation but also the necessity of regional empirical analysis besides the all-prefecture analysis.

In sum, of the 19 prefectures and cities, I used 13 for the treated group and further divided this treated group into four subgroups to assess regional differences. The control group includes the remaining six prefectures and cities that are not likely to be affected by the THSR.

3.3.2 Data

I used administrative statistics provided by the statistics offices in Taipei,China. Specifically, I obtained nominal prefecture-level land prices from the Urban Land Price Indexes (base year is 1993) provided by the Department of Land Administration, Ministry of the Interior. The prefecture-level data on household consumption were drawn from the annual report of the Survey of Family Income and Expenditure provided by the Statistical Bureau. The annual prefecture-level data on unemployment rates and population growth rates as well as the data on inflation rates used to calculate real variables using consumer price indices (base year is 1993) also were provided by the Statistical Bureau. The time series data on interest rates—to capture monetary policy changes—made use of interbank call rates provided by the central bank.

Table 3.2: Descriptive Statistics

	Obs.	Mean	Std. Dev.	Min.	Max.
All-Prefecture Sample (19)					
Real land prices (Index)	475	85.4	18.6	47.2	143.1
Unemployment rate (%)	475	3.8	1.2	0.8	12.1
Population growth rate (%)	475	0.9	8.4	-15.9	30.4
Real household consumption (NT\$)	475	541,718	110,456	320,888	845,509
Interest rate (%)	25	1.6	2.4	0.1	6.9
Control-Prefecture Sample (6)					
Real land prices (Index)	150	82.0	21.8	47.2	133.7
Unemployment rate (%)	150	3.9	1.1	1	6
Population growth rate (%)	150	-2.4	5.0	-12.5	14.7
Real household consumption (NT\$)	150	471,571	68,606	320,888	646,248

continued on next page

Table 3.2 *continued*

	Obs.	Mean	Std. Dev.	Min.	Max.
North-Prefecture Sample (5)					
Real land prices (Index)	125	94.8	17.8	63.5	143.1
Unemployment rate (%)	125	3.7	1.4	0.9	12.1
Population growth rate (%)	125	10.5	8.2	-15.9	30.4
Real household consumption (NT\$)	125	669,251	96,034	456,662	845,509
Mid-Prefecture Sample (4)					
Real land prices (Index)	100	82.8	13.2	56.8	106.1
Unemployment rate (%)	100	3.6	1.2	1	5.9
Population growth rate (%)	100	2.9	8.4	-9.6	29.2
Real household consumption (NT\$)	100	495,915	81,283	343,536	678,529
South-Prefecture Sample (4)					
Real land prices (Index)	100	82.7	15.1	54.0	109.8
Unemployment rate (%)	100	3.8	1.1	0.8	5.9
Population growth rate (%)	100	1.5	5.1	-9.8	18.2
Real household consumption (NT\$)	100	523,441	63,707	351,535	623,350

Sources: Department of Land Administration, Ministry of the Interior, Central Bank, the Statistical Bureau, and author's calculation.

I combined and harmonized the annual national and prefecture-specific datasets and constructed a panel covering all 19 prefectures on the island from 1993 to 2017. This 25-year panel allowed me to observe the long-term effects caused by the THSR by yielding a sufficient number of years before and after the THSR project started. Table 3.2 presents descriptive statistics for all of the variables used in the analysis, categorized by regional groups.

3.3.3 The Model

Specification Using All-Prefecture Sample

I first estimated the spillover effects of the THSR on land prices using the all-prefecture sample as the baseline. To check the spillover effects in different periods as shown in Table 3.1, I specified three time-binary variables, $T_{construction}$, T_{1st} , and T_{2nd} , which refer to the construction period, the first operation period, and the second operation period, respectively. To find the effect differences between THSR station-located areas and

THSR route-passing areas, I created two binary variables, $d_{station}$ and d_{route} . The DID estimation equations follow the traditional Card and Krueger (1994) form:

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta (T_{construction} \cdot d_{station}) + X_i' t \beta + \varepsilon_{it} \quad (2)$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta (T_{1st} \cdot d_{station}) + X_i' t \beta + \varepsilon_{it} \quad (3)$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta (T_{2nd} \cdot d_{station}) + X_i' t \beta + \varepsilon_{it} \quad (4)$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta (T_{construction} \cdot d_{route}) + X_i' t \beta + \varepsilon_{it} \quad (5)$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta (T_{1st} \cdot d_{route}) + X_i' t \beta + \varepsilon_{it} \quad (6)$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta (T_{2nd} \cdot d_{route}) + X_i' t \beta + \varepsilon_{it} \quad (7)$$

where $\ln LP_{it}$ is the log of real land prices, i refers to each prefecture or city, and t denotes the period. $T \cdot d$ is the interaction term of two binary variables indicating whether the observation belongs to the treated group after given time periods. X_{it} is the vector of the control variables to lower the bias of the omitted variables, which include time-varying variables at the prefecture level such as population growth, real household consumption, and unemployment rate, and time-varying variables at the economy level such as the interest rate. γ_i is a time-invariant prefecture effect; λ_t is the year-specific effect common across all prefectures; and ε_{it} is the error term, which is assumed to be independent over time.

I based the selection of control variables on empirical findings and the availability of prefecture-level data. As shown in section 3.2, economic growth variables such as real GDP are likely to affect land prices in Taipei, China, so including prefecture-level real GDP variables as control variables may be a good choice to lower omitted variable biases. However, because the economy of Taipei, China is rather compact, there are no official prefecture-level GDP statistics. Instead, I used the average real household consumption data as a proxy variable for prefecture-level real GDP. I also added the unemployment rate combined with real household consumption to serve as indicators of prefecture-level economic growth, which may affect land price movement in addition to THSR projects. Demography is also an important factor in determining land price movement (Poterba, Weil, and Schiller 1991), so I included the prefecture-level data for the population growth rate as a control variable. Based on the findings in section 3.2, national monetary policy fluctuations significantly affect land price dynamics, so adding the interest rate variable to the control variable vector is essential as well. Details on the data sources were presented in the previous subsection.

It is important to keep in mind that long-term autocorrelated time series (e.g., land prices) may generate inconsistent standard errors when employing the DID methodology, as has been criticized by Bertrand, Duflo, and Mullainathan (2004). Following their approach—which has been widely adopted in the infrastructure evaluation literature, including by Yoshino and Abidhadjaev (2017)—I solved this problem by employing heteroscedasticity- and autocorrelation-consistent (HAC) standard errors that are clustered at the prefecture level.

Specification Using Regional Sample

To address the regional differences of the spillover effects of the THSR on land prices, I re-estimated the model using regional treated group samples: north-prefecture sample, mid-prefecture sample, and south-prefecture sample (Table 3.2). The control group to be compared remained unchanged. The setting of the model is the same as the baseline version, and the DID estimation equations also use the same form as the baseline case (see previous subsection for an explanation of the variables):

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta (T_{\text{construction}} \cdot d_{\text{station}}) + X_i' t \beta + \varepsilon_{it} \quad (8)$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta (T_{1st} \cdot d_{\text{station}}) + X_i' t \beta + \varepsilon_{it} \quad (9)$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta (T_{2nd} \cdot d_{\text{station}}) + X_i' t \beta + \varepsilon_{it} \quad (10)$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta (T_{\text{construction}} \cdot d_{\text{route}}) + X_i' t \beta + \varepsilon_{it} \quad (11)$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta (T_{1st} \cdot d_{\text{route}}) + X_i' t \beta + \varepsilon_{it} \quad (12)$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta (T_{2nd} \cdot d_{\text{route}}) + X_i' t \beta + \varepsilon_{it} \quad (13)$$

3.3.4 Estimation Results

This subsection contains my empirical results concerning how the THSR affected local land prices using whole sample and regional sample data. To that end, I compared the land prices during the construction period, the first operation period, and the second operation period to those during the pre-construction period.

Baseline Results

Table 3.3 reports the spillover effects of the THSR on land prices using the all-prefecture sample for all six specifications: each one with or without including route-passing prefectures for the given time period.

Table 3.3: Baseline Results

	Real Land Prices					
	Station Located			Route Passing		
	Construction	First Operation	Second Operation	Construction	First Operation	Second Operation
<i>DID</i>	0.045 (0.071)	0.178** (0.087)	0.168 (0.109)	0.120 (0.079)	0.199* (0.106)	0.191 (0.121)
Unemployment	-0.019 (0.015)	-0.059** (0.026)	-0.022 (0.016)	-0.016 (0.014)	-0.064** (0.027)	-0.022 (0.016)
Household Consumption	-0.047 (0.090)	0.264** (0.123)	0.082 (0.106)	-0.066 (0.088)	0.300** (0.136)	0.078 (0.109)
Population growth	-0.00004** (0.00002)	-0.00002 (0.00002)	-0.003*** (0.001)	-0.00003** (0.00002)	-0.00002 (0.00002)	-0.003** (0.001)
Interest rate	0.102*** (0.028)	-0.044*** (0.015)	0.148*** (0.037)	0.104*** (0.028)	-0.045*** (0.016)	0.146*** (0.040)
Constant	4.612*** (1.144)	1.557 (1.563)	2.633* (1.465)	4.846*** (1.113)	1.144 (1.729)	2.716* (1.459)
Observations	266	342	171	266	342	171
R ²	0.432	0.360	0.154	0.452	0.352	0.156

DID = difference-in-difference.

Notes: Regressions estimate equations (2)–(7) where the treated group uses all-prefecture sample data. The pre-construction period refers to 1993–1999. DID captures the spillover effects on real land prices resulting from the high-speed rail in Taipei, China. Heteroscedasticity- and autocorrelation-consistent (HAC) standard errors are reported in the parentheses. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Source: Author's estimation.

For the station-located areas, the impact of the THSR on the local land prices was positive for all three time periods. During the first operation period (2007–2015), the THSR increased local land prices by 17.8%, with statistical significance at the 5% level. Region-specific control variables such as real household consumption were wide-ranging and only statistically significant during the first operation period. Population growth was not as important as it is in theory and hardly had an effect on land prices. The unemployment rate was statistically significant at the 5% level during the first operation period, which negatively affected the land prices, capturing the fact that a better economy leads to higher land prices. Other control variables such as the interest rate (representing monetary policy changes) also showed significant effects during all three time periods.

In the route-passing areas, the THSR showed more significant effects on local land prices during the first operation period with 19.9% (statistically significant at the 10% level) growth in land prices. Control variables that showed significance in explaining land price changes were the same as those in the station-located areas. The THSR therefore appeared to have significant positive effects on local land prices both in the station-located and the route-passing areas during the first operation period, while in other periods such effects did not appear.

Regional Results

Table 3.4 reports the spillover effects of the THSR on land prices using the north-prefecture sample for all six specifications that were the same as the baseline case.

Table 3.4: Regional Results—North Region

	Real Land Prices					
	Station Located			Route Passing		
	Construction	First Operation	Second Operation	Construction	First Operation	Second Operation
<i>DID</i>	0.133 (0.096)	0.347*** (0.114)	0.430*** (0.137)	0.203** (0.090)	0.384*** (0.123)	0.426*** (0.145)
Unemployment	-0.012 (0.014)	-0.052 (0.032)	-0.011 (0.014)	-0.006 (0.011)	-0.049 (0.030)	-0.007 (0.010)
Household consumption	-0.058 (0.162)	0.197 (0.162)	-0.081 (0.154)	-0.264* (0.145)	0.016 (0.217)	-0.218 (0.158)
Population growth	-0.00003 (0.00002)	-0.00002 (0.00003)	-0.004 (0.003)	-0.0001*** (0.00002)	-0.00005 (0.00003)	-0.006** (0.002)
Interest rate	0.112*** (0.042)	-0.049** (0.020)	0.153*** (0.050)	0.117*** (0.041)	-0.048** (0.019)	0.154*** (0.046)
Constant	4.679** (2.074)	2.472 (2.100)	4.715** (2.193)	7.340*** (1.805)	4.833* (2.808)	6.501*** (2.131)
Observations	154	198	99	154	198	
R ²	0.409	0.397	0.324	0.471	0.405	

DID = difference-in-difference.

Notes: Regressions estimate equation (8)–(13) where the treated group uses north-prefecture sample data. The pre-construction period refers to 1993–1999. DID captures the spillover effects on real land prices resulting from the high-speed rail in Taipei, China. Heteroscedasticity- and autocorrelation-consistent HAC standard errors are reported in the parentheses. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Source: Author's estimation.

In the north region, the THSR had greater effects on local land prices in the station-located areas compared to baseline results. The THSR contributed to a 34.7% increase in local land prices (statistically significant at the 1% level) during the first operation period and an even higher 43% (statistically significant at the 1% level) during the second operation period. For the route-passing areas in the north region, the THSR contributed to 20.3% local land price growth during the construction period (statistically significant at the 5% level), and this positive effect became even larger in the first operation period with a 38.4% increase in land prices (statistically significant at the 1% level) and 42.6% growth during the second operation period. The larger increase in land prices observed during the second operation may have been affected by the newly built Nangang station. Control variables such as household consumption only showed significance in the route-passing areas during the construction period, and population growth only showed significance in the route-passing areas during the construction and second operation periods. Unemployment showed no significance in either the station-located or route-passing areas during any of the periods. Conversely, the interest rate had significant effects in both the station-located and route-passing areas during all three periods.

Table 3.5 shows the impact of the THSR on land prices in the mid region. For both the station-located and route-passing areas, the THSR did not appear to have any significant effect during any of the three time periods. Although the new stations in Miaoli, Changhua, and Yunlin prefectures were completed in the second operation period, the THSR's effects on land prices become smaller compared to the effects during

Table 3.5: Regional Results—Mid Region

	Real Land Prices					
	Station Located			Route Passing		
	Construction	First Operation	Second Operation	Construction	First Operation	Second Operation
<i>DID</i>	-0.060 (0.065)	0.156 (0.107)	0.051 (0.123)	0.114 (0.098)	0.147 (0.096)	0.051 (0.123)
Unemployment	0.006 (0.025)	-0.056 (0.036)	-0.020 (0.043)	0.016 (0.025)	-0.069** (0.033)	-0.020 (0.043)
Household consumption	0.213 (0.154)	-0.093 (0.218)	-0.068 (0.245)	-0.260 (0.168)	-0.096 (0.185)	-0.068 (0.245)

continued on next page

Table 3.5 *continued*

	Real Land Prices					
	Station Located			Route Passing		
	Construction	First Operation	Second Operation	Construction	First Operation	Second Operation
Population growth	0.0001*** (0.00004)	0.00005 (0.0001)	-0.003 (0.004)	-0.00004 (0.00003)	0.00003 (0.00003)	-0.003 (0.004)
Interest rate	0.156*** (0.055)	-0.034 (0.024)	0.136** (0.055)	0.145*** (0.041)	-0.038* (0.022)	0.136** (0.055)
Constant	6.383*** (1.924)	6.151** (2.751)	4.679 (2.972)	7.045*** (2.118)	6.281*** (2.355)	4.679 (2.972)
Observations	140	180	90	140	180	
R ²	0.507	0.425	0.284	0.511	0.438	

DID = difference-in-difference.

Notes: Regressions estimate equation (8)–(13) where the treated group uses north-prefecture sample data. The pre-construction period refers to 1993–1999. DID captures the spillover effects on real land prices resulting from the high-speed rail in Taipei, China. Heteroscedasticity- and autocorrelation-consistent (HAC) standard errors are reported in the parentheses. *p<0.1; **p<0.05; ***p<0.01.

Source: Author's estimation.

the first operation period. For the control variables, unemployment only showed a significant effect in the route-passing areas during the first operation period. Population growth only showed a significant effect in the station-located areas during the construction period. Household consumption generally had no significant effect on land prices throughout the whole time period. The interest rate generated significant effects during most periods.

Finally, Table 3.6 presents the impact on land prices in the south region resulting from the THSR. Similar to the mid region, there was no statistically significant effect in either the station-located or route-passing areas. For the control variables, the interest rate showed significant effects on land prices during the construction and second operation periods. Population growth showed significant effects in the station-located areas during the construction and second operation periods, as well as in the route-passing areas during the construction period. Unemployment had significant effects on land prices during the first operation period. Other explanatory variables such as household consumption only showed a significant effect on land prices in the route-passing areas during the construction period.

Table 3.6: Regional Results—South Region

	Real Land Prices					
	Station Located			Route Passing		
	Construction	First Operation	Second Operation	Construction	First Operation	Second Operation
<i>DID</i>	0.023 (0.098)	0.073 (0.130)	0.122 (0.133)	0.100 (0.091)	0.108 (0.117)	0.094 (0.133)
Unemployment	-0.007 (0.020)	-0.072** (0.031)	-0.033 (0.026)	-0.002 (0.019)	-0.071** (0.029)	-0.033 (0.024)
Household consumption	-0.232 (0.162)	-0.026 (0.208)	-0.078 (0.195)	-0.240* (0.123)	-0.077 (0.183)	-0.114 (0.163)
Population growth	0.0001*** (0.00003)	0.00001 (0.00005)	0.006* (0.003)	0.0001*** (0.00003)	0.00000 (0.00005)	0.005 (0.004)
Interest rate	0.153*** (0.046)	0.043 (0.028)	0.127** (0.057)	0.161*** (0.044)	0.042 (0.027)	0.126** (0.054)
Constant	6.701*** (2.032)	5.408** (2.651)	4.917** (2.204)	6.738*** (1.521)	6.073*** (2.321)	5.389*** (1.837)
Observations	140	180	90	140	180	90
R ²	0.523	0.414	0.298	0.551	0.422	0.293

DID = difference-in-difference.

Notes: Regressions estimate equation (8)–(13) where the treated group uses north-prefecture sample data. The pre-construction period refers to 1993–1999. DID captures the spillover effects on real land prices resulting from the high-speed rail in Taipei, China. Heteroscedasticity- and autocorrelation-consistent (HAC) standard errors are reported in the parentheses. *p<0.1; **p<0.05; ***p<0.01.

Source: Author's estimation.

In all, the regional results suggest that the positive effects brought about by the THSR in the baseline model were mostly driven by the significant effects from the north region. There do not appear to have been any significant impact on land prices from the THSR in either the mid or south regions, which largely explains why the results for the whole sample are not as plausible as in the case of the north region. This finding also raises concern about “straw effects” caused by the THSR in the mid and south regions because the local benefits from the THSR mainly flowed to the north region.

3.3.5 Robustness Test

To examine whether or not the common trends assumption was problematic, I conducted a robustness test by adding region-specific

linear time trends to the DID models.² If the common trends assumption holds, the impact from the THSR on local land prices is smaller or less significant during the time periods before the start of a given period. Given the long-term time series of my data, I can estimate the 6-year pre-project effect. More specifically, I checked the effect of the THSR on land prices during 1994–1999 (pre-construction period), 2001–2006 (pre-first-operation period), and 2010–2015 (pre-second-operation period), while the influence of other control variables remained unchanged. In the pre-construction period, no THSR spillover effect existed, because the construction of the THSR had not started. During the pre-first-operation period, the THSR remained under construction, so the change in local land prices should be weaker compared to the baseline model results. During the pre-second-operation period, the THSR had already seen its first operation, so the effect may not be weaker compared to the baseline case, and therefore I expected a higher growth in land prices will be observed.

Table 3.7 reports the DID coefficients specified by the time period dummy variables. The foot of the *DID* means a given year dummy for each time period, which refers to *DID*_{construction, first operation, second operation}. We can see that the effect of the THSR on land prices was weaker or less significant compared to the construction and first operation periods in the baseline model. The THSR had a larger or more significant impact on land prices compared to the second operation period in the baseline

Table 3.7: Robustness Test

	Station Located			Route Passing		
	Construction	First Operation	Second Operation	Construction	First Operation	Second Operation
DID1999,2006,2015	0.039 (0.068)	0.169** (0.085)	0.177 (0.109)	0.111 (0.078)	0.195* (0.105)	0.198 (0.120)
DID1998,2005,2014	0.040 (0.066)	0.161* (0.084)	0.184* (0.105)	0.108 (0.077)	0.190* (0.103)	0.204* (0.115)
DID1997,2004,2013	0.039 (0.063)	0.153* (0.083)	0.188* (0.101)	0.101 (0.075)	0.187* (0.102)	0.208* (0.110)

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² I only present the robustness test for the baseline model to save space; robustness test results for the regional analysis were similar.

Table 3.7 *continued*

	Station Located			Route Passing		
	Construction	First Operation	Second Operation	Construction	First Operation	Second Operation
DID1996,2003,2012	0.028 (0.060)	0.146* (0.082)	0.187* (0.098)	0.087 (0.073)	0.183* (0.101)	0.210** (0.106)
DID1995,2002,2011	0.030 (0.062)	0.141* (0.079)	0.184* (0.094)	0.070 (0.072)	0.176* (0.099)	0.209** (0.101)
DID1994,2001,2010	0.020 (0.064)	0.133* (0.077)	0.167* (0.090)	0.043 (0.075)	0.169* (0.097)	0.185* (0.100)

DID = difference-in-difference.

Notes: The treated group uses all-prefecture sample data. DID captures the spillover effects on real land prices resulting from the high-speed rail in Taipei, China. Heteroscedasticity- and autocorrelation-consistent (HAC) standard errors are reported in the parentheses. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Source: Author's estimation.

case, which is as expected. The robustness check therefore confirmed the reliability of my estimation results for the spillover effects of the THSR on local land prices.

3.4 Concluding Remarks

In this chapter, I evaluated the spillover effects from the THSR on local land prices. To highlight the important role of land-price movements in the economic growth of Taipei, China, I adopted a structural VAR analysis providing empirical evidence that a land-price growth leads to a persistent increase in real GDP.

With this empirical finding, I followed a DID approach to estimate the effect of the THSR on local land prices in the station-located and route-passing areas. I also differentiated the time periods into construction, first operation, and second operation to check the different impacts of the THSR during these different periods. The results of the baseline model using all-prefecture data indicate that the THSR significantly increased the local land prices in the station-located areas by 17.8% during the first operation period. These positive effects were even larger in the route-passing areas, where a 19.9% increase in local land prices was observed during the first operation period. Despite the lack of statistical significance, positive impacts on local land prices from the THSR were also estimated, and the robustness test shows that the estimation results are reliable.

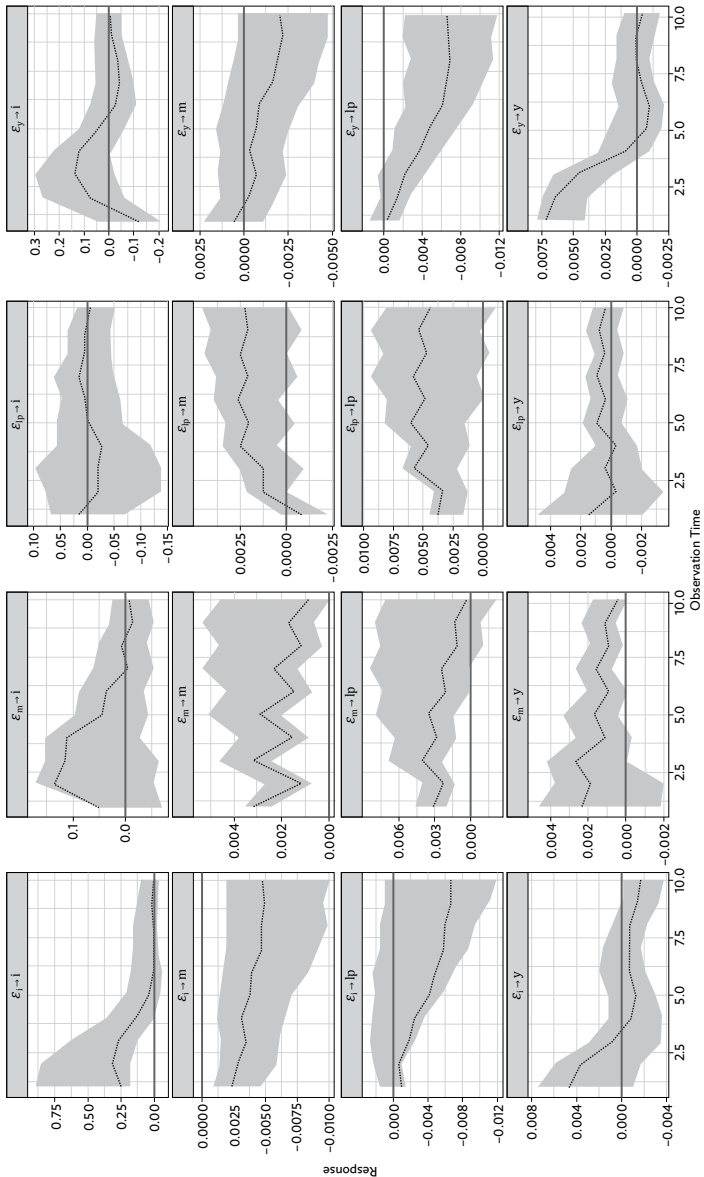
To observe the heterogeneous performance of land-price movements that may be masked by the all-prefecture estimation, I also employed a regional analysis by dividing the THSR-affected areas into north, mid, and south regions, in addition to the baseline whole sample results. The analysis results suggest that the THSR had a significant effect on local land prices in the north region, larger than the baseline results, while there was no statistically significant increase in the mid and south counterparts. This may indicate the regional inequality of land-price movements resulting from the THSR, which raises concern about “straw effects” that potentially occurred in the mid and south regions. Policy makers should carefully consider this issue if there are any future plans for extending the THSR route to the eastern areas of Taipei, China. In conclusion, I have provided evidence of the positive impact of the THSR on local land prices, while the growth of land prices had heterogeneous movements among regions.

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Appendix A3

Figure A3: Impulse Responses—Robustness Check by Changing Weight Matrix



Note: The shaded areas enclose 95% confidence intervals calculated by Runkle's (1987) Monte Carlo simulation method.
Source: Author's estimation.

4

How High-Speed Rail Fosters Japan's Regional Agglomeration Economy

Jetpan Wetwitoo

4.1 Introduction

Literature regarding agglomeration on specialization and diversity are ambiguous with respect to which is best at contributing to local productivity. Local specialization favors the original idea of Marshall (1920) that better productivity from agglomeration can be expected in areas where firms in similar sectors are located close to each other. Conversely, industrial diversity represents the idea proposed by Jacobs (1969) that innovation growth is stimulated by industrial variety, which better synthesizes diverse ideas and information than specialization. Although empirical analysis from past literature suggests the importance of diversity over specialization, the concept of specialization is still intriguing and should not be ignored. It is interesting to understand why the effects of industrial diversity benefit the overall economy, whereas industrial specialization is rarely suggested in past empirical studies.

Specialization or diversity agglomeration is usually discussed on the basis of the spatial interaction between activities (e.g., interaction between firms and workers). By taking spatial issues into account, it is certain that transportation improvement can enhance the performance of spatial interaction between activities. Better transportation reduces the cost of travel and also encourages more meetings, discussions, and activities such as workshops between firms. All this hastens the learning process, accelerates firms' technology advances, and results in better productivity. Transportation literature, such as that of Graham (2007), Graham, Gibbons, and Martin (2009), Melo, Graham, and Brage-Ardao (2013), and Melo et al. (2016), considers transportation as one of the factors for agglomeration economies and shows that improvement

in accessibility by transportation in terms of “effective density” could create a better agglomeration environment. However, deliberation of the transportation effect has only considered the size of agglomeration. Considering the specialization or diversity effect of transportation from a theoretical viewpoint, one fact can be extracted from the New Economic Geography (NEG): lower trade cost resulting from better transportation leads to a greater variety of goods in the economy (Krugman 1991). Yet, there is a lack of empirical study to support NEG's idea. This is especially true in the case of high-speed rail (HSR), which mainly involves passenger transport (in contrast to NEG's focus on freight transport) and thus implies a different effect than that proposed by NEG. In this chapter, I address two concepts: exploring the relationship between industrial specialization or diversity and productivity, and empirically analyzing how HSR affects local industrial specialization or diversity.

4.2 Literature Review

Past literature provides many perspectives on agglomeration economies. Rosenthal and Strange (2004) categorized these agglomeration perspectives into four scopes: industrial scope, temporal scope, geographical scope, and organization scope. In this chapter, I focus on the industrial scope, which is the most widely discussed topic in the literature regarding agglomeration economies. Within the industrial scope, Rosenthal and Strange (2004) provide two subscopes commonly discussed in the literature. The first focuses on the size of the industrial agglomeration: whether the size of the agglomeration within the same industry (localization agglomeration) or the size of total agglomeration in the economy (urbanization agglomeration) is more beneficial to productivity in the agglomerated area. With the contribution from transportation infrastructure such as HSR, localization agglomeration was shown to produce higher agglomeration benefits for the economy (Wetwitoo and Kato 2017). However, this chapter discusses the other subscope: whether an agglomerated area with more specialization or diversity is more beneficial to productivity. In general, the localization or urbanization agglomeration scope and the specialization or diversity agglomeration scope appear similar, since the concept of Marshall's economy could apply to both localization agglomeration and specialization agglomeration, while the concept of Jacobs' economy could apply to both urbanization agglomeration and diversity agglomeration. Table 4.1 provides a further explanation to distinguish the characteristics of the subscope within the industrial scope.

As mentioned, past empirical literature may favor the benefit from localization agglomeration rather than urbanization agglomeration.

In the specialization or diversity scope, surprisingly, the positive significance to the economy of diversity agglomeration has been highlighted more than specialization. Some studies underscore the benefit of specialization agglomeration, but only from a conceptual perspective. Helsley and Strange (1990) provide a model emphasizing the job-matching process. They conclude that more specialization means a larger pool of workers with a similar skill, allows for better matching, and eventually leads to greater productivity. The general equilibrium model proposed in Duranton and Puga (2001) suggests the importance of both specialized and diversified environments, where the diversified city could be suitable for firms in their early stages, while matured firms find larger benefit in a specialized city.

In the empirical studies, however, diversity agglomeration is found to be more beneficial to the economy than specialization agglomeration. Glaeser et al. (1992) analyze the growth of the top six industries in 1956, concluding that specialization does not encourage growth. Similarly, Henderson, Kuncoro, and Turner (1995) conclude that specialization made no positive contribution to growth in high-technology industries in the 1970–1987 period. They further suggest that employment growth is higher in the area with more employment diversity, which is measured by the Herfindahl–Hirschman Index (HHI) of employment. Thus, results from empirical studies tend to favor the importance to the economy of diversity agglomeration rather than specialization agglomeration.

Nevertheless, past literature remains inconclusive on several issues regarding specialization or diversity agglomeration. Although, intuitively, the mechanism of diversity agglomeration is similar to urbanization agglomeration, the reason why larger benefit is usually associated with the localization agglomeration effect (rather than urbanization) should be discussed, along with the specialization or diversity scope. Another issue for consideration involves the indexes to measure specialization or diversity. Usually, two types of indexes are used to measure the degree of specialization or diversity: the first type considers industrial distribution only in its own area to which HHI is usually applied, and the second type considers the distribution of each industry across every area, along with the distribution across industry in its own area. In the latter type, the indexes derived from Ellison and Glaeser's (1997) agglomeration index are usually introduced in the analysis. The question is which type of index can best explain the condition of industrial synthesis mentioned in Jacobs' economy. Furthermore, indexes used in past literature often neglect the neighboring effect, especially the first type of index, which only considers the activity distribution in its own area. With respect to my assertion that an agglomeration discussion should include spatial

Table 4.1: Characteristics of the Localization/Urbanization and Specialization/Diversity Agglomeration

Concept	Measurement	Size of Agglomeration	Distribution of Agglomeration
Marshall's economy		Localization agglomeration	Specialization agglomeration
Jacobs' economy		Urbanization agglomeration	Diversity agglomeration

Source: Author.

consideration, incorporating the neighboring effect shows that the degree of specialization or diversity could be varied across spatial unevenness also.

Until now, no literature has investigated the effect of transportation on specialization or diversity, especially HSR. Past literature usually has assumed that industrial promotion depends on a specific policy and is not affected by infrastructure investment such as HSR. Therefore, I propose a new causal effect assuming that new transportation modes such as HSR service induce a change in the industrial agglomeration structure.

4.3 Methodology

Although past literature favors the effect from diversity agglomeration rather than specialization agglomeration, one important issue is how the indexes are selected to explain the characteristics of specialization or diversity. The ideal index should be the index that best captures the characteristics of Marshall's economy or Jacobs' economy. While Marshall's concept of industrial scale of economies does not mention the interaction of the scale of economies between industries, Jacobs' concept does not restrict any industrial specialization. Thus, it is possible that diversity and specialization could be considered in separate frameworks. For instance, Batisse (2002) and Thabet (2015) consider specialization as a ratio between a share of industry within a zone and a share of industry from the whole country, while diversity is separately defined as an inverse of normalized HHI of industry concentration. Paci and Usai (1999) and Van Der Panne (2004) measure industrial diversity using an index based on a reciprocal of the Gini index. Though some past studies have used separate variables for specialization or diversity, they could be intuitively considered together using the same index,

as they can be viewed as opposing factors. The index used in Batisse (2002) and Thabet (2015) shows that diversity is defined as an index of industry concentration, and this concentration can be also considered as specialization.

I have pointed out several other issues, such as incorporation of the neighboring effect, in order to express the actual “agglomeration.” Employment growth is the most commonly used indicator for measuring specialization or diversity agglomeration (Glaeser et al. 1992; Henderson, Kuncoro, and Tuner 1995; Paci and Usai 1999; Van Der Panne 2004), although other indicators, such as value added, is also applied, such as in the studies by Batisse (2002) and Thabet (2015). These indexes still fail to capture the neighboring effect. In order to capture this effect, this study applies the following indicator to measure regional agglomeration:

$$A_{i,k} = \sum_j \frac{E_{j,k}}{g_{j \rightarrow i}}, \quad (1)$$

where $A_{i,k}$ represents the agglomeration of industry k in zone i , $E_{j,k}$ represents the activity of industry k in zone j , and $g_{j \rightarrow i}$ represents the generalized cost of transport from zone j and zone i . In this study, I simplify the activity $E_{j,k}$ as industry k employment in zone j , and generalized cost $g_{j \rightarrow i}$ is simplified as the Euclidian distance between zones i and j . The calculation of activity in zone j includes intra-zone activity, where $j = i$ as well. This indicator is an application of the gravity model used in past studies, such as Stewart’s (1947) so-called “population potential” index or later in Graham (2007) and other transportation-related studies as an “effective density” index.

Index selection with respect to industrial distribution must consider whether agglomeration should be confined to its own zone or the whole study area. For example, the specialization index used in Glaeser et al. (1992), Paci and Usai (1999), and Batisse (2002) considers agglomeration of the whole study area as a ratio between regional specialization and global specialization. On the other hand, the HHI and Gini index considered an agglomeration only in its own zone, since the share of industry is considered only within its own region. From these two concepts, I propose two indexes based on the coefficient of variation. The first case presents agglomeration only in its own zone:

$$CV_{A_i} = \frac{\sigma_{A_i}}{\mu_{A_i}} = \frac{\sqrt{\frac{1}{n} \sum_{k=1}^n (A_{i,k} - \mu_{A_i})^2}}{\frac{1}{n} \sum_{k=1}^n A_{i,k}}, \quad (2)$$

where CV_{A_i} represents the specialization or diversity agglomeration index of zone i in the first case, σ_{A_i} represents the standard deviation of agglomeration across every n industries in zone i , and μ_{A_i} represents the mean of agglomeration across every n industries in zone i . This index range displays a perfect diversified zone and perfect specialized zone from 0 to ∞ , where the perfect *diversified* zone means the agglomeration level of every industry is uniformly and equally distributed, and the perfect *specialized* zone means there is only one industry agglomerated in the zone.

In the second case, agglomeration of the whole study area is considered, and the coefficient of variation is determined by the local agglomeration concentration, in contrast to the first case. The local agglomeration concentration is determined by:

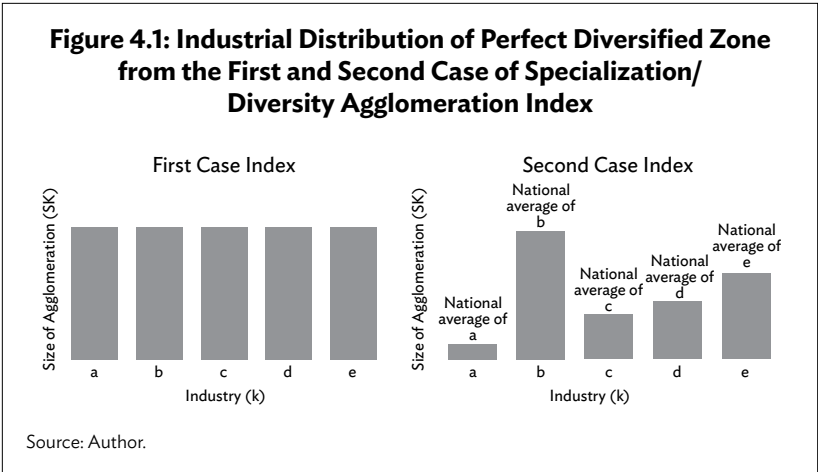
$$s_{i,k} = \frac{A_{i,k}}{\frac{1}{n} \sum_{k=1}^n A_{i,k}}, \quad (3)$$

where $s_{i,k}$ represents local agglomeration concentration of industry k in zone i , which is determined by the ratio of agglomeration of industry k in zone i to average agglomeration in zone i . The specialization or diversity agglomeration index in the second case is formulated as:

$$CV_{s_i} = \frac{\sigma_{s_i}}{\mu_{s_i}} = \frac{\sqrt{\frac{1}{n} \sum_{k=1}^n (s_{i,k} - \mu_{s_i})^2}}{\frac{1}{n} \sum_{k=1}^n s_{i,k}}, \quad (4)$$

where CV_{s_i} represents the specialization or diversity agglomeration index of zone i in the second case, σ_{s_i} represents the standard deviation of local share of agglomeration across every n industries in zone i , and μ_{s_i} represents the mean of local share of agglomeration across every n industries in zone i . This is the index range of a perfect diversified zone and perfect specialized zone from 0 to ∞ . However, in the second case, the perfect *diversified* zone is achieved if the distribution of industry in such a zone is equal to the global industrial distribution. The perfect *specialized* zone is the case where there is only one industry agglomerated in the zone, as seen in the first case.

Once again, it should be noted that proposed indexes are calculated from regional agglomeration with a spatial consideration. Therefore, it is unlikely to observe a drastic change in the specialization or diversity level across neighboring zones. Figure 4.1 shows the industrial distribution of five industries in the first and second cases where the zone is perfectly diversified.



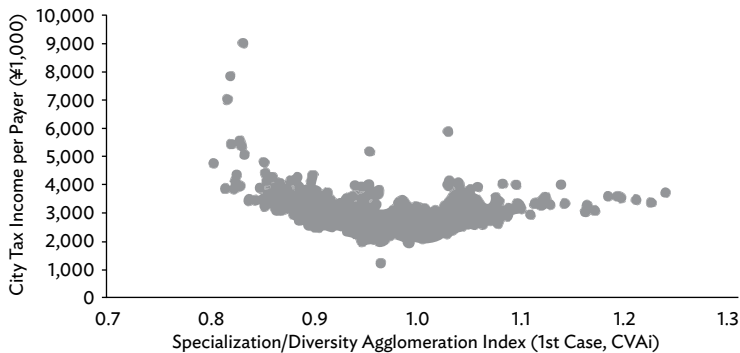
4.4 Specialization or Diversity Agglomeration and Local Productivity

Past studies tend to consider specialization and diversity in separate contexts. This separate framework could be logical from the perspective of small industry (e.g., in terms of employment). For example, in a region with a highly concentrated information technology (IT) industry, such region could be considered highly specialized in the IT industry. Still, the region maintains a high level of diversity because its share of IT employment is relatively low compared to industries such as manufacturing and other general services. However, from the perspective of large industry, this separate framework may not be effective since a high concentration of large industry always leads to lower diversity. In other words, depending on the size of agglomeration, a marginal increase of specialization of industry might lead to an increase or decrease in marginal diversity. Thus, it depends on how specialization and diversity are defined to best match the concepts of Marshall's and Jacobs' economies. In this study, I define "specialization" as a city's specialization, not industrial concentration, as defined in other studies. In other words, if the city has a high concentration of any industry, regardless of which industry, such city will be defined as a specialized city by my definition. Using this definition, it is possible to investigate specialization agglomeration and diversified agglomeration as opposing factors with the same index.

Here, I investigate the effect of specialization or diversity agglomeration on local productivity in a Japanese municipality (city). I measured the agglomeration level from the number of employees across 17 industrial categories from 1,907 Japanese municipalities and the Euclidian distance between the city hall of each municipality. Local productivity is measured by municipality corporate tax income per number of taxpayers. The cross-sectional data are based on the 2014 Economic Census for Business Frame from the Japanese Ministry of Economy, Trade and Industry. Figure 4.2 shows the relationship between specialization or diversity agglomeration indexes and local productivity in the first case, where only agglomeration in its own zone is considered.

Considering the relationship between the index and the productivity from the specialization or diversity agglomeration index, I found the U-shaped relationship in the first case index (Figure 4.2). By assuming that a uniform distribution of agglomeration size across industries is the perfect diversity case, the U-shaped relationship could be explained through both Marshall's economy and Jacobs' economy at the same time. Plots on the left half of Figure 4.2 could follow the explanation of Jacobs' economy, where cities with more diversity (although not perfectly diversified or $CV_{Ai} = 0$) have more opportunity to obtain the spillover effect from different businesses. Marshall's economy could explain the situation of cities in the plot on the right half of the figure, where the benefit from specialization agglomeration within a few industries

Figure 4.2: City Productivity and Its Specialization or Diversity Agglomeration Index (First Case)

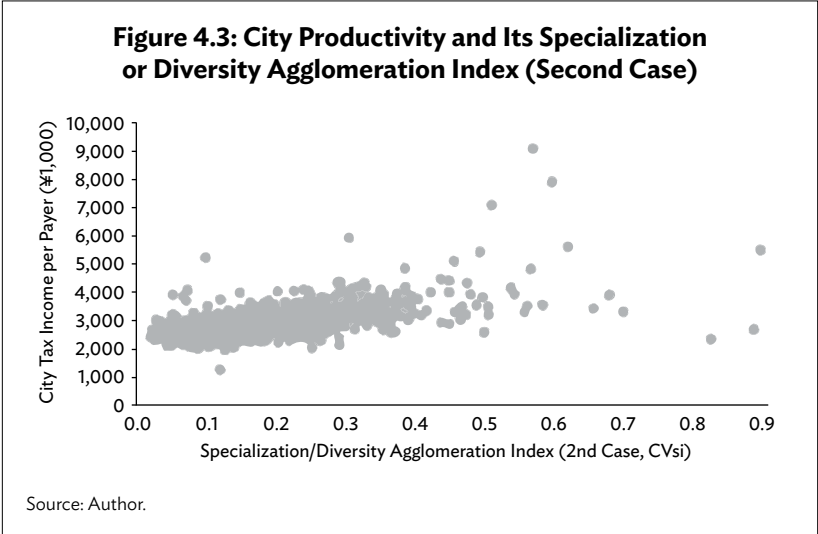


Source: Author.

becomes significant. However, cities situated along the middle of the plot are the losers; diversification of industry is not large enough nor is the specialization of any dominant industry strong enough to enjoy an agglomeration benefit. Therefore, according to this plot, the temporal shift of the level of specialization (CV_{A_p}) should be planned carefully. For example, if a city on the right half of the plot wishes to increase its productivity in the next 10 years, changing its industrial distribution to be more specialized (at least more than the average global trend in the next 10 years) should guarantee better productivity. Otherwise, it should implement aggressive plans to promote more diversity in the city in order to shift its position from the right half to the left half of the plot.

As for the second case, where agglomeration of the whole study area is considered, the relationship between specialization or diversity agglomeration indexes and local productivity is portrayed in Figure 4.3.

The relationship between the index and the productivity from the specialization or diversity agglomeration index is linear in the second case index (Figure 4.3). By assuming that the average national distribution of agglomeration size across industries is the perfect diversity case, the national average distribution could be interpreted as not productive. This could further explain why an uneven spatial concentration can be observed across the country as firms might avoid locating their industries where the industrial agglomeration distribution is close

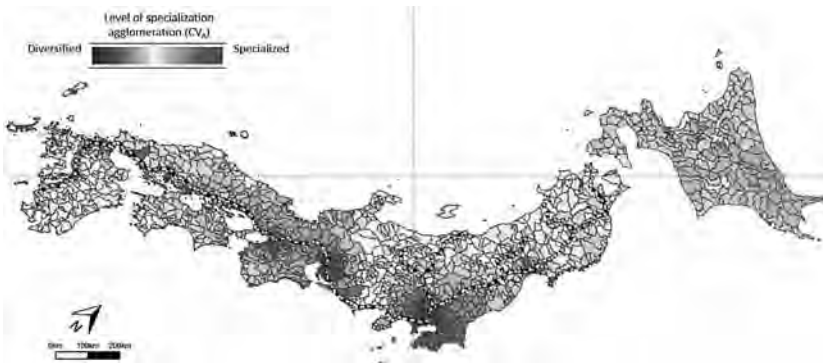


to the national average. Viewed with this index, as a city develops its specialization, it can enjoy more clustering benefit through the concept of Marshall's economy. However, the ideal concept of Jacobs' economy may not be explained by this index, as the average national distribution is not the ideal industrial distribution portrayed by Jacobs' economy. Therefore, if a city wishes to improve its productivity, it should try to avoid composing its industries along the lines of the national average. Since the index in the second case (CV_{s_i}) presents only a one-way relationship, going forward I focus on only the first index (CV_{A_i}) so that the dynamics of productivity with respect to both specialization and diversity can be discussed.

4.5 High-Speed Rail and Specialization or Diversity Agglomeration

In this section, I investigate the relationship between HSR and the level of specialization agglomeration in order to link the effect of HSR to productivity through specialization agglomeration. First, I present the discussion of the specialization or diversity situation and HSR in Japan. Then, I further analyze the effect of HSR and specialization agglomeration through regression analysis. CV_{A_i} used in both discussions are based on the data presented in earlier sections.

Figure 4.4: Specialization or Diversity (First Case) Agglomeration Index, 2014



Note: The lines and dots represent high-speed rail routes and stations in 2014.

Source: Author.

Several findings can be drawn from the plot of in the first case, at the Japanese municipality level (Figure 4.4). Comparing the east and the west regions, the west side tends to be more specialized than the east side, due in large part to the high industrial diversity in the Tokyo metropolitan area. To be precise, specialized industries with a lower share of workers, such as the finance and IT sectors, are concentrated in Tokyo. This makes our index more diversified, because the share of small industry is larger in Tokyo than other regions. It is also possible to say that Tokyo is a highly specialized area for such industries. However, the index used in this study defines specialization as applying to the whole economy, not any specific industry. This index also considers the neighboring effect, so regions close to Tokyo are highly affected by the neighboring agglomeration, especially when the agglomeration level in their own regions is significantly smaller. In addition to the distinction between west and east, the difference between regions located along HSR routes and those located farther away can be observed as well. The regions along HSR lines tend to be more specialized, with some exceptions. Nevertheless, more analysis is needed to explain the relationship between HSR and level of specialization agglomeration.

To better understand the relationship between HSR and level of specialization agglomeration, CV_{A_i} is applied as a dependent variable for regression analysis. Dependent variables consist of HSR-related variables and other socioeconomic variables. The general model specification can be defined as follows:

$$CV_{A_i} = f(\alpha(HSR), \gamma(\phi)), \quad (5)$$

where CV_{A_i} is the specialization/diversity index (first case), $\alpha(HSR)$ is the function of HSR-related variables, and $\gamma(\phi)$ is the function of other socioeconomic-related variables.

Here, the effect of HSR ($\alpha(HSR)$) is determined as a function of the distance from city i to the nearest HSR station. Furthermore, I assume the effect of HSR to specialization to be a quadratic function. This assumption is based on the three cases of trade cost proposed in Ottaviano, Tabuchi, and Thisse (2002). I also applied the technique of spatial lag and time lag to this estimation. The spatial lag term incorporates the effect of the specialization agglomeration level in neighboring cities weighted by distance. The time lag takes into consideration the level of specialization agglomeration in lagged years. In summary, the function to be estimated is structured as follows:

$$\begin{aligned}
CV_{Ai} = & \beta_0 + \beta_1 HSR_i + \beta_2 HSR_i^2 + \\
& + \beta_3 WCV_A + \beta_4 CV_{Ai,2012} + \beta_5 U_i + \beta_6 U_i^2 \cdot \\
& + \beta_7 DID_i + \beta_8 DID_i^2 + \beta_9 PD_i^2 + \beta_{10} OH_i + \\
& + \beta_{11} TW_i + \beta_{12} DC_i + \beta_{13} MF_i
\end{aligned} \tag{6}$$

where

- HSR_i = distance from city i to the nearest HSR station (in kilometers);
 WCV_A = matrix of product between reciprocal of distance between city i to other cities and specialization index of other cities in 2014;
 $CV_{Ai,2012}$ = specialization agglomeration of city i in 2012;
 U_i = unemployment rate in city i ;
 DID_i = percentage of densely inhabited districts of the prefecture in which city i is located;
 PD_i = population density of city i (in persons per square kilometer);
 OH_i = rate of owned house in city i ;
 TW_i = percentage of workers in the tertiary industry in city i ;
 DC_i = designated city dummy, equals 1 if city i is a designated city, 0 if not; and
 MF_i = male-to-female population ratio in city i .

Table 4.2 shows the estimation results based on equation 6. The estimate of HSR parameters shows a positive value in β_1 and a negative value in β_2 . In other words, the parabolic curve follows an inverse U-shape if the distance to the HSR station is plotted on the x-axis and the specialization index is plotted on the y-axis. Based on this relationship, the interpretation of the results can give rise to three cases. First, cities along the HSR lines receive an agglomeration benefit, which is strengthened by HSR. This agglomeration benefit attracts firms from other regions to relocate in order to enjoy that benefit. Thus, cities along HSR lines tend to be more diversified, because various types of businesses relocate to them. Second, cities located farther away from HSR lines (those on the apex of the inverse U-shaped curve, according to the estimation, located approximately 270 kilometers away) tend to be more specialized, because many businesses relocated to cities along HSR lines; only the type of businesses that did not benefit from the agglomeration remains in the city. This industry eventually becomes the dominant industry, which

Table 4.2: Estimation Results

	Estimates	Standard error	t-statistic	p-value
Constant	-0.9747	0.0028	-343.735	0.000
<i>HSR</i>	2.16E-05	4.48E-06	4.814	0.000
<i>HSR</i> ²	-3.94E-08	7.59E-09	-5.194	0.000
<i>WCVA</i>	0.9979	0.0015	673.697	0.000
<i>CV</i> _{A2012}	0.9894	0.0033	300.525	0.000
<i>U</i>	0.0155	0.0023	6.621	0.000
<i>U</i> ²	-0.0017	0.0003	-5.113	0.000
<i>DID</i>	4.11E-04	8.08E-05	5.085	0.000
<i>DID</i> ²	-4.26E-06	6.53E-07	-6.523	0.000
<i>PD</i> ²	-73.9864	6.8397	-10.817	0.000
<i>OH</i>	-1.76E-06	1.64E-07	-10.740	0.000
<i>TW</i>	-7.73E-05	2.12E-05	-3.649	0.000
<i>DC</i>	0.0060	0.0009	6.435	0.000
<i>MF</i>	-2.87E-04	3.02E-05	-9.519	0.000
<i>R</i> ²				0.9913

Note: For an explanation of the variables, see equation 6.

Source: Author's calculations.

causes the city to be more specialized. Third, in cases where cities are located very far from HSR lines (according to the estimation, those located approximately 540 kilometers away), firms may decide not to relocate because the agglomeration benefit could be smaller than the trade cost. If firms relocate, the premium from agglomeration could be less than the cost to transport their products from a city along an HSR line to a city very far from an HSR line. Thus, it would be better to produce and sell in the same area. This situation causes cities that are very far from HSR lines to diversify because they do not relocate. In our dataset, however, the level of diversity in these regions is still smaller in comparison to regions along HSR lines.

4.6 Conclusion

The analysis in this chapter aims to answer two questions related to specialization agglomeration: How does industrial specialization agglomeration affect a city's productivity? And how does HSR affect

industrial specialization agglomeration? The answers to these questions can be drawn from the analyses in this study as follows:

- Specialization agglomeration benefits productivity. Diversity agglomeration also benefits productivity. The loser in this productivity competition is cities whose industrial diversification is not large enough or whose specialization in any dominant industry is not strong enough to enjoy the agglomeration benefit.
- The introduction of HSR could shape the spatial distribution of specialization agglomeration into the cases where a city is diversified, or specialized, depending on the distance to HSR services.

The concept of specialization agglomeration is quite straightforward; a single dominant industry leads to more agglomeration benefit. However, the concept of diversity agglomeration is still unclear. What is the best combination of industry to maximize the diversity agglomeration as defined in Jacobs' economy? This study only assumed two types of perfect diversity agglomeration: uniform distribution and national average distribution. This study proves that the national average distribution is not the ideal diversity agglomeration. However, it remains unclear whether or not the uniform distribution is the best answer for diversity agglomeration. Further analysis and discussion are needed. I suggest that the distribution of the agglomeration (specialization or diversity) and the concept of the size of the agglomeration (localization or urbanization) be employed together to identify the best industrial combination to achieve Jacobs' agglomeration.

This empirical result from Japan could be one piece of evidence of how HSR shapes the new spatial distribution of industrial agglomeration. For countries wishing to introduce HSR services, a possible policy implication is for cities to prepare for a change in industrial distribution, transforming into a diversified or specialized city, according to the new HSR service. The case of Japan is advantageous because there is very little intervention from government policy, and changes in industrial distribution are supervised mainly by the private sector. However, central and local governments could signal a change in industrial distribution to best capture the agglomeration benefit along with HSR investment. Thus, this result could serve as a reference for the public sector to guide the private sector in the best direction.

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5

Modeling the Spatiotemporal Urban Spillover Effect of Infrastructure Development

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5.1 Introduction

5.1.1 Background

High-speed rail (HSR) development stimulates the local and regional economy mainly due to the large-scale development project itself and the connectivity to other markets (Albalade and Bel 2012). This is especially notable in the People's Republic of China (PRC) with the rapid growth of the national economy (Yin, Bertolini, and Duan 2015). Still, one of the major challenges of HSR projects is the high cost of the infrastructure development (Nakamura et al. 2019). Typically, regional governments cover the construction cost, as they will benefit from residential or corporate income tax and the increase in tourist inflow. Infrastructure development such as an HSR project creates a spillover effect on incremental tax revenues, improving the performance of private investors (ADBI 2018; Seetha Ram and Bharule 2019).

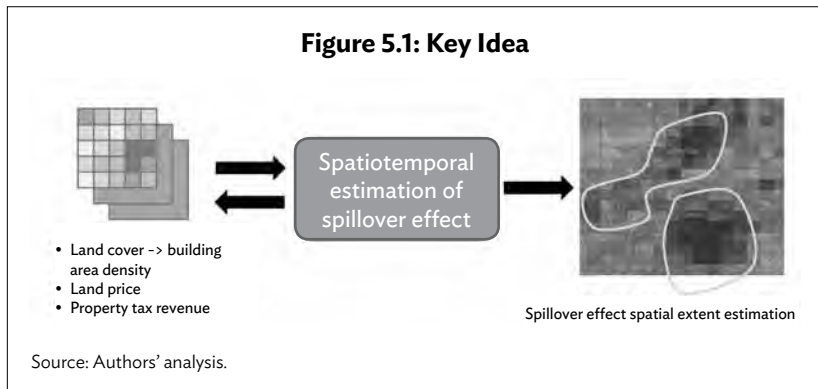
This study introduces and applies the concept of spillover effects to HSR development to formulate the economic impact on increasing regional tax revenue (Yoshino and Abidhadjaev 2017). It covers the development of the Kyushu *Shinkansen* (Kagoshima Route) in the Kyushu region in Japan. Construction started in 1991; operation commenced in 2004 and reached full operational capability in 2011. According to our study, the regional tax revenue increased especially during the construction period and after the line became fully operational.

In addition, to ensure a long-term positive effect on the economy, planning interventions are needed to assure quality-of-life improvement,

such as safety and amenities in station areas for greater transit ridership (Nakamura et al. 2017). This is partially observable in the spatiotemporal change in the land cover and land price, eventually also improving the local property tax revenue. Several studies have investigated the effect of HSR on land values (Chen and Haynes 2015; Kanasugi and Ushijima 2017); incorporating the land cover change and property tax revenue is also important to understand the more comprehensive state of land development along HSR.

5.1.2 Key Idea

Figure 5.1 summarizes the key idea of this work. Our target case is the Kyushu *Shinkansen*, which the Kyushu Railway Company (JR-Kyushu) has developed. This study aims to extend the idea to spatiotemporal modeling by developing a spillover effect extent estimation model. Our goal is to propose a new policy framework for boosting investment in infrastructure by tapping the spatial spillover effect on local development and the land market.



This work has the following key characteristics that make it unique compared with previous research.

- Spatial extension of the spillover effect: this study extends the concept of the spillover effect to urban development and the land market to investigate how the effects of the development of the railway propagate spatially.

Also note that this work has the following limitations.

- The statistical evaluation is conducted only on the municipality scale instead of using grid-based modeling, which would require more extensive data processing.
- The study conducts property tax revenue estimation on the municipality level.

The rest of this chapter is organized as follows. Section 5.2 summarizes the related work. Section 5.3 introduces the data, and section 5.4 describes the method. In Section 5.5, we present the results and discuss the implications, and finally section 5.6 concludes the chapter.

5.2 Related Work

5.2.1 Accessibility

One of the most studied effects of HSR is the impact on regional accessibility. Cao et al. (2013) investigated the accessibility impacts of planned HSR in the PRC by comparing it with other transportation modes. Zhao and Yu (2018) expanded the idea and conducted door-to-door accessibility studies on a proposed HSR route.

5.2.2 Local Economy

Another prominent area of study is the evaluation of the impact on the local economy. In addition to the aforementioned studies on regional tax revenue (Yoshino and Abidhadjaev 2017), there are studies on industrial location (Han et al. 2012), regional productivity (Wetwitoo and Kato 2017), property prices (Andersson, Shyr, and Fu 2010), and urban area expansion (Long, Zheng, and Song 2018). In particular, Hernández and Jiménez (2014) incorporated spatial analysis into the difference-in-difference method in Spain by using a multiple distance buffer for the empirical analysis, arguing that the growth in public revenues and the fiscal gap are most significant in municipalities located within a 5-kilometer (km) radius of HSR stations. For the potential impact of an HSR project on the land market, Kanasugi and Ushijima (2017) investigated the change in the balanced panel data of the land price.

5.2.3 Geospatial Data Processing

For the spatiotemporal modeling of the spillover effect, geospatial data are an essential input. Several related studies have adopted these data.

For example, studies have usually created land use classification data from earth observation data, such as satellite imagery. Some studies have combined satellite imagery and auxiliary data to improve land use classifications (Seto and Kaufmann 2003; Hu and Wang 2013). They can then use the land use and cover classification data for several urban planning studies, including urban expansion (Long, Zheng, and Song 2018) and socioeconomic trends (Proville, Zavala-Araiza, and Wagner 2017). Panel survey data with geospatial attributes are also useful for spatial analysis and modeling. Land price panel data and property trade data are typical examples that studies have widely adopted for modeling spatiotemporal economic impacts (Kanasugi and Ushijima 2017).

5.3 Data

5.3.1 Infrastructure Development Timeline

The railway construction of the Kyushu *Shinkansen* started in 1991. The southern part (from Shin-Yatsushiro Station to Kagoshima-chuo Station) commenced operation in 2004. The northern part (from Hakata Station to Shin-Yatsushiro Station) began operation in 2011, connecting the whole line to the existing Sanyo *Shinkansen*. We adopt the time frame from Yoshino and Abidhadjaev (2017) and adjust it slightly due to the limited availability of data (Table 5.1).

Table 5.1: Time Frame for the Study

Period	Construction (and Operation I)			
	Preconstruction	Operation I	Operation I	Operation II
Years	1982–1990	1991–2003	2004–2010	2011–2013
Land cover change (from–to)	1987–1991	1991–2006	2006–2009	2009–2014
Land price change (from–to)	1987–1991	1991–2006	2006–2009	2009–2014
Tax revenue change (from–to)	1989–1991	1991–2006	2006–2009	2009–2014

Source: Authors' analysis.

5.3.2 Land Cover

We assume that different land uses influence the economic impact on the area. We downloaded the land use class data from the National Land Numerical Download service¹ of the National Land Information Division, National Spatial Planning and Regional Policy Bureau, Japan.

The bureau has produced these data every few years (1976, 1987, 1991, 1997, 2006, 2009, and 2014) using multiple satellite images for each year. It is a 1-km grid-based dataset in which each grid contains the area values (in square meters) of different land cover classes (Figure 5.2 and Table 5.2) based on manual classification.

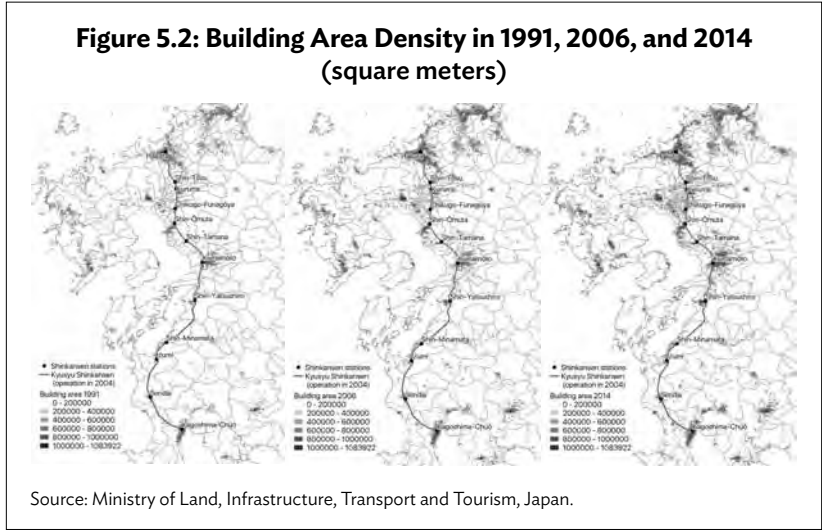


Table 5.2: Land Cover Classes

Code	Corresponding Details
1	Paddy Fields
2	Other Agricultural Land
5	Forest
6	Wasteland

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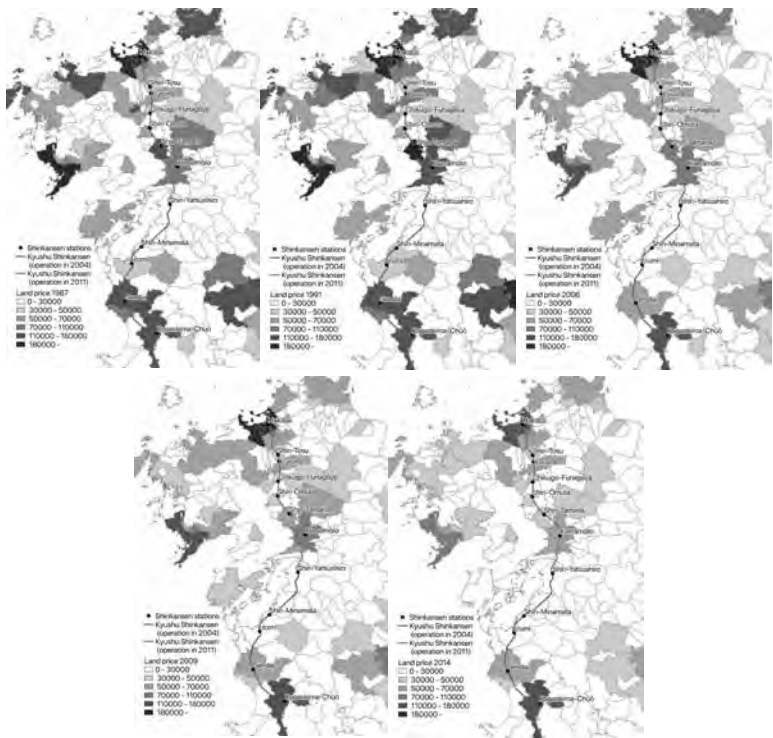
¹ Available at <http://nlftp.mlit.go.jp/ksj-e/index.html>

Table 5.2 continued

Code	Corresponding Details
7	Land for Building
9	Trunk Transportation Land
A	Other Land
B	Rivers and Lakes
E	Beach
F	Body of Seawater
G	Golf Course

Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan.

Figure 5.3: Average Land Price in Each Municipality, 1987, 1991, 2006, 2009, and 2014 (¥ per square meter)



Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan.

5.3.3 Land Price

As a proxy for property tax revenue, we use the publication of land price data, also from the National Land Numerical Download service. This is the annual sample panel data from the national government to regulate the property value and resulting property tax revenue for municipalities. Each year, there are new or discontinued points for the panel data. However, we only use the points available in the 2014 data and the historical values for the points (Figure 5.3).

5.3.4 Property Tax Revenue

We use the annual reporting of the property tax “settlement” revenue data of municipalities from e-Stat.² The settlement revenue represents the ideal value of the revenue, which excludes any delinquency or overdue payment from the previous year. Some municipalities have merged with neighboring municipalities over the years. To aggregate the tax revenues of those merged municipalities, we use the administration boundary in 2014 and perform a spatial join to summarize the revenues for the merged municipalities (Figure 5.4).

² Available at <https://www.e-stat.go.jp/en>.

where t_1 and t_2 are the start and end years, respectively. After each aggregation, we calculate the CAGR from the aggregated values.

5.4.2 Aggregation to the Municipality Boundary

To show the broad spatial trend, we aggregate the building density, land price, and property tax revenue with respect to the municipality boundary. In 1987, there were 520 (including different “wards”) municipalities in the Kyushu region; following several mergers, there are 249 municipalities as of 2014.

5.4.3 Aggregation to the Station Buffer

Then, we conduct a buffer analysis on the areas around each station to compare the trend of station areas. To start, we create buffers around each station and aggregate the values that intersect with the buffer. By comparing the trends, we can identify the characteristics of each station area.

5.4.4 Difference-in-Difference Estimation Model

To evaluate the statistical significance of the spillover, we employ the difference-in-difference (DID) method (Card and Krueger 1994). Under the parallel trend assumption, DID estimates the effect of a policy (i.e., the introduction of HSR).

We can formalize the model as follows:

$$Y_{it} = \beta_0 + \beta_1 c_i + \beta_2 t_t + \beta_3 DID_{it} + \theta \delta_{it} + \varepsilon_{it} \quad (2)$$

where

- Y_{it} = the dependent variable in region i in year t ;
- c_i = the treatment effect: 0 if i belongs to the control group and 1 if i belongs to the treatment group;
- t_t = the time effect: 0 if t is before the policy introduction and 1 if t is after the policy introduction;
- DID_{it} = the DID effect, which equals ;
- δ_{it} = a vector of control variables in region i in time t ;
- β, θ = unknown coefficients; and
- ε_{it} = error component.

We estimate the parameters using the ordinary least squares (OLS) method. The estimated coefficients (β, θ) indicate the effect of DID on the control variables in the model.

In this chapter, we analyze the effect of the introduction of HSR in the Kyushu region on the property tax revenue per area (in yen per square meter, ¥/m²) of each municipality. We also use the aforementioned building area density and land price values as the control variables.

The empirical model is as follows:

$$Y_{it} = \beta_0 + \beta_1 c_i + \beta_2 t_t + \beta_3 DID_{it} + \theta_1 BA_{it} + \theta_2 LP_{it} + \varepsilon_{it} \quad (3)$$

where

- Y_{it} = the ln tax revenue in municipality i in year t ;
- c_i = the treatment effect: 0 if i belongs to the control group and 1 if i belongs to the treatment group;
- t_t = the time effect: 0 if t is the beginning of the period and 1 if t is the end of the period in the time frame (Table 1);
- DID_{it} = the DID effect, which equals ;
- BA_{it} = the ln building area density of municipality i in year t ;
- LP_{it} = the ln average land price of municipality i in year t ;

Among 232 target municipalities, we select the treatment group based on the distance from Kyushu HSR stations, *DistHSR*. We experimentally set *DistHSR* = 5 km first. We label the municipalities located within the distance from Kyushu HSR stations as the treatment group and the other municipalities as the control group. The treatment group has several subgroups to investigate the spillover effect on particular stations (Table 5.3). For all of the treatment groups, the control group only includes municipalities other than those in treatment group 1.

Table 5.3: Treatment Groups

Name	Description	Included Stations
Treatment group 1	All Kyushu high-speed rail stations	Hakata, Shin-Tosu, Kurume, Chikugo-Funagoya, Shin-Omuta, Shin-Tamana, Kumamoto, Shin-Yatsushiro, Shin-Minamata, Izumi, and Kagoshima-Chuo
Treatment group 2	Non-terminal stations	Shin-Tosu, Kurume, Chikugo-Funagoya, Shin-Omuta, Shin-Tamana, Shin-Yatsushiro, Shin-Minamata, and Izumi
Treatment group 3	Southern part (operational in 2004)	Kumamoto, Shin-Yatsushiro, Shin-Minamata, Izumi, and Kagoshima-Chuo
Treatment group 4	Northern part (operational in 2011)	Hakata, Shin-Tosu, Kurume, Chikugo-Funagoya, Shin-Omuta, Shin-Tamana, and Kumamoto

Source: Authors' analysis.

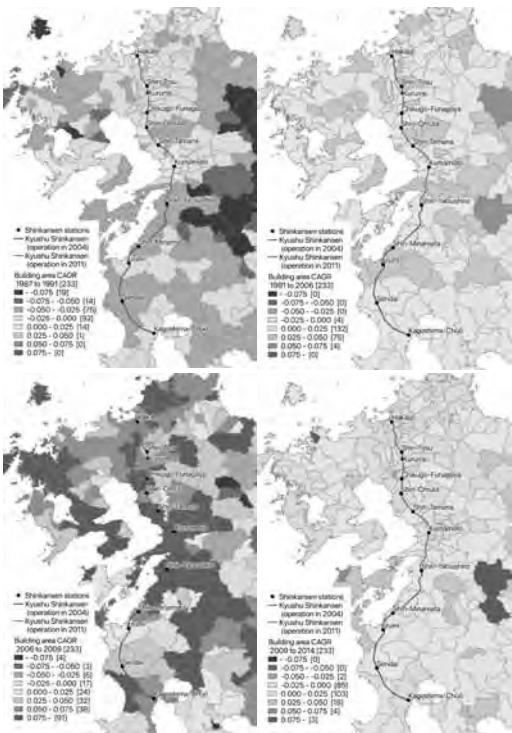
5.5 Results

5.5.1 Aggregation to the Municipality Boundary

Building Area

Figure 5.5 shows the CAGR of the building area density in each phase. During the preconstruction phase, only small parts of the Kyushu region experienced positive building area growth (e.g., Fukuoka and Kumamoto). During the construction and operation I phases, a larger area experienced significant growth. After the connection of the Kyushu *Shinkansen* to larger cities, the growth around the southern part of Kyushu stayed positive. Note that, since the land cover classification

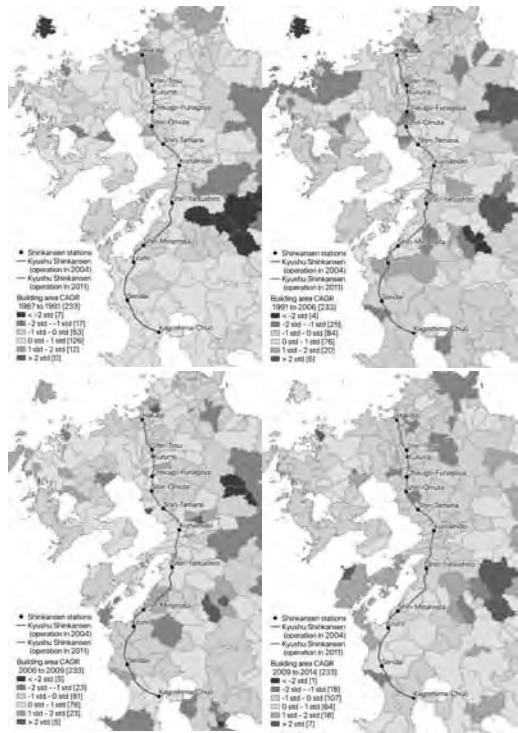
Figure 5.5: Compound Annual Growth Rate of the Building Area, 1987–2014



CAGR = compound annual growth rate.
Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan.

involves different datasets for each year, the overall trend of the CAGR from the data might not reflect the actual change in the building area. For example, as the resolution of satellite imagery increases, physical structures become clearer, making the classification more precise. This could result in both increasing and decreasing the total area depending on the surroundings. Conversely, as Figure 5.6 shows, the classification of the CAGR based on the mean and standard deviation values highlights the spatial difference. During the preconstruction phase, the CAGR of the building area around the rail was significantly higher than the average of the region. In addition, in the following phases, the CAGR of the building area around smaller stations, such as Shin-Tosu and Shin-Tamana, was significantly higher than the average.

Figure 5.6: Compound Annual Growth Rate of the Building Area Classified Based on the Mean and Standard Deviation, 1987–2014

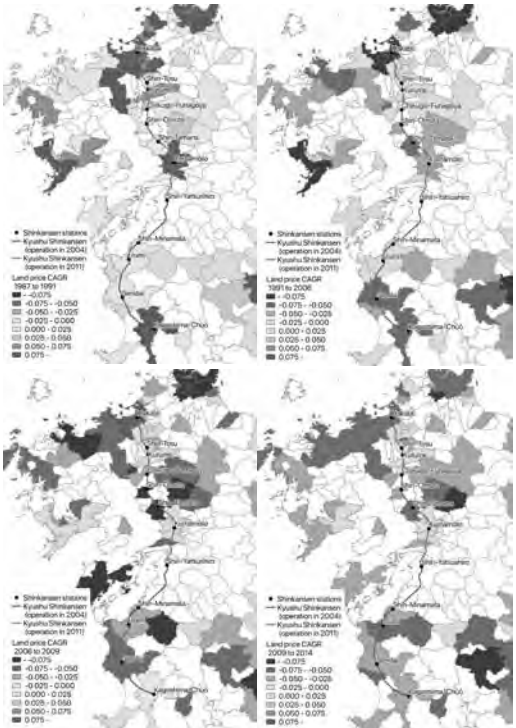


CAGR = compound annual growth rate.
Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan.

Land Price

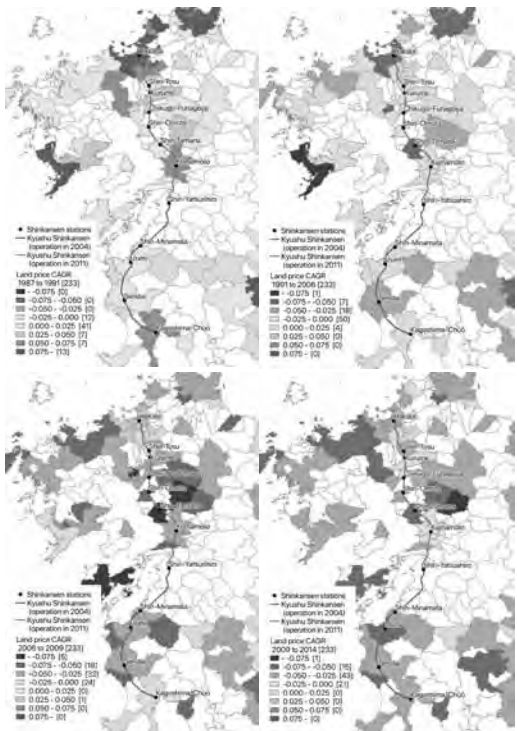
Figures 5.7 and 5.8 show the CAGR of the land price in each phase. The overall trend is positive in the preconstruction phase and negative in the following phases. The differences in the aggregation based on the mean value in each municipality (Figure 5.7) and the maximum value (Figure 5.8) are trivial. Large cities (Fukuoka, Kumamoto, and Kagoshima) tend to have a more positive trend than the rest of the region.

Figure 5.7: Compound Annual Growth Rate of the Land Price (Maximum), 1987–2014



CAGR = compound annual growth rate.
Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan.

Figure 5.8: Compound Annual Growth Rate of the Land Price (Average), 1987–2014

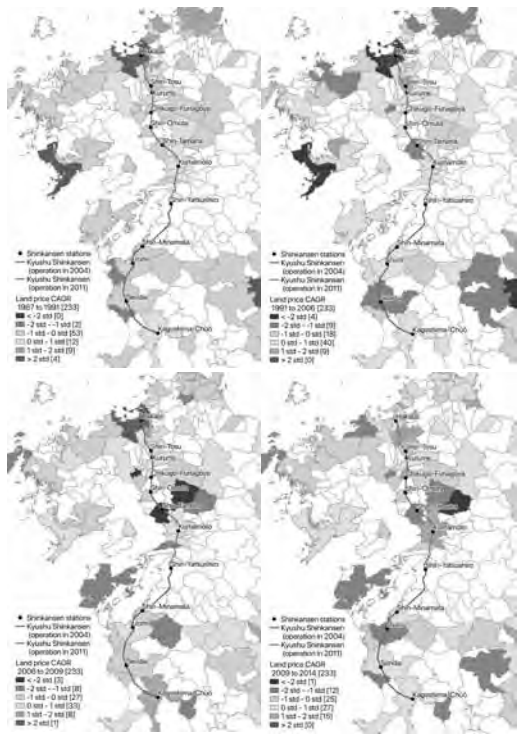


CAGR = compound annual growth rate.

Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan.

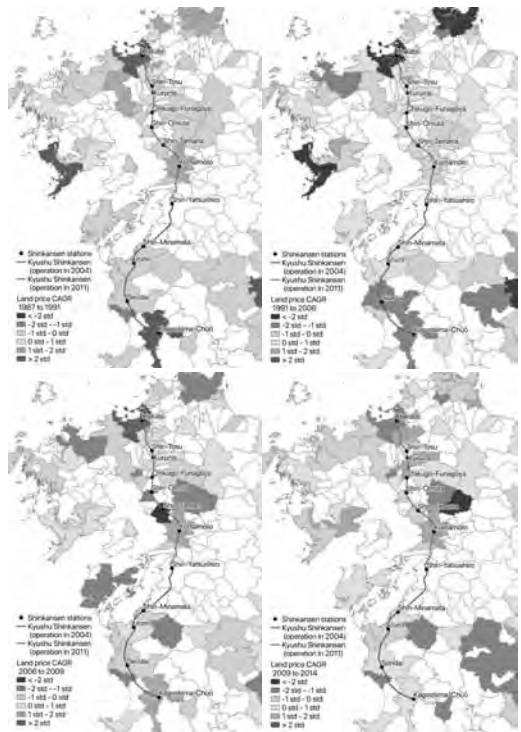
Figures 5.9 and 5.10 show the classification CAGR based on the mean and the standard deviation. Here, the figures show that the growth in smaller cities around the Kyushu *Shinkansen* was more positive than that in some larger cities during the construction and the following phases. This suggests that the construction and operation of the HSR may have stimulated investment in the land market of those smaller cities.

Figure 5.9: Compound Annual Growth Rate of the Land Price (Mean) Classified Based on the Mean and Standard Deviation, 1987–2014



CAGR = compound annual growth rate.
Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan.

Figure 5.10: Compound Annual Growth Rate of the Land Price (Maximum) Classified Based on the Mean and Standard Deviation, 1987–2014



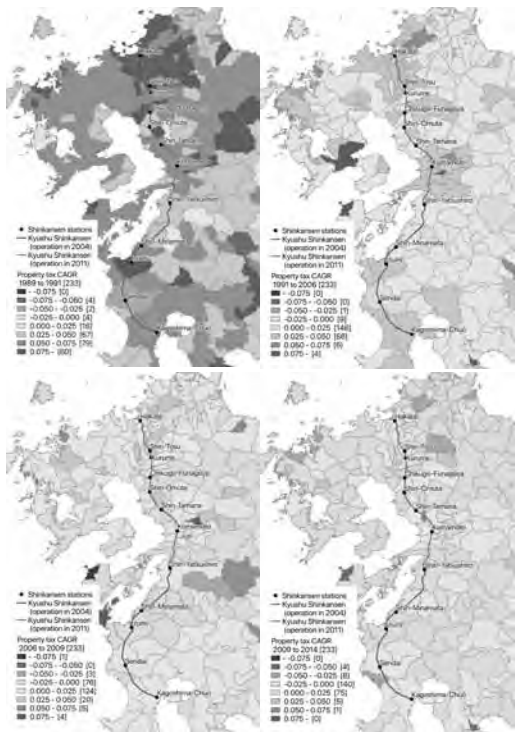
CAGR = compound annual growth rate.

Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan.

5.5.1.3 Property Tax

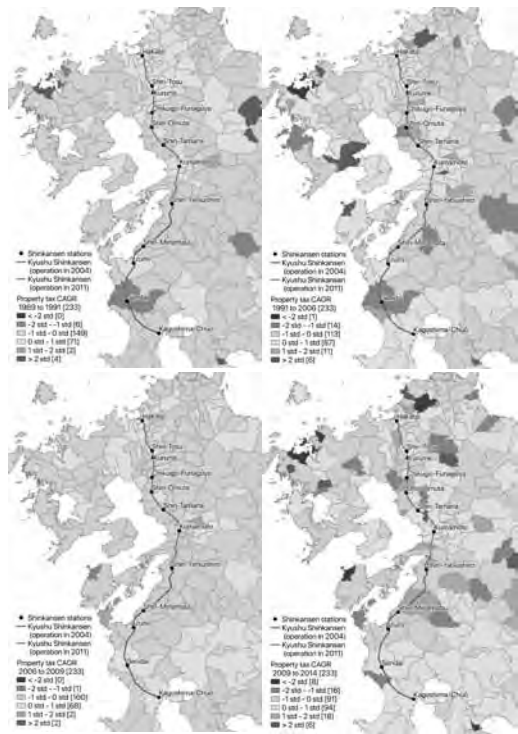
Figures 5.11 and 5.12 show the CAGR of property tax and its classification based on the mean and the standard deviation value, respectively. The overall trend is the transition from positive growth to negative growth, although some of the municipalities have maintained positive growth in recent phases. One notable feature is that, during the construction phase, most of the municipalities with the highest growth rates are those around the Kyushu *Shinkansen*. This significant development is observable in the same phase in Figure 5.5, while the negative trend apparent in Figure 5.7 may have contributed significantly to the positive growth in total.

Figure 5.11: Compound Annual Growth Rate of Property Tax, 1989–2014



CAGR = compound annual growth rate.
Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan.

Figure 5.12: Compound Annual Growth Rate of Property Tax Classified Based on the Mean and Standard Deviation, 1989–2014



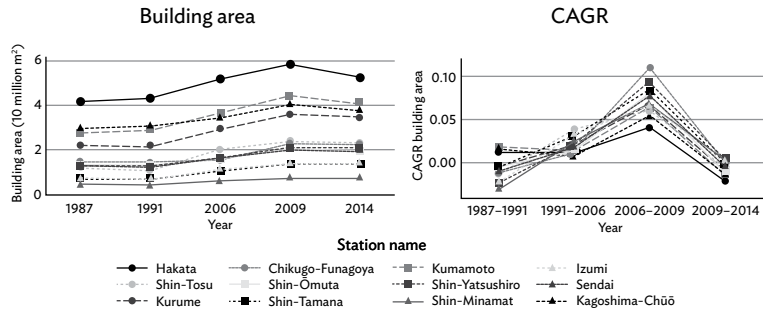
CAGR = compound annual growth rate.

Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan.

5.5.2 Station Buffer Analysis

Figure 5.13 shows the aggregated building area and the CAGR of the building area within 5 km around each station. Large stations, such as Hakata, Kumamoto, and Kagoshima-Chuo, have a bigger building area than other stations throughout the time period; however, the CAGR around most smaller stations (e.g., Shin-Tosu) surpassed that of the large stations during the construction phase (1992–2006) and remained higher after the operation phase.

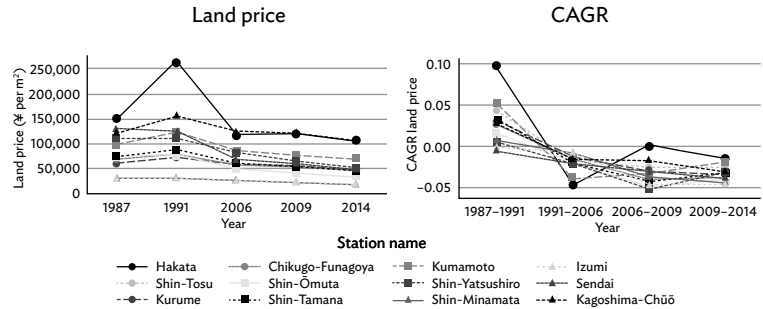
Figure 5.13: Aggregated Building Area and the Compound Annual Growth Rate of the Building Area within 5 Kilometers around Each Station



CAGR = compound annual growth rate.
Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan.

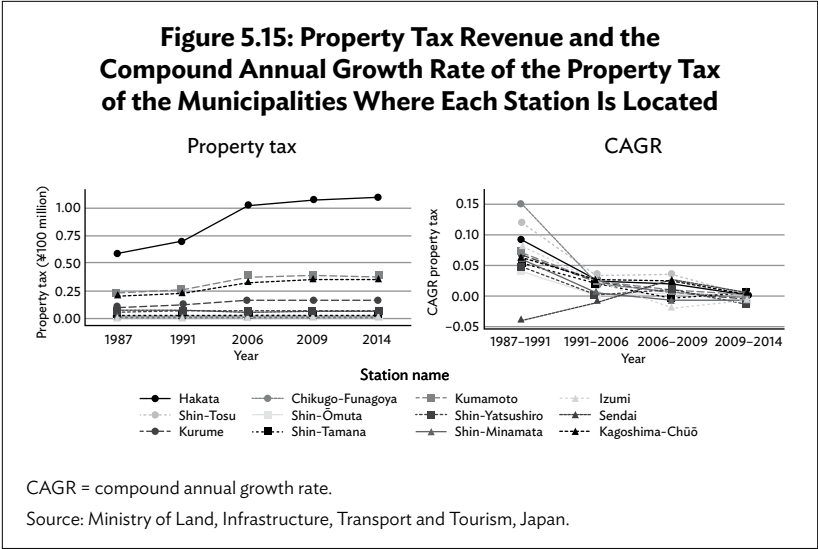
Figure 5.14 shows the aggregated land price and the CAGR of the land price within 20 km around each station. We chose 20 km as the buffer size to ensure that the buffers cover all the HSR stations. Here too the overall growth trend became negative; large cities, such as Hakata and Kumamoto, experienced a sharp dip during construction, but the long-term growth was better than that of other cities.

Figure 5.14: Aggregated Land Price and the Compound Annual Growth Rate of the Land Price within 20 Kilometers around Each Station



CAGR = compound annual growth rate.
Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan.

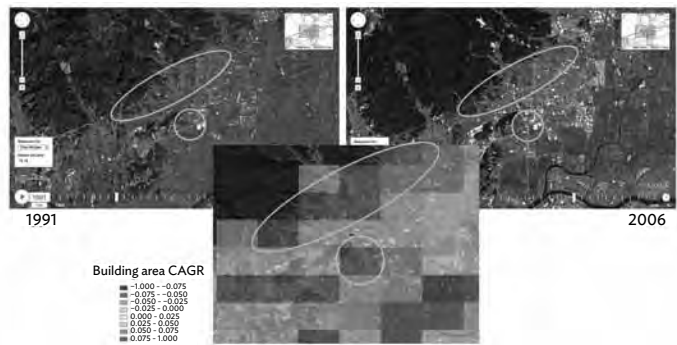
Figure 5.15 shows the property tax revenue and the CAGR of the property tax of the municipalities where the stations are located. Interestingly, the CAGR of the property tax revenue during the preconstruction phase varied significantly (mostly positive) but became very similar over time. From this result, it is hard to identify the biggest beneficiaries among the stations.



Figures 5.16 and 5.17 show the building area CAGR in a 1-km grid and historical satellite imagery from Google Earth Engine Time Lapse.³ The white oval shapes indicate the same locations. Some significant development can be observed in areas with a high building area CAGR during the period. It suggests the potential validity of the method, even though more extensive statistical modeling would be necessary for a comprehensive evaluation.

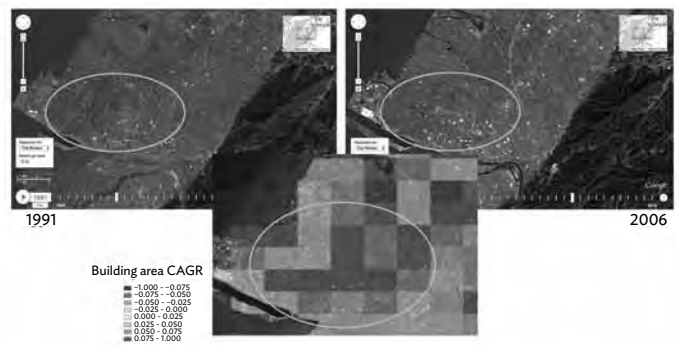
³ Available at <https://earthengine.google.com/timelapse/>

Figure 5.16: Building Area Compound Annual Growth Rate around Shin-Tosu Station, 1991 and 2006



CAGR = compound annual growth rate.
Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan.

Figure 5.17: Building Area Compound Annual Growth Rate around Shin-Yatsushiro Station, 1991 and 2006



CAGR = compound annual growth rate.
Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan.

5.5.3 Difference-in-Difference Estimation Model

Tables 5.4–5.7 summarize the result of the DID model. The correlation with BA_{it} and LP_{it} is less than 0.5 for all the models. Overall, the adjusted R^2 is consistently high, with high significance of the building area and land price values for all the groups. Still, the DID effect is not significant in any model. We also test different distances from Kyushu HSR stations $DistHSR$ from 5 km to 50 km, but the statistical significance of the DID effect never changes. This implies that the spillover effect that the previous analyses suggest is not statistically significant in the whole Kyushu region or is an even smaller-scale effect than the municipality scale (Figures 5.16 and 5.17).

Table 5.4: Estimation Results of the DID Model for Treatment Group 1

Period	Preconstruction			Construction		
	Estimate	t-stat.	Sig.	Estimate	t-stat.	Sig.
Const.	-3.070	-7.963	***	-3.064	-7.510	***
c	0.096	1.695	*	0.075	1.385	
t	0.187	2.518	**	0.056	0.763	
DID	-0.018	-0.241		-0.029	-0.386	
BA	1.246	28.401	***	1.251	30.402	***
LP	0.167	5.805	***	0.183	6.026	***
Adj. R^2		0.889			0.905	
N			156			
Period	Operation I			Operation II		
	Estimate	t-stat.	Sig.	Estimate	t-stat.	Sig.
Const.	-3.642	-8.889	***	-4.077	-10.767	***
c	0.039	0.808		0.037	0.834	
t	-0.203	-3.220	**	0.022	0.373	
DID	0.000	0.006		0.013	0.219	
BA	1.263	35.338	***	1.264	37.609	***
LP	0.243	7.347	***	0.264	8.498	***
Adj. R^2		0.928			0.938	
N			156			

BA = building area, DID = difference-in-difference, LP = land price.

Note: ***: $p < 0.001$; **: $p < 0.01$; *: $p < 0.05$.

Source: Authors.

**Table 5.5: Estimation Results of the DID Model
for Treatment Group 2**

Period	Preconstruction			Construction		
	Estimate	t-stat.	Sig.	Estimate	t-stat.	Sig.
Const.	-3.032	-7.833	***	-3.034	-7.391	***
c	0.083	1.290		0.078	1.276	
t	0.181	2.454	*	0.065	0.873	
DID	-0.004	-0.056		-0.063	-0.743	
BA	1.259	0.043	***	1.262	31.503	***
LP	0.167	5.771	***	0.1835	5.985	***
Adj. R ²		0.888			0.904	
N			144			
Period	Operation I			Operation II		
	Estimate	t-stat.	Sig.	Estimate	t-stat.	Sig.
Const.	-3.599	-8.692	***	-4.053	-10.566	***
c	0.014	0.251		0.021	0.422	
t	-0.208	-3.320	***	0.025	0.665	
DID	0.007	0.096		0.007	0.104	
BA	1.273	36.40	***	1.273	38.562	***
LP	0.242	7.254	***	0.265	8.420	***
Adj. R ²		0.927			0.937	
N			144			

BA = building area, DID = difference-in-difference, LP = land price.

Note: ***: p < 0.001; **: p < 0.01; *: p < 0.05.

Source: Authors.

**Table 5.6: Estimation Results of the DID Model
for Treatment Group 3**

Period	Preconstruction			Construction		
	Estimate	t-stat.	Sig.	Estimate	t-stat.	Sig.
Const.	-2.940	-6.639	***	-2.968	-6.308	***
c	0.283	1.441		0.229	1.204	
t	0.189	2.446		0.053	0.675	
DID	-0.048	-0.174		-0.148	-0.551	

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Table 5.6 *continued*

Period	Preconstruction			Construction		
	Estimate	t-stat.	Sig.	Estimate	t-stat.	Sig.
BA	1.256	24.291	***	1.250	25.716	***
LP	0.157	4.865	***	0.175	5.058	***
Adj. R ²		0.862			0.880	
N			130			
Period	Operation I			Operation II		
	Estimate	t-stat.	Sig.	Estimate	t-stat.	Sig.
Const.	-3.470	-7.404	***	-3.832	-9.023	***
c	0.065	0.395		0.096	0.648	
t	-0.205	-3.132	**	0.017	0.296	
DID	0.037	0.160		-0.005	-0.025	
BA	1.262	30.281	***	1.270	33.260	***
LP	0.227	6.071	***	0.243	7.042	***
Adj. R ²		0.911			0.928	
N			130			

BA = building area, DID = difference-in-difference, LP = land price.

Note: ***: $p < 0.001$; **: $p < 0.01$; *: $p < 0.05$.

Source: Authors.

Table 5.7: Estimation Results of the DID Model for Treatment Group 4

Period	Preconstruction			Construction		
	Estimate	t-stat.	Sig.	Estimate	t-stat.	Sig.
Const.	-3.060	-7.532	***	-3.127	-7.276	***
c	0.143	1.102		0.112	0.894	
t	0.188	2.514	*	0.058	0.771	
DID	-0.040	-0.235		-0.016	-0.096	
BA	1.267	26.738	***	1.258	28.405	***
LP	0.170	5.676	***	0.190	5.978	***
Adj. R ²		0.891			0.906	
N			148			

continued on next page

Table 5.7 *continued*

Period	Operation I			Operation II		
	Estimate	t-stat.	Sig.	Estimate	t-stat.	Sig.
Const.	-3.733	-8.596	***	-4.157	-10.313	***
c	0.084	0.766		0.061	0.601	
t	-0.202	-3.163	**	0.023	0.394	
DID	-0.017	-0.118		0.037	0.277	
BA	1.263	32.691	***	1.265	34.731	***
LP	0.251	7.187	***	0.272	8.236	***
Adj. R ²		0.928			0.938	
N			148			

BA = building area, DID = difference-in-difference, LP = land price.

Note: ***: $p < 0.001$; **: $p < 0.01$; *: $p < 0.05$.

Source: Authors.

5.6 Conclusion

In this chapter, we introduced the spatial extension of the spillover model and demonstrated the potential contribution of our method to spatial analyses. This study extends the concept of the spillover effect to urban development and the land market to investigate how the effects of the development of the railway propagate spatially. The spatial analysis shows the regional trend of Kyushu and highlights some significant small-scale trends around HSR stations. To sum up, the building area around smaller HSR stations has increased significantly compared with larger cities and areas without HSR stations. The land price has decreased regionally, except in a few large cities, such as Fukuoka and Kagoshima. The growth in property tax revenue in most municipalities with HSR stations has stayed positive, although the regional trend is turning negative. The DID model results show no statistical significance of the effect. Future work requires the application of a clustering algorithm to the 1-km grid data to highlight the smaller-scale differences in the spatiotemporal spillover effect. It is also important to evaluate the scalability of the model with a more globally available dataset.

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6

The Potential of Big Data for Boosting the Social Impact of Infrastructure Projects

*Ryosuke Shibasaki, Satoshi Miyazawa,
KE Seetha Ram, and Shreyas Bharule*

6.1 Introduction

Infrastructure drives urban development and land use change. At the same time, it is closely related to the surrounding land price, which is a critical index for revenue generation of local governments. For every infrastructure development project, acquiring detailed geographic information system (GIS) data—past, present, and predicted future—is essential for estimating and maximizing positive social impact. Emerging economies exhibit a rapid pace of urban expansion, but collecting and maintaining such data has been a significant challenge. In a world state as transient as today, traditional methods of data collection that have been conducted for decades have become costly and time-consuming. Now there are new promising frontiers for the collection of spatiotemporal data that are beneficial for infrastructure development. This chapter introduces some ongoing research for developing data archives to aid impact evaluation of transportation infrastructure investments and efforts to visualize the impacts of such investments.

The Shibasaki and Sekimoto Laboratory at the University of Tokyo has spearheaded big data modeling to address real-world issues. The lab has worked in countries such as Sri Lanka, Mozambique, and Sierra Leone to create people flow data from anonymized mobile phone global positioning system (GPS) trajectory datasets (Sekimoto et al. 2011; Shibasaki et al. 2018). Mobile big data helps to visualize how transportation infrastructure development affects the movement of people. Simultaneously, using a historical archive of geospatial

data, researchers can conduct empirical studies on the impact of transportation infrastructure and the contribution of the investments.

6.2 Bangkok: Transition with Modal Shift

The Greater Bangkok Plan (1960) and Bangkok Transportation Study (1971) started the tradition of transportation planning in Thailand. Until the late 18th century, paddle boats were the primary source of transportation, and narrow streets offered accessibility on foot (Jittrapirom and Jaensirisak 2017). However, city planning influences from Europe and the Americas in the early 19th century changed Bangkok's urban landscape.

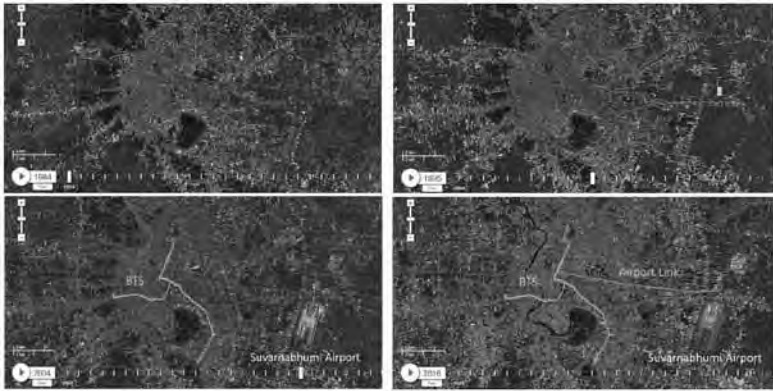
The Bangkok Transportation Study covered the period between 1972 and 1975 and proposed several transport infrastructure systems, such as expressways, mass rapid transit (MRT), and road changing (Jittrapirom and Jaensirisak 2017). However, the government only constructed expressways. The 2017 Global Traffic Scorecard report stated that the city spans over 1,569 square kilometers, but only about 113 square kilometers, or 7.2%, is covered by roads, which is nowhere near the world standard of 20%–25% of road area coverage within a city (The Nation Thailand 2018).

Over the past decade, the government has been successfully implementing various transport plans and has recently revised the Bangkok Master Plan 2009 to develop the MRT system. Large-scale transport infrastructure development such as the MRT usually affects land cover and all kinds of land uses. The Google Earth Engine provides a platform for scientific analysis and visualization of geospatial datasets. It hosts archives of satellite images that cover the entire globe for over 40 years (Gorelick et al. 2017). Moreover, the platform adds new satellite images daily for data mining on a global scale.

Extracts of the satellite images of Bangkok City's urban expansion between 1984 and 2016 are shown in Figure 6.1. Specifically, they focus on the development of Suvarnabhumi International Airport, which began operations in 2006. The consequent impact on land cover of the surrounding land uses can be observed in the 2004 image when the airport was under construction. Meanwhile, densification of built forms around the airport can be seen in the 2016 image when the airport was connected to an existing transportation infrastructure system: the Skytrain (Bangkok Mass Transit System, or BTS) with an airport link.

Today the airport link is used not only by air travelers but also very intensively for commuting purposes, as is reflected by the land cover changes around the airport link. The impact of the airport can be also analyzed using different data sources, one example of which is flight radar.

Figure 6.1: Development of Bangkok City Area and Suvarnabhumi Airport, 1984–2016



BTS = Bangkok Mass Transit System.

Source: Author.

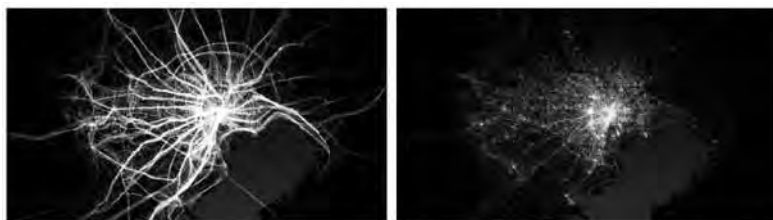
6.3 Real-Time Location Database

Flightradar24 is also a global archive but of the real-time location of individual flights.¹ While observing such real-world movement is an enjoyable exercise, collecting actual data and preparing a chronological archive gives tremendous value to such a repository. For instance, the flight radar information may not be the real data at all, but visualizing representative flight paths between international airports may show how development of a second international airport (Suvarnabhumi International Airport) has contributed in reinforcing and strengthening the hub capability of Bangkok. Simultaneous analysis of the traffic congestion within the city area may represent how traffic jams used to be distributed and how the distribution has changed before and after the BTS introduction and airport link.

However, access to data and data collection efficiency vary across the world. For instance, restricted data such as random price data to observe and research the operation of a new railway services are much

¹ Flightradar24 is a global flight tracking service that provides you with real-time information about thousands of aircraft around the world. <https://www.flightradar24.com/>

Figure 6.2: Effects of Suspension of Commuter Rail Services before (left) and after (right) an Earthquake Event in Tokyo



Note: Each point represents one data provider.

Source: Abe (2014).

more easily accessible in Japan compared to other countries. Thus, such data accessibility drives the robustness of the analysis provided by institutes of actuarial sciences to derive future predictions. Moreover, the data aid in the design and designation of land uses around the stations and other transport nodes. Such data analysis may also provide inferences to track behavior of individuals in the event of a disaster or natural calamity. Figure 6.2 shows results of a study conducted in Tokyo to observe individual behavior in the event of an earthquake that took place in 2013. Individual trajectories appear to follow commuter rail lines moments before an earthquake. However, due to suspension of rail services in the event of an earthquake, individual trajectories are drastically changed, with most relying on transport modes other than railways.

GPS trajectories have emerged as assets in making future predictions. In Japan, GPS datasets archived by private sector organizations offer great diversity of data. Such archives are now regarded as one of the most important economic assets, as data distribution, computing, and interpretation have helped several corporations create value from the data. Nevertheless, the inferences drawn from such datasets globally often are increasingly intense and require monitoring and enforcement for privacy protection. In light of potential threats, the European Union (EU) has introduced new privacy protection rules called the General Data Protection Regulation (GDPR),² which empowers the

² The General Data Protection Regulation 2016/679 (see <https://gdpr-info.eu/>) is a European Union law concerning data protection and privacy for all individual citizens of the European Union and the European Economic Area.

data provider with a right to data portability.³ The introduction of such management schemes that offer data providers new rights to their personal information not only empowers providers but also restricts accessibility to sensitive data.

However, in a world increasingly dependent on mobile services, acquiring personal information such as travel location history requires consent. Services such as Google Takeout offer such information to each individual subscriber. Such information might emerge imperative for future data needs. For instance, internet-related service providers such as Google record the location data every 10 seconds from users' mobile phones. This dataset could be a comprehensive source to visualize the movement of people. Given that Google services such as location history are one of the most subscribed mobile application services, the impact of such a dataset may result in both beneficial and unfavorable interpretation and usage.

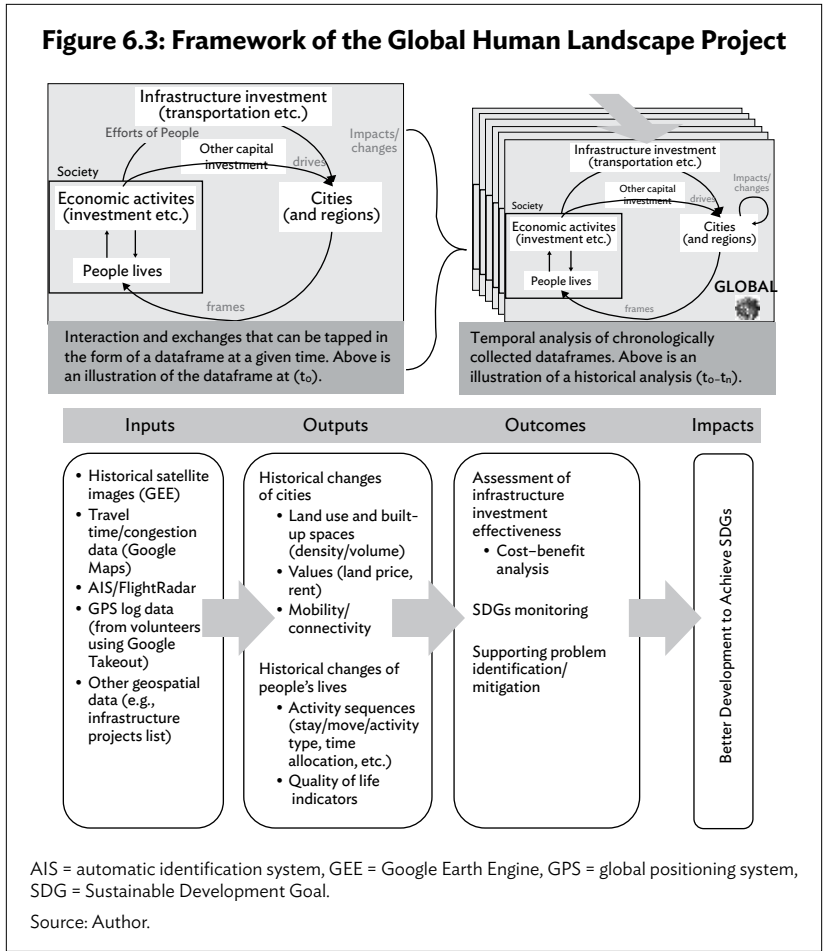
Given the global scale of the available data and the above highlighted potential, such efforts could be scaled to macro- and micro-regions to estimate and visualize the impact of transportation infrastructure. However, as the GDPR example shows, efficient data governance would determine the robustness and quality of the data while assuring anonymity to the data provider. Hence, researchers and policy makers need to find efficient ways to encourage people to provide data, participate in evidence-based infrastructure development, and receive its benefits in the form of better services.

6.4 Concluding Remarks

The Shibasaki and Sekimoto Laboratory has initiated a small-scale project referred to as the Global Human Landscape Project. It aims to visualize how a landscape changes, especially due to transport infrastructure development. Figure 6.3 shows the framework of the project. The initial findings of the research project state that economic activities affect people's lives in diverse ways. The simultaneous and transient changes that transport infrastructures bring that shape the city may have different effects on the lifestyles of different age groups even if the individuals are from the same household. Further, the economic activity needs of such individuals must be addressed in the investment for transportation infrastructure. Finally, these investments need to be planned in an incremental way to create long-term benefits while considering the changes in the city.

³ Article 20 GDPR: Right to data portability. Source <https://gdpr-info.eu/art-20-gdpr/>

Figure 6.3: Framework of the Global Human Landscape Project



The project deduces that visualizing data from the past could be a good basis to encourage researchers to initiate quantitative research studies. Researchers and policy makers may recognize the contribution of transportation infrastructure in that the investment holds high social impact. Given that data services may contain all the data for land cover changes, data providers would add their location history. However, constructing an equally refined, historical transportation infrastructure project dataset is still an obstacle.

6.5 Way Forward

Our discussions with economists at the Asian Development Bank revealed that such kind of landscape changes or other land use changes might be important (Miyazawa, Wetwito, and Seetharam 2019). At present, there is no long-term historical archive of the kinds of transportation transfer projects that have been carried out, including their location and geographic range. We believe those data are already recorded in documents, although they are scattered across different libraries, warehouses, or researchers' bookshelves. By starting with selecting such data and mapping them to the long-term or historical satellite images, it would be possible to visualize additional contributions.

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PART II

High-Speed Rail Stations and Development Ecosystems

Key Messages

Evidence from academic work emphasizes that intercity and interregional high-speed rail (HSR) investments can create regional imbalances. When city or region pairs have different levels of development, such HSR investments may work in favor of larger, so-called primate cities or regions at the expense of weaker surrounding areas. Along a proposed corridor, cities with access to HSR through a station may accrue benefits, although the distribution of impacts and gains requires rigorous study. Cities of regional importance might benefit to the detriment of neighboring hinterlands, although various researchers have argued that countries with dominant cities tend to accumulate net benefits.

HSR systems are built to reinforce accessibility and strengthen interregional, as well as intraregional, relations. The rail corridors are set between pairs of cities, which represents a paradigm shift for interregional mobility, boosting the national economy. In this regard, the seven chapters in Part II individually explore the impact of transport infrastructure on three different scales: regional, local, and station level. They contain valuable lessons from cases around the world with specific takeaways to enhance the quality of life at each geographic scale.

Chapter 7 introduces Japan's 50-year history in running and utilizing the *Shinkansen* for regional development, which is a great resource for countries planning HSR projects. In the light of several ongoing HSR development plans across the world, the Japanese experience in *Shinkansen*-related regional development provides useful cases to learn from for national economic planning, tourism promotion, and development around HSR stations. Thus, the chapter highlights critical lessons and presents a case of advising on the development of the Kuala Lumpur–Singapore HSR line based on the Japanese experience. The chapter notably concludes that HSR is not a *sufficient* condition but a *necessary* condition for regional development.

Chapter 8 explores the trend among many metropolitan cities in Asia, which, in addition to HSR development, are planning and implementing extensive investment in mass transit networks. Thus, they are now on the threshold of becoming so-called transit cities. In this progression, the promotion of transit-oriented development (TOD) policies will be key. The chapter examines cases of TOD in cities that considered a transit-oriented regional growth management strategy, drawing lessons from the United States, Southeast Asia, and East Asia. It summarizes the factors for successful implementation of TOD in Asian cities.

Chapter 9 introduces the history of railway development in Tokyo and draws lessons to enable and design TOD-based urban development policies without excessive dependence on road transport. In recent years, industrial transformation has accelerated the shift in economic orientation from agriculture to industry and services, which has resulted in significant economic growth in countries all over the world. A major social challenge in cities accompanying this economic growth has been road traffic congestion. The chapter stresses adopting a TOD-based city development policy, which in megacities such as Tokyo has emerged as an effective solution to deal with the transportation challenges.

Chapter 10 examines the importance of accessibility and environmental impact, among other factors to consider, when selecting a location for an HSR station. It presents a process to measure the overall utility of an HSR station by analyzing the extent to which location satisfies desirable requirements. This quantification and identification process could be useful to planners in assessing an area and determining the most suitable station locations for an HSR project. The Mumbai–Ahmedabad HSR in India is used as a case study for identifying potential station locations along the corridor and comparing the obtained results with actual planned locations of the project.

Chapter 11 looks at the potential impacts on institutional territories and existing transport infrastructure of a region, which are among the first affected by introduction of HSR infrastructure. For instance, the initial stretch of the proposed HSR in India from Mumbai to Ahmedabad falls under the jurisdiction of the Mumbai Metropolitan Region Development Authority and includes three of the 12 proposed HSR stations. The chapter examines the travel and land use impacts of the proposed HSR by applying a four-stage travel demand model, which incorporates all the land use and transport network developments across the Mumbai Metropolitan Region until 2041, replicating the existing travel behavior. In addition, it estimates the improvement of accessibility in the peripheral areas due to proximity of an HSR station and its associated impact on the current intense activity areas of the region.

Chapter 12 studies integrated interoperable rail systems that facilitate HSR train movement on conventional intercity lines, and vice versa. Hence, the preferred location of HSR stations for rail systems would be at existing intercity rail stations. The chapter proposes an HSR station location identification approach along existing intercity rail stations based on a geographic information system (GIS) to identify suitable integrated interoperable HSR and intercity station locations. The model uses the Mumbai–Ahmedabad conventional intercity corridor as a case to demonstrate its efficacy by identifying possible HSR station locations.

Chapter 13 elaborates on the successes of the Kyushu Railway Company (known as JR Kyushu), one of the six companies formed after the privatization of the Japanese National Railways. The company adopted several strategies to enhance its privatized image, including increasing the number of stations, expanding the frequency of trains, upgrading operating speeds, designing new rolling stock, and improving services for local access. As a result, a wide variety of diversified businesses were introduced, including real estate development, integrated station buildings, food and beverage establishments, retail outlets, tourism services, and leisure facilities. Over the years, the profits drawn from the diversified businesses supported annual revenues, keeping the railway business deficit free.

7

The Relationship between High-Speed Rail and Regional Development

Kazuaki Hiraishi

7.1 Introduction

With respect to the relationship between high-speed rail (HSR) and regional development, the answer to the question whether HSR contributes to regional development is of course “yes.” The larger question, however, is how does it contribute to regional development?

In this chapter, I conjecture that HSR is not just a sufficient condition, but a necessary condition, for regional development. This means that HSR construction is not the ultimate goal; it is a milestone. The ultimate goal is using HSR for regional development.

I explore this idea by first introducing a case from Japan: the Joetsu *Shinkansen* and the Sado Island tourism promotion project. Then, I draw lessons from a study of various Japanese benchmark cases to see how they apply to developing and emerging economies in the process of developing HSR.

7.2 The Joetsu *Shinkansen* and Sado Island Tourism

A typical example of the relationship between HSR and regional development is the Joetsu *Shinkansen* and Sado Island tourism.

Sado Island is located in Niigata prefecture. The distance between Sado Island and Niigata City is around 45 kilometers. Travel from Sado to Niigata via high-speed vessel (jetfoil ferry) takes 1 hour.

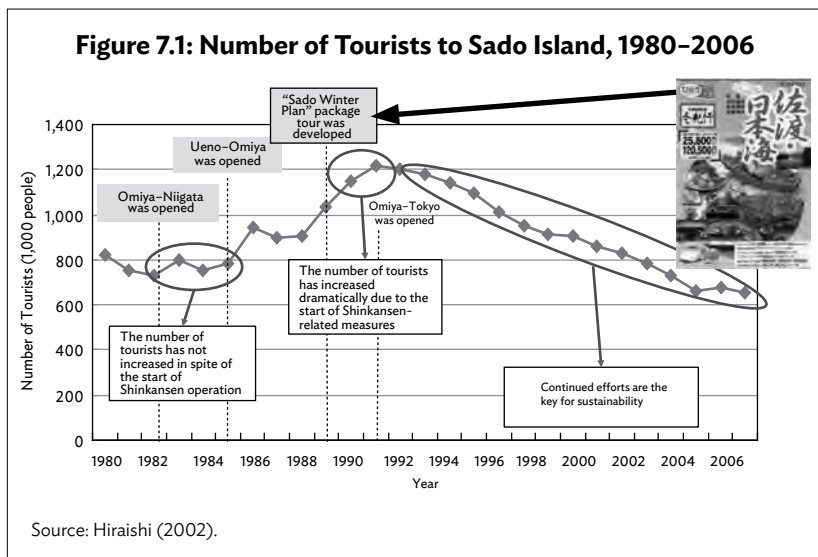
The Joetsu *Shinkansen*, which connects Omiya (in Saitama prefecture) and Niigata, started operation in 1982. Using the *Shinkansen*

and high-speed vessels, travelers from Tokyo are able to reach Sado Island within 4 hours. It is widely accepted that the number of tourists to Sado Island increased dramatically thanks to the Joetsu *Shinkansen*.

Figure 7.1 shows the number of tourist arrivals in Sado Island from 1980 to 2006, which illustrates three trend periods worth noting. The first starts in 1982 when the Joetsu *Shinkansen* began operating, although the number of tourists did not increase immediately despite its presence. This indicates that the start of the HSR service was not sufficient for regional development.

The second period to note spans 1989–1990 when 1989 and 1990, the number of tourists increased dramatically. This spike is the result of measures undertaken by the *Shinkansen*, such as a package tour called the Sado Winter Plan, which offered an overnight tour including a stay in comfortable hotels and excellent fish cuisine limited to the winter season. This package tour was created by four key players: the East Japan Railway Company (JR East), which operates the Joetsu *Shinkansen*; Sado Kisen, which operates the car ferry and jetfoil ferry services to Sado Island; Niigata Kotsu, which operates the tourist bus on Sado Island; and the Sado hotel association. This package tour raised tourism to Sado Island by over 20% during the 1989–1990 winter season.

The rationale behind the tour was that summer is the traditional tourism season on Sado Island; fewer tourists visit in the winter. The



four previously mentioned key players worked together to reach their common goal of attracting more tourists to Sado Island during the winter season. Hence, they created a high-quality and reasonably priced package seasonal tour. The package encompassed a 2-day trip, which is a standard length for an overnight tour in Japan. Thanks to the *Shinkansen*, the target area for the tour captured the large tourist market from the Tokyo metropolitan area.

The third time period of interest occurs after 1990, when the number of tourists began to gradually decrease. Since the promotional package tour in 1989, subsequent tourism development on Sado Island has been unremarkable. As other areas in Japan were developing similar package tours to attract tourists from Tokyo, the number of tourists to Sado Island decreased. Thus, continued efforts are needed for sustainable growth.

7.3 Lessons from Japanese Benchmark Cases

Japan's development of its *Shinkansen* network began in 1964, when the Tokaido *Shinkansen* started its operation. In the process of this HSR development, many regional development projects along the route have been executed with mixed results: some were successful, while others failed. These experiences are valuable not only for Japan, but for emerging and developing countries that are planning to introduce HSR.

When imparting Japanese infrastructure know-how to emerging and developing countries, it is important to convey the experiences in HSR-related regional development as well as HSR technology itself. Japan has been sharing its experiences with partner countries, a typical example of which is the Kuala Lumpur–Singapore HSR.

The HSR between Kuala Lumpur and Singapore was planned to start its operation in 2026. Due to a regime change in Malaysia, however, the project is currently halted. Whether the project restarts depends on the decision of the Government of Malaysia. In the event that the project does resume, it will be essential for Malaysia and Singapore to make good use of HSR for their regional development.

For this purpose, we carried out a benchmark study for the Kuala Lumpur–Singapore HSR, using a “back-casting” approach to effectively convey Japan's experiences (Figure 7.2). The study followed three steps. First, we set a goal of stimulating regional development along the HSR route based on Malaysia's strategic development framework.

Second, we selected the following 10 Japanese benchmark cases that provide useful information for the Malaysian HSR:

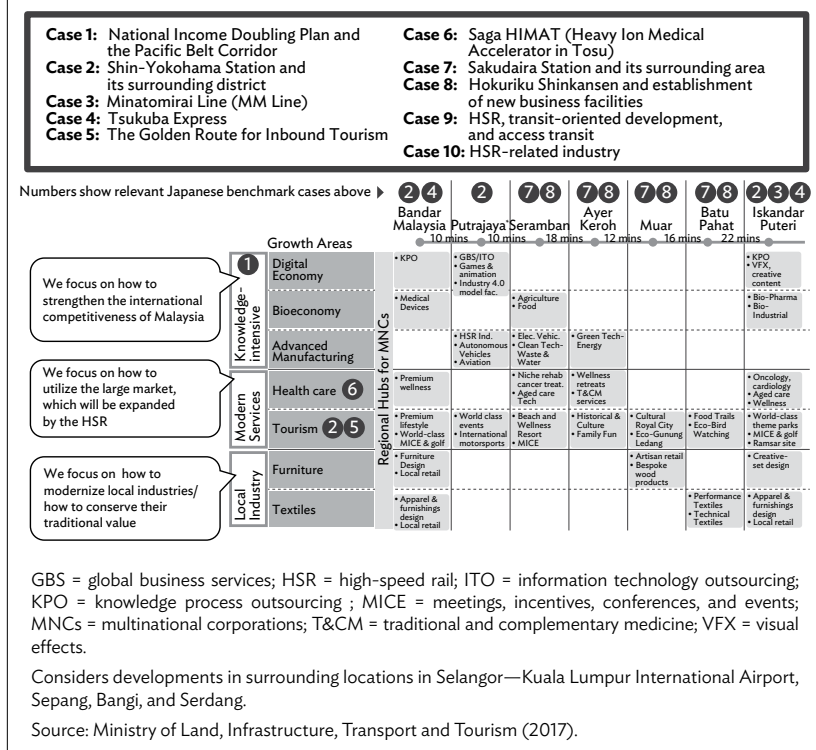
- (1) National Income Doubling Plan and the Pacific Belt Corridor
- (2) Shin-Yokohama Station and its surrounding district
- (3) Minatomirai Line

- (4) Tsukuba Express
- (5) The Golden Route for Inbound Tourism
- (6) Saga HIMAT (Heavy Ion Medical Accelerator in Tosu)
- (7) Sakudaira Station and its surrounding district
- (8) Hokuriku *Shinkansen* and establishment of new business facilities
- (9) HSR, transit-oriented development, and access transit
- (10) HSR-related industry

Third, based on the goal and the Japanese cases, we offered some suggestions on how to proceed with regional development in Malaysia.

Of the 10 cases, I detail three cases (1, 2, and 5) with their implications for Malaysia.

Figure 7.2: Growth Areas in Malaysia's Strategic Development Framework and Japanese Benchmark Cases

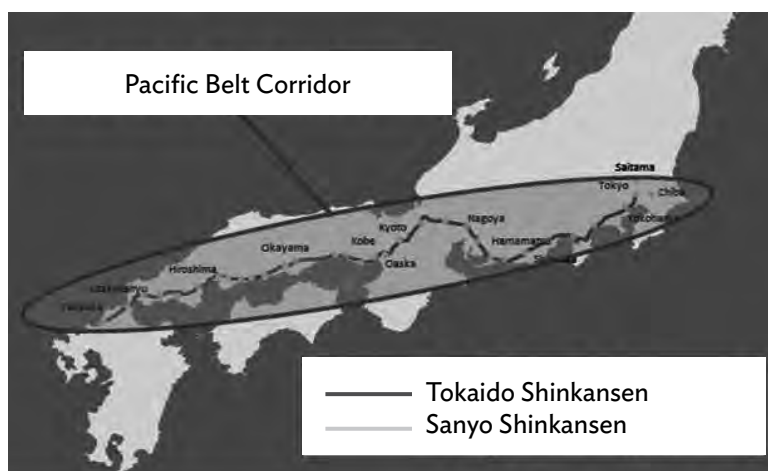


7.3.1 National Income Doubling Plan and the Pacific Belt Corridor

The first case is the National Income Doubling Plan and the Pacific Belt Corridor. This plan was the most successful among the Japanese national economic plans. It proposed developing an economic corridor called the Pacific Belt Corridor (Figure 7.3). This was a driving force for the Japanese economy during the period of high economic growth in the 1960s.

The Pacific Belt Corridor's essential infrastructure included the Tokaido *Shinkansen*, the Sanyo *Shinkansen*, and several expressways. Large investments were made in the heavy and chemical industries, which drove the economy in the 1960s in Japan. Investments were concentrated in the areas along the corridor, and Japanese international competitiveness has been enhanced ever since.

Figure 7.3: The Pacific Belt Corridor



Source: Mitsubishi Research Institute.

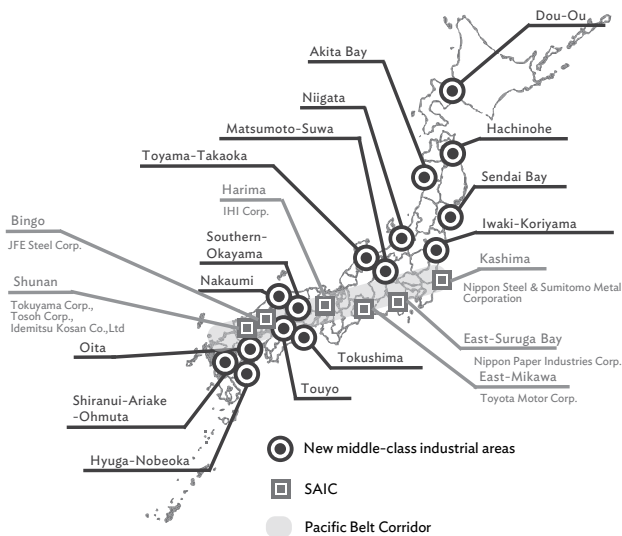
One typical measure was the Special Area for Industrial Consolidation (Figure 7.4). These were new, middle-class industrial areas along the Pacific Belt Corridor concentrating on heavy and chemical industries. At the time, four major industrial areas (Keihin, Chukyo, Hanshin, and Kitakyushu) had already been saturated.

To further industrial development, Japan allocated a large amount of investment to these special areas located on the Pacific Belt Corridor.

The Special Area for Industrial Consolidation experience gave rise to the following recommendations for Malaysia:

- Attach a high value to the Kuala Lumpur–Singapore HSR in the national economic plan. Malaysia had already created its Strategic Development Framework in which it set regional development along the HSR corridor as a goal.
- Form an industrial corridor along the Kuala Lumpur–Singapore HSR to enhance Malaysia’s international competitiveness, and concentrate various measures in certain special development areas along the corridor.
- Place importance on promoting private investment, e.g.
 - prepare a master plan for special development areas;
 - develop infrastructure such as industrial parks, industrial water supplies, roads, rails, ports, etc.;
 - seek financial backing from local governments in charge of infrastructure development; and
 - encourage tax reduction for enterprises.

Figure 7.4: Special Area for Industrial Consolidation



SAIC = Special Area for Industrial Consolidation.

Source: Ministry of Land, Infrastructure, Transport and Tourism (2017).

Figure 7.5: Implications for Malaysia

Japan		Malaysia
National Income Doubling Plan	Plan	National Physical Plan and SDF
Pacific Belt Corridor	Corridor	Kuala Lumpur–Singapore Economic Corridor
Heavy and chemical industry	Driving Industry	Knowledge-intensive industry
Tokaido and Sanyo Shinkansen	Infrastructure	Kuala Lumpur–Singapore High-Speed Rail

SDF = Strategic Development Framework.
Source: Ministry of Land, Infrastructure, Transport and Tourism (2017).

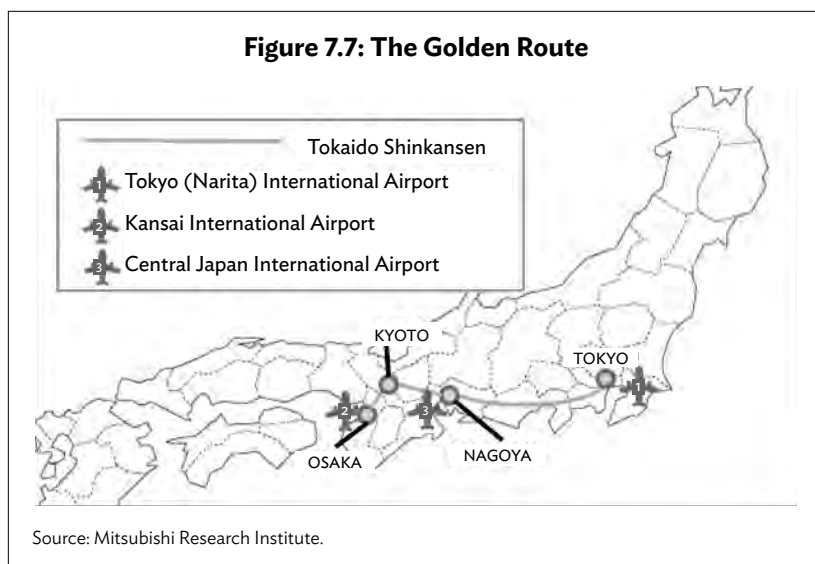
7.3.2 Shin-Yokohama Station and Its Surrounding District

Shin-Yokohama Station is a newly developed *Shinkansen* station, located 5 kilometers from the central business district (CBD) of Yokohama City. In this case, transit-oriented development (TOD) is essential.

The most important role of local government is to make a master plan as the first step for TOD. Yokohama City designated the Shin-Yokohama district as the subcore of the city in their master plan (Figure 7.6). The city also developed access transit to the CBD. In addition to the conventional Japan Railways line, a subway line was newly constructed between Shin-Yokohama and the CBD.

Then, Yokohama City developed the area around Shin-Yokohama Station. Typical for urban development facilities are Nissan Stadium, which is a soccer stadium used for international games such as the FIFA World Cup, and Yokohama Arena, which is a concert hall where international music events are held frequently.

These attractive facilities not only promote TOD but increase the number of *Shinkansen* passengers. As these facilities were developed, more people came to visit the Shin-Yokohama area, and the number of passengers using Shin-Yokohama Station increased. As the number of passengers increased, the railway operating company (JR Tokai) revised the train timetable to increase the number of trains stopping at Shin-Yokohama Station. Previously, the higher-category train *Nozomi* did not stop at Shin-Yokohama Station, but now all higher-category trains stop

Figure 7.7: The Golden Route

inbound tourists. Moreover, cooperation among multiple international airports, the HSR, and tourism sites along the HSR attracts more inbound tourists.

In Japan, the *Shinkansen* has been contributing to the promotion of inbound tourism. A typical example is the so-called Golden Route of inbound tourism along the Tokaido *Shinkansen* (Figure 7.7). Approximately 60% of the inbound tourists are on the Golden Route.

They arrive at either Narita or Haneda International Airports and visit Tokyo to enjoy, for instance, the Asakusa area or Tokyo Disney Resort. After that, they might go to Nagoya by the Tokaido *Shinkansen* to visit the automobile plant of Toyota Motor Corporation or similar, then on to Kyoto by the Tokaido *Shinkansen* to visit the World Heritage temples and shrines. Last, they might enjoy Osaka and Kobe before leaving Japan from Kansai International Airport.

The most important aspect of the Golden Route is the cooperation among the *Shinkansen*, the international airports, and the tourism sites along the *Shinkansen*.

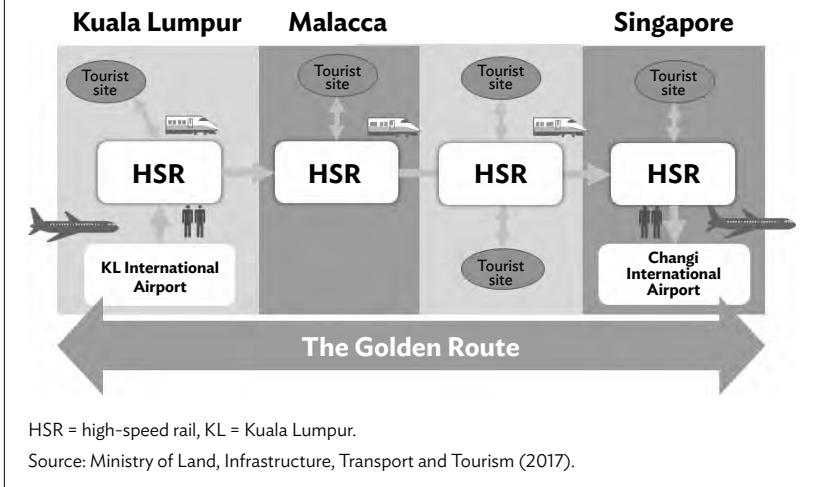
Based on this case, we developed the following recommendations for Malaysia:

- Develop an inbound tourism route that involves Kuala Lumpur International Airport, Changi International Airport, the Kuala

Lumpur–Singapore HSR, and sightseeing sites along the HSR, including Malacca, a World Heritage site (Figure 7.8).

- Develop a tourism route like the Golden Route that contributes to increased inbound tourists, not only for major sites such as Malacca, but other sites in Malaysia.
- Improve the connectivity between the HSR and major sightseeing spots and between the HSR and international airports.
- Keys to success for development of tourism routes are
 - good accessibility between the HSR and international airports;
 - improvement of railway services for inbound tourists;
 - development of excursion tickets with integrated chip cards, which include the fare for the HSR, access transit, restaurants, shops, etc.; and
 - have a leader or coordinator among stakeholders as well as a support system.

**Figure 7.8: Implications for Malaysia
(The Golden Route for Inbound Tourism)**



7.4 Conclusions

Finally, to sum up the implications for emerging and developing countries that are planning to develop HSR in the future.

As for the relationship between HSR and regional development, HSR contributes to regional development. It is not just a sufficient condition; it is a necessary condition for regional development. To use HSR for regional development is an ultimate goal, and HSR-related measures should be conducted.

Since 1964 when the Tokaido *Shinkansen* started its operation, Japan has been celebrating the *Shinkansen* for over 50 years. The country has abundant experiences of regional development that make good use of the *Shinkansen*. Thus, Japan is well situated to transfer its knowledge in the field of infrastructure development and related regional development.

In the event that Japanese experiences with HSR are conveyed to other countries, the “back casting” approach is effective for localization of Japanese experiences.

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8

Transit-Oriented Development Policies and Station Area Development in Asian Cities

Tetsuo Kidokoro

8.1 Introduction

Many metropolitan cities in Asia are planning and implementing extensive investment in mass transit networks. They could thus go one of two ways: become transit cities or car-saturated cities. The promotion of transit-oriented development (TOD) policies will be a key to the progression toward transit cities. Some of the key characteristics of the new directions for sustainable development in cities can be widely observed (OECD 2012): dense and proximate development patterns, urban areas linked by public transport systems, and accessibility to local services and jobs. It is apparent that these characteristics of sustainable urban development are compatible with TOD policies. However, automobile-oriented urban patterns have formed extensively in the meantime, as governments have vacillated between road and rail due to the huge investment costs necessary for the construction of urban railways. Once an automobile-oriented city forms, it has a lock-in effect; it becomes very hard to transform such a city to take on a mass transit orientation. As a result, although many cities are gradually introducing mass transit modes, the reality is that changing the urban patterns and realizing the synergy potential in the transport sector is not an easy task. In Asia particularly, many megacities are now on the threshold of either transforming into transit-oriented cities or becoming entrenched as automobile-oriented traffic-saturated cities.

To examine the possible paths to transform the pattern of urban development from automobile oriented to transit oriented, this chapter first looks at the characteristics of urbanization in Asian cities in conjunction with TOD policies. Second, it examines four cases from

cities in Japan (Tokyo and Toyama), the United States (Denver), and Malaysia (Kuala Lumpur). Finally, it discusses the lessons regarding the application of TOD policies.

8.2 Characteristics of Asian Urbanization and Its Implications for Transit-Oriented Development

Many studies and policy documents discuss the guidelines for TOD policies. Based on careful examination of the existing documents (e.g., Ditmar and Ohland 2003; Curtis, Renne, and Bertlini 2009; Salat and Ollivier 2017; Thomas et al. 2018), the following summarizes the key issues concerning the application of TOD policies:

- (1) Transit-oriented development planning
 - Density
 - Transit accessibility
 - Pedestrian friendliness
- (2) Station area development
 - Connectivity to the surrounding neighborhood
 - Livable public space
 - Development surrounding the station area
 - Affordable housing and accessible living
 - Mixes uses and forms
- (3) Collaboration with stakeholders and community
- (4) Value capture

In conjunction with the application of these key points of TOD policies, several aspects require careful consideration in fast-growing Asian cities. First, many developing Asian cities are facing serious urban environmental problems, such as traffic congestion and air pollution. It is therefore important to determine the synergies between the solutions to urban environmental problems and the enhancement of mobility through the application of TOD policies.

Second, equally important is to seek synergies in the mitigation of and adaptation to climate change. Disaster risks clearly are higher in Asian countries than in the rest of the world. One of the characteristics of urbanization in Asia is that urban agglomerations have developed in low-lying delta regions. Hence, Asian cities, including those located in arid regions in inland areas, are vulnerable to the impacts of climate change. Considering the synergies between mitigation and adaptation is necessary when applying compact city policies to fast-growing Asian cities. It is a considerable opportunity for cities to apply TOD policies

to realize compact city forms that can contribute to both mitigating and adapting to climate change. These aspects must therefore be considered when formulating TOD plans.

Third, urban sprawl and motorization increasingly are becoming a characteristic tendency of urbanization in Asian countries (Jenks, Kozak, and Takkanon 2008). Due to rapid motorization, sprawl-type developments prevail, particularly in fast-growing Asian cities. Although the conventional image of Asian cities as high-density and mixed-use still applies in the central built-up areas, urbanization patterns in the fringe areas of fast-growing Asian cities are gravitating more toward low-density development and automobile-oriented traffic with segregated land use. This ongoing expansion of urban sprawl could be detrimental to value capture due to the difficulty of development along transit routes. Thus, making station area developments more attractive will be a key to the successful implementation of TOD policies.

Fourth, the existence of informal settlements is an important feature of many Asian cities. These informal settlements provide affordable housing for the urban poor. About 30% of Asia's population still lived in slums in 2010, and the total number of slum dwellers is continuing to rise (UN-HABITAT 2012). The Asian region remains host to 505.5 million slum dwellers—over half of the world's slum population (Dahiya 2012). Careful consideration of the existence of those informal settlements is necessary, particularly regarding the development of station areas.

8.3 Case Studies

This section reports on case studies of cities with different maturities of TOD policy application in Japan, the United States, and Malaysia to distill the key factors for their successful implementation.

8.3.1 Tokyo, Japan

Tokyo is one of the most transit-oriented megacities in the world, and large-scale urban development projects are ongoing in the station areas of the city center. The redevelopment project in the Tokyo Station area is among the largest projects in the city center of the capital (Figure 8.1). Tokyo Station is the central station, connecting four *Shinkansen* high-speed rail lines and many commuter and subway lines. The Tokyo Station Area Redevelopment Project covers Japan's central business center, whose major financial institutions, insurance companies, information and communication technology companies, mass media, and trading companies are located directly adjacent to the station. In terms of value capture, various redevelopment schemes are underway to provide the

Figure 8.1: Model of Tokyo Station Area Redevelopment Project

Source: Photograph by author.

necessary public infrastructure at and around the station, including the Land Readjustment Project, the Transfer of Development Rights, and the Urban Renaissance Special District (URSD). Once an area has received URSD designation, the local government cancels and decides anew the existing land use controls, floor area ratio, building coverage ratio, height limitation controls, and building line limitations. It has applied URSD to the redevelopment area and deregulated the floor area ratio from 1,200% to 1,590% maximum by taking into consideration this project's contributions to urban regeneration for the whole neighboring area.

Regarding the stakeholder collaboration, the public-private partnership (PPP) in the city center (120 hectares) around Tokyo Station (the Otemachi-Marunouchi-Yurakucho or OMY area) began with the establishment of the OMY Redevelopment Project Council, which brought together property owners to think about the direction of the urban renewal for the area. The formation of the council was based on Chiyoda Ward's approach, which positioned PPP as a key urban development policy in its urban master plan. The council continued discussing the direction of urban regeneration, and the property owners

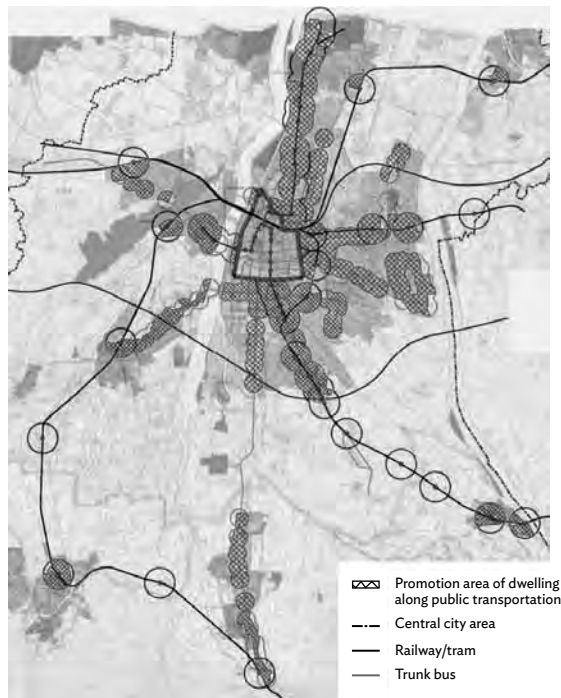
reached a basic agreement in 1994 on the principles of redevelopment to follow when reconstructing their office buildings. Furthermore, with the OMY Redevelopment Project Council as the foundation, the Tokyo Metropolitan Government, Chiyoda Ward, and the East Japan Railway Company (JR East) joined and formed the Advisory Committee on OMY Area Development for a true PPP. In 2000, the committee created the city planning guidelines, which state the vision for the area and the building rules that property owners should follow. The guidelines are positioned as evolutionary in the sense that they maintain principles but avoid rigid, long-term planning and aim to achieve the overall vision incrementally through individual projects. The details of the guidelines are also flexibly adjustable in accordance with the changing economic and social conditions. In fact, the committee has revised the guidelines on three occasions to date: in 2005, 2008, and 2012. It follows that typical project-based urban development through PPP is occurring in the OMY area.

Consensus making for the project has taken place within the OMY area. As discussed, the property owner association known as the OMY Redevelopment Project Council has been the main platform for consensus making, and the Advisory Committee on OMY Area Development covers the PPP arena. Chiyoda Ward acted as a catalyst by approaching property owners to create a platform for consensus making and to foster relational development rights. At the same time, the Tokyo Metropolitan Government acted as an enabler by making a major shift from plan-led to project-led urban development policies in response to movements in the OMY area. The central government also supported these movements by making the necessary institutional arrangements.

8.3.2 Toyama, Japan

Toyama City is a regional core-level city and the capital city of Toyama Prefecture. Through the annexation of neighboring towns and villages in 2005, Toyama City became the 11th largest city in Japan in terms of area coverage. Though the administrative area is wide, the ratio of habitable land is 38.2%, and almost 70% of the city area is covered by forest. People regard Toyama City as a champion of compact city policies, and the United Nations Climate Summit named it a model city for the District Energy in Cities Initiative in 2014.

Toyama City has recently changed its urban development policies from expansive urban development to a compact city under the strong leadership of Mayor Masashi Mori. Several issues underlie this recent policy change: the decline of the city center, low-density urban development, high dependency on automobiles, an increase in

Figure 8.2: Transit-Oriented Development Policy in Toyama City

Source: Toyama City.

administrative costs, population aging, an increase in CO₂ emissions, and so on. These are common to small and medium-sized cities in Japan.

To cope with these problems, Toyama City has implemented compact city policies since Mayor Mori took office in 2002, with TOD in particular being a key compact city policy. The city's basic policy is to strengthen public transportation, including rail, light rail transit (LRT), and buses, and to concentrate urban facilities along public transport corridors (Figure 8.2). There are three main measures with regard to TOD in Toyama City: strengthening public transportation, regulating and guiding development, and revitalizing the city center (Table 8.1).

The city's master plan has designated public transportation corridors consisting of railway and tram lines in the city and selected bus lines. These run frequently (more than 60 services a day) between the city center and suburban centers and between the city center

Table 8.1: Main Measures for Realizing Transit-Oriented Development in Toyama City

Measure	Objective	Example of Initiatives in Toyama City
Strengthening public transportation	Networking light rail transit (LRT) and tram	• Toyama Light Rail (TLR): the first LRT line in Japan • Experimental increase of frequency for the Japan Railways (JR) Takayama Line • Loop-line service for the city tram* • Run-through service on TLR, city tram, and a suburban rail line
	Improving bus service	• Improvement of trunk bus vehicles and bus stops • Community bus service to assure mobility
	Supporting the elderly	• Fare discount for intracity trips to/from city center* • Support for surrender of driving licenses
Regulating and guiding developments	Regulating developments	• Regulation on trip-attracting developments in light-industrial zones and loose regulation areas • Regulation on sporadic residential developments in suburban areas
	Guiding population distribution	• Financial support for constructing, acquiring, and renting houses in the city center and “dumplings” (concentration of houses) along public transportation corridors** • Support for elderly households to move into the city center**
Revitalizing the city center	Making public transportation more convenient	• Target: Increase ridership of city tram by 30% in 5 years • Elevation of railway lines around Toyama Station • Land readjustment in the area around Toyama Station • Community bus service to support intracentral area trips (see also measures marked * above)
	Creating a lively city core	• Target: Increase pedestrian flow in the city center by 30% in 5 years • Renovation of Toyama Castle Park • Development and operation of several key facilities • Mixed-use redevelopment projects including retail and residential • Refurbishment of exteriors under a unified concept • Special deregulation zones for attracting major retail developments • City Center Thanksgiving Day: free parking and celebratory events
	Promoting residence in the central area	• Target: Increase population of the central area by 10% in 5 years • Several redevelopment/development projects including residences (see also measures marked ** above)

Source: Takami and Hatoyama (2008).

and important facilities (including the university, hospitals, and the airport). The city government opened the 7.6-kilometer Toyama LRT (TLR), which converted the conventional suburban rail into a modern LRT system, and started the loop-line service in the city center, which connects the city tram and TLR with run-through services between the TLR, the city tram, and a suburban rail line. The city government constructed and operates the TLR applying the PPP principle: construction of the TLR was implemented using a national subsidy, and a “third-sector company,” Toyama Light Rail, operates it. Toyama city (33.1%), the prefecture government (16%), and various local companies (50.8%) share in the equity of Toyama Light Rail. The Land Adjustment Project (Figure 8.3) constructed the public facilities at and around Toyama Station, including a station plaza and the north–south connection through the station.

Figure 8.3: Aerial View of Land Readjustment Project at Toyama Station, Toyama City



Source: Toyama City.

8.3.3 Denver, United States

Denver, United States, has implemented extensive TOD policies, including a mass transit development plan (\$4.7 billion FasTracks Plan) as well as station area developments based on the city’s TOD strategic plan. Under the FasTracks Plan, the city has developed an extensive mass transit network and undertaken station area development at and around the central station (Denver Union Station). In terms of the value capture, the sales tax surcharge notably covers a large part of the implementation costs of the FasTracks Plan: 71% from the 0.4% surcharge of Denver City and County, 19% from the federal subsidy, 2% from the city, and 8% from others.

The flagship project is the 50-acre Denver Union Station Project at and around Denver Union Station (Figure 8.4). To coordinate the

Figure 8.4: Denver Union Station Project



Seamless connection of light rail
transit and free city bus



Underground long-distance
bus terminal



Renovated station building

Source: Photographs by author.

planning and implementation of the multi-stakeholder project, the city established the Denver Union Station Project Authority in 2008. The project comprises the redevelopment of the project site as an intermodal transit (Amtrak, commuter rail, LRT, intercity bus, and city bus) district surrounded by TOD, including a mix of residential, retail, and office space. Various schemes are funding the \$487.7 million cost, including tax increment financing, special improvement districts, land sales by the Regional Transportation District, joint development, federal subsidy, and so on. To use the tax increment financing mechanism in Denver, a project site must meet the definition of “blight” as defined in statutes and reported by the Denver Urban Renewal Authority. Joint development is taking place between the district and private developers for the joint use of transit facilities or property with an incidental (non-transit) use, including the use of air rights. The joint development may involve private developers’ air rights, ground leases to private developers, or the outright sale of land.

8.3.4 Kuala Lumpur, Malaysia

Among the Southeast Asian cities, Kuala Lumpur is extensively promoting TOD policies, in particular transit-oriented zoning. It has designated the areas surrounding mass transit stations as transit planning zones with additional floor area ratio and stipulated (i) that land use activities should be transit supportive; (ii) that mixed-use activities are encouraged within the transit planning zone with street-level activities to promote vibrancy and safety; (iii) that higher-intensity development support the transit system; and (iv) that good urban design prioritize pedestrians.¹ As regards the station area development, Kuala Lumpur utilizes a PPP scheme extensively. The largest station area development project in the city is the Central Station Development Project, which covers 72 acres for commercial and residential properties and the transit hub of six rail networks (the Kuala Lumpur International Airport or KLIA Ekspres Rail Link, KLIA Transit, Rapid KL (Putra), KTM Komuter, KTM Intercity, and KL Monorail Services). The site was formerly a marshalling yard for Malaysia’s national rail operator (KTMB), and the government awarded the privatization of Stesen Sentral in 1994 to Kuala Lumpur Sentral Sdn Bhd, a consortium under the leadership of a private developer (Malaysian Resources Corporation Berhad). It tasked Kuala Lumpur Sentral Sdn Bhd with building and surrendering the central

¹ An overview of the Transit Planning Zone of the Kuala Lumpur Structure Plan 2020 is available on the DBKL (Kuala Lumpur City Hall) webpage.

station (Stesen Sentral) to the government in exchange for development rights over the surrounding 72-acre freehold commercial land.

8.4 Conclusion

This chapter examined some best practices for the application of TOD policies in different cities. The following is a summary of some of the requirements for the successful application of TOD policies from the case studies:

- (1) a transit-oriented regional growth management plan;
- (2) station area zoning regulations (mixed-use, minimum density, maximum parking, etc.);
- (3) joint development among local governments, transit agencies, and private developers; and
- (4) an institutional mechanism for public and private cooperation in station area development.

Many Asian cities are currently trying to apply TOD policies as an important component of sustainable urban development, yet are faced with obstacles given their current situation. In light of the above lessons, cities could consider the following recommendations toward the successful application of TOD policies:

- (1) a shift from highway-based zoning to transit-oriented zoning;
- (2) the creation of an institutional mechanism for public and private cooperation in station area development: a balance between public benefit and private benefit;
- (3) the connection of transit services and affordable housing; and
- (4) multimodal connection planning, including walking.

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9

Strategy to Realize a Railway-Oriented City: A Transit-Oriented Development Policy Imperative

Takashi Yamazaki

9.1 Introduction: The Urban Traffic Problem

Japan's railway history is unique because development of this small Asian island country's railway system started over half a century after the railways in Europe and the Americas but quickly caught up. Japan pioneered high-speed rail and privatizing its railway network into several companies.

In recent years, an accelerated industrial transformation has changed economic orientation from agriculture to industry and services, which has achieved significant growth in countries all over the world. Economic growth followed by road traffic congestion issues in large cities has become a major social challenge. Large-scale population inflows from hinterlands to large cities continue to escalate vehicle registrations.

However, Japan's experience of motorization suggests a steep shift after gross domestic product (GDP) per capita exceeds \$3,000. Although GDP per capita of emerging economies in the world is still around \$2,000, they soon will face serious road traffic congestion challenges. Congestion may not only cause loss to the economy, but it also entails high social costs in the form of traffic accidents and environmental pollution.

On the other hand, road construction takes time and costs; it does not make progress in a short period. Therefore, traffic congestion has become a major challenge in many cities—with no solution—thereby creating a demand for alternative transportation to avoid congestion problems.

There are three subsectors in urban transportation: rail transport, road transport, and urban development. This chapter draws lessons from the case of Tokyo, a city where railways are highly developed and the modal share of railway transport is extremely high compared to major cities around the world. Tokyo is a typical megalopolis that has been achieved by transit-oriented development (TOD). Adopting a TOD-based city policy has emerged as an effective solution for the transportation challenges in megacities such as Tokyo. The chapter introduces the history of railway development in Tokyo and draws lessons to enable and design TOD-based urban policies for urbanization without excessive dependence on road transport.

9.2 History

A unique feature of Japan's railway system is the large number of railway operators. As of 2019, there were 216 rail operators in the country (MLIT 2019). The megacity of Tokyo achieved TOD during the past century with private railway companies playing an important role both in constructing lines and expanding cities along their metropolitan and commuter lines. These companies succeeded due to a business model in which railway construction is endogenously financed by town development profits (Yajima et al. 2014).

Historically, private companies in Tokyo had two main strategies regarding their railway business. First, they ran a monopoly of lines that used stations on the Yamanote circular line, one of the busiest and convenient Japan Railways routes in Tokyo, as terminals. Private companies accommodated the expansion of lines and stations to developing towns along the lines and setting up shopping centers on top of their stations, thereby managing railway construction along with town development in a sustainable way. Second, they utilized their land so that the railway business and town development business positively affected each other.

Most commuters from the suburbs usually go to downtown office areas for work in the morning and return to the suburbs in the evening. This makes the railway business inefficient because fewer people use the railways to transfer from downtown areas to the suburbs in the morning and back in the evening. To compensate for these inefficiencies, railway companies invite factories, research institutions, and universities as well as housing developers to suburban areas so they can increase demand for commuting from the downtown areas to the suburbs.

Consequently, surprisingly large amounts of private railway companies' revenue are generated from their real estate business.

It is estimated that more than half of the railway companies in Tokyo earn between 30% and 50% of their total revenue from businesses other than running railways (Yajima et al. 2014).

9.3 Urbanization of Tokyo and Railway Development

Tokyo has urbanized through three phases. Figures 9.1–9.3 illustrate the trends in population growth, railway growth, and the number of cars registered in the Tokyo Metropolitan Region, respectively. They also highlight the three phases discussed further in this section. In Phase I from 1920 to 1935, the population increased rapidly due to the development of light industry. Phase II from 1955 to 1970 after World War II was a period of high economic growth. The largest population increase achieved was due to the development of the heavy chemical industry during the early 1950s. In Phase III from 1980 to 1995, the population increased significantly due to the advancement of heavy technologies and service industries.

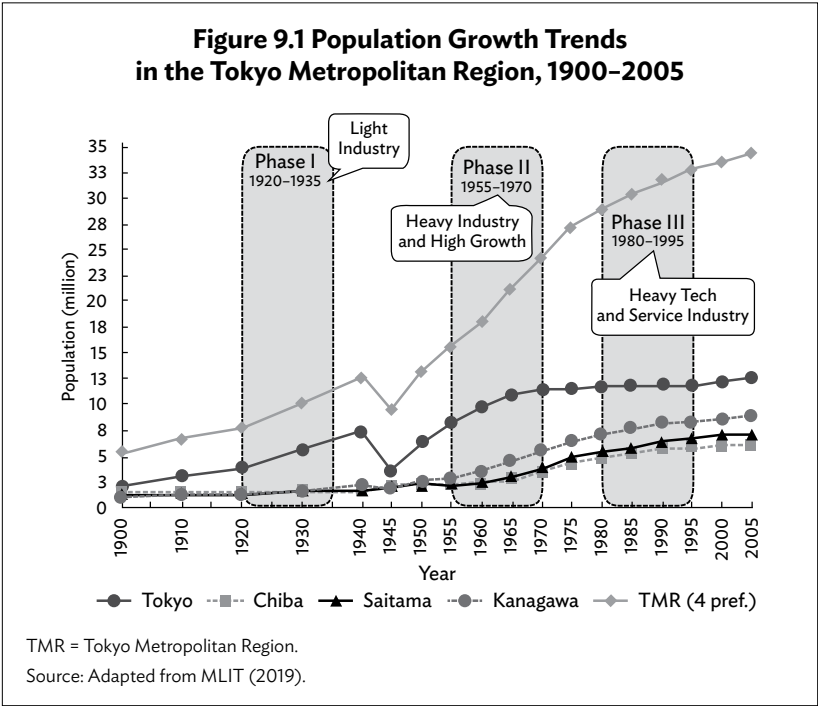
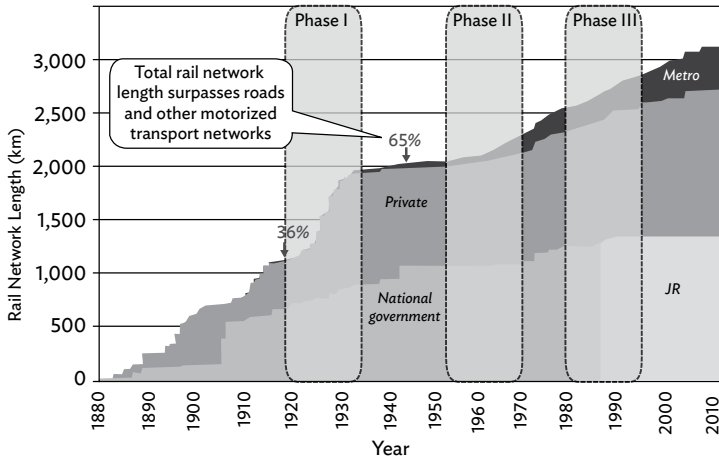


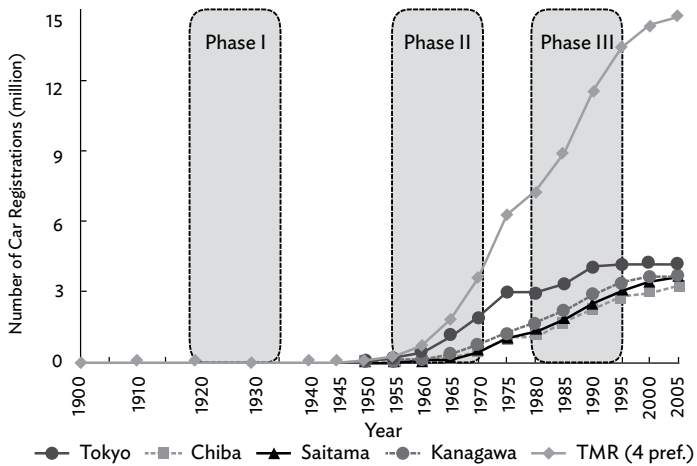
Figure 9.2 Trends of Railway Development in the Tokyo Metropolitan Region, 1880–2010



JR = Japan Railways, km = kilometer.

Source: Adapted from MLIT (2019).

Figure 9.3 Trends in Car Registrations in the Tokyo Metropolitan Region, 1900–2005



TMR = Tokyo Metropolitan Region.

Source: Adapted from MLIT (2019).

Railway development in Tokyo can be summarized into the following four periods:

- (1) Pre-urbanization period: before the 1920s
- (2) Phase I – First urbanization period: 1920–1935
- (3) Phase II – Second urbanization period: 1955–1970
- (4) Phase III – Third urbanization period: 1980–1995

The basic railway network was completed by 1930, and the satellite cities along the routes developed dramatically. Fortunately, the railway transport was completed before the development of road transport.

The private railway companies enthusiastically expanded their network in Phase I. Before 1935, 2,000 kilometers (km) of the railway network were constructed, which is 65% of the present-day network in Tokyo (Figure 9.2). In Phase II, this railway network was fully utilized to address the so-called population explosion problem.

Meanwhile, during the postwar reconstruction, there was a large population movement to the Tokyo Metropolitan Region, which raised the price of land significantly, as a result of which most households had difficulty buying a house. Therefore, the government initiated new town development in the suburban areas of the Tokyo Metropolitan Region, which encouraged railway companies to construct lines along the newly developed towns. Urbanization in the suburbs of Tokyo intensified the congestion in trains. The railway companies developed several models of rail-based development to support the ever-increasing transport demand through continuous improvements in work procedures, increase in transport capacity, construction of new lines, and diversification of the railway business.

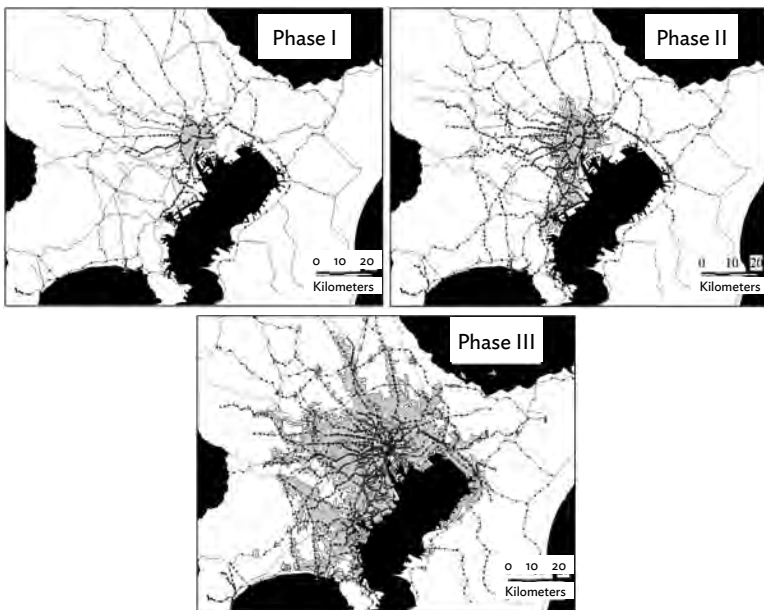
Moreover, as the supply of housing became a major issue, large-scale residential land developments were carried out in the suburbs. Along with such large-scale township development, construction of a new railway line progressed. Accessibility was of paramount importance in the development of the urban transport system of rail corridors. These new railway corridors connected with stations on the central Yamanote loop line and were later developed as transit interchange hubs. These corridors adopted *ensen kaihatsu*, meaning TOD through corridor development along the railway line, the prevalent method of rail corridor development in Japan since the early 1900s. Following the corridor development method, the rail project corridors would have several planned developments in the form of entertainment, leisure, and education districts between the suburban areas (residential) and the central business district (work).

On the other hand, motorization in Japan arrived over 50 years after the United States and did not occur in Phase I (Figure 9.3), although

congestion on city roads increased significantly in Phase II. During the postwar reconstruction period, the government particularly stressed road construction. Consequently, road traffic played a significant role in the urbanization of Tokyo during Phases II and III despite the critical role of railways. Railway companies strive to continue to improve services and introduce new models for further integration and seamless connectivity.

The reason that railways have developed so much is largely because railways historically were operational before the road network. Thus, the efforts undertaken in Phase I formed a rail-based network geometry of the urban region. Subsequent efforts to improve the rail network during Phases II and III were mainly through rail capacity expansion and direct operation from the suburbs to the city center, though these expansions were planned to form key subcenters and hubs (Kii 2001) in the larger Tokyo Metropolitan Region as shown in Figure 9.4.

Figure 9.4 Rail Network Development and Subsequent Urbanization within the Tokyo Metropolitan Region

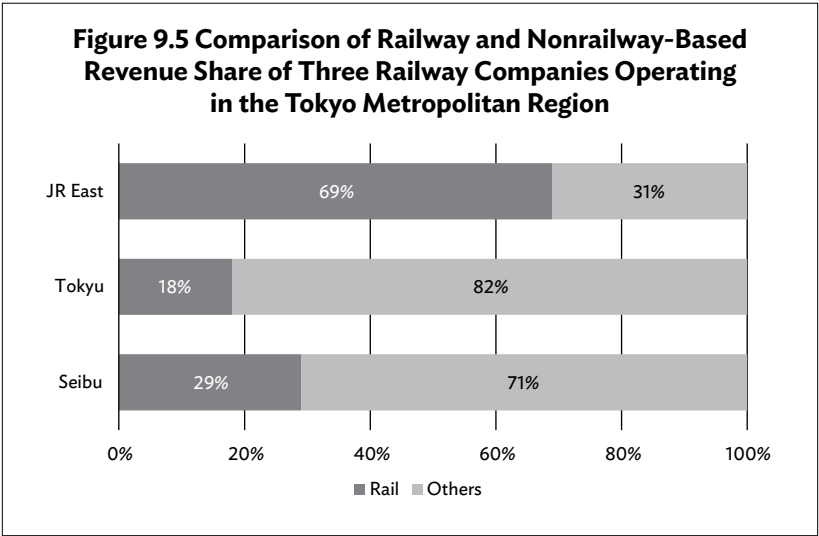


Source: Kii (2001).

9.4 Transit-Oriented Development Policy: An Imperative Shift

The observed relationship between urban development and railway development in Tokyo provides some notable lessons from the city’s TOD. First, to promote and shift to a TOD-based urban policy, promulgate user-friendliness in rail transport to increase the value of railways. Second, transmute the policies to adopt rail-based urban plan preparation resulting in a gradual transformation of the urban structure. Finally, establish collaborative regimes between the railways and the city governments to nurture and form mutually beneficial development businesses.

Japan’s railway system has taken several such measures. First, make railways user-friendly meaning safe, bright, clean, fast, punctual, convenient, cheap, and attractive to users. Second, improve the convenience of railways by continuous development of the railway network. Third, conduct transfer-free operation from the suburbs to the city center, encouraging development of residential areas in the suburbs. Fourth, develop station buildings and utilize the inside of stations, or *eki-naka* developments, to diversify the railway company business. Finally, increase nonfare incomes of the railway company to strengthen the financial base and achieve a sustainable railway business. Figure 9.5



illustrates the revenue gains distribution of railway businesses. The above collectively form the core of the continuous success of railway operations and management businesses.

To shift to a TOD-based policy, it is imperative to bring together actors and stakeholders from railways and city governments. The Tokyo case offers three integral steps to transform urban development: (i) rail-integrated city development plan preparation; (ii) adopting policy to promote rail usage; and (iii) policy cooperation beyond the limits of political and territorial administration.

9.5 Conclusion

Urban development using railways is beneficial for urban transportation, socioeconomic development, and environmental protection, although rail-based development is difficult to adopt—and realizing the effects often takes several decades.

While railway infrastructure investments are integral transport investments, they alone do not promote rail-based city development. It is necessary to construct access roads and simultaneously develop other connections to form a system—and such systems often demand a robust policy framework. However, city plans in emerging economies need to adopt a station-centered city development approach. The experience of Japan illustrates that adopting a station-centered city development approach initiates a change in user demand, enhances accessibility through supporting infrastructure, and thus promotes a rail-based urban structure.

However, cooperation among stakeholders is a crucial factor for the development of a rail-oriented city. Adopting a piecemeal approach in the cooperation may not help in realizing these policies. Nevertheless, cooperation beyond territorial and administrative barriers will remain the starting point, including developing collaborative planning systems and innovative finance distribution models. Strategic remodeling of a city is a prolonged process, although a rail-based city would secure preeminence in urban transportation, possess distinct socioeconomic development aspects, reduce the environmental impact, and possess long-term sustainable benefits to add to the quality of life of its citizens.

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10

Optimizing Station Location Based on Accessibility and Environmental Impacts

Sandeepan Roy and Avijit Maji

10.1 Introduction

High-speed rail (HSR) services are train services that operate at speeds in excess of 200 kilometers per hour, on exclusive or grade-separated rights-of-way (European Union 1996). They provide short and competitive travel time between strategically important locations. HSR planners identify regions or major cities that have adequate gross domestic product, population, and ridership potential, and that satisfy interstation distance and travel-time requirements (Takeshita 2012). An HSR line is developed by identifying appropriate locations for terminal and intermediate stations and connecting them with suitable alignment. The determination of station locations is not always a straightforward problem. In addition to optimizing ridership and travel time, planners aim to select locations that optimize the overall utility or benefit of the stations for the adjacent environment and population. This is achieved by satisfying various desirable requirements: improved access to, and intermodal integration with, existing transportation facilities and services (airports, train stations, bus stops, etc.); avoiding environmentally sensitive land parcels (water bodies, wetlands, forest, etc.) and land with higher right-of-way costs; and meeting strategic necessities such as proximity to city centers and socioeconomic development hubs. The existing station location identification process is manual in nature and carried out during the planning stage of HSR development. It involves identifying locations by overlaying maps of the study area with relevant information regarding locations of the transportation facilities, residential population distribution, land use details, geographic features, and so on. This approach indirectly factors in certain desirable requirements but

cannot always guarantee a station location with maximum utility because not all feasible locations will be evaluated and no exact quantification of utility is available.

Geographic information systems (GIS), with their advanced mapping, geo-processing, and visualization capabilities, could be used in the spatial analysis of potential station locations. GIS data, in the form of maps of land use and land cover, property data, and other facility locations within the study area, could be utilized in the process. A model that quantifies the desirable requirements and presents as a utility score would greatly benefit planners by helping them identify optimal station locations within potential HSR regions. Hence, the objective of this chapter is to develop a GIS-based HSR station location optimization model. For this purpose, an analytical model is specifically developed to identify a pool of candidate locations for HSR stations by quantifying the desirable requirements. Overall, it helps in identifying the station location with the highest utility. The desirable requirements of HSR station locations are estimated using utility functions and integrated into the GIS-based analytical framework. A real-world case study is presented to demonstrate the efficacy of the proposed model.

10.2 Literature Review

Station location identification is a facility location decision or analysis problem. The aim of this type of problem is to find the optimal feasible location for a facility that satisfies various predetermined selection criteria. The easiest way to identify feasible locations for stations is by using the simplest suitability analysis or map-algebra approach (McHarg and Mumford 1969). The map-algebra approach for a potential location involves measuring some form of accessibility score (and/or available utility value) (Cervero, Rood, and Appleyard 1999) using distance decay functions (exponential, power, binary, kernel form, etc.) (Kronbak and Rehfeld 2000; Skov-Petersen 2001; Hipp and Boessen 2017) based on the existing residences (or services and facilities) located elsewhere. There are various studies on location decision problems with small numbers of pre-identified feasible locations (Vorhauer and Hamlett 1996; Baban and Parry 2001; Vlachopoulou, Silleos, and Manthou 2001). In such studies, no further analysis or modeling was necessary apart from the suitability analysis. However, selecting one alternative over another becomes difficult when problems have large numbers of available feasible locations. Extensive location-allocation modeling, apart from the suitability analysis, is necessary in such cases (Murray 2010). These models attempt to find the best facility locations by optimizing one or more objectives (minimum weighted distance, minimax distance,

maximum utility, capacity constraint, etc.) (Fisher and Rushton 1979). Researchers obtained the optimal location for a facility by minimizing the maximal service distance required to reach the facility (Church and ReVelle 1974), by maximizing the expected profit of a convenience store in a region (Ghosh and Craig 1984), by maximizing the utility measured as a function of facility attributes and distance to the location (Drezner 1994; Drezner and Drezner 1996), by maximizing the total budget share of retail facilities under budget constraint (Drezner 1998), and by minimizing the weighted distance from demand points to the facility location (Yeh and Chow 1996; Church 1999). Numerous possible combinations should be examined to obtain the best solution to solve these types of problems.

Previous studies assumed the possible location of stations as *a priori* information (Bruno, Gendreau, and Laporte 2002; Schöbel 2005; Laporte et al. 2011). Also, the local attribute details of a study area, such as right-of-way cost details, accessibility from existing public transportation facilities, environmentally and geographically sensitive locations, and availability of sufficient land for station location, were excluded to simplify the problem (Bruno, Gendreau, and Laporte 2002; Schöbel 2005; Repolho, Antunes, and Church 2013). These simplifications of relevant information could yield suboptimal results. Certain studies integrated study area information from an urban rail perspective. However, there was no exclusive literature on HSR station locations. Therefore, a methodology to identify a feasible station location would be greatly useful in the HSR planning process. It should include various desirable requirements and constraints to assist in quantifying the desirable requirements by means of utility functions and thus help in identifying the station location with the most utility. GIS can be particularly useful in developing such a methodology due to its advanced geo-processing, mapping, and visualization capabilities in managing various data types (such as property data, land use and land cover maps, maps showing other important facility locations, and demographic information). Hence, the aim of this chapter is to develop a GIS-based HSR station location identification model that considers relevant desirable requirements and constraints.

10.3 Desirable Requirements and Constraints for High-Speed Rail Station Locations

HSR station locations typically need to satisfy certain desirable requirements based on accessibility, environmental concerns, geographic and spatial concerns, and physical requirements and conditions. These

requirements can be represented mathematically and used in developing suitable utility functions to check the feasibility of a candidate site location. In this study, the main focus is on environmental and accessibility-based requirements. These desirable requirements, their mathematical representations, and the utility functions are as follows:

- Stations should avoid environmentally sensitive areas (e.g., forests and wetlands), topographically infeasible areas (e.g., lakes and rivers), and historically sensitive areas (e.g., cemeteries, places of worship, historical sites, and ruins). Let C_{sa} and S_{if} be the study area and the set of infeasible locations or areas, respectively. Then the feasible set of station locations S_f can be represented as follows:

$$S_f = (C_{sa} \cap \overline{S_{if}}) \quad (1)$$

where S_f is a set of feasible station locations.

A sharp threshold value can be assigned to avoid environmentally sensitive regions. This type of model is known as an isochronic definition (Cervero, Rood, and Appleyard 1999) or cumulative opportunities measure (Handy and Niemeier 1997). A binary model can be introduced to assign a fixed value of 1 and 0 to the locations which are feasible and infeasible, respectively. Let G_i denote the candidate station location. The binary model can be represented as follows:

$$\gamma_i = \begin{cases} 1 & \text{if } G_i \in S_f \\ 0 & \text{if } G_i \in S_{if} \end{cases} \quad (2)$$

- Terminal stations (stations at both ends of the corridor) should be located close to the city center or downtown area of large regional cities to enhance the ridership potential (Menéndez et al. 2002). Let D_i be the distance of candidate station G_i from the downtown area, and D_{th} be the threshold distance from downtown. This distance should be less or equal to the threshold distance as follows:

$$D_i \leq D_{th} \quad (3)$$

A sharp threshold value can be used to model the proximity of station locations to the city center or downtown area. A binary

model can be formulated to assign a fixed value (1 or 0) to the locations closer than the given threshold value:

$$U_{i1} = \begin{cases} 1 & \text{if } D_{ij} \leq D_{Th} \\ 0 & \text{if } D_{ij} > D_{Th} \end{cases} \quad (4)$$

- Stations should avoid locations with extensively developed neighborhoods that have very high right-of-way costs. Since the region encompassing the station locations might have a high variance of land cost, a utility function based on a normalized cost (the values would be in the range [1,0]) can be formulated as follows:

$$U_{i2} = \left(1 - \frac{C_{ijROW} - C_{iMin\_ROW}}{C_{iMax\_ROW} - C_{iMin\_ROW}}\right) \quad (5)$$

where:

- C_{iROW} = cost of land or right-of-way cost for candidate station G_i ;
- C_{Min_ROW} = minimum cost of land or right-of-way cost; and
- C_{Max_ROW} = maximum cost of land or right-of-way cost.

- Stations should be located near existing transportation facilities (e.g., airports, railways, bus stops, and highways) for ease of accessibility and intermodal integration. Let D_i^m be the distance of candidate station G_i from the existing transportation facility m , and D_w be the threshold average walking distance, then, as per the accessibility requirements, it is represented as follows:

$$D_i^m \leq D_w \quad (6)$$

Distance decay functions are commonly used to model accessibility of facilities in spatial analysis (Skov-Petersen 2001). Hence, a utility function can be modeled using equation 6, which assigns the maximum utility value, i.e., 1, on satisfying the accessibility criteria, and a continuously decreasing utility value up to 0, with increasing distance as follows:

$$U_{i3} = \begin{cases} 1 & \text{if } D_i^m \leq D_w \\ \frac{1}{e^{\left(\frac{D_i^m}{D_w} - 1\right)}} & \text{if } D_i^m > D_w \end{cases} \quad (7)$$

10.4 Problem Formulation

The objective of the study is to optimize the station location by satisfying the desirable requirements. A positive utility score can be assigned to each location in the study area, which is estimated using the utility functions developed for each desirable requirement. Relevant weights are assigned to each desirable requirement j . The summation of all weights is equal to 1. Therefore, the utility score for each location would be the weighted summation of positive scores, based on the number and extent of desirable requirements satisfied. The problem can thus be formulated as the maximization of this total utility score for candidate station locations in the study area. The station location identification is thus formulated as a mixed-integer programming problem:

$$\text{Max } \sum_{i=1}^{ng} \sum_{j=1}^{nj} \alpha_i * \gamma_i * W_j * U_{ij} \quad (8)$$

subject to

$$\sum_{j=1}^{nj} W_j = 1, 0 < W_j < 1, \quad (9)$$

$$0 \leq U_{ij} \leq 1 \quad (10)$$

where:

$$\alpha_i = \begin{cases} 1 & \text{if location } i \text{ is selected;} \\ 0 & \text{otherwise} \end{cases};$$

U_{ij} = utility score based on desirable requirement j for location i ;

W_j = weightage assigned to requirement j ;

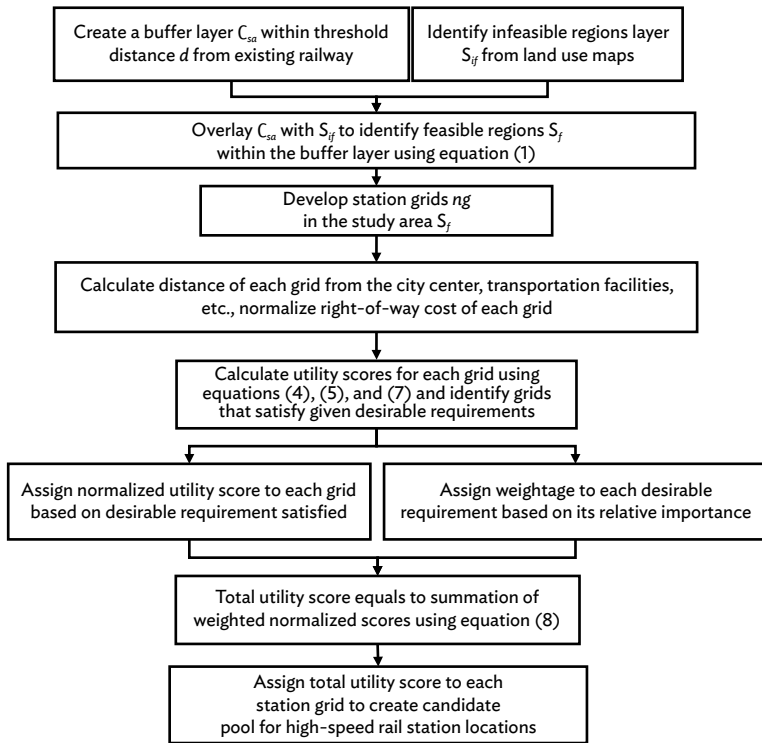
ng = total number of candidate locations in study area; and

nj = total number of desirable requirements for station location.

10.5 Methodology

Infeasible locations are identified *a priori* and screened out from the study region. Subsequently, the feasible region is divided into grids of sizes equal to station location areas. A positive utility score is assigned to each feasible grid location for each desirable requirement considered. Relevant weights are assigned to each desirable requirement, based on their relative importance. The total utility score for each feasible station location is thus calculated as the weighted summation of the positive scores assigned to a station location. The various steps of the station location identification process are illustrated in Figure 10.1. The station locations that have a total utility score close to 1 are the most suitable for HSR station locations.

Figure 10.1: Data Preparation and Initial Screening for High-Speed Rail Station Locations



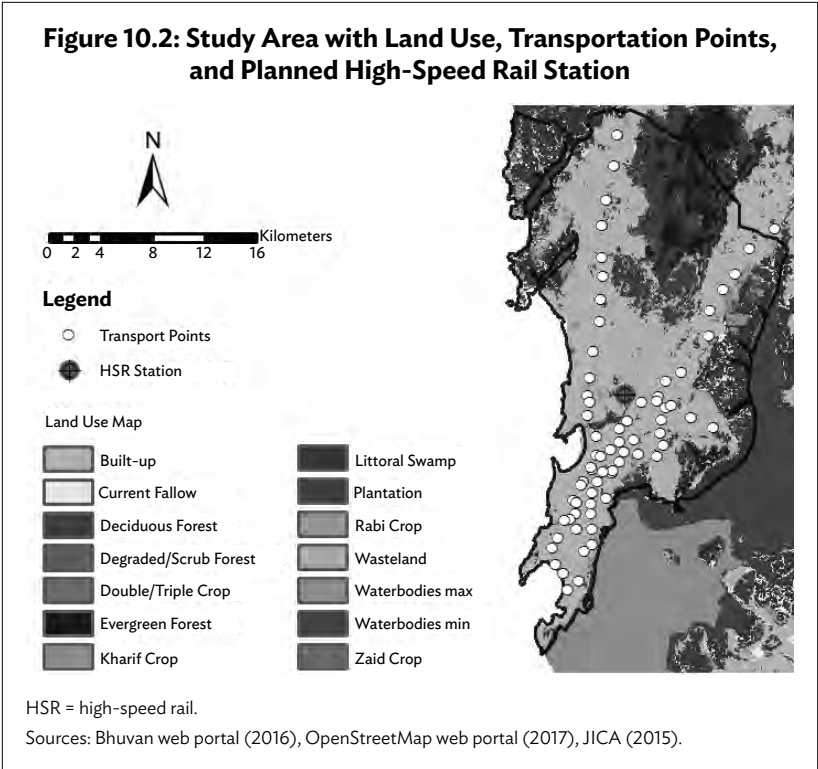
Source: Model developed by authors.

10.6 Case Study

The proposed Mumbai–Ahmedabad HSR corridor connects Ahmedabad in the state of Gujarat with Mumbai, India’s economic hub, in the state of Maharashtra. It will be the country’s first HSR line. Mumbai is chosen as a case study. The city is densely populated with a well-connected transportation network and variable land cost. The data collection process, type, usage, and sources of data collected for this study are described in the subsequent subsections. The data collected were processed, and GIS operations were applied accordingly for further analysis.

Land use and land cover map data. Land use data in the form of raster maps in GeoTiff format, with a 1:250,000 resolution, were downloaded from the Bhuvan web portal (2016). The land use and land cover maps had 18 classifications. The maps were used to identify environmentally sensitive areas, such as forests, rivers, wetlands, and swamps. These land use categories were extracted in GIS and used as the infeasible layer.

GIS shapefiles. GIS data in the form of vector shapefiles were downloaded from the OpenStreetMap web portal (2017). This included point shapefiles for locations; transportation points (bus stops, railway stations); polyline shapefiles for railways, highways, and road networks; and polygon shapefiles for buildings, political or administrative boundaries, and water bodies. The shapefile showing the administrative boundaries was used to generate a grid layer with user-specified grid size. Figure 10.2 shows the study area with land use information, the locations of the existing transportation points, and the planned HSR station.



Property data. Data on urban land property costs were downloaded from property brokerage websites (99acres 2017; Magicbricks 2017). These rates were used to calculate the possible price of land by using the following equation (Chakravorty 2013):

$$C_{iROW} = (C_{iProp} - C_{CC}) * FSI \quad (11)$$

where:

C_{iROW} = possible price of land or right-of-way cost for grid G_i ;

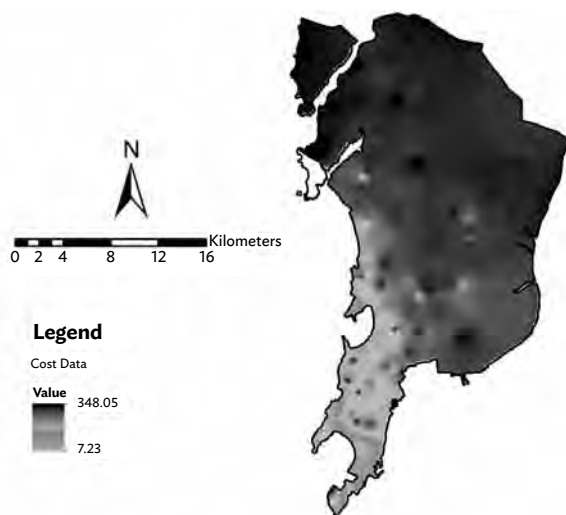
C_{iProp} = cost of the property for grid G_i ;

C_{CC} = construction cost; and

FSI = floor space index.

Vector shapefiles in the form of points were created throughout the study area using ArcGIS 10.2. The data on land prices obtained from equation 11 were input as attribute data for point shapefiles at respective locations. These data were then interpolated to get the price of land for urban and built-up areas for the entire study area. Figure 10.3 represents the raster cost dataset obtained for the study area. Table 10.1 shows the parameters used in this case study.

Figure 10.3: Raster Cost Dataset



Source: Results interpolated by authors, derived from equation (11).

Table 10.1: Parameters and Corresponding Values

Description	Parameter	Value	Source
Threshold distance for the buffer layer	d	13 kilometers	RITES (2013)
Grid size for station locations	Ar_G	70 acres, 15.35 acres	Brinckerhoff (2004)
Threshold average walking distance	D_w	400 meters	Guerra, Cervero, and Tischler (2012)
Threshold distance from the downtown area	D_{Th}	3 kilometers	Authors' assumption

Source: Compiled by the authors.

Weightage assigned for desirable requirements. Nine different weightage scenarios were considered to determine the effect of the weightage assigned on the utility of a location. Each scenario had a separate set of weightage assignments for the respective desirable requirements. Each of these sets of weightages was then used to evaluate the utility scores. The resulting utility scores were then compared to find the weightage set that maximized the utility score. The most suitable weightage assignment should maximize the total utility for the actual stations selected.

Table 10.2 shows the weightage assignment for all the scenarios considered in this study. Proximity to the city center was given the highest weightage in scenario 1. The next highest weightage was given to the cost of land and accessibility to existing transportation points, to avoid land with very costly right-of-way and to have ease of access, respectively. Similar to the base scenario, proximity to city center was assigned the highest weightage in scenario 2. The next highest weightage was given to accessibility to existing transportation points and cost of land. The cost of land was given the lowest weightage. In scenarios 3 and 4, the highest weightage was assigned to accessibility to existing transportation points. The next highest weightage was assigned to cost of land, for scenario 3, and proximity to city center, for scenario 4, respectively. The highest weightage was assigned to cost of land, followed by proximity to city center, for scenario 5, and accessibility to transportation points, for scenario 6, respectively. Proximity to city center was assigned the total weightage, in scenario 7. Similarly, cost of land and accessibility to existing transportation points were assigned the total weightage in scenarios 8 and 9, respectively.

Table 10.2: Weightage Assigned for Desirable Requirements

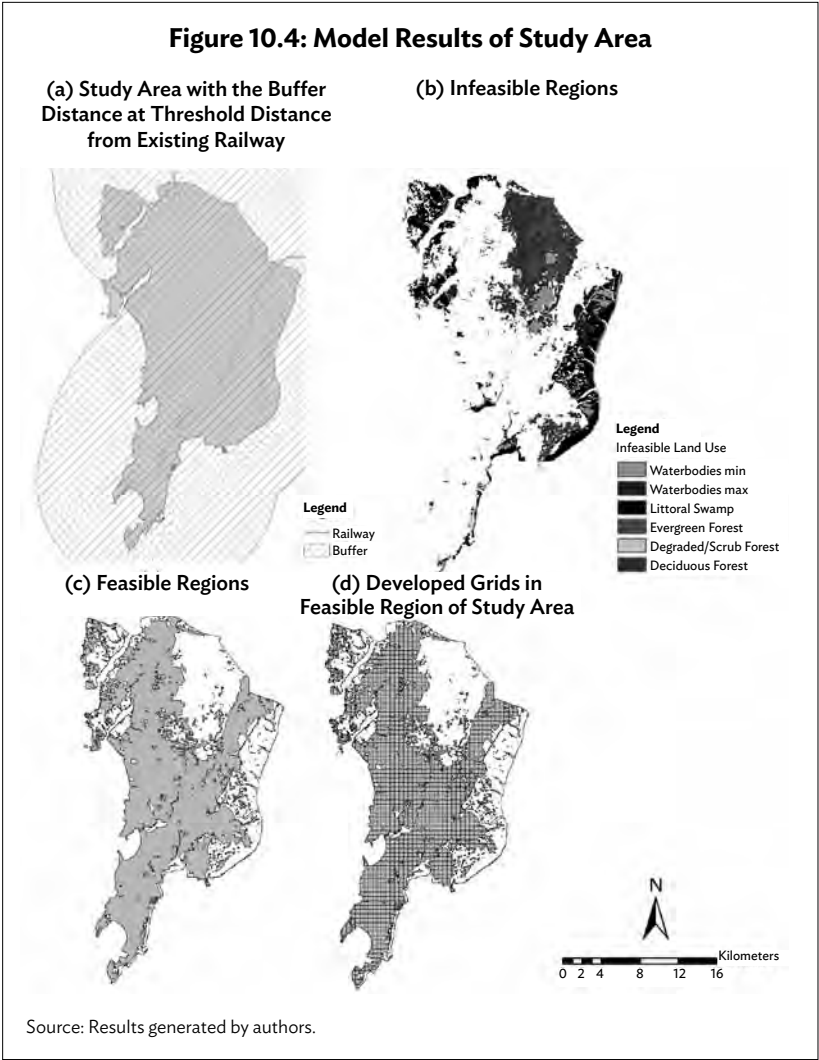
Notation	Desirable Requirement	Weightage								
		S1	S2	S3	S4	S5	S6	S7	S8	S9
U_{i1}	Close proximity to the city center	0.5	0.5	0.2	0.3	0.3	0.2	1	0	0
U_{i2}	Avoiding high right-of-way cost	0.3	0.2	0.3	0.2	0.5	0.5	0	1	0
U_{i3}	Accessibility to existing transport points	0.2	0.3	0.5	0.5	0.2	0.3	0	0	1

Source: Weightage scenarios considered by authors.

10.7 Results

This section presents the step-by-step geo-processed results obtained when the proposed model was applied to the study area data. Figure 10.4(a) shows the study area along with the buffer distance at a threshold distance from the existing railway. Figure 10.4(b) shows the infeasible regions obtained from the land use data. When these two data layers were overlaid, the feasible regions of the study area were obtained. Figure 10.4(c) shows the feasible regions identified from the study area. The station grid locations were then developed from the feasible regions using the grid size mentioned earlier. Figure 10.4(d) shows the developed grids in the feasible region of the study area. These were the candidate locations for HSR stations. Figure 10.5(a)–(c) show the normalized individual utility scores for the feasible regions of the study area. Individual desirable properties and respective utility score variation can be observed. Figure 10.5(a)–(c) show the variation of the utility score for the feasible regions with respect to city center proximity U_{i1} , avoiding high right-of-way cost U_{i2} , and accessibility to existing transportation points U_{i3} , respectively. The total utility score of all the locations in the feasible region of the study area (i.e., the weighted summation of the normalized utility scores) was obtained based on the weightage assignment provided in Table 10.2. It is displayed in Figure 10.6(a). The total utility score obtained for the feasible regions was then assigned to each grid location to create a candidate pool for HSR station locations. Figure 10.6(b) and (c) show the candidate pool for station locations after the scores were assigned to the grids having different grid sizes. Figure 10.7 shows the variation of the total

utility score for the various weightage assignments given in Table 10.2. Table 10.3 shows the value of each of the desirable requirements satisfied along with the respective individual utility score for the planned HSR station location in Mumbai.



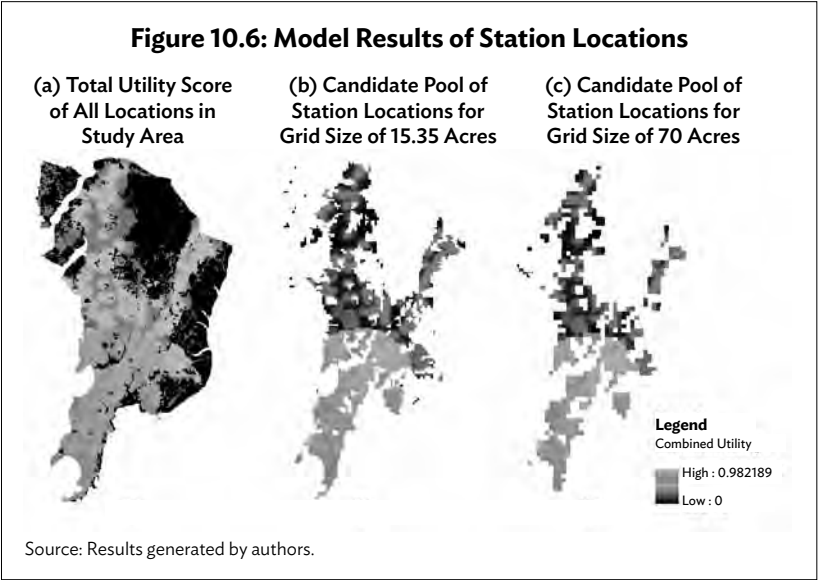
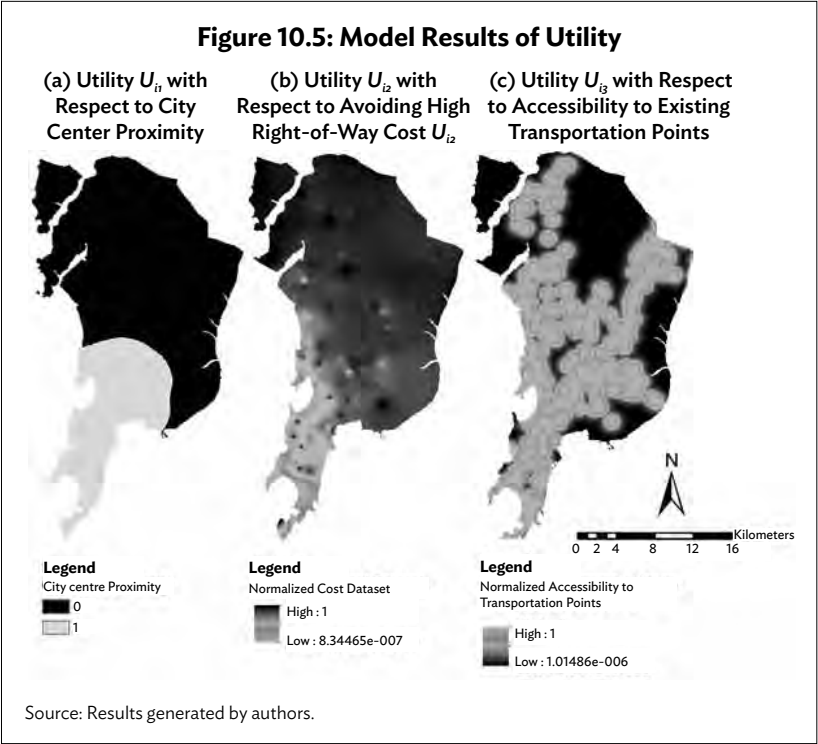
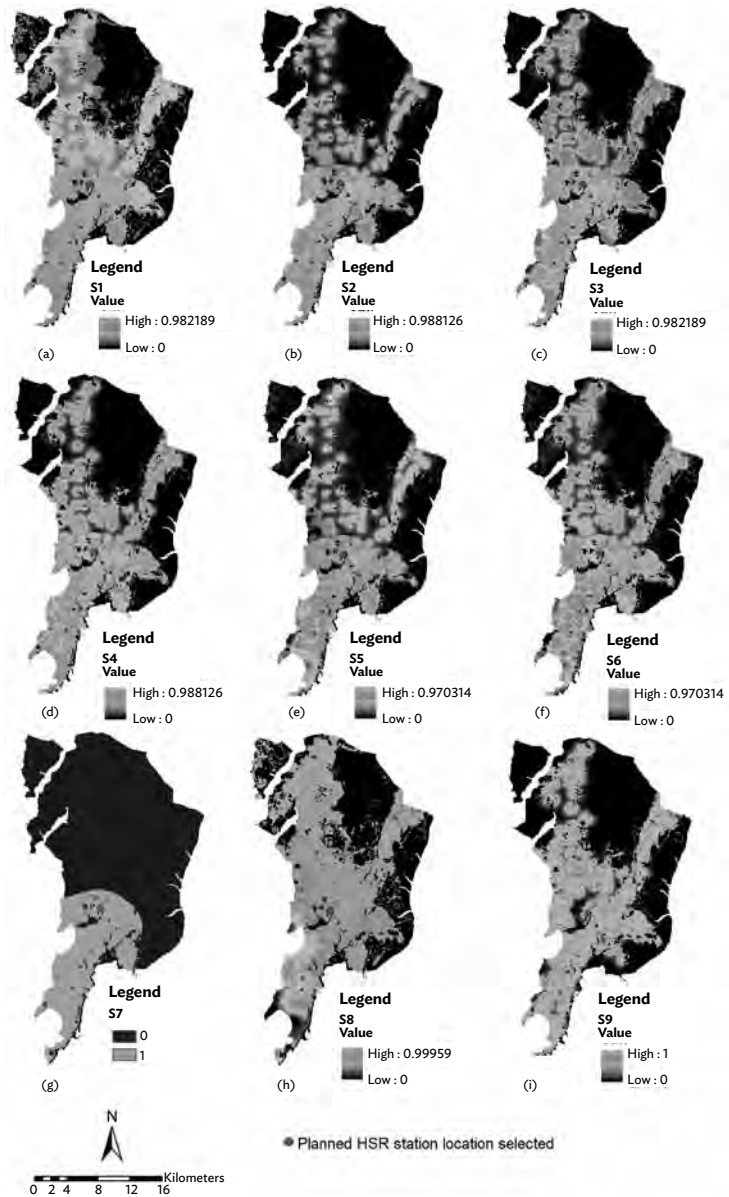


Figure 10.7: Variation of Total Utility Scores for Different Weightage Assignment for Mumbai



HSR = high-speed rail.
Source: Results generated by authors.

Table 10.3: Variation in Total Utility Scores for Different Weightage Assignments

Desirable Requirement	Desirable Requirement Values	Individual Utility Score	Weightage Assignment	Total Utility Scores
Close proximity to the city center (kilometer)	0.36	$U_{i1} = 1.00$	S1	0.930
			S2	0.850
			S3	0.931
Avoiding high right-of-way cost (₹ million per acre)	879.2	$U_{i2} = 0.768$	S4	0.904
			S5	0.824
			S6	0.884
Accessibility to existing transport points (walking distance) (meter)	300	$U_{i3} = 1.00$	S7	1.00
			S8	0.768
			S9	1.00

Source: Results generated by authors.

Table 10.3 shows that the station location selected is at close proximity to the city center (less than 3 kilometers) and is within accessible walking distance from the existing transportation points (within 400 meters). Hence, the station location was given the highest possible individual utility score, i.e., 1, for both desirable requirements (U_{i1} , U_{i3}). It also can be seen that the right-of-way cost for the selected station location is ₹879.2 million per acre, which is neither the lowest cost (₹3.68 million per acre) nor the highest (₹3,000 million per acre). Hence, the utility score was neither 1 nor 0. Further, it shows the variation of utility scores as they pertain to different assigned weightage for the planned HSR station location in Mumbai. It is evident from Table 10.3 that the station location selected for this case study reports high utility scores for each of the assigned weightage, the lowest being 0.768 for S8, where the right-of-way cost has the highest weightage. This station location completely satisfies two desirable requirements (accessibility and proximity to the city center) and partially satisfies the third desirable requirement (right-of-way cost). Also, the selected station location in Mumbai is not on environmentally sensitive land. Hence, it can be concluded that the station locations selected for the given case study should provide high utility to the adjacent population, based on accessibility, land cost, proximity to the city center, and environmental impact factors.

10.8 Conclusion

HSR station locations are vital as they provide access to the riders, serve as multimodal transportation hubs (with connections to regional and local transit), and are prime locations for transit-oriented development. This chapter presents a GIS-based analytical model that optimizes the desirable requirements that are specific to station location. These include—though are not necessarily limited to—improved accessibility and intermodal integration with existing transportation facilities and services, avoidance of environmentally sensitive areas and land with higher right-of-way costs, and other strategic necessities. Suitable utility functions are developed to estimate the utility of a candidate location associated with its respective requirements, which are integrated into the identification process of station locations. Appropriate weights are assigned based on the relative importance of each requirement. The overall utility of a location is then estimated as the weighted summation of these utility scores. In other words, our study quantifies the overall utility of an HSR station by analyzing the extent to which a location satisfies these desirable requirements, using appropriate utility functions and weightages. These vital components were mostly ignored in previous HSR models.

The developed methodology demonstrates how an available GIS database can be used in the real-world planning stage of the development of an HSR project. Station location identification is modeled and covered in this methodology, which is a primary aspect of HSR development. This utility-based quantification methodology has the capability of easily identifying feasible station locations in the HSR corridor. Such quantification can be used by the planners for further analysis and station location selection. This study demonstrates the applicability of the methodology in HSR planning, using the city of Mumbai in India as a case study. The results obtained are compared with the planned real-world station location identified for the city of Mumbai and show promising results. The developed methodology is expected to help the planners in identifying station locations, in particular, and their overall planning of HSR, in general.

The future scope of work in this methodology could be the inclusion of additional socioeconomic requirements relevant for station locations, modeling, and examining subsequent steps of HSR development. These steps include using the configuration of stations to develop an HSR alignment for the corridor.

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11

Metropolitan Travel and Land-Use Impacts

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11.1 Introduction

India has a wide network of rail routes spread across the country. The Indian rail system is the fourth largest in the world by size, covering around 68,000 kilometers (km) of route length. Based on the sanctioned speeds, rail lines are classified into four categories, details of three of which are given in Table 11.1. Even though the sanctioned speeds for these lines are good enough, the realized journey speeds are very low.

High-speed rail (HSR) is a type of rail system that operates significantly faster than the traditional rail system. After its inception by Japan in 1964, many economies have adopted this emerging technology, including France; Germany; the People's Republic of China (PRC); the Republic of Korea; the Russian Federation; Taipei, China; Turkey; the United Kingdom; and the United States. The PRC has the biggest network of HSR in the world. In fact, in Europe, HSR crosses

Table 11.1: Classification of Indian Rail Lines
(kilometer per hour)

Line Classification	Sanctioned Speed	Realized Journey Speed
Group A	160	80–100
Group B	130	65–75
Group D	110	55–65

Note: Suburban sections of Mumbai, Delhi, Chennai, and Kolkata are classified as Group C lines.

Source: <http://www.indianrailways.gov.in>

international borders. In India also, the National High Speed Rail Corporation Limited has undertaken the task of implementing an HSR corridor between Mumbai and Ahmedabad with the help of the Japan International Cooperation Agency. This so-called Mumbai–Ahmedabad “bullet train” will run at an average speed of 320 km per hour and a maximum speed of 350 km per hour, covering the 508 km stretch in less than 3 hours. It will stop at 12 railway stations on the route, but only for 165 seconds each.

Civil aviation in India is the third largest in the world and is growing at a rate of 17%–22% per annum. Considering that HSR railway stations are usually built closer to city centers than airports are, the HSR has a travel time advantage over planes for distances less than 1,000 km (Givoni 2006). Thus, there is a possibility that many air passengers will shift to the Mumbai–Ahmedabad HSR for commuting purposes. Evidence from five existing European HSR plans demonstrates that around 30% of the HSR demand is the shift from air, 15% from road, 30% from conventional rail, and 25% from induced traffic (Preston, Albalade, and Bel 2013). A similar trend is expected to be followed in India as well.

Due to overcrowded mass transit systems and congestion on the roads coupled with the higher financial status of people in Mumbai, a considerable number of commuters will be expected to shift to HSR. This will cause peak hour relief for the mass transit systems, but it will also affect business travelers who want to travel from Mumbai to Ahmedabad. Thus, this study examines the variation in the ridership of metro, suburban rail, bus, and other public transport systems in the Mumbai Metropolitan Region (MMR) due to the introduction of HSR. People’s decisions to purchase houses are based on social infrastructure, travel time to workplaces, and affordability. However, when housing is excessively expensive in core city regions, individuals are compelled to either travel long distances from rural or suburban areas or to live in compromised slum-like situations inside the core metropolitan area. Due to high land use prices inside MMR, more people are moving to the outskirts, and this is also being supported by government schemes such as Pradhan Mantri Awas Yojna for affordable housing for the urban poor. This study evaluates the improvement in accessibility of such peripheral areas due to the proximity of HSR stations and the associated impact on the current intense activity areas of the region.

11.2 Literature Review

One of the main objectives of this study is to determine the improvement in accessibility in the peripheral region of MMR due to the introduction

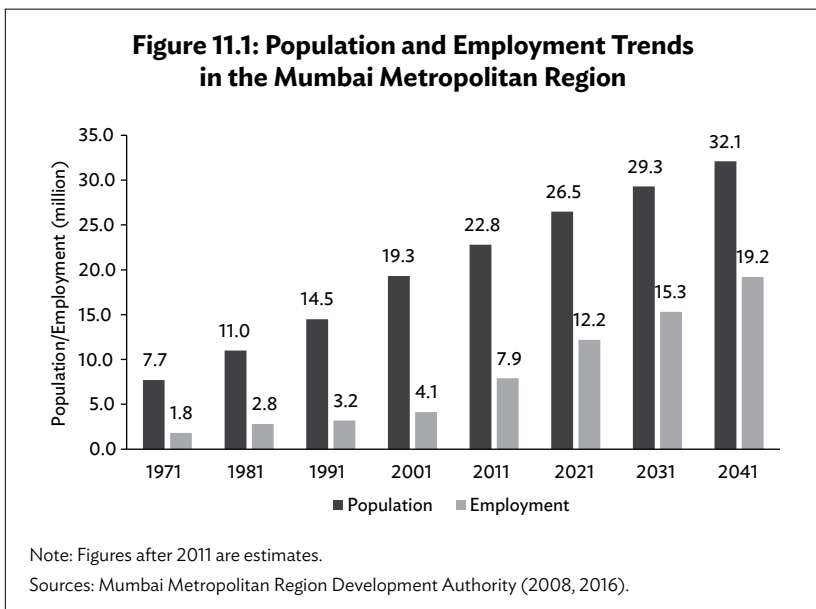
of HSR. Hansen (1959) defined accessibility as the opportunity which an individual at a given location possesses to take part in a particular activity or set of activities—that is, a facility connected to a large number of commercial, residential, and industrial places will have high accessibility.

Construction of the HSR requires a huge economic investment and hence is expected to increase economic development. For this to happen, an improvement in accessibility and other measures conducive to economic growth are required (Banister and Berechman 2000). For this reason, researchers have conducted preliminary analyses to assess the accessibility impact of HSR. Martínez Sanchez-Mateos and Givoni (2012) used travel time to London as a primary criterion to measure the accessibility of HSR stations in the United Kingdom. Cao et al. (2013), Kim and Sultana (2015), Wang et al. (2016), Jiao, Wang, and Jin (2017), and Yu and Fan (2018) used the weighted average travel time and potential accessibility indicators. The weighted average travel time gives the accessibility in terms of travel time, while the potential accessibility describes the ease with which travel can be done from origin to destination in terms of friction in distance. Xu et al. (2018) combined a connectivity indicator with Hansen's accessibility to evaluate the impact of HSR in terms of connectivity and accessibility. The formulation of Hansen's accessibility is very similar to the potential accessibility. In addition to the deterrence function, the travel time component can also be taken into consideration. Thus, considering geographic spread, the alignment of the Mumbai–Ahmedabad HSR, and the availability of data, Hansen's accessibility potentially is a very good measure for the present study. Also, most studies have been done at an aggregate level with the complex HSR network being considered. The literature review for this study revealed no study that has evaluated the improvement in the accessibility of a small region due to a single HSR line. Jiao, Wang, and Jin (2017) concluded from their study that HSR in the PRC has definitely helped improve the connectivity of the cities. Kamga (2015) reported that, in the United States, HSR could complement airplanes, conventional rail, and cars, and help rebalance these modes so that each is used in the most efficient and suitable niche. For Mumbai–Ahmedabad, Pal (2016) estimated that 39% of the HSR demand would be from classic rail, 39% from bus, 13% from air, and only 9% from car, assuming no generation or changes in modal shares due to other factors (such as income growth). However, looking at existing travel between Mumbai and Ahmedabad, it is hard to believe that introducing HSR will not induce travel. This study, to some extent, helps future researchers re-examine this assumption by considering the impact of HSR on metro and suburban rail in MMR.

11.3 Study Area

The area of interest for the current study is the Mumbai Metropolitan Region, a metropolis in the state of Maharashtra, consisting of the financial capital of India, Mumbai, which is also the state capital. MMR is the biggest urban conglomeration in India and one of the most populous metropolises in the world. Spread over an area of 4,355 square kilometers, it comprises 8 municipal corporations and 15 smaller municipal councils and covers five districts (Mumbai City, Mumbai Suburban, parts of Thane, Raigad, and Palghar). With a population of more than 22 million—and a forecasted population of 29.3 million by 2031—the region has witnessed unprecedented economic development in the past. This has laid the foundations for the growth to continue in the future, mainly due to the presence of the financial capital of India, its strategic location giving it an advantageous access to the western world, and the flourishing growth centers and special economic zones that are on the rise in the region.

Population and employment growth for MMR in the past and the future are represented in Figure 11.1.



The continuous large-scale immigration of people into MMR has taken its toll on the transportation infrastructure of the region. The suburban network, the lifeline of the city, is already operating at a super-dense crush load, carrying over 8 million passengers per day. Brihanmumbai Electric Supply and Transport, which is the primary bus service in Mumbai, has a fleet of 3,600 buses carrying 2.5 million passengers on over 445 routes. There are also other public bus services such as Thane Municipal Transport, Navi Mumbai Municipal Transport, Kalyan-Dombivali Municipal Transport, and Mira-Bhayandar Municipal Transport, which make travel convenient in Mumbai. Auto-rickshaws and taxis provide last-mile connectivity and also act as feeders to public transit. The metro network in Mumbai is planned to be built in three phases over 15 years. With only one metro line, 11.4 km long (Versova–Andheri–Ghatkopar) being operational at present, a large network (i.e., about 230 km of metro systems) is planned to ease the commuting across the entire MMR by 2025.

11.4 Methodology

The objectives of this study are twofold: (i) an assessment of variations in the ridership of metro and suburban rail systems with and without HSR and (ii) an evaluation of improvements in accessibility due to the introduction of HSR. In order to achieve these objectives, a robust travel demand model is the prime requirement. Hence, a four-stage travel demand model for MMR is developed using the state-of-the-art CUBE voyager platform. This model is based on the Comprehensive Transportation Study conducted by the Mumbai Metropolitan Region Development Authority (MMRDA) in 2008.

11.4.1 Travel Demand Modeling

The methodology for developing the four-stage model and its application for estimating the ridership on various public transit systems including HSR follow four steps:

- (1) base year origin–destination (OD) matrices generation and validation,
- (2) travel demand model development,
- (3) travel demand forecasts for horizon year 2041, and
- (4) estimation of metro and suburban corridors' ridership with and without HSR.

The following sections briefly describe each of these steps.

Base Year Origin–Destination Matrices Generation and Validation

The base year for this study is 2018. The base year travel pattern is obtained by using the available travel demand model, which was developed by the MMRDA. Population, employment, and vehicle ownership are the planning variables used for the base year in the trip generation analysis. These OD matrices, obtained after applying the trip distribution and mode choice models, are then validated using the traffic volume count data on selected links of the study area.

Travel Demand Model Development

The internal passenger travel of MMR is obtained using recalibrated trip end models with planning variables and the validated base year OD matrix from the first step. For trip distribution, a single gravity model is recalibrated with the help of validated trip ends and generalized cost skims. Generalized cost skims are obtained as initial values from the assignment process. Cost skims are revised after successive iteration of modal split and traffic assignment to calibrate the gravity model. In order to find the share of public transport and private vehicles, a basic logit model is used. The logit model mainly consists of transport system attributes. Person-trips by private vehicles such as cars and two-wheelers are included in the private vehicle matrix. Person-trips by public transit such as bus, rail, auto, and taxi are included in the public transport matrix. Calibration of the mode choice model is based on cost skims obtained from trip assignment. During the assignment step, the peak hour public transport matrix is assigned on the public transport network. The public transport network consists of (i) all bus routes of Brihanmumbai Electric Supply and Transport, Navi Mumbai Municipal Transport, Thane Municipal Transport, and Kalyan-Dombivali Municipal Transport; (ii) intermediate public transport routes coded on the road network; and (iii) the railway network, which includes suburban rail and metro with all the existing links. The generalized time is the basis of public transport assignment, which is mainly derived from the waiting time, in-vehicle travel time, number of transfers, level of discomfort, and fare in time units. The stated preference survey approach is adopted to obtain the above parameters of generalized time.

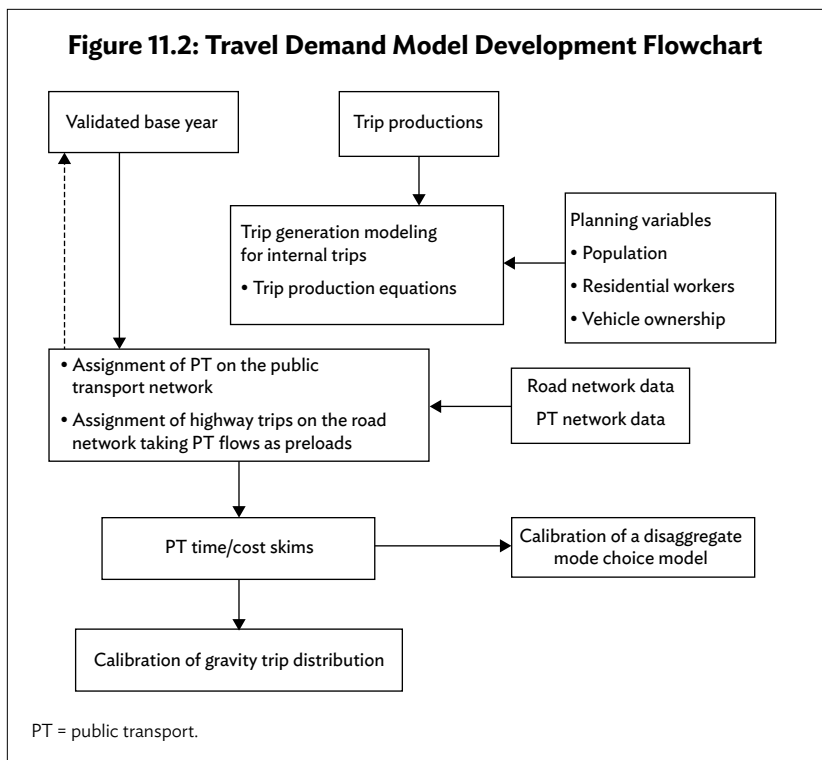
Public transport assignment mainly consists of path building and trip loading on these paths. Path building is the process of identifying all reasonable paths between all OD pairs and gives associated generalized travel time information. The path and generalized time information obtained from the path building step is used in the loading step to obtain the proportion of trips using each path. The maximum share of trips is loaded on to the path with the smallest generalized time between any

pair of zones. Paths with a relatively higher generalized time will be conversely loaded with a very small number of trips. The generalized time-based logistic choice function is used to find the proportion of trips that need to be loaded on each path. The modal share of public transport assignment should reflect the actual observed modal share. In order to achieve the observed modal share, the stated preference survey is conducted which gives parameters of generalized time that are used in the model. The assigned flow across screen lines from the model after assignment is checked with the observed flows from the survey to simulate the actual traffic condition.

Similar to public transport assignment, highway assignment is carried out for peak hours. The highway network is preloaded with peak hour public transport and commercial vehicle flows. Peak hour public transport flows are obtained from the daily public transport flow factored with the ratio of peak hour flow to daily flow. As public transport and commercial vehicle flows are preloaded on the network in terms of the passenger car equivalent (PCU), the passenger flows obtained need to be converted to PCU using an appropriate passenger-to-PCU conversion ratio. Now the obtained peak hour public transport and commercial vehicle flows are preloaded on the highway network before loading the private vehicle OD matrices. Similar to public transport, private vehicle matrices are converted into peak hour PCU units by utilizing the conversion factors for passenger-to-PCU and regional peak hour ratios. These factors are obtained from the occupancies observed at screen lines during the survey. In the case of private vehicle assignment, the user equilibrium procedure is followed, which is based on the generalized cost (sum of operating cost of vehicle, time cost, and toll, if any). After assigning private trips, the public transport network also needs to be revised with the speeds. On the revised network, the assignment of public transport is performed, and again the next iteration of private vehicle assignment is carried out, considering preloads of public transport. The whole iterative process between private and public transport is repeated until no considerable change is observed in the link loadings and link costs. The updated highway time and highway cost skims obtained from the loaded network are further used for calibration of the gravity model; the mode split model, distribution, modal split, and trip assignment is repeated until the OD matrices become stable. The above recalibration process is described with the help of the flow diagram in Figure 11.2.

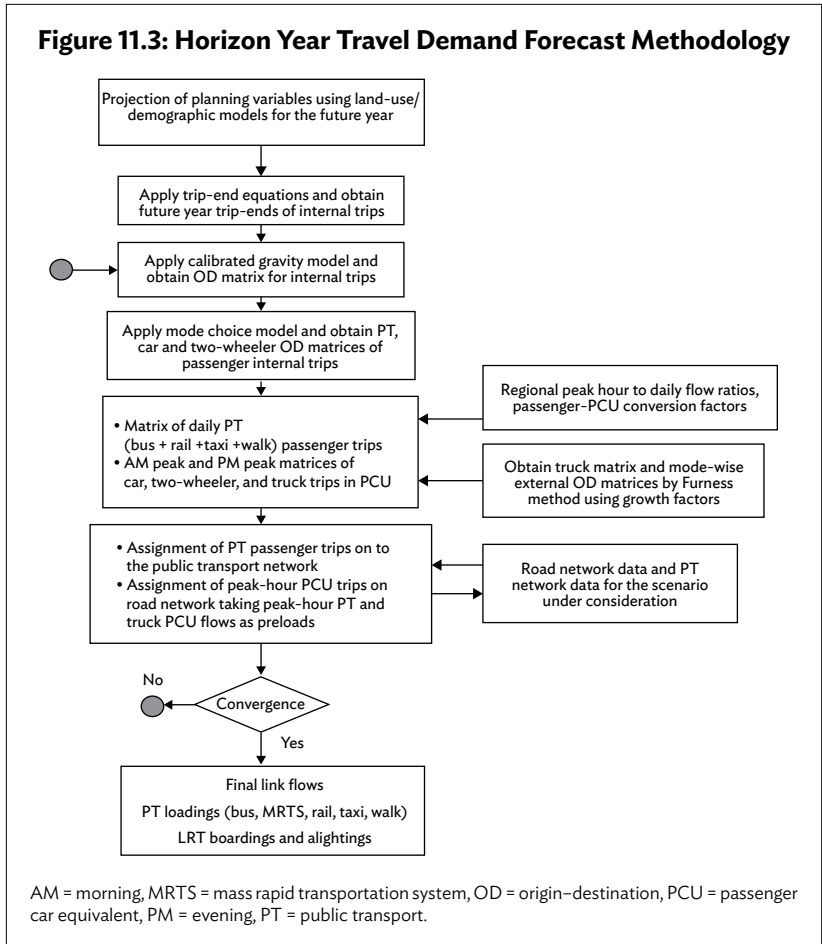
Horizon Year Travel Demand Forecasts

The recalibrated base year travel demand model is used for forecasting the horizon year (2041) loadings on each public transport mode on all the links. The planning variables for the horizon year are forecast based

Figure 11.2: Travel Demand Model Development Flowchart

on demographics and inputs from planning agencies. The planning variables thus forecast form the input to the travel demand model along with the future highway network and proposed metro corridors. The base year highway skims are used to estimate trip ends. Trip ends thus obtained are fed into the calibrated gravity model along with the base year highway skims. The OD matrix forms input to the mode split model, which gives the output in terms of mode-wise OD matrices.

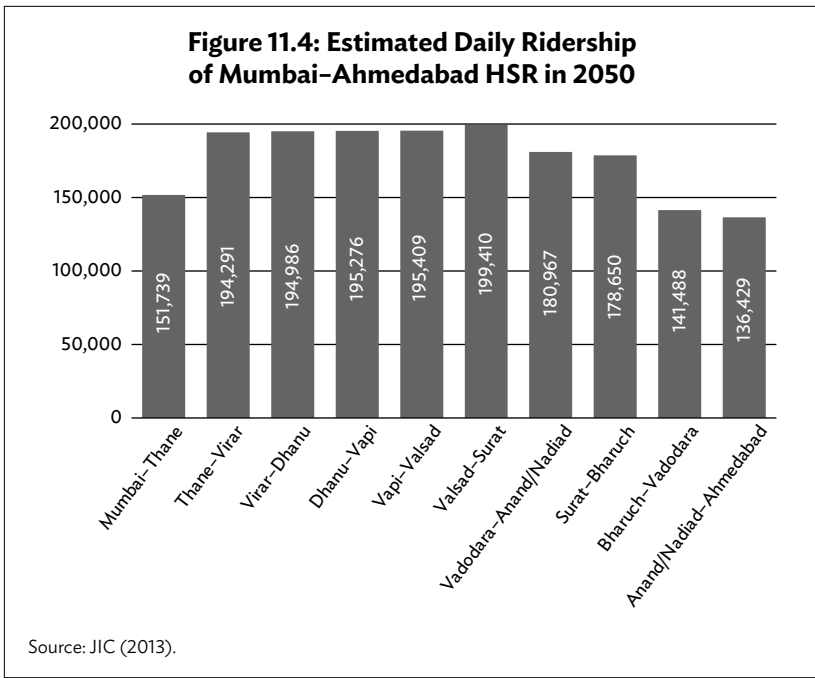
The internal portion of the OD matrix thus obtained is added to the external passenger OD portion, as well as commercial vehicle trips, which are estimated by the Furness method. The combined total OD matrix obtained consists of daily trips. The daily trip OD matrix is converted into a peak hour OD matrix. The peak hour OD matrix is loaded on both the public transport and highway network. The updated highway and time skims obtained during the assignment process are taken as input in the gravity model, and trip redistribution is done.



From the updated skims, mode-wise OD matrices are estimated and loaded on the network, and again the whole cycle is repeated until stable skims are achieved. The flowchart of the procedure followed is shown in Figure 11.3.

Ridership Estimation of Metro and Suburban Corridors with and without High-Speed Rail

To examine the travel and land use impacts of HSR in MMR, coding of HSR is restricted to the region with the inclusion of one external



node. The estimated ridership for this HSR corridor is obtained from the *Joint Feasibility Study for Mumbai–Ahmedabad High Speed Railway Corridor* (July 2015) and is shown in Figure 11.4. From this ridership data, the number of passengers commuting to and from MMR by HSR are obtained and directly assigned to this external node. These data have also been used for recalibration purposes, as the earlier model was built without considering HSR. This model with and without HSR has been applied on the CUBE voyager platform to obtain ridership variations in the metro and suburban rail.

11.4.2 Accessibility

To evaluate the improvement in accessibility due to the HSR, researchers have used different indicators. In this study, Hansen's accessibility is used, as it considers opportunities available to residents of the study area to conduct a particular activity or set of activities. The general form of Hansen's accessibility is:

$$A_i = \sum_j B_j f(c_{ij}) \quad (1)$$

where B_j is the opportunities at zone j for a given purpose, C_{ij} is the travel cost from i to j , and $f(\cdot)$ is a deterrence function representing a resistance to travel.

The most famous form of Hansen's accessibility considers the deterrence function as the inverse of the travel time and the opportunity available as employment. Thus, Hansen's measure used in this study is:

$$A_i = \sum_j E_j / t_{ij}^\alpha \quad (2)$$

where E_j is the employment at zone j , and t_{ij} is the travel time from zone i to zone j .

Many researchers have previously used a potential accessibility indicator that is very similar to Hansen's accessibility. For potential accessibility, typically, in international and national-scale analyses, the value of α is taken as 1, whereas at a regional level, a higher value of α is used. However, the majority of these studies takes α as 1 (Wang et al. 2016). Even the MMRDA Comprehensive Transportation Study suggests the value of α to be 1; hence, the same is adopted for this study.

The Hansen's accessibility of 1,030 zones of MMR with and without HSR is calculated using the forecast employment data of 2041 and the travel time skims obtained from the four-stage travel demand model.

11.5 Results and Discussion

11.5.1 Variations in Ridership of Metro and Suburban Rail

Initially, the ridership on the metro and suburban rail systems for horizon year 2041 without HSR is obtained using the travel demand model developed. Then, HSR is coded onto the 2041 transit network and the ridership is re-estimated on the metro and suburban rail systems. The observed change in the ridership in the peak hour is represented in Table 11.2. The major change in the suburban ridership is observed on the western suburban rail since the HSR runs almost parallel to it.

From Table 11.2, we can observe a significant decrease in the ridership on the western railway, which is generally extremely overcrowded during the peak hour. This could be attributed to the close proximity of the Bandra station of the western railway and the Bandra Kurla Complex (BKC) station on the HSR. The case is similar for the

Table 11.2: Ridership Variation in Western Railway and Metros

Passengers in Peak Hour	Western Railway	All Metro Corridors
Without HSR ('000)	747	972
With HSR ('000)	701	1,022
Difference ('000)	-46	+50

HSR = high-speed rail.

Source: Authors.

Virar stations of both, so suburban commuters from Bandra to Virar are likely to switch to the HSR due to its speed advantage. On the other hand, the metro shows a substantial growth in ridership. This may be because the metro acts as a feeder for long-distance commuting through the HSR. The greatest growth in metro ridership is observed on metro lines 2B, 3, and 6.

Metro lines 2B and 3 have a common station with the HSR at BKC and thus act as direct feeders to the HSR. Metro line 6 acts as a feeder to metro line 3, which in turn carries the passengers to the HSR BKC station. Even though there is a reduction in the ridership for some other metro lines, there is an overall growth in metro ridership.

The BKC node is proposed to be a metro station in the near future as well as the first station on the HSR (from Mumbai). Hence, a large interchange of passengers is observed from the travel demand model. The number of passengers using the proposed BKC station during the peak hour is estimated to be about 15,000 and 39,000 for the HSR and the metro (lines 2B and 3), respectively. This huge passenger demand needs to be considered during the design of the BKC station.

11.5.2 Impact on Accessibility

Hansen's accessibility measure has been utilized to compute the accessibility of each of the 1,030 zones for the scenarios with and without HSR. Zones near the northern peripheral region of MMR (i.e., near the HSR Virar station) have experienced significant improvement in accessibility. There is also an increase in the accessibility in some of the other zones of MMR near BKC. However, the increase is not as great as in the Virar area (Table 11.3).

The increase in Hansen's accessibility in the zone containing Virar station is 25.5% and in the region near Boisar station 19.6%. Thus, introducing HSR will promote rapid development in these developing regions.

Table 11.3: Accessibility Changes in High-Speed Rail Station Area

HSR Station	Hansen's Accessibility		
	Without HSR ('000)	With HSR ('000)	Increment (%)
Virar	226	284	25.5
Boisar	156	186	19.6
BKC	589	605	2.7

BKC = Bandra-Kurla-Complex, HSR = high-speed rail.

Source: Authors.

11.6 Conclusion

This study has primarily focused on assessing variations in ridership of the metro and suburban rail systems, and the improvement in the accessibility of different regions of MMR due to the introduction of HSR. Applying the travel demand model developed during this study demonstrates a significant decrease in the ridership on the western suburban rail and an increase in the ridership of some of the proposed metro lines in 2041. The decrease is because the HSR runs almost parallel to the western suburban rail, and a shift in suburban commuters to HSR is very likely due to its speed advantage. Hence, peak hour relief of the congested western suburban rail is likely a result of the introduction of HSR. The increase in metro ridership may be considered a result of the metro systems acting as feeder services to long-distance commuting through the HSR within MMR (Bandra–Virar).

In the past, the Vasai–Virar region was not a part of MMR. Since the suburban lines were extended to these regions, however, rapid development has been observed. Similarly, the population has increased from 0.69 million in 2001 to 1.54 million in 2016. Pradhan Mantri Awas Yojna is an affordable housing scheme with more than 240,000 housing units sanctioned for construction. The accessibility of the peripheral areas of MMR near Virar station is reported to show considerable growth due to the introduction of HSR. The underdeveloped Boisar region near Virar, which has housing prices way below the rest of MMR (Table 11.4), will benefit extensively from the HSR.

The MMRDA is planning to include Boisar in MMR and convert it into a central business district similar to the existing ones in MMR. With the inclusion of Boisar in MMR, coupled with the vital connectivity

Table 11.4: Land Prices in the Mumbai Metropolitan Region

Location	Land Prices (₹ per square foot)
Greater Mumbai	50,000–70,000
Western Suburban	22,000–55,000
Eastern Suburban	14,000–38,000
Thane	9,000–18,000
Vasai–Virar	3,000–5,200
Boisar	1,200–2,800

Source: Housing.com. Heat Maps. <https://housing.com/dsl/heatmaps/mumbai/buy>

provided by the HSR, a similar trend of rapid development to that in Vasai–Virar is expected. The increase in accessibility combined with low prices is expected to change the existing travel scenario within MMR, and hence people may start to reside in such peripheral areas and commute via the HSR.

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12

A Station Location Identification Model for an Integrated Interoperable High-Speed Rail System

Sandeepan Roy and Avijit Maji

12.1 Introduction and Background

High-speed rail (HSR) services are train services that operate with considerably higher speeds than conventional ones. As per the European Union Directive 96/48/EC, HSR services operate at speeds greater than or equal to 250 kilometers per hour (km/h) on specially built high-speed lines and at speeds greater than or equal to 200 km/h on upgraded high-speed lines. The first areas that engaged in HSR projects were Japan and European countries such as France, Germany, and Italy. Major HSR projects are being implemented or developed currently in various countries in Asia and North and South America. The People's Republic of China (PRC) already has the longest HSR network in the world, with 19,000 kilometers (km) of HSR lines in service and another 12,000 km to be built by 2020 (MORPRC 2004; LFRC 2007; Chen and Zhang 2010; Repolho et al. 2013). In the United States, 13 HSR corridors are being developed across 31 states (US DOT 2009; Landers 2010; Repolho, Antunes, and Church 2013).

Various critical characteristics must be addressed while planning an HSR system. These include technical design details such as the type of HSR technology and rolling stock; choice of gauge; operational characteristics, i.e., whether the system will operate on an exclusive right-of-way, a grade-separated right-of-way or a shared right-of-way with existing conventional rail and/or freight trains, HSR systems almost always operate on exclusive right-of-way or grade-separated

right-of-way (European Union 1996). However, in certain cases, when the infrastructure is designed to facilitate the movement of HSR on conventional intercity lines or vice versa, this flexibility of operation is known as interoperability (ERA 2016). This is typically observed when the HSR corridor being designed coincides with an existing conventional and/or freight corridor. Various prerequisites govern interoperability, including common technical specifications for HSR and conventional rail-like track gauge, signaling, existing spare line capacity for HSR, and appropriate facilities (such as stations) capable of serving the existing HSR demand (ERA 2016). Examples of integrated interoperable rail systems include Société Nationale des Chemins de Fer Français (SNCF) in France, where HSR services share certain portions of the right-of-way with conventional rail services; Alta Velocidad Española (AVE) in Spain, where HSR lines are used by conventional trains; InterCity Express (ICE) in Germany; and Eurostar Italia, where HSR trains share the intercity rail lines with conventional trains. The advantages of such an integrated system include a seamless mode of transfer and accessibility benefits for the passengers; a reduction of infrastructure cost as existing tracks and stations can be used; and optimized utilization of existing rail network.

Hence, HSR stations are preferably placed at existing intercity rail station locations. However, all existing intercity stations may not satisfy the ridership potential and interstation spacing requirements necessary for HSR operation. Providing more stations increases access to intermediate locations, which boosts ridership. However, this increases overall travel time. On the contrary, fewer stations or stops reduces overall ridership of the HSR. A trade-off or balance between both these objectives would yield the optimal number and location of HSR stations. A multi-objective nonlinear mixed integer model is developed in this study, which considers ridership maximization and travel time minimization. Avoiding environmentally sensitive land (e.g., wetlands and forests) as well as other requirements such as threshold interstation distance, travel time between intended station locations, and threshold population of the intended station region are included as environmental and corridor-specific constraints, respectively. This study proposes a heuristic methodology based on artificial intelligence and geographic information systems (GIS) to evaluate and obtain the candidate set of station locations that maximize ridership and minimize travel time, such that an integrated interoperable HSR and intercity corridor can be developed. The Mumbai–Ahmedabad conventional intercity corridor is used as a case study to demonstrate the efficacy of the proposed model by identifying possible HSR station locations.

12.2 Literature Review

Addressing interoperable HSR station location and route identification involves minimization and/or maximization of objectives such as ridership and travel time along with a variety of constraints such as interstation spacing, corridor length, and threshold population. These constraints reflect system performance requirements and/or resource limitations. This type of problem can be classified as the maximum ridership coverage or shortest path or travel time problem (Current, ReVelle, and Cohon 1985; Wu and Murray 2005). Literature focusing exclusively on this type of HSR problem is lacking. However, the objectives and constraints features are similar to those of bus and rail transit design problems. The existing methods used to solve bus and rail transit route problems include analytical optimization models for idealized solutions and meta-heuristic approaches for practical situations. Analytical models are applied to predetermined transit route networks to determine one or several design parameters such as route length, route spacing, stop spacing, and location. Notable models include works by Vuchic (1969); Byrne and Vuchic (1972) on rail transit, and Lesley (1976); Wirasinghe and Ghoneim (1981); Saka (2001); Newell (1979); LeBlanc (1988); Boffey and Narula (1998); Current and Schilling (1989, 1994); Hachicha et al. (2000); and Wu and Murray (2005) on bus transit. These methods were successful for problems with smaller networks or fewer decision variables, but their performance efficiency decreased for networks of larger size, having many parameters (Fan and Machemehl 2006). Meta-heuristic approaches, which can simultaneously deal with design of the transit route and associated parameters such as service routes, frequency, timetable, and schedules, were developed to address the inherent complexity of such problems. Earlier works used general heuristic approaches (Silman, Barzily, and Passy 1974; Dubois, Bel, and Llibre 1979; Ceder and Israeli 1998), artificial intelligence-based methods (Hasselstrom 1981; Van Nes, Hamerslag, and Immers 1988; Baaj and Mahmassani 1991; Shih, Mahmassani, and Baaj 1997, 1998), genetic algorithm (Pattnaik, Mohan, and Tom 1998; Chien, Yang, and Hou 2001; Fan and Machemehl 2004) and simulated annealing (Fan and Machemehl 2006; Yan et al. 2013) in solving the problem. It is evident from the review that the design of an integrated interoperable HSR and intercity conventional system needs exploration.

12.3 Problem Formulation

This chapter proposes a model that considers a trade-off between ridership and travel time or distance in the selection of station locations from an existing conventional rail line. In this model, total ridership and

system travel distance or time is utilized to reflect the service quality. There is one major difference between the classic maximum ridership coverage model or the shortest path model and the proposed model. The classic model is applied in determining a new transit route where no transit system exists, whereas the proposed model can be used for an existing transit system. The following section describes the proposed model formulation.

Let $G = (S, E, D)$ be a complete weighted graph of station locations, where s is the set of station locations denoted as $(s_1, s_2, \dots, s_{N_s})$; E is the set of edges connecting any pair of station locations denoted as $\{e_{ij} \mid s_i, s_j \in S\} \forall i, j \in \{1, 2, \dots, N_s\}$; D is the distance matrix representing the pairwise distance between the given station locations denoted as $(d_{ij})_{N_s \times N_s} \forall i, j \in \{1, 2, \dots, N_s\}$; and R is the set for ridership values for the station locations denoted as $(r_i)_{N_s} \forall i \in \{1, 2, \dots, N_s\}$. Let IDS_{min} be the minimum distance between any two station locations, TDS_{max} the maximum distance between terminal station locations, N_s the total number of stations selected, NS_{max} the maximum number of stations in an HSR corridor (based on the number of HSR station regions), and NS_{min} the minimum number of stations in an HSR corridor. The objective function that maximizes the ridership and minimizes the travel time or distance for a selected route can be formulated as follows:

$$Max Z_1 = \sum_{n=1}^{NS_{max}} \alpha_n * r_n \quad (1)$$

$$Min Z_2 = \sum_{i=1}^{NS-1} \sum_{j=2, j \neq i}^{N_s} \sigma_{ij} * d_{ij} \quad (2)$$

subject to

$$N_s = \sum_{i=1}^{NS_{max}} \alpha_n \quad (3)$$

$$N_s \leq NS_{max} \quad (4)$$

$$N_s \geq NS_{min} \quad (5)$$

$$\sum_{i=1, i \neq j}^{NS-1} \sigma_{ij} = 1, j \in \{2, \dots, N_s\} \quad (6)$$

$$\sum_{j=2, j \neq i}^{N_s} \sigma_{ij} = 1, i \in \{1, 2, \dots, N_s - 1\} \quad (7)$$

$$\sum_{i=1}^{NS-1} \sum_{j=2, i \neq j}^{N_s} \sigma_{ij} = N_s - 1 \quad (8)$$

$$d_{n,m} \geq IDS_{min} : \forall \alpha_n = 1, \alpha_m = 1, m = n + 1 \quad (9)$$

$$Z_2 \leq TDS_{max} \quad (10)$$

$$\sigma_{ij} = [0,1] \quad (11)$$

$$\alpha_{ij} = [0,1] \quad (12)$$

where

$$\sigma_{ij} = \begin{cases} 1 & \text{if the route goes from station } s_i \text{ to } s_j \\ 0 & \text{otherwise} \end{cases}$$

$$\alpha_n = \begin{cases} 1 & \text{if the route covers station } s_n \\ 0 & \text{otherwise} \end{cases}$$

In this formulation, the constraint related to the total number of stations for the selected route, which indirectly indicates the ridership coverage for the selected route, is represented in equation 3. Similarly, the constraint indicated by equation 4 ensures the maximum number of stations required for the selected route. Considering no intermediate stations in between the terminal stations, the minimum number of stations in an HSR corridor is two, as represented by equation 5. Further, equations 6 and 7 ensure that each intermediate station is connected to exactly two different stations. The maximum number of edges or paths between selected stations is constrained by using equation 8. To ensure appropriate cruising speed and adequate distance for safe brake application, there should be sufficient distance between the consecutive stations of an HSR corridor; the constraint indicated by equation 9 ensures this. The total distance between terminal station locations should not be more than the maximum possible distance beyond which HSR travel becomes a less viable option compared to air travel (in terms of distance and travel time). Hence, the obtained route distance between the terminal stations should satisfy the maximum distance criteria; the constraint indicated in equation 10 ensures this. A weighting method (Zadeh 1963; Current, ReVelle, and Cohon 1985) is used to combine the two objectives (equations 1 and 2) into a single objective problem:

$$Z = \emptyset Z_1 / (1 - \emptyset) Z_2 \quad (13)$$

where $\emptyset$ is the assigned weightage; and the objective functions, Z_1 and Z_2 , are the normalized form of equations 1 and 2, respectively. It helps in representing both objective values within a common range of $[0, 1]$. An approximation of the non-inferior solution set can be derived by systematically varying the weight, $\emptyset$, and solving the associated single objective model.

12.4 Solution Methodology

The exact solution can be obtained through a brute force method, which uses the pairwise distance and ridership between all stations to check for all possible permutations between the given stations. This method is convenient for a smaller number of locations, but its efficiency decreases with a larger number of locations. This study uses ant colony optimization (ACO), similar to the one presented by Dorigo and Gambardella (1997) and Dorigo and Di Caro (1999), to develop the route connecting the station locations. The main reason for choosing ACO is its quick convergence and efficiency in solving a Hamiltonian path problem (e.g., traveling salesman problem) over other artificial intelligence-based heuristic algorithms, such as the genetic algorithm, particle swarm optimization, and shuffled frog leaping algorithms (Brucal and Dadios 2017; Saud, Kodaz, and Babaoğlu 2018). ACO uses ants' foraging behavior by means of a pheromone trail to find the optimal solution. In this method, each ant perceives pheromone concentrations in its local environment and selects the direction with the highest concentration. This yields the best alternative—i.e., the shortest path satisfying the required constraints between the two terminal stations. The working principle of ACO for the study problem is described in the subsequent paragraphs.

The number of ants, $k = 1, \dots, n_k$, are placed at the starting terminal station. N_i^k represents the set of feasible stations connected to station s_i , with respect to ant k . Let, $T^k(t)$ denote the path or route for the ant k at time step t . Each ant k will choose the next station based on the pheromone trail associated with that move. If ant k is currently located at location s_i , then it selects the next location $s_j \in N_i^k$, based on the transition probability as follows:

$$P_{ij}^k(t) = \begin{cases} \frac{[\vartheta_{ij}(t)]^\beta [\delta_{ij}(t)]^\gamma}{\sum_{u \in N_i^k(t)} [\vartheta_{iu}(t)]^\beta [\delta_{iu}(t)]^\gamma} & \text{if } j \in N_i^k(t) \\ 0 & \text{if } j \notin N_i^k(t) \end{cases} \quad (14)$$

where ϑ_{ij} is the pheromone intensity between locations (i, j) and δ_{ij} the visibility or attractiveness of the of location s_j from location s_i , which is set as $(r_i + r_j)/d_{ij}$, whereas β and γ are the positive constants used to amplify the influence of pheromone intensity and increase the attractiveness or desirability toward the other locations, respectively. The ACO is initiated by adding a small random value of pheromone concentration on each link. The initial amount of pheromone

concentration, ϑ_{ij} , is either equal to a constant value ϑ_0 or to a random value in the range of $[0, \vartheta_0]$. From a station, an ant k would choose the next location based on the pheromone concentration-based transition probability given in equation 14. Based on the transition probability, it selects the connecting edges and incrementally progresses toward the terminal station to develop the path or corridor. Let $T^k(t)$ denote the path or corridor between the terminal stations for an ant k at time step t . Once a path is developed, the ants deterministically retrace their movement to the starting terminal station and deposit pheromone in each link, (i, j) of the corresponding path, T^k . The pheromone intensity on each link is updated after each ant leaves its pheromone trail. The pheromone trail of an ant k on each link (i, j) of the route T^k is proportional to the ridership $R^k(t)$, and inversely proportional to the total length $L^k(t)$ of the route traced by the ant. In other words, routes with shorter paths and higher ridership will leave a larger pheromone trail:

$$\Delta\vartheta_{ij}^k(t) = R^k(t)/L^k(t), (i, j) \in T^k(t) \quad (15)$$

where

$$L^k(t) = \sum_{i,j=i+1}^{N_S-1} d_{ij}, (i, j) \in T^k(t) \quad (16)$$

$$R^k(t) = \sum_i^{N_S} r_i, i \in T^k(t). \quad (17)$$

The pheromone trail is estimated using equation (15), the length using equation (16), and ridership using equation (17).

Also, pheromones evaporate with time. The pheromone evaporation on each link (i, j) , is estimated at each time step using a constant evaporation rate of μ ($0 \leq \mu \leq 1$):

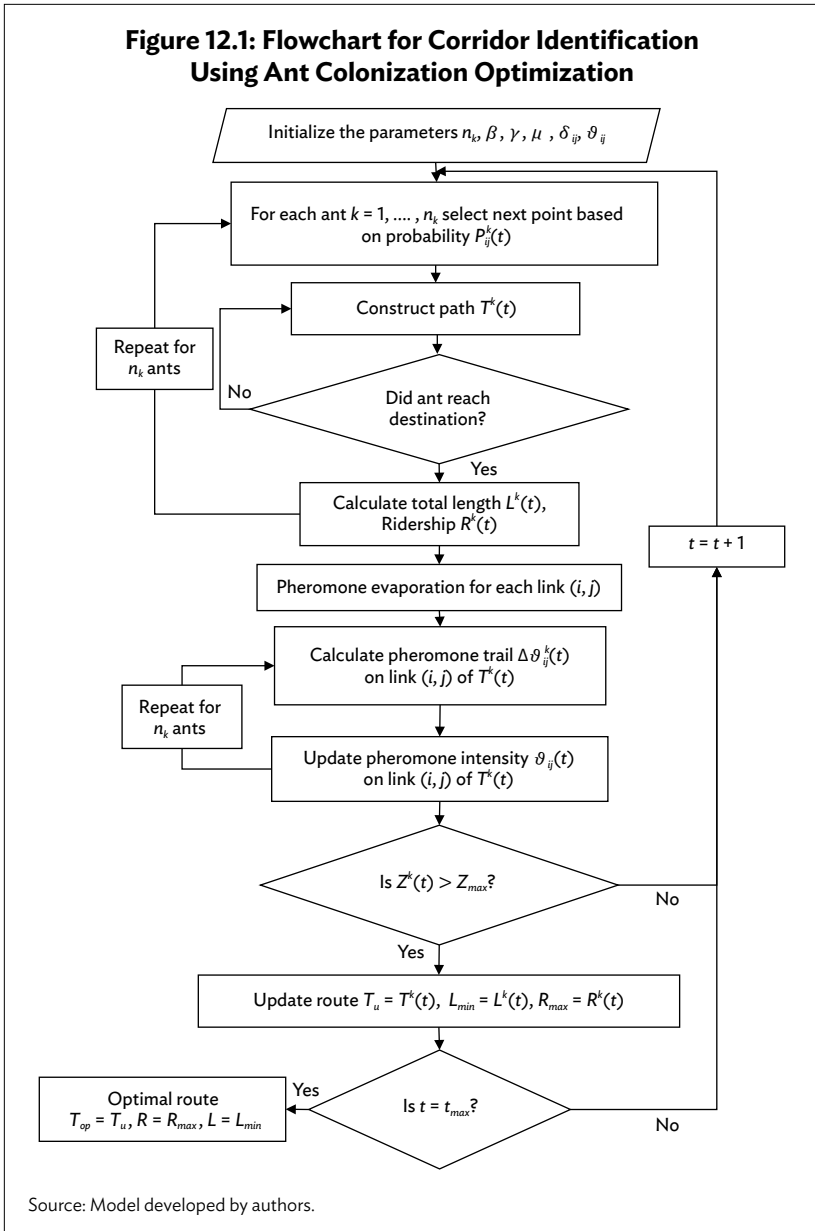
$$\vartheta_{ij}(t+1) = (1 - \mu)\vartheta_{ij}(t) \quad (18)$$

Combining equations 15 and 18, the updated total pheromone concentration on each link (i, j) at time step t can be estimated as follows:

$$\vartheta_{ij}(t+1) = (1 - \mu)\vartheta_{ij}(t) + \sum_{k=1}^{n_k} \Delta\vartheta_{ij}^k(t) \quad (19)$$

The process continues until the stop criteria are met. In the end, the route with the highest pheromone concentration is considered the shortest possible route with maximum ridership. The working principle of the ACO is illustrated in Figure 12.1.

Figure 12.1: Flowchart for Corridor Identification Using Ant Colonization Optimization



12.5 Case Study

The proposed Mumbai–Ahmedabad HSR corridor connecting the cities Ahmedabad in Gujarat and Mumbai in Maharashtra is considered as a case study. It is India's first HSR project. The Mumbai–Ahmedabad conventional intercity rail corridor is analyzed using the proposed model to identify the possible HSR station locations. The conventional intercity rail corridor between Mumbai and Ahmedabad has about 28 major stations with as many as 69 long-distance trains (Erail 2018).

Number of intercity origin–destination pairs. The threshold value of population in cities along a corridor for HSR implementation is 500,000 (Takeshita 2012). The latest census data available for Maharashtra and Gujarat are for 2010–2011 (Chandramouli and General 2011). They were extracted from the Census of India website (ORGCC 2016) in Excel spreadsheet table format. The population data were available for each state, district, subdistrict or *taluka*, city, and village. A search program was developed using Python programming language to identify subdistricts and cities with estimated population levels over the threshold value for HSR implementation. In the process, 11 potential regions satisfying the population threshold were identified in the states of Maharashtra and Gujarat. They included Ahmedabad, Anand, Bharuch, Vadodara, Surat, Valsad, Vapi, Thane, Boisar, Vasai-Virar, and Mumbai.

GIS shapefiles. GIS data were downloaded from the OpenStreetMap web portal (2017) in the form of vector shapefiles. They included point shapefiles for locations; transportation points (bus stops, railway stations); polyline shapefiles for railway, highway, and road networks; and polygon shapefiles for buildings, political or administrative boundaries, and water bodies. The shapefile showing conventional rail station locations was used as input. Table 12.1 shows the input parameters used in this study, and Figure 12.2 represents the study area along with the existing intercity railways, railway stations, and HSR potential regions.

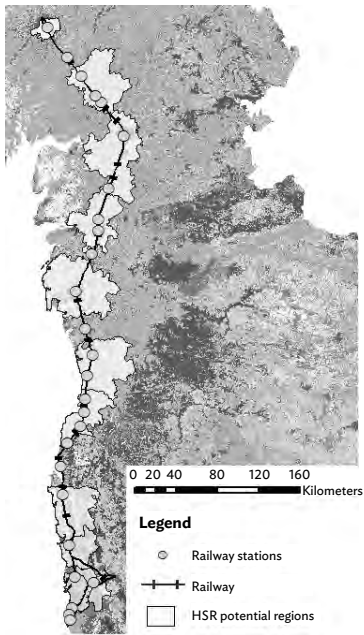
Ridership data. Ridership data were obtained from the report on the Joint Feasibility Study for Mumbai–Ahmedabad High Speed Railway Corridor (JICA 2015) in the form of boarding and alighting passengers per day in both directions. The ridership data adopted for this study were for the horizon year 2023.

Table 12.1: Input Parameters

Input Parameters	Values	Source
Factors controlling trail β	1.0	Brezina and Čičková (2011)
Factors controlling visibility γ	2.0	
Pheromone evaporation rate τ	0.5	
Number of ants n_k	500	Authors' assumption
Maximum number of generations	400	
Distance between consecutive stations IDS_{min}	24 kilometers	Stanford Research Institute (1968)
Maximum distance between terminal stations TDS_{max}	800 kilometers	Takeshita (2012)
Minimum number of stations in the corridor NS_{min}	2	Authors' assumption
Maximum number of stations in the corridor NS_{max}	11	UTES (2013); JICA (2015)

Source: Compiled by authors.

Figure 12.2: Study Area



HSR = high-speed rail.
Sources: Bhuvan web portal (2016), OpenStreetMap web portal (2017).

12.6 Results

The ArcGIS version 10.2, a commercial GIS package by ESRI Inc. was used for travel time, distance estimation, data management, and result visualization. Furthermore, a Python-based script, supported by ArcGIS, was specifically developed to implement the proposed model. A 3.6 GHz Intel® Core™ i7 processor-equipped personal computer, with 8-gigabyte memory, was used to run the GIS-integrated Python script. It was run by varying the values of weightage factor for a sufficient number of iterations until the results converged. The obtained results are displayed in Table 12.2.

Table 12.2: Ridership Coverage and Travel Distance Trade-Off

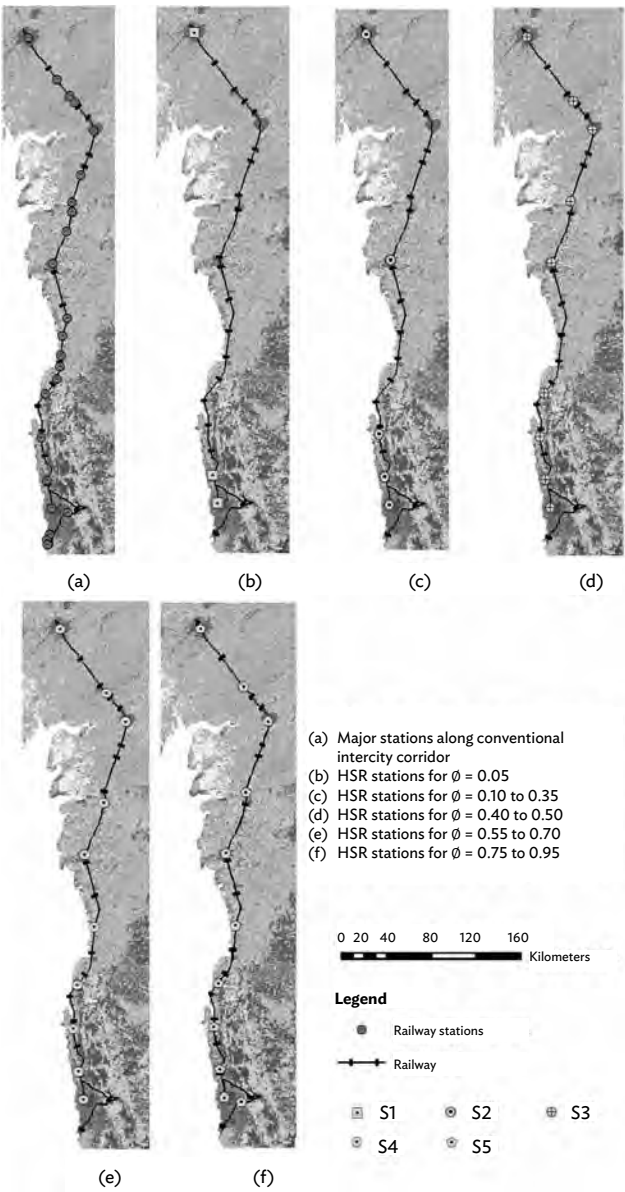
Weightage $\emptyset$	Ridership Covered Z_1 (passenger/day)	Travel Distance Z_2 (kilometer)	Ridership per Distance Unit	Number of Stations	Number of Generations
0.05	53,000	421.48	125.7474	3	2
0.10	59,000	422.96	139.4931	5	6
0.15	59,000	422.96	139.4931	5	6
0.20	59,000	422.96	139.4931	5	6
0.25	59,000	422.96	139.4931	5	5
0.30	59,000	422.96	139.4931	5	8
0.35	59,000	422.96	139.4931	5	7
0.40	72,000	445.70	161.5436	9	2
0.45	72,000	445.70	161.5436	9	9
0.50	72,000	445.70	161.5436	9	11
0.55	73,000	448.29	162.841	10	7
0.60	73,000	448.29	162.841	10	17
0.65	73,000	448.42	162.7938	10	7
0.70	73,000	448.42	162.7938	10	9
0.75	76,000	472.69	160.7819	11	9
0.80	76,000	472.69	160.7819	11	32
0.85	76,000	472.69	160.7819	11	19
0.90	76,000	472.69	160.7819	11	13
0.95	76,000	472.69	160.7819	11	13

Source: Result estimated by authors.

The trade-off between ridership coverage and travel distance is presented in Table 12.2. A steep change in travel distance, ridership, and access coverage can be observed when $\emptyset$ changes from 0.35 to 0.4. A similar phenomenon was observed when $\emptyset$ changes from 0.7 to 0.75. Hence, for this study, a weightage factor variation between 0.4 and 0.7 would provide a reasonable trade-off between ridership, access coverage, and travel distance, as the variation in travel distance with ridership and access coverage is significantly smaller within this range. Figure 12.3 shows the station locations for the existing intercity corridor and the station locations that satisfy the criteria for an integrated interoperable HSR system.

The major station locations in the study area are presented in Figure 12.3(a). The station locations for weightage factor of 0.05 (indicated by S1) are shown in Figure 12.3(b), which has the minimum end-to-end travel distance and the least number of intermediate stations. However, the ridership coverage is also the lowest due to limited access (see Table 12.2). Similarly, Figure 12.3(c) represents the station locations (indicated by S2) for the weightage factor varying from 0.10 to 0.35. This route has a total of three intermediate stations and satisfies a higher ridership coverage due to higher access points. The ridership coverage increases at weightage factor of 0.40 and remains steady until it reaches a factor of 0.50. Figure 12.3(d) represents the station locations (indicated by S3) for the weightage factor between 0.40 and 0.50. It increases again at weightage factor 0.55 and remains steady until it reaches 0.70. The station locations (indicated by S4) for this range of weightage factors are presented in Figure 12.3(e). The ridership per unit distance also shows an increasing trend up to these weightage factors. Thereafter, for weightage factors between 0.75 and 0.95, the ridership coverage increased but the ridership per unit distance decreased. The station locations (indicated by S5) for this range of weightage factors are presented in Figure 12.3(f). As indicated earlier, the ridership per unit distance is maximal for weightage factor between 0.4 and 0.7. Thus, the station locations presented in Figures 12.3(d) and 12.3(e) may be considered suitable for the integrated interoperable HSR system.

Figure 12.3: Stations along the Mumbai–Ahmedabad Corridor



Source: Result generated by authors.

12.7 Conclusion

Integrated interoperable rail systems facilitate the movement of HSR trains on conventional intercity lines and vice versa. Hence, it is preferred that HSR stations exist at intercity rail station locations. However, all existing intercity stations may not satisfy the ridership potential, corridor length, and interstation spacing requirements necessary for the HSR operation. Providing more stations increases access to intermediate locations, which boosts ridership. However, it also increases overall travel time and distance. On the contrary, fewer numbers of stations or stops reduce overall ridership of the HSR. Hence, a trade-off or balance must be obtained, where a required amount of ridership potential is met without increasing the travel time and distance significantly.

This chapter proposes a GIS-based interoperable HSR station location identification approach along existing intercity rail lines to identify suitable integrated interoperable HSR and intercity station locations. A problem formulation maximizing ridership while minimizing travel time or distance is developed. Suitable weightage factors are used to combine these conflicting objectives into a single objective function. The threshold interstation travel time or distance between the selected station locations, total end-to-end corridor travel time or distance, and the threshold population of the selected station regions are included as corridor-specific constraints. A heuristic approach is used to evaluate and obtain the candidate set of station locations. This study utilizes ACO as the heuristic method to optimize the formulated problem. The Mumbai–Ahmedabad conventional intercity corridor is used as a case study to demonstrate the efficacy of the proposed model by identifying possible HSR station locations along the intercity rail corridor.

Variation in station location results can be observed with the change in weightage factor. For the case study considered, higher weightage toward ridership coverage (more than 0.7) increases the travel distance significantly, whereas lower weightage (less than 0.35) yields poor ridership results. It can be inferred that HSR planners can propose station locations along conventional intercity rail lines that satisfy the travel time or distance and ridership requirements necessary for developing or designing an interoperable HSR system. However, the weightage factor should be selected judiciously. The intermediate station locations that do not satisfy the selected criteria can be eliminated beforehand. It would reduce the computation time.

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13

Adding Value to the Railway Business: Station Building, Station Front, and Urban Development

Yoshitaka Ishii, Shreyas Bharule, and Kai Xu

13.1 Introduction

Japan Railways (JR) has over 150 years of history, including its time as a national railway. In the early 1960s, a recession hit Japan's railway business. Over the next 2 decades, due to the rapid development of the Japanese economy, boosted by the Japanese National Railways (JNR), the Japanese were able to afford private cars. In addition to the popularization of air travel, and growing motorization, railway use for both short- and long-distance travel declined.

In 1964, when the world-renowned *Shinkansen* opened, JNR fell into deficit for the first time, which is an ironic contrast. Eventually, the situation became one of severe deficit and debt. In 1987, the government implemented a reform of JNR. The reform consisted of divisionalization and privatization. JNR was divided into six regional passenger companies and one freight company without rail infrastructure.

This chapter discusses the strategies of JR Kyushu, one of the six regional passenger companies established after privatization occurred. JR Kyushu adopted several strategies to enhance the privatized image, including increasing the number of stations and the frequency and speed of trains, improving the design of the trains, and operating sightseeing trains. Although the company successfully created the brand of "Beautiful and Happy JR Kyushu," it would forever be in deficit if the railway business alone was in focus. Therefore, a wide variety of diversified businesses were introduced, including real estate development, integrated station buildings, food and beverage businesses,

retail outlets, tourism, and leisure businesses. Over the years, the profits from the diversified businesses maintained the annual revenue and made the railway business a deficit-free success. Chapter 17 elaborates on the JR Kyushu journey.

13.2 The JR Kyushu Experience

The companies formed after the privatization of JNR adopted different financial business models to run the businesses within their service region. The investments in transport infrastructure over time have established a central axis of population concentration in Japan, commonly known as the Taiheiyo Belt or Pacific Belt. Three of the six rail companies in Japan operate in the belt region, thereby maintaining a maximum revenue from the rail service business.

The three companies have geographically divided their services on Honshu Island in the following form: the JR Tokai company operates between Tokyo and Osaka, JR East operates north of Tokyo, and JR West operates between Osaka and Hakata, thus forming three big JR corporations. On the other hand, the three smaller companies operate between other areas and terminals of the three large corporations. The smaller companies, JR Hokkaido, JR Shikoku, and JR Kyushu connect the remote cities of Japan to the Pacific Belt. Given a lower population concentration between the remote cities and Kyushu's central belt, the smaller companies are destined to generate a small amount of revenue from the railway business and hence resort to diversification of business.

The JR Kyushu business diversification experience has been unique. The company generates more than half of its annual revenues from nonrailway businesses, and it generates more revenue from nonrailway businesses compared to other JR corporations. The following section discusses the strategies JR Kyushu adopted to add value to the railway business.

13.2.1 The JR Kyushu Strategy

The opening of high-speed rail (HSR) services in Kyushu in 2004 has played a key role for JR Kyushu. The HSR services on Kyushu Island created three interrelated effects. First, the direct effects such as a reduction in travel time brought new types of railway businesses such as passenger safety services, human resource training, and travel-quality monitoring agencies.

Second, the company developed a distinctive brand image by upgrading the services and rolling stock of the existing railways. The newly emerging benefit of HSR is express cargo. The company has

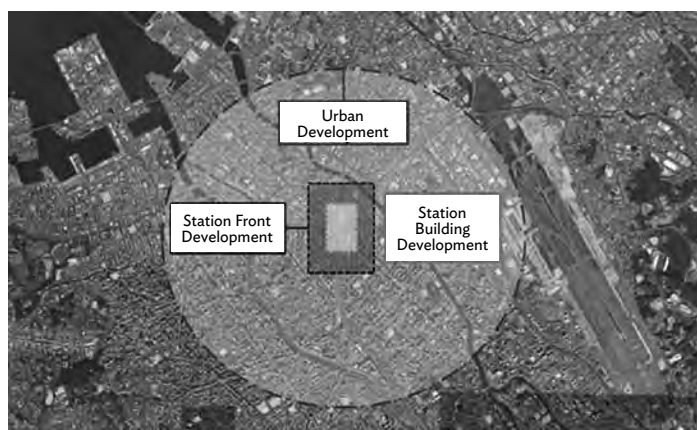
developed plans to use HSR for cargo in Japan (See chapter 17). The aim to adopt these strategies is to develop a railway business that expands, while maintaining the level of services and incrementally increases passenger convenience.

These continuous and sustained efforts gave birth to a third, related “spillover” effect of station–city integration projects, resulting in the rail companies’ participation to develop efficient connections with the city through station buildings, station fronts, and urban development projects. The following section discusses the case of JR Kyushu’s Hakata Station.

13.3 JR Kyushu’s Hakata Station, Fukuoka

JR Kyushu’s Hakata Station is in Fukuoka, the sixth-largest city in Japan. Over time Hakata Station has undergone several renewals and has adopted a modern architectural form that now integrates the station and city. The rail company evolved the station with three categories of development: the station building, followed by the station front, and finally, participating in the development of the urban area. Figure 13.1 illustrates the concentric nature of the station-based developments in Fukuoka City.

Figure 13.1: JR Hakata Station Location and Concentric Nature of the Station-based Development in Fukuoka, Japan



Source: Author.

13.3.1 JR Hakata Station Building Development

The most critical change JR Kyushu adopted was the transformation from the traditional concept of a station as a building only to board and disembark trains, to the concept of a station as a city. At the core of the concept was an aim to enhance passenger convenience while the rail operators tried to move passengers to the next destination from the station as quick as possible. The concept thus adopted was known as “JR Hakata City”. Under this adopted concept, the company was successfully able to transform the traditionalist view toward railway stations into a place where people can enjoy and stay. The concept extended to create and provide city amenities for leisure and entertainment within the station building. Figure 13.2 illustrates the transformation of the JR Kyushu Hakata Station building in Fukuoka.

Figure 13.2: Old Hakata Station, before Redevelopment in 2005 (left), “JR Hakata City” Station after Completion of Redevelopment in 2011 (right)



Source: These files are licensed under the Creative Commons Attribution-share alike CC 4.0 International.

Now the station building is a host to several shops, fine-dining restaurants, food courts, movie theaters, bookstores, and rooftop gardens (Figure 13.3). The station building also connects to the largest department stores in the city. Besides, the entrance canopy area offers rental space to host small exhibitions, farmers’ markets, and temporary pop-up stores (Figure 13.4).

Figure 13.3: Rooftop Garden on JR Hakata City Station Building



Source: Author.

Figure 13.4: Temporary Pop-up Stores during Christmas at Entrance Canopy



Source: Author.

13.3.2 JR Hakata Station Front Development

The station front is one of the crucial elements in the planning of a Japanese station area and integration of the station with the city. The station front plaza serves as a transition space to connect with the city, provides access to local urban transportation, as well as caters to pedestrian traffic. Besides, in the case of Hakata Station, the plaza serves as a public space and urban amenity to host events. It also serves as a landmark for locals and helps in orienting tourists.

13.4 JR Kyushu's Participation in Urban Development

Under the “point to city” initiative, JR Kyushu aims to develop real estate centered around JR Kyushu railway stations. Cooperation between the Fukuoka City government and JR Kyushu launched the “Hakata Connected” program. Under the program, Fukuoka City focused on the area within a 500-meter radius around Hakata Station.

The rail operator contributes to city-building initiatives in Fukuoka in both tangible and intangible ways has formed the Hakata City-Building Promotion Council. Through cooperation between the government sector and the private sector, the program envisions to undertake redevelopment and urban infill projects to enhance the quality of life, while extending the dynamism and vibrancy of Hakata Station to its surrounding area. The Hakata Connected initiative envisions the

formation of cooperative councils with landowners in the area around Hakata Station to establish the Station Area Development Council.

As a company, JR Kyushu also has developed diversified businesses with over 240,000 square meters of commercial space in the station building—the “Ropponmatsu 421” commercial development in the station front area. Under the peripheral business plan for urban development in Fukuoka City, JR Kyushu has also developed over 50,000 square meters of office space, over 350 units of rental apartments, and several hotels with a total of over 400 rooms.

JR Kyushu’s regional development vision is driven by its stations along the Kyushu *Shinkansen*. The company has followed the Hakata Connected model to develop such projects at Kokura, Oita, Kumamoto, and Kagoshima-chuo *Shinkansen* stations located along the Kyushu *Shinkansen* corridor, although all the projects are centered as station-based developments.

13.5 Lessons for Developing Countries

Among the countries investing in HSR projects, most are emerging economies with various levels of urban-regional development and diverse demography. It is important to note that to develop a robust and profitable HSR company the ancillary businesses are imperative. Thus, emerging economies need to focus on channeling ongoing infrastructure projects to create an ecosystem for future investment in HSR infrastructure.

HSR by itself is often not profitable as a stand-alone business. Therefore, it is essential to simultaneously develop plans for station building development, station front development, and a long-term vision for their implications on the long-term plan for urban development in the station surroundings. Moreover, to develop an extensive integrated station-city system, it is necessary to establish cooperation between the rail operator, the urban local bodies, and other local stakeholders such as landowners and private partners in the preliminary stages of the project.

Based on the experience in Japan, emerging economies like India that operate an extensive rail network of conventional railways and are developing an HSR corridor have specific opportunities. Building synergies and avenues to connect existing conventional rail with the proposed HSR poses a challenge as well as an opportunity to diversify the railway business. The integration of such different systems is complex, although it would avoid a “lock-in” situation through the early introduction of nonrailway businesses in an integrated station complex.

Finally, evolving technology is and will keep creating opportunities for new businesses around the railway business. For instance, cashless

payment for rail travel services is the most used cashless payment system in Japan. Emerging economies usually have young populations that can serve as an advantage to develop indigenous technology to form ancillary businesses. However, with the required capacity building and training of human resources, innovative and unique new businesses would add value to station surroundings.

Note

The content of this chapter (including all the figures) were presented by Yoshitaka Ishii, at the ADBI special session titled “Transport Infrastructure and Quality of Life” at the World Conference on Transport Research, 28–30 May 2019, Mumbai. <https://www.adb.org/sites/default/files/related/145966/adbi-transport-infrastructure-and-quality-life-agenda.pdf>

PART III

**Case Studies
and Messages
to Policy Makers**

Key Messages

Since its inception in Japan in 1964, high-speed rail (HSR) has spread far and wide and made an impact on the quality of life everywhere. Early HSR development was more of a race to achieve faster speeds, and its initial success led policy makers around the world to believe in the power of HSR for catalyzing economic development and growth. From the first 515-kilometer line in Japan, the HSR network has grown to 46,000 kilometers the world over in the past 5 decades. The global HSR network has seen astonishing growth and is expected to reach 98,000 kilometers by 2050. Like all infrastructure projects, however, HSR has also been faced with criticism.

Such criticism of HSR development is usually aligned with the returns on investment in infrastructure projects. In the past decade, the People's Republic of China alone has built about 30,000 kilometers of HSR in total. The growth of this network has been in alignment with the economic development of the country, but has raised the question of whether investment in HSR infrastructure is good for the socioeconomic development of countries. Such issues must be addressed in the early stages of HSR development. In this regard, Part III presents case studies from across the world, identifying essential lessons for policy makers about the practical implementation of such large-scale infrastructure projects.

Chapter 14 elaborates on the development and planning process of HSR in the People's Republic of China. *Gaotie*, the country's HSR system, is expanding its network at a rapid pace to improve the competitiveness of railways in the passenger market and facilitate intercity accessibility. However, city centers remain the major starting and destination terminals for most HSR passengers in the country, especially businesspeople who use its service frequently. A reliable and high-quality public transit service, connecting HSR stations and city centers at the launch of HSR operations, is essential to curb the increasing dependence on private cars and taxis. The chapter concludes that instead of building a big HSR station in the city periphery, constructing multiple stations around the city center will greatly enhance travel efficiency and reap more benefits from the transport investments.

Chapter 15 discusses how to analyze the way in which new transport infrastructure may lead to the restructuring and rebalancing of local and regional economies through structural change and the relocation of activities. The chapter reviews arguments in favor of measuring direct

benefits, the progress made in implementing wider impacts in appraisal, and the limitations of such an approach. Focusing mainly on productivity and economic growth due to increased accessibility, evidence from HSR networks in Europe and the People's Republic of China is presented to examine changes in specialization, the impacts on knowledge-intensive sectors, and new firm formation.

Chapter 16 aims to assist decision makers, transportation planners, system designers, and operators as well as political leaders who need to understand HSR operational boundaries for intercity travel to determine which HSR will outperform the others and under which conditions. Using a time–distance factor analysis, the chapter demonstrates the dominance. A case study based on geospatial metadata from the Northeast Corridor in the United States details the system efficiency challenges and emphasizes a need to convert independent dead-end terminals into integrated through-running stations by prioritizing HSR services.

Chapter 17 introduces the 30-year post-privatization experience of Japan Railways (JR) Kyushu in Japan. The chapter explains the company's challenges following privatization of the Japanese railways and the creation of the business foundation to prepare for its transformation into a private operation. Because the railway system is important for long-term economic development, the chapter summarizes the meaningful philosophies and ethical values that the company introduced, with implications of Japan's experience for broader railway systems.

Chapter 18 draws lessons from the experiences in Japan that are critical for initiating station area development projects in emerging economies such as India. The introduction of HSR in Japan in 1964 has drastically diversified travel on railways and thus offers insight on the dire need to consider station area development in this context. With case studies on Tokyo Station and Shibuya Station, the chapter illustrates critical stages of station area development planning such as design of interventions for smoother intermodal transfer, diversification of railway businesses including consumer services, and design of interventions to enhance last-mile connectivity for a better overall travel experience for passengers.

14

Gaotie in the People's Republic of China

Pan Haixiao and Gao Ya

14.1 Introduction

The People's Republic of China (PRC) is a large country and, with its recent rapid economic growth, there is a huge demand for land transport between regions. Rail transportation plays an important role in this demand. Since the 1990s, the proportion of rail transport in the intercity passenger sector has declined because of the development of highways and civil aviation. However, too much reliance on highway transport could cause several environmental, energy, and safety problems. Weather factors such as fog and road congestion can reduce the efficiency and reliability of highway transport as well (Maria 2014). Thus, to provide fast and reliable interregional transportation, rail service has become important.

This chapter reviews the development of different modes of intercity transport in the PRC since 1978. The use of rail, measured in rail passenger-kilometers, has grown far less than other modes, especially highways. To provide better rail options, the PRC began experimenting with high-speed rail (HSR) in the late 1990s. The speed of HSR has increased from its initial 200 kilometers (km) per hour to 350 km per hour.

The Government of the PRC has updated the national railway networks plan with eight “vertical” (north–south) and eight “horizontal” (east–west) passenger corridors, and, on their completion, the national HSR system will be over 30,000 km long in 2020 and 38,000 km long in 2025 (NDRC 2016). Meanwhile, the development of regional HSR will also continue.

Many researchers believe that HSR can bring economic, environmental, and social benefits to the regions and cities that it serves (Feng 2009; Xiao 2011). Researchers have also asserted that areas

situated outside the HSR network, but efficiently linked to it, could benefit from the diffuse effects of major urban agglomerations (Javier, Rafael, and Gabriel 1996). Researchers in the United States have argued that, in addition, HSR can enable big cities to connect further into the hinterland, where housing and commercial space are more affordable (Sean 2012). However, capturing these benefits also requires attention to station location and design (Yu, João, and Luis 2014).

Chen and Peter (2011) found that the PRC's HSR services have substantial and demonstrable effects in aiding the economic transition of cities that are within 2 hours' travel from major urban regions, helping to generate renewed economic growth. To accelerate the HSR network construction, the PRC has standardized work processes. To reduce the difficulty of land acquisition, it has mostly located new HSR stations in suburbs, away from large urban centers. This means that access to stations can require a long trip from the city center. The improvement in accessibility that HSR offers has realized the expected development around suburban stations.

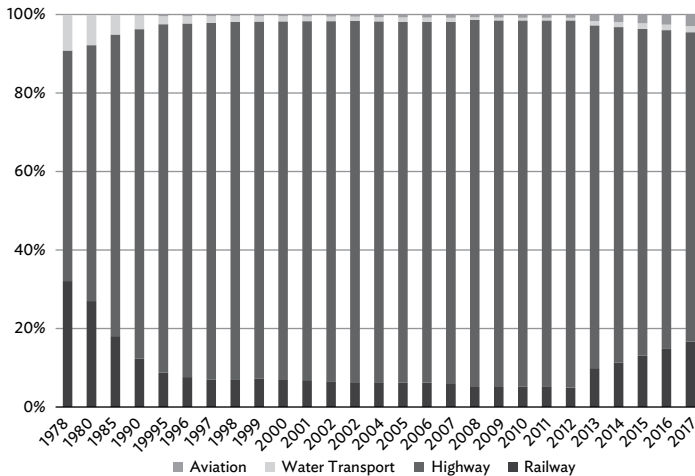
In this study, we also investigate and analyze HSR passenger travel behavior and mode choices, using the Shanghai Hongqiao and Shaoxing Stations as a case study.

11.2 Multimodal Intercity Transport

The PRC's railway length grew from 51,700 km in 1978 to 127,000 km in 2017. The number of rail passengers is also increasing, reaching 3,084 billion trips in 2017. This is a 278.40% increase in passengers over 1978 with an average annual growth rate of 3.47%. Over the last decades, the average annual growth rate of passengers has been even higher, reaching 10% in recent years. Moreover, rail passenger intensity (the number of passengers carried per km) has grown quickly since 2007, to 22,694 passengers per km in 2016, which is almost seven times the highway passenger intensity. Railway transportation grew from 1,093 billion passenger-km in 1978 to 12,579 billion passenger-km in 2016, which is an increase of 1,051%. The number of passenger-km is growing by 12.52% per year (Fan 2011). As more HSR lines start service, the passenger volume carried by rail transportation is expected to grow continuously.

However, despite the growth in the rail service and its use, the rail share of intercity travel had dropped before 2011. The loss of market share reflects the tremendous developments in highway transport (and associated increases in automobile ownership) that have occurred over the last few decades. The PRC's highway length grew from 890,200 km in 1978 to 4,770,000 km in 2017. Civil aviation also attracted a substantial share of the intercity passenger growth in these decades. Consequently,

Figure 14.1: Proportion of Intercity Passengers Carried by Different Transport Modes, 1978–2017



Note: Data for 1978 and 1980 are from the 1981 China Statistical Yearbook.

Source: National Bureau of Statistics of the People's Republic of China, 1981–2018.

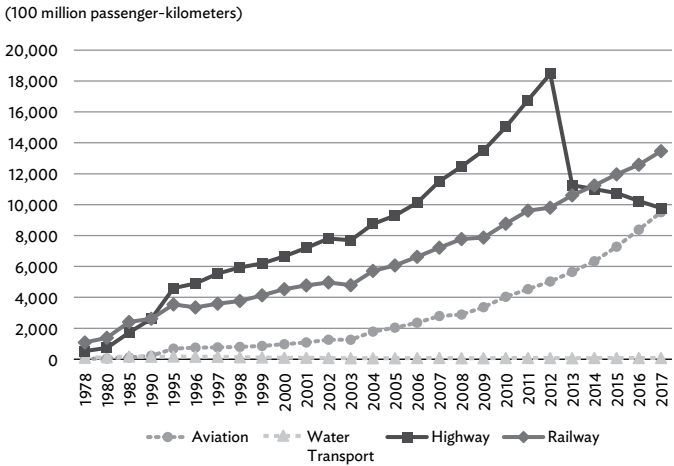
the railway's share in the intercity passenger market fell dramatically from over 30% in 1978 to around 5% in 2001 and remained constant at around 5% for the following decade (Figure 14.1).

This changed after 2011. Measured in passenger-km, the rail and aviation volumes have shown a fairly steady climb in recent years. However, the shrinking of growth in the highway sector is notable (Figure 14.2). Since 2014, rail has become the dominant sector for intercity travel in terms of passenger-km.

Rail transport has now displaced highways as the dominant means of travel in the intercity passenger transport market. This is true even for travel distances over 300 km, for which rail should be highly competitive. The proportion of civil aviation is also increasing analogously to rail.

Thus, many researchers view HSR as a substitute for other intercity transportation modes such as traditional rail (Givoni 2006; Givoni and Dobruszkes 2013), aircraft (Dobruszkes, Dehon, and Givoni 2014; Bergantino, Capozza, and Capurso 2015), and automobiles (Campos and De Rus 2009). In the PRC, the launch of HSR also changed the mode share for intercity travel. For instance, the Wuhan–Guangzhou Corridor is an HSR line, connecting two megacities with a total distance of 1,069 km.

Figure 14.2: Passenger Volumes of Different Transport Modes, 1978–2017



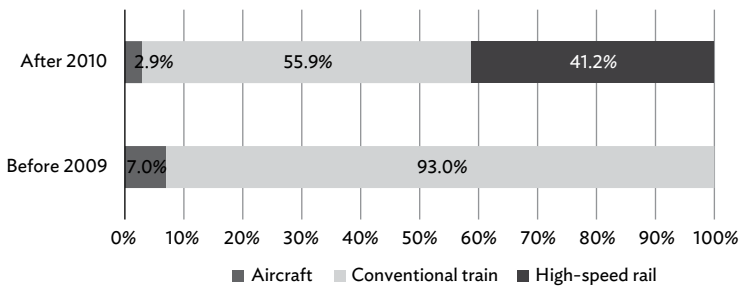
Note: Data for 1978 and 1980 are from the 1981 China Statistical Yearbook.

Source: National Bureau of Statistics of the People's Republic of China, 1981–2018.

Wu et al. (2014) conducted a survey showing that conventional rail was the dominant mode of transport along this corridor before the Wuhan–Guangzhou HSR. Since it started operation in 2009, however, HSR has become a significant alternative to traditional rail and aviation (Figure 14.3). For passengers using the HSR, 42% have shifted from road, 52% from conventional rail, and 6% from civil aviation.

Our analysis and comparisons of data obtained from a survey in Shaoxing furthermore allow us to address the role of HSR in intercity leisure travel. According to the PRC’s Ministry of Culture and Tourism, the rise of domestic tourism in the PRC has been impressive, with an annual growth rate of over 10% for the past 5 years. The country’s traffic congestion has attracted the attention of academia and the government (Albalade and Bel 2010; Cuccia and Rizzo 2011). In particular, severe congestion on highways during national holidays has been a frequent headline given the country’s rapid motorization. The construction of the HSR has extended the tourist market. For example, the number of tourists visiting the famous historical city of Shaoxing, with three World Heritage sites, reached 100 million in 2017. Our survey shows that the

**Figure 14.3: Rail and Air Share
in the Wuhan–Guangzhou Transport Corridor**



HSR = high-speed rail.

Source: Wu, Nash, and Wang (2014).

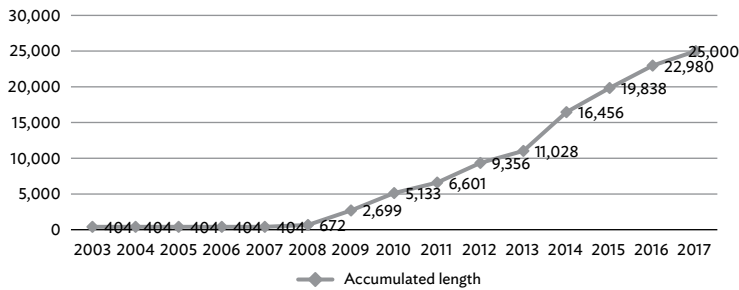
average distance travelled of visitors to Shaoxing has increased from 304 km to 473 km, reflecting the much enlarged tourist market after the launch of the HSR in 2013. Moreover, 30% of tourists traveled by HSR to Shaoxing. Despite the sharp rise in motorization, the opening of the HSR resulted in a 6.7% reduction in the use of cars to travel to Shaoxing. An improvement in the ticketing system for family and other tourist service packages may further increase the use of the HSR.

According to previous studies, rail allows more efficient use of land for transportation than highways and helps cut pollution compared with automobiles (Wee, Janse, and Brink 2005). Because of the scarcity of land and the high population density, the PRC is seeking to make efficient use of land and reduce pollution by promoting rail use. The PRC has been planning HSR construction since the 1990s, as early signs suggested that rail could become more attractive than civil aviation or automobiles with the rise in income and the growth of the economy.

14.3 Network Planning and Construction

The construction of HSR in the PRC started in the beginning of the 21st century. The Qinhuangdao–Shenyang line, with a top speed of 200 km per hour, was started in October 2003 and has been the cornerstone of the HSR age. To speed up the rail development, the State Council passed the Mid-term and Long-term Railway Network Plan in January 2004. It was revised in 2008 (NDRC 2008), then in 2016, expanding the national railway program to create over 150,000 km of national railway lines by 2020,

**Figure 14.4: Expansion of High-Speed Rail
in the People’s Republic of China
(kilometer)**



Source: Ministry of Transport (2003–2017).

with over 30,000 km of HSR lines (NDRC 2016). It also decided that the intercity HSR should cover the main cities in economically developed and densely populated areas such as the Yangtze River Delta, the Pearl River Delta, and the Shandong Peninsula. By January 2018, the HSR development had reached 25,000 km (Figure 14.4). The 109,600 square km (km²) Yangtze River Delta is one of the most developed areas in the PRC, with 20% of the national gross domestic product output and a high urbanization rate. The construction of the HSR network will cover four city centers: Shanghai, Nanjing, Hangzhou, and Hefei (NDRC 2010).

The system is designed for a “traffic circle” of 1–2 hours between major cities and their adjacent cities, with transfers allowing passengers to arrive at all other cities in the delta within 3 hours. Such a network could allow these four cities and their smaller counterparts to function as a single integrated urban megaregion. During the last decades, the PRC has constructed 16 railway lines, including Hefei–Nanjing, Zhengzhou–Xuzhou, and Quzhou–Jiujiang (Table 14.1). To allow for fast construction, it has planned many HSR stations (e.g., Quzhou Railway Station and Xuzhou East Railway Station) in suburban locations away from city centers.

In 2009, the National Development and Reform Commission also passed the Intercity Rail Transportation Network Plan for the Pearl River Delta Region (Revision). The rail network proposed in the plan comprised 23 lines with a total length of 1,890 km, reaching a network

Table 14.1: High-Speed Rail Lines in the Yangtze River Delta

No.	Name of High-Speed Rail Line	Number of Stations Passed	Designed Speed	Length	Start
1.	Quzhou–Jiujiang	10	200 km/h	334 km	Dec 2017
2.	Zhengzhou–Xuzhou	9	350 km/h	362 km	Sep 2016
3.	Jinhua–Wenzhou	7	200 km/h Highest: 250 km/h	189 km	Dec 2015
4.	Nanjing–Anqing	14	250 km/h	257 km	Dec 2015
5.	Hefei–Fuzhou	21	350 km/h	813 km	Jun 2015
6.	Hangzhou–Changsha	21	350 km/h	921 km	Sep 2014
7.	Nanjing–Hangzhou	11	350 km/h	249 km	Jul 2013
8.	Hangzhou–Ningbo	7	300 km/h Highest: 350 km/h	152 km	Jul 2013
9.	Hefei–Bengbu	9	350 km/h	131 km	Oct 2012
10.	Beijing–Shanghai	24	380 km/h	1,318 km	Jun 2011
11.	Shanghai–Hangzhou	9	300 km/h	165 km	Oct 2010
12.	Shanghai–Nanjing	22	300 km/h	301 km	Jul 2010
13.	Ningbo–Taizhou–Wenzhou	12	250 km/h	275 km	Sep 2009
14.	Wenzhou–Fuzhou	13	250 km/h	298 km	Sep 2009
15.	Hefei–Wuhan (planned)	13	250 km/h Highest: 300 km/h	360 km	Apr 2009
16.	Hefei–Nanjing	7	250 km/h	156 km	Apr 2008

km = kilometer, km/h = kilometer per hour.

Source: Authors.

density of 4.8 km of rail per million km² of land by 2030 (NDRC 2009). Among the 23 lines, the construction of 15 will take place by 2020. The network design comprises three rings and eight axes and will link nine cities of the Pearl River Delta region and extend to other parts of Guangdong Province; Hong Kong, China; and Macau, China. By February 2018, the total rail length in Guangzhou reached 4,510 km. Of this, 1,542 km could allow HSR services with speeds of 200 km per hour and higher.

14.4 Station Location

In the PRC, the “HSR new town” model has dominated government planning in the site selection for HSR stations. In this model, most new station sites are located in suburbs or exurbs away from the densely populated centers. The hope is that HSR stations will trigger the development of new towns.¹ The plan is to stimulate local economic development by offering an attractive alternative location to the crowded city centers.

Take the example of the 1,318 km Beijing–Shanghai HSR line. Of the 24 cities connected by the line, 18 chose to build HSR stations in suburbs. The reasons for suburban site selection include ensuring lower costs, capturing rising land values, and relieving pressure on the central areas of the cities. Since there is less densely developed land in the suburbs, it is possible to reduce the cost of land acquisition compared with that in the city centers. Suburban station development may also generate land value increment profits due to positive spillover effects. Finally, many cities are interested in promoting the transformation of the urban spatial structure from a single center into a polycentric structure to alleviate the pressures of high population density and intense commercial activity in the central cities.

The railway authorities also want to locate HSR stations in suburbs. This simplifies HSR track alignment, allowing straight lines that reduce the project construction costs as well as the operation costs of HSR. Their preference for suburbs may be compounded, as the railway authorities are not responsible for the connecting transport for passengers accessing stations.

In addition, the location of HSR stations varies according to the influence of the local government in the cities through which it passes or which provides a station. Because of the PRC’s hierarchical administrative system, large cities are more influential in controlling negotiations between the local government and the railway authority than smaller cities. Thus, in megacities, most HSR sites are located in suburbs. In most medium and small cities, however, new stations are located in the exurban fringe (shown in Table 14.2), where it is difficult to provide a good public transport service. Hence, smaller cities have greater local car traffic associated with stations.

Shanghai Hongqiao HSR Station is a typical example. The station is part of the Hongqiao Integrated Transport Hub (Figure 14.5), which includes an international airport and the Hongqiao business zone. The Hongqiao area plan is intended to guide development in the vicinity

¹ Comparable to what may be referred in other countries as major metropolitan subcenters or districts.

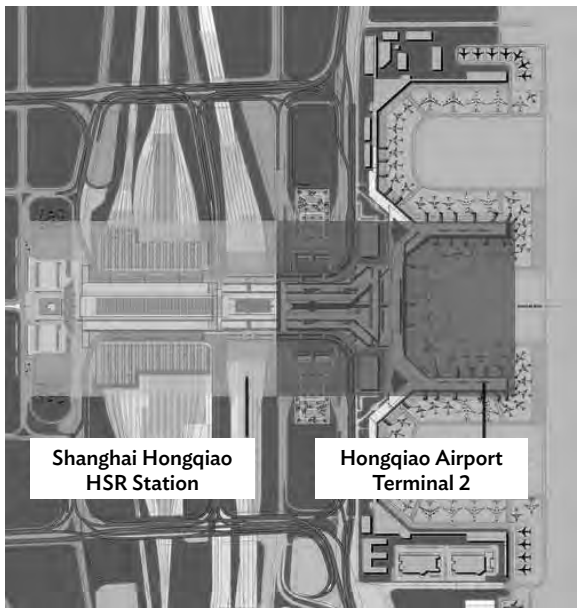
Table 14.2: Major High-Speed Rail Station Site Locations and Rail Line Plans

Name of High-Speed Rail Station	Start	Number of Metro Lines (at Present)	Location of Station	Linear Distance from the Center (kilometer)	Operation Situation of Metro Lines
North Xi'an Station	Jan 2011	0	Suburban	13	Line 4: not opened Line 13: not opened
East Zhengzhou Station	Sep 2012	1	Suburban	8	Line 1: Dec 2013 Line 5: not opened
East Hangzhou Station	Jun 2013	2	Suburban	13	Line 1: Nov 2012 Line 4: Jan 2018 Line 6: not opened
Shanghai Hongqiao Station	Jul 2010	3	Suburban	15	Line 2: Jun 2000 Line 10: Apr 2010 Line 17: Dec 2017
South Guangzhou Station	Jan 2010	2	Suburban	18	Line 2: Sep 2010 Line 7: Dec 2016 Line 22: not opened Foshan Line 2: not opened
South Nanjing Station	Jun 2011	4	Suburban	10	Line 1: Jun 2011 Line 3: Apr 2015 Line S1: Jul 2014 Line S3: Dec 2017 Line 6: not opened
South Beijing Station	Aug 2008	2	Near city center	6	Line 4: Sep 2009 Line 14: Dec 2015
West Jinan Station	Jun 2011	1	Suburban	12.5	Line 1: Jan 2019 Line 3: not opened Line R1: not opened
Wuhan Station	Dec 2009	1	Suburban	10 (to subcenter)	Line 4: Dec 2014 Line 5: not opened
Tianjin Station	Aug 2008	3	City center	1	Line 2: Jul 2012 Line 3: Oct 2012 Line 9: Oct 2012
South Changsha Station	Dec 2009	2	Suburban	10	Line 2: May 2016 Maglev Line: May 2016 Line 4: not opened

Source: Collected by the authors.

of the transport hub. The station is located 15 km from Shanghai city center (Figure 14.6) and links the Beijing–Shanghai HSR with the Beijing–Shanghai railway and the Shanghai–Nanjing intercity railway to the north as well as the Shanghai–Kunming railway, the Shanghai–Hangzhou–Ningbo passenger dedicated line, and the Shanghai–Hangzhou intercity railway to the south. The station

Figure 14.5: Hongqiao Integrated Transport Hub Project



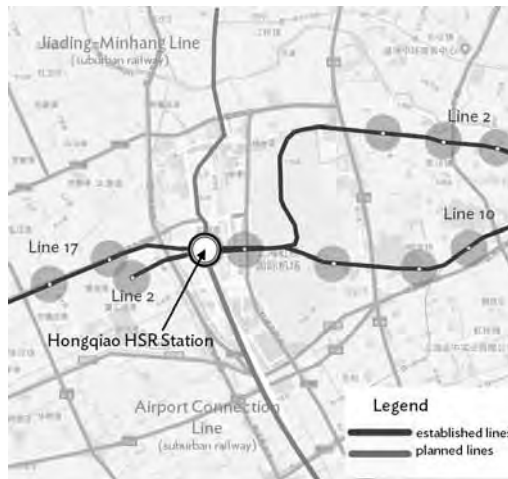
HSR = high-speed rail.
Source: Authors.

Figure 14.6: Location of Hongqiao High-Speed Rail Station and Its Transport Connections



HSR = high-speed rail.
Source: Authors.

Figure 14.7: Hongqiao High-Speed Rail Station and Metro Connection



HSR = high-speed rail.

Source: Authors.

opened in July 2010 with predicted yearly passengers of 120 million–140 million people by 2020. The daily passenger dispatch volume reached 169,800 in 2017 (around 62 million for the year), double the number in 2011 (68,800 passengers per day).

Newly constructed expressway networks and rail transit networks enhance the connection between Shanghai city center and the Yangtze River Delta region through the station. So far, the three metro lines (lines 2, 10, and 17) that provide seamless transfer from Shanghai city center extend to the station (Figure 14.7).

14.5 Station Design and Services

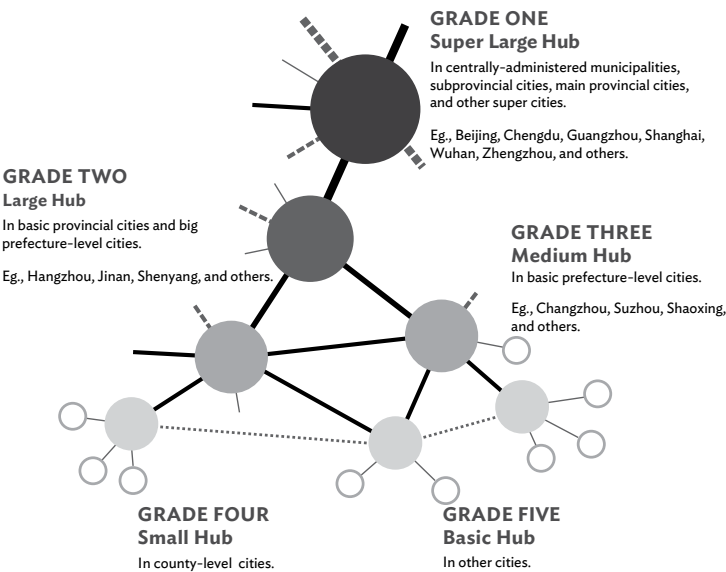
The development of HSR has involved the construction of a large number of stations. Stadium-sized stations act as city landmarks, with a well-designed exterior, high-standard construction, and modern facilities. According to Chen, Hickman, and Saxena (2014), the rail stations in the PRC can be divided into five types—super large, large, medium, small, and basic hubs—based on the local governments' plans and their roles. For hubs with different grades and roles, the facilities and services can be

different (Figure 14.8). For instance, Guangzhou South Railway Station, 17 km south of the downtown area, is 500 meters long and 450 meters wide, with a covered area of 486,000 square meters.

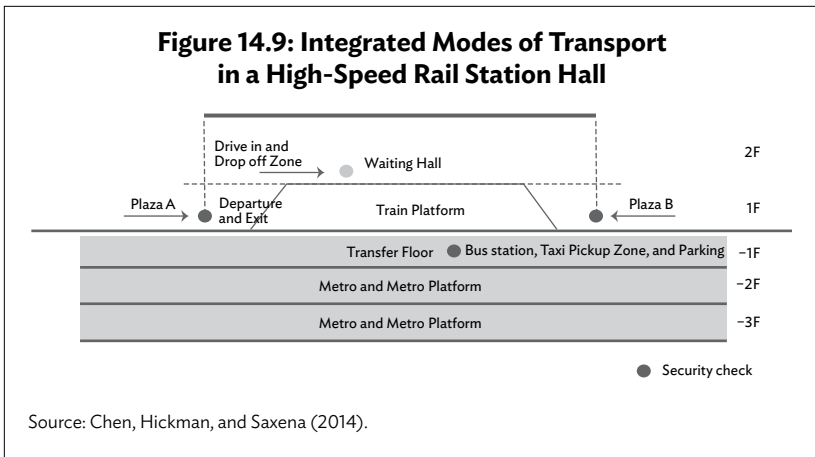
A multilevel infrastructure can integrate multiple modes of transport into the station, including cars, public transit, metros, taxis, and intercity buses. For example, Shanghai Hongqiao Railway Station is connected to the city center through three metro lines, an elevated motorway, and 14 bus routes. Since the traffic volume is high on national holidays, there is a large square at the front of the railway station.

HSR stations also have large parking lots. According to the *Code for Urban Parking Plan* (the standard parking plan in the PRC), all rail stations should provide one parking space per 100 peak passenger volume (Ministry of Housing and Urban-Rural Development and General Administration of Quality Supervision, Inspection and Quarantine 2016). For example, Guangzhou South Railway Station has parking space for 2,300 vehicles. At Shanghai Hongqiao Station, there is space for 3,000 vehicles.

Figure 14.8: Grades of High-Speed Rail Stations



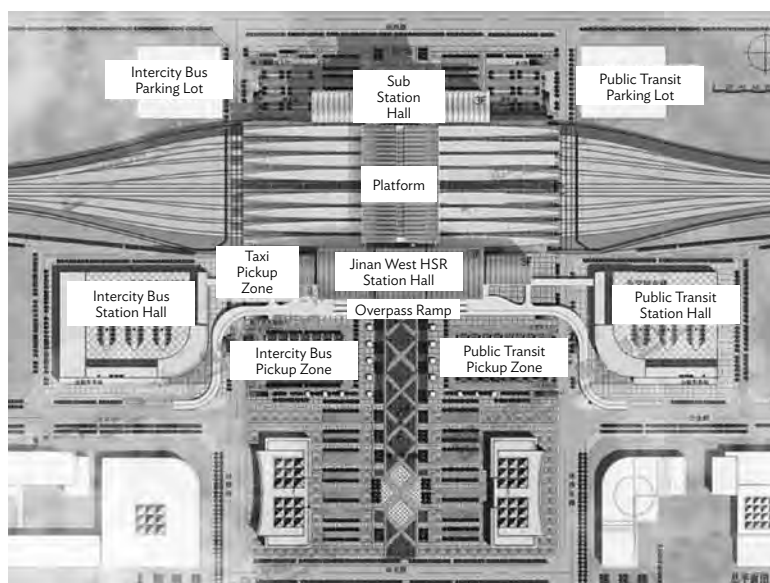
Source: Chen, Hickman, and Saxena (2014).



As taxis play an essential role in the passenger flow, the layout of pick-up zones aims to make them convenient for passengers. The pick-up areas usually are located on both sides of the HSR station halls. Inside the station hall, different modes of transport are integrated through various floors, called multidimensional traffic organization, as Figure 14.9 shows. With a waiting hall located on the second floor, passengers arriving by car can enter the station directly from the second floor through an overpass ramp, as Figure 14.10 shows. However, the exit and arrival areas for passengers are usually located on the same floor as the train platform, while parking lots, taxi pick-up zones, and public transit stations are underground. The metro is located on the second and third basement floors. Plenty of escalators help to carry streams of passengers.

In terms of HSR service, the departure process is relatively complex, since a passenger needs to take a reserved ticket and pass through a security check before entering the waiting hall for the train. Staff automated machines check their tickets 15 minutes before the departure of the train. Most waiting halls are huge to accommodate the super-peak period rush and are enclosed buildings with air conditioning, as Figure 14.11 shows. Online bookings now allow passengers to pay for their tickets using an app, the official website, or a hotline. HSR stations on certain corridors even allow passengers to board the train directly with their personal identification card, easing the ticket-checking process. However, there is only a standard fare ticket without other package choices (e.g., family ticket, weekend ticket, or advanced ticket) for passengers.

Figure 14.10: Overpass Ramp Moving Passengers Directly to the Departing Floor in Jinan West Station



Source: The road network design of the vicinity of Jinan West Station (<http://www.thupdi.com>).

The HSR service is safe and reliable. Until now, there have been almost no major security lapses, and the punctuality rate is high. Even during the Spring Festival, a period of peak passenger volume, the on-time rate is close to 100%. Any delay is displayed on large electronic display screens in the station hall or conveyed through messages on mobile phones. Passengers also receive information about gate numbers to the trains and reserved seats. Even for business travel, HSR is cost-effective. Compared with other countries, the HSR ticket price in the PRC is relatively low, at only CNY42 per 100 km for second-class travel. Therefore, many people living in cities surrounding a metropolis use HSR to commute. In the city cluster regions, such as the Pearl River Delta, the Yangtze River Delta, and Beijing–Tianjin–Hebei, where the economic interaction between cities is strong, the HSR corridor is extremely busy. For example, the departure interval of HSR services from Suzhou to Shanghai during the morning peak hours is just 5 minutes, and it serves as an urban public transit system. Nevertheless,

there are some stations where the HSR service frequency is low, for example at Xianlin Railway Station (in Nanjing), from which there is only one train to Shanghai per day.

Figure 14.11: Waiting Hall at Guangzhou South High-Speed Rail Station



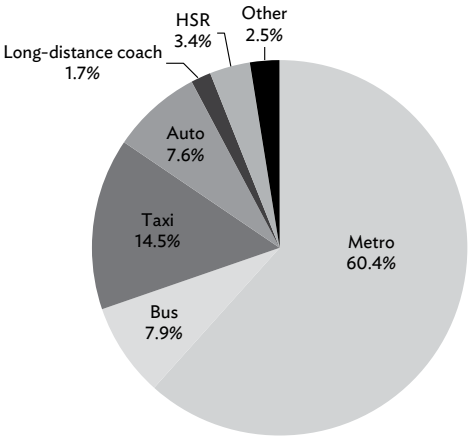
Source: Chen, Hickman, and Saxena (2014).

14.6 High-Speed Rail and Access Mode

Since HSR stations are far from the city centers, where there is a high demand for travel, the PRC has put considerable effort into improving the transport between the stations and the city centers, such as providing public transit services (bus, metro, or both) simultaneously. In Jiaxing, where the HSR station is 8 km away from the city center, only a bus connects them. According to the survey and analysis by Ye, Chen, and Liu (2017), passengers using taxis and public transit account for over 90% of passengers in big cities. Passengers value time more than expense.

Figure 14.12 shows the modal split that we observed in a survey at Shanghai Hongqiao Station. We found that 60.4% of passengers accessed HSR by urban rail transit and an additional 7.9% used the conventional bus system, bringing the total users of public transport to access HSR to 74.9%. This is far in excess of the planning forecast share for transit, which was 50%. Of the private transit modes, only 7.6% of passengers take cars to Hongqiao Station, while 14.5% take a taxi. The forecasts for the project predicted considerably higher private transport access.

Figure 14.12: Modal Split of Transit to Shanghai Hongqiao High-Speed Rail Station

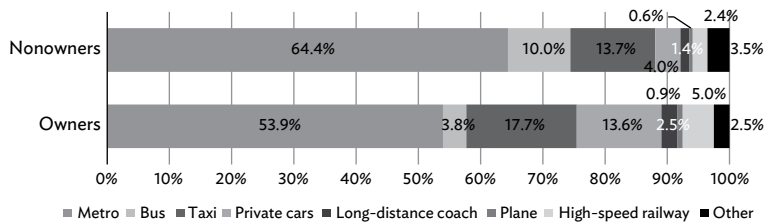


HSR = high-speed rail.
Source: Authors.

Figure 14.13 shows the mode of access to HSR stations by car owners and those without a car. Even among HSR users who possess a car, only 13.6% drove to the station. These private car-owning passengers showed a preference for the metro, with 53.9% using the metro to travel to the station. Private car-owning passengers use bus transit much less than passengers who do not own a car. These results show the importance of the provision of high-quality public transport for connecting city centers and HSR stations to reduce the demand for car travel. The investment in metros to HSR stations undoubtedly reduced car journeys to stations located far away from city centers—a boon from the traffic and air pollution perspective.

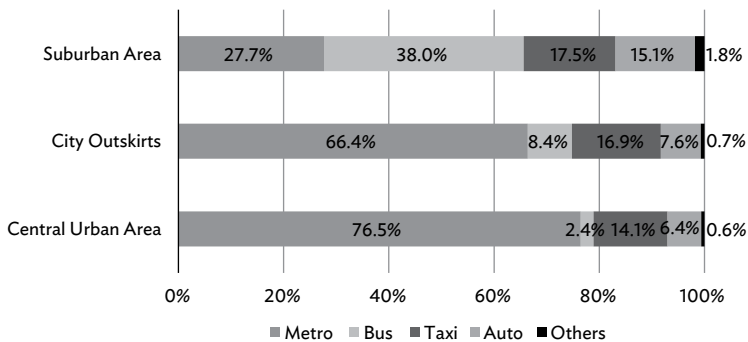
Comparing the modal choice of travel to the HSR station from various districts of Shanghai, we found that 76.5% of passengers from the central urban area take urban rail to the HSR station, while only 7% use cars. Passengers from suburban areas, which are less well served by the urban rail network, rely more on conventional bus transit, with 38% taking buses to the station and only 27.7% using urban rail. From suburban areas, the demand for travel to the HSR station by car is 15.1%, double that of the central urban area (Figure 14.14).

Figure 14.13: Station Access Mode Choice of Car Owners and Nonowners



Source: Authors.

Figure 14.14: Modal Split of Transit to the High-Speed Rail Station from Different Regions of Shanghai City



Source: Authors.

To provide a better service, HSR now also connects Shanghai Railway Station, located closer to Shanghai city center. People can take public transport to the station, such as metro lines 1, 3, and 4, as well as the normal bus. Of the HSR passengers to Shanghai Railway Station, 44.6% use the metro, normal buses account for 15.7%, and taxis account for 27.4%.

The survey from Wuchang Railway Station in Wuhan shows that 92% of passengers take transportation other than rail: 20% intercity buses, 26% metros, and 23% city buses (Table 14.3). To improve the interconnection to public transit systems, the distance is shortened to 70 meters, while the walking distance to private cars is 166 meters (Chang and Ye 2009).

**Table 14.3: High-Speed Rail
Access Modes at Wuchang Station**

Transfer Modes	Proportion (%)
Rail	8
Intercity Bus	20
Public Transit	26
Metro	23
Taxi	6
Auto	8
Others	10

Source: Chang and Ye (2009).

These results indicate that people who take HSR are more sensitive to time, reliability, and flexibility. There is a need to upgrade urban public transport services along with the construction of HSR, metro, or other facilities to prevent congestion around HSR stations.

14.7 New Town Plan

The PRC cities' local governments expect HSR to boost the city economy and development. There are several plans, such as a station area master plan and urban design plan, to guide the construction in the vicinity of HSR stations. For cities like Nanjing and Shanghai, HSR stations provide a prospective zone, a subcity center, or even a new town, which is called an "HSR new town." Taking Nanjing as an example, the catchment area of Nanjing HSR South New Town is 184 km², with a projected population of 1.6 million, which will be one of the three subcenters of the city following the master plan. Changsha HSR New Town, with 0.5 million people, occupies 46.9 km². The plan for Jinan West New Town shows the same population but an area of 55 km².

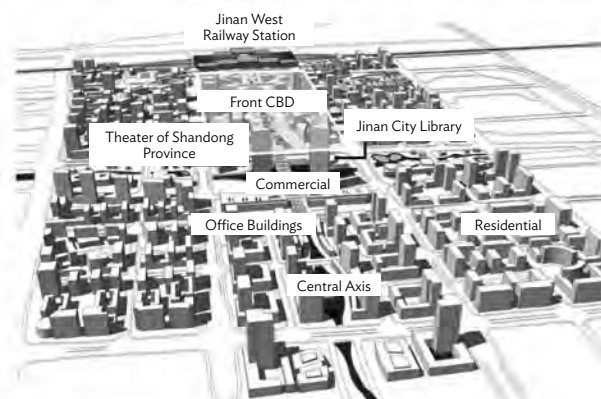
Usually, new clusters of high-rise buildings for businesses, offices, and commercial activities surround HSR stations. Sometimes, public facilities such as museums, exhibition centers, and libraries are also located near the stations. Figure 14.15 shows the master plan of the Tianjin West HSR Station area, with an exhibition center, a sports center, and clusters of office and commercial buildings to the north of the station as well as hotels to the south. The design is for a mixed-used area to attract people to live, work, and entertain.

Figure 14.15: Master Plan of the Tianjin West High-Speed Rail Station Area



Source: Liu, Zhou, and Chen (2008).

Figure 14.16: Planned Model of the Jinan West High-Speed Rail Station Area



Source: The road network design in the vicinity of Jinan West Station (<http://www.thupdi.com>).

Jinan has built its West Station on greenfields. There is an axis in front of the station, with a city library and a theatre on its two sides. The public facilities aim to promote the development of peripheral regions (Figure 14.16). The city has barely realized this aim in terms of the functions that the plan defines; except the HSR station, many supportive elements do not exist.

14.8 Station Location and Travel Efficiency

As many HSR stations are located far from city centers, empirical data are necessary to analyze their impact on the travel characteristics of passengers and the urban spatial structure, including the travel distance distribution, changes in travel time, and HSR passenger distribution in different geographic locations. This information will be useful in improving the travel efficiency of intercity HSR services through the station location or connecting transport service options as well as the design of stations.

We conducted a survey of 1,834 respondents from 27 February 2012 to 3 March 2012 at Hongqiao HSR Station. Passengers in the waiting hall were selected randomly for face-to-face interviews and asked about their trip origin and destination, on-board HSR travel time, mode of travel to the HSR station and travel time to the station, and demographic characteristics.

From this survey, we learned about passengers' social and economic attributes. We also collected information for each segment of their travel—from origin to destination—and their travel characteristics before and after the opening of the HSR station. Based on these data, we can analyze the impact of the location of HSR stations and the connecting transport system on the travel efficiency for HSR passengers in terms of time and cost. We can also compare the actual findings with transit planners' forecasts made in preparation for the development of HSR services and stations. The following research questions are explored in this study:

- (i) How far will passengers travel by HSR, and which factors will influence the passenger volume between Shanghai and a destination city?
- (ii) Where do the passengers traveling to Shanghai originate? As the location of the station is closer to neighboring provinces of Zhejiang and Jiangsu, how many passengers are from regions outside Shanghai?
- (iii) What is the proportion of time spent in each segment of travel, and how can we improve travel efficiency?

The PRC covers a vast geographical territory, and the construction of a national HSR network will facilitate interregional connections. To see how passengers are distributed from Hongqiao Station to their destinations, we conducted a regression analysis based on the variables of passenger numbers, the population of the destination city, and the distance between Shanghai and that city. We found that the number of passengers is in direct proportion to the destination city's population but in inverse proportion to the distance between Shanghai and the city (Table 14.4). In other words, the larger the population of the destination city, the more passengers travel from Shanghai to the destination city; the shorter the distance to the destination city, the more the passengers travel via HSR.

The research reveals that the average passenger travel distance is 377.4 km, which is not as far as the expectation before the opening of

Table 14.4: Number of Passengers as a Function of the City Population and Distance

Model	B	t	Sig.
Constant	1	2.71	0.015
City population (10,000 persons)	0.086	2.76	0.013
Distance (kilometer)	-0.125	-3.01	0.008

Source: Authors' calculations based on the survey data.

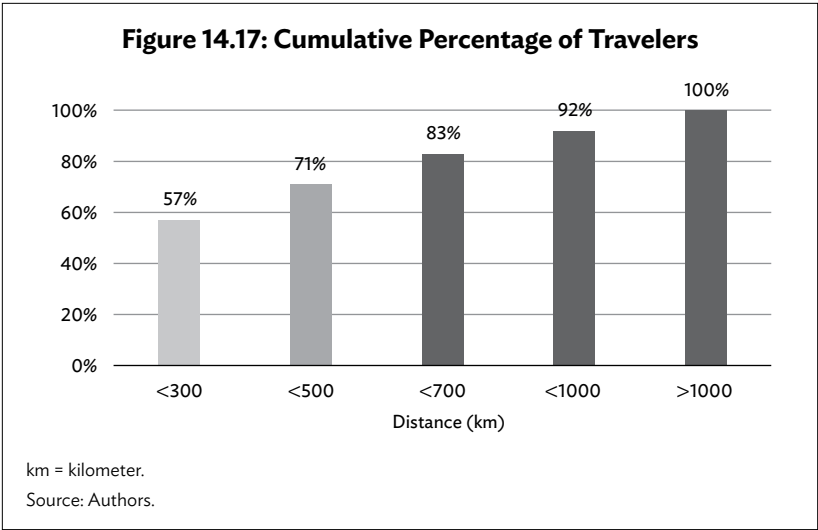


**Table 14.5: Origin of Surveyed Passengers
at Hongqiao High-Speed Rail Station**

	Number of Passengers	% of Passengers
Hongqiao Airport transfer	75	4.1
Within Shanghai	1,595	88.1
Outside Shanghai	141	7.8

Source: Authors' calculations based on the survey data.

HSR indicated. It can be concluded from the travel distance distribution that short- and medium-distance passengers still comprise the majority of HSR travel, with 57% of them traveling less than 300 km and 71% traveling less than 500 km (Figure 14.17).

From Table 14.5, we can see that 88% of the passengers surveyed are from different districts in Shanghai, 4.1% transferring from the nearby Hongqiao Airport and 7.8% from outside Shanghai.

To analyze the geographic location of passengers from Shanghai, we divided the 17 districts in Shanghai into three major categories—the central urban area, the city outskirts, and the outer suburban districts (Table 14.6 and Figure 14.18).

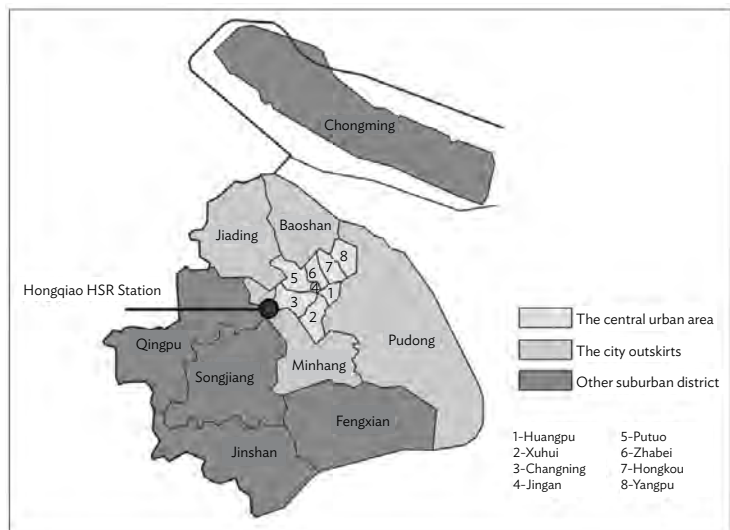
Table 14.5 reveals that approximately half of HSR passengers come from the central urban area of Shanghai, 40% from the city outskirts, and only 10% from the outer suburban areas. Further analysis of the

Table 14.6: Administrative Districts' Distribution in Shanghai

Location	District Name	
Central urban area	Huangpu district	Hongkou district
	Zhabei district	Changning district
	Jing'an district	Yangpu district
	Xuhui district	Putuo district
City outskirts	Baoshan district	Pudong new area
	Jiading district	Minhang district
Outer suburban districts	Chongming district	Songjiang district
	Fengxian district	Qingpu district
	Jinshan district	

Source: Authors.

Figure 14.18: Shanghai District and County Administrative Divisions

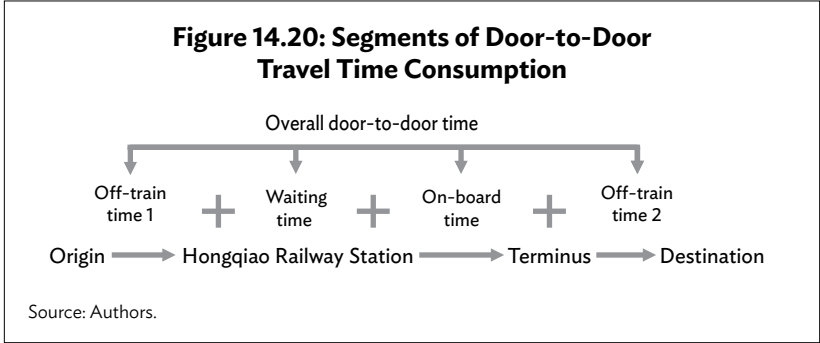
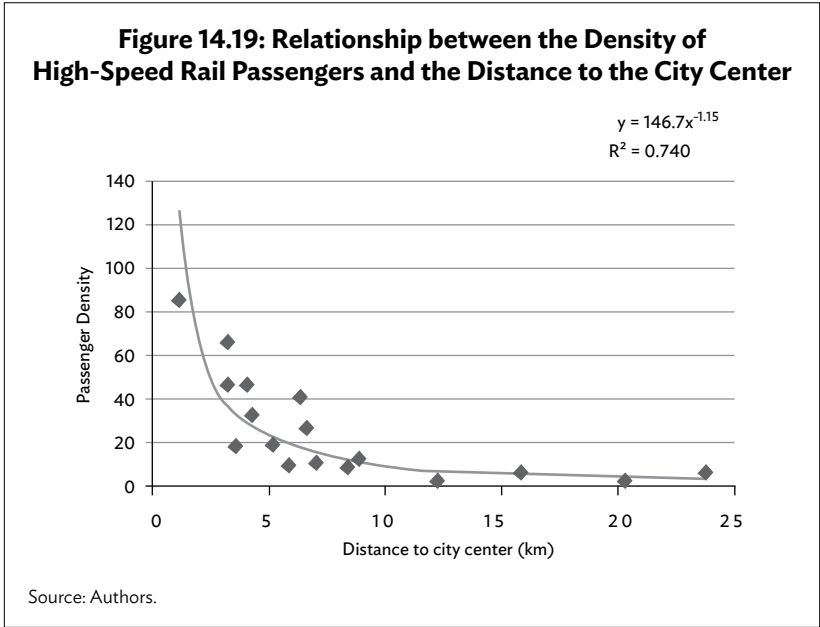


HSR = high-speed rail.

Source: Authors.

passenger intensity from various administrative districts of Shanghai (where intensity is the number of passengers divided by the population of the district) shows that the passenger intensity is in inverse proportion to the distance to the central urban area (Figure 14.19). In other words, the majority of passengers come primarily from the dense central urban areas and adjacent districts. Thus, an HSR station located in a suburb will require the majority of passengers to travel extra distances.

As Figure 14.20 illustrates, the total door-to-door travel time for HSR comprises four parts: the time from the origin to Hongqiao HSR

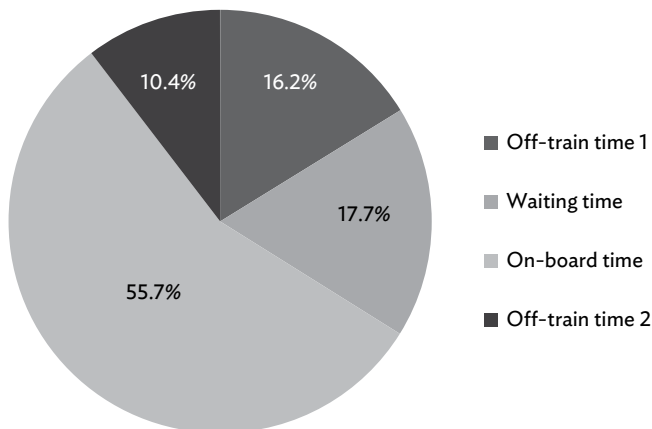


Station, the waiting time at the station, the travel time on board the HSR service, and the time from the destination HSR station to the point of destination.

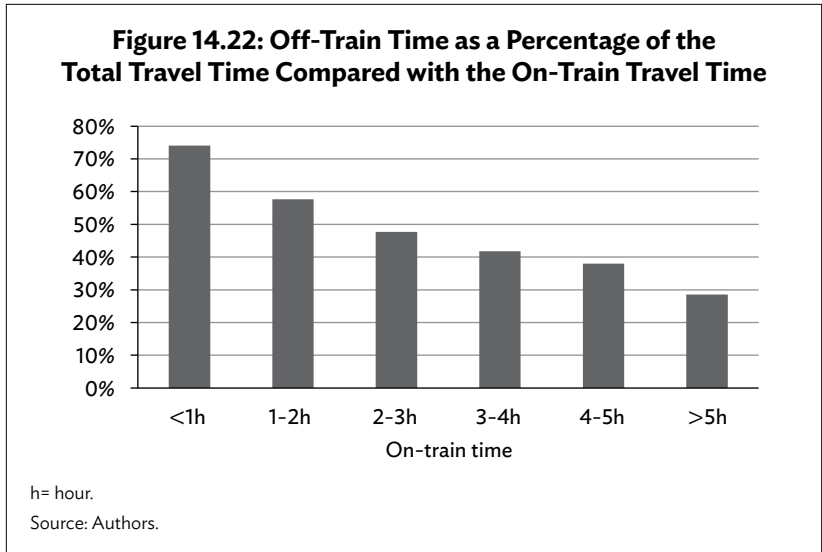
As the speed of HSR is high, the on-board time between two stations is greatly reduced compared with traditional rail or highway travel. However, if people travel a relatively short distance, the on-board time may comprise only a small portion of the total travel time. In this sense, during the planning and construction of HSR, it is necessary to pay attention to the access modes serving HSR stations. A large improvement in travel efficiency through HSR can only be realized when the connecting travel time from the origin to the HSR station and the egress time to the travel end point can be kept down in proportion to the overall travel time. If the planning does not account for this, the increase in train speed may make a limited contribution to the total travel efficiency.

Our survey makes apparent that the average on-board HSR travel time is 192 minutes, accounting for 55.7% of the total travel time, and the transit time to Hongqiao HSR Station is 56 minutes, and the waiting time for the HSR trains 61 minutes (Figure 14.21). For shorter trips under 300 km, the on-board travel time for HSR only accounts for 25% of the total travel time, as shows in Figure 14.22. Thus, for shorter trips, the higher train speed will produce less benefit in improving travel efficiency, and efforts during HSR planning to reduce the off-train time are really the key.

Figure 14.21: Total Passengers' Door-to-Door Time Composition



Source: Authors.



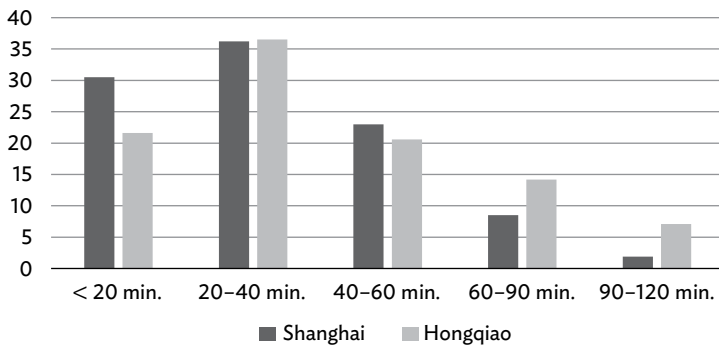
Before the opening of Hongqiao HSR Station, people could take traditional or high-speed trains at either Shanghai Railway Station or Shanghai South Railway Station, both of which are located quite close to the city center. Comparing passengers' average access time to those two stations with the average access time to the newly built Hongqiao HSR Station, the average access time has increased by 18%, from 50 minutes to 59 minutes (Table 14.7). The passengers whose access time increased the most are those whose origins were central urban districts. Passengers in the suburban southern part of Shanghai benefit from the location of Hongqiao HSR Station in the form of reduced access time to the station. However, the passenger intensity is relatively low there. The large-scale expansion of the Shanghai urban rail system over the past several years has partially mitigated the effects of having an HSR connection located farther away, and it appears that the travel time increase is acceptable to most passengers.

One study has compared the access time to the two stations after the opening of the HSR service in Shanghai, showing that the access time to Hongqiao HSR Station is longer than that to Shanghai Railway Station (Figure 14.23). People will also pay CNY3 more to travel to Hongqiao HSR Station on average.

Table 14.7: Access Time Changes in Different Districts of Shanghai

Location	District	Average Access Time to Hongqiao High-Speed Rail Station (minutes)	Average Access Time to Shanghai or Shanghai South Railway Stations (minutes)	% Change
Central urban area	Jingan	40	36	11.1
	Huangpu	46	37	24.3
	Hongkou	46	40	15.0
	Yangpu	70	54	29.6
	Zhabei	50	33	51.5
	Putuo	44	43	2.3
	Xuhui	40	41	-2.4
	Changning	27	41	-34.1
City outskirts	Baoshan	66	52	26.9
	Pudong	61	49	24.5
	Minhang	46	47	-2.1
	JIADING	51	67	-23.9
Outer suburban area	Songjiang	61	72	-15.3
	Qingpu	47	73	-35.6
	Jinshan	78	97	-19.6
	Fengxian	70	61	14.8
	Chongming	147	118	24.6

Source: Authors.

Figure 14.23: Comparing the Access Time to Hongqiao High-Speed Rail Station and Shanghai Railway Station

min = minute.

Source: Authors.

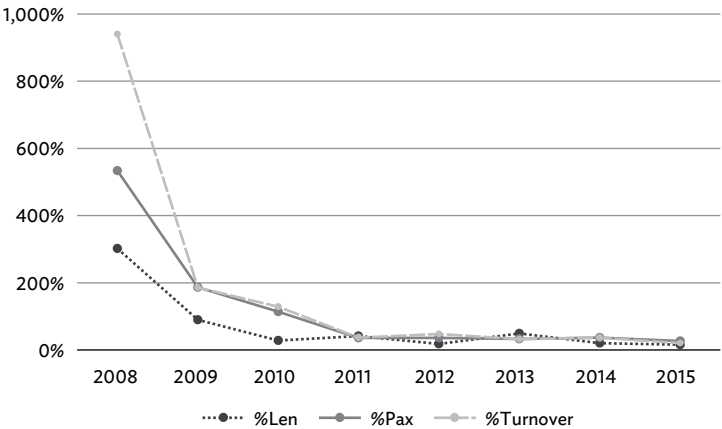
14.9 Passenger and Economic Impact

The large-scale HSR network and service has attracted a large number of passengers. In 2008, passengers taking HSR accounted for only 0.5% of the total railway passengers in the PRC. In 2016, 43.4% of railway passengers traveled by HSR. In 2012, the PRC built around 10,000 km of HSR. From that year, the increase in passengers and passenger-km traveled became more stable (Figure 14.24).

The economic impact of investment in transport has been the subject of a long debate. Jia and Qin (2014) categorized the research on the economic impact of HSR into three types: the study of the input–output balance, the interaction intensity between cities reflected by a time–space map or other methods, and statistical models to analyze the impact of accessibility on economic changes.

First, increased spending is likely to raise the economic output, whether on transport infrastructure or on something else. Recent developments in economic geography have placed particular stress on agglomeration economies as a source of productivity growth. Improving the connectivity between firms and their suppliers, competitors and

Figure 14.24: Growth Rate of the High-Speed Rail Network Size, Passengers, and Passenger Turnover



Len = length, Pax = passenger.

Source: Authors.

customers, and existing and potential sources of labor may enable specialization, the exploitation of economies of scale and productivity, and hence increased output. Jia and Qin (2014) suggested that HSR construction should take the passenger demand into consideration to strike a balance between input and output. Therefore, the HSR corridor has to link metropolises with high population density, serious congestion problems, and limited aviation services.

Second, in terms of the location of economic activity, studies have suggested that HSR will tend to benefit core cities rather than the periphery (Puga 2002). The impact of investment in HSR is most likely to concentrate in large business-oriented cities, mainly located in the eastern and the southeastern parts of the PRC, such as Beijing, Tianjin, Shanghai, Wuhan, Changsha, Jinan, Xuzhou, Suzhou, and Guangzhou, as well as provincial capital cities. Today, the more economically advanced HSR corridors (e.g., Beijing–Tianjin, Wuhan–Guangzhou, and Beijing–Shanghai) generate much more traffic than the corridors located in the central and western areas of the PRC. Lu et al. (2013) investigated the spatial distribution patterns of HSR economic zones and showed that the HSR network has replaced the evenly distributed spatial economic model with a clustered distribution and accordingly increased the urban agglomeration effect in metropolitan areas such as the Yangtze Delta region. However, there are internal spatial economic differences between regions. For instance, Shanghai and Guangzhou form a radial inflow model, Wuhan and Beijing belong to a “ring-layer” model, and Chongqing presents a centrifugal outflow model. Jiang et al. (2017) in another study compared the change of city accessibility on the Harbin–Dalian railway corridor and the Zhengzhou–Xi’an railway corridor. The research showed that, though the accessibility of cities along HSR lines has improved, the degree of improvement of the Harbin–Dalian corridor is stronger. Besides, HSR enlarges the accessibility gap of some regions, especially the marginalized ones (Jiang et al. 2014).

HSR affects the tourism market in a similar way. According to Yin (2012), the Zhengzhou–Xi’an HSR corridor has strengthened the tourism attraction of Zhengzhou, Luoyang, and Xi’an and further attracted the tourism industry clustered into these three traditional tourism cities.

However, because of the high cost of HSR, some researchers have argued that, in some areas, especially in the western parts of the country and the poverty-stricken areas in the central parts, building advanced conventional railways would be preferable. In a country as vast and diverse as the PRC, it is important to take regional differences into account rather than adopting a single approach to rail investment.

14.10 Conclusions

Since 2003, the PRC Railway Authority has been implementing the national strategic plan for widening the railway's reach, prioritizing HSR along with interregional cargo rail. The HSR network in the PRC is now the largest in the world.

HSR is an excellent mode of transport for the PRC's rapidly growing demand for intercity travel. Its high speed and capacity and its modest land and resource requirements are good for a country with a large territory and many large cities, a dense and increasingly urban population, and serious resource and environmental constraints.

Operating at 350 km per hour, the PRC's HSR is faster than car travel and competitive with domestic air travel for the majority of intercity trips. It even competes with air travel for journeys of over 1,000 km. Shanghai and many other cities have chosen suburban and exurban HSR station locations because they are less expensive to build, allow straighter alignments and faster rail services, and may stimulate subcenter growth.

Our survey of passengers at Shanghai Hongqiao Station, a typical new HSR station, showed that over 70% of passengers travel on HSR for distances of less than 500 km. For these travelers, the time taken to access the HSR station is a major consideration; the higher train speed makes a decreasing contribution to total travel efficiency. Therefore, the challenge is to balance the location of HSR stations with the provision of improved urban center transit connections and higher HSR passenger intensity. The Shanghai case shows that extending connections, especially rail transit connections, to the HSR station can attract many passengers. However, this comes at a high cost, and HSR access still takes more time for travelers than the earlier system. In-city stations are also required.

Instead of constructing a large HSR station in a distant suburb, planners should consider direct connections of HSR to the existing traditional rail stations, where the access to HSR stations is easier in the passenger-intensive urban areas. This will simultaneously decrease road transportation, and thus air pollution and road infrastructure costs. The overall efficiency and benefit to society may be greater. With the introduction of HSR services for intercity travel, we cannot neglect the need to improve the high-quality public transport system within a city. HSR passengers prefer reliable and comfortable access modes to HSR stations. An HSR service with a poor urban public transport service will induce more car traffic to access the stations, resulting in severe traffic congestion or parking problems.

The high concentration of HSR passenger traffic in economically dense areas indicates that HSR is a justified solution for increasing the capacity in those areas. In less developed areas, more sophisticated operation is necessary to balance the relative traffic volume, the operation and maintenance cost, and the political equity policy. Upgrading the normal train service is also required in the less developed areas in the PRC.

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15

Quantifying the Economic and Social Impacts of High-Speed Rail: Europe and the People's Republic of China

Chia-lin Chen and Roger Vickerman

15.1 Introduction and Motivation

Transport as a determinant of land use and economic development has been the subject of much controversy. In the past, it was thought that quantifying such effects would run the danger of double counting since direct user benefits through, for example, time savings would be reflected directly in changes in land values or employment. This assumes, however, that all of the markets using transport are in perfect competition such that any changes in the generalized cost of transport pass directly and completely into prices and costs in the transport-using sector. Once imperfect competition in these sectors is allowed for, this relationship breaks down such that rent seeking by firms can allow for impacts that are either larger or smaller than the direct user benefits. Such wider economic impacts (WEIs) may lead to significant additions (or reductions) in the total benefits associated with a project (SACTRA 1999).

Yet, WEIs are only an extension of traditional cost-benefit analysis (CBA). Allowing for WEIs incorporates the likely impact of imperfect competition through measuring the impact of changing generalized cost on accessibility, and removing the assumption of self-balance in a perfectly competitive economy has an impact on agglomeration and productivity. However, this approach continues to assume that changes are marginal; the resulting elasticities do not allow for

fundamental changes in behavior (Vickerman 2017b). Recent work has improved our understanding of how changes in accessibility affect the performance of firms, productivity, and labor markets, but this is still in the same marginal response framework and mainly about single cities in which agglomeration effects are more obvious. The question is whether this approach can be applied to “megaprojects” that cause step changes in supply, involve multiple metropolitan areas, and whose primary objective is to “rebalance the economy” (Vickerman 2017a, 2018).

15.2 Defining Objectives

The traditional objectives of new infrastructure projects have mainly been about user benefits. Thus, demand modeling has dominated the benefit side of CBA appraisal methods and the user benefits have been largely driven by the value of time savings. For the majority of projects, which are essentially those determining the capacity of a link needed to cater for peak-time travel, time savings are relatively small (marginal) but relate to large numbers of people traveling frequently.

Large-scale infrastructure projects, such as the construction of new high-speed rail (HSR) links, are now seen to be more about delivering wider economic benefits (Vickerman 2017a, 2017b). The search for such WEIs is often seen as necessary for the viability of such projects as the direct user benefits may be insufficient to match the typically high construction costs. Time savings in such projects may be larger, but relate to smaller numbers of people traveling less frequently on fewer regular journeys. Demand modeling is less easy and less reliable in such cases—and it may be thought that traditional values of time savings are less appropriate for such projects.

This raises a number of fundamental questions. First, should we abandon a CBA-based approach for an alternative, and if so what? Is the emphasis on macroeconomic indicators such as gross domestic product (GDP), gross value added (GVA), or productivity correct? If large-scale projects are seen to be about rebalancing the economy by promoting development in lagging regions, how do we measure regional rebalancing as an objective? Moreover, how do we ensure that such rebalancing is not just a redistribution in a zero-sum game, but allows for positive benefits in all affected regions? It may be that instead of a focus on aggregate indicators, structural change may be more relevant, and this could relate not just to differential growth and specialization of different sectors but also to specialization in terms of skills and occupations. While the primary concern may be the appraisal of transport measures, these need

to be seen alongside other policy interventions that help validate these transport measures.

15.3 Getting the Components Right

In the light of these concerns, the question arises as to whether large-scale comprehensive modeling is the right approach to provide the basis for the appraisal of projects such as HSR. The danger of approaches such as spatial computable general equilibrium (Bröcker and Mercenier 2011) or land-use transport interaction (Wegener 2011) models is that they are all based on existing patterns of behavior and interaction and rely essentially on the response to marginal changes. What is needed is a framework more focused on adaptable models to ensure that the building blocks are right. System dynamics models that offer an opportunity to consider dynamic feedback through such models are numerical rather than analytical and depend, perhaps too much, on the “creativity of modelers” (Rothengatter 2014). The key elements clearly require more work.

Essential to this is understanding the behavioral response to step changes in supply. HSR projects make nonmarginal changes to accessibility and time savings, essentially changing the time-space geography. This can lead to significant behavioral changes on the part of both individuals and businesses relating to the location of activities. In some cases, this may lead to the increasing centralization and concentration of activities; in others, it could lead to decentralization and greater convergence of regional economies as demonstrated theoretically by the “new economic geography” (Krugman 1991; Fujita, Krugman, and Venables 1999).

Changes in speed that lead to changes in economic geography may also have implications for the valuation of time savings and especially of business time savings (Hensher 2011; Mackie, Graham, and Laird 2011). Step changes in accessibility may not be evaluated in the same way as a multiple of small time savings, although it is not clear *a priori* whether these would be larger or smaller. A small time saving on a regular commuting journey may have a higher value per minute than a potentially more usable larger saving on a less frequent longer journey. However, if the new link opens up opportunities for activities that did not exist previously, the value could be larger. This issue is compounded in the case of business time savings by the argument over whether, given the availability of comfortable conditions and the potential for communications such as Wi-Fi, the saving of time is not so important in terms of increased productivity. If passengers can keep in touch with

their office and work effectively on the train, then is there an argument for reducing the perceived value of time savings? This is clearly an area where more research is needed to assess how effectively passengers can work. In addition, if the creation of a high-speed link leads to new business opportunities that generate new journeys, including the potential for more day return trips, then it is reasonable to include this value in the overall benefits. It may be prudent to test the sensitivity of these benefits to variations in the value of time savings, but not to discount them entirely.

This generation of new business will depend on the way firms respond to changing connectivity between cities. Much of the work on agglomeration has been carried out in the context of individual metropolitan areas and has focused mainly on labor market impacts rather than business relocation (Graham 2007; Combes and Gobillon 2015). This relocation could arise in two ways. The first and obvious response is that firms could relocate their entire business, the outcome envisaged by theoretical work on the new economic geography, which generates convergence or divergence. The alternative is that firms recognize that the productivity benefits of agglomeration typically occur at the level of skills and occupations and undertake internal reorganization to benefit from the greater ease of access between different locations (Venables 2013). There is some evidence that this has happened as a result of the introduction of the HSR in France, with firms relocating activities between Paris and provincial cities such as Lyon or Lille but without any tendency toward overall concentration or deconcentration of employment (Plassard and Cointet-Pinell 1986; Burmeister and Colletis-Wahl 1996).

As suggested, agglomeration has been largely studied in the case of improvements of access across a single metropolitan area. This relates to the long-standing interest in the relationship between city size and productivity (Rosenthal and Strange 2004; Glaeser and Gottlieb 2009). This can be extended to consider the effects of the introduction of an HSR between two cities in which the impact may depend on the initial advantages or disadvantages of each city and the extent of the change in accessibility between them. Does the larger and initially more productive city have an advantage in exploiting any change in accessibility or will firms in the smaller city be able to exploit the reduction in transport costs to capture market share? However, in a multicity context, these considerations may become more complex. Will the improved accessibility between the second-order cities enable them collectively to gain a competitive advantage over the primary city? Some estimates of the impact of the rapidly developing network

in the People's Republic of China (PRC) suggest this may be occurring (Chen et al. 2016; Chen 2019), and estimates of the impact of the full HS2 network in the United Kingdom (UK) suggest much larger relative gains than those arising just from the first stage link between London and Birmingham (HS2 2013a, 2013b).

Large-scale projects carry significant risk and degrees of complexity that make it difficult to make forecasts with the degree of accuracy achievable in less complex projects. This raises problems as decision makers may feel nervous of committing to projects where there are significant confidence intervals around the central forecast. This is especially the case where public money is involved, which makes the importance of the narrative surrounding the project greater. A clear exposition of the objectives of a project is necessary to ensure that there can be an appropriate commentary from both its promoters and any objectors. This is particularly true with HSR projects as there is a tendency to focus on the speed and time-saving aspects at the expense of any wider economic or social impacts; making clear from the outset the importance of these objectives in helping transform or rebalance economies may help reduce later confusion. Understanding the process of change helps to increase the transparency and accessibility of the appraisal framework so that debates can be conducted against a common framework.

15.4 Measuring Wider Economic Impacts

At the heart of any discussion about WEIs must lie some quantifiable elements (Laird and Venables 2017). It is important to recognize that these are not necessarily the sum total of all such impacts—and especially in the case of large HSR networks these may seriously underestimate the total effect. Four main elements can be identified as the core economic impacts:

- agglomeration impacts,
- output change in imperfectly competitive markets,
- labor supply impacts, and
- move to more or less productive jobs.

The easiest of these to measure are the agglomeration impacts, which depend on an estimate of each location's access to economic mass. This is defined as d , a measure of the way that for a given scenario S in location i in year f , the generalized costs g for each sector k using mode m with a distance decay parameter of α , given total employment E in each location j , such that:

$$d_i^{S,k,f} = \sum_{j,m} \frac{E_j^{S,f}}{(g_{i,j}^{S,m,f})^{a^k}}. \quad (1)$$

Then, comparing the access to economic mass in scenarios *A* and *B*, the impact on productivity from this change in accessibility in year *f* with an elasticity of productivity with respect to *d* in sector *k*, of ρ^k gives a wider economic impact of:

$$WII_i^{k,f} = \left[\left(\frac{d_i^{A,k,f}}{d_i^{B,k,f}} \right)^{\rho^k} - 1 \right] GDPW_i^{B,k,f} E_i^{B,k,f}. \quad (2)$$

These estimates depend critically on being able to estimate the key elasticities, both of productivity with respect to agglomeration and the distance decay implicit in changes in generalized costs. Historically these estimates have been derived from changes in city size in an aggregate way. Research based on disaggregate data at firm or sector level suggests considerable variation in such elasticities with service sectors typically having rather larger elasticities than manufacturing industry, and it is service sectors that are more likely to be impacted by HSR (Graham 2007; Melo, Graham, and Noland 2009).

For urban applications, the other elements identified in defining WEIs are normally considered less important. The labor market impacts are largely captured in the productivity effects as they involve bringing into the labor market marginal workers for whom the net real wage has increased with lower transport costs and also enabling workers to move to jobs where they are more productive. These labor market participation and labor sorting effects have usually been estimated at the sector level, but may be more important at the level of skills or occupations.

Allowing for imperfect competition is the driving force of theoretical models of new economic geography as it is the price-cost margin that is changed by lower transport costs and how the imperfectly competitive firm reacts to this is not clear a priori. Furthermore, the aggregate impact on a city or region will depend on the collective reaction of firms in different industries and their competitors in the other cities or regions. This uncertainty has made it difficult to use empirical estimates leading to a tendency to use averaged add-ons based on the extent of typical price-cost margins in imperfectly competitive industries.

15.5 Application to High-Speed Rail

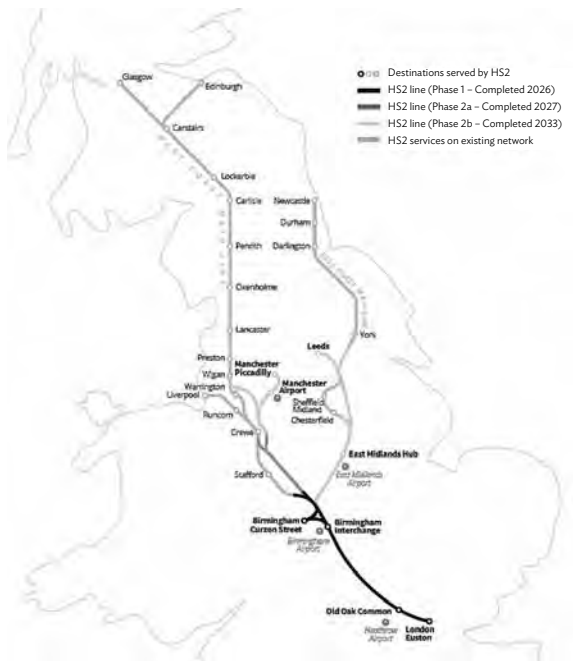
There are problems in trying to apply simple agglomeration-based estimates of WEIs to HSR. The distance decay effects found in urban applications where the benefits decline steeply with distance from a station would suggest that there are very small benefits of this type from intercity applications (Graham and Melo 2011). Is it, however, logical to apply the same labor market approach as in the urban cases, and is there an alternative? New HSR projects are more about the impact of adding labor markets together than extending single labor markets, so this is less about agglomeration effects than the potential for transformation and rebalancing of regional economies. There will be an agglomeration effect, but this may be less important than changing the competitive position of cities and regions. In such circumstances, the degree of imperfection in local markets and the resultant competitiveness of firms may be more important and needs further analysis. This reinforces the view that estimates of agglomeration elasticities are not easily transferable between applications.

The key question to address is therefore whether new transport investments can change a city's or a region's economic situation. This depends on whether such investments are centralizing or redistributive, raising the question of whether there is a net national economic benefit rather than the impacts being essentially a zero-sum game.

A standard wider economic benefits approach has been used in the UK to augment user benefits in a CBA framework. Here we look at some *ex post* estimates of the first HSR, HS1, and *ex ante* estimates of the impact of the more significant HS2 network. HS1 links London with the Channel Tunnel but also provides regional high-speed commuting services for towns in the county of Kent, saving 35–40 minutes on the commuting time to London. HS2 is initially providing a link between London and Birmingham, the two largest cities in England, but is ultimately planned to create a network linking to Manchester and Leeds and serving the majority of industrial cities in the Midlands and the North (Figure 15.1).

Table 15.1 summarizes the impact of HS1. This shows that standard WEIs were of the same order of magnitude as the direct user benefits and that including these was necessary to achieve a benefit–cost ratio (BCR) greater than 1. In addition, the evaluation by the National Audit Office (2012) identified the potential for a further set of regeneration benefits of the order of three times the level of standard WEIs.

Figure 15.1: Proposed HS2 Network



Source: HS2 Ltd.

Table 15.1: Ex Post Evaluation of HS1

	Present Value (£ million, 2008 prices)
1. International transport benefits	2,500
2. Domestic transport benefits	1,200
3. Congestion relief	100
4. Total transport benefits (1+2+3)	3,800
5. Wider economic impacts (WEIs)	3,800
6. Total benefits (4+5)	7,600
7. Net costs	-3,900
8. Additional costs to achieve economic impacts	-400
9. Total costs (7+8)	-4,300

continued on next page

Table 15.1 *continued*

	Present Value (£ million, 2008 prices)
10. Benefit-cost ratio (BCR) (ratio 4/9)	1.0
11. BCR including WEIs (ratio 6/9)	1.8
12. Regeneration benefits	10,000

Source: National Audit Office (2012).

Table 15.2 summarizes the basic economic case for HS2 made in 2013. In this case the conventional estimate of WEIs suggests a relatively small addition to all benefits that are dominated by benefits to business users dependent on high values of time savings. The contribution of WEIs, even on the standard basis of estimation of agglomeration benefits, can be noted to be relatively larger in the case of the full network, raising the BCR to more than 2.

Table 15.2: Standard Case Cost-Benefit Analysis for HS2
(2011 Present Values)

Components		Phase One (£ billion)	Full Network (£ billion)
1. Transport user benefits	Business	16.9	40.5
	Other	7.7	19.3
2. Other quantifiable benefits		0.4	0.8
3. Loss to government of indirect taxes		-1.2	-2.9
4. Net transport benefits (1+2+3)		23.8	57.7
5. Wider economic impacts (WEIs)		4.3	13.3
6. Net benefits including WEIs (4+5)		28.1	71.0
7. Capital costs		21.8	40.5
8. Operating costs		8.2	22.1
9. Total costs (7+8)		29.9	62.6
10. Revenues		13.2	31.1
11. Net costs to government (9-10)		16.7	31.5
12. Benefit-cost ratio (BCR) without WEIs (ratio 4/11)		1.4	1.8
13. BCR with WEIs (ratio 6/11)		1.7	2.3

Source: HS2 Ltd. (2013a).

Part of the case for HS2 has been its potential to rebalance the regional structure of the UK economy by increasing connectivity to cities in the North and Midlands. Tables 15.3 and 15.4 summarize the estimates made of these effects. Table 15.3 summarizes the regional distribution of transport user benefits based on traffic forecasts. It confirms the relative benefit to the provincial regions from the full network. Although London is still the largest net beneficiary, the relative size of its benefit is lower in the case of the full network. Attempts have been made to refine the estimates of the total regional effect to allow for impacts beyond the standard case (KPMG 2013). One of these is shown in Table 15.4 (HS2 2013b). The detailed methodology of this has been questioned (Overman 2013), and it is thought that the absolute value of the estimated gains may be on the high side (see Vickerman [2018] for a fuller discussion), but the distribution of the gains confirms the case for a transformational effect and also for a net national benefit; although some individual regions will lose, there are net gains for the sum of all regions outside the direct influence of HS2.

**Table 15.3: Estimated Regional Distribution
of Transport User Benefits from HS2
(£ million)**

Region	Phase One	Full Network
London	339 (42%)	726 (35%)
South-East	22 (3%)	58 (3%)
West Midlands	211 (26%)	303 (15%)
North-West	164 (20%)	342 (17%)
East Midlands	15 (2%)	157 (8%)
Yorkshire and Humber	6 (1%)	225 (11%)
North-East	1 (0%)	69 (3%)
Scotland	19 (2%)	91 (4%)
Other (East England, South-West, Wales)	31 (4%)	76 (4%)
Total	809 (100%)	2,047 (100%)

Source: HS2 Ltd. (2013a).

**Table 15.4: Regional Distribution of Estimated Gains
(£ billion)**

	Gross Domestic Product Impact per Year	
	“Low” Business Location Scenario	“High” Business Location Scenario
Greater Manchester	1.3	0.6
West Yorkshire (Leeds city region)	1.0	1.0
South Yorkshire (Sheffield city region)	0.5	0.9
East Midlands (Derby and Nottingham city regions)	1.1	2.2
West Midlands (Birmingham city region)	1.5	3.1
Greater London	2.8	2.5
Rest of Great Britain	7.0	5.0
Total impact on GB economy	15	15

Source: HS2 Ltd. (2013b).

15.6 Going beyond Standard Wider Economic Impacts

How to measure change has thus become a critical factor. The standard approach has always been essentially about the impact on productivity and growth as these can easily be incorporated into a standard CBA based on user benefits and costs. Justifying projects on the basis of impacts on economic aggregates allows them to be considered in terms of an economic rate of return, but this tends to ignore the mechanism by which this overall effect comes about. Understanding the mechanism may be as important as measuring the overall effect if it involves the redistribution of economic activity or structural changes within each urban or regional economy. Focusing on which sectors and which occupations are most affected gives us a greater understanding of the full economic impact of HSR. For example, agriculture or manufacturing industries may be less affected by HSR than by fewer major improvements to the classic rail or road networks where goods are more likely to be carried. For these sectors there may be a relatively minor impact on business travel or commuting. It is difficult to identify the extent of such travel in national accounts and estimate its significance to different sectors. In service sectors, however,

and particularly those engaged in the knowledge economy, such travel is more likely to be a significant factor as proximity is a key factor in traditional Marshallian external economies of localization and in the sort of urbanization economies that depend on urban public goods such as those related to knowledge and culture.

Regeneration and transformation may be more important objectives, as we have already seen in the case of HS2. This involves a set of related indicators implying changes in specialization and structural change in terms of sectors or skills and occupations. Such changes are driven both by business and household relocation, by new firm formation, and by restructuring of the internal organization of businesses to incorporate the presence of HSR into a reappraisal of the optimum location of specific activities.

Cheng, Loo, and Vickerman (2015) compared changes in specialization following the introduction of HSR services in northwestern Europe (the region between Paris, Frankfurt, Amsterdam, and London) and in the Pearl River Delta region of the PRC (in the period after the speeding up of rail services but before the full introduction of new infrastructure).

Using the Krugman Specialization Index, which measures the degree of variation in the industrial specialization of a city S_i relative to a benchmark S_i^* as follows:

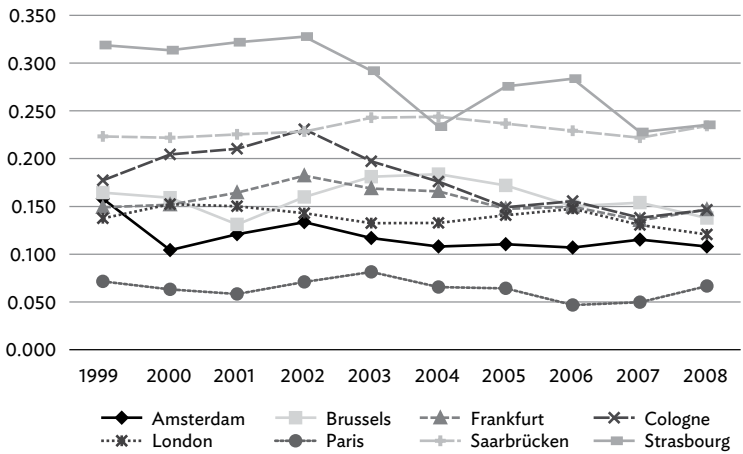
$$I = \sum_i |S_i - S_i^*|, \quad (3)$$

it was found that cities in Europe (Figure 15.2) were generally more similar (an index closer to 0) and tending toward convergence than in the PRC case (Figure 15.3). This suggests that in the more mature European economy, improvements to transport had a general tendency toward regional convergence. In the case of the rapidly changing PRC economy, transport improvements generally led to increasing specialization and divergence.

In a further study, Chen and Vickerman (2017) compared some more detail of the impacts on individual cities in Kent in the UK and the Yangtse River Delta in the PRC following the introduction of new HSR services. Two indicators were used: changes in GDP or GVA and changes in employment in the knowledge economy. The latter, it was hoped, would capture structural changes that would be less evident in the aggregate economic indicators.

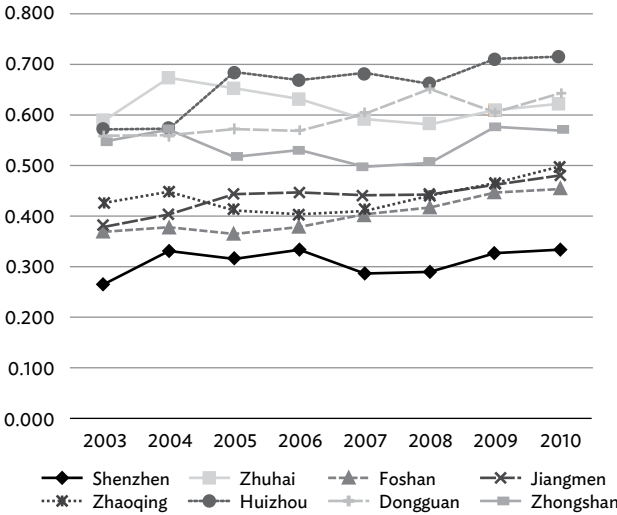
In the case of Kent (Figure 15.4), the areas most affected by the introduction of regional HSR services in 2009 did not show the greatest growth in GVA, with the exception of Dartford (the location

Figure 15.2: Specialization Index of Core European Cities



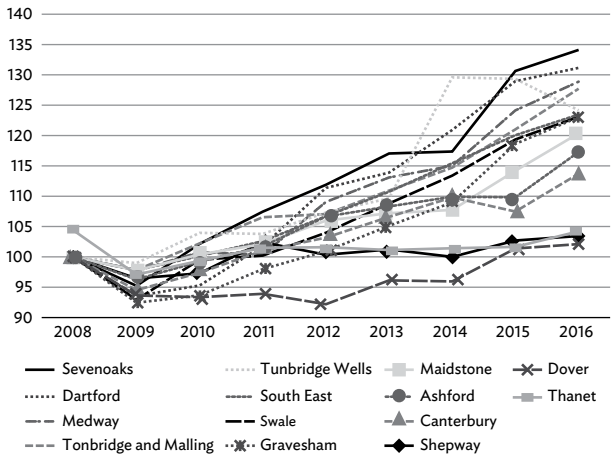
Source: Cheng, Loo, and Vickerman (2015).

Figure 15.3: Specialization Index of Cities in the Pearl River Delta Region, People's Republic of China



Source: Cheng, Loo, and Vickerman (2015).

Figure 15.4: Changes in Gross Value Added in Kent Districts, United Kingdom, 2008–2016 (2008=100)



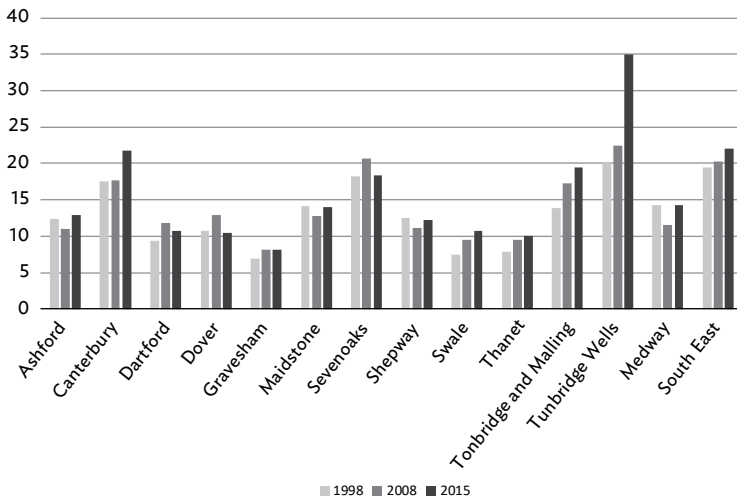
Source: Kent County Council (based on Office for National Statistics data) in Chen and Vickerman (2017).

of Ebbsfleet International Station on HS1). Ashford, which has the greatest proportional gain through time savings, was one of the poorer performers. Generally, the picture is one of better performance in those areas closer to London, with very little repositioning resulting from the introduction of HSR. Changes in the knowledge economy suggest a more varied picture (Figure 15.5), but, again, the largest gain was in a town unaffected by HSR (Tunbridge Wells), although Canterbury, with a large university and research base as well as significant time reductions to London brought by HS1, also showed one of the larger positive responses, and growth since 2008 has been more marked than in the previous decade (Vickerman 2018).

Economic impacts from HSR in the Yangtse River Delta region of the PRC show slightly less variation in terms of the aggregate GDP index (Figure 15.6). Although there was a general tendency of decline in employment in secondary industry and growth in the knowledge economy, some cities moved in the opposite direction to this trend,

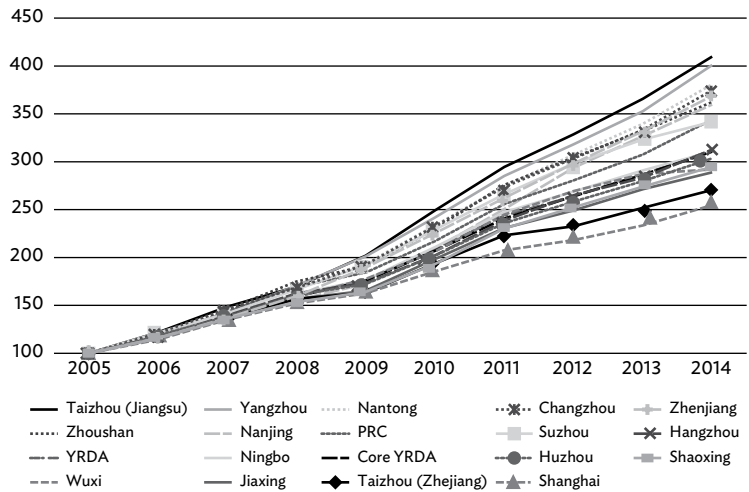
suggesting again that a process of greater specialization was in progress (Figure 15.7). Since much of the change affected the location of new and relocating firms, an analysis was carried out of new firm formation in one city of the Yangtse River Delta region, Suzhou (Chen, Chen, and Vickerman 2018). In the 5 years before the introduction of HSR, just under 15,000 new firms were registered; in the 5 years after the HSR, the number increased to nearly 43,000. Table 15.5 compares the distribution of these between manufacturing and knowledge-based firms both overall and in the zones around stations and outside these buffer zones. This suggests that proximity to an HSR station was not an overwhelming priority, although knowledge economy firms were more likely to select a closer location, while overall manufacturing industry firms were a declining share of all firms.

Figure 15.5: Employees in Knowledge Economy in Kent Districts, United Kingdom, 1998, 2008, and 2015
(%)



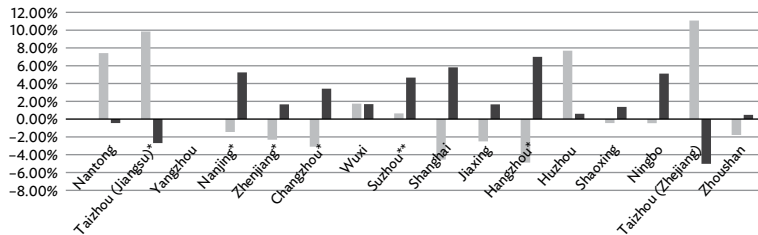
Source: Kent County Council (based on Office for National Statistics data) in Chen and Vickerman (2017).

Figure 15.6: Changes in Gross Domestic Product by Prefecture-Level City, People's Republic of China, 2005–2014 (2005=100)



PRC = People's Republic of China, YRDA = Yangtze River Delta Area.
Source: Statistical yearbooks of various YRDA prefecture-level core cities, 2006–15, in Chen and Vickerman (2017).

Figure 15.7: Employees in Secondary Industry and Knowledge Economy, by Prefecture-Level City, People's Republic of China (% change 2009–2014)



YRDA = Yangtze River Delta Area.
Source: Statistical yearbooks of various YRDA prefecture-level core cities, 2006–15, in Chen and Vickerman (2017).

Table 15.5: New Firms by Sector and Location before and after High-Speed Rail, Suzhou, People's Republic of China (Industry percentage, %)

Period	In Whole Study Area		In Station Buffer Zone		Out of Station Buffer Zone	
	Knowledge Economy	Manufacturing	Knowledge Economy	Manufacturing	Knowledge Economy	Manufacturing
2005–2010	30.3	22.4	31.5	12.4	29.6	27.6
2011–2015	36.9	10.0	38.5	4.6	35.7	14.2

Source: A modified version of Chen, Chen, and Vickerman (2018).

Looking more closely at the precise locations of new firms, what seems to have happened after the introduction of HSR is that previous clusters tend to dissolve and shift to other cluster places across the urban area. This may reflect the way that the multiple HSR stations in a city give firms access to a wider range of connections in a range of urban areas. Improved intra-urban transport links associated with the arrival of HSR may also play a part in this process. For firms with large capital investments, the findings make evident a shift of concentration from one zone to another, reflecting the policy objective of creating large-scale clusters as well as being caused by HSR.

This research suggests that looking in more micro detail at the local contexts and the way firms react to the arrival of HSR is important. This is similar to the findings of French research that identifies internal restructuring as a response to the new opportunities offered by HSR links (Burmeister and Colletis-Wahl 1996).

We have gone beyond the simple application of estimates of WEIs that remain within a CBA framework to look at the extent to which restructuring occurs in response to HSR and provides the basis for assessing whether HSR can be transformative. This still focuses on basic economic indicators, and it may be necessary to look beyond the economic impacts as demographic change and changing lifestyle choices may be further factors. This implies a need for more behavioral analysis of individual and household responses to new transport opportunities to match the micro analysis of firm responses.

15.7 Concluding Remarks

The basic premise of this chapter is that standard CBA is inadequate for megaprojects such as new HSR networks. WEIs, measured in a conventional way in terms of accessibility-related productivity changes, may show benefits (and costs) beyond the direct user impacts, largely related to changes in agglomeration, but do not capture the transformational impacts that megaprojects such as HSR could create. In looking at evidence of the impacts of HSR on different cities, including impacts on the transformation, structural change, and location of new firms, clear differences emerge between Europe and the PRC. These suggest potentially important lessons for less developed or transitional economies. Above all, HSR investment needs to be seen as one element in a comprehensive policy of regeneration and transformation; HSR cannot create change on its own. There is a considerable research agenda suggested by the preliminary finding reported in this chapter, and it is argued that the research effort should focus on these structural changes before embarking on even less measurable impacts.

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16

High-Speed Rail as a New Mode of Intercity Passenger Transportation in the United States

Eugene Chao, Vukan R. Vuchic, and Aleksandr Vashchukov

16.1 An Overview of High-Speed Rail in the United States

The United States (US) once had one of the world's best passenger rail systems, but today it lags far behind its peer industrialized and developed countries in developing high-speed rail (HSR). When Amtrak, the US national rail system, was founded in 1971 (Amtrak 2017), it would have been logical for the federal government to develop and operate it as a high-speed intercity rail system since it connects many major metropolises, as well as to provide substantial financing for major improvements and modernization of its obsolete services. However, these have never occurred. The federal and state funding assistance programs have been low and inadequate compared with the investments made by Asian and European nations with a similar standard (Amtrak 2018b; ECA 2018). Since the modest investments by the US have been unpredictable, Amtrak has had to fight for survival in each budgetary year (CRS 2013, 2017, 2018; DOT 2011, 2018). How can an agency plan a major upgrade when it has unpredictable financing and when several presidents have even threatened to cut its subsidy?

Such seasonal allocation forced Amtrak to maximize its revenue as a priority rather than maximizing the ridership and economic and comprehensive effects. Amtrak became a transportation system mostly for businesspersons and high-income travelers instead of a public transportation system, as found throughout most of the world, which

serves all categories of people, from students and workers to tourists and retired persons as well as executives. As an example, fares from Philadelphia to New York, about 150 kilometers (km) apart, vary from \$58 to \$275 (Schabas 2012), leading many travelers to shift to cars and buses (Amtrak 2010, 2012, 2017, 2018a, 2018b).

HSR is a prime candidate for the busiest corridors across high-population metropolises. More than 25 countries have built HSR systems, and they have been very successful in upgrading intercity travel. In worldwide cities' competition for economic growth, business friendliness, national events to boost visibility, and tourist attraction (Le Maout 2012), US cities are far behind their peers with respect to intercity mobility. A recent international example was the 2018 FIFA World Cup in the Russian Federation. The Sapsan HSR has been indispensable for intercity travelers between Moscow and Saint Petersburg and between Moscow and Nizhniy Novgorod since 2009. The Sapsan HSR is building another line between Moscow and Kazan with a total length of 770 km, which will shorten the travel time from 14 to 3.5 hours (Sapsan 2018). Most large cities have several intercity passenger railway stations. Moscow has nine, London nine, Paris five, and Tokyo more than a dozen. The airports in Beijing, Frankfurt, London, Moscow, Munich, Tokyo, Zurich, and many other cities also have direct rail transit lines. The city of Moscow has a 30-minute headway of Aeroexpress train travel regularly throughout the day from Sheremetyevo International Airport to the integrated Belorusskiy railway station, where passengers can transfer to the Moscow Metro system to enter the central city. The newly opened Moscow Central Circle enables passengers who live in the suburbs to transfer at the integrated Okruzhnaya Station without entering the central city (Vashchukov 2018). The price of the Aeroexpress ticket from the airport to Belorusskiy station was P500 (equivalent to about \$7.5 using the September 2018 exchange rate) (Aeroexpress 2018), which is more affordable and offers better comfort and more regular services than Amtrak. In contrast, Chicago, New York, Philadelphia, and most other cities in the US have only one Amtrak station and another in the suburbs (Baltimore, Boston, and Washington, DC).

Cities around the globe are either in the transition stage of repositioning their long-term competitiveness or in the development stage of scalable metropolitan planning, or simultaneously undertaking the transformative process of tackling both. The cities of Atlanta, Baltimore, Chicago, Cleveland, Denver, Miami, Minneapolis, Oakland, Philadelphia, Phoenix, Portland, San Francisco, Seattle, and St. Louis have recently built light rail transit, metro, and regional rail lines, but New York has only recently opened rail transfer lines to John F. Kennedy International Airport and Newark Liberty International Airport and

has none to LaGuardia Airport. Los Angeles, Houston, Orlando, and Pittsburgh have no rail access to their airports yet. Regarding overall passenger rail, both the HSR development and the political willingness to scale the network are far behind those of global cities. In the case of the Russian Federation, the central diameter is currently under construction in Moscow, with a total of 54 km in length and 31 new stations. On completion, the length of the network will double to a total of 1,050 km. Although it is a case of urban transit, the Moscow Central Circle project reveals the government's ambition and determination to develop an integrated rail service (Vashchukov 2018).

16.2 History and Performance Comparison between Conventional Rail, High-Speed Rail, and Air Transport

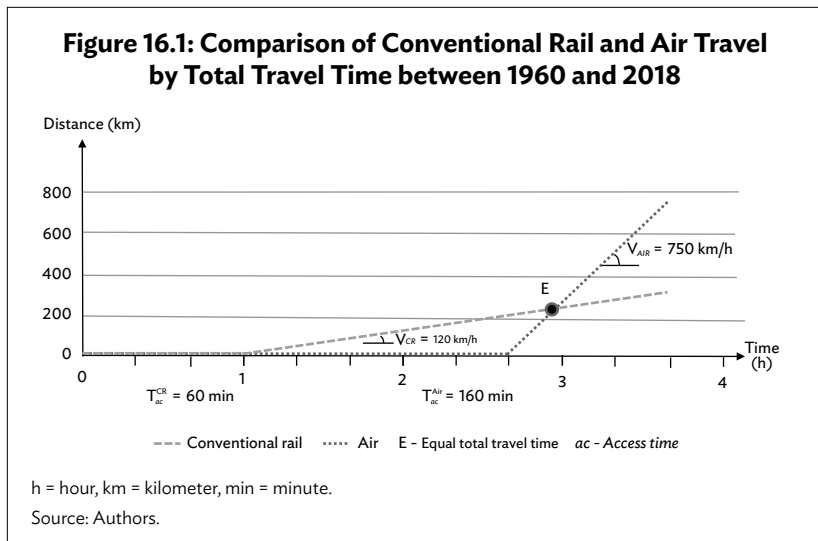
HSR is a new transportation mode suitable for intercity travel with greater advantages on medium-haul distances from 150 to 800 km and long-haul or long distances over 800 km. In US society, until the 1950s, private cars were used extensively within cities, but they were inefficient for trips of several hundred miles because of the low average speeds, particularly through urban areas and en route on the major corridors, such as the Northeast Corridor–Boston–Washington, DC section. When the US Interstate Highway System was built in 1956–1972, the average car travel speeds increased on the highway to become uninterrupted at 80–120 km per hour (km/h) (FHWA 2018). The auto-highway became a different mode of transport, with its domain extending to a longer distance, even coast to coast, starting to overlap with rail and air in the competition. A similar change occurred in overseas travel. Until 1960, propeller planes offered US–Europe travel in tiring journeys of 18–22 hours strapped into seats. Steamships took 5–6 days to cross the Atlantic Ocean, but they offered much more comfortable travel. As jet planes were introduced around 1960, the trip times reduced to 7–9 hours. With upgraded airplane propulsion, the new mode of jet planes took over most of the long-distance trips from ships (except tourist cruise ships) and some overland passengers from railroads, buses, and automobiles. In the 1960s, conventional passenger trains operated at 60–100 km/h, and in some countries the maximum speeds were reaching 150 km/h. The first HSR line, the *Shinkansen* in Japan, built in 1964 between Tokyo and Osaka, had a speed of 210 km/h. France's line was faster in 1981 at 270 km/h. In the following decades, Spain, Germany, the Republic of Korea, and other economies operated trains at speeds of 300–360 km/h. The world

record maximum speed achieved on a special track in France was 575 km/h (Le Maout 2012).

The progress in rail technology resulted in the development of a new mode: HSR. When conventional trains traveled at 60–100 km/h, they could not compete with car travel on freeways or with airplanes on distances over 150 km. With speeds exceeding 300 km/h, HSR is 2–5 times faster than cars, and it competes with airlines in the total travel time, shorter access times, and much higher comfort levels up to distances of about 1,200 km. HSR is the only all-electric mode of intercity travel—a goal of energy saving and climate protection that all other modes are pursuing at a much slower pace of transformation. All-electric propulsion makes HSR a new intercity transportation system compared with both conventional rail, which in North America was mostly diesel powered, and the air and highway modes (NCRRP 2015).

The distance–time–speed diagrams in Figures 16.1 and 16.2 show the relationship of speeds between the three high-speed modes: conventional rail, air, and HSR—with overlapping domains in the medium- and long-haul range of 150–1,200 km.

Figure 16.1 shows a comparison of the total travel time by conventional rail and air modes. For each mode, the figure shows the approaching and departure times along the abscissa and then adds on-line travel as the line with the average travel speed as its slope. The equilibrium point (E) represents the distance below which conventional rail is faster and above which air is faster (Vuchic 2018).



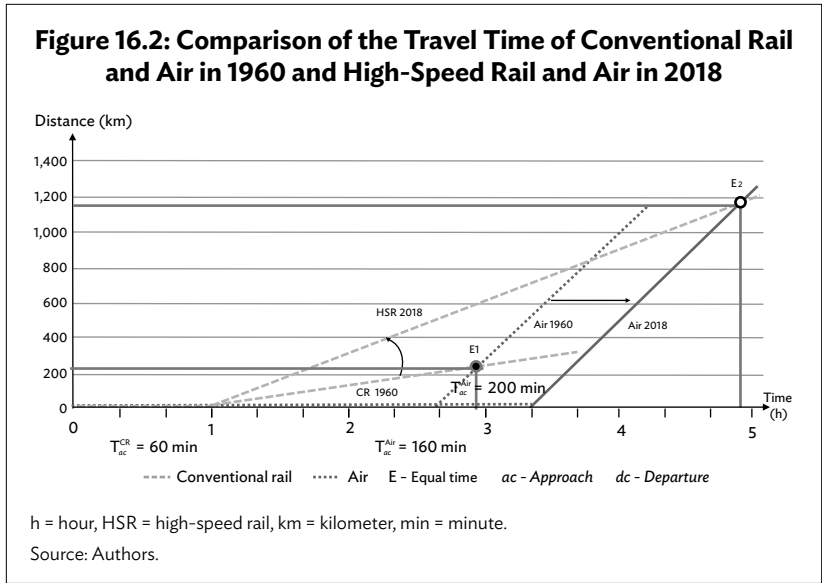


Figure 16.2 shows that the introduction of HSR increased the rail domain compared with air, using the common values from Table 16.1 for the two cases. Case 1 shows the travel time and speed of conventional rail and jet planes in about 1960, resulting in an equilibrium point at about 250. Case 2 shows the comparison of the travel time of HSR and air in 2018. The diagram shows that two major differences arose between 1960 and 2018 as the technology advanced:

- (1) The access times for rail did not change relative to conventional rail, but the average speed increased drastically from 120 km/h for conventional rail to 300 km/h for HSR.
- (2) The average air travel speed did not change significantly, but the access time to the airport increased by at least 40 minutes, from 160 to 200 minutes, due to longer check-in times, security procedures, and delays in take-off and landing.

These two changes resulted in an increase in the equilibrium point (E) from 250 km to nearly 1,200 km. Many countries' HSR services have corroborated this. For example, the travel time on the 1,200 km Beijing–Shanghai line (built in just 3.5 years) decreased from 11 hours on conventional rail to 4.5 hours on the HSR line.

**Table 16.1: Travel Time of the Conventional Rail,
High-Speed Rail, and Air Modes, 1960 and 2018**

	1960		2018	
	Conventional Rail	Air	High-Speed Rail	Air
T_{ap} [min]	40	120	40	160
T_{dp} [min]	20	40	20	40
T_{ac} [min]	60	160	60	200
V_{max} [km/h]	150	900	350	900
V_{av} [km/h]	120	750	300	750

km/h = kilometer per hour, min = minute.

Source: Authors.

While the minimum total travel time is an important factor influencing the choice between HSR and air, the following elements also influence passengers' selection:

- Access to terminals: rail stations are typically in a city center, accessible via many transit lines or walking. Airports are farther away and depend on access mostly by private cars. Many cities are now improving the access by bus or rail transit.
- Passenger comfort and environment: HSR cars offer increasingly comfortable seats and allow passengers to walk to bars for food and beverages, some joint tables, and a view of the surroundings during travel. Airplanes offer strapped, increasingly tight seats and often dark cabins (Narayanan and Batta 2003).
- Pricing: HSR travel often offers a less expensive rate than the combination of airfare, surcharge, and airport amenity fee.
- The weighted travel time elements vary between HSR and air: most travelers consider waiting and other in-terminal times to be much more objective than the time spent traveling in a vehicle.
- Ancillary business activities: besides the technical superiority of railway services, some railway stations include coffee shops, restaurants, and even duty-free shops (Trainsrussia 2006).

All these elements have led HSR to become more competitive with air travel. The discussion about mode choice, system comparison, and effective changes, a necessity to apprehend the major operating HSR

elements and trade-offs, would lead to an objective assessment of its comprehensive effect.

16.3 Operational Dissection and Performance Measure of High-Speed Rail

HSR network design requires meticulous technical planning and decision making regarding major elements (HNTB 2012; Li and Xu 2016; ADBI 2018; APTA 2017; Jacobs 2018). These elements have a sophisticated interrelation. Negligence would lead to a series of operating nightmares. Therefore, the study selects four distinct elements: (i) the passenger access time and travel time associated with the total on-line travel time; (ii) the area coverage associated with the station density; (iii) the station density associated with the speed; and (iv) the transit unit size, frequency, and loading factor associated with the independent line capacity. Studying the severity and sophistication of such interrelated complexity offers a thorough procedure for decision making regarding the planning, design, and operation of an HSR line and its comprehensive effect.

16.3.1 Passenger Access and Travel Time

The travel time of passengers on a transit line, the passenger time (PT), consists of two main concepts: the access to and from the stations, including the passenger access time (PT_a) and the on-line travel time (PT_t), as Figure 16.3 shows:

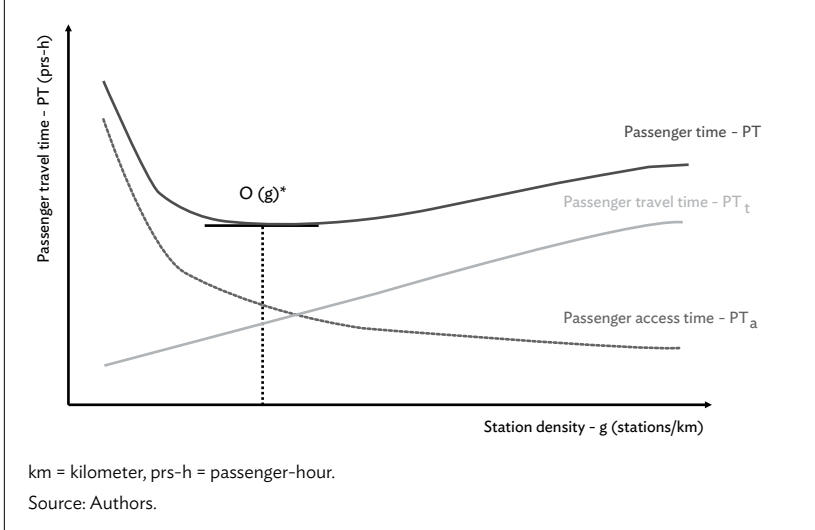
$$PT = PT_a + PT_t \quad (1)$$

The number and location of stations along a line influence both the access and the travel time. Analyses of the number of stations on a line with a given distance often use the station density (g), defined as stations per km, or the inverse of the average station spacing. For example, if the average spacing is 0.8 km, the station density is $g = 1/0.8 = 1.25$ stations per km.

Considering the passenger travel time, it is necessary to base the station density on the optimum value trade-off between the access (PT_a) and the travel time (PT_t):

- (1) An increase in the station density (g) results in a decrease in the average distance and access time to the station (PT_a).
- (2) An increase in the station density (g) on the line results in an increase in the passenger travel time (PT_t).

**Figure 16.3: Passenger Travel Time
as a Function of Station Density**



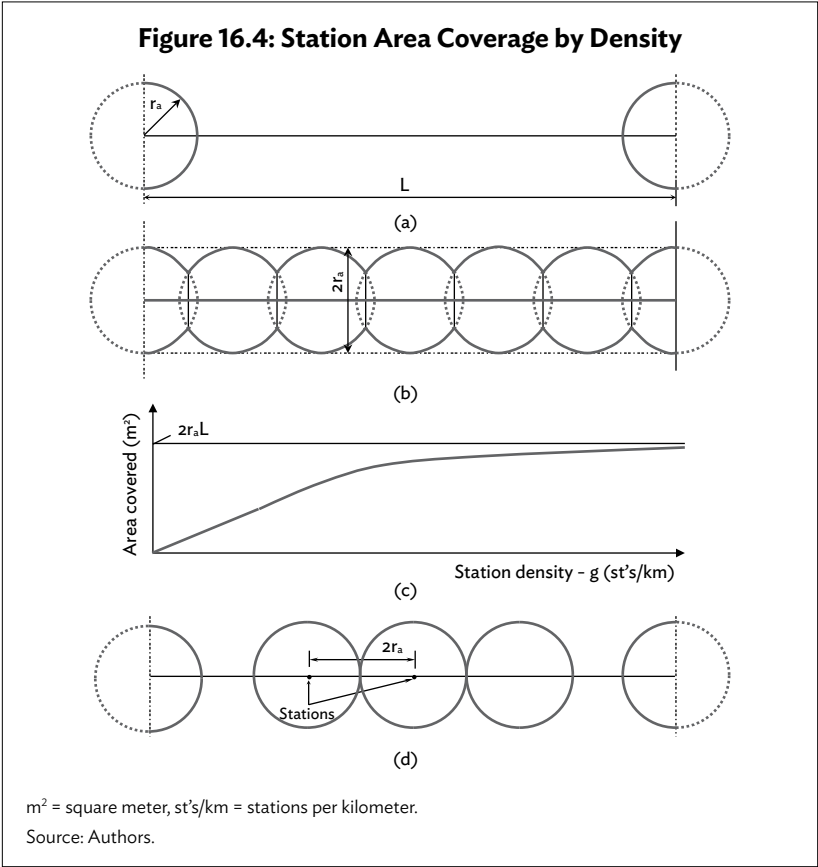
When the station spacing becomes too short for trains to reach their maximum speed, an additional delay happens so that the marginal increase in travel time begins to decline. The total passenger time (PT) curve shows the optimal station density: $O(g)^*$. If the passenger distribution along a line is uniform, it is possible to determine the optimal station density through the trade-off. If the passenger distribution is non-uniform, such distribution influences the optimal station locations and results in variable spacing (Vuchic 1985, 2005).

16.3.2 Area Coverage

The area coverage represents the basic element of transit system accessibility. It is defined as the percentage of the total area within 5 minutes or 400 meters (primary) and 10 minutes or 800 meters (secondary) walking distance of transit stations. Maximizing the area coverage is one of the important priorities in network planning and design, because the system usage depends on both the technical operations and the ability to attract passengers. The area coverage is a direct result of the station density. For simplicity, the study makes two very liberal assumptions:

- (1) A station can be placed at any location along a line.
- (2) There is ubiquitous access; that is, people can access any station in a straight line. This makes the area coverage of a station a circular surface with a radius of the maximum walking distance (r_a).

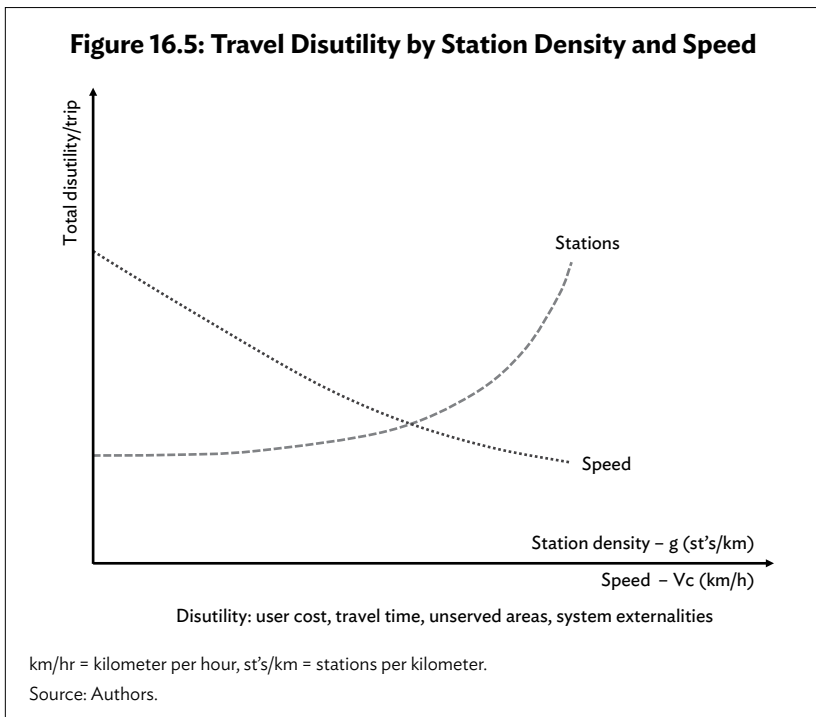
If a line segment with length L has only two stations, the area coverage is limited to two circles around them with radii equal to r_a , as Figure 16.4a shows. Each additional station increases the area coverage by another $2r_a \times \pi$ area until these areas touch and then begin to overlap (Figure 16.4b). The increase in coverage begins to diminish if the station-to-station distance begins to overlap too much. The theoretical maximum coverage of a line, $2r_a \times L$ (Figure 16.4c), would be achieved by a continuous station (Figure 16.4d) (Vuchic 1976, 2005).



In short, the planning of stations faces a fundamental dilemma: closer stations (with short spacing between them) result in better area coverage and easier access for a larger number of potential passengers. However, short station spacings cause a lower operating speed and possibly a larger vehicle size as well as higher construction and station maintenance costs. Longer station spacings result in the opposite situation: high speed and better operation, but a line that passes through areas without serving them since there are no stations. A portion of potential passengers is then lost (Vuchic and Newell 1968).

16.3.3 Station Density and Speed

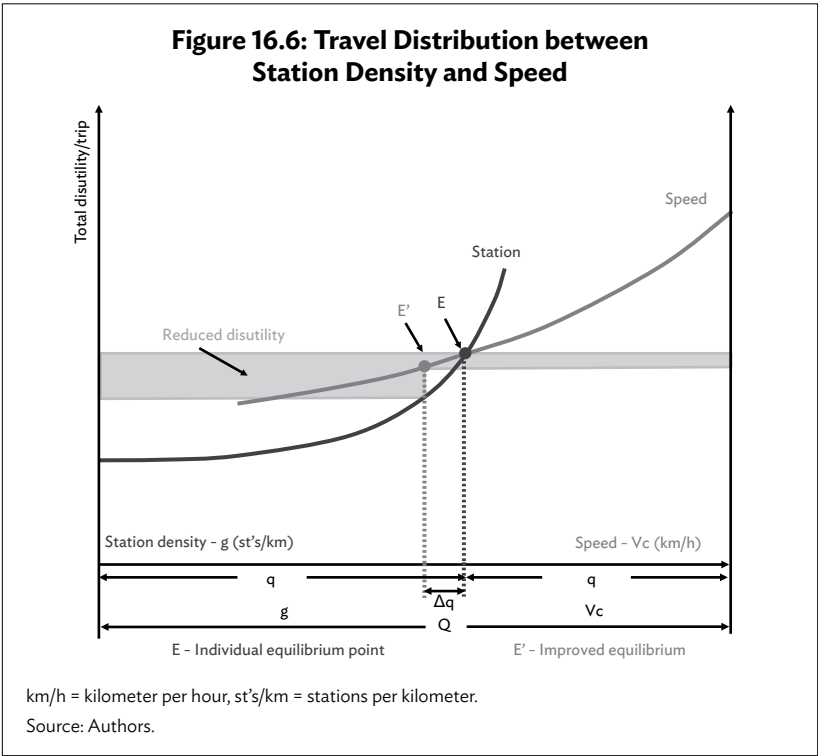
The operation and passenger attraction of HSR has high elasticity between the number of stations, the speed, and the disutility. As Figure 16.5 shows, when the station density g (stations per km) is low (e.g., only two terminal stations for a single line), the travel speed can be very fast, but the total disutility is also very high, mainly due to the many unserved areas (resulting in low ridership). As the station density



increases, the speed will become lower and then the railway will serve more passengers, although the overall travel time will increase. This will also result in a lower cost per passenger.

Figure 16.6 shows the distribution of Q stations in a single line (from the left) and the speed (from the right). HSR lines mostly operate under the lower disutility scenario, and the distribution between stations and speed will be at the equilibrium point E : q_g , the number of stations, and q_{vc} , the operating speed. This situation exists in the real world, where there is an HSR system with an average speed of 350 km/h and another conventional rail system with an average speed of 120 km/h. If one could make an impact on the other, for example, Δq shows the number of travelers deciding to travel on a single line; when the number of stations decreases, its operating speed can increase. Therefore, the travelers on the line would benefit, so identifying the station density and speed leads to a system optimum: minimum total disutility.

HSR challenges the existing modes of transportation and creates a new mode to shorten the intercity passenger commuting time massively.

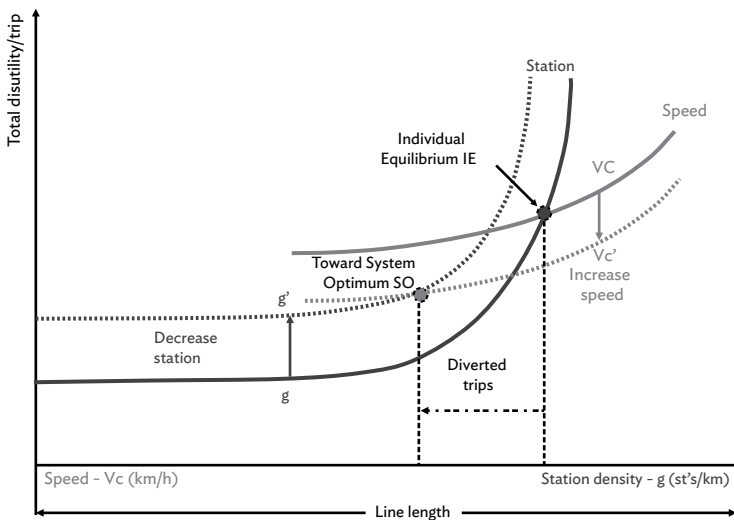


One must understand this relationship between the station density and the operating speed, as well as the application of the two design principles and the corresponding operating strategy to plan for a “flexible” HSR system. The term “flexible” in transportation system planning always comes with trade-offs (Vuchic 1971). As mentioned above, the trade-offs are between the passenger access time and the passenger travel time, the area coverage, and the station density and speed. Thus, if pursuing the maximum speed of this new mode of transportation (only if the line reaches its offered capacity), one should understand the importance of the two interchangeable principles:

- Method I: Increase the speed
- Method II: Decrease the station density

Figure 16.7 shows how these two sets of measures result in a shift of the equilibrium point from the individual equilibrium point (IE) toward the system optimum (SO) point: to increase the speed, move the V_C curve down to V_C' , whereas the station density moves the g curve up to g' . The result is a shift from operating more stations to operating fewer

Figure 16.7: Operation Strategy for Shifting the Individual Equilibrium to the System Optimum



km/h = kilometer per hour, st's/km = stations per kilometer.

Source: Authors.

stations so that trains can travel at a higher speed, known as skip-stop and express services; this moves from the initial IE toward the SO due to the individual decisions of travelers and operators, and it remains stable thereafter. The diagram shows the total disutility of travel in both modes, which was initially at the IE level and has reduced to the SO level.

The corresponding measures of station spacing on any section along a line should be the ratio of the number of passengers with origins and destinations along the ridership distribution vs. the number of passengers on the trains passing through the same section who prefer to skip the stop due to time loss. The greater this ratio, the more stations the line should establish. Conversely, when the volume of through-passengers dominates the volume of local passengers, the station spacing should be long. In brief, the station density (g) varies with the distribution of the passenger demand along the line (Vuchic and Newell 1968; Vuchic 1969, 2005; US DOT 2011).

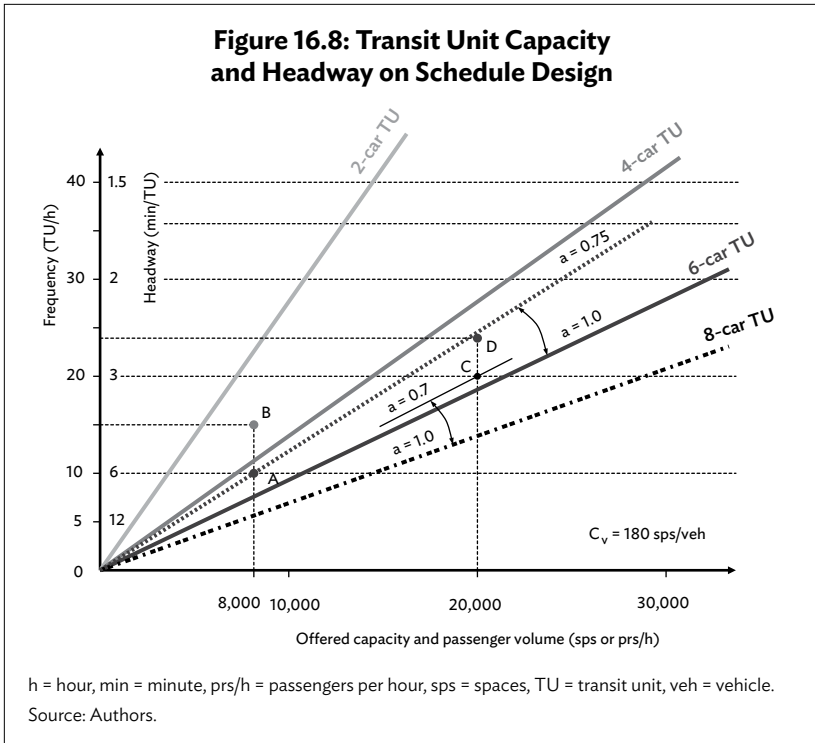
16.3.4 Guidance for the Transit Unit Size, Frequency, and Load

The system capacity has a comprehensive effect on an HSR network. The examination of the system capacity requires an in-depth analysis of engineering elements. The following equation enables the selection of the optimal combination of transit unit (TU) size (n), operating speed (C_v), service frequency (f), headway (h), and load factor (α) for any scheduling period of the day:

$$C = n \times C_v \times \alpha \times f \quad (2)$$

Figure 16.8 is based on the equation. It shows four different trains comprising transit unit sizes of two, four, six, and eight cars as well as the line capacity with operations at different frequency or headway and load factor α . Each slope line shows the values for a given transit unit size at full occupancy, $\alpha = 1$. The gray-dashed line shows the capacities offered by six-car transit units with $\alpha = 0.75$.

Assume that the offered capacity is 180 seats per vehicle. During the midday period, $P_{\max} = 8,000$ passengers per hour, the reasonable choices would be to operate six-car transit units at $h = 6$ minutes with $\alpha = 0.75$ (point A on the diagram) or four-car transit units at $h = 4$ minutes with $\alpha = 0.75$ (point B). Supposing that the peak period has $P_{\max} = 22,000$ passengers per hour, then the choices may be to operate eight-car transit units at $h = 3$ minutes with $\alpha = 0.70$ (point C) or six-car transit units at $h = 2.5$ minutes with $\alpha = 0.77$ (point D) (Vuchic 2005). The selection of the



transit unit size has an impact on the system capacity, fleet, and schedule management.

16.4 A Case Study: Pennsylvania Station, New York—Existing Challenges and Corresponding Engineering Measures

In a comparison of the US cities and major corridors with the passenger rail services in peer locations—Paris, Munich, Moscow, or Madrid, not to mention Tokyo and Beijing—their rail services are incomparably better than Amtrak's, even those between Washington, DC and Boston. Amtrak offers services that are slower (Acela trains are an exception), less frequent, less reliable, and less comfortable, and they involve tedious boarding and alighting. Amtrak's tickets are grossly overpriced

not because of its services but because of the lack of a consistent funding stream from the government (Burns 2012). Such a fact forces intercity travelers to choose low-cost buses and cheap domestic airlines. Highway and airline lobbyists and special interest groups are still challenging the role and necessity of Amtrak in the US intercity travelers' market by asking how other corridors besides the Northeast Corridor in North America could benefit from the construction of HSR. In fact, ambition and political willingness never create the right conditions for Amtrak and other HSR networks in the US (FRA 1997; RPA 2011). For example, Florida was ready to build an HSR, but Governor Jeb Bush vetoed it. Later, Governor Rick Scott refused federal funds as part of President Barack Obama's American Recovery and Reinvestment Act of 2009. Since then, the operation of HSR in Florida has commenced, with further expansion and higher speeds planned. Major planning efforts are taking place in Texas, the Midwest, Toronto–Montreal, Seattle–Portland, and others. The leader among these efforts is California. With a steadily growing population, it is leading the way by constructing HSR connecting most cities between San Diego and Sacramento (Vuchic 1985, 2018; WSDOT 2017).

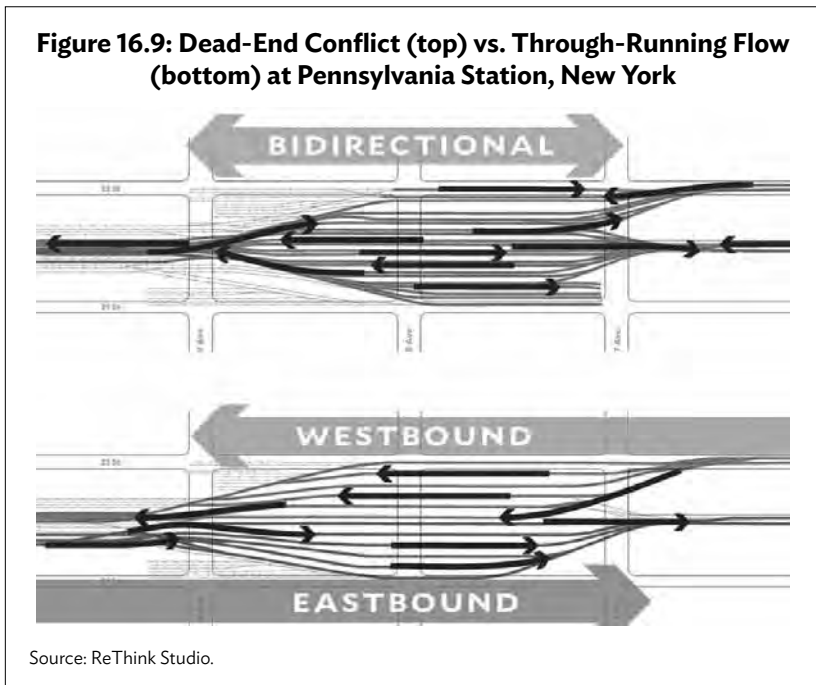
The Northeast Corridor is unique due to its geographic, economic, and population conditions and the fact that it has good services from Amtrak and several regional rail networks (Long Island Rail Road, Metro North, Southeastern Pennsylvania Transportation Authority, and others). Therefore, the study naturally focuses on Pennsylvania Station, a choking point in New York's regional connectivity. To solve the problem, the city would require transformative action to rethink its urban strategies: to connect the disconnected parts and increase the efficiency gain from an integrated network (Sayer 2016).

To quantify HSR's comprehensive and spillover effects, complex network modeling would be demanded to explore the geospatial metadata on the population distribution, origin–destination survey, transit connectivity, land use pattern, and prediction scenarios of future urban growth. The selected case study focuses on the tristate region (New York, New Jersey, Connecticut) due to the accessibility of publicly available data. Instead of boiling down to the metadata, the study presents specialized detail. The detail brought a practical application to Amtrak to transform a semi-HSR system into an actual HSR system. The construction phasing plan mapped a series of schematic station designs for platform expansion, track reengineering, and network realignment at the currently underperforming Pennsylvania Station. This section dissects three major challenges and provides corresponding engineering measures to convert an independent dead-end terminal into an integrated through-running station, which are the totality of an

initial step to convert Amtrak into an accelerated HSR service (ReThink Studio 2017a).

16.4.1 Low Network Capacity vs. Flexible Track Alignment for Higher Operation

First, the current tracks at Pennsylvania Station are operating at maximum network capacity. It is impossible for the inflexible alignments to accommodate extra services or any incidental changes. The so-called following trains have to wait in tunnels for 15 minutes as leading trains exit the station. The station is operating as a terminal rather than as a through station. Trains must cross each other as they enter and leave the station (Figure 16.9, top). The countermeasure of through-running avoids congestion by scheduling eastbound traffic on southern tracks and westbound traffic on northern tracks (Figure 16.9, bottom). Each train would enter the station, prepare for passengers boarding and alighting, and continue without ever crossing the incoming and outgoing traffic (ReThink Studio 2017b).

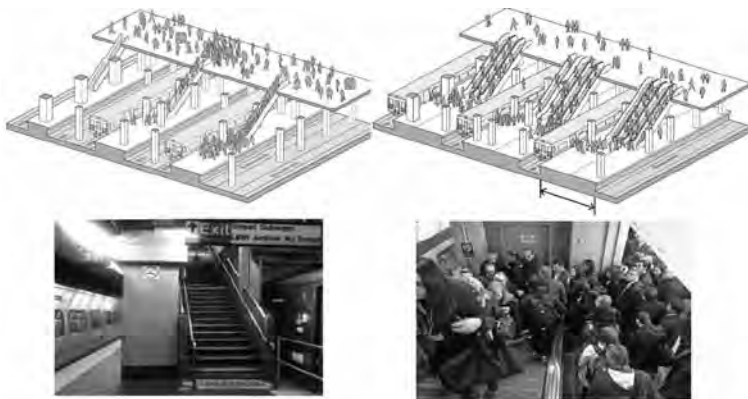


To enable the steady flow of through-running operation, the study comprehensively examined the feasibility of the phasing plan, incorporating track reengineering, network realignment, and minimization of construction and demolition for normal operation. It identified a total of 10 phases to convert the existing independent dead-end terminal into an integrated through-running station (Figure 16.10, left). Each phase has a counter-operating strategy to follow (Figure 16.10, right). The phase plan balances the construction and demolition timelines without disrupting the normal commuting services (ReThink Studio 2017b).

16.4.2 Limited Passenger Circulation vs. Platform Expansion to Expedite the Boarding and Alighting Process

Second, narrow platforms present a safety issue. Staged boarding mitigates overcrowding on platforms, forcing outbound passengers to wait on the mezzanine level until all the passengers on the leading train have alighted. Limited vertical circulation (stairs and escalators) produces chaotic passenger flows and rushed transfers, especially for New Jersey Transit passengers (Figure 16.11 upper-left and lower

Figure 16.11: Existing Platform Condition (upper-left and two lower) vs. Engineering Improvement of Vertical Circulation (upper-right) at Pennsylvania Station, New York



Source: ReThink Studio.

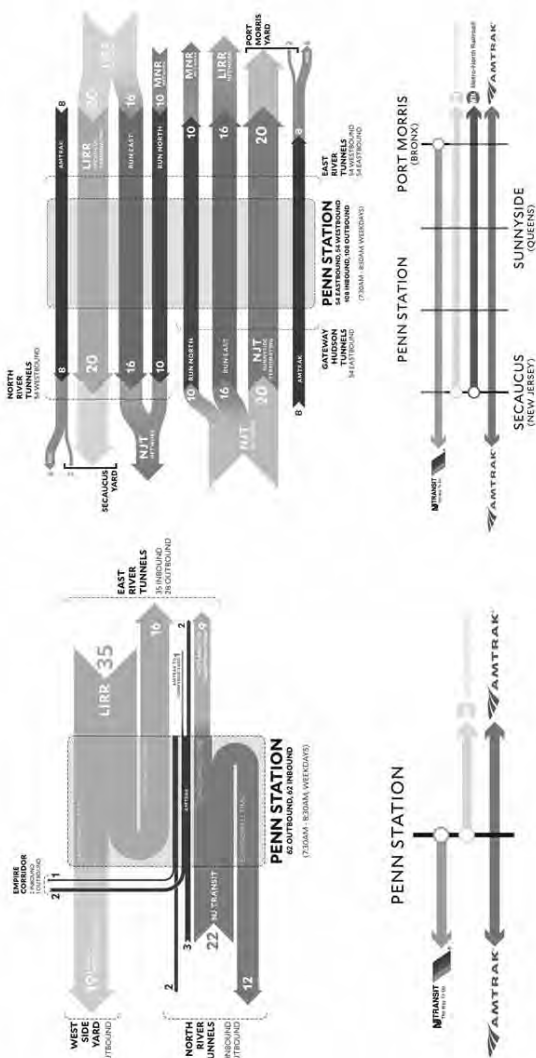
two). Without even discussing the possibility of protective screen door installation, overcrowding drastically reduces the system's reliability. In contrast, a through-running station would allow single-track configuration to widen the platform and additional space for vertical circulation (Figure 16.11 upper-right). Such an engineering effort would offer greater safety and increase passengers' boarding and alighting process at the platform and mezzanine levels (ReThink Studio 2017c).

16.4.3 Disconnected Network Services vs. a Unified Network to Increase Regional Connectivity

Third, the New York regional rail services are disconnected. Different land masses (Manhattan, New Jersey, the Bronx, and Long Island) have different transit agencies. Passengers who would like to travel between New Jersey and Long Island must experience Pennsylvania Station's narrow platforms and unreliable boarding and alighting process. Those who would like to transfer from Pennsylvania Station to Grand Central Station must use the Metropolitan Transportation Authority (MTA) subway. To enable Pennsylvania Station's through-running capability, the adjustment of terminal functionalities includes the relocation of railyards, the reduction of long dwelling times at platforms, and the execution of the two abovementioned measures (sections 16.4.1 and 16.4.2). Instead of operating a single nucleus terminal in the center of downtown Manhattan, the plan is to distribute the ridership by leveraging the gravity of satellite cities and incubating the growth in Port Morris, the Bronx, and Secaucus, which will become multimodal transit hubs (Leland 2016).

Although Amtrak connects major cities in the Northeast Corridor, effort must be put into unifying New York's regional rail services. The construction phasing plan provides a schematic adjustment for platform expansion, track reengineering, and network realignment at the currently underperforming Pennsylvania Station to enable the through-running services to become a cohesive regional network. In Figure 16.12, the system throughputs and service density have increased, and the regional connectivity and fleet utilization performance have improved (ReThink Studio 2017c).

Figure 16.12: Comparative Analyses of Dead-End (left) vs. Through-Running (right) Network Capacity at Pennsylvania Station, New York



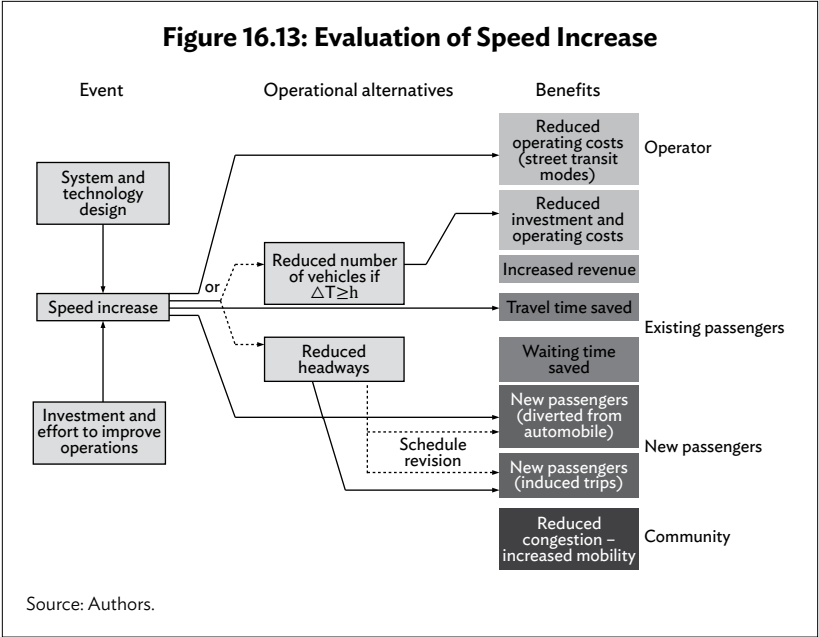
Source: ReThink Studio.

16.5 Conclusion

Unlike in the People's Republic of China, the Russian Federation, Japan, and European countries, the development of HSR in the US has encountered administrative contradictions and managerial barriers. However, a relentless effort must be devoted to understanding the technicality of planning, designing, and operating HSR and its comprehensive effect on the long-term economic growth of metropolitan areas as well as the network efficiency for economic value contribution. The development needs to happen while avoiding mutually conflicting policies to achieve an intermodal balanced transportation system. This chapter reviewed the history of HSR development in the US and made a comparison with that in peer countries. Then, the analyses compared medium- and long-distance intercity passenger modes of car, air travel, conventional rail, and HSR regarding the total travel time and speed within the given time frame (1960–2018). After discussing which mode would outperform another under which conditions, the study presented a thorough dissection of sophisticated interrelations among selected variables. Figure 16.13 evaluates the gain of a speed increase for four beneficiaries.

Many global cities are either in the transition stage of repositioning cities' long-term competitiveness or in the development stage of large-scale metropolitan planning. Common actions are observable in these two settings: the outstanding commitments to the modernization of efficient urban and intercity rail systems and the transformative mind-set for the recapitalization of a city's assets, both developable and underutilized lands, within the central business district and surroundings. The Northeast Corridor in the US accounted for 23.6% of the national gross domestic in 2017 (Amtrak 2017; BEA 2018). The economic contribution reflects its importance to the country. Naturally, studying and upgrading this corridor has become a critical task. In the case of Pennsylvania Station, New York, reengineering efforts to convert an independent dead-end terminal into an integrated through-running station will result in a more efficient regional unified network. Three incremental steps will start modernizing the inflexible Pennsylvania Station track geometry, overcrowded platforms, and uncoordinated regional and intercity passenger rail services. A plan always comes with a purpose. A broad vision of a city's transportation relationships and the creation of regional unified networks are interdependent on countries' long-term competitiveness.

Figure 16.13: Evaluation of Speed Increase



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17

Japan's Post-Privatization Experience

Yoshitaka Ishii and Kai Xu

17.1 Experience of the Japanese National Railway Reform

The railway business in Japan was hit by a recession in the 1960s. Due to the rapid development of the Japanese economy, given a boost by the railways, the Japanese were able to afford private cars. In addition to the popularization of air travel, railway use for both short- and long-distance travel declined. Railways were defeated by the service competition. In 1964, when the world-renowned *Shinkansen* opened, the Japanese National Railways fell into deficit for the first time, which is an ironic contrast.

Eventually, the situation became one of serious deficit and debt. In 1987, the Government of Japan implemented a reform of the Japanese National Railways, which basically consisted of divisionalization and privatization. The Japanese National Railways was divided into six regional passenger companies and one freight company without rail infrastructure. About 100,000 employees were dismissed, leaving a total of 180,000 for the seven companies.

The state took over the past debt obligation. Among the six passenger companies, the three big companies with a larger scale on the mainland enjoyed a surplus; the other three small companies, namely the companies for the three small islands, with a scale of less than one-tenth of the bigger companies, faced a deficit, as shown in Table 17.1. For revenue adjustment, the three big companies took on a partial debt burden, while the three small companies were given support funds. However, this did not work well due to a sudden fall in the interest rate, and the three small island companies faced many difficulties.

Table 17.1: Passenger Companies after Japan's National Railway Reform

	Company					
	East	Tokai	West	Hokkaido	Shikoku	Kyushu
Fund (¥ billion)	N/A	N/A	N/A	6,822	2,082	3,877
Debt (¥ billion)	35,936	5,217	12,832	745	261	801
Capital (¥ billion)	2,000	1,120	1,000	90	35	160
Year of stock listing	1993	1997	1996	N/A	N/A	2016

N/A = not available.

Source: Compiled from JR Group reports.

Yoshitaka Ishii worked for 15 years as the first president and chairman of the Kyushu Railway Company (Japan Railways [JR] Kyushu), one of the three island companies. When he took charge of the company, he started to create the business foundation for the transformation into a private company.

In the case of JR Kyushu, the privatized image was enhanced by several strategies, including increasing the number of stations as well as the frequency and speed of trains, improving the design of the trains, and operating sightseeing trains. Although it successfully created the brand “Beautiful and Happy JR Kyushu,” it would be forever in deficit if focusing solely on the railway business. Therefore, a wide variety of diversified businesses were introduced, including real estate development, the construction of residential and station buildings, food and beverage businesses, retail, service, tourism and leisure businesses, and so on (Figure 17.1). The profit from the diversified businesses made up the deficit of the railway successfully (Figure 17.2). International high-speed shipping routes utilizing close points to the Republic of Korea were also in the business scope.

It is hard for railway staff to compete with people in existing businesses in the nonrailway field. To support the diversified businesses, the company adopted two strategies. First, it sent on-site employees to small and medium-sized private enterprises for about 2 years to learn about the severity and gain know-how of the sector. Second, it allowed mid-level executives to take charge of the diversified businesses other than the railway to build up the management capacity. These two JR

Figure 17.1: Diversified Businesses of the JR Kyushu Group

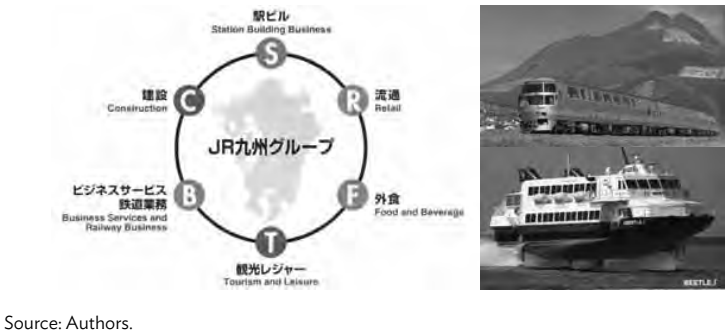
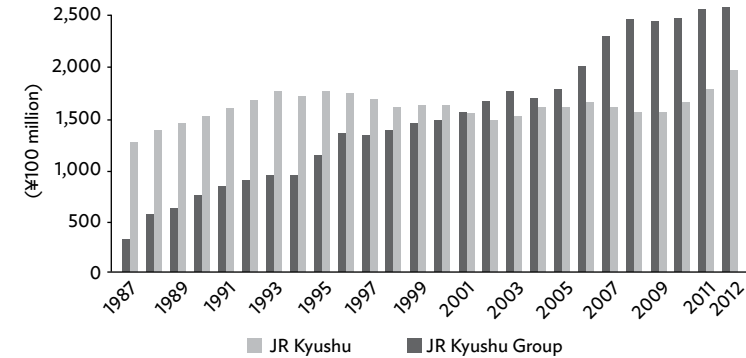


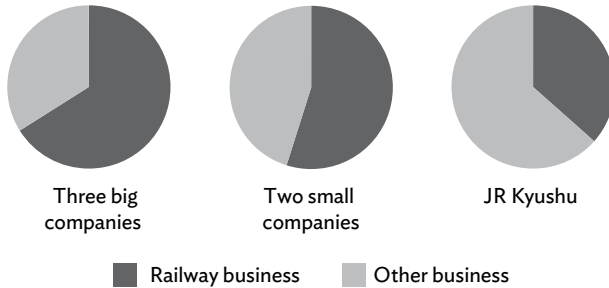
Figure 17.2: Sales Progress of the JR Kyushu and JR Kyushu Group Companies, 1987–2012



Source: Compiled from JR Kyushu publications.

Kyushu-only strategies succeeded. After the privatization, the three big mainland companies were listed publicly, while JR Kyushu was the only one of the three small companies to be listed, even though it took 29 years longer. The business prospects of the other two small companies and the freight company are still not clear. There are also system problems, such as the fact that there are no organizations to discuss nationwide

Figure 17.3: Business Composition of the Japan Railways Companies



Source: Compiled from JR Group reports.

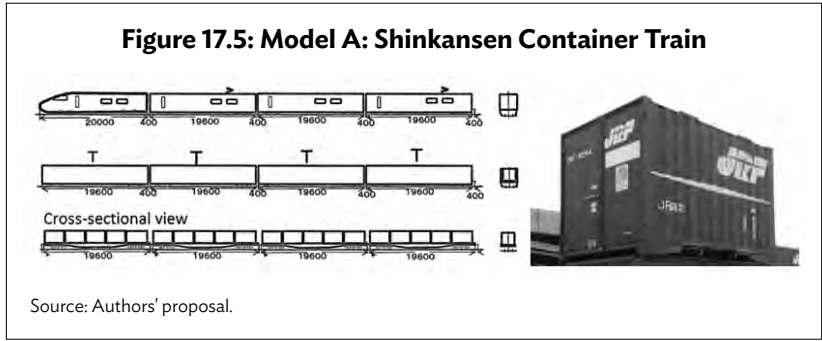
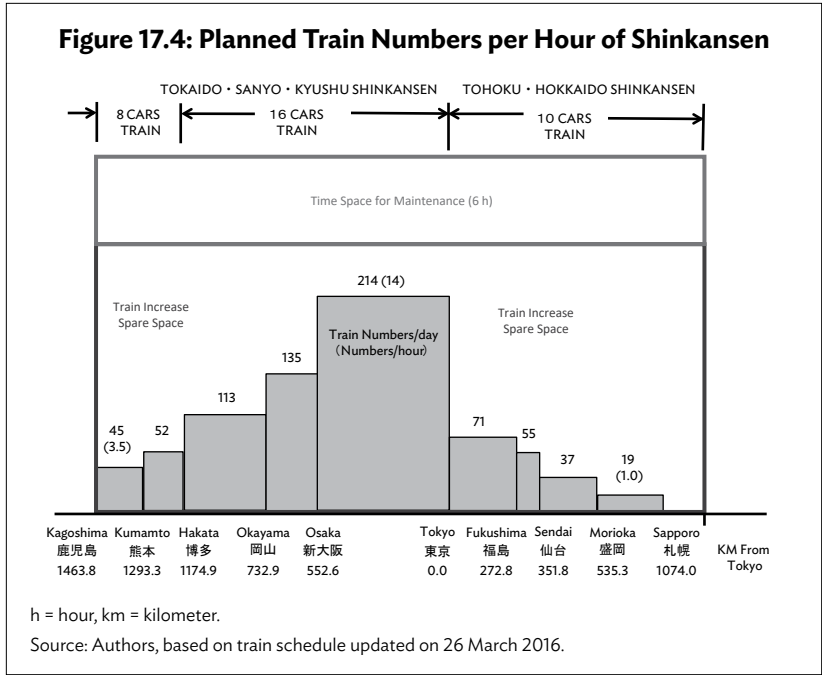
passenger and freight issues in combination because of the absolute separation of the seven companies after the privatization.

17.2 Future Task of Railways

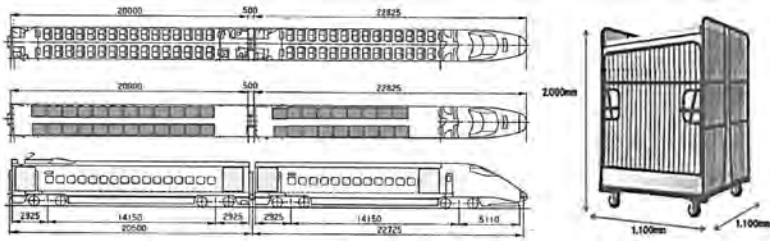
Considerable changes have occurred in the past 30 years. From Kyushu to Hokkaido, the *Shinkansen* has become the aorta running through the Japanese islands. The total length of the network is about 2,700 kilometers as of 2018.

Schedule-wise, for the central part of the system, 14 trains operate per hour, while, at both ends, there are only 1–5 trains per hour. There are no trains for 6 hours (for maintenance) late at night, and this has remained unchanged for the past 50 years (Figure 17.4). The profitability of the *Shinkansen* is low for regions with a low population density if only passengers are targeted. Therefore, the companies are considering freight train operations in this vacant time zone.

There are two models for freight *Shinkansen*. The first one is the *Shinkansen* Container Train, which utilizes containers (Model A, Figure 17.5). At the northern end of Honshu Island, the containers are transported by automated equipment from narrow-gauge conventional trains to specialized standard-gauge *Shinkansen* trains and then sent to the Seikan Tunnel and Hokkaido. The other one remodels the old *Shinkansen* trains to carry the Roll-Jit-Box (Model B, Figure 17.6). Boxes are arranged in order inside the cars. The latter is easy to implement



due to the relatively low investment. Either model can transport freight in one-third of the time of the narrow-gauge conventional line and the expressway. Nowadays, it is difficult to ensure the supply of long-distance truck drivers. In addition, the railway has the merit of one-seventh of the carbon dioxide emissions and one-tenth of the energy consumption of trucks.

Figure 17.6: Model B: Roll-Jit-Box Transport

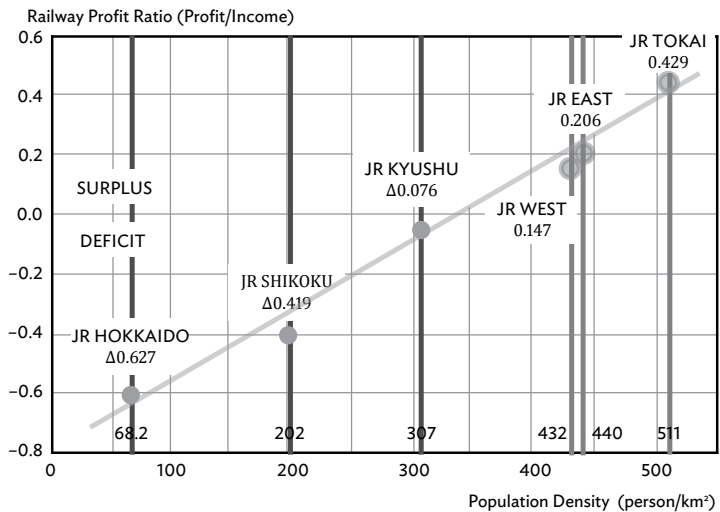
Source: Authors' proposal.

Let us think about the characteristics of railways based on the knowledge gained from 30 years' experience of the breakthrough privatization of the Japanese railway. The profit ratio of a passenger railway is perfectly proportional to the population density (Figure 17.7). Although the proportional multiplier will change on the basis of a country's characteristics, such as its gross domestic product, the law is universally applicable. In Japan, the railway is in surplus for areas with a density of over 350 people per square kilometer and in deficit for areas with lower density. This is the reason why the railway substructure (e.g., tracks and train transportation) is vertically separated in Europe where population density is low. The vertical separation of the railway cannot be likened to the relationship between roads and cars, because the railway is an integrated equipment industry. Although Japan did not adopt the separation, it may become a problem in the future considering the ongoing population decrease, and the situation could be similar to that in Europe in 35 years' time.

Japan is facing problems of population decline, birthrate decline, an aging society, and depopulation in rural areas. The faster the passenger transportation is, the greater the population concentration in metropolitan areas and the depopulation in rural areas will be. Conversely, freight transport promotes the localization of the population, so in that sense it is important to accelerate the freight transport.

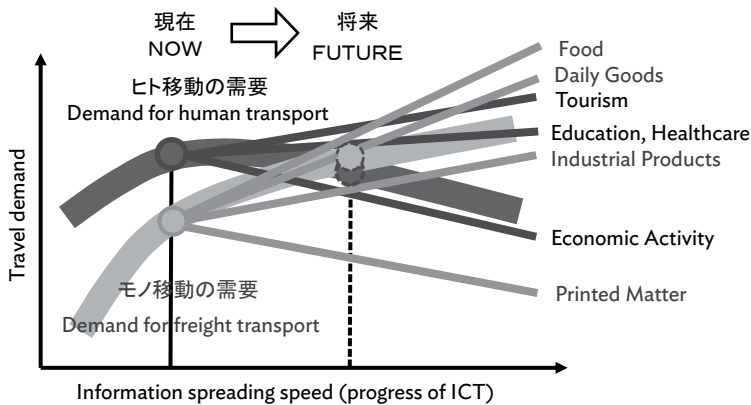
The rapid development of information and communication technology (ICT) is reducing the need for human mobility but increasing the need for logistics mobility (Figure 17.8). Strengthening logistics is the trend of the times. Especially for large countries (e.g., India) and elongated countries (e.g., Japan), railway logistics are a necessary

Figure 17.7: Railway Profit Ratio of JR Companies (as of 2015)



km² = square kilometer.
Source: JR Group reports; population estimates by Ministry of Internal Affairs and Communications, Japan.

Figure 17.8: Forecast of the Hard Demand for Human and Freight Transport



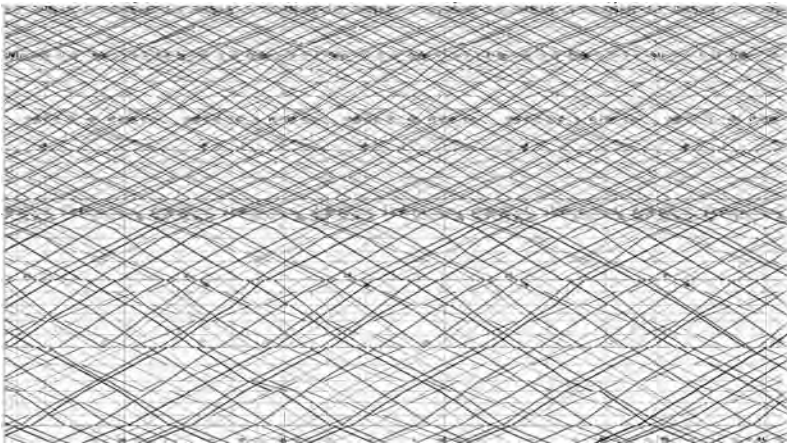
ICT = information and communication technology.
Source: Authors.

strategy for economic development. The development of ICT will deeply affect the speed of information dissemination, which will have an influence on the economy, the population transition, and the quality of life. An integrated transport system that considers the high-speed rail strategy for both passengers and freight is necessary. While developing the hub ports and hub airports, it is also important to improve the domestic railway logistics.

The era of the second-stage reform of the JR Group is approaching, as Japan is undergoing a time of slow growth and depopulation. The experience of such a series of railway growth, maturation, decline, reform, and second stage in Japan will be helpful for countries that are entering the development period.

In particular, we believe that Japan is very advanced in the world due to the *Shinkansen* technology, which connects medium distances at high speed, and the precise transportation system of large metropolitan areas such as Tokyo. The Tokaido *Shinkansen* trains run almost every 4 minutes (see Figure 17.9); Tokyo metropolitan commuter trains run almost every 2 minutes. Figure 17.9 shows the Tokaido *Shinkansen's* fabric, where each fiber is actually a diagram for one train. High frequency while maintaining high safety and accuracy is the proud feature of the Japan

Figure 17.9: Tokaido Shinkansen Operation Schedule Diagram



Source: Tetsumichi- Room Blog (<https://www.tetsumichi-room.com>).

railway. In realizing this, it is very important to ensure the capacity of employees, as well as their dedication and motivation. Furthermore, it is important to foster a sense of trust in the railway among the citizens, who are customers as well, and to create conventions for railway use. The achievement of a safe and punctual railway system in Japan is based on the cooperation between railway employees and citizens. We believe that this is largely supported by the national character of the Japanese people.

Heinrich's law applies to accident management (Figure 17.10). Behind one serious accident lie 29 minor incidents or "troubles," and, behind those incidents are 300 "near misses" or small signs. If 300 "near misses" occur on a daily basis and companies take countermeasures, they can avoid 29 minor incidents and one serious accident. Accordingly, the employees' serious attitudes toward precise work and honest reports are important. In this regard, the Japanese are very cooperative.

The cooperation of local residents along the railway is also necessary. Although the railway dramatically modernizes the living conditions in rural areas, there is still opposition from affected people, especially those who lost land that they regard as their inherent

Figure 17.10: Herbert William Heinrich's Law



Source: Authors.

property. The companies should persuade them that all local residents will benefit rather than only some privileged classes. Moreover, they should incorporate measures that really benefit local residents to the implementation. Japan found it difficult to acquire land along the *Shinkansen* lines. When the Tohoku *Shinkansen* line opened, due to a delay in the land acquisition, there was a temporary opening at Omiya Station for 3 years, which is just 26.7 km from the current starting point, Ueno Station.

17.3 Messages for the Railways

The full-scale development of railway infrastructure is the most important national project, especially for Asian countries. As everyone knows, high-frequency mass transport with high safety and accuracy are extremely important for railways. As mentioned, Japan has accumulated know-how based on its achievement, and we are confident that this experience will be useful for other countries as well.

There is a belief that the standard *Shinkansen* train in Japan will be the best model when introducing high-speed rail, considering the economic conditions, even if it is not the best in terms of maximum speed. The manufacturing of railway cars is not automated, different from the automobile industry, but a labor-intensive process with various detailed designs for each car. Therefore, it is necessary to assign the important parts to skilled workers. After cultivating skilled workers in Japan, the next stage is realizing domestic manufacturing as well as possible future exports. The railway can be used as a tool for economic exchange and peaceful diplomacy in the future.

The improvement of large-scale, high-speed freight transportation between major domestic bases, particularly industrial, agricultural, and mineral regions, and important export-related ports will greatly influence the future economic development. On the American continent, 200 years ago, with the intention to connect the east and west coasts as quickly as possible, many curves were built into the rails, making long-distance freight transport on the railway system very difficult now.

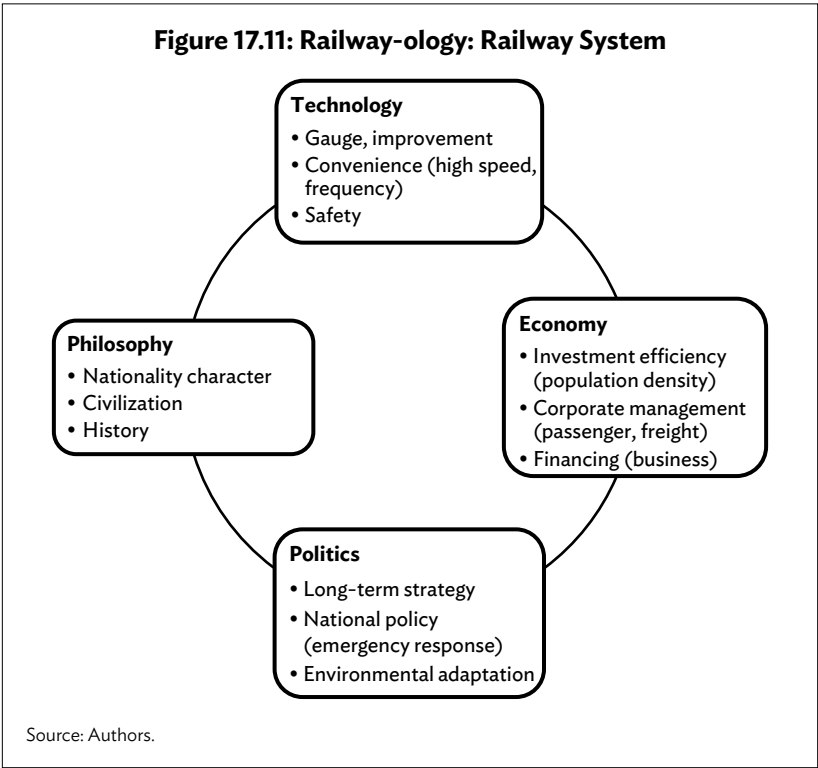
It is important to keep in mind not only passenger transportation but also freight transportation when improving the speed and convenience of conventional railways. In the case of Japan, the improvement focused on passenger transportation shortly after World War II. This may be because the country is surrounded by sea, but some reflection on the development history is necessary.

The improvement of over 20,000 kilometers of conventional lines is also a major issue. The conventional lines in Japan seem to have

been improving recently; they were a problem for commuters in the Tokyo metropolitan area for about 5 years after 1945. Due to the limited capacity, commuters could not board the trains. To counter this, cheap cars were supplemented and more employees recruited to resolve the worst situation in those 5 years.

The distance between rails (gauge) is important for railways. Countries around the world use different types of railway gauge. Very often, routes with the same gauge width become one economic route or sometimes an economic zone, as a direct connection between different gauges is impossible. Moreover, once complete, such a long-term economic zone could last for 100–200 years. The Russian Federation’s Trans-Siberian Railway is a wide-gauge economic zone, while the People’s Republic of China’s Belt and Road Initiative is a standard-gauge economic zone. The railway gauge issue deserves special attention when making a long-term development plan.

Figure 17.11: Railway-ology: Railway System



Finally, we would like to propose a “Railway-ology,” which summarizes our understanding of and perspectives on the railway system based on 30 years’ experience. We believe in the necessity of a comprehensive railway science that integrates technology (T), economy (E), politics (P), and philosophy (P) (Figure 17.11). Comprehensive railway study at influential universities and institutions is important for research improvement, policy making, and human resources development.

18

Lessons from Japan for High-Speed Rail and Station Area Development in India

*Yoshihiro Kumamoto, Takashi Yamazaki, Toshiji Takatsu,
Seiichiro Akimura, and Shreyas Bharule*

18.1 Introduction

The first high-speed railway (HSR) project in India is being carried out between Mumbai and Ahmedabad. HSR emits low levels of CO₂, compared with planes, vehicles, buses, or conventional railway. However, connecting smoothly with urban public transit systems or individual transport modes at the HSR station is vital to realize a low carbon transit environment, not only for the interstate areas but also for the inner urban areas. This chapter mentions the usefulness of HSR in terms of the lower carbon intercity transport system and spotlights opportunities to develop integration with intracity transport in the form of station area development. It draws several lessons from Japan for high-speed rail and station area development in India.

18.2 Background of High-Speed Rail for Mumbai to Ahmedabad

The Indian Railways white paper “Vision 2020” (Government of India 2009) identified the Mumbai–Ahmedabad HSR (MAHSR) line, among six other HSR corridors, for conducting technical feasibility studies in 2009. Through several intergovernmental developments, a “Memorandum of Cooperation between the Government of Japan

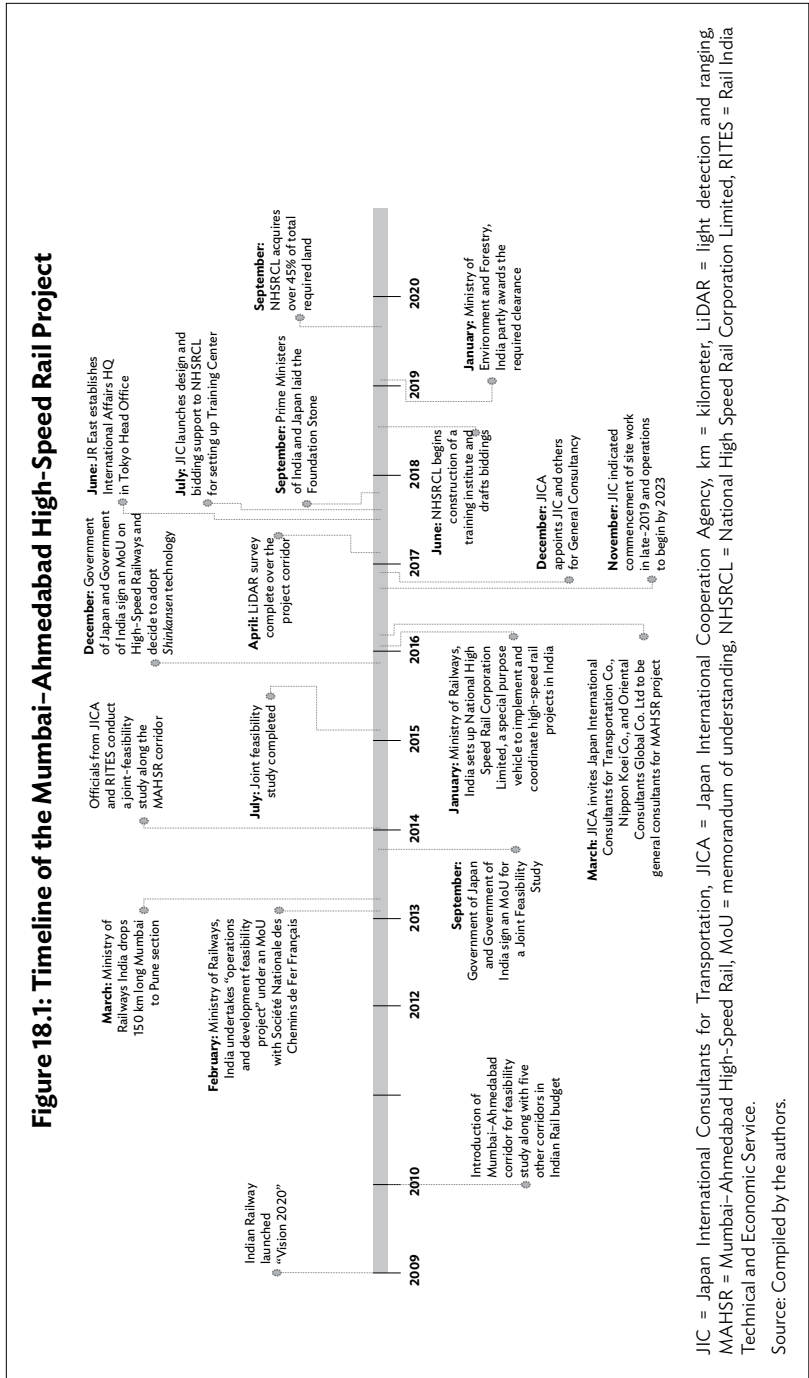
and the Government of India on High-Speed Railways” was signed in December 2015. The memorandum stated Japan’s bullet train system—the *Shinkansen*—as the optimally suitable method for the MAHSR plan.

The Japan International Cooperation Agency (JICA) in early 2016 assigned Japan International Consultants for Transportation, Co., Ltd. (JIC) for consulting services in formulating the technical standards for high-speed rail through conducting a follow-up study for the MAHSR corridor. At a consultation meeting between the two governments held in late 2016, the meeting also discussed the findings of the follow-up study report, stating the progress of the MAHSR plan. The report also indicated the schedule for the work as expected to commence in 2018 and operations to commence in 2023.

By late 2016, JIC, Nippon Koei Co., Ltd. and Oriental Consultants Global Co., Ltd. formed a consortium to provide general consultancy services for the MAHSR project. The awarded general consultancy contract included services such as the formulation of design and tender documents (draft) for the MAHSR construction project.

In mid-2017, Japan Railways (JR) East established the International Affairs Headquarters in the Tokyo Head Office, and JIC launched design and support bidding operation services for the HSR training center proposed in Vadodara, India. In the same period, under JICA’s capacity building and training program to gain knowledge of Japan’s HSR system, a team of executives from the National High Speed Rail Corporation Limited (NHSRCL) visited Japan. During the program, NHSRCL exchanged views with executives from JR East concerning the operation of railway companies and toured the JR East Generation Education Center to understand JR East’s efforts in human resources development and the passing on of technologies. Besides, under the contract with JICA, JIC has been organizing training for about 300 junior officials from the Ministry of Railways of India, every fiscal year starting in 2017, to support them in acquiring knowledge on Japanese railways.

Figure 18.1 summarizes the timeline of the MAHSR project. While many overseas railway projects are in progress, the organizations collectively aim to nurture efficient management and human resources that can help the efficient delivery of infrastructure in challenging international business scenarios. JR East will continue to provide technological and physical support in these operations conducted by JIC, capitalizing on experience as a *Shinkansen* operator.



JIC = Japan International Consultants for Transportation, JICA = Japan International Cooperation Agency, km = kilometer, LIDAR = light detection and ranging, MAHSR = Mumbai-Ahmedabad High-Speed Rail, MoU = memorandum of understanding, NHSRCL = National High Speed Rail Corporation Limited, RITES = Rail India Technical and Economic Service.

Source: Compiled by the authors.

18.2.1 Outline of Mumbai–Ahmedabad High-Speed Rail

The MAHSR is planned to cover a distance of about 508 kilometers (km) between Mumbai and Ahmedabad in around 2 hours, with an initial maximum speed of 320 km/hour. The proposed MAHSR corridor has 12 stations planned along the alignment. The follow-up study team conducted a meticulous analysis of the locations of the 12 stations based on the population of the nearest city, trends in travel behavior, distance from the terminal station, and present status of development in the surroundings of the proposed stations. The report concluded declaring Mumbai, Ahmedabad, and Sabarmati as busy stations and Surat and Vadodara as semi-busy stations. Table 18.1 describes the findings and estimations of the follow-up study.

Three of the proposed HSR stations, Vadodara, Ahmedabad, and Sabarmati, are either in the vicinity of an existing conventional line or are located on top of a conventional line station. The metro lines are under construction adjacent to the proposed HSR Ahmedabad Station and nearby the planned HSR Sabarmati Station. In the Bandra Kurla Complex (BKC) a new central business district in Mumbai, a metro station of the 2B line is planned to be developed and to connect with the Mumbai–BKC HSR underground station.

The statistics compiled by Japan's Ministry of Land, Infrastructure, Transport and Tourism indicates the comparison of CO₂ emissions among interregional transport modes within Japan. Table 18.2 summarizes the findings of the comparison between passenger and freight transport based on the CO₂ emission basic unit. In terms of passenger transport, the values of basic units of emissions for individual cars, planes, and buses each are higher than the railways by 7.1, 4.9, and 3.4 times, respectively.

However, an HSR station is also a vital transportation hub. HSR needs to connect with other low carbon transit systems, such as metro, light-rail transit, or automated guideway transit, for reducing CO₂ emissions in an integrated manner. In this context along the MAHSR corridor, the proximity to existing and infrastructure under development provides a unique opportunity to explore integrated station area development (SAD) in India and subsequently enhance the quality of life in its surroundings. The following section draws lessons for HSR in India from two relevant cases located in the Tokyo metropolitan area, Japan.

Table 18.1: Outline of Proposed Stations along the MAHSR

State	Station		Distance from Mumbai (km)	Metro. area Population (million)	Estimated Ridership (pax/day)		Type of Station (Location)	Mass Feeder Transit			Future Urban Planning Stance	Pilot Study done for Station Area Dev.
	No.	Name			2023	2053		Existing	Under Construction	Planned / Potential		
Maharashtra	1	Mumbai	---	12.00	30,000	158,000	Underground (Urban core)		Metro 2B Line			
	2	Thane	28	1.20	3,000	16,000				Railway (CR)		
	3	Virar	65	1.20	2,000	11,000						
	4	Boisar	104	0.15	1,000	4,000						
	5	Vapi	168	0.16	2,000	10,000	Elevated (Suburban)					
	6	Bilimora	217	0.05	1,000	5,000						
Gujarat	7	Surat	265	4.50	5,000	24,000				Metro	Smart city challenge	√
	8	Bharuch	323	0.22	1,000	5,000						
	9	Vadodara	397	2.00	6,000	31,000	Elevated (Urban core)			Railway (WR)		
	10	Anand/ Nadiad	448	0.85	4,000	18,000	Elevated (Suburban)					
	11	Ahmedabad	500		21,000	110,000	Elevated (Urban core)			Railway (WR)	Metro	√
	12	Sabarmati	506	6.30	3,000	14,000	Elevated (Rail ROW)			Railway (WR)	Metro	Smart city challenge

CR = Central Railway, km = kilometer, MAHSR = Mumbai–Ahmedabad High-Speed Rail, ROW = right-of-way, WR = Western Railway.
Sources: Authors' compilation based on JICA and JIC (2018). Follow-up Study for MAHSR Corridor; National High Speed Rail Corporation Limited; and Smart City Challenge, India.

**Table 18.2: Comparison of Emissions among
Interregional Modes of Transport**

Contents	Individual car/truck	Commercial truck	Airplane	Bus	Ship	Railway
Passenger (gCO ₂ /passenger-km)	141		98	67		20
Magnification in Railway = 1.0	7.1		4.9	3.4		1.0
Cargo/Freight (gCO ₂ /ton-km)	1,159	240			39	21
Magnification in Railway = 1.0	55.2	11.4			1.9	1.0

g = gram, km = kilometer.

Source: Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Japan. http://www.mlit.go.jp/sogoseisaku/environment/sosei_environment_tk_000007.html (in Japanese).

18.3 Station Area Development in Japan

In Japan, at many railway stations, the railway operator has been improving the better transfer of passengers among railway lines, urban public transit, and individual transport modes, in cooperation with the national and local governments and the local community. Also, the railway operator has taken efforts to develop a symbolic facade for the station building and utilizes the spaces of “In-Station,” “Station-Plus,” and “Station Area” for consumer services business. The following section draws lessons from two such examples of SAD that are known to bring about the transformation in urban development.

18.3.1 Tokyo Station: The “Gateway to Japan”

Tokyo Station caters to about 3.24 million passengers as the daily passenger traffic in the station area. This daily passenger traffic comprises 1.26 million passengers in the JR Tokyo Station, 212,000 passengers in Station-Plus, and 749,000 passengers in the Station Area. Table 18.3 further elaborates on the passenger numbers.

The station opened with four platforms in 1914, and the station surroundings have undergone several redevelopments to date. Focusing on passenger convenience and ease of transfer, the station now operates

Table 18.3: Distribution of Daily Passenger Traffic in Tokyo Station Area

Location (Area m ²)	Type	Number of Lines	Operator	Daily passenger trips (estimated)
In-Station (92,400)	Shinkansen (Bullet rail)	6	JR East	157,236
		1	JR Central	195,600
	Intercity/Intracity rail	10	JR East	905,098
	In-Station subtotal			1,257,934
Station-Plus (175,400)	Bus, Taxi, Individual Car		Public and Private	(1,021,000)
	Metro (Subway)	1	Tokyo Metro	211,558
	Station-Plus subtotal			1,232,558
Station Area (899,200)	Metro (Subway)	5	Tokyo Metro	653,845
		1	Tokyo Metro. Gov.	94,834
	Station Area subtotal			748,679
Total (1,167,000)				3,239,171

m² = square meter.

Sources: JR East, JR Central, Tokyo Metro, and Tokyo Metropolitan Government.

with seventeen JR line platforms including seven *Shinkansen* lines, seven metro lines, and other urban transport modes such as long-distance and intracity buses, taxis, and private transport.

The Marunouchi (Maru-no-uchi) Station building, with its red brick facade was initially developed in 1914 and in 2003 it was designated as one of Japan’s important cultural properties. The original building was severely damaged in bombings during World War II and had partly been demolished. The efforts to restore the building according to its original plans were completed by 2012. Figure 18.3 depicts the present-day Marunouchi building.

Restoration of the Marunouchi Station building was realized with funds from the sale of the excess floor area ratio (FAR) sold as transferable development rights (TDR) to other implementing bodies for building redevelopment projects (Figure 18.2). Figure 18.4 shows the projects that were also carried out at the same time, along with the amount of FAR each project drew from the central station. The projects were developed using the newly-developed “exceptional FAR districts system” of the Japanese government.

Figure 18.2: The In-Station, Station-Plus, and Station Area Range of Tokyo Station

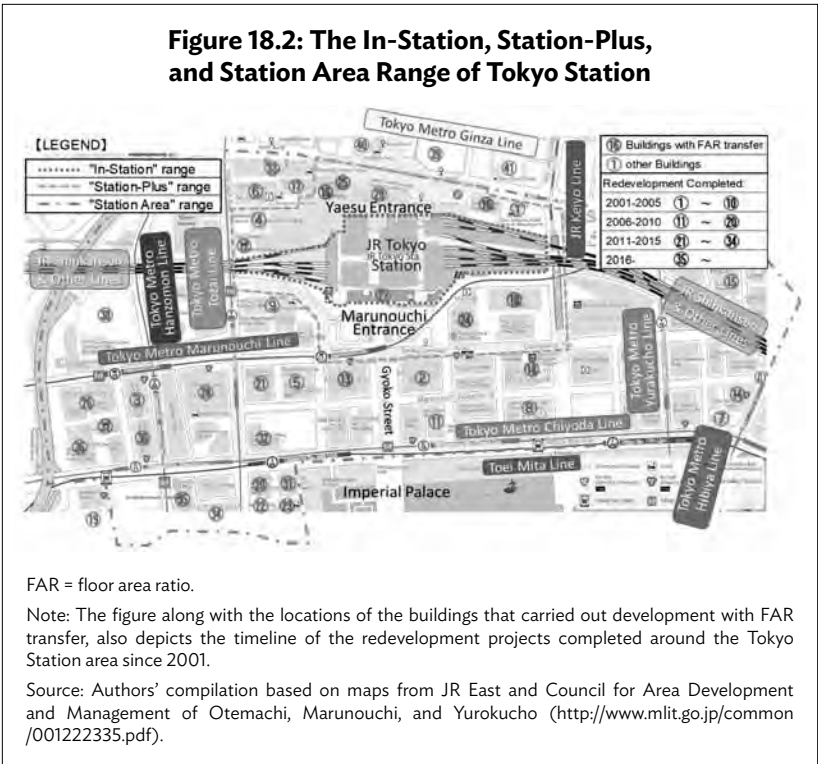


Figure 18.3: Tokyo Station Marunouchi Building



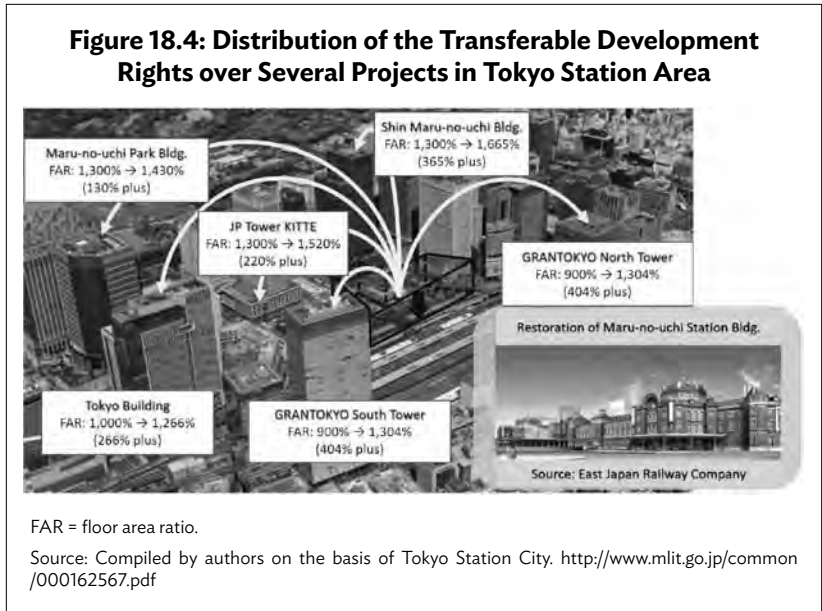


Table 18.4: Breakup of the Total Land Area in the Tokyo Station Area

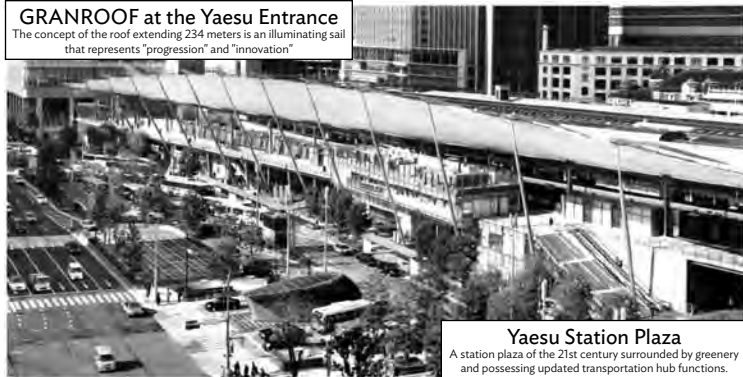
Contents	Land area (m ²)	Building height (m)
In-Station	92,400	
Station Plus	Marunouchi Entrance	43,300
	Yaesu Entrance	30,360
	Others	101,740
	Station + Total	175,400
Station Area	899,200	
	Total	1,167,000

m = meter, m² = square meter.

Sources: Ministry of Land, Infrastructure, Transport and Tourism, Tokyo Metropolitan Government, JR East.

Additionally, the station plazas of both Marunouchi and Yaesu Station entrances were further improved with supportive collaboration of the Tokyo Metropolitan Government and JR East. While the Marunouchi Station facade was retained, the Yaesu Station entrance

**Figure 18.5: The Improved Yaesu Station Plaza
and a Newly Developed “Granroof” as Part of the
New Yaesu Station Entrance Building**

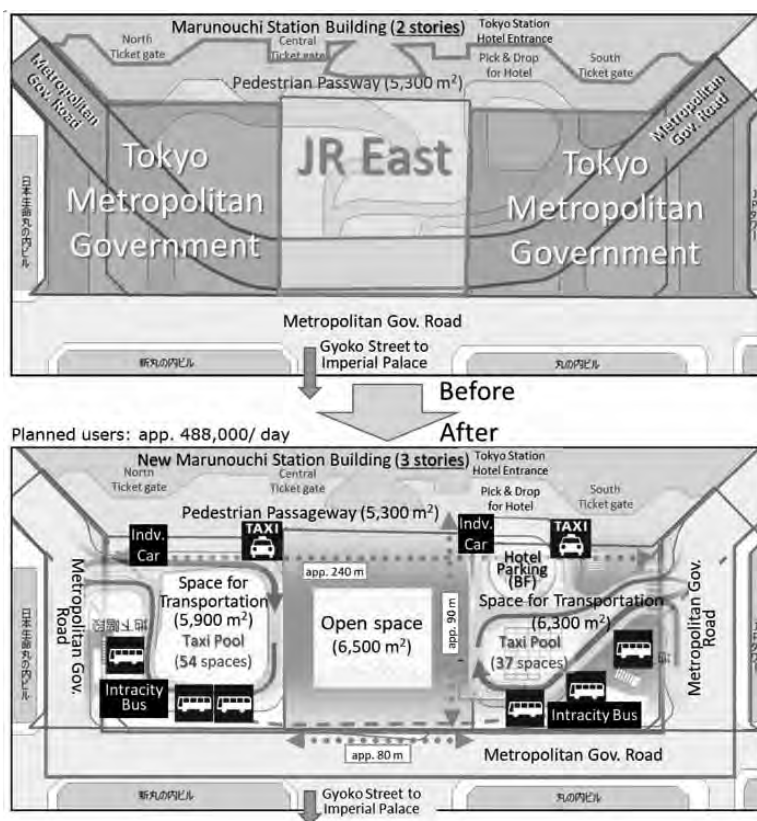


Source: JR East. Tokyo Station City.

building adopted a modern appearance (Figure 18.5). The facades of the station entrances stand out complement their surroundings. At the same time, buildings blend into the urban development context, a quality unique to Japanese urban development. Architectural symbolism, as is rooted in Japanese architecture and planning methods, a decision to adopt the analogous complementarity in facades is crucial to symbolize Tokyo Station being the “Gateway of Japan” to connect individuals to any part of Japan through the various railway systems.

However, established iconic station buildings alone would not solve the challenges of intermodal transfer. Thus, along with the station buildings, the developers also redeveloped the station front and the station plaza on either side of the station. Figure 18.6 shows the “before and after” views of the Marunouchi Station Plaza project. Through the project, a new open space of 6,500 square meters and two spaces of a total of 12,200 square meters for transportation were developed, relocating two Tokyo Metropolitan Government road sections. JR East undertook the relocation and readjustment work for these roads upon request of the Tokyo Metropolitan Government to complete all works within the deadline. As a result of this project, pedestrians can smoothly access the public and private transport modes, and easily move in the direction of the Imperial Palace. Moreover, the view of the Imperial Palace was improved.

Figure 18.6: Marunouchi Station Plaza Readjustment



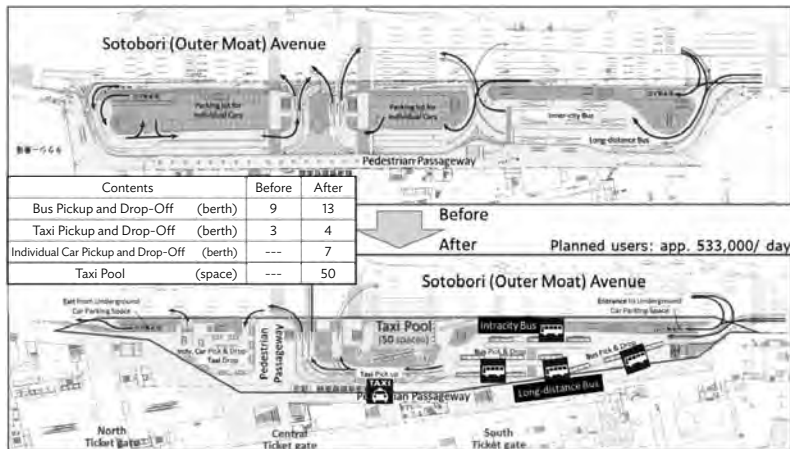
m = meter, m² = square meter.

Source: JR East. <https://www.jreast.co.jp/press/2014/20140704.pdf>

In addition to the Marunouchi Station Plaza, the Yaeu Station Plaza was also redeveloped. Figure 18.7 shows the redeveloped transport facilities for “pick up and drop off” taxi stops and carpools, while intercity and inner-city bus stops were expanded with newly-installed bays to accommodate additional buses and airport shuttle services.

However, the remodeling of the station plazas to accommodate and increase the intermodal transfer capacity led to a demand for excess passenger traffic management in the concourse of the station. The challenge was addressed by enlarging three corridors within the

**Figure 18.7: Development Plan for
Yaesu Station Plaza, Tokyo Station**

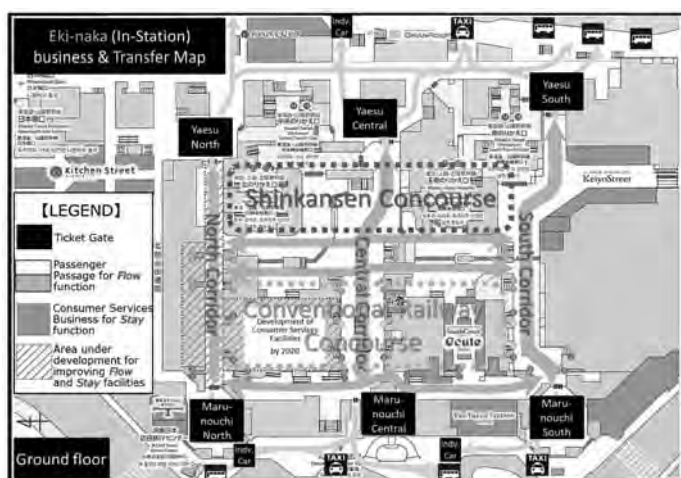


Source: <http://library.jsce.or.jp/jsce/open/00061/2005/32-04-0013.pdf>

In-Station area that connected the Marunouchi and Yaesu Station entrances to enhance the flow function. Figure 18.8 illustrates the In-Station area development projects also known as *eki-naka* developments in Japan.

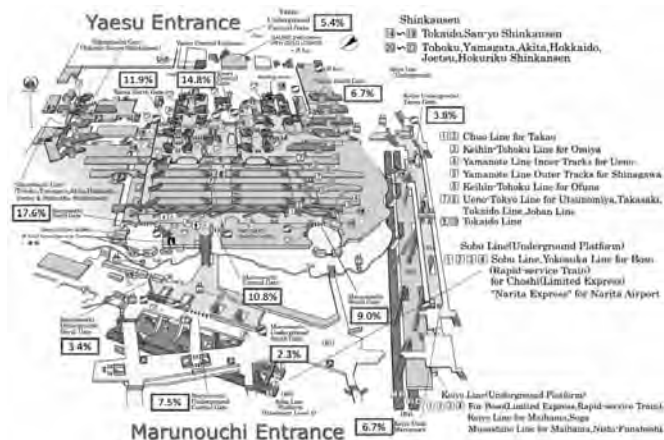
The *eki-naka* development project in Tokyo Station's case was carried out at the ground and basement floor levels to enhance the "stay" function and convenience for passengers as well as orienting passengers arriving from the *Shinkansen* and conventional railways in the concourse of In-Station toward other transport modes located in the station plaza area of the Station-Plus zone, catering for intercity and intracity buses, taxis, individual cars, and airport shuttle services. In addition to the station-front redevelopment, the stay function, "In-Station" space expansion for consumer services, the projects for expanding consumer services business have been implemented earnestly since privatizing Japanese National Railways in 1973 into JR East and six other railway companies. The series of redevelopment projects in and around the station not only increased the efficiency of the station as a whole but also diversified passenger access and egress at each of the ticket gates. Figure 18.9 illustrates the distribution of passenger access and egress in station concourse. Passenger movement diversification reduced congestion at individual ticket gates, which subsequently led to smoother intermodal transfers.

Figure 18.8: Eki-naka Development Plan for Concourse



Source: Authors' compilation on the basis of JR East Tokyo Station map of Development of Consumer Service Facilities, 2020.

Figure 18.9: Distribution of Passenger Movement Through Ticket Gates, Tokyo Station



Source: Compiled by authors based on <http://www.jreast.co.jp/e/stations/e1039.html>; <http://www.jeki.co.jp/transit/mediaguide/pdf/MD15.pdf>

JR East started the “New Frontier 21” (2001–2005) project as its mid-term vision to direct its management in 2001. The management project focused on the daily-life services business. Under a newly formed “Station Renaissance Policy”, JR East envisioned to create and develop *eki-naka* projects in various stations run by JR East, the plan known as the “Cosmos Plan” focused on bigger stations within the Greater Tokyo region. The Cosmos Plan was an upgrade of a former “Sunflower Plan”, which focused on similar aspects. However, launched in 1999, the Sunflower Plan catered for far fewer daily passengers, as shown in Table 18.5.

Japan faces a unique demographic disadvantage that poses a challenge in infrastructure design. The declining birthrate and increasingly aging population in Japan is an indication of the shrinking

Table 18.5: Tokyo Region-wide Station Redevelopment Plans

Plan	Starting year	Stations applied	Location	Characteristics
Sunflower Plan	1999	Number of daily passengers: 30,000 to 200,000 (about 220 stations)	In-Station Station-Plus	- reallocation of limited railway operation related facilities - short-term project - use of low utilized land in Station-Plus
Cosmos Plan	2001	Number of daily passengers: over 200,000 (32 stations), or major terminal stations	In-Station	- entirely reshuffle railway operation related facilities - artificial slab floor could be installed over the railway track as necessary to expand consumer services space

Sources: JR East.

number of commuters and rail passengers in the near future. Hence, given the shrinking population, the diversification of the rail business to the consumer services business that contributes over 30% of the annual revenue for JR East is critical. The consumer services business includes (i) retail for goods and food, restaurants, hotels organized and managed by JR East group companies, and (ii) retail store space leasing, contracted for commercial purposes.

Since 2005, JR East has mainly introduced retail in its stations. In Tokyo Station, retail services operate under several brand names: South Court (Ecute Tokyo), North Court, GranSta, Kitchen Street, and Ecute Keiyo Street. New spaces located in the ground and basement floors are being developed for consumer services and are expected to begin service in 2020.¹

In the process of the formation of the present-day Tokyo Station area, more than 35 urban redevelopment projects were implemented in Station-Plus and Station-Area spread across three districts of Otemachi, Marunouchi, and Yurakucho (OMY) spanning approximately 1.2 square kilometers, while seven buildings were redeveloped with the transfer of development rights. The Council for Area Development and Management of OMY, comprising private companies established in the OMY district, has managed various activities to realize continuous regeneration that brings new values to the city.

18.3.2 Shibuya Station: An Entertainment Hub in Southwest Tokyo

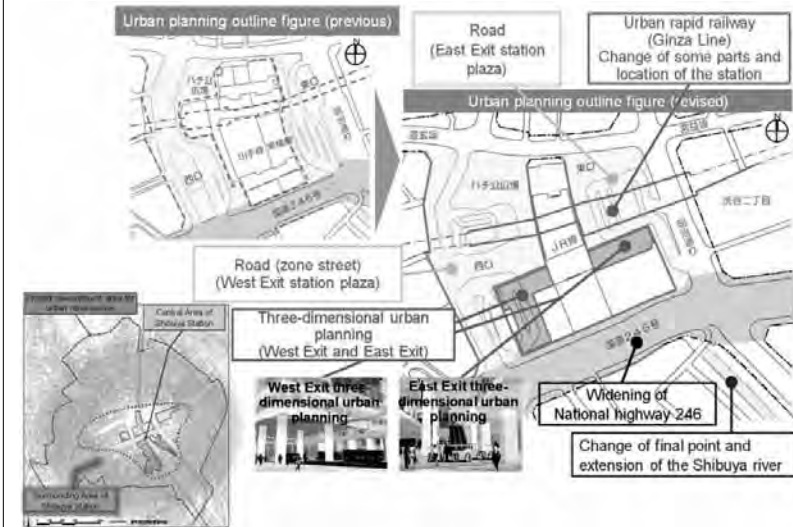
Opened in 1885, Shibuya Station attracts much attention from Asia and the rest of the world, drawing tourists from overseas and within Japan. The railway station area is a junction of eight railway lines in total—two lines of JR East, two lines of the Tokyu Corporation, three lines of Tokyo Metro Co., Ltd. and one line of the Keio Corporation, as well as other urban transport modes such as buses, taxis, and private transport. In recent years, the Shibuya area has seen tremendous growth in creative industries like music, art, and fashion that form its unique identity within Tokyo. The station area collectively serves more than 5 million passengers daily and is one of the most complex urban nodes in Tokyo.

Recently, the Shibuya Station District Land Readjustment Project has been carried out in the Shibuya Station district and its vicinity in cooperation with three railway operators, landowners, and the national, Tokyo Metropolitan, and Shibuya Ward governments. Although slated for completion in 2027, the project will enter its last phase in 2020. Within the identified central area of the Shibuya Station district (Figure 18.10) the stakeholders of the project identified challenges that they wanted to address through the station district land readjustment and redevelopment projects. The stakeholders presented the following challenges in their respective domains:

¹ New Eki-Naka commercial space at Tokyo Station, "Gransta Tokyo" (<https://www.jreast.co.jp/press/2019/tokyo/20200218-to03.pdf>) (in Japanese).

- (i) Railway operators (JR East, Tokyu Corporation, and Tokyo Metro): First, station buildings and facilities within have aged and needed renewal. Second, the significant distance between railway lines and urban transport modes hampers smoother transfers for “last-mile connectivity”.
- (ii) Landowners: Privately-owned buildings were old and required redevelopment.
- (iii) National Government, Tokyo Metropolitan Government, and Shibuya Ward Government: Over time and with increasing popularity of the Shibuya district, the public facilities were not adequate to serve and required renewal.

Figure 18.10: Shibuya Station District Land Readjustment Project, Highlighting Various Areas of Intervention

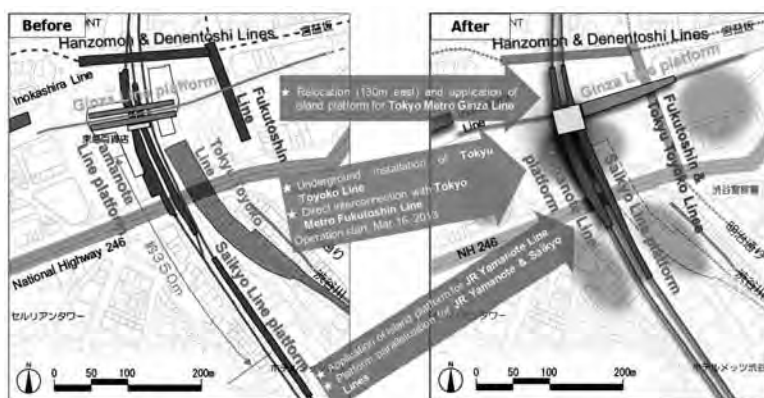


Source: Shibuya Ward Government website.

Landowners’ participated the least. However, in order to resolve these issues, the other stakeholders discussed the challenges in a collaborative and integrated manner. Understanding the complexity involved the stakeholders laying out the following steps to carry out the station area regeneration project:

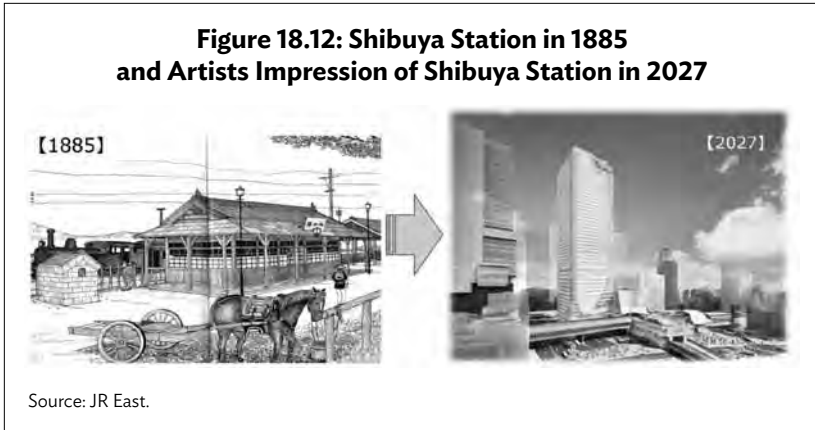
- Step 1.** Legally position the Shibuya Station area as an internationally important base for the Tokyo region since it serves as one of innovation cores and needs immediate revision in its urban planning.
- Step 2.** Consolidate land and adopt the land-readjustment method to enhance the functionality of the renewed facilities.
- Step 3.** Relocate and consolidate railway platforms and facilities of three railway operators, optimizing the consolidated space for smooth intermodal transfer (Figure 18.11). The readjusted land would also be used to redevelop public facilities such as national highways, rivers, and station plazas.
- Step 4.** Build new station buildings around the redesigned railway station to accommodate pedestrian paths for smooth access and egress and intermodal transfer conceptualized through the above steps.

Figure 18.11: Relocation and Consolidation of Railway Stations in Shibuya Station Area



Source: Shibuya Ward Government.

Following the public announcement of the regeneration project, landowners commenced urban renewal projects in cooperation with the local government. Subsequent land readjustment and redevelopment projects within the Shibuya Station district and its



surroundings have made a globally-renowned case study. The case presents the importance of developing strategies for a long-term vision of sustainable development through stakeholder agreements and project management such that it brings value to the quality of life of its users. Figure 18.12 illustrates the scale of the transition that the Shibuya Station area has undergone over more than 100 years of redevelopment.

18.4 Further Roles of the High-Speed Rail Station and a Direction for Station Area Development

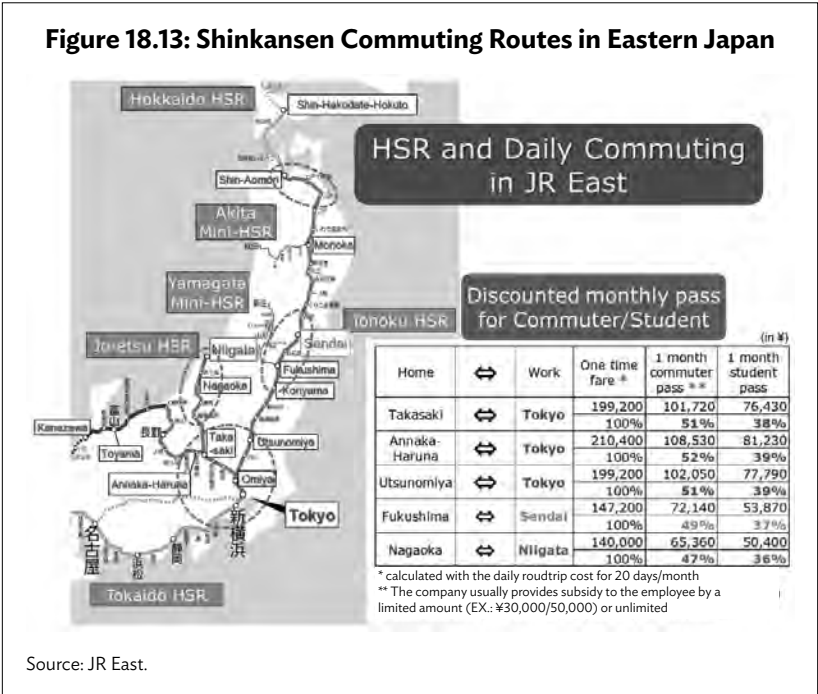
The proposed MAHSR project in India has a great potential to increase economic and social impacts in the proposed region. Drawing lessons from Japan's experience the following three aspects could be discussed further to expand HSR's project impacts:

- (i) intercity commuting with HSR,
- (ii) promotion of existing industrial centers and forming new industrial centers in the proposed region, and
- (iii) development of existing tourism centers and the formation of new tourist destinations.

Following this, the HSR station and its station area would require a symbolic facade. Moreover, the station facilities that are representative of the region tend to become a "gateway" to the serviced region.

18.5 Commuting with High-Speed Rail: Experience in Japan

The advent of the *Shinkansen* has brought ease to long distance commuting in Japan. In 2016, JR East observed that about 13% of all *Shinkansen* passengers were commuters, a figure of about 129,000 commuters daily. The assurance of reaching on-time HSR commuting is popular in Japan. The average commuting distance in case of conventional line train commuters was 19 km. However, comparing the distance with *Shinkansen* commuters, they ride about 90 km on average, over four times further. Researchers have observed that a more important aspect in commuting with HSR is reduced time. If the ride time is about 1 hour or less, people would use the *Shinkansen* instead of a conventional train, with an additional premium fare for the *Shinkansen*. In this context, on the MAHSR corridor, Surat would be a good HSR commuting location with less than 1-hour distance from Mumbai and Ahmedabad or Sabarmati Stations. Figure 18.13 illustrates the case of *Shinkansen* commuting in eastern Japan.



Commuting passengers assure fixed ridership to the rail operators, enabling the operator to estimate the annual revenue. Such fixed ridership makes it easier for the operator to start additional services of value-added convenience for its loyal customers. JR East has been providing the periodical commuter pass with about 50% discount compared with the one-time fare. Also, JR East has provided special trains mainly for *Shinkansen* commuters every morning, with good connection between JR's conventional and metro lines in the *Shinkansen* terminal stations. Moreover, many companies and government institutions provide a commuting fare subsidy to their employees. Adopting such an integrated strategy would contribute to realize commuting comfort for HSR passengers in India, too.

18.6 Industrial Promotion

MAHSR is in the southern part of the Delhi–Mumbai Industrial Corridor (DMIC). Financial assistance and support for DMIC projects, such as industrial estates and clusters as well as transport infrastructure, commercial and residential cores, would be expected from the Indian and Japanese public and private sectors. HSR could actively contribute in enhancing domestic and foreign direct investments. As in the case of Japan, since the time Tokaido *Shinkansen* opened in 1964, connecting two of the largest cities in the country, the corridor has aided information of the “Pacific Industrial Belt”.²

18.7 Tourism Development

Tourism development in India or the MAHSR corridor is limited, so far. Table 18.6 shows the differences in the number of visits in Japan and India for tourism purposes. The table indicates Japanese tourists travel about 12 times more frequently than Indian tourists.

While coastal areas in Maharashtra and Gujarat States, for example, are yet to be well developed for receiving domestic and foreign tourists, HSR would innovate the transport environment to take passengers smoothly to tourism destinations and help local tourism development in the mid- to long-term basis.

² The Pacific Industrial Belt also known as the Taiheyo Corridor emerged as an extension of the Tōkaidō Corridor. The Taiheyo Corridor is the name for the megalopolis in Japan extending from Ibaraki Prefecture in the northeast to Fukuoka Prefecture in the southwest of Japan. Running for almost 1,200 km, the corridor is formed along the Tokaido and Sanyo *Shinkansen* lines.

Table 18.6: Comparison of Japanese and Indian Tourism

Contents	No. of visits in Japan (in-bound)			Japan's national population	No. of visits in India (in-bound)		India's national population
	Japanese Tourism*	Business*	Foreign tourists*		Indian tourists	Foreign tourists	
Statistic value (million in 2015)	1,755.3	230.4	41.1	127	1,432.0	23.3	1,259
No. per capita	13.81	1.81	0.32	/	1.14	0.02	/
Magnification in India's value = 1	12.1	/	17.5	/	1	1	/

* Provisional values.

Source for Japan: Tourism Statistics and the National Census.

Source for India: India Tourism Statistics at a Glance 2017 and the National Census.

18.8 Conclusions and Recommendations

The described cases from Japan offer an insight on the dire need to consider SAD in the early planning stages of a rail transportation project. The following lessons are critical for initiating SAD and station redevelopment projects for emerging economies like India:

- (i) Design interventions for smoother intermodal transfer between HSR passengers and other public and private transport modes in the station area.
- (ii) Diversify railway businesses, while simultaneously zoning the station concourse and station area to add services and convenience facilities for passengers and visitors in and around the station.
- (iii) Especially in the case of HSR passengers reducing time to enhance last-mile connectivity will enhance the overall travel experience for businesses and tourists.

Quick and comfortable transport to the destination is one of the primary goals for an HSR investment, and therefore, it requires a complete ecosystem to deliver the experience. Realizing and expanding the above lessons, the following need to be considered at the planning stage of the project:

- (i) improvement of transport infrastructure, especially the alignment of pedestrian paths for quick and smooth transfers,

- (ii) development of a business ecosystem to create comfortable spaces for consumer services business, and
- (iii) development of a station building with a facade that symbolizes a gateway to the destination.

However, the complexity involved in the governance of any station area project is unique. From the experience in Japan, to execute an integrated SAD project around planned HSR stations, a collaboration of the public and private sector is essential in terms of financial, technical, and institutional aspects. In this context, under JR East's new management vision "Move Up 2027," (2018) JR East will respond to increasing the number of railway projects within Japan and overseas. Together with Indian partners, the developers and consultants from the Japanese government aim to foster human resources through these projects, offer more affluent lifestyles for global markets to enhance the quality of life, and secure a sustainable future.

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PART IV

**Institutional
Development for the
Successful Operation
and Management of
High-Speed Rail**

Key Messages

The objective of this last part of the handbook is to review the successful practices of developing organizational and institutional structures and to offer valuable practical lessons for countries willing to adopt high-speed rail (HSR). The complexity involved in the successful design, construction, and operation of an HSR project cannot be tackled alone. The project influences and is influenced by stakeholders with diverse needs and with varying degrees of power. Project sustainability requires a harmonious relationship between all stakeholders. The onus is on policy makers to adopt a comprehensive perspective accommodating the diverse demands of the project stakeholders. However, effective implementation of the policies demands support of the underlying robust institutional and organizational structures. These structures delineate the responsibilities of the various stakeholders for a given project while avoiding gaps or overlaps. Even when the responsibilities are adequately defined, every organization or institution faces challenges in fulfilling its responsibilities, such as under financial and capacity constraints, and so on. A robust institutional structure thus also defines the basis on which to develop the intra-organizational support necessary to complement each other's drawbacks. This basis is selected to ensure that the project itself does not suffer the consequences when one organization fails to fulfill its obligations. The countries with successful HSR cases have also created robust institutional and organizational support structures so that reviewing them offers valuable lessons for countries embarking on the journey of HSR development.

The most compelling message of Part IV is related to the basis of intra-organizational coordination. The seven chapters in this part suggest that for a project to be sustainable, all decision-making processes must center on the HSR users or the general public. The theoretical framework is provided by Maslow's hierarchy of needs triangle, which identifies the importance of safety, accessibility, and affordability, among others, in the success of HSR as a transport mode. All chapters discuss the details of organizational and institutional structures supporting one or several of these needs, including aspects related to safety, reliability, quality, accessibility, and revenue.

Chapter 19 provides a detailed comparison of the safety culture and organizational decision-making processes between Indian Railways and East Japan Railway Company (JR East), a prominent HSR operator in Japan. The chapter identifies the practices that could be improved for

both organizations and describes the specific roles of top management in improving these practices. Chapter 20 discusses the successful history of Indian Railways in ensuring safe, affordable high-speed travel by rail. The two chapters focus on the organizational practices and aspects that could be transferred from countries with established HSR systems, such as Japan, to countries with existing railway systems marching ahead in HSR development, such as India.

Chapter 21 studies how Japanese private HSR companies work to uphold the safety and reliability of their operations. While HSR technology itself is designed to minimize most risks, the remarkable safety and reliability levels of the Japanese HSR also owe much to underlying human resource and organizational factors. By providing an overview of the factors affecting the safety of HSR, the chapter identifies the most important responsibilities of the top management within HSR operators. Further, the chapter comments on the required level of support from the corresponding laws and policies that support HSR safety.

Chapter 22 dives deeper into the issue of training and human resource development in Japanese HSR operators. With emphasis on the maintenance-related activities, the chapter provides detailed examples of how JR East ensures their employees have the necessary skill levels, particularly through skill development of front-end employees who play an essential role, but are often neglected in railway systems in other parts of the world.

Chapter 23 tackles the issue of training and capacity building from a different perspective, namely using an academic curriculum lens. While the issue is undoubtedly crucial from an organizational perspective, it also merits consideration nationally. The challenges of a skill gap affect both developing and developed economies when putting together large-scale complex projects such as HSR. In developing countries, the challenge lies in the limited skill level of the workers, whereas in developed countries, the problem lies in securing enough numbers. The chapter discusses the theme around a university engineering curriculum in India and the necessary reforms to reduce the skill gap by drawing parallels between the education and training systems for engineering and medical students.

Chapter 24 illustrates a framework to achieve successful public transport integration at railway stations. The framework proposes three levels of integration: physical, informatory, and monetary. It offers a comprehensive list of aspects that should be considered for integrating HSR with other travel modes at an urban level. By prioritizing the needs of the users and the general public, the framework demonstrates how a win-win solution can be created for all. In such a solution, the HSR

operators can enjoy profitable operations, and, in turn, provide safe, accessible, and affordable services to the passengers, as well as create a highly-functioning station space that serves the public.

Finally, Chapter 25, brings the attention back to the original proposition of the handbook: monetizing the spillover effects of HSR infrastructure to improve the financial returns on the HSR investments. It focuses on framing a revenue stream through taxes upon investment in transport infrastructure. The chapter details the architecture of a regional infrastructure and development authority that can ensure coordinated project planning and equitable sharing of the monetized benefits.

The last part of the handbook thus concludes by offering practical approaches for institutional development in implementing the essential theoretical concepts discussed throughout all the preceding chapters.

19

Top Management Decisions and Safety Culture

Nikhil Bugalia, Yu Maemura, and Kazumasa Ozawa

19.1 Introduction

Evans (2013) argues that because of strong institutional, legal, and political pressure, a number of railway safety measures are adopted despite low benefit–cost ratios. Indeed, for users and operators, safety is considered the fundamental value of a railway. In particular for high-speed rail (HSR), it is expected that if railways are perceived as a safety threat to neighbors, the environment, customers, or staff, society will choose not to use them (International Union of Railways 2018). Safety performance can thus have a dramatic impact on the quality of such cost-intensive investments as HSR.

From the perspective of a railway organization, acknowledging the importance of safety implies that an *integrated safety approach* may be necessary to gain trust from the public and the government (Hale 2000). In such an integrated approach, the basic design of a technology should aim to simultaneously minimize the consumption of material, energy, and land; environmental pollution; as well as external and occupational safety and health risks. In addition, Hale (2000) describes the need for the railway industry to have a *dynamism of safety culture* to cope with ever-changing safety issues that emerge from a changing socioeconomic environment. Multiple scholars (Hale and Borys 2013a, 2013b; Hale 2000; Parker, Lawrie, and Hudson 2006; Westrum 1996) have argued for the need to shift safety cultures from being calculative or reactive toward becoming proactive or generative (these terms will be defined and discussed later in the chapter).

Despite the adequate attention given to safety in the academic literature and by industry leaders, railways across the world continue to face various challenges related to safety culture.

In Japan, even after the early recognition of the importance of human factors in safety management (Saito 2002), discussions on safety culture in the context of railways have been rather limited (Itoh, Andersen, Seki 2004). Furthermore, the development of superior technology to eliminate hazards (even those posed by human errors) and efforts to maintain asset quality have been central to safety management (Arai 2003; Saito 2002). The zero-fatality record of the Japanese HSR in 50 years of operation is often touted as a testimony to the success of their safety management system (Saito 2002). However, a serious accident in 2005 in western Japan highlighted the problems with a prevailing punitive safety culture in some of the Japanese railway organizations (Atsuji 2016; Chikudate 2009; Okamoto 2016). The accident prompted an initiative by the Ministry of Land, Infrastructure, Transport and Tourism in 2006 (Okamoto 2016), in which top management was pressured to become more involved with respect to developing a positive safety culture. India, a country that plans to import Japanese railway technology, has also seen the safety performance of Indian Railways (IR) improve dramatically over the last few decades (see section 19.3.1), but high-level reports identify a number of pressing issues related to the safety culture in the organization (Kakodkar 2012).

Safety culture issues observed both in Japan and India must be considered carefully for the upcoming Mumbai–Ahmedabad HSR project planned in India. The Mumbai–Ahmedabad HSR system will be based on the current system utilized by JR East’s HSR operators while being implemented by an Indian entity, a majority of whose management staff are likely to be from IR. Many unanswered questions remain such as how to evaluate the characteristics of the safety culture, how to affect change or develop this culture, and what the role of top management is in doing so. A thorough understanding of these aspects will help the design and implementation of new mechanisms for improving safety culture for the Mumbai–Ahmedabad HSR.

In this context, the objective of the present study is to assess the current safety culture in Japan and India through case studies of JR East and IR and to illustrate the role of top management in improving the state of organizational safety culture. The study also aims to identify the challenges in improving safety culture. An understanding of the safety culture and challenges should generate important lessons for both Japan in sustaining their exemplary safety records, as well as for partner countries such as India in implementing planned new HSR projects.

The remainder of the chapter is organized as follows. Section 19.2 discusses the evolution of safety concepts in the context of railways and highlights the need for a continuous shift in safety management. The

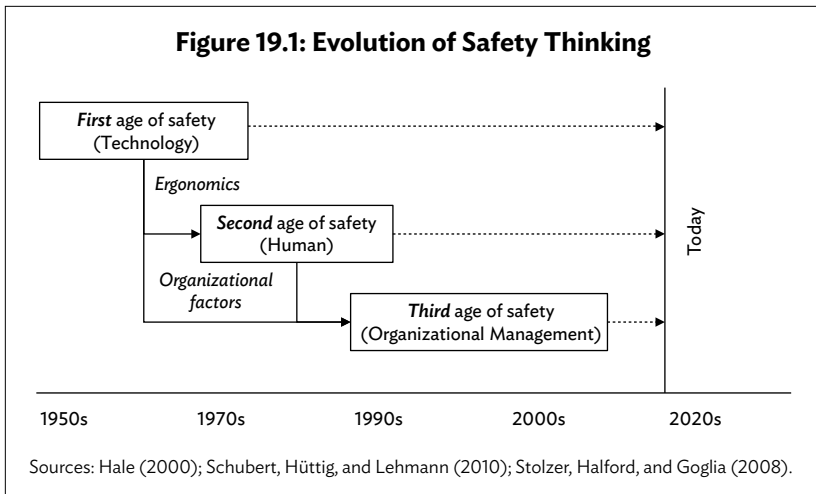
relationship between safety culture and safety is explored in detail, and a framework suitable to assess the current state and dynamics of safety culture within HSR operators is identified in this section. Section 19.3 provides an overview of safety performance at IR and JR East. Section 19.4 provides details on the methodology adopted to apply the selected framework in the current study. For this study, we conducted interviews with railway officials and combined these insights with secondary sources. Section 19.5 summarizes the results obtained from the application of the framework for IR and JR East, respectively, providing detailed information on the current state of safety culture in both organizations. Section 19.6.1 discusses the necessity of a multipronged approach by top management in improving the state of safety culture within the organization through an in-depth review of examples obtained in the interviews. Section 19.6.2 then discusses the challenges associated with improving the safety culture of organizations and proposes a novel approach to assess these challenges and find solutions. Finally, limitations of the study are summarized before conclusions are presented.

19.2 Literature Review

19.2.1 Paradigm Shifts in Railway Safety Management

Based on an analysis of the European railway industry, Hale (2000) describes paradigms of safety thinking in railways (Figure 19.1). The early safety inspectors (first age) were engineers who sought answers to technical failures and their technical solutions. Technology improvements continue to be an important factor in railway safety management, especially to eliminate hazards, in that the use of technology as a means to manage safety has become proactive in nature (reporting and monitoring), as opposed to reactive (corrective actions) (Saito 2002), and it is gradually becoming predictive (safety modeling). For example, Arai (2003) describes how railway companies in Japan have developed technologies that can predict potential hazards associated with natural disasters and suggests appropriate countermeasures that not only improve safety performance but also improve other parameters of service quality such as punctuality.

While there is no denying the importance of technical enhancements as a means of eliminating hazards for safety management, nearly 200 years of experience in the railway industry suggests that such systems tend to be complex and unpredictable under emergencies (Rasmussen and Duncan 1987). As the industry increasingly began to acknowledge the importance of human–technology interfaces or the



ergonomics of safety management, human factors became a central element of safety management, bringing about the second age of safety (Bainbridge 1983; Hale 2000; Ugajin 1999).

A detailed review of ergonomic studies in railways is beyond the scope of this chapter, but readers can find comprehensive discussions in Wilson et al. (2007) and Wilson and Norris (2005, 2006). Ergonomic studies have had a significant impact on improving railway safety, through design improvements to procedural components such as cabin monitors and signal visibility.

Despite the combined emphasis of technology and human factors, technical failures and human errors are still the leading cause of safety-related incidents (Baysari, McIntosh, and Wilson 2008). Kyriakidis, Majumdar, and Ochieng (2018) make a similar observation based on European and American experiences. Recent studies have focused on identifying the underlying causes of failures and thus, have highlighted the need for yet another paradigm in safety thinking, the organizational management of safety.

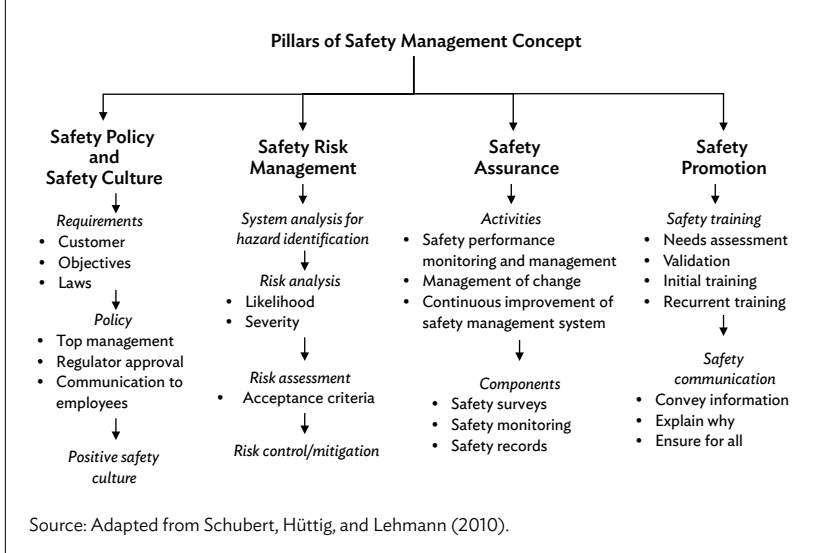
For example, Baysari, McIntosh, and Wilson (2008) found that there was at least one organizational factor behind the technical and human failures and errors for the Australian railway industry, such as a lack of maintenance. Research that further investigated human errors (Reason 1990, 1997), suggests that accidents were a result of errors caused not only by frontline operators but also by errors of designers, managers, supervisors, and maintenance staff. In recognizing the need for

addressing *organizational factors* for safety management, Hale (2000) highlights the need for *integrated planning*, while describing how railway employees tend to manage all of the risks for their domain without due consideration of the cost or redistribution of the resources to other priority areas, and thus calls for the adoption of an organization-wide perspective on safety management. Hale (2000) and other researchers (Wilson and Norris 2006) examine the use of safety rulebooks as a means of managing human errors and updating organizational rules, identifying a problem whereby the creation of new rules after every accident would lead to the formation of ever-increasing rulebooks. Hale (2000) sees such an arrangement as a one-off, top-down, reactive approach where top management does not invest any more consideration in proactive planning. Atsuji (2016), Chikudate (2009), and Hale (2000) regard the workforce's attitude toward these rules as rather worrying. Studies have identified problems such as employees reporting that there are too many rules that often conflict and hinder other operational tasks, and which are perceived as a tool for pinning blame rather than promoting understanding (Hale and Borys 2013a). Punitive rules can also lead to a situation where the staff become habitual and professional violators of rules (Atsuji 2016; Reason 1997, 1990). Such a context stresses the need for a system where employees can self-regulate and continuously improve a safety management system in lieu of the ever-changing safety requirements for railways.

Considering the challenges posed by the first two ages of safety, studies increasingly target the need to bring systems thinking to railway safety management (the third age of safety). This approach focuses on the *integration* across components (technical, human, managerial) and management levels, and the *dynamism* to cope with changing demands placed on railways (Doi 2016; Kawakami 2014; Rajabalinejad and van Dongen 2018; Santos-Reyes and Beard 2003; Sussman et al. 2007; Wang, Weidmann, and Wang 2017). The performance states of safety or punctuality are seen as emerging properties of the systemic interaction of its components, and an explicit focus on systems thinking is evident through its adoption by many high-level railway bodies across the world (International Union of Railways 2018).

19.2.2 The Concept of Safety Culture

Safety management systems refer to an approach that is designed to manage safety elements in the workplace. Figure 19.2 describes the key system components as per Schubert, Hüttig, and Lehmann (2010) for the airline industry, but the concept is considered generic and relevant to the railway industry (Kawakami 2014). An important pillar of such

Figure 19.2: Pillars of the Safety Management Concept

systems is safety risk management. This includes elements such as hazard identification, risk analysis, risk assessment, and risk control and/or mitigation. Considering the third age of safety, a number of recent studies have adopted a systems thinking approach (dynamic interaction of technology, human resources, and management) to identify hazards and risks at various levels (Kawakami 2014; Salmon et al. 2018). Further, safety culture as a pillar for safety management systems has gained attention partly because a number of railway accidents have been attributed to a negative safety culture within organizations (Atsuji 2016; Chikudate 2009; Okamoto 2016). However, Reiman and Rollenhagen (2014) have highlighted that, in practice, safety culture is seldom truly integrated with systems thinking.

The literature provides various concepts that can act as tools for assessing the dynamism of safety culture in the context of railways. Clarke (1998) describes the key elements of a safety culture, as comprising beliefs and attitudes that are shared among employees and are expressed in the day-to-day behavior of the staff. Clarke (1999) goes on to suggest that improvements in safety culture can be more effective than rigorous supervision. Reason (1997) has shown the necessity for a safety culture to continuously identify hazards. Effective safety cultures incorporate safety information systems that collect, analyze, and

disseminate safety data, and they encourage employees to report their mistakes for learning purposes.

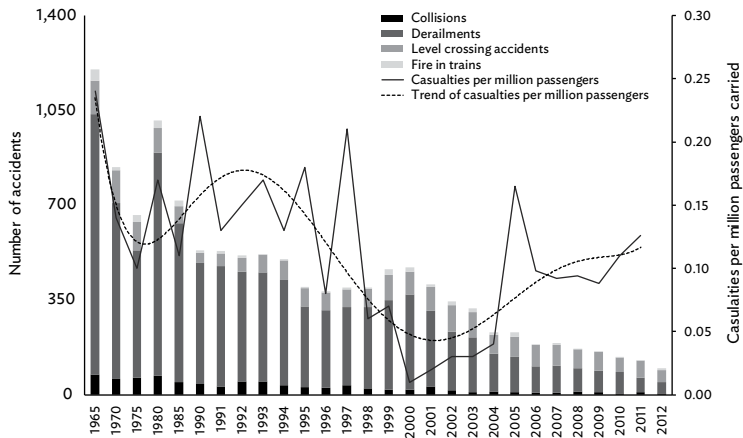
A few studies have identified challenges in assessing safety culture (Parker, Lawrie, and Hudson 2006). As a safety culture is likely to change within a single organization (Parker, Lawrie, and Hudson 2006; Zohar 2000; Itoh, Andersen, and Seki 2004), it is necessary to use a dynamic framework that can integrate formal safety systems with the safety-related behavior of all employees of the organization. Furthermore, safety culture is a multidimensional concept that includes individual factors such as the perception of senior management's attitude with respect to safety (Clarke 1999), communication skill, and hazard reporting (Zohar 1980) on railways, as well as organizational factors such as auditing and company policies (Parker, Lawrie, and Hudson 2006). Considering the different levels of sophistication in safety culture (Westrum 1996), this study adopts the framework of Parker, Lawrie, and Hudson (2006).

This framework is applicable to the railway industry for various reasons. First, it demonstrates how an organization could shift toward an advanced and mature safety culture, whereas the need to continuously improve railway safety management has been well established (Hale 2000). The framework can be applied at different employee levels, and it can then be used to identify positive and negative elements within the organization, an issue that railway organizations often face (Itoh, Andersen, and Seki 2004). Furthermore, the framework is suitable for identifying the intangible and abstract aspects of a safety culture that can be combined with tangible safety assessments to provide a comprehensive assessment, as necessitated by the systems thinking approach for railways (Reiman and Rollenhagen 2014).

19.3 Overview of the Safety State for Indian Railways and JR East

19.3.1 Overview of Safety at Indian Railways

Despite the significant improvements seen in safety over the past 5 decades, Indian Railways is still facing a number of issues. The casualties per million passengers have increased despite the decrease in accidents (Figure 19.3), suggesting a need for increased safety measures in lieu of increased passenger volume and human interaction at Indian Railways. Notably, there are still no reliable data for injuries or fatalities of people trespassing on the railway tracks (Kakodkar 2012). Moreover, the proportion of accidents attributed to errors of

Figure 19.3: Long-Term Safety Trends for Indian Railways

Source: Indian Railways (2013).

railway staff has been well above 70% since 1965 (Indian Railways 2013). Consequently, Indian Railways has expressed an explicit focus on improving safety culture in its corporate safety plans in 2003–2013, recognizing the importance of achieving higher safety levels (Ministry of Railways 2003).

In terms of organizational structure, the Ministry of Railways is the apex body providing policy guidelines and budget approvals. The Railway Board is the main body leading the control, planning, and monitoring of actions of the entire Indian Railways. It is at this level that the chairperson of the Board is placed in charge of safety (as head of the safety directorate). However, there is no explicit representation of the safety organization at this level. Indian Railways is instead categorized into 17 zones, which are further divided into multiple divisions headed by a divisional railway manager. Safety organizations are present at all these divisions and zones. With assistance from members of each department (mechanical, electrical, civil, etc.), the safety organizations are led by dedicated safety officers who report directly to the respective divisional railway manager. This highlights the importance of the safety organizations in Indian Railways and their equivalence to other departments. The main functions of the safety organizations are to audit, oversee emergency responses, conduct safety seminars, educate staff, and conduct accident analysis.

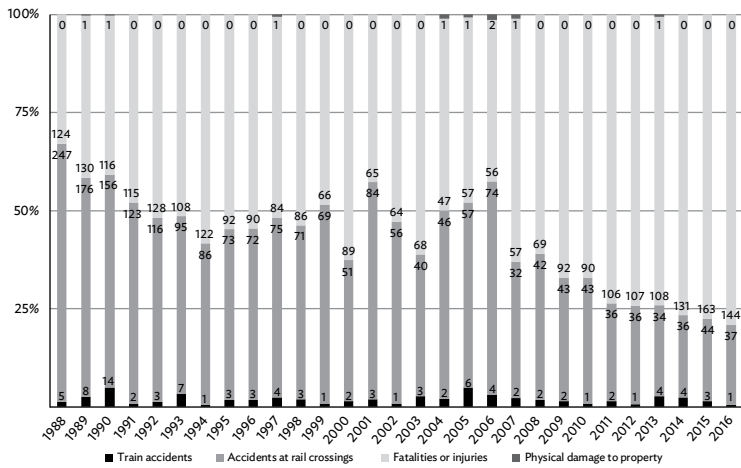
19.3.2 Overview of Safety at JR East

At present, JR East operates approximately 7,500 kilometers of urban rail and regional trains, including approximately 1,200 kilometer of HSR lines. The total number of safety-related cases has been reduced to about half since 1988 (Figure 19.4). Most of this reduction has been achieved by efforts in reducing accidents at railway crossings. The number of “train accidents,” which includes occasions of fire, derailments, or collision, has historically been low but have continued to decrease gradually. However, fatalities or injuries, including customers on platforms or trespassers on tracks encountering trains as well as customers falling onto the tracks from platforms, have grown as a proportion of total accidents and in absolute terms. Safety has been a priority of top management since the inception of the company (JR East 2017). In pursuit of zero accidents involving passenger injuries or fatalities, and zero accidents involving employee fatalities (including group and partner companies), JR East has emphasized learning from past accidents and employs an approach of continuous development of tangible and intangible safety aspects through coordination and teamwork. Since 1988, JR East has adopted 5-year group safety plans to prioritize safety-related efforts. Recent safety plans—fifth (2009–2013) and sixth (2014–2018)—have explicitly mentioned a need to focus on improving the safety culture within the organization.

The safety-related organizational structure at JR East is as follows. Led by its president, JR East is divided into three levels: headquarters, branch offices, and field offices. Field offices include stations, rolling stock depots, drivers, and conductors’ depots. Safety responsibilities are distributed throughout the organization, but each person involved in safety works closely with top management for various safety activities. At headquarters, the transport safety department reports to the president through the director general of railway operations. Similar duties are performed by transport safety sections at each branch office, which are presided over by the general manager. The transport safety department has a strong presence with equal status among other departments. It undertakes activities such as investment planning, accident analysis, countermeasure design, safety system development, design of safety standards and procedures, disaster training, and inspection of vocational attitudes for the drivers. In addition, the safety strategy team within the safety department undertakes measures for improving the safety culture and developing personnel in charge of safety.

A quick comparison of the organizational structure of the railways in the two countries reveals that the safety department at JR East undertakes comprehensive responsibilities in close coordination

Figure 19.4: Safety Trends for JR East (%)



Source: JR East (2017).

with its top management when compared with Indian Railways. Additionally, there is an explicit focus on improving the safety culture in the responsibilities of the safety department. In the next section, we focus on evaluating the safety culture at both organizations. We will revisit the discussion on safety-related organizational structure and its relationship with safety culture in later sections.

19.4 Methodology

Westrum (1996) suggested that one way to distinguish between organizational cultures was to observe how organizations internally handled safety-related information. Consequently, he proposed three levels of safety culture: pathological, bureaucratic, and generative. Considering suggestions by Reason (1997), Parker, Lawrie, and Hudson (2006) have improved this three-level system to a five-level safety classification as shown in Table 19.1. Two additional levels—reactive and proactive—allow for more subtle classifications. In addition, the framework proposed by Parker, Lawrie, and Hudson (2006) investigated 11 tangible and 7 intangible aspects (prepared for multinational oil

Table 19.1: Level of Safety Classification

Safety Level	Description
Pathological	Who cares about safety as long as we are not caught?
Reactive	Safety is important; we do a lot every time we have an accident.
Calculative	We have systems in place to manage all hazards.
Proactive	We try to anticipate safety problems before they arise.
Generative	Safety is how we do business here.

Source: Authors, as per the framework by Parker, Lawrie, and Hudson (2006).

Table 19.2: Organizational Aspects of Safety Culture

Tangible Aspects	Intangible Aspects
- Trend analysis - Audits and review - Incident/accident reporting, investigation, and analysis - Hazard and unsafe act reports - Work planning - Contractor management - Workers’ interest in competency training - Worksite job safety - Daily safety responsibility - Size of the safety department - Rewards for good safety performance	- Who causes the accident in the eyes of management? - What happens after an accident? - How do safety meetings feel? - Balance between safety and profitability - Is management interested in communicating safety issues with the workforce? - Commitment level of workforce and level of care for a colleague - What is the purpose of procedure?

Source: Authors, as per the framework by Parker, Lawrie, and Hudson (2006).

companies) of safety culture (Table 19.2). A full description of the proposed framework is not presented here and can be found in Parker, Lawrie, and Hudson (2006). The framework thus proposed is generic and was adopted in the current study, assuming that each aspect is also relevant for railways, and has been validated through the application of the framework.

To apply the framework, we conducted interviews with management officials at Indian Railways and JR East. The management officials interviewed had more than 10 years of work experience in various departments of the organizations. Each interview lasted approximately 2 hours and officials were asked to comment on current practices related to various tangible and intangible safety aspects at their respective organizations. The questions were framed as “what” and “how” questions to identify the current state of the system rather than discussing the challenges in achieving the current state of the system.

In addition, the relevance of these aspects to the railway industry was also confirmed. The interviews were unstructured, and aspects were not discussed in a sequential manner. To avoid biases, the interviewee was not informed about the safety level classifications beforehand. Interviews with Japanese operators were conducted in Japanese with simultaneous interpretation in English. Interviews with Indian officials were conducted in Hindi by telephone, with a native Hindi speaker. In the case of Japan, additional information on safety management from the safety reports of the company (JR East 2017) was also assessed.

The answers received from the interviews were then summarized into two to three sentences for each aspect. We categorized each aspect into the level of safety referring to detailed definitions provided in Parker, Lawrie, and Hudson (2006). The classification and the summarized sentences were then sent to the officials for their confirmation. Short descriptions were modified to reflect their feedback, and the final description is shown in Tables 19.3–19.5. The next section presents a few examples of the classification process, where results from the interviews are summarized. Naturally, one interview cannot suffice to account for variations in safety culture across management levels and railway organizations. However, interviews were helpful in identifying and comparing general aspects of safety culture within actual organizations.

19.5 Measurement of Safety Culture at Indian Railways and JR East

19.5.1 Safety Culture at Indian Railways

Identifying trends for safety-related issues is one of the key responsibilities of the safety organization at Indian Railways. The interviewee stated that “we believe that accidents do not occur because of a one-time event but the underlying causes accumulate over time.” This response captures the underlying philosophy behind trend analysis as a proactive means to search for risks. The purpose of trend analysis is to recognize patterns, identify their solutions, and provide suggestions for effective countermeasures—and not to benchmark year-on-year performance of employees or management. The system of trend analysis appears to be aimed at anticipating the safety problems before they arise and, hence, is categorized as being proactive. A calculative organization would have focused exclusively on summarizing the incident data, however, whereas a generative organization would have combined the knowledge obtained from other resources to look for solutions involving all levels of management.

In addition, the safety organization also performs frequent regular safety audits and mock drills to further assess safety responses. Although independent safety audits are reserved only for major accidents, interdivisional and interzonal cross-audits are conducted regularly. Management sees safety audits as genuine learning opportunities for procedural lapses, as well as technical and managerial challenges in their respective departments. A positive attitude toward being audited itself can be seen as management’s understanding of their own biases and proactive acceptance of help to reduce risks. An organization with a generative safety culture in this aspect could be expected to have a system to audit behavioral aspects.

Table 19.3: Descriptions of Current State of Tangible Safety Aspects

Aspect	Indian Railways	JR East
Tangible aspects		
Benchmarking, trends, and statistics	Trends are identified, understood, and solutions are found at all levels of management. Absolute safety may not be practical; hence, zero tolerance to risks. (<i>Proactive</i>)	Trends are analyzed and utilized at all levels of management combined with “soft” lessons from previous accidents. Management is seeking zero accidents. (<i>Generative</i>)
Safety audits	Extensive cross-auditing. Audits are seen as a learning opportunity. Audits focus on the system level. (<i>Proactive</i>)	–
Incident reporting, investigation	Detailed procedures for reporting accidents and incidents. Trends are systematically analyzed, and lessons learned are shared across the organization. (<i>Proactive</i>)	Analysis driven by deep understanding of accident causation (4M: man, machine, media, management). Follow-up is systematic. (<i>Generative</i>)
Hazard and unsafe act reports	All are encouraged to report near misses and/or hazards. Reports also focus on identifying possible improvements. Follow-up is done but not by all employees. (<i>Calculative</i>)	–
Work planning	Hazard analysis is included in the work plan but only for track-related work. A standardized process is followed with occasional feedback. (<i>Calculative</i>)	Safety is an integral aspect of the planning where employees continuously think, anticipate, and review the work plans and are thus prepared. (<i>Generative</i>)

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Table 19.3 *continued*

Aspect	Indian Railways	JR East
Contractor management	Safety track record is not mandatory, but Indian Railways keeps internal record of safety performance, and banning of business is practiced for contractors with negative records. Indian Railways assigns safety staff to contractor for ensuring safety. (<i>Calculative</i>)	–
Workers' interest in competency training	Training is done to maintain the safety attitude. Competency matrices are still under development. There is some on-the-job training. (<i>Calculative</i>)	Leadership realizes the importance of continuous improvement in on-the-job training. Safety leaders working closely with employees identify the training requirements. (<i>Generative</i>)
Worksite job safety	Experienced supervisors are staffed at work sites. Plans are also discussed with contractors. Workforce awareness of safety is a challenge. (<i>Calculative</i>)	–
Daily safety responsibility	Site activities are regularly checked as per the written procedures. Everyone is encouraged to check safety. Internal cross-audits at all management levels. However, a few opportunities to improve are missed. (<i>Calculative</i>)	Everyone checks for hazards, for themselves and for others. Management promotes "Stop trains" policy whenever there is a doubt about safety. (<i>Generative</i>)
Size of the safety department	Safety department has equal status as other departments. People with experience in train operation receive priority to work in the department. Experience in the department is highly valued (<i>Proactive</i>)	Safety is distributed throughout the company. The department is powerful and considered an important job. The safety department reports to top management. (<i>Proactive</i>)
Rewards for safety performance	Good safety performance is considered in appraisals. Evaluation is of safety process followed. Good performance is recognized across Indian Railways. (<i>Proactive</i>)	Individual safety behavior is recognized by top management. Recognition is seen as being of high value. (<i>Generative</i>)

– = Conclusive information could not be obtained at the current stage of interviews.

Source: Authors.

The safety organizations conduct safety seminars where good safety behavior by employees is rewarded with prize money and division- or zone-wide appreciation (which is considered more valuable than prize money). Employees are also appraised for their safety consciousness. In addition, regular safety training for employees is deemed essential for business operations at Indian Railways. Although safety training is an important means to introduce new rules, remind employees of existing safety rules, and introduce best practices, the training is often designed in a top-down manner with unidirectional communication (trainers to employees). The quality of trainers is often an issue and prospects of on-the-job training are limited. Such a system could be categorized as being calculative and is in the scope for improvement for Indian Railways. A more detailed description of the current state of culture related aspects can be seen in Tables 19.3–19.5. There are positive examples where the safety culture at Indian Railways has reached higher safety levels, e.g., the purpose of a procedural lapse is not to blame the violators but to identify the reasons why the rule could not be followed. In addition, to improve compliance with the rules, Indian Railways issues local safety circulars that are suitable for local needs and incorporate existing tacit knowledge. However, considerable scope for improvement exists for a few intangible aspects such as in establishing a balance between conflicting demands (safety, punctuality, and profitability) or in cooperating with the community to improve safety performance.

19.5.2 Safety Culture at JR East

The strength of JR East's safety culture lies in its comprehensive on-the-job and off-the-job training systems. JR East has taken a bottom-up approach in its safety training management. Under such a system, people who have demonstrated excellent safety acumen in their own work, as well as retirees who have extensive safety experience, are on the frontline engaging in continuous improvement in safety training. Furthermore, a system of close mentoring during training has enabled JR East to disseminate its safety lessons and tacit knowledge, as well as transfer the principles and philosophy behind safety rules to young recruits. In addition, the interactive presentation of training materials and mutual communication between staff and trainers during on-the-job training enable training needs to be identified based on the requirements of the staff. Such a system that enables active participation for all employees is categorized as being generative.

Additional descriptions of the various aspects of safety culture are given in Tables 19.3–19.5. The visible commitment of top management to ingrain five practices (prompt and proper reporting, hazard recognition

and sharing, honest and open discussion for accident investigation, continuous learning and awareness, and think and take safety actions) is also among the strengths of the safety culture at JR East. JR East's involvement of top management includes regular visits by the president with employees to hold discussions about elements of safety culture, making a majority of the safety culture dimensions generative. In addition, the safety challenge campaign encourages employees to take active roles in improving safety, and winners are acknowledged and awarded by their department as well as by the president. Such a system, which has shifted from "punish to correct" to "praise to encourage," is employed to give employees a feeling of accomplishment and encourage further actions to support a generative safety culture—that is, to be an organization that places its highest priority on safety.

Table 19.4: Descriptions of Current State of Intangible Safety Aspects

Aspect	Indian Railways	JR East
Intangible aspects		
Who causes the accident?	Failure in processes and procedures are looked upon, in addition to technical and human failure. Management identifies the need for self-improvement. (<i>Calculative</i>)	Management accepts/takes responsibility of the accident and strives to remove the root cause. Accident causation follows the 4M principle. (<i>Generative</i>)
What happens after an accident?	Independent investigations focus on underlying causes and are reported to supervisors. Management asks about the well-being of those involved. Follow-up is top-down and systematic, not participative. (<i>Calculative</i>)	Investigations focus on underlying causes and are reported to supervisors. Management is seen as taking a leadership role in response. Follow-up is bottom-up with direct coordination with top management. (<i>Generative</i>)
How do safety meetings feel?	At higher levels, meetings are regular and interactive. At lower levels, meetings are rather one-way. (<i>Calculative</i>)	–
Safety and profitability	Preventive maintenance is priority, but absolute safety is thought as costly. Some cost escalations are accepted to achieve safety standards. (<i>Calculative</i>)	Safety and profitability are seen in total balance, as safety is seen as making money. The company minimizes delays while ensuring full safety. (<i>Generative</i>)

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Table 19.4 *continued*

Aspect	Indian Railways	JR East
Safety and punctuality	Safety is prioritized over punctuality, but situations where there is a need to balance the two arise often. Some delays are accepted to achieve safety. (<i>Calculative</i>)	Safety is the top priority. Effective measures are taken to improve punctuality while striving for zero accidents. (<i>Generative</i>)
Safety communication	Management shares a lot of safety information with workers, but the process is rather one-way. (<i>Calculative</i>)	Management shares a lot of safety information with workers, and a two-way process is in place. Staff are invited to speak about safety at the head office. (<i>Proactive</i>)
Commitment level for workforce	There is increasing safety awareness due to efforts by top management. Safety issues are seen as something to avoid. Pride is beginning to develop. (<i>Proactive</i>)	Levels of employee commitment are very high, and employees demonstrate passion to live up to the aspirations. (<i>Generative</i>)
Cooperation with community	Community awareness steps are undertaken to stop accidents at the crossings. Community representatives are sometime consulted. (<i>Calculative</i>)	Community is considered a key stakeholder in safety design and in managing safety solutions. (<i>Generative</i>)
Purpose of procedures	Procedures spread best practices. But noncompliance of rules is investigated properly. Local adaptation of procedures is implemented. (<i>Generative</i>)	–

– = Conclusive information could not be obtained at the current stage of interviews.

Source: Authors.

19.6 Discussion

Based on the interviews, additional tangible and intangible aspects were identified that were not contained within the adapted framework from Westrum (1996) and Parker, Lawrie, and Hudson (2006). These aspects are the balance between safety and punctuality (intangible), and safety measures in cooperation with the community (intangible). Table 19.5 presents the classification of different aspects into the safety levels introduced in section 19.4, in line with examples from interview testimony (as explained by the example in section 19.5). The purpose of this exercise is not to provide a one-on-one comparison of the two systems, but to highlight a useful contrast in the current state of

Table 19.5: Scope of Safety Culture Improvement at Indian Railways and JR East

Aspects	Calculative	Proactive	Generative
Purpose of procedures			
Size of the safety department			
Benchmarking, trends, and statistics			
Safety audits			
Incident reporting, investigation			
Hazard and unsafe acts reports			
Rewards for safety performance			
Commitment level for workforce			
Cooperation with community			
What happens after an accident?			
Daily safety responsibility			
Work planning			
Contractor management			
Workers' interest in competency training			
Worksite job safety			
Who causes the accident?			
How do safety meetings feel?			
Safety and profitability			
Safety and punctuality			
Safety communication			
Indian Railways		JR East	

Source: Authors.

safety culture across the two organizations and to highlight the scope for improvement in Indian Railways. The next section will focus on highlighting the role of top management in improving the safety culture.

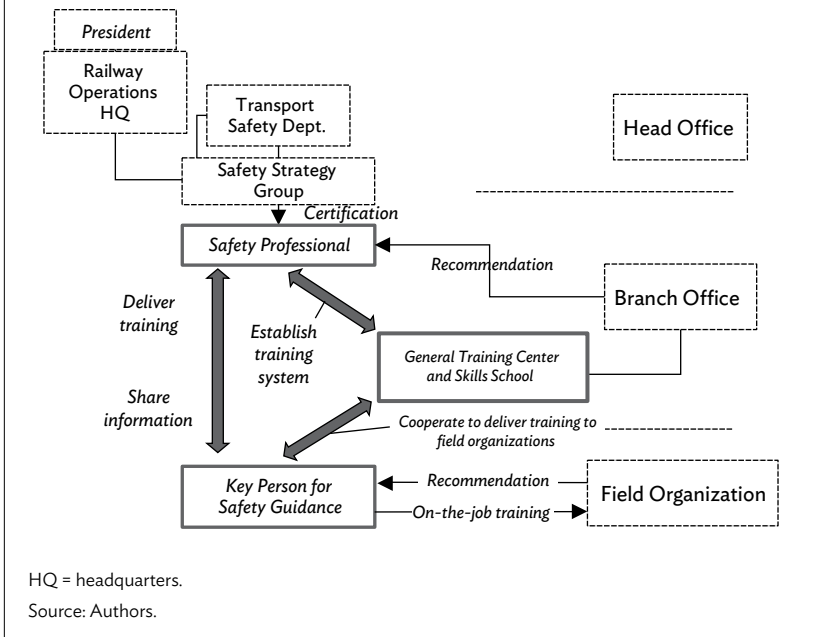
19.6.1 Role of Top Management in Improving the Safety Culture

We hypothesize that top management must adopt a multipronged approach to improve the safety culture of an organization. There is no one-dimensional management strategy that is sufficient for improving the level of an organization's safety culture. For example, the overt involvement of

top management can have a significant impact on improving the safety level from being *proactive* to *generative* for both tangible and intangible aspects. In contrast, organizational and/or structural changes along with sustained leadership efforts are necessary to improve the safety levels from *calculative* to *proactive*, and even *generative*.

In the context of integration of the railway and the community in which it operates, an examination of key stakeholders for each of the railway organizations will clarify the role of top management in improving the safety culture. For JR East, top management has acknowledged the regions or communities surrounding the railway's infrastructure as its key stakeholders (JR East 2017). The inclusion of this group as stakeholders improves the public accountability of the organization and puts additional demand on the safety performance of the organization. Such increased demand in the level of safety requirements then manifests in on-the-ground implementation of increased safety measures and puts pressure on the safety culture. For example, JR East actively monitors the deaths and injuries of trespassers or passengers at the stations, leading to increasing awareness among employees about such issues as well as measures such as installing barriers at the stations. In addition, JR East engages the local communities and residents nearby crossings to codesign solutions. Such solutions are also effective in the long term due to enhanced community ownership. At present, such a practice does not exist within Indian Railways (Kakodkar 2012). Hence, initiatives adopted by Indian Railways are not based on community participation and may have limited effects. For example, Indian Railways uses street plays to raise public awareness, but the effect is arguably short term. Explicit acknowledgment of the communities in the stakeholder groups will also provide opportunities to mainstream some safety practices in a coordinated manner. For example, collecting information on injuries and casualties of trespassers could be mainstreamed through initiatives of the top management, which will then require an increasing focus on safety by the employees.

A similar discussion, in the context of the effectiveness of safety departments, reveals the necessity of sustained efforts by the top management in addition to slight changes required in organizational structure. The president of JR East is directly involved in various railway safety promotion committees (both at headquarters and at branch offices). These committees engage in trend analysis. Members of each department are integral in these safety committees. Such an arrangement thus ensures effective coordination and integrated decision-making across departments and increases the accountability of each department toward safety. At Indian Railways, however, safety committees only report to immediate supervisors, and top management is not directly

Figure 19.5: Safety Training System at JR East

involved. In addition, the safety department must coordinate with each department as they are not directly represented within the safety department. We consider that Indian Railways could also benefit from such a system of integrated decision making, where only active efforts from top management along with slight organizational restructuring could improve the efficacy of investigation and workings of the safety department. Such a recommendation was also made by the high-level safety review committee for Indian Railways (Kakodkar 2012).

A shift in safety culture through strengthening training systems will require organizational reforms along with sustained efforts from top management. One of JR East's strengths lies in its comprehensive training system. As highlighted in Figure 19.5, the safety strategy team at headquarters oversees the development of persons in charge of safety. There are two types of such personnel in JR East: safety professionals and key persons for safety guidance. A safety professional, who understands the mechanisms of safety in the organization, is recommended by the branch office and certified by headquarters. The safety professionals

are responsible for handing down safety expertise to branch offices. They, along with the key persons for safety guidance, are responsible for developing off-the-job training programs at various training centers. The key persons for safety guidance are located at any of the field offices (e.g., station head in the case of a station) and possess familiarity with weak points, safety rules, and past accidents of the field office. The prime responsibility of the key persons for safety guidance includes providing on-the-job training, which focuses not on the “know-how” but on the “know-why” and “show-how.”

There are certain characteristic features of this training system. First, the safety professionals possess exemplary safety experience. Their extensive experience is something that makes them suitable to closely analyze the difference between rules and real practice, and to formalize tacit knowledge. Through their close interactions with employees, they are expected to have familiarity with the training needs of the employees. In addition, the quality of trainers is assured through certification and recommendations of various intermediate management levels.

There are some fundamental differences in the training system at Indian Railways. Rules related to the selection of trainers are not enforced by management, and the training abilities of trainers have been questioned (Kakodkar 2012). This highlights the need for sustained efforts from the leadership in ensuring the quality of training systems. In addition, the role of the safety department in designing the training is limited to circulating information on rules. Moreover, informal on-the-job trainers are not formally recognized in the safety department. Thus, the full potential of the experienced staff is not realized in imparting adequately the designed training materials and methods. This issue can only be solved by involving top management in redefining the roles and responsibilities of employees within the organization.

The discussions presented in this section highlight the role of top management in improving the safety culture at an organization. The actions by top management become even more prominent when shifting from a proactive safety culture to a generative culture. Sustained efforts from leadership are required to set incremental targets, take an active involvement in enforcing safety practices, increase coordination within the organization, and develop a positive safety culture. In addition, top management has the ability to create the necessary organizational and/or structural reforms to steer the safety culture in the organization. Our discussion suggests that a variety of strategies are necessary to manage improvements in the safety culture, and there is no “one size fits all” solution.

19.6.2 Challenges in Improving Safety Culture and the Need for an Integrated Dynamic Framework

An examination of safety training systems also reveals an important lesson about railway operators overall—that is, safety culture and its dynamics cannot be considered in isolation but must be integrated with other elements of the safety system. In other words, cultural aspects must be studied in tandem with technology, human, and management aspects. This integrated nature of safety culture then poses challenges for top management as there are many indirect factors that affect safety culture and performance. Here we discuss examples that we obtained through our interviews and secondary sources.

The high-level report on safety (Kakodkar 2012) highlights the “top-heavy” situation at Indian Railways. Such a state in an organization results when there are far fewer employees at a working level than at the manager level and when executive powers are too centralized at the manager level. Such a “top-heavy” organization, coupled with lack of feedback from the executive staff, can lead to excessive pressure on executive staff and could negatively affect the safety attitude of the employees as well as gradually weaken the safety culture of the organization. A complex interconnected system produces situations in which impacts are only observed after a time lag. Considering the examples discussed here, we would like to emphasize the need for an integrated framework that could capture the dynamic interactions between technology, human resources, management, and culture. Such a framework, when converted to a quantitative or non-linear system dynamic model, could well serve as a policy or performance analysis tool for the top management of railway organizations, providing them with an opportunity to analyze long-term implications of management decisions.

19.7 Limitations of the Study and Future Strategy

Previous sections of this chapter demonstrated advantages of our study methodology. Juxtaposing the states of the safety culture for the two organizations reveals contrasts and is effective in highlighting the role of top management in improving the safety culture for a number of tangible and intangible aspects. However, the methodology could be improved further.

First, the present study assumed that the original framework presented by Parker, Lawrie, and Hudson (2006) is applicable for the

case of railways, but the interviews revealed new aspects. Hence, there is a need to conduct an exercise similar to that of Parker, Lawrie, and Hudson (2006) and extend the survey to more executives to refine the framework.

Second, the framework used is qualitative in nature and tends to capture the mere existence of some of the systems. It does not delve into the details of the efficiency of these systems, which can only be assessed through more detailed and quantitative assessments. For example, in the case of Indian Railways, cross-auditing within the organization is perceived as a positive norm, which should be categorized as proactive as per Parker, Lawrie, and Hudson (2006). However, Kakodkar (2012) has found these audits to be too frequent, with a time gap between audits that was, in fact, shorter than the time required to implement recommendations from previous audits. Under such conditions, the number of recommendations will continue to increase without any implementation, leading to a situation where improvements in the level of safety are throttled despite the presence of a proactive safety culture. We plan to continue exploring the inclusion of quantitative aspects of the methodology.

Finally, the present study attempts to derive lessons from one organization for another. However, we believe that it will be meaningful to apply the methodology to different points of time within the same organization. A temporal profile thus created can divulge important underlying dynamics related to various aspects of the safety culture and, more importantly, highlight the challenges faced by the organizations in improving their safety cultures. Future work should focus on generating such findings that can be contextualized in the socioeconomic environment to reveal generalizable and transferable lessons.

19.8 Conclusion

This chapter has examined the current state of the safety culture at a Japanese HSR operator and at an Indian operator, to highlight the role of top management in improving it, a significant issue and challenge for managers involved in the development of HSR projects in developing countries.

We adopted a multidimensional framework suitable to highlight the dynamics of the safety culture and modified it to apply to the railway industry. At this stage, the framework was developed and refined through interviews with two senior officials—one from Japan and one from India. To improve the robustness of the framework, more interviews at different organizations should be conducted.

We found the present methodology suitable for developing and comparing temporal profiles of safety culture within organizations. When the descriptions for the current level of safety for different organizations are juxtaposed, a contrast is clearly visible. Detailed discussions illustrated the importance of sustained efforts from leadership in taking an active involvement in safety aspects, increasing the coordination within the organization, and developing a positive safety culture. In addition, a multipronged approach is necessary for the top management to steer the safety culture across multiple dimensions. However, we have also highlighted a need to carry out more interviews, as well as conduct a quantitative assessment, to improve the present methodology.

Finally, we argue that safety culture and its dynamics cannot be considered in isolation but must be integrated within the systems thinking framework—that is, the dynamics between technology, human resources, management, and culture must be considered simultaneously to develop an understanding of the temporal profile of safety performance and to develop analytical tools for evaluating management policy.

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20

Policies for Speed and Socioeconomic Development

Neelakantan Ravi

20.1 Introduction to Indian Railways

Indian Railways, over the last 160 years, has brought about deep and irreversible change across India, hauling the country toward modernity, one step at a time. It has been a journey that has kept abreast of the available technologies in rail transport, while incorporating these into the Indian railway system based on affordability and its domestic capacity to indigenize these technologies, thereby enhancing performance. A crucial contribution of Indian Railways has been connecting and networking communities and markets. However, the basic approach of considering the railways as their “socioeconomic lifeline” has seldom changed. Whether in terms of travel comfort or speed or safety, the all-round growth of the railways in India has been guided by a steady hand, across decades, keeping in mind the requirements of feisty travelers and freight tonnage while fostering safety:

Given the strategic role played by railways in the transportation space, rail transportation has been one of the three areas reserved for the public sector in successive industrial policies of the country (the others being atomic energy and defense). (National Transport Development Policy Committee 2013, Volume III, Part I, p. 3)

Indian Railways is managed directly by the Ministry of Railways, which owns and operates most of India’s rail transport. Indian Railways had a total route network of 67,368 kilometers (km) in 2016–2017. It operates more than 22,300 trains daily (13,098 passenger trains plus 9,202 freight trains) and has 278,000 wagons, 69,322 coaches, and 11,461 locomotives. Over 23 million passengers travel by train daily in India.

The passenger traffic stood at 8.3 billion in fiscal year (FY) 2018 and is expected to increase to 15.18 billion by FY20. In FY51, the passenger traffic was 1.3 billion. Around 1.2 billion tons of freight was transported via trains in FY18 and 2.2 billion tons is expected in FY20. In FY51, the freight carried was 73.2 million tons. This includes a huge variety of goods such as mineral ores, iron, steel, fertilizers, petrochemicals, and agricultural produce (India Brand Equity 2018).

20.2 Growth of Railways through 5-Year Plans

India’s economy was actively driven by 5-year plans for the 5 decades after independence in 1947. The objectives and targets of Indian Railways were always reflected in the plan document, usually in a separate chapter dealing with railways. The concerned chapters of the plan periods were examined and checked for any reference to high-speed rail travel. However, no document until the Eleventh Five Year Plan mentioned high-speed train travel with any degree of emphasis. Table 20.1 gives some details of objectives and developments under the various plans. The first plan was launched in 1951 and the 10th in 2002.

Table 20.2 gives details of the original and present state of India’s first three superfast trains, providing a clue to the way in which the engineering objective of safe high-speed travel gets compromised by

**Table 20.1: Major Objectives Designated for
Railways Development under Each 5-Year Plan in India**

Time Period	Name of Plan	Major Objectives	Miscellaneous Developments
1951–1956	First Five Year Plan	Track renewals	
1956–1961	Second Five Year Plan	Continue track renewals, install better signaling technology, and enhance line capacity	Examine and permit higher speeds on main trunk routes such as Mathura–Baroda, Wardha–Bezwada, and Delhi–Kalka
1961–1966	Third Five Year Plan	Complete track renewal programs along with rail and sleeper renewals	
1966–1969	Annual Plans	No specific mention	

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Table 20.1 *continued*

Time Period	Name of Plan	Major Objectives	Miscellaneous Developments
1969–1974	Fourth Five Year Plan	Run higher-speed trains on long-distance routes where overcrowding is high	On 3 March 1969, the first Rajdhani Express, a high-speed nonstop service, started between Delhi and Howrah (i.e., Kolkata). On 17 May 1972, the second Rajdhani Express, another high-speed nonstop service, started between Delhi and Bombay (now Mumbai)
1974–1978	Fifth Five Year Plan	Electrification of tracks, acquisition of more powerful locomotives, and efficient freight movement	On 7 August 1976, the Tamil Nadu Express, a superfast train, started service between Delhi and Madras (i.e., Chennai)
1978–1980	Annual Plans	No specific mention	
1980–1985	Sixth Five Year Plan	Assessment of quality and quantum of railway assets; their efficiency/performance	Overall evaluation was that all assets were being utilized optimally
1985–1990	Seventh Five Year Plan	Electrification of high-density routes; upgradation of such networks for speedier trains by seeking more funding for new projects	Indian Railway Finance Corporation (IRFC) set up in 1987 as the financing arm, borrowed from the market for projects, owing to reduced budgetary support. Introduction of the high-speed Shatabdi Express between Delhi and Agra in November 1988
1991–1992	Annual Plans	No specific mention	
1992–1997	Eighth Five Year Plan	Enhance reliability and quality of service through modernization programs, energy conservation, ensuring greater safety, pursue financial viability	
1997–2002	Ninth Five Year Plan	Initiate measures to regain railways' role as the principal transport mode for passengers and especially freight	

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Table 20.1 *continued*

Time Period	Name of Plan	Major Objectives	Miscellaneous Developments
2002–2007	Tenth Five Year Plan	Focus on increasing capacity on the Golden Quadrilateral; tackle problems arising out of old technologies; measures to tackle prevalence of slow train speeds	
2007–2012	Eleventh Five Year Plan	Building of dedicated freight corridors on the Delhi–Mumbai and Delhi–Kolkata routes	Introduce high-speed train (with maximum speeds of 150 kilometers per hour) between more city pairs (e.g., Delhi–Agra)

Source: Planning Commission of India (2018).

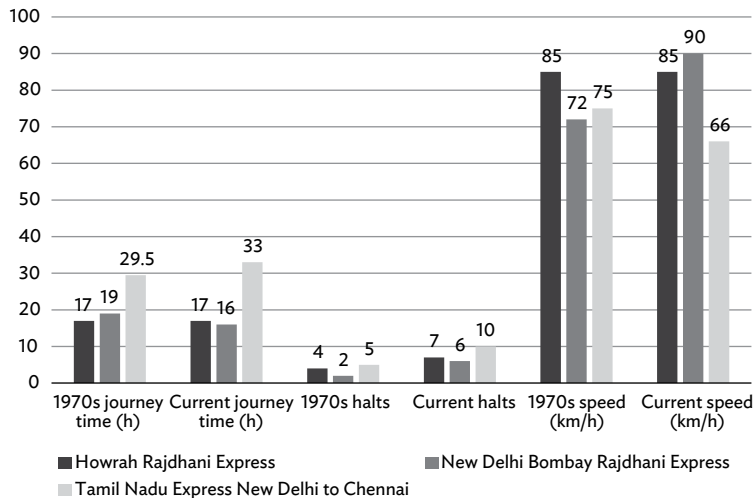
sociopolitical compulsions (see also Figure 20.1). This is revealed by the initial and present number of halts and the speed. We thus find that the 1970s were the first years when relatively high-speed trains were introduced between the four major cities in India.

Table 20.2: Comparison of India’s First Three Long-Distance Superfast Trains

Train Number	12302	12952	12622
Train Name	New Delhi Howrah Rajdhani Express	New Delhi Bombay Rajdhani Express	New Delhi Madras Tamil Nadu Express
Date of Introduction	3 March 1969	17 May 1972	8 August 1976
Original Time Taken, Distance and Speed	17 hours 1,450 km 85 km/h	19 hours 1,385 km 72 km/h	29.5 hours 2,188 km 75 km/h
Time Taken and Speed Today	17 hours 85 km/h	16 hours 90 km/h	33 hours 66 km/h
Original Halts	None (only 4 technical halts)	1 passenger halt and 1 technical halt	5 passenger halts
Passenger Halts Today	7	6	10

km = kilometer, km/h = kilometer per hour.

Sources: Compiled from the Indian Railway Catering and Tourism Corporation (www.irctc.co.in); the India Rail Info Website (www.indiarailinfo.com); the Indian Railways Fan Club Website (www.irfca.co.in); and Information on Superfast Rail Services in India (<http://www.nationalrailplan.in>) (accessed 8 October 2018).

Figure 20.1: High-Speed Trains of India, 1970s and Today

km = kilometer, km/h = kilometer per hour.

Source: Compiled from the Indian Railway Catering and Tourism Corporation (www.irctc.co.in); the India Rail Info Website (www.indiarailinfo.com); the Indian Railways Fan Club Website (www.irfca.co.in); and Information on Superfast Rail Services in India (<http://www.nationalrailplan.in>) (accessed 8 October 2018).

On the 200 km Delhi–Agra route, a high-speed train (the Shatabdi Express) with a maximum speed of 150 km per hour was introduced in November 1988. It was proposed that similar trains be introduced between selected city pairs. Currently, there are about 25 pairs of such trains running in various regions across India connecting important cities that thrive on business, tourism, and pilgrimage.

It was in the Twelfth Five Year Plan (2012–17) document (Planning Commission of India 2012) that “Developing High-Speed Rail Corridors and Upgradation of Speeds” was dwelt upon in some detail. For instance, the Ministry of Railways had selected the following six corridors for conducting prefeasibility studies for the development of high-speed rail (HSR) corridors:

- (1) Delhi–Chandigarh–Amritsar (450 km)
- (2) Pune–Mumbai–Ahmedabad (650 km)
- (3) Hyderabad–Dornakal–Vijayawada–Chennai (664 km)
- (4) Chennai–Bangalore–Coimbatore–Ernakulam–Thiruvananthapuram (849 km)

- (5) Howrah–Haldia (135 km)
- (6) Delhi–Agra–Lucknow–Varanasi–Patna (991 km)

The document aimed to undertake at least two detailed project reports and develop one corridor of about 500 km for construction. The Ahmedabad–Mumbai HSR project is the first one taken up for construction. The viability of each corridor identified for a prefeasibility study under examination by consultants is at different stages of progress. The present status vis-à-vis the various corridors is given in the following Table 20.3.

Table 20.3: Status of Various Corridors Selected for Conducting Prefeasibility Studies

High-Speed Rail Corridors – Studies/Status			
Sl. No.	Route Description	Study Status	Agency
Diamond Quadrilateral Routes			
1	Delhi–Mumbai	Feasibility study in progress	Consortium of Third Railway Survey and Design Institute Group Corporation (People's Republic of China) and Lahmeyer International (India) Pt. Ltd, India
2	Mumbai–Chennai	Feasibility study in progress	SYSTRA – RITES – E&Y Consortium
3	Chennai–Kolkata	Yet to be taken up	
4	Delhi–Kolkata	Feasibility study in progress	Consortium of M/s INECO (SPAIN) – M/s TYPASA – M/s Intercontinental Consultants and Technocrats Private Limited, India
5	Delhi–Chennai	Delhi–Nagpur section of this corridor is being taken up as Phase I under government-to-government cooperation	Planning study report for this high-speed rail corridor by China Railway SIYUAN Survey and Design Group Co. Ltd has been completed. Project feasibility study is yet to be taken up by SIYUAN.

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Table 20.3 *continued*

High-Speed Rail Corridors – Studies/Status			
Sl. No.	Route Description	Study Status	Agency
6	Mumbai–Kolkata	Mumbai–Nagpur section of this corridor is being taken up as Phase I under government-to-government cooperation	ADIF, Spain and INECO, Spain
Other Important Corridors			
7	Mumbai–Ahmedabad	Project under implementation	National High-Speed Rail Corporation Ltd (NHRCL), under Japanese financing
8	Delhi–Chandigarh–Amritsar	Prefeasibility study completed	SYSTRA – RITES Consortium
9	Howrah–Haldia	Prefeasibility study	INECO, Spain
10	Delhi–Patna	Prefeasibility study	Mott McDonald, India
11	Thiruvananthapuram–Mangalore	Detailed project report completed	DMRC, India
12	Hyderabad–Dornakal–Vijayawada–Chennai	Prefeasibility study	Parsons Brinckerhoff India Pvt. Ltd
13	Chennai–Bengaluru–Coimbatore–Ernakulam	Prefeasibility study	Consortium of JARTS (Japan Railway Technical Service) and Oriental Consultants

Source: Information drawn from respective chapters dealing with Indian Railways in all the five-year plan documents (www.planningcommission.nic.in, accessed 15 August 2018).

As if it were a run-up to the introduction of HSR in India, during the 12th Five Year Plan period, Indian Railways applied for a safety certification to run a new semi-HSR service between Delhi and Agra, a distance of 200 km. Called the Gatimaan Express, the service was expected to run at top speeds of 160 km/h. Although scheduled to be launched in 2015, safety requirements of the Commission of Railway Safety caused delays. Originally planned to cover the stretch in 90 minutes, the trial run on 22 March 2016 took 113 minutes, just four minutes faster than the time taken by the Shatabdi Express (Dastidar 2016).

After 30 years of research and development in railway technologies, with a focus on high-speed travel, the Gatimaan Express posted only a very modest achievement. This indicated that the existing network can

only support so much speed and no more. The need of the hour was a new system with a clear break from the past. The HSR system is that clear break in technology and is waiting to be embraced.

The Twelfth Five Year Plan document also proposed setting up an autonomous National High Speed Rail Authority, through a bill in Parliament for the implementation of HSR corridor projects by Indian Railways. This authority was to be entrusted with the planning, standard setting, and implementing and monitoring these projects. However, the actual establishment of such an authority was slightly altered in procedure. The High Speed Rail Corporation of India Limited was incorporated as a subsidiary of Rail Vikas Nigam Limited on 25 July 2012 and was launched on 29 October 2013 in New Delhi.¹

Amid these circumstances in February 2010, nearly 2 decades after the start of the economic liberalization process in India, the Government of India set up the National Transport Development Policy Committee as a high-level committee. Its final report titled *India Transport Report: Moving India to 2032* (National Transport Development Policy Committee 2013) had many recommendations for Indian Railways. These are discussed in the following paragraphs.

For long-term sustainability, railways have to be run as a business based on sound commercial principles. However, the social and/or national responsibilities of Indian Railways prevent it from operating on a purely commercial basis. While the organization has to fulfill both roles, it is essential that the commercial and social roles be kept distinct and separate.

The lack of clarity between its public service obligations and commercial objectives affects several other operational practices or systems of Indian Railways, such as investment planning, project execution, costing and tariff practices, the accounting system, and so on, making it even more difficult to reconcile these roles. This, and the need to implement India's first HSR project, resulted in the establishment of the national HSR authority.

In order to meet the ambitious goals set for 2032, the major issues confronting the network were classified under the following broad headings:

- capacity constraints,
- lack of clarity on social and commercial objectives,

¹ A special-purpose vehicle created to undertake project development and mobilization of financial resources, and implement projects pertaining to strengthening the Golden Quadrilateral and port connectivity. The company was incorporated in New Delhi as a public limited company on 24 January 2003 as Rail Vikas Nigam Limited. It is an organization associated with Indian Railways among whose tasks is to build engineering works required by Indian Railways.

- safety,
- inadequate research and development,
- optimization of land use,
- energy conservation, and
- organizational and human resource issues.

20.3 High-Speed Rail: Basics and Background

According to the International Union of Railways (UIC), the definition of HSR is a grounded, guided, and low-grip transport system, which could be considered a railway subsystem. The most important change comes from the speed. As travel times had to be reduced for commercial purposes, speed emerged as the main factor. HSR meant a jump in commercial speed; this is why the UIC considers a commercial speed of 250 km/h to be the principal criterion of HSR (UIC 2018).

20.4 Indian Railways Enters the 21st Century

Keeping the above definition in mind, it would be useful to examine the evolution of the Indian approach. From time to time, various white papers and other important documents have been released by Indian Railways that list contemporary objectives. For the purposes of this chapter, those released over the last decade are considered.

One principal document is titled *Indian Railways Vision 2020*, which was presented to the Indian Parliament on 20 December 2009 (Ministry of Railways 2009). It focused on four strategic national goals:

- (1) inclusive development, both geographically and socially;
- (2) strengthening of national integration;
- (3) large-scale generation of productive employment; and
- (4) environmental sustainability.

The document touched on all aspects of India's development of its railways. These covered, among others, the areas of high-speed travel, capacity augmentation, passenger services, safety, freight movement, technology upgradation including enhanced telecommunications, investment goals, and public-private partnership. It was also emphasized that Indian Railways would remain under government control for the foreseeable future.

Specific points in the vision document include the following:

- **Enhancing capacity:** This meant doubling or quadrupling of selected lines and complete segregation of passenger and freight lines on high-density routes. With this, more than 30,000 km of route would be of double or multiple lines, of which more than

6,000 km would be a quadrupled line with segregation of lines. This would include the main routes from Delhi to the three other major metropolises (Kolkata, Mumbai, and Chennai), with the building of dedicated freight corridors.

- **Speed of trains:** On Indian Railways, the speed of freight trains, which had stagnated at around 25 km/h, would be raised to a maximum of 60–70 km/h. Passenger services that are slow by international standards would see an increase in their maximum permissible speed of 130 km/h (for Rajdhani or Shatabdi trains) and 110 km/h (for other mail or express trains) to between 160 km/h and 200 km/h, respectively. As regards HSR travel, the vision document aimed to raise the speed of regular passenger trains to between 160 km/h and 200 km/h on the segregated routes.

However, *Vision 2020* document (Ministry of Railways 2009) also laid down the objective to implement “at least 4 high-speed rail projects to provide bullet train services running at between 250 and 300 km/h.” Specifically, six corridors were listed:

- (1) Delhi–Chandigarh–Amritsar
- (2) Pune–Mumbai–Ahmedabad
- (3) Hyderabad–Dornakal–Vijayawada–Chennai
- (4) Howrah–Haldia
- (5) Chennai–Bangalore–Coimbatore–Ernakulam
- (6) Delhi–Agra–Lucknow–Varanasi–Patna

The *Vision 2020* white paper observed that these could be built as elevated corridors in keeping with the pattern of habitation and the constraint of land in India. The railways will use the public–private partnership mode for investment and execution and draw on frontier technologies incorporating the highest standards of safety and service quality.

Part of the vision document deals with the suburban segment. It needs to be mentioned here that even though HSR networks connect the city centers, the importance of suburban rail in the system framework cannot be overlooked. These would provide further efficient connection to specific destinations within the urban and/or suburban areas.

The vision document refers to “partnership with state authorities for development of suburban rail systems.” In the same context, it also clarifies an aim for railways to integrate the metro and suburban rail systems under a single management in partnership with the respective state or city authorities. This would be one area for deeper study in the realm of public policy.

When a new government came to power in the middle of 2014, a new white paper subtitled “Lifeline of the Nation” was released in February 2015 (Indian Railways 2015). The thrust was to convert Indian Railways into being “... the backbone of India’s economic development,” as the Prime Minister put it at the time of the release of the document. In the words of the then Minister of Railways: “The objective of this paper is to show the challenges that the organization is facing today. It also shows that Indian Railways is perched on a precipice but is capable of flying off and attaining great heights. The organization, especially its staff, has inherent strength and I am confident that a clear direction, targeted investments, and well-defined priorities can make the organization grow by leaps and bounds.”

The foreign direct investment chapter of the document makes clear reference to the high-speed trains project as well as to the Ahmedabad–Mumbai HSR under the projects identified for domestic and foreign direct investments in railways. The document is more focused on the overall development of the railways sector with special emphasis on the finances required and on the pattern of the public–private partnership required to meet the objectives of the white paper.

The following year, on 8 December 2016, the incumbent Minister of Railways launched the National Rail Plan, 2030 website,² with the objective to “develop the National Rail Plan (NRP 2030) in consultation with all the stakeholders including state governments, public representatives, and other relevant central ministries” and thereby provide a long-term perspective. The plan endeavors to harmonize and integrate the rail network with other modes of transport and create synergy for achieving a seamless multimodal transportation network across the country. The website, under the heading “Existing and Planned Rail Network,” details both the HSR corridors and dedicated freight corridors.

At this point, it can be concluded that the HSR idea is now firmly embedded in the policy framework of the entire government apparatus, including possibly across the political spectrum.

At present, the Ahmedabad–Mumbai HSR project is in the initial stages of implementation with major financing from the Japan International Cooperation Agency. The total cost of the project is ₹1.08 trillion (approximately \$13.6 billion). Of this amount, ₹0.88 trillion (approximately \$12 billion) is in the form of a loan from the Japan International Cooperation Agency, with the remainder being funded by

² This unique website (accessible at <http://www.nationalrailplan.in>) was developed for all stakeholders to give their inputs for a purposeful study to enable long-term growth of Indian Railways in a comprehensive manner.

the Indian Ministry of Railways and the Gujarat and Maharashtra state governments.

Since early October 2018, the implementation of the project has been running into problems over land acquisition and compensation (*Indian Express* 2018). An estimated 312 villages in Gujarat and Maharashtra will have to give up land for the Ahmedabad–Mumbai HSR project. Additionally, 7,974 plots belonging to the forest department and railways will have to be acquired in the two states. The progress on these fronts is currently less than 50% of the target. Potential litigation could lead to further delays.

In addition, issues such as diverting 80 hectares of forest land, cutting 80,000 trees to enable track construction, endangering environmentally sensitive zones in the coastal areas, and disturbing bird migration patterns in proximate water bodies are coming into focus, causing possible project delays.

The Ahmedabad–Mumbai HSR, with its proposed capacity of 730 passengers per trip, is expected to travel at speeds of 320–350 km/h, thereby reducing the travel time between Ahmedabad and Mumbai to 3.5 hours or less (from the current 8 hours). It is hoped that it will divert passengers from those currently using other modes. Some figures are given in Table 20.4 (*Indian Express* 2018).

The Ahmedabad–Mumbai HSR project is planned to be completed by August 2022. However, protests from tribespeople and farmers have halted or delayed geotechnical investigations, hydrological surveys, and utility mapping procedures. Two organizations, Bhumi Adhikar Andolan and Shoshit Jan Andolan, have approached the National Human Rights Commission demanding an investigation into the “illegal” detention of activists during protests earlier in 2018.

Table 20.4: Travel Time and Fares of Transport Modes between Mumbai and Ahmedabad

Mode	Time Taken (minutes)	Fare (Range) (₹)
Air	60	1,500–5,000
Bus	540	600–1,200
Train	340–380	1,500–2,500
Bullet train	120–180 (<i>proposed</i>)	2,500–3,000 (<i>proposed</i>)

Sources: Websites of Indian Railway Catering and Tourism Company, India Rail Info, and Indian Railways Fan Club (last accessed 20 October 2018).

20.5 Spillover Effects for India's Conditions

Against this background, it would be pertinent to examine the steps that need to be taken for the spillover effects from HSR to be beneficial across the socioeconomic spectrum. As the Indian HSR project gathers speed, as a first step, a guide to the use of high-tech facilities and other HSR assets so created should be issued and given the widest form of publicity.

Three categories of persons would need to be trained: the operations personnel on board the HSR and their corresponding crew on the ground; the service personnel on board the HSR with support personnel on the ground; and the users. Without a doubt, the training of operations personnel would have to be done exclusively by the parent organization with help from Japanese trainers.

However, a special effort should be made in training not only the users, who will come from different social and economic backgrounds, but also service providers inside the train, who will also have varied social backgrounds. For example, well before the HSR service commences, training modules on how to board and disembark and how to use the special features of the HSR are among the elements to be covered extensively in the user manual and service training. In fact, a massive public awareness campaign should be launched through all forms of media by 2020, so that when the actual service commences, the users and the providers of the HSR service are on par with regard to the appropriate use of the HSR assets in an optimal manner.

An additional area of focus could be the extensive use of icons for rail track signs and symbols for the HSR project at the various stops on a given route. Simultaneously, the use of applicable icons in the non-HSR portions of Indian Railways can also be promoted. Most of the symbols used currently by Indian Railways owe their origins to days prior to the computerization of activities in India's railway operations. A separate module for both categories should be designed to ensure consistency and ease of recognition.

The Japanese railway is well known for the high standard of its service personnel, especially the cleaning staff, who complete their task in a bullet train in around 7 minutes during a turnaround. To achieve comparable levels of productivity for Indian personnel, appropriate guidance and, where needed, special training modules would have to be designed. Further, the technology that goes with the provision of the service or maintenance would have to be specially designed to suit Indian climatic as well as community conditions.

For instance, Japanese engineering-based activities are supported solidly by the practice of preventive maintenance. When such activities for the HSR in India are designed, the cost of operation should remain

within limits. In this context, focus should be on aspects such as redundancy, which Japanese technology is famous for, especially for high-value assets. Admittedly, redundancy in engineering systems enhances reliability, but this should not increase the implementation costs of the Indian HSR to uncontrollable levels.

It needs to be remembered that levels of compliance between Japanese and Indian personnel (both users and service providers) vary significantly. For the HSR assets created at enormous cost to last a long time, appropriate care must be given to these assets from the beginning, including specially trained people who are appointed for a given task.

One important task for public policy specialists is to look at alternatives that correctly balance (i) the overall costs of construction, (ii) the maintenance cost of the assets thus created, and (iii) the overarching need to make HSR services available at an affordable cost to the user over the long term.

Indians, like people from other countries, enjoy traveling during holidays, especially by train. Undoubtedly, this would ensure higher occupancy rates. Even though travel habits have changed over the years, certain aspects of behavior that arise from Indians traveling in groups differ widely from the Japanese practice and routine. This may require a modified design for the movement of both passengers and their baggage inside the HSR carriages. From seat design to luggage racks, a new approach may be called for. Yet again, the challenge would be to design a system that caters to the distinctive demands of the service provider and the user in the Indian context. A thorough examination of all facets followed by an extensive exchange of views on this would be an absolute necessity if the high-value HSR is to ensure exceptional levels of service at high speeds.

Currently, of the following six corridors under consideration, four are in peninsular India. A crucial question that arises is whether one should wait for the Ahmedabad–Mumbai HSR project to be completed before taking up the other projects in the list. In the context of proposed high-speed corridors, Table 20.5 lists the current time taken to cover the existing distance by train and the time that is likely to be taken if HSR is introduced between the concerned destinations.

The first Ahmedabad–Mumbai HSR is being constructed in an area that has very high levels of economic development going back well over a century. However, other routes should also be looked at. The next most talked-about route is the Bangalore–Chennai corridor as part of the proposed Chennai–Ernakulam/Trivandrum HSR corridor.

Table 20.5: Comparison of the Current Journey Time to the Assumed Values for High-Speed Rail Corridors in India

Route	Present Distance (kilometers)	Current Time by the Fastest Train (minutes)	Proposed High-Speed Rail Distance (kilometers)	Likely Journey Time (Assumed Values) (minutes)
Ahmedabad–Mumbai	491	430	534	120–180
Bangalore–Chennai	362	300	340	90–120
Chennai–Hyderabad	715	760	664	150–220
Chennai–Bangalore–Ernakulam	N/A	N/A	649	150–220
Delhi–Jaipur–Ajmer–Jodhpur	553	610	591	130–190
Delhi–Patna	983	700	991	220–330

N/A = not applicable.

Source: IRCTC (2018), with data downloaded from Raghuram and Udayakumar (2016).

A desk study compared the present capacity available on the Bangalore–Chennai corridor through all modes to arrive at a suitable conclusion with regard to capacity and pricing for a possible HSR on the corridor. The number of seats available in air-conditioned comfort across modes was calculated and comparative data derived from a hypothetical journey from Bangalore to Chennai by various modes, for a hypothetical journey on 17 October 2018 (Table 20.6).

Table 20.6: Travel Time and Fare Range Comparison of Transport Modes from Bangalore to Chennai

Mode	Time Taken (minutes)	Fare (Range) (₹)
Air (4,400 seats daily)	60	2,500–10,700
Bus (3,400 seats daily)	360	650–1,800
Train (2,400 seats daily)	300–360	550–1,500
Bullet Train	90 (nonstop)	

Source: National Rail Plan. <http://www.nationalrailplan.in> (accessed 8 October 2018).

20.6 Areas Likely to Be Influenced by High-Speed Rail

The introduction of HSR in India is certain to stimulate active interest, both commercial and technological, in transportation in general and in railways in particular. India is among the latest entrants in the HSR segment. Japan, Germany, France, Spain, and the People's Republic of China (PRC) have already established the norm for their respective systems.

The 2013 report of the National Transport Development Policy Committee, dealing with the railway sector, states the following regarding HSR projects:

A review of the most important projects carried out today around the globe highlights that the potential demand for services must be particularly high in order to make investment in them socially profitable and that these projects must target the corridors linking densely populated metropolitan areas, suffering from severe road congestion, and having deficient air links.

A closer examination of the statement reveals the crucial phrase “socially profitable.” This is one of the most important parameters whenever any high-cost infrastructure project is considered in India. The viability has to meet not only the private cost-benefit analysis but also the social cost-benefit analysis norms prevalent at any given point in time. Using the latter yardstick for assessing the proposed HSR project in India would reveal many weaknesses that may well negate the idea.

The present decision of the governments of Japan and India to go ahead with the construction of HSR would appear to be driven by the futuristic vision of the respective leaders. They look at the project as bringing the two countries closer together economically, commercially, and technologically for the foreseeable future.

What effect HSR will have on Indian Railways is difficult to predict. However, in a large and highly populated country such as India, the effects are likely to emerge over a period of time. One thing, however, is certain: the introduction of the new technology of high-speed transport is certain to have a decisive effect on the existing system. Transportation at higher speeds and economic productivity are directly linked. If a given task can be completed in less time, productivity goes up automatically.

In Japan, as people shifted from ordinary trains to the *Shinkansen*, productivity levels increased, and the economy benefited. Since the corridors identified in Table 20.5 are mostly business, commerce, and industry oriented, the possibility is high that a similar productivity increase in the Indian context will be observed also by the middle of this century. This could also form the basis for a deeper analytical study in the realm of public policy.

20.7 Spillover Effects

Apart from providing a reliable, fast, and timely service, HSR helps in two other ways. It has the capacity to divert and absorb traffic from the air mode and the automobile (bus and car) mode and also to have an effect on reducing the carbon footprint over a period of time. The other is the demonstration effect that HSR can have on other transportation modes in India. HSR may well replicate the effect that the automobile and the highway sectors have had on road transportation in India in the 21st century.

According to the European Environment Agency, the following are the CO₂ emissions per passenger-kilometer for various modes of transport (Table 20.7):

**Table 20.7: Carbon Dioxide Emissions
for Various Transport Modes in Europe**

Transport Mode	Passenger Average	Emissions (grams of CO ₂ per passenger-kilometer)
Train	156	14
Small car	4	42
Big car	4	55
Bus	12.7	68
Motorbike	1.2	72
Small car	1.5	104
Big car	1.5	158
Plane	88	285
Ship	–	245

Source: Figures obtained from European Environment Agency. <https://www.eea.europa.eu/transport> (accessed 23 October 2018).

A UIC (2016) study on HSR in France and the PRC concluded that the carbon footprint of HSR can be up to 14 times less carbon-intensive than car travel and up to 15 times less than aviation travel, even when measured over the full life cycles of planning, construction, and operation of the different transport modes. This is even more important where there are predictions of changes to the technology of all transport modes, such as cars, and even airplanes, powered by electricity.

In the case of India, the potential for renewable sources for electricity production, especially wind and solar energy, can really help in this regard. Further, in a country like India, where there is always a perennial shortage in the supply of railway accommodation, any new high-speed alternative will always be fully subscribed. Given Indians' innate urge to travel for business and pleasure, a modal shift is bound to occur, thereby reducing the carbon footprint even further. Since an average high-speed train is expected to carry about 700–800 passengers, the carbon footprint will certainly grow smaller in the long run.

An average high-speed train emits no direct carbon dioxide. Emissions depend on the mode of electricity generation used to run the train. Keeping the above in mind, the possible carbon dioxide emission levels in the Bangalore–Chennai corridor were calculated based on actual seats available. The results take into account the desk study on the number of seats available in each mode for the Bangalore–Chennai corridor, and the amount of emissions is compared depending on the load factor for a given mode (Table 20.8).

**Table 20.8: Carbon Dioxide Emission Estimations
for Bangalore–Chennai Corridor**

Transport Mode	Total No. of Air-Conditioned Seats	Capacity Utilization Approximation (%)	Passengers Traveling	Distance (kilometers)	Emissions (grams of CO ₂ per passenger-kilometer)	Total Emissions (ton)
Air	4,400	70	3,080	350	285	307.2
Bus	3,400	90	3,060	350	68	72.9
Rail	2,800	80	2,240	350	14	10.9
HSR	5,600	90	5,040	350	6 ^a	10.6

^a UIC (2016).

Source: EEA (n.d.).

20.8 A Lesson from the Recent Past

To a large extent, the paradigm shifts in road transport in India were a result of the construction of the Golden Quadrilateral highway project. It came into prominence after a decisive leap in technology through foreign investment in the manufacture of cars and commercial vehicles. The innumerable models of cars and buses available in India, particularly over the last decade, has made road travel very comfortable. There is no denying the fact that it was the government that built the roads on which these vehicles travel. However, the choice available to the user from a private car to the most comfortable air-conditioned bus has changed the culture of road travel in the country. Today, the three models of cars and three major models of trucks that defined the Indian motoring landscape in the 20th century have disappeared.

Owing to the better quality of roads, constructed around the turn of the century, and the availability of luxury buses, long-distance travel has blossomed in India over the last decade and a half. In this case, however, it was the private bus operators who took the lead in acquiring modern buses and providing very comfortable services connecting major cities in various regions of India. This, in turn, compelled the various state-run road transport corporations to buy the same luxury buses, just to be able to compete. Long- and medium-distance travel (up to 600 km) has now resulted in a Pareto equilibrium in bus–road travel in many parts of the country.

It is very likely that HSR will compel Indian Railways, possibly through the demonstration effect, to change its method of functioning and operations to help give greater comfort to passengers, enhance timely departures and arrivals, and thereby post higher revenues along with greater efficiency. Two activities are already underway: the construction of dedicated freight corridors and the expansion of carrying capacity by doubling or quadrupling the number of railway lines on high-density routes. This will reduce congestion and also help the non-HSR sector to improve its average speeds, thereby enabling a reduction in travel time across long distances.

Depending on the capacity of a given HSR, there would certainly be a shift away from the road to HSR, thereby freeing up both the road and a part of the existing railway system. This would, in turn, reduce congestion across the board. This freeing up of space will not only help with achieving higher speeds for passenger trains on normal tracks but also help freight trains move faster.

20.9 Competition from Cyberspace?

From another angle, let us take just two corridors: one between Chennai and Bangalore and the second between Chennai and Hyderabad. Travel by HSR in these two sectors is possible in about 90 minutes and 180 minutes, respectively. All the peninsular cities or city pairs mentioned earlier are heavily commerce and business oriented. Thus, the customer base for an HSR service is significantly large. Their ability to pay more for a better and faster service is also a favorable factor. The assistance that such a facility will render to the business community will be immense, especially to those who need to physically travel to the termini or to the intermediate stops. Further, a trip between the above city pairs can be completed by businesspersons in the space of 1 working day. Such time savings will certainly lead to greater efficiencies.

At the same time, just as the mobile phone revolution has comprehensively connected India, the appeal and pull of high-speed travel will be such that it will have to compete with the modern technology of instant voice and image communications embellished by other facilities offered by high-speed internet. An average businessperson, in charge of a small or medium-sized enterprise, would normally tend to save time and costs. Thus, unless travel by HSR becomes an inevitability or is a source of pleasure, that segment of the market may use it more for the latter than the former. Therefore, HSR will face competition from the facilities offered by high-speed connectivity in cyberspace both at the individual and at the industrial level, unless trips are taken purely for pleasure. Simultaneously, however, varying with the distances involved, HSR may encourage that segment of the population that can afford to travel short distances to try and take an HSR alternative just for the sake of it.

Here, it would be appropriate to quote from an article from the *Free Press Journal* dated 1 June 2018 about the oldest high-speed journey train, called the Deccan Queen, which has run between Pune and Mumbai for nearly 90 years:

On 1 June 1930 (88 years ago), the Indian passenger train Deccan Queen Express started its service between Mumbai and Pune. It was started as a weekend train during the British rule and was a medium for rich people from Bombay (now Mumbai) to attend horse racing at Pune racecourse. The train started its initial services on weekends but was soon converted to a daily service running from Bombay Victoria Terminus (now Chhatrapati Shivaji Maharaj Terminus [CSMT]) to Pune Junction.

Deccan Queen is one of the longest-running train services of Indian Railways to never run on steam power. It has been running using electric locomotives from the start and also used a diesel locomotive in case of original locomotive failure. It was the first train to have a “ladies only” coach and among the first to feature a diner. It was also one of India’s first vestibule trains.

Currently, Deccan Queen is the fastest train service linking CSMT in Mumbai and Pune station. It has an average operating speed of 58 km/hr and a top speed of 105 km/hr. The train leaves Pune Junction every day at 7:15 a.m. and reaches CSMT at 10:25 a.m. The train departs from CSMT every day at 5:10 p.m. and reaches Pune Junction at 8:25 p.m.

There are hundreds of Pune residents who take this train to Mumbai on a daily basis for work and return the same day. This is also what the HSR service hopes to achieve in India, but in the 21st century. There are bound to be lessons from this train’s operations for the HSR planners in catering to the commuters who would travel for work daily for a few hundred kilometers and return home the same day.

It would be useful to conduct a detailed study on a public policy canvas about those routes that could face competition from cyberspace, as technology increases the speed of data transmission almost by the day. In the same context of advances in technology, NITI Aayog (successor to the Planning Commission) could undertake studies on identifying sources of funding and creating new assets in the HSR universe. This should include studies by Indian Railways on the introduction of new technologies and how these can be indigenized over a period of time. They should also conduct studies on how traffic patterns can be improved and economy of operations can be made more cost-optimal. The Ministry of Finance, which has now included the railway budget within its own ambit, should enable public policy studies on pricing of services and sources for funding, especially for asset maintenance and renewal.

No discussion on HSR is complete without a mention of the achievements that the PRC has posted in this sector. The country today has the world’s longest HSR network. Long-distance travel of more than 2,000 km is now operational, including the journey between Beijing and Hong Kong, China, which began its commercial operations on 23 September 2018. It takes about 9 hours to cover the distance of 2,300 km between the two cities. The line is the world’s longest HSR route and cuts travel time by more than half.

A similar route in India could link the capital Delhi with major southern cities such as Chennai, Bangalore, Hyderabad, and Trivandrum during the course of a day or through comfortable overnight journeys. Even if it is in the realm of imagination, India needs to think ahead in terms of how the reliability and speed of the trains in the country can better serve the socioeconomic objectives of India in general and the country's railways in particular.

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21

Safety and Reliability¹

Yoshihiro Kumamoto, Nikhil Bugalia, and KE Seetha Ram

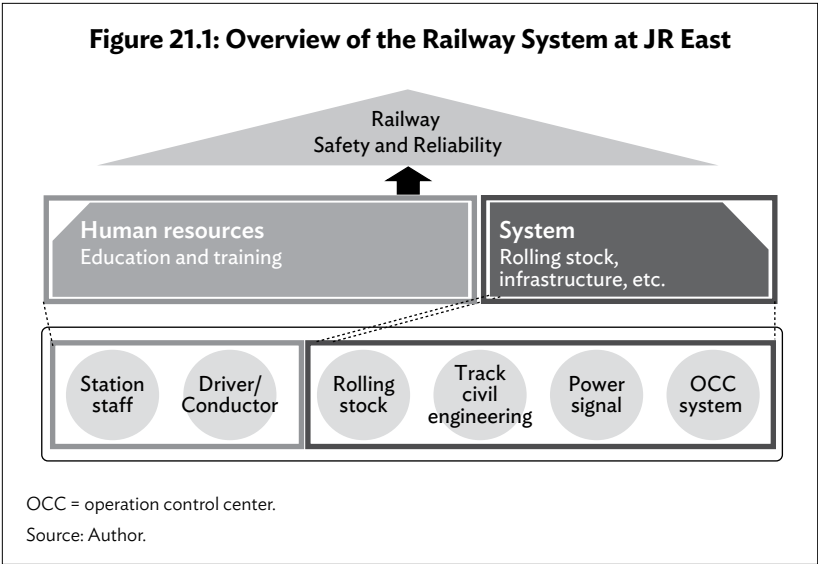
21.1 Introduction

The East Japan Railway Company (JR East) is instrumental in providing efficient transportation services in the eastern part of Japan. When it comes to high-speed rail (HSR, or *Shinkansen* in Japanese), JR East operates a network spanning about 1,470 kilometers. At the maximum commercial speed of 320 kilometers per hour, the network's 337–428 daily operating trains serve approximately 290,400 passengers per day. At peak times, Tokyo Station could be serving 15 trains per hour. Even after such a high-capacity utilization of the infrastructure, the average delay per train in the past 15 years has been about 36 seconds, with zero passenger fatalities or injuries.

21.2 Systems Perspective for Safety Management of High-Speed Rail

This chapter summarizes the practices of JR East for achieving the high standards of safety and reliability commonly associated with Japanese HSR. JR East adopts a “systems perspective” to ensure the safety and reliability of its services, the critical components of which

¹ The content of this chapter (including all figures) was presented by Yoshihiro Kumamoto at the Asian Development Bank Institute (ADBI) special sessions titled “Transport Infrastructure and Quality of Life” at the World Conference on Transport Research in Mumbai, India, on 28–30 May 2019 (<https://www.adb.org/sites/default/files/related/145966/adbi-transport-infrastructure-and-quality-life-agenda.pdf>). It was then revised to include additional information regarding the safety management system at JR East based on the case study conducted by Nikhil Bugalia as part of his research at The University of Tokyo and ADBI. The purpose of the present case study is to offer valuable learning opportunities for practitioners by describing the practices prevalent at one of the leading HSR operators in Japan. The study does not provide any evidence for adopting any specific practices and should be treated as such.



will be discussed. A fundamental aspect of the systems perspective is to ensure that the weaknesses of one element of the system (technology or human) are adequately compensated by the other (human, technology, or its management) in the case of the human-machine system that comprises HSR. Hence, the chapter also enumerates the company's human resource development strategy. Finally, the chapter details the safety management system at JR East and illustrates critical messages about its safety policy, objectives, plans, procedures, and so on. The basic outline of the railway system is shown in Figure 21.1.

21.3 Core Technical System Using State-of-the-Art Technology

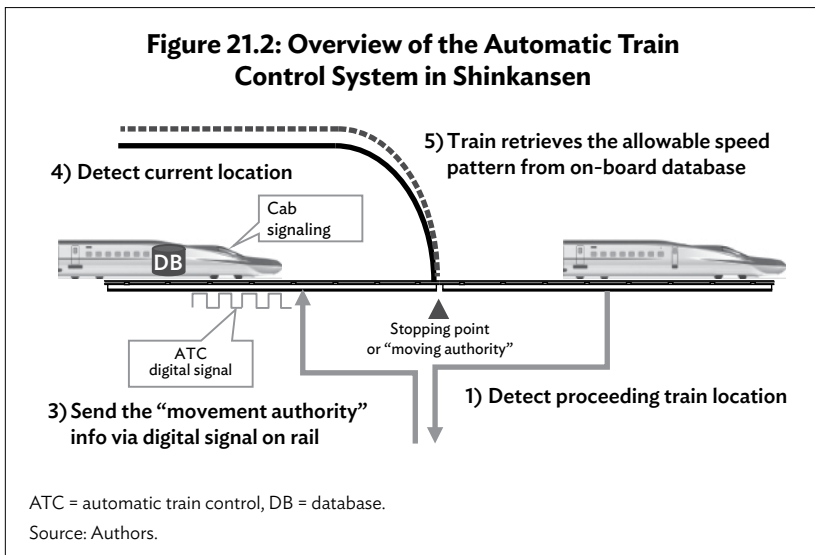
The core technical system of the *Shinkansen* is its rolling stock and infrastructure, such as the tracks, the power signals, and the traffic control system. A life-cycle approach is necessary to ensure the efficient functioning of the core system. During the design stage, the system works in a way that minimizes dependence on human action. To achieve this, state-of-the-art technology is used to the greatest extent possible, and technical systems are continuously improved using technological innovations as they become available.

The introduction of new technology is complemented by extensive running tests using real prototypes before proceeding with actual operations. These running tests are then used in analyzing the system's performance (not the individual component's performance) and reveal some of the hidden risks. Based on the results obtained from the running tests, the system is continuously improved throughout the design stage.

21.3.1 Redundancy to Ensure Safety

The fundamental design principle of the core technical system is to have redundant systems for critical components to ensure fail-safe safety—that is, the system should be safe even when a component fails. Redundancy in the system ensures that in the event of a failure of one component, safe operations can still be provided using the other components. For example, the rolling stock of Shinkansen comprises multiple types of brakes, such as electromagnetic and conventional pneumatic brakes (capable of working efficiently at the maximum operating speed). Both types of brakes work independently; hence, in the event of a failure of one, the other can be used to ensure the safety of operations.

Another example of system redundancy includes the functioning of the automatic train control (ATC) system, which is essential for safe braking at high speeds. Figure 21.2 shows an overview of the *Shinkansen*



ATC system. In the ATC system, if the so-called generated movement authority (MA) is wrong, a train collision could happen. MA refers to the speed profile that a train has to follow to avoid an accident. Hence, the MA is calculated simultaneously using two sets of sensors connected to two different computers. A third computer is then used to check if both MAs match. If they do not, a third computer runs a test program to differentiate the correct MA signal from the faulty one and use only the proper sign for applying the brakes. Such redundancy thus ensures system safety even when an individual component fails.

21.3.2 System Maintenance: A Necessity

While having a robust system design is essential, an excellent system design can sustain performance only when the system is adequately maintained. Any system in the world is bound to deteriorate over time, making maintenance essential to ensure the system's performance over time. In this regard, JR East utilizes a condition-based monitoring approach to maintain its infrastructure assets. A special HSR inspection car named East-i is used to collect data on the condition of the assets, such as of tracks and electrical equipment. East-i can run at high speeds and can thus be scheduled during regular operating hours. The inspection data collected are then used for planning the maintenance activities. The steps have also been taken to automate the maintenance activities as much as possible; for example, a rail grinding machine is mounted on cars for faster maintenance. Asset maintenance is such an integral part of JR East's business activities that it is integrated with the operation plan and a dedicated 6-hour window post midnight is kept for performing all maintenance activities. This 6-hour window is strictly maintained, and there are currently no plans for nighttime operations given the high capacity utilization of the *Shinkansen* network.

21.3.3 Protection against External Factors: Technical Solutions

Several hazardous situations for HSR can occur because of the factors within the railway system—for example, overturning accidents while navigating curves at high speed or collisions at high speed. Hence, the core technical system is essential in providing safety. However, safety issues can also be due to factors beyond the control of stakeholders within the system, for example, potential safety concerns arising from natural disasters. The core technical system should thus be strengthened to handle the impact of such external factors.

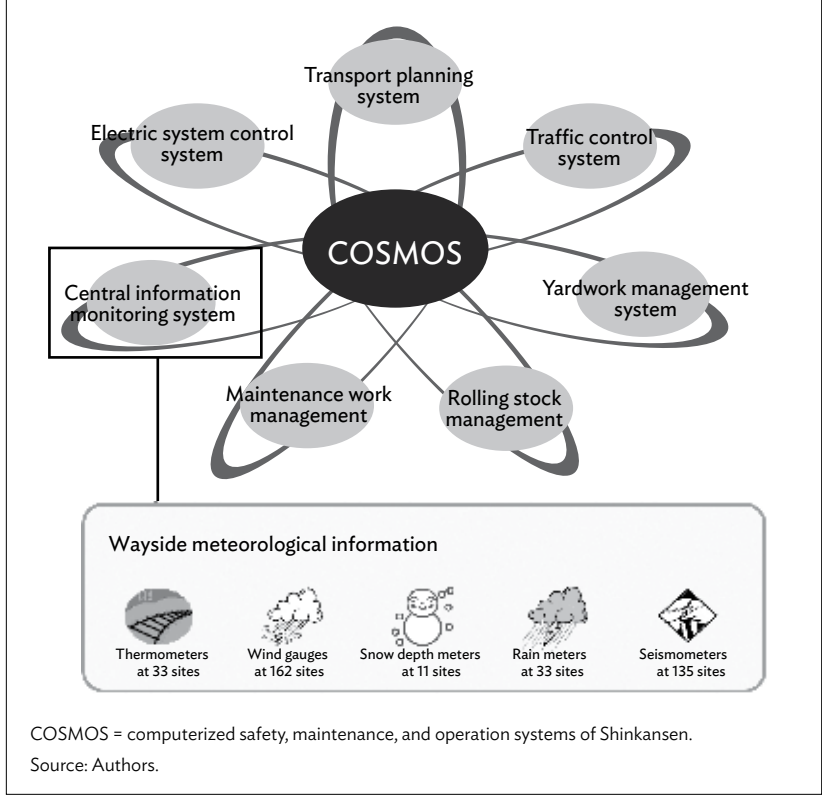
Japan is one of the most disaster-prone countries. It is frequently affected by strong typhoons, and the country's mean annual precipitation is about double the world average. Many parts of the JR East network experience heavy snowfall in the winter. Every year, almost 10% of the earthquakes greater than magnitude 5 on the Richter scale occur in Japan. Under such severe conditions, the HSR system of JR East is designed to be resilient against a variety of natural disasters.²

JR East's approach to managing the impact of such natural disasters is to monitor their status and take appropriate measures. For example, JR East has installed a set of 135 seismometers along its network, which can detect the early, weaker waves of an earthquake and apply the emergency brakes before the strong waves reach the structure. This system has proven to be effective even during the strongest earthquakes that Japan has faced. In 2011, when the Great East Japan Earthquake (greater than magnitude 9) hit, all 25 of JR East's operational trains came to a halt without causing any derailments. Similarly, sensors also collect information (wind gusts, rains, snow depths, etc.) and are effectively utilized for setting up operational speed limits and so on, so that operational safety can be achieved.

As can be clearly seen from the above example of the inspection data collection through East-i, the safety of HSR in JR East is dependent on a large amount of real-time data, and appropriate measures must thus be taken for time-bound analysis of the data and its circulation to proper stakeholders as quickly as possible. In this regard, JR East has implemented, a large-scale, comprehensive data management system called COSMOS, short for computerized safety, maintenance, and operation systems of *Shinkansen*. All the information collected from the various sensors monitoring natural disasters is readily analyzed and shared with the other six components of COSMOS: electrical system control system, transport planning system, traffic control system, yardwork management system, rolling stock management, and maintenance work management system. Yet again, the principle of system redundancy is applied here, and a backup COSMOS is also prepared. Figure 21.3 shows an overview of the COSMOS components.

² All data have been collected by JR East.

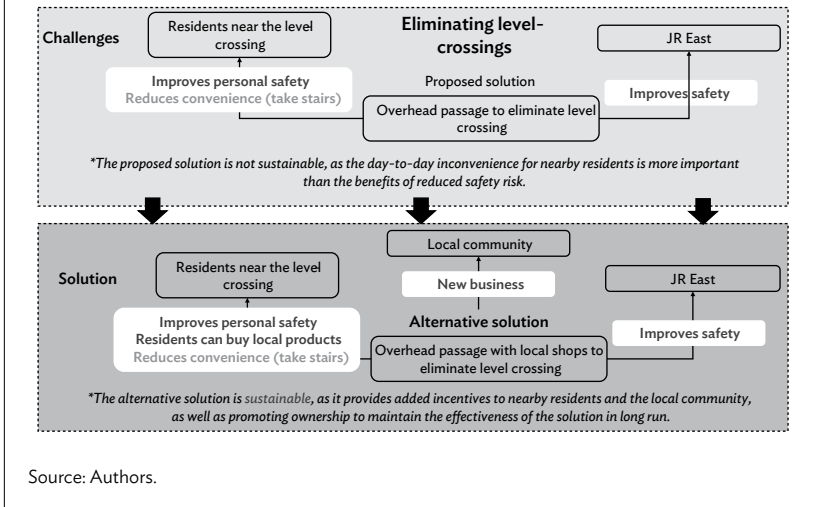
Figure 21.3: Overview of COSMOS at JR East



21.3.4 Protection against External Factors: Social Solutions

While the impact of many external factors can be reduced by using effective technology, there is no universal approach that can solve all problems. In addition to nature, there are also human-induced external factors such as those involving social factors (e.g., people falling from platforms or accidents at level crossings, although these are not applicable for the *Shinkansen* as it runs on dedicated tracks). Unlike many railway organizations in the world, JR East has taken a participatory approach for such issues by adopting both hardware and software measures. Hardware measures include installing platform doors and eliminating level crossings; software

Figure 21.4: Example of Stakeholder Coordination for Improving Safety Performance



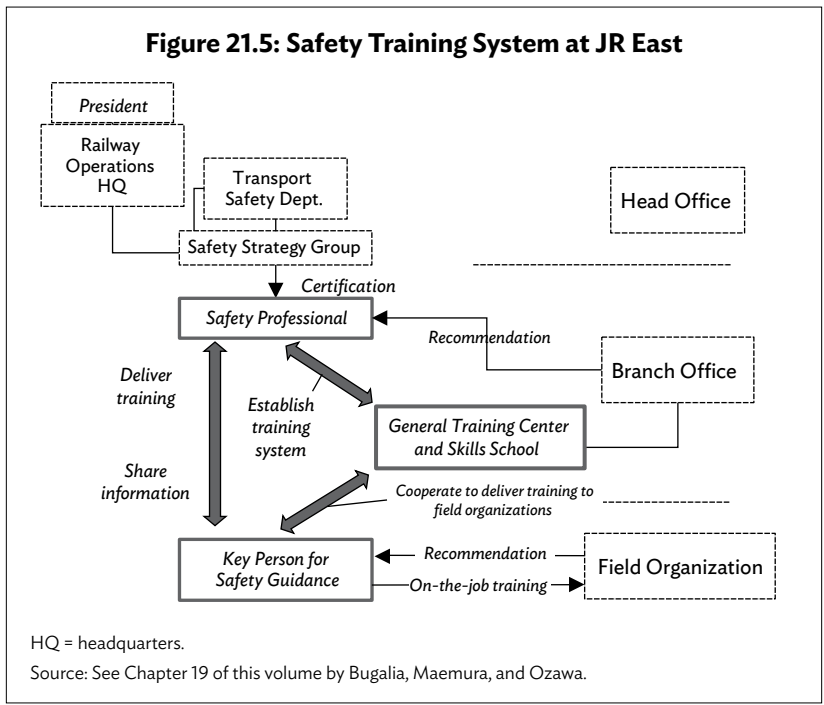
measures include coordinating with stakeholders to codesign the most acceptable technical solution and promoting the effectiveness of the implemented solution thereafter. In a recent activity (Figure 21.4), JR East coordinated with residents and regional product sellers to build an overpass and eliminate a level crossing. Sellers were invited to set up their shops on the new overpass structure, creating new business opportunities for them and thus increasing acceptance of the overpass in the wider community. Similarly, the incentive of visiting the newly opened shops may entice the pedestrians to use the overpass instead of the preferred crossing despite the inconvenience of having to use stairs. This led to a long-term sustainable solution, which was effective in ensuring safety.

21.4 Human Resource Development

An excellent system will not be useful without staff who can operate it meticulously. In order to ensure high-quality human resources, continuous training and education of all staff is very important. The three main components of human resource development at JR East are (1) on-the-job training, (2) self-improvement, and (3) group training.

During on-the-job training, each member is assigned tasks regarding practical actions that they are expected to perform during the normal system operations. Follow-up and close guidance provided by the manager is then helpful for employees in improving their skill. In the era of portable smart devices, education by correspondence plays a vital role for the self-improvement of employees. They can revisit the training materials at their convenience using smartphones. JR East also has a policy to support their employees in acquiring qualifications.

However, apart from individual training, group training supplements the on-the-job training. Various group training centers are located at the headquarter level as well as geographically divided field offices. These training centers serve essential local and universal training needs for the employees.³ An overview of the organizational structure supporting the training program is shown in Figure 21.5.



³ For more details for the approaches on human capacity development of JR East, please refer to Chapter 22 of this volume.

21.5 Safety Management System

Safety is an emergent system property that can be achieved only through continuous improvement in the activities targeted to achieve safety. These activities should be revised based on their measured impact on achieving safety. The safety performance of a given sociotechnical system can degrade over time due to natural causes such as material degradation or due to adaptation at the various human and organizational components of the system such as gradual deviation from safety procedures to optimize the local performance goals, for example minimizing the time taken to conduct an activity. Hence, continuous management through a safety management system is essential in an organization. In this regard, a Plan–Do–Check–Act (PDCA) cycle may be necessary. In terms of safety management, such PDCA cycles can be translated to risk assessment and management (Plan), safety promotion activities (Do), safety assurance (Check), and safety policy and culture (Act). The previous sections provided details on various safety promotion activities for technical and human components in JR East. This section will briefly discuss the remaining aspects of JR East’s safety management plan and safety policy, and so on. Detailed information on JR East’s safety management system can be found in the company’s sustainability report (JR East Group 2018).

First, the risk assessment and management strategies of JR East. For JR East, continuous learning from past experience is an essential tool for improving the deficiencies of the system. Any catastrophic accident is likely preceded by several disorders and near misses. A systematic collection of such incidents and thorough analysis using principles such as 4M4E enables JR East to identify multiple accident causal factors and their interrelations at various levels of the system. For example, for each erroneous incident, elements can be identified using the 4M classification: man, machine, media (communication), and management (organization). Consequently, their improvement measures are determined using the 4E principles: education, engineering, environment, and enforcement.

The findings from such extensive analysis then feed into developing organization-wide safety plans for JR East. Since 1988, JR East has been focusing on safety through a system of 5-year safety plans. Such plans cover the fundamental concepts and policies related to safety, which are put into practice across the company. Each 5-year plan addresses current challenges, and the implementation of such plans has been an ongoing process from the time the company was established. In these safety plans, the top management of JR East indicate a clear policy direction regarding safety to people both inside and outside the company. The seventh safety plan called “Group Safety Plan 2023” is currently ongoing in JR East.

Second, JR East's strategies related to safety assurance. As with the physical systems, where a large quantity of data is collected to monitor the current state of the system to identify the decision on future actions, monitoring is also implemented for various organizational levels within the JR East organization. Tools that are regularly employed include surveys related to employee perception on safety, tools to assess safety understanding of different employees, and the effectiveness of the communication, among others.

Third, the governing principles of decision-making based on the current situation (i.e., ACT). In any system, various components (such as humans) consistently make decisions. Their decisions are primarily governed by their *safety culture*, which in turn depends on the safety policy of the organization. The safety policy of an organization sets up the cardinal principles of decision making within an organization and thus has a tremendous impact on safety. JR East's safety policy comprises five cardinal principles:

- (1) Safety is the highest priority for the transport business.
- (2) Safety can be ensured by compliance with and strict enforcement of regulations along with continuous training.
- (3) Implementation of inspections and close communication are the most critical points in ensuring safety.
- (4) Cooperation, regardless of assigned duty, is of utmost importance to ensure safety.
- (5) When in doubt, do not panic, think for yourself, and choose the safest way.

The safety policy at JR East emphasizes five types of safety culture that are promoted. The first is a culture of correct reporting, which aims to help active reporting incidents and near misses. The second is a culture recognizing the promotion of vigilance among all employees to identify safety-related concerns and sharing them with others in the organization. The third is a culture focusing on open discussion of accident analysis without having to worry about blame. The fourth is a culture of learning, in which the focus is to promote continuous safety learning among employees not only limited to their usual responsibilities but also related to the duties of their co-workers. The final type is related to the culture of acting, which focuses on promoting critical safety thinking among employees under emergency conditions to encourage employees to think and choose the safest possible way in such emergency conditions.

One of the biggest challenges from the organization's perspective is to imbibe these cultural values among all its employees. There are several initiatives that JR East has taken to achieve the same. The most

significant step is the “Challenge for Safety” campaign. In this campaign, each employee is expected to take the lead in efforts that are effective in improving safety. It is a bottom-up approach where employees are motivated to take safety actions rather than develop a forced safety action. Another purpose of the campaign is to promote safety discussions among employees. These discussions are useful for individual as well as collective safety learning. Finally, it is also essential to spread the small group safety discussions across the organizations. JR East achieves the same by recognizing individual efforts and publishing the successful cases in the company newsletter.

21.6 Role of Top Management for Safety at JR East

Fundamental to improving safety management at an organization is the role of its top leadership. Decisions executed by top management determine the priority assigned to safety within the organization, for instance through financial control. As highlighted previously, a well articulated and communicated safety policy is a prerequisite for an effective safety management system, and it is the responsibility of senior leadership to articulate and communicate the safety policy. In addition, top management serves as the leader or role model for other employees. Hence, their actions influence the safety perception of the employees. JR East also recognizes this crucial role of its top management, which consequently has taken a number of initiatives.

- (1) The top management at JR East holds regular dialogues with employees at various management levels to obtain feedback on policies and the current safety state and concerns of the employees. Such actions by top management also reinforce the safety attitude for each employee.
- (2) Safety promotion committees at various levels (headquarters and branch office) have been formed, which undertake investigations for major accidents, monitor trends in accidents, and design countermeasures to deal with safety issues. Important to note is that the JR East president is directly involved in these committees. Through such an overt involvement from top management, coordination and communication across management levels are enhanced for critical safety decisions, without having to reorganize the company structure.
- (3) Top management recognizes positive actions and favorable results by departments and presents them with awards to give

employees a sense of accomplishment and encourage further safety activities. Such steps by top management are helpful in shifting from a “punish to correct” value system to a “praise to encourage” system.

21.7 Key Messages for Organizations

Managing High-Speed Rail Safety

This chapter has presented a systems perspective on HSR safety at JR East. A railway system can never be safe enough. Hence, a railway organization’s pursuit of safety should never stop. For complex sociotechnical systems such as railways, safety should be achieved through harmonized coordination between robust technology and qualified personnel. Proven redundant technical systems relying on up-to-date information about the system status are necessary to execute effective control and ensure safety performance. For personnel, in addition to continuous training, efforts must be made to improve their safety awareness through activities aimed at communicating the company’s safety policy and promoting positive safety behavior. The role of top management of the organization is thus deemed essential in setting up a clear safety policy, communicating it, demonstrating a strong commitment toward safety, and reinforcing positive safety behavior through appropriate rewards for safety actions. Further, any railway system is bound to be affected by external influences, which calls for a comprehensive approach of utilizing the hard (physical systems) and the soft measures (social systems) that are deemed useful in mitigating the effects from such external influences.

21.8 Key Messages for Policy Makers

While the chapter so far has discussed the important strategies for a railway operator in managing safety, the issue must also be discussed in the broader context of the socioeconomic factors affecting the HSR system. As a public transportation system, HSR safety, like any other system, comes at a price. For adequate management of safety, the costs of safety should also be distributed among the three main stakeholder groups—the regulator, the operating organization itself, and the users. The HSR cost structure is such that regulators do not bear the cost of safety, and the operator has the main responsibility of safety provision. While in many of the countries, the regulatory-based safety requirements are almost at par with those of developed countries, the challenge lies in their effective enforcement. Given the complexity of the

system, regulatory-based enforcement is inherently difficult and often ineffective even in developed countries. Hence, many countries have adopted a safety model based on self-regulation where the operators are responsible for maintaining the level of safety.

In this self-regulation model, transferring the safety cost to the end users becomes necessary. To enable such a cost transfer, the first important policy from the government should be ensuring the financial sustainability of the operator, either by providing them support for developing side businesses or in the form of flexible pricing reflective of the safety costs. Development of side businesses will surely require long-term planning and continuous commitment from both the public and the private sectors. On the other hand, even with a flexible pricing model, the transfer of safety costs to its users may not be viable for the operators, as generally HSR competes fiercely with other transport modes. Hence, the policy should also be targeted to modify user behavior. From an individual's perspective, the price of safety has two components: the damage to the self as a result of an accident and the liability damage inflicted upon others as a result of an accident. While an individual may exhibit risk-taking behavior by having a lower perception of self-value, if the price of the liability damage could be increased and effectively enforced through government policy, it will prompt a user to shift from personal vehicles, a relatively unsafe transport mode, to safer modes of public transportation such as HSR. These users who shift transport modes will also have more expectation from the transport operators for safer services, thus providing sufficient incentives for the operators to implement the strategies discussed in this chapter.

Hence, the chapter has presented lessons that are important not only for the managers within an HSR organization but also for policy makers. It is only when the commitment from top management can sustain the often conflicting demands of safety and financial sustainability that an HSR organization can truly deliver on its promise of zero passenger fatalities in 50 years.

Reference

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Salient Features of Human Resource Development¹

Michikazu Mukoyama and Nikhil Bugalia

22.1 Introduction

East Japan Railway Company (JR East) was founded in 1987 and has played an instrumental role in providing efficient transportation services in the eastern part of Japan. The company currently operates a total network of 7,457 kilometers comprising interregional high-speed rail, regional trains, and trains in the Tokyo metropolitan area. The company transports about 17.8 million passenger per day and operates approximately 12,200 trains per day.

The railway sector is an open and complex sociotechnical system, which is undoubtedly influenced by the socioeconomic changes in its operating environment. The railway companies in Japan are also going through a set of challenges, which, sooner or later, many other countries are going to face—that is, aging and rapidly evolving disruptive technologies. This chapter describes the key challenges confronting the railway business in aging Japan and JR East's approach to tackling these challenges. JR East has taken a comprehensive strategy of relying on new technology without losing sight of the importance of human resource development. We focus on illustrating innovative capacity-building and training strategies to tackle the challenges in the railway

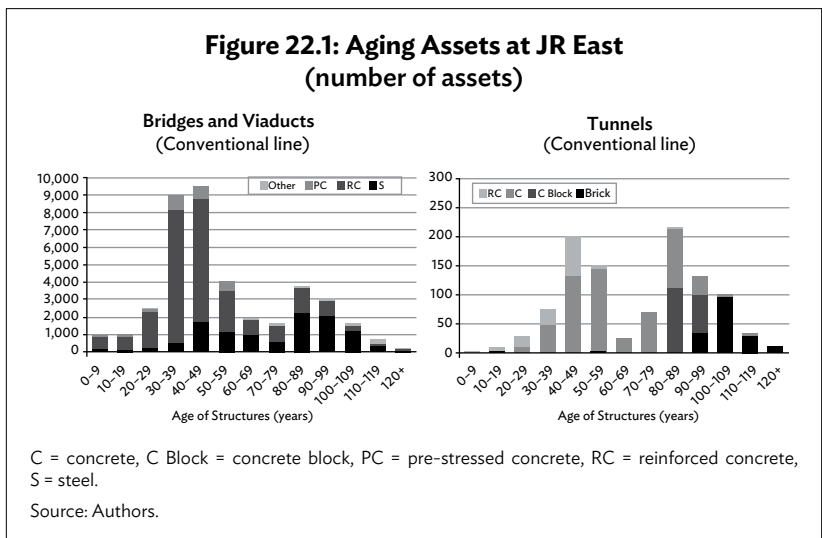
¹ The content of this chapter (including all the figures) were presented by Michikazu Mukoyama at the Asian Development Bank Institute ADBI special sessions titled “Transport Infrastructure and Quality of Life” at the World Conference on Transport Research in Mumbai, India, on 28–30 May 2019. <https://www.adb.org/sites/default/files/related/145966/adbi-transport-infrastructure-and-quality-life-agenda.pdf>. The purpose of the present case study is to offer valuable learning opportunities for practitioners by describing the practices prevalent in one of the leading high-speed rail operators in Japan. The study does not provide any evidence for adopting any specific practices and should be treated as such.

business environment. Essential lessons from Japan are also highlighted for their application elsewhere.

22.2 Challenging Business Environment for JR East

Japan's working-age population (15–64 years) is rapidly declining, along with the total population due to the country's declining birthrate, whereas the number of older people (aged 65 years or more) is increasing at an unprecedented rate. The current trend suggests that the ratio of the working-age population is going to decline by 30% compared to the figure in 2015.² The effect of the declining working-age population is also evident at JR East, where the number of skilled track workers (railway maintenance experts, etc.) are expected to decline by 35% in next 20 years.

However, the demand for maintenance of existing assets is going to remain the same, if not increase. Many infrastructure assets at JR East are growing old (Figure 22.1): some of the bridges and tunnels are more than 130 years old and are still in use for daily services. As part of its activities, JR East is committed to ensuring the soundness of these assets through appropriate maintenance. Given the constraints in



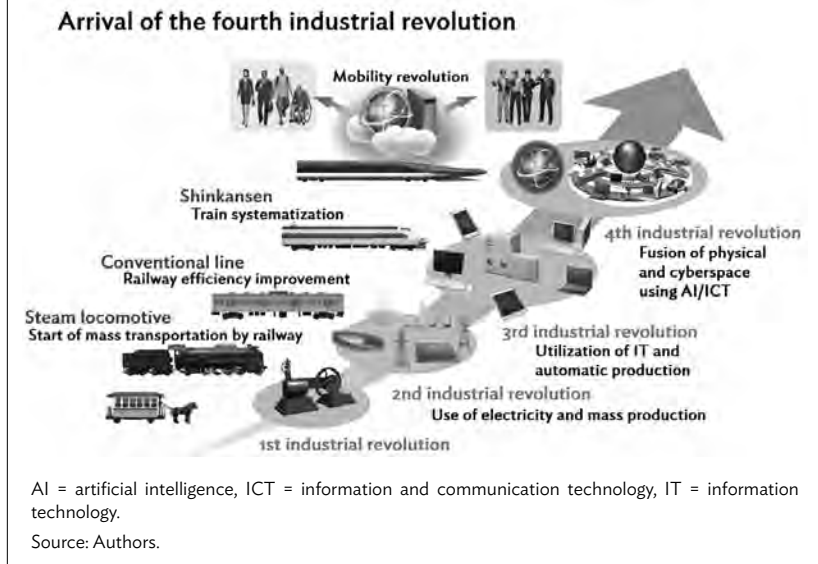
² See Statistics Bureau of Japan. Statistics on Japan. <http://www.stat.go.jp/data/nihon/index1.htm> (in Japanese).

securing skilled personnel for maintenance, JR East needs to manage the growing imbalance between maintenance supply and demand.

Further, the railway business itself needs to transform as the fourth industrial revolution approaches. Historically, JR East has adopted a strategy to advance its railway business by effectively utilizing the latest technology, such as information technology (IT) and automatic production to systematize railway operations (Figure 22.2). Moving forward, a revolution in mobility is necessary as the physical space and cyberspace become more integrated through technologies such as artificial intelligence (AI) or information and communication technology (ICT) in the fourth industrial revolution.

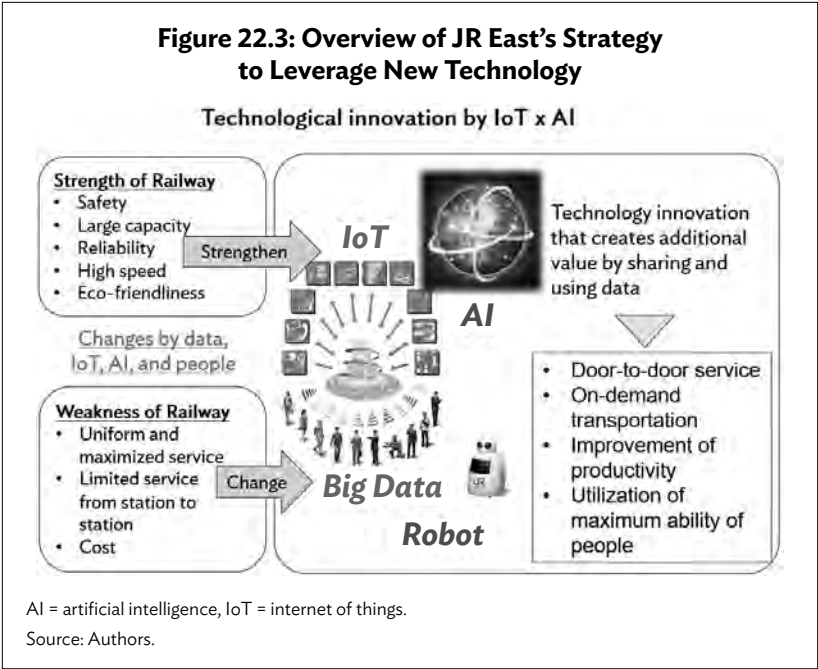
In the automobile industry, the use of ICT in car sharing and realization of automatic driving has already started, covering the weaknesses of the past business and realizing new services. As for railways, there is a need to achieve seamless services using on-demand transportation and cooperation with the secondary traffic network, thus shifting from conventional methods of moving from station to station based on a fixed schedule.

Figure 22.2: Transition of Railway Business with the Advent of Industrial Revolutions



JR East is on the right path to utilize the fourth industrial revolution and deliver on its customers' demand for revolutionized mobility. The company considers that by leveraging the strengths of the internet of things (IoT), AI, big data, robots, and so on, it will be able to generate further efficiencies to strengthen the railway business, such as offering highly safe and reliable services at high speeds while achieving high utilization of the infrastructure capacity. Additional value can be generated through using and sharing big data to overcome the weakness of the traditional fixed schedule transport of railways (Figure 22.3).

In summary, JR East is experiencing a rapid change in the generation of employees due to the decreasing birthrate. At the same time, the social environment is rapidly changing with the advances of the fourth industrial revolution, and other transportation modes are responding to this change. For JR East to maximize the potential of the new technology, it is obvious that its functioning needs to be transformed, and its employees are going to require a range of new skills. Thus, human resource development is at the heart of JR East's transformation strategy, which is highlighted in the next section.



22.3 Innovative Means for Capacity Building and Training

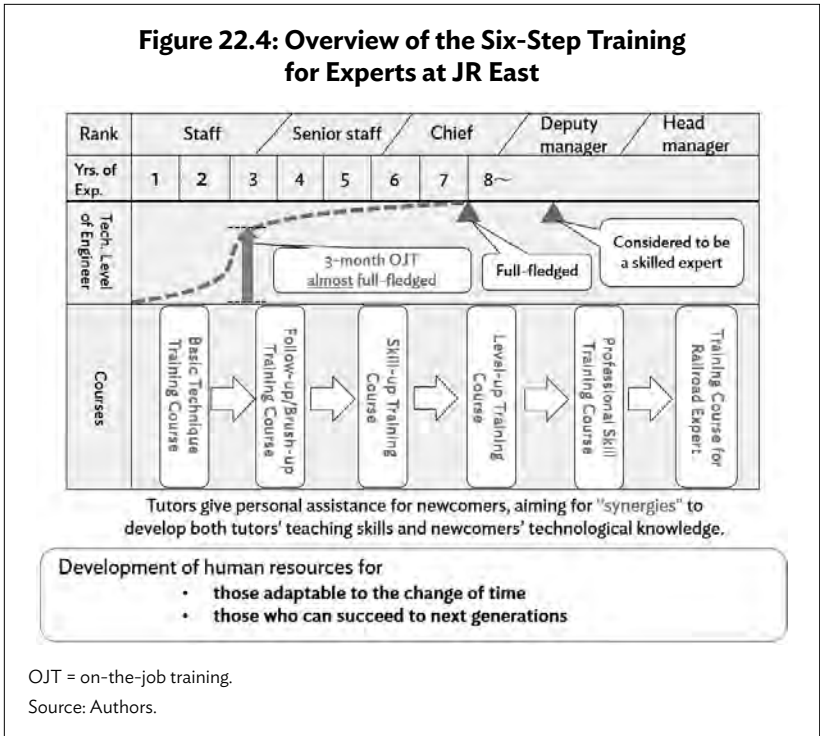
Maintenance work requires skills and knowledge to spot the signs of maintenance needs in time, as the deformation in structures usually progresses slowly. The nature of the job is such that the practical aspects of training must be emphasized. However, because of the extensive focus on maintenance in the past, abnormalities occur infrequently. Such rare occurrences then lead to a situation in which not all employees can accumulate lessons from past failure. Parallels could be drawn from the medical profession, where doctors cannot experience all cases through their patients. Hence, they learn by sharing their case knowledge with each other. In the absence of frequent failure, maintenance workers must be continuously trained using previous case studies through collaborative learning and should be provided the experience of “reality” using innovative tools such as training simulators. JR East’s top priority is to further level up safe and stable transportation. Hence, the training aims to foster maintenance experts who can plan and conduct appropriate maintenance with efficiency as well as incorporate new technologies such as ICT to transform these changes into opportunities.

JR East has thus adopted a framework to facilitate continuous lifelong learning for employees. Employees are hired as new graduates or by mid-career recruitment. They undergo a long-term training course to learn the basic knowledge and skills of maintenance experts. Following this, an effective combination of various on-the-job training methods and off-the-job training as part of group education helps them become “full-fledged” experts. It takes around 7 years in total for employees to be fully trained (Figure 22.4). Further, this system ensures that the next generation of trainers is simultaneously honing their skills of knowledge transfer.

The JR East General Training Center is a facility for education and training. In addition to classrooms and accommodation, a variety of training facilities are provided for the different divisions (life-sized turnouts, tunnel segments, etc.). These training facilities offer an excellent infrastructure for practical lessons to gain the basic skills necessary for various subsystems within the railways.

In addition to the General Training Center, each of the 12 branch offices has its own training center that is responsible for maintenance in their specific geographical segment. The focus here is to impart training on issues that reflect the climate, environment, or other features in each region. These training centers provide training using replicas of

Figure 22.4: Overview of the Six-Step Training for Experts at JR East



the tools that are in operation. Hence, the training conditions are very similar to actual potential situations on-site. To further support the real experience during training, virtual reality technology and other types are used in simulators (as shown in Figure 22.5). These simulators can reproduce experiences of typical operations and accidents related to maintenance works.

The key characteristics of the maintenance worker training program at JR East are as follows. The maintenance requires highly specialized skills, and the quality of the maintenance work is dependent on the capacity of the maintenance workers. The essence of the maintenance worker training program lies in its framework of lifelong continuous training, which introduces all the necessary skills systematically to the employees. These training programs rely heavily on providing the experience of “real conditions” as much as possible, for example, by using instruments currently in operation or through simulators. The training programs are flexible as they provide employees with general skills as well as skills specific to their local conditions. However, in a

Figure 22.5: Examples of Virtual Reality-Based Training Simulators at JR East



HMD = head-mounted display, VR = virtual reality.

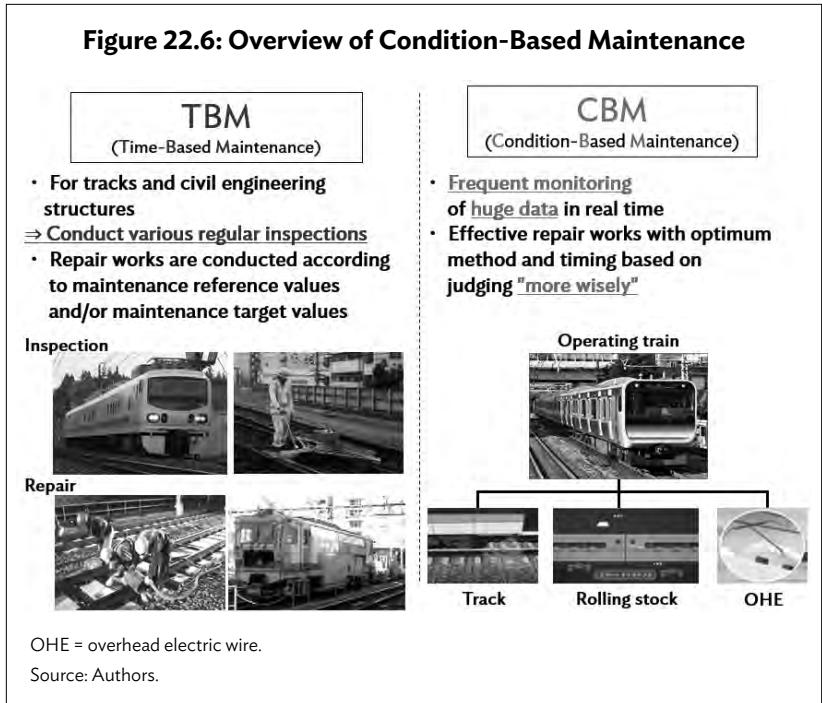
Source: Authors.

situation where the total number of skilled maintenance workers at JR East is expected to decline and there are fewer opportunities for learning from real trouble situations, the challenge ahead is to protect the organizational learning by effectively transferring the knowledge from one generation of employees to the next. Hence, the objective of the training programs is not only to provide training to incoming personnel but also to prepare the next generation of trainers who can then effectively utilize the modern tools to transfer the organizational learning across generations.

22.4 Innovative Approaches for Efficient Maintenance

The training approaches discussed so far are strategies that ensure the quality of maintenance work in a challenging business environment. However, innovation can also be realized by reimagining the entire process of infrastructure maintenance. This section discusses such approaches that can achieve efficiency in the maintenance work itself.

To enhance the overall performance of the asset and prepare for future risks, along with maintenance, upgrade works may also be necessary. Hence, the assets should be strategically upgraded. For example, to mitigate the risk from earthquakes, the entire elevated sections for the JR East HSR have been upgraded in accordance with the revised earthquake standards of the country. The focus is also on adopting labor-saving maintenance methods, such as through mechanization and



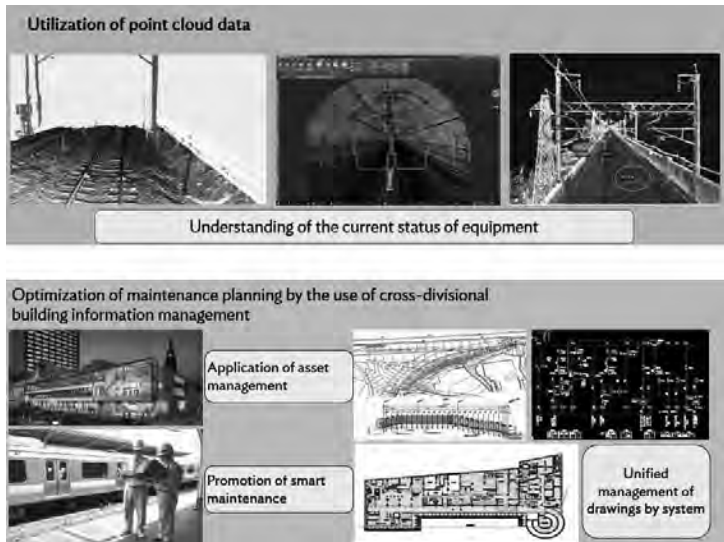
use of robots. Such a process then leads to efficiency, labor savings, and reduction in workplace injuries, among others. Further, fundamentally new approaches to maintenance have also been devised at JR East. The first of these is a shift from conventional time-based maintenance to condition-based maintenance (Figure 22.6). In time-based maintenance, repair works are conducted on a pre-agreed reference or inspection target schedule. However, under the new condition-based maintenance regime, sensors can be mounted on trains in operation, which can then collect a wide range of information from tracks while under operation. Example of data that these train-mounted sensors collect include rail alignment or current collection performance from overhead electric wires. Under condition-based maintenance, the maintenance resources are then optimally allocated to the parts of assets which require them. Moreover, such extensive inspection data prove helpful in detecting potential problems ahead, and different maintenance strategies can hence be planned accordingly.

Further, efficiencies can also be created through full digitalization of asset information. By developing a “digital twin” of the asset (using point

cloud data), the real status of the asset is always available. This information can then be integrated with building information management tools, which can then help in planning detailed maintenance procedures etc. and improve coordination among workers on the ground (Figure 22.7).

The use of fundamentally new approaches to maintenance is beneficial, but a shift toward them creates new demands for employee skills. For example, the introduction of modern methods such as condition-based maintenance and building information management necessitates training the employees for these new skills. However, teaching these skills may prove to be further challenging, as they are very different from conventional skills already possessed by workers. For example, the knowledge of both civil engineering (already acquired) and data science (to be newly acquired) may be necessary to interpret correctly the vast information obtained from sensors. Thus, even with rising automation, human-machine integration is still required, so the training methods and procedures will need to be continuously revamped instead of the classical notion of mechanization replacing humans entirely.

Figure 22.7: Smart Project Management—Coordination between Building Information Management and Integrated Database with Application Programming Interface



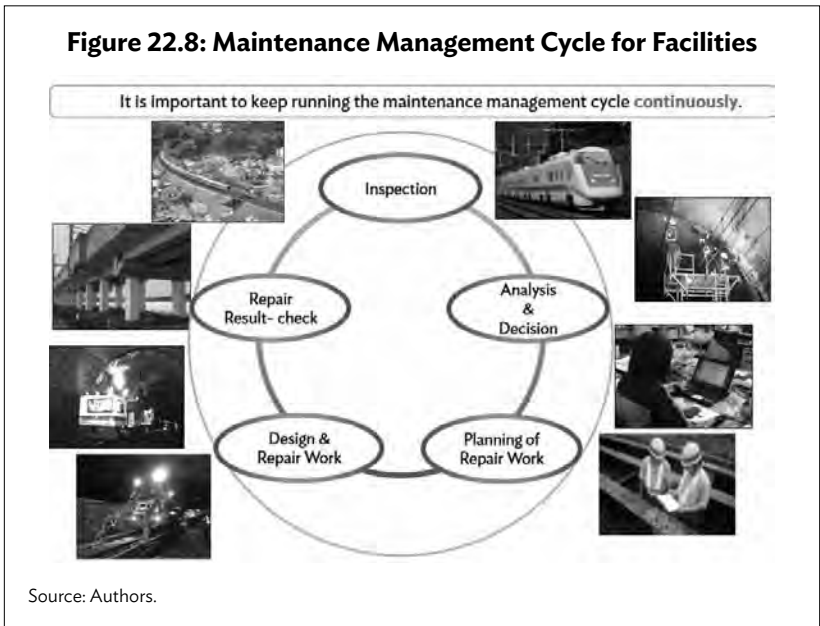
Source: Authors.

22.5 Lessons from JR East’s Experience

The challenges facing JR East’s business are not unique. The aging society is going to affect the supply of skilled labor in many countries, and the manifestations of the fourth industrial revolution are already visible in many other transport modes. For railways to maintain its competitive advantage, new value for passengers must be created, and a comprehensive approach is focus on improvement for both humans and machines. With the advent of new technologies such as AI, the role of humans in the railway system is expected to transform. Hence, further efforts in capacity building and training are necessary.

In JR East’s experience, a long-term continuous approach is necessary for imparting training on specialized skills that are necessary for railway maintenance. Hence, employee training should be integrated into their career growth trajectories at their respective organization. The focus should also be on long-term retention of highly skilled employees, for which assessment of employees’ needs is necessary to plan the incentives optimally.

The training should also be representative of the real conditions as much as possible. Thus, apart from the generalized material for all,



individual task- or environment-specific training should also be offered. In this regard, innovative training methods should be developed that adapt to individual learning capabilities.

Further, the objective of the training programs should be to prepare the next generation of trainers. Since trainers are crucial for sustaining organizational knowledge, the job must be awarded to employees with appropriate skills and credentials. The social reputation of trainers in an organization should also be maintained on par with others, if not enhanced.

For proper maintenance of railways and other large-scale infrastructure, it is essential to continuously and steadily run the maintenance cycle (Figure 22.8). Developing the system, as well as the supporting human resources, is essential to achieve this.

For organizations looking to improve their training curriculum, human resource development plans should be developed at least 5 years ahead of, for example, the planned technical interventions. In doing so, detailed efforts must be taken to clarify the overall organizational structure, roles, and responsibilities of individual actors. Gradually, the comprehensive training needs and required facilities should be identified. Facilities and training plans must be implemented accordingly. Finally, the training process must begin well ahead of the planned utilization.

For the case of the upcoming Mumbai–Ahmedabad HSR project in India—and the many more to come in other countries—human resources must be developed systematically before the commencement of the services.

23

Capacity Development for Transport Infrastructure

Sudhir Misra

23.1 Introduction

It is often said that engineering graduates in general—and civil engineering graduates in particular—are not taught the things needed by the industry. Depending on who in the industry is talking, there is a different wish list of topics and subjects that the industry feels must be part of the curriculum for a bachelor of technology. In that sense, it is alleged that the curriculum followed in colleges is incomplete. For the sake of simplicity and convenience, further discussion here is confined to the civil engineering domain, though the principles are easily extendable to other fields. Although there cannot be a doubt on the need to continually change the curriculum to remove obsolescence and keep it up-to-date with the latest professional developments, on the one hand, and to keep the hopes and aspiration of the young students, on the other, the limitations faced by the educators also need to be borne in mind. It should also be clearly understood that the economic principle of “let market forces govern” cannot be applied to deciding an academic curriculum for good reason.

This chapter attempts to explain the basic contours on which the exercise of curriculum design is carried out, using what is done at the Indian Institute of Technology Kanpur (IIT Kanpur) as a case study. The case study illustrates some of the challenges that IIT Kanpur faces in “failing to meet” the industry demand. This chapter also seeks to make some simple comparisons of the education in the areas of medicine and engineering, to bring to the fore some critical gaps in the college curriculum of the latter, especially in the case of civil engineering. The ideas for filling these gaps are then identified by drawing lessons from international practice. The chapter also clearly highlights the need for the employers of engineering graduates to

develop appropriate training modules both at the inception of new employees and during their careers to supplement their college education. An underlying assumption in the thought process presented in this chapter is that civil engineers are better positioned to build, operate, and maintain infrastructure, and hence are the easiest to train for this role.

23.2 The Education Process: Analogy with a Manufacturing Unit

This section draws an analogy between engineering education at the undergraduate level and the manufacturing industry. The incoming students can thus be looked as *raw material*, the knowledge imparted through different courses during their stay as the overall process, and the graduating engineers as the *finished product*. The discussion in the following paragraphs is based on this broad schematic framework.

23.2.1 Raw Material

Colleges “select” their raw material from students after they finish high school (typically with a specific background in physics, chemistry, and mathematics). This selection process differs by country. For example, in the United States, admissions are primarily based on the SAT; in countries such as India, they are mainly based on highly competitive joint entrance examinations in some colleges (e.g., Indian Institutes of Technology) or students’ performance in high school (in terms of marks secured). The allocation or selection of academic disciplines or branches may be based on similar criteria, such as rank, number of seats available, and the preferences of students.

23.2.2 The Education Process

The design of this process mostly follows the academic program, consisting of compulsory courses (science, engineering science, humanities, departmental or professional) and elective courses, which could be from within the department or outside. The exact contents of each course are the critical elements of the process. The structure is decided, keeping in mind the characteristics to be imparted to the finished product (e.g., a civil, mechanical, or electrical engineer) and the resources available in the college in terms of faculty, laboratories, and so on. Under this larger umbrella, several other constraints define and limit the coverage in the curriculum, as will be discussed later.

23.2.3 Output and/or Product

A graduate civil engineer is then ready to be employed and serve as a useful member of society. The characteristics of the products largely depend on the process it has been put through. It is when evaluating this “product” that the industry, as the “end user” of the products, complains that the product is not “user-friendly” or “user-ready.” In this context, it is essential to understand the following:

- (a) details of the process—in other words, the course structure that constitutes the educational curriculum in civil engineering; and
- (b) diversity in the potential employers—ranging from regulatory bodies to construction companies to design and consulting companies, keeping in mind also that some students of any given graduating class choose to pursue higher studies and then pursue a career in teaching and research.

23.3 Civil Engineering Curriculum at the Indian Institute of Technology Kanpur: A Case Study

23.3.1 The Basic Contours

The curriculum is designed from the point of view that at the end of the education, the finished product, as discussed earlier, has the qualities expected from an educated graduate, an engineering graduate, and finally an engineer with a degree in a certain specialization—more or less in that order. The following define the basic contours within which the exercise for curriculum development is carried out:

- (1) The curriculum should be completed in a specific time (e.g., 8 semesters, or 4 years).
- (2) Each semester will be taken to be of a particular duration (e.g., 14–15 weeks).
- (3) The total number of courses in any semester should be decided such that (i) the quantity does not exceed a given number (e.g., six); (ii) the contact hours, i.e., that the student spends in classes, tutorials, and laboratories, does not exceed a given number (e.g., 25 per week); and (iii) the total load, including the time for home assignments and laboratory reports, does not exceed a given number (e.g., 45 hours per week).
- (4) Total credits to complete a bachelor’s degree range from about 420 to 430, depending on the department (which translates to

about 50–55 credits each semester), and there are conditions on how these credits can be accumulated from among the different baskets of courses as briefly described in the following paragraphs. A detailed discussion of how the credits for a course are decided has not been included here.

23.3.2 The Course Structure

The following paragraphs provide an outline of the basket of courses that students go through as part of their education in civil engineering at IIT Kanpur. To facilitate understanding, the courses have been divided into different groups.

Nondepartmental Core Courses

These are compulsory courses at the institute level that all bachelor of technology program entrants need to take, regardless of their specialization. They can be further divided into courses from different disciplines, as briefly discussed in the following:

- **Basic sciences:** Incoming students have different levels of understanding of the basic sciences, which form the essential foundation of engineering education. To create a level playing field, basic courses in physics and chemistry, including a laboratory component, are part of the initial basket of “core compulsory science courses” in the first year. Whereas the physics and chemistry courses are scheduled only in the first year, instruction in mathematics and applied mathematics continues over three semesters. A compulsory course in life sciences was added to this basket in the last revision in 2011. The basket comprises about 60–65 credits in the program.
- **Engineering sciences and science options:** Courses such as strength of materials, rate processes (introduction to fluid mechanics, heat and mass transfer), material science, applied probability and statistics, numerical methods, earth and environmental sciences, thermodynamics, and a course in a computer programming language form the “bridge” courses between natural sciences and core engineering subjects. Depending on their relevance, a department either requires its students to take specific courses or leaves it to the students to choose some of them. In all, students are expected to complete about 40–45 credits from courses in this basket.
- **Technical arts:** There are courses in engineering graphics as well as mechanical and metallurgical workshops to expose students to another aspect of engineering and introduce them

to the shop floor. These courses occupy space equivalent to about 25–30 credits in the engineering curriculum.

- **Humanities and social sciences:** Apart from economics, which is almost an integral part of engineering understanding and decision making, exposure to courses in other humanities and social sciences streams, such as sociology, psychology, and philosophy, provide students an opportunity to see the development and functioning of human society in an advantageous way. Such courses also expose them to a slightly different method of thought and exploration. Depending on their interest and availability, students are expected to complete four to five courses during their stay at IIT Kanpur from this basket, which thus has a share of about 45–50 credits.
- **Open electives:** About five courses (or 50 credits) are left in this slot to allow students to explore areas which they may not be able to do otherwise, since they study in a given department. Of course, a student can take departmental courses also in this slot, provided the timetable permits.

Departmental Courses

With a history as old as civilization, civil engineering has an unenviable spread in its scope, which is reflected in 7–10 graduate programs within the department in various universities in the world (in IIT Kanpur, the number is seven). Almost all traditional departments in civil engineering across the world have courses in structural, geotechnical, environmental, transportation, hydraulics and water resources engineering, surveying and geoinformatics, etc. (IIT Kanpur, n.d.). To cover these areas, the departmental curriculum may be divided into two parts: compulsory and elective, which could comprise 13 courses (about 110–115 credits) and four courses (about 35–40 credits), respectively.

Table 23.1 gives a brief description of the compulsory courses in the departmental curriculum as far as IIT Kanpur is concerned.

After obtaining an overview of the whole spectrum of the profession through the compulsory courses, students are required to take about four elective courses from within the department in the “departmental elective” slot in order to get more exposure and insight to a specific stream depending on the student’s choice. Of course, it is imperative for the department to offer an appropriate number of elective courses in different streams to provide the students with a reasonable basket to choose from.

Table 23.1: Description of Compulsory Departmental Courses in Civil Engineering

Sub-discipline	Description	No. of Courses
Structural engineering	Analysis, design of reinforced concrete structures, design of steel structures, prestressed concrete structures	3
Environmental engineering	Air pollution, fresh and wastewater treatment, solid waste management, design of related facilities	2
Geotechnical engineering	Soil mechanics, different types of foundation systems and their design, ground improvement	2
Transportation engineering	Traffic engineering, pavements—rigid and flexible	1
Hydraulics and water engineering	Hydrology, irrigation systems, hydraulic structures, water supply and its network	2
Surveying and geoinformatics	Traditional and modern surveying, introduction to remote sensing and its applications in civil engineering	1
Others	Construction materials, basic construction management	2

Source: Author's compilation.

23.3.3 Some Comments on the Course Structure and Curriculum

In a nutshell, on the basis of the earlier discussion, it can be stated as follows:

- (a) Although the data in the discussion have been borrowed from IIT Kanpur, the situation is similar in other engineering colleges as well, and there is no major change in the overall tenor of the arguments presented, albeit some specifics may not apply if more similar data are collected.
- (b) Although the curriculum provides a sound scientific foundation to the engineering program, the practical components (e.g., methods and management of construction, quality, safety and economics of construction, contract management, and financing of construction projects) and new concepts such as sustainable construction are visibly absent from the curriculum.

- (c) The diversity in employers, ranging from consultants in diverse areas to construction companies, designers of various systems and processes, and regulatory bodies, implies that different employers require different skill sets from their employees, which makes the task of creating a (universal) user-ready product virtually impossible, especially in light of inherent constraints.
- (d) Given the mostly self-imposed constraints (e.g., academic load for effective learning and absorption, or program length), though it is fair to say that the product (graduating student) is not “user-ready,” it is difficult to say that the curriculum per se is incomplete, as there is simply not enough space in the time available.

This section aims to establish the basic argument that a curriculum in civil engineering in a college can only provide the foundation on which employers need to create a superstructure of their choice through serious, concentrated, and planned training programs both at the initial (orientation) level and at different points in their employees' careers.

23.4 Comparison between Medical and Engineering Education

Reference has been made to the absence of a practical orientation in the engineering curriculum at large and in the civil engineering curriculum in particular. This section provides a qualitative comparison with medical education, which has some striking similarities as well as differences with the approach adopted in engineering. Both disciplines—medicine and engineering—seek to train professionals who can practice their profession. In addition, their education and practice, in either case, is or indeed should be based on the different pure and applied sciences.

23.4.1 Medical Education

Like engineering, medicine is a science-based practice-oriented profession, and no matter how much scientific classroom instruction a student receives in optics, anatomy, and so on, for example, an ophthalmologist should be able to piece together and synthesize the classroom instruction to the benefit of a patient who complains of difficulty in vision. The same argument can be built for a surgeon or a physician, although there is a reasonably justifiable argument that whereas science can be taught in classrooms, the “practice” cannot be

taught and must be learned through experience. At this stage, the critical answer to seek is how such synchronization of science and practice happens in medical education.

In this context, the following are some important points that need to be borne in mind:

- (1) A medical college is usually linked with a hospital, which serves as a “live laboratory” for practical training of medical students and supplements any other laboratory or demonstrations that may be held in the medical college as part of the classroom discussion. Of course, it cannot be over emphasized that “education” in the hospital happens—and indeed should happen—under very careful guidance and supervision.
- (2) The faculty in medical colleges are also regular doctors in hospitals. In other words, they are expected to play a dual role: treating patients, on the one hand, and teaching and overseeing the education and training of students in the medical college, on the other. Education here refers to that for the students who are supplementing their classroom instruction, whereas training refers to on-the-job training of interns who have completed their classroom instruction and are working, practically full-time, in the hospital as trainee or junior doctors.
- (3) The abovementioned synergy between education and training ensures that the “data” from the practice (i.e., at the hospital) are readily available for analysis in the educational environment of the medical colleges. Further, such synergy facilitates the supervised introduction of research findings in the practical domain and keeps the student abreast of the latest developments, research challenges, and importance of trials at different levels.
- (4) Medical education is also an outstanding example of having the students in medical college work in an environment that keeps them very close to their future profession. Such a system merely has too many positive “spillover” effects, including some of the following:
 - (a) The students witness equality and inequality in society closely, and know the joys of birth, creation, and cure, as well as the sufferings of disease and illness, and through all these the importance of health and the value of human life.
 - (b) There is no disillusionment with the profession once the students graduate, which is a common condition that affects engineers and they leave their jobs within a few months.

- (c) The students in medical colleges closely see the concept of specialization and super-specialization.
- (d) The students are trained with the larger picture in the backdrop of their education, and see how different systems, some of which are nontechnical, such as stores and inventory, maintenance of infrastructure, and interface with legal and social institutions, interact with each other at different levels.

Although the descriptions in this section highlight the important role that the hospitals play in the training of doctors, it should be emphasized that this happens under strict regulatory mechanisms to ensure that the health and interests of the patients are not compromised. This also brings to the fore an important dimension of the role of professional bodies in designing and developing the curriculum and overseeing its implementation, as well as the certification and licensing of professionals. Whereas the professional bodies are quite active in medicine, their involvement in engineering education is somewhat limited to more developed areas of the world, where there is a well-developed system of professional certification, accreditation, and so on.

23.4.2 Engineering Education

Even though engineers are expected to apply scientifically gathered knowledge for human welfare, their curriculum is (almost) exclusively confined to classrooms and laboratory training as may be imparted in educational laboratories. The equivalence with the “education” that happens in hospitals in the case of medical education as discussed earlier is virtually absent. Hence, the following comments can be made:

- (1) Although some colleges have an academic and a non-academic requirement for practical training, it is mostly limited to a summer term of about 6–8 weeks. Practical training is usually scheduled at the end of the third year, when it is believed that students have enough understanding of the engineering principles to be able to understand what goes on in the field. This “exposure” has too many limitations, including:
 - (a) the training happens in an environment that is not even remotely a part of the educational environment;
 - (b) the mentor in the field has virtually no understanding of the background of the trainee and at times has minimal idea of what the expected outcome of the training is; and,
 - (c) the training of different students happens at various establishments, and it is difficult for the students to share

and learn from each other's experiences. For example, if different students from a civil engineering class go to sites dealing with concrete and steel construction, or a design office for their internship, their experience of the field is simply not comparable.

- (2) The teachers in engineering colleges are themselves quite often not directly involved with the industry, and that limits their ability to relate classroom instruction to field practices.
- (3) Information about field practices, problems, and their solutions, most of which are developed and implemented by field engineers, is retained by the field engineers and the companies involved and is very rarely shared with the academic world, aggravating the situation of (2) above.
- (4) There are a lot of professional documents and codes of practice, which are basic provisions for practicing engineers and which were developed because of the need for uniformity and standardization. They are revised from time to time and are very often country-specific. Further, given the widespread use of these documents in the profession, instruction in colleges sometimes is based on these practice-oriented documents rather than scientific principles.
- (5) The disconnect between the academic world where the learning happens and the real world where the practice happens causes an almost complete lack of understanding of the latter when the students graduate and find themselves in the world of practice. This disconnect quite often leads to disillusionment and causes engineers to change jobs quickly in the initial period when they try to find a place of employment suited to their expectations.

23.5 Concluding Remarks and Role of Employers and Importance of On-the-Job Training

A highly simplified description of the overall curriculum used to train a civil engineer in an engineering college has been presented in the preceding paragraphs, along with a comparison with medical education, which can be looked upon in a similar vein, given that both disciplines can be considered professions that involve “application of scientific principles from diverse fields.”

The civil engineering curriculum at IIT Kanpur has been used as a case study to highlight the fact that given the balance of credits and the space available in the curriculum, the departmental courses at IIT

Kanpur vary roughly by 35%–45%, depending upon the kind of courses the students take in the open elective slot. Although this distribution is only approximate, it is indicative of the fact that structural changes in the curriculum thinking are necessary to prepare the engineers better for their (future) jobs. Further, given the spread of subareas within civil engineering and the fact that the entire department's share in the overall curriculum is only about 35%–45%, it can hardly be expected that students will be really ready to “hit the ground running” when they join a company involved in the planning, design, construction, operation, or maintenance of infrastructure.

The challenges for developing the overall capability of engineering graduates, specifically civil engineering, are thus multifold. On the one hand, universities are seemingly limited in their ability to impart even the vast amount of existing knowledge (basic and field specific) to their students, let alone having a clear focus on knowledge about new emerging fields. On the other hand, there is an apparent disconnect in engineering education between what is taught at the universities and the realities of the field. The advantage of a medical school-like model is that by removing the disconnect between the education and the practice, synergies can be realized, ultimately leading to students capable of handling the complexities of the real world upon graduation. The need for the hour is thus to identify the innovative solutions that can reduce the gap between education and actual practice for engineering education.

Several higher vocational education programs in other countries have supposedly proven to be useful in this regard, for example in Germany (*The Atlantic* 2014), Sweden (Swedish Council for Higher Education 2019), and Singapore. These programs start right after graduation from high school, or even earlier. For programs in Sweden, approximately 25% of the time is spent on workplace training. Such workplace training is an excellent chance for a future employer to get to know a possible new employee and furthers the chances of a student's professional development. The Swedish National Agency for Higher Vocational Education inspects and audits the quality of the programs and handles feedback from students and the industry. The standardized programs ensure that all the students are learning similar things at the same time, allowing greater flexibility in choosing career paths and apprenticeship opportunities. Upon graduation, such “finished products” can readily be hired by the industry. Some universities also accept the credits earned through higher vocational education for their graduate programs.

One of the biggest challenges implementing such advanced higher vocational education programs in India will be destigmatizing vocational

training (*The Economic Times* 2018). Yet again, lessons must be learned from countries with successful programs and localize the solutions according to the specific challenges.

The discussion in this chapter also highlights the importance of the role of employers in training the engineers through structured training programs. These need to be designed keeping in view the specific skill set a particular employer wants their employees to be honed in. For example, whereas a training program may focus more on construction management-related issues for companies involved in construction, it may focus more on developing software relating to design in the case of designers and consultants. Within the latter too, structural consultants may have a different niche compared to other consultants who work more in the area of environmental impact assessment and so on. At the same time, the educational institutions need to make sure that foundation courses are provided to the graduating engineers in the different fields so that they are able to quickly understand and grasp the material covered in these programs.

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Quality-of-Life Implications of Public Transport Integration

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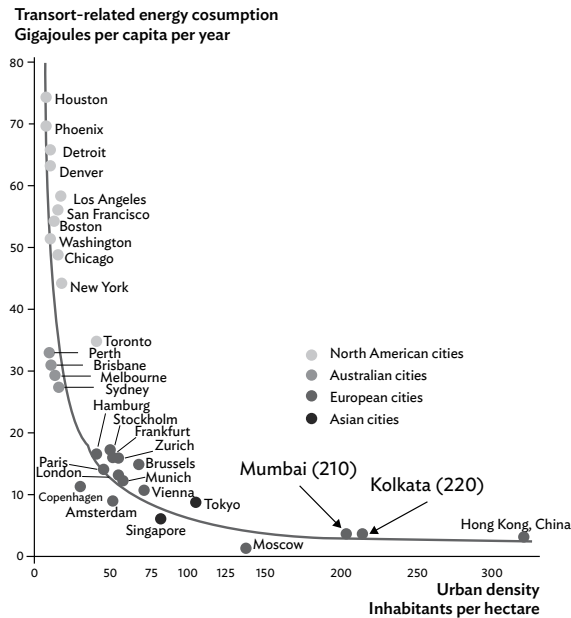
24.1 Background: Opportunities for Asian Cities

A report by NEA Transport Research and Training (2003) defined transport integration as “the organizational process through which the planning and delivery of elements of the transport system are brought together, across modes, sectors, operators, and institutions, with the aim of increasing net social benefits.” From the definition itself, transport integration has been identified as the intervention that ultimately leads to societal benefit. This is because commuters are better connected to their destinations, which satisfies their needs (workplace, market, etc.). This is in turn responsible for improving commuters’ satisfaction. For example, if a commuter undertakes a journey with different schedules and transfers but without adequate coordination of passenger information, the commuter often feels dissatisfied.

Furthermore, a World Bank report by Zimmerman and Fang (2015) suggested that amalgamating timetables, fares, and stops between the commuter rail, subway, and buses will not only make it more convenient for commuters, but will also improve the operational revenue of these public transit modes. They also suggested that seamless and integrated public transportation “is particularly important in urban environments with fast growing economies,” such as the People’s Republic of China and India, such that public transport competes with private vehicle usage.

Fortunately, Asian cities are blessed with an advantage that is conducive for promoting public transportation. Newman and Kenworthy (1989) pointed out that there is an inherent advantage for cities with high urban densities: as urban density increases, transport-related energy consumption decreases. This is because a more compact city will lead to fewer vehicle-kilometers traveled in comparison to a spread-out urban

Figure 24.1: Relationship between Urban Density and Transport-Related Energy Consumption



Source: Newman and Kenworthy (1989) overlaid with the urban density of Kolkata and Mumbai.

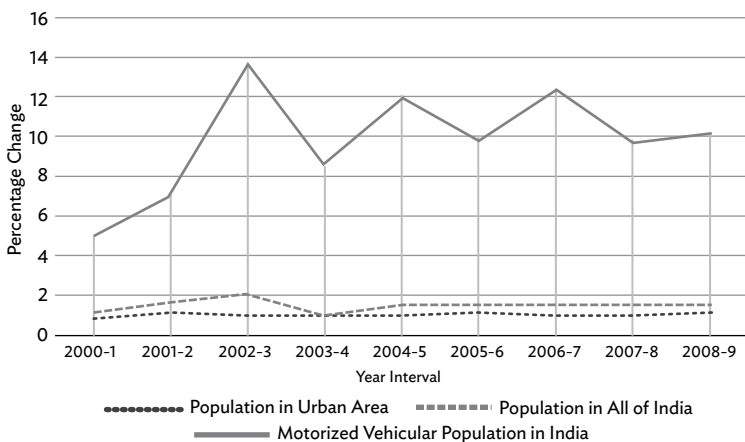
configuration. This phenomenon can be seen in Figure 24.1, where the black dots represent Asian cities, all of which have a consumption rate that falls below 10 gigajoules per capita per year. Overlaying the urban densities for Mumbai and Kolkata in Figure 24.1, we see that Indian cities also fall under this low transport energy consumption rate. Additionally, Sung and Oh (2011) demonstrated that high-density cities such as Seoul can improve their public transit ridership by applying public transport integration strategies. Thus, there is an opportunity for such cities to boost public transit ridership with the right set of strategies.

24.2 Introduction: Public Transport Integration

Berlepsch et al. (2018) ascertained that public transit could be made attractive by enhancing service quality and integrating all modes of public transportation. A report from the Ministry of Statistics and Programme

Implementation of India (2017) showed that the average yearly growth in urban vehicular population in the country is an alarming 10.07%, which was higher than the average yearly urban population growth of 3.2% between 2001 and 2015 (Figure 24.2). Building wider roads to accommodate this extra traffic will no longer be a solution, as not only does the extra capacity induce further traffic, but, at the same time, land is a limited resource in congested urban areas. The only solution to buck this trend is to reduce the number of vehicles on the road—moving people rather than vehicles and influencing more people to use the mass transit systems. High-speed rail (HSR), categorized as high speeds of 200 kilometers per hour or more, plays a crucial role in this aspect, especially in the case of intercity travel. The multimodal connectivity with HSR could be a positive driving force in realizing significant societal and economic benefits for the country. HSR infrastructure should include not only tracks, propelling technology, and signaling systems, but also the facilities in and around the HSR stations. The station area connects to feeder services and the last-mile infrastructure, and therefore designing such transfer facilities is of utmost importance. Bharule (2019) identified that apart from social capital building, extensive case studies have helped build empirical research on the local impacts of HSR stations on urban development. Therefore, such an intervention is likely to have positive economic repercussions.

Figure 24.2: Rising Vehicular Population in Indian Cities



Source: Compiled by authors from various sources.

This chapter therefore focuses on a framework for public transport integration around station areas. Such integration, with other modes and the transport network, would not only make HSR intermodal but also help increase its ridership, as indicated by Chava, Newman, and Tiwari (2018). Most of the transit-oriented development (TOD) is creating neighbourhood gentrification as a result of higher housing prices. Hence, the contribution of TOD policies toward sustainable transportation goals remains unclear. The study by Chava, Newman and Tiwari (2018) uses Bangalore, India, as a case study to examine the effects of TOD gentrification on transit ridership. In Bangalore, station areas are witnessing the influx of large capital on condominiums, in response to TOD policies and accessibility to transit. These condominiums are expensive and attract the affluent, leading to new build gentrification. The study evaluates the impact of such new build gentrification on transit ridership. Data analysis suggests that, gentrifiers contribute significantly toward metro ridership because of the metro's high level of service. The next section of this study deliberates on the different components required for integration, followed by real-world practice examples from Asian cities that demonstrate such integration.

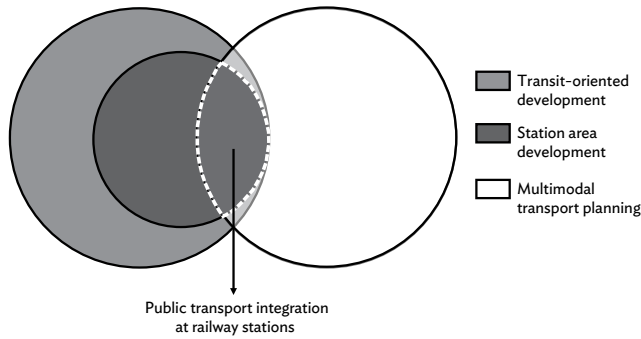
24.3 Conceptual Components for Integration

Transport integration draws closely from two domains of knowledge: (i) station area development, which is a part of the larger concept of TOD, and (ii) multimodal transportation planning (see Figure 24.3). Multimodality in transportation planning refers to considerations for various modes and the interconnections between them. Multimodal considerations may vary from interventions in transportation nodes, such as integrating a railway station area with public transit, to the transportation mode itself, such as allowing bicycles on the subways or having a bicycle storing facility on board public buses. Station area development refers to the upgrading of the station area in such a manner that it enhances transport integration, which, in turn, will further drive the development of the adjacent area. Hence, station area development is depicted as a subset of TOD in Figure 24.3. The intersection of these three knowledge domains gives rise to the basic components that favor public transport integration. These components are described in detail in the following subsections.

24.3.1 Transit-Oriented Development: Station Area Development Principles

Transport integration in station area development is the first step toward integration in the true sense as it accommodates the design

Figure 24.3: Conceptual Domains of Public Transport Integration at Railway Stations



Source: Authors.

in the physical level. Sands (1993) categorized HSR stations at two levels: (i) HSR introduced to an existing conventional railway infrastructure and (ii) new stations built for HSR exclusively. There is a fine difference between the two levels in terms of station area. Terrin (2011) described an HSR station area (as quoted in Bharule 2019) as “a new kind of mobility infrastructure that is a hybrid of an airport hub, service-oriented shopping space, while remaining a multi-cultural public space at the same time.” Evidently, the difference in an HSR station area and an existing railway station area remains in the form of additional service upgradation. However, the basic functional layout of spaces and their integration to other public transit modes remains the same.

In their report for the Institute for Transportation and Development Policy, Bhatt, Paradkar, and Fliert (2012) provided a guide for station area planning in Indian cities, enumerating 10 key principles:

- (1) Aligning the development character with the transit and place type
- (2) Creating a walkable urban street network
- (3) Promoting a comprehensive street network
- (4) Managing public and private parking to curb car use
- (5) Designing better public spaces and amenities
- (6) Ensuring integrity of natural systems and the environment
- (7) Conserving the built heritage
- (8) Preserving affordable housing close to the station area

- (9) Involving key stakeholders
- (10) Generating value for financial sustainability

These principles focus heavily on the built environment aspect (key principles 2–8). Further, principles 2–5 focus on developing the surrounding built environment of the station area, whereas principles 6–8 are related to the conservation, preservation, and maintenance of the surrounding infrastructure. Therefore, it can be concluded that the physical space is an important part of the station area.

The location and character of the surrounding area is an important consideration. The first key principle stresses this aspect, which is further supported by Loukaitou-Sideris et al. (2012). These researchers discussed six variables that intervene and influence the development of the station area: geographical context, ridership, station location, network type, type of guideway, and type of parking. Therefore, location and context are significant concerns, due to which a model station area plan may not be replicable between different stations and may warrant specific considerations based on the surrounding site.

Reiterating the inferences so far, physical integration is a must for public transport integration to the station area. However, true integration would not be possible if the modal transfers are not seamless and coordinated. Therefore, there must be other levels of integration, which are explored in the following subsections.

24.3.2 Multimodal Transportation Planning

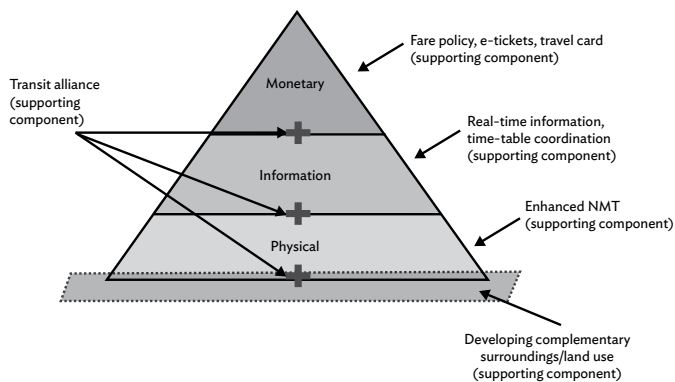
Once the physical integration is in place, the other components need to be incorporated, much like the hierarchy of needs as proposed in psychology by Maslow in 1943 (McLeod 2007). He suggested that individuals must satisfy lower-level deficit needs to a certain extent before progressing on to meet higher-level growth needs. Bivina and Parida (2019) extended this concept to the needs of pedestrians and their expectation of the walking environment. The lowest level of pedestrian need is for a safe walking environment, followed by their own security; thereafter, there is a need for unimpeded mobility and efficient infrastructure. Lastly, the pedestrian's need is for a comfortable and convenient walking experience. Similar to the concept of the hierarchy of needs, the commuter's need for utilizing a multimodal transit system could also be categorized. Berlepsch et al. (2018) suggested that a commuter's need will entail convenience, easy access, comfort, affordability, competitive travel times, and safety. Barring comfort and safety, which are characteristic of the mode being used, the remaining four needs are addressed through a transport integration strategy. As explained earlier, physical integration between public transit

modes would be a good intervention for enhancing convenience. Close proximity between the modes would ensure easy accessibility for the commuters.

Once the physical integration is in place, it would enable travel decisions to be made by commuters such that they save time and money. This leads to the next stage of integration at the information level. Consistent travel time information and well-coordinated transit schedules would help commuters plan their journey well in advance. Commuters will select between modes and routes to complete their journey. This will open up a number of possibilities and therefore give access to a more equitable distribution of transportation benefits. However, the complete transfer of benefits to the economically weaker sections will not take place if these joint travel decisions are not supported with affordability. The multimodal experience will only be complete with fare integration.

Fare integration is the last level of integration in the conceptual hierarchy of needs model. An integrated fare policy will not only save the hassle of booking separate tickets but also make a total journey affordable. Most integrated fare policies, in an effort to make the transit experience attractive, support subsidized fare amounts for longer and multimodal routes. Thus, cognitively, commuters plan journeys that are optimally suited in terms of time, money, or both.

Figure 24.4: Integrated Public Transport Hierarchy of Needs



NMT = nonmotorized transport.

Source: Authors.

Therefore, along with physical integration, information and monetary (fare) integration form the hierarchy of needs for an integrated public transport commuter using the railway station. Figure 24.4 gives a conceptual depiction of the same. It is interesting to note that Berlepsch et al. (2018) further subdivided the information levels into (i) integrated passenger information, and (ii) coordinated timetables and real-time information.

24.3.3 Supporting Components

To support this pyramid, other elements need to be present so as to provide a seamless integration experience for commuters. Physical integration would be amiss without the site-specific support of proper nonmotorized transport (more precisely walking) infrastructure. Commuters alighting and boarding between modes in an integrated public transit station area will be in close proximity; therefore, it is intuitive to provide walking infrastructure for the interconnection between these modes. Therefore, nonmotorized transport support is an important requirement.

Information integration would be impossible without proper access to the timetable information for the various modes. For this purpose, the station area would need an upgrade regarding the visual design of information. Real-time updating of information is also a useful component, as it helps commuters plan both beforehand and on the go.

Monetary integration is supportive only if the fare policies of the different modes are brought together as one. Smart travel cards and other e-ticketing systems act as good interventions for seamless and hassle-free travel.

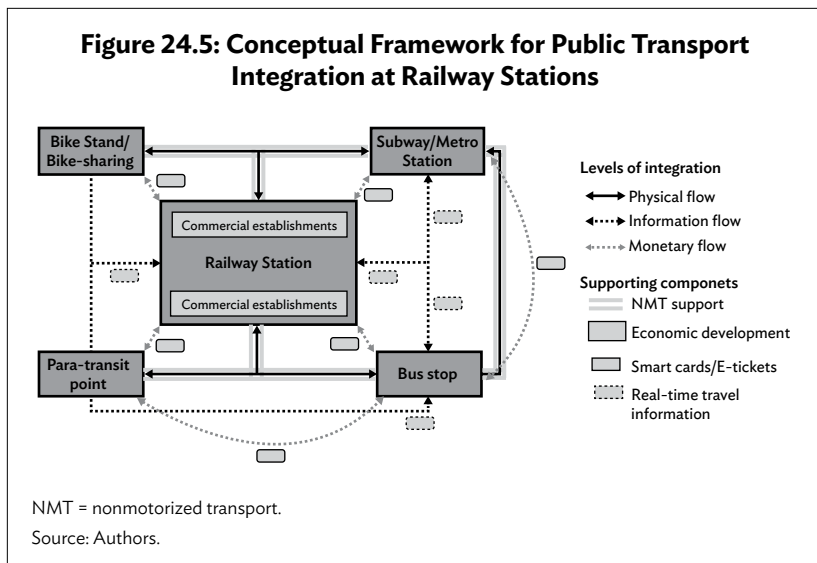
Transit alliance, as defined by Berlepsch et al. (2018), is an organizational option for integrated public transportation planning. Under this intervention, there are alliances between public transport operators and public transport administrations. The task of such an alliance would be (i) planning transport network and services, (ii) organization of fare system and ticketing, (iii) planning coordinated timetables and dissemination of information, and (iv) service quality control. Under such an alliance, all the needs in the hierarchy are systematically served.

24.4 Schematic for Integration

Utilizing the conceptual components from the previous section, it could be concluded that along with physical, information, and monetary integration, supporting elements play an important role to sustain

the integrative environment. A diagrammatic representation of these relationships is given in Figure 24.5.

An important point to be noted in Figure 24.5 regarding the integration between each mode is that it is through the railway station. The physical flow is deliberately made absent between the bicycles and para-transit, since it is unlikely that users of such modes will have to come to the railway station to avail themselves of them. The only integration between these modes are through the railway station and/or the bus and metro modes. The information flows are also unidirectional for bicycles and para-transit—that is, the information regarding the railway timetable needs to be shared with the users arriving to the station area premises using these modes and not the opposite, since bicycle and para-transits do not have fixed timetables. However, fare integration remains the same, as it is convenient.



24.5 Case Study and Policy Interventions from Asian Cities

In this section, we study various integrated railway station areas from Asian cities and investigate the components, as described in earlier sections. Refer to Table 24.1 for a summary.

Table 24.1: Case Studies on Integrated Public Transport Rail Stations in Asian Cities

Case Study	HSR/Non-HSR	Physical Level	Information Level	Monetary Level	Supportive Elements
West Kowloon Station, Hong Kong, China	HSR; also houses intracity subway.	Set in a “rail village” location; provides transfer between light rail and buses. Primarily in the form of pick-up and drop-off points.	Available on display screens but not for all modes. Information available to commuters through online applications such as Google Maps. Coordinated timetable was not evident.	Smart card available along with e-ticketing. Partial subsidy in fare integration on specific routes.	• Pedestrian and motorized segregation. • Integrated rail–property development policy—land use–transport interface. • Economic development of area evident due to real estate and commercial development. • Transit alliance not observed.
Kyoto Station, Japan	HSR; also houses municipal subway system.	Provides transfer for light rail, city buses, and taxis. Taxi ranks present in a pick-up and drop-off pattern. City buses can be used at bus bays present outside the station.	Information booth for tourists that is prefecture- and station-specific. Travel information presented at Kyoto Station website. Coordinated timetable was not evident.	Smart card available with integration between Shinkansen (HSR), light commuter rail, and city rail. No fare integration with taxi. Smart card integration with city buses available on certain routes.	• Commercial development within station premises. • Walking infrastructure well connected between HSR, light commuter rail, and city rail. • Transit alliance not observed.
New Delhi Railway Station, India	Non-HSR; heavy rail for long distance travel.	Provides transfer with Delhi metro located at station premises. Para-transit integration includes taxis and auto-rickshaws.	Integrated information for rail commuters only.	Smart card for express and local rail only. No fare integration between modes.	• UBER (ride-sourcing agency) taxi integrate public transit information with Delhi metro station. • Transit alliance not observed.

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Table 24.1 continued

Case Study	HSR/Non-HSR	Physical Level	Information Level	Monetary Level	Supportive Elements
Marina Bay, Singapore	Non-HSR; urban metro in the form of MRT.	Provides transfer to public transit modes, such as bus and LRT, and acts like feeder services. In addition, it provides better integration with para-transit modes, such as taxis, and the integrated mixed use of the urban district with comprehensive pedestrian and cycling networks.	Coordinated and comprehensive information on all aspects of traveling on bus, MRT, and LRT in a single booklet and online. Real-time information through i-transport platform. Coordinated timetable between the MRT and bus is established.	Smart card called "EZ card" as common fare card for all bus, MRT, and LRT services.	- Transit station is integrated with retail and commercial spaces with walking network. - A land transport authority is formed, which combines the functions of planning and regulatory agencies of both private and public transport. - Transit alliance observed.
Kuala Lumpur Central Station, Malaysia	HSR with intermodal transport hub.	Provides transfer to monorail, intercity commuter rail, electric train, airport HSR, rapid bus transit, and taxis. Attractive communities created with strong cycling and walking network.	Display screens with transit information is provided at all transit interchanges. Information is printed in booklets and distributed to tourists at a tourist service booth at the transit hub. Website and apps are created to provide information to commuters with scheduled time of all transit. Coordinated time is established between the intercity rail and bus transport.	Smart reloadable cards can be used for fare payment on public transport. MyRapid Card can be used to pay the fares of HSR, LRT, monorail, and rapid bus transit. Touch n Go card works on all types of public transport. A 20% discount is provided on public transport fares on both the cards.	- Station area is divided into different economic generative development localities like office spaces, housing, retail, and commercial locations. - Land public transport commission has been set up to regulate and improve the land transport matters. - Cashless card used to pay the fares of public transport can be used to pay the multi-level parking facility at many stations. - Transit alliance is observed.

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Table 24.1 continued

Case Study	HSR/Non-HSR	Physical Level	Information Level	Monetary Level	Supportive Elements
Seoul Station, Republic of Korea	HSR with LRT facility.	Development of transit center at transfer hub connecting feeder lines and shorter transfer distance with LRT, subway metro, intercity bus terminal, urban rapid bus transit service. It provides para-transit services such as taxis, minibuses, and bikes. In addition, parking spaces are provided for bus, bike, car, and bicycle. Regional plan is integrated with railway station.	Information on rail, bus, and taxis are provided using smartphone apps and websites. A real-time location of public transport of all modes is made available in apps. The commuter receives travel information on his/her mobile phone about the trip with all the details. Transport Operation and Information Service (TOPIS) of the Seoul Metropolitan Government gathers and processes the city's road traffic and subway train information in real time to enable the city to efficiently manage the intervals between buses and trains.	Cashless and e-ticketing facility is available to pay the fare for public transport. Transfer from bus to bus and even bus to subways at the station is allowed free. A 30% discount is provided on public transport fares on both the cards. The smart card can also be used at convenience stores, parking lots, and shopping malls and for online shopping.	• Integrated administration is developed between land use, transport, and infrastructure to establish institutional integration. • Network and operation integration between intercity transport through multimodal connectivity through rail and rapid bus, inner city connectivity through suburban bus and taxis and last mile.^a • Development of economic generation areas such as shopping malls, office spaces, and retail and commercial spaces are integrated with walking from station. • Public spaces are developed to attract more people around the station area. • Transit alliance is observed.

HSR = high-speed rail, LRT = light rail transport, MRT = mass rapid transport.

^a Last mile is a term used in transportation planning to describe the movement of people and goods from transportation hub to final destination. In case of railways, last mile can be described as connectivity between the railway station and final destination of a passenger. In recent years, "last mile connectivity" has emerged as a research area in transportation planning and supply chain management studies.

Source: Compiled by authors from various sources.

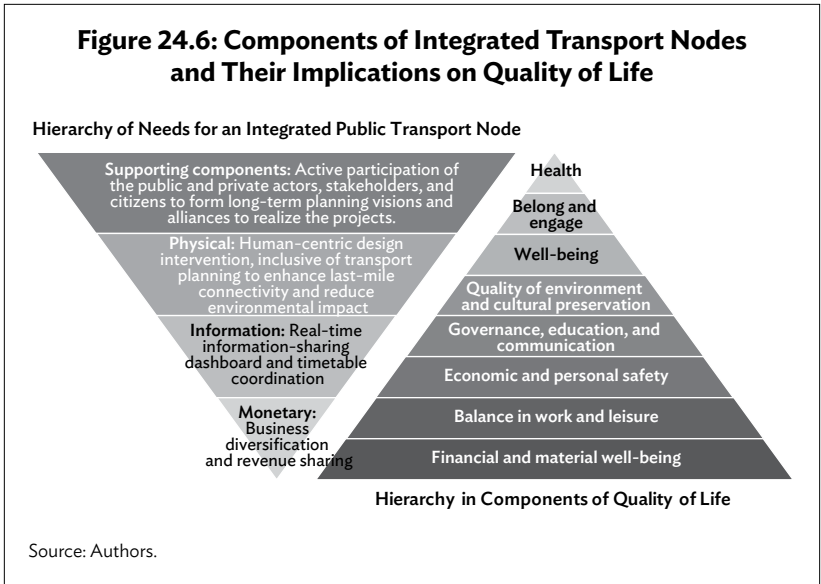
24.6 Components of Integrated Transport Nodes and Their Implications on Quality of Life

The case studies and the preceding two sections explicitly illustrate the critical need for integrated transport infrastructure. The case studies provide insight on the current efforts to integrate different transit modes in Asia. In this section, the implications of integrated transport infrastructure on quality of life is addressed. The lessons drawn from the study cases, based on the hierarchy discussed earlier, are described below and summarized in Figure 24.6.

Institutions operating transport infrastructure often face revenue deficits and lack an adequate level of service. Monetary needs of a transport business require immediate attention, with financial deficiencies addressed by diversification of businesses and developing models for revenue sharing. Such models provide ease of added convenience with in-station commercial services, introduction of an integrated smart card, and other value-added services. These services not only offer financial stability and assure the well-being of the system; they also become a data exchange node for the stakeholders and the users.

Real-time data collected from the user services are vital in keeping a transport node functional. Stakeholders and actors need to receive processed data in a relevant context. For instance, for a transport node, passengers need to receive delay alerts so as to reduce congestion in the serviced areas; rail operators need to be informed about health of the railway coaches to manage and maintain regular services; civic authorities need to know the footfall in the station precinct to plan future parking and design adequate street networks; para-transit operators need timetable information to synchronize their services with the railways; and so forth. However, to form such an ecosystem requires meticulous and visionary long-term planning, while putting in place a sound institutional mechanism to maintain it. Establishing such monitoring, governing institutions, and applied research centers to learn from the collected data would not only aid effective communication among stakeholders to enhance passenger safety and security but also help in designing an evidence-based, data-driven system to plan station areas.

A well-integrated transport node, in most instances, operates with evidence-based frameworks. Collected real-time information aids in understanding passenger behaviors in the paid and unpaid areas of a transport node. Research on passenger behavior data becomes the basis for human-centric, context-sensitive design interventions, and sharing



the information with stakeholders provides an opportunity to plan and develop inclusive and smooth transfer of passengers. Evidence-based frameworks create an opportunity for the service providers to take an initiative that is sensitive to the local cultural context that in turn nurtures social well-being in its users. Successful implementation of such frameworks enhances the overall quality of the environment.

A transport node well rooted in the local context often becomes a landmark in the local urban context and offers a feeling of belonging to its citizens. While the complete process of transport node and station area development is complex, it also requires equal amounts of participation from its stakeholders and engagement from the involved actors to form alliances. Such alliances serve to augment the sense of belonging of the citizens and assures actor engagement in developing the planning vision of the transport infrastructure, thereby securely forming a healthy and connected society.

24.7 Conclusion

This chapter proposed a generalized framework for public transport integration at transport nodes. The case studies depict the components of this framework, including physical, information, and financial integration, at various railway stations in Asian cities. Integration of

public transportation at a railway station should be designed such that sustainable transportation goals are achieved. Good integration between modes should always be economically beneficial, ecologically non-impacting, and socially acceptable, and should enhance the quality of life of its users. Before the integration plan is formulated, an initial analysis must be undertaken to understand the context of the railway station's surrounding area. Existing service quality must also be assessed through user perception. This information will help formulate a tailor-made plan for a particular railway station area. The levels of integration discussed in this chapter also need to be supported by additional interventions, such as ones that enhance user perception of transit service quality, provide contextual information of the surroundings, and garner active participation of the stakeholders, which will in turn enhance the sense of belonging and aid in augmenting users' quality of life.

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25

Governance Institutions: Key Elements for the Integrated Planning and Equitable Deliverability of High-Quality Transport Infrastructure

Grant B. Stillman and Shreyas Bharule

25.1 Introduction

In the 10 years since the publication of our *Infrastructure for a Seamless Asia* (ADB and ADBI 2009), the quality of debate on how to approach megaprojects¹ has risen appreciably in both the specialist and general communities. National politicians across the developed and developing world are routinely calling for infrastructure that is not only job-creating, environmentally and socially sensitive, but must now be of the highest, long-lasting quality, and resilient to natural and financial shocks. The Group of Twenty (G20) and Think20 (T20) processes, supported by international financial institutions, think tanks, project preparation platforms and hubs, and the infrastructure industry, have done much to flesh out the core principles now seen as most likely to secure an equitable and sustainable transport project (Annexes I, II, and III).

At the same time the utility of growth corridors has been proven in many diverse geographical settings and economic situations; some of which span international borders (ADB 2018; ADB and ADBI 2016).

¹ Megaprojects may be understood as infrastructure, which is potentially large-scale, complex, long-term, involving novel, challenging, or untried engineering and with a wide range of stakeholders (after Quality Principle (QP) 6.3, listed in Annex I).

Meanwhile, governments also have long experience with special development or economic (trade or industry) zones. Better ways for the public and private sectors to work together to each other's advantage continue to be found and new sources of project funding are being proposed and pilot tested (Yoshino, Helble, and Abidhadjaev 2018).

Finally, the multidimensional aspects of development proposals and their unintended impacts on vulnerable or marginalized communities are much better understood (Perera 2014). Starting from a core conviction that a proposed high-speed rail (HSR) project should do no harm, the new ambition is to integrate affected people and neighbors willingly into the benefits of the project both at the beginning and distant back end. Affected people should want the HSR and not be seen as in the way of progress, so they have to be moved to another location. Rather, they are the very first beneficiaries of the HSR project, which must help them remain in place, improve their livelihood, educational and employment prospects, and general quality of life.

Government at every level continues to dominate the economies of most countries. For our purposes, the public sector's laws and regulations, as well as tax and spend priorities, pervasively influence the scope and role of how other actors can enter and participate in the provision of infrastructure and its financing. Using the broadest definitions, we should understand institutions as encompassing everything from "rules of the game for a society to particular organizational entities and agencies." Moreover, there is a growing recognition that the quality of institutional development and the exercise of governance are major keys to a country's economic success, including its ability to implement showcase megaprojects (Bhatta 2020).

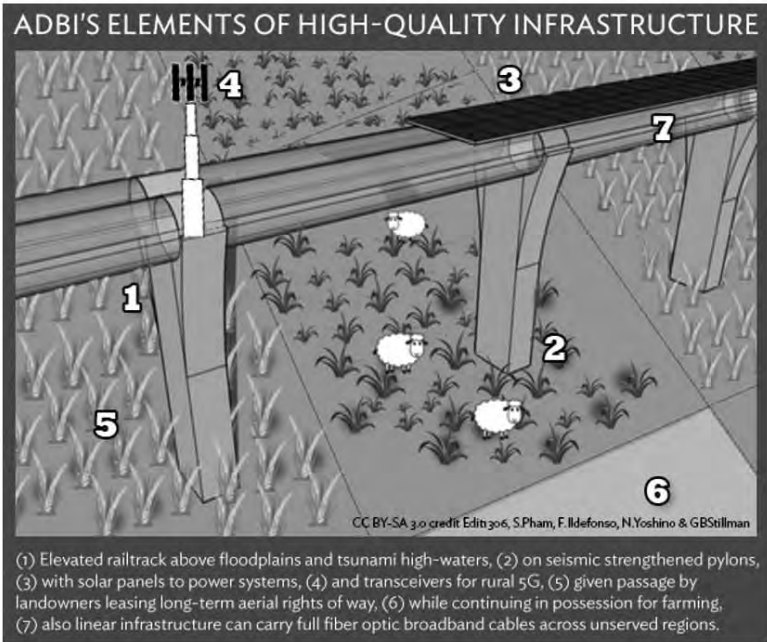
One purpose of this handbook is to unite the practical experiences gained from successful projects with the latest thinking of preserving or improving the quality of life of those being served by transport infrastructure, especially HSR. In this chapter, we will concentrate on how regional infrastructure and development-focused specialized entities or authorities have advantages in comprehensively planning integrated HSR megaprojects and related subprojects for betterment, combined with new technological answers to securing equitable guideways for rail tracks.² The G20 Infrastructure Working Group has

² Sections in this chapter are updated and summarized from the lead author's collected writings on the subject: viz. Chapter 11. Back to the Future: Instructive Features from Past Innovations in Raising Private Finance for Infrastructure, and Appendix and Annex in Yoshino, Helble, and Abidhadjaev 2018; ADBI Policy Brief 2017-3 on Introducing the Tax-Kicker Bond (<https://think-asia.org/bitstream/handle/11540/7415/adbi-pb2017-3.pdf?sequence=1>) and Asia Pathways—ADBI blog posts (<https://www.asiathways-adbi.org/2019/09/dont-be-derailed-by-rights-of-way/>)

also recognized the potential of coordinating *specialized authorities* “at different levels of administration with the capacity to move through the entire process.” (PIP p.1) (G20 Principles for the Infrastructure Project Preparation Phase prepared by the G20 Infrastructure Working Group, see Annex II).

According to the first G20 Quality Principle (QP), all anticipated positive outcomes that facilitate trade, investment, and economic

Figure 25.1: Elements of High-Quality Infrastructure



Note: According to ADBI, these are the key elements of high-quality infrastructure that can better accommodate social and environmental concerns while minimizing disruptions and resettlement: seismic-strengthened pylons minimize the ecological footprint of elevated (above floodplain) railway over conserved farmlands, allowing for reduced crop cultivation and the grazing of herds by smallholders continuing in possession while leasing aerial rights-of-way. Note also solar panel placement to power systems that contribute excess electricity to nearby farms and off-grid communities. Pylons can even perform a double duty by supporting 5G transceivers and carrying full fiber optic broadband cables across unserved areas, opening another revenue stream. Diagram by Edit1306 after SpaceX, available Wikimedia Commons; 5G and ground elements remixed by Sarah Pham and Fernando Idefonso. CC BY-SA 3.0.

Sources: Yoshino et al. (2019), T20 Secretariat (2019); Susantono (2019), Yoshino and Stillman (2019).

development would need to be addressed in any HSR project design and plan. This is an ambitious agenda that would make burdensome demands upon most sophisticated central or municipal government planning agencies, therefore a functionally integrated and transparent authority able to call on cross-departmental expertise but with an integrated, long-term approach seems more suitable. An integrated authority, spanning connected cities and district boundaries, should be well positioned to consult extensively with beneficiaries, independent experts, and promoters to secure an equitable consensus that implants the project successfully inside local development strategies. In this way quality HSR would more likely be tailored to individual country conditions and be consistent with local laws and regulations (QP 1.2).

A continuing authority should possess the necessary longer-term perspective, not subjected to the whims of political cycles, to be able to systematically anticipate and periodically reassess—beyond what the current concessionaire might—the life-cycle costs and risks of operation and maintenance, disaster proofing, scheduling of renovations, and possible disposal or reversion to original uses if the project is not selected for upgrading or conversion to a future technology (QP 2).

In the opinion of the Global Infrastructure Hub (2019), there could be large gains in inefficiency, productivity, safety, and inclusivity if the infrastructure sector was to embrace new technologies comprehensively. ADBI's recommended elements (Figure 25.1) highlight the importance of innovative technologies being deployed not only at construction but throughout the life cycle of the HSR. If improved technology or an engineering breakthrough becomes available in the future, the project definitely needs to weigh the costs and benefits of making the upgrades to extend its life. If not, the life-cycle quality of the infrastructure begins to deteriorate, and ridership falls off. Continuing renewal and upgrading are the hallmark of the more successful HSR operations around the world that are able to raise their economic efficiency even as they age (Japan's and France's HSR systems being the most obvious examples). Faced with too many crumbling postwar bridges and dams, outdated assumptions that infrastructure could be built cheaply and need only last 30 to 50 years have been replaced by the build-back-better principle (LePatner, 2010). Most promising technologies currently on the horizon include extended viaduct and tunneling rail tracks (or hyperloops) avoiding at-grade disruptions; low-emissions and biodiversity-engineering; longer-lasting concrete and more seismic-resistant durable building materials and designs; satellite-aided planning; parallel provision along trackside of 5G and fiber optic broadband services; and systemwide data collection with machine-learning, predictive operation and maintenance (O&M), especially for monitoring use, defects, performance, and safety (QP 2.3).

Quality Principle 3 recognizes that a project should also be used as an opportunity to introduce positive environmental developments and adaptations. For instance, areas prone to landslides endangering villages or leveling forests can be stabilized over the long term by related embankment improvements as the guideway passes through or is subsequently realigned. The continuing authority should also share responsibility with the relevant state and local authorities for developing a comprehensive disaster risk management plan, including quick starts for re-establishing disrupted services (QP 4.1).

The quality of lifestyles of rural and urban communities is directly influenced by the degrees of inclusiveness, economic participation, and open access guaranteed by HSR projects serving or affecting them (PIP p.2). Broad stakeholder engagement and consultation is required throughout a project cycle and not only at the appraisal and preplanning phases (QP 2.2 and QP 5). The Asian Development Bank's newly-elected president, Masatsugu Asakawa, has called attention to the problem of widening inequalities between urban and rural areas, and even intracity, as having the potential to endanger social stability (ADB 2019). A broad authority with a continuing mandate to care for the well-being, opportunities, empowerment, housing, and education of all classes of inhabitants, workers, and visitors found within its catchment area of responsibility would hopefully have the foresight to mainstream complete integration of social considerations into infrastructure development. If it ever comes up short in any area, the aggrieved stakeholders could utilize any independent inspection functions and eventually resort to the mediation and dispute resolution machinery available internally to hold the decision takers accountable for their failing goals or broken promises; particularly when it comes to environmental and social safeguards, such as resettlement and post-project income and lifestyle recovery or improvement (PIP pp.3 and 4).

25.2 Regional Infrastructure and Development Authorities for Integrated Master-Planning and Holistic Governance

At the start of 2020, there were scores of existing, in progress, and proposed economic corridors weaving their way across numerous regions and occasionally countries, such as the ambitious Belt and Road initiative, that connect over 60 countries. Most corridors in Asia are underpinned by some form of existing or proposed navigation

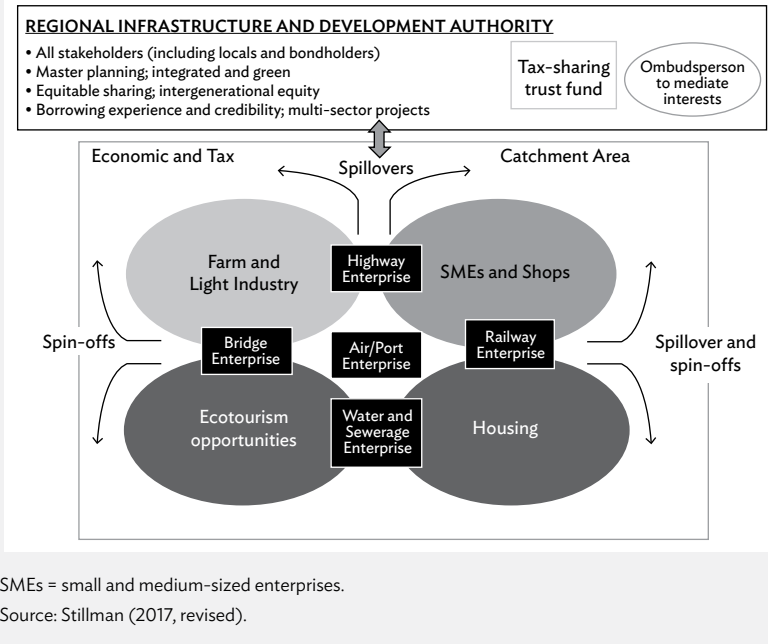
along highways, railways, or waterways (Reconnecting Asia).³ Many governments, regional organizations, and international financial institutions have been calling for the evolution of these corridors from mere convenient transportation lines linked by friendship bridges into efficient trade and investment routes or belts, and ultimately sophisticated and integrated economic areas that encompass many countries and multisectors through increased interconnectivity (Zhang 2017). Several ongoing scoping studies are looking at a specific area, city, or location and trying to match it with its assessed economic potential, such as a market niche or transit hub, to generate any planned investment and future economic activities efficiently from that potential, although there may not be a definite pattern and form that defines an economic corridor (The News 2017; Brunner 2013).

Whatever the long-term goals may be, it is evident these natural corridors could form the spines along which broader economic catchment zones might expand, and in which taxes and newly-generated jobs and wealth from megaprojects might grow as predicted by the difference-in-difference method. Inside these economic and tax catchment areas or zones, a responsible and dedicated regional infrastructure and development authority might be able to manage the development and holistic exploitation of the area using a more integrated, greener, and higher quality approach, and to reap the spillover and spin-off effects of different projects rather than approaching each new development ad hoc (Box 25.1).

Many current infrastructure projects will set up a specific financing or construction entity or enterprise (often later an operating concessionaire) to cover the immediate needs of that discrete installation alone, but a standing regional authority can exist over a much longer timespan and undertake many well-coordinated and integrated improvements so as to *maximize potential linkages, overlaps, and alignment* with other projects and sectors (PIP p.2). As an example of complex master planning of hundreds of infrastructure projects within a region, the Aberdeen Roads public-private partnership was the largest ever closing in Scotland and involved major civil engineering across roads, rivers, underpasses, and wildlife bridges (Norton Rose Fullbright 2015). In an urban, transit-oriented setting, the Hudson Yards Development Corporation manages on behalf of the state and city of New York, a modern, mixed-use central business district comprising new offices, retail, and affordable housing in a park-like setting and pedestrian-friendly streetscape on top of a subway

³ Other corridors might follow busy sea-lanes, source-to-market pipelines, or power transmission grids and even fiber optic networks.

Box 25.1: Schematic of a New Unified Model for Integration and Deliverability of High-Quality Infrastructure



extension and station redevelopment (Hudson Yards Development Corporation website).

Sometimes historic mega-authorities, such as those charged with the planning and development for the Tennessee Valley (United States), Latrobe Valley (Australia), or Rourkela Steel Town (India) in the 20th century, even possessed the power within their regions to establish completely new company townships, garden cities, green belts and worship, recreation and community centers; first for workers but later open to the general public or relocated, project-affected families. Given the problems of finding suitable relocation areas for affected people or shifting them too far away, making the standing authority primarily responsible for looking after those it wants to disrupt and move around may have greater chance of success than passing that sensitive task off to an overworked central government department, poorly-resourced civil society organization, or reluctant neighboring province (Perera 2014).

Leaving aside for the present the not insubstantial complications of international border crossings projects (PIP p.2) and sharing of

resources and income from transnational natural features (see, e.g., the attempted integrated and sustainable management of transboundary water resources in the Amazon River Basin project of the Global Environment Facility, United Nations Environment Programme (FAO 2015), let us imagine a potential authority controlling a section of a river valley within one province or local area. If that authority or more usually the subnational political entity to which it belongs was to have the power to raise and collect taxes from the properties, residents, visiting tourists, and businesses within that zone, it could fairly easily promise to share the tax (or other values added or wealth generated by the development) with private investors at a later date. It might even become possible for that zone to develop its own estimate of how much it expects in future tax or wealth growth and begin to offer that for most of its new back-end tax participation projects, whether they are highways, railways, bridges, or airports (Box 25.1). Although not recommended in theory, there might also be a pragmatic opportunity to cross-subsidize the more profitable projects with those that are slower to show the promised returns. For instance, if not in breach of a priority lien, spillovers from a successful road project might sometimes be paid into a regional viability fund or a general tax-sharing fund to be used to close a funding gap in that region's water and sewerage system that might not be very marketable or attractive to private investors.

An integrated authority, as proposed here, can learn from each new project, gain a track record in the market, and reap the rewards from any newly-implemented infrastructure for itself, the communities enjoying the services (not forgetting undocumented landowners, informal settlers, rough sleepers, and pavement dwellers), and other stakeholders, including transient travelers and passing-through nomads. These are also excellent places to convene together to assess and mitigate conflict, resolve disputes, and to give voice to the local people being served, as well as the distant bondholders who want to ensure that their money is being well spent.⁴ As more difference-in-difference analyses would be conducted within a particular catchment zone for various projects (assuming that suitable non-affected control areas continue to exist nearby for comparison), it might even be possible to derive an average for any expected rate of increase from implanted infrastructure that

⁴ A common complaint of bond financing for infrastructure projects is that there is no convenient single point-of-entry venue for the interests of diverse holders, as opposed to a closely monitored bank loan where the loan officers watch the building progress and business results and can adjust the terms and covenants of the loan as the conditions change (Norton Rose Fulbright 2015). ADB's Midterm Review of Strategy 2020 also called for affected persons and civil society to be more involved in the design and implementation of projects, and in monitoring the resultant activities and outputs (ADB 2014).

could be used for benchmarking or marketing. Certainly, for the concept to work in practice one would expect to see individual projects (or the area's average) outperform the country's general gross domestic product or annual increase in the tax categories dedicated as the sources for the future back-end participation (Table 25.1). Indubitably, each country has its own unique tax complications, and where the designated types of taxes are collected centrally there must be a fair and justifiable procedure to share those taxes earmarked from the infrastructure spillovers back to the province, state, city, or authority, which may or may not be the issuer of investment securities or builder of the individual project. However, as many jurisdictions have worked out ways to share taxes among different collectors and recipient entities, it should not be difficult to incorporate regional infrastructure and development authorities as long as there is political will and a spirit of cooperation (see, generally Araki and Nakabayashi 2019).

25.3 Overall Core Considerations for Funding Mobilization

The viability of the authority or one of its special-purpose vehicles or construction enterprises being able to fund any individual infrastructure project will depend on several key factors and risks that will vary among different jurisdictions and projects, but include the following:

- (1) the specific nature of the project, sector, or use of proceeds, as well as unique engineering risks or doubts;
- (2) the project's timing, in that greenfield projects inherently carry more risk and uncertainty and will be penalized on pricing compared with operational (brownfield) projects with a known revenue track record;
- (3) the credit rating (or lack thereof) of the issuer or special-purpose vehicle;
- (4) the sovereign state's reputation and record of supplying an underlying rating, whether it is a member of the International Monetary Fund, it has a track record of international borrowing, or a liquid yield curve exists;
- (5) the tax collection authority's history of successful collection of the taxes to be denominated as sources of designated revenue to share;⁵

⁵ Of concern, two of the most ambitious infrastructure-building countries—the Philippines and Indonesia—have some of the lowest tax collection rates in Southeast Asia, with Indonesia barely able to achieve tax revenue of 11% of its gross domestic product (GDP) in 2015 as estimated by the World Bank (Curran, Rodrigues, and Salna 2017).

- (6) the record (or lack thereof) of sharing tax arrangements, fiscal transfers, and tax percentage allocations among collectors and other subnational entities or implementing authorities;
- (7) the existence of suitable enabling legislation empowering authorities to issue bonds in their own name and tax collectors to allow back-end participation in the incremental revenue of certain designated taxes;
- (8) the extent and credibility of the limited or partial guarantees;
- (9) the historical uncertainty as to the reliability of the type of revenue stream, either globally or from the region and/or country;⁶
- (10) the marginal cost of alternative transportation and/or services if the pricing of the tolls or user charges rises too high;
- (11) the level of leakages from the revenue stream of tolls and charges, and the collection of designated taxes for future participation;
- (12) the novelty and uniqueness of the deal (the more uncertainty the higher the costs for the issuer and government obligor); and
- (13) the general market conditions affecting investment decisions by foreign bondholders, including exchange rate fluctuations, underlying sovereign credit ratings, and the risk-return profile of the assets or bond yield patterns.

25.4 Recycling Equitable Tax-Share from Future Wealth Creation

Considering these overarching goals and experiences of various models, we turn to the question of how to achieve more inclusive governance for private financing of transport infrastructure in the future. As the historical record shows (Yoshino et al. 2019; Yoshino and Stillman 2017a), private financing of public infrastructure is possible and desirable, not only in Asia but also worldwide (Carrasco and Lau 2020). However, extra help is usually needed in the form of “deal sweeteners” required—not unreasonably—by financiers and builders, especially in the initial

⁶ Traditional revenues are defined broadly to include all tolls, charges, fees, rents, interest, and profits, earned, given or vested in, or demanded or received by the infrastructure operator-issuer. The bond agreement or debenture customarily contains a strict, legal definition of what constitutes the project’s revenues to be charged and secured for servicing revenue-sourced bonds.

years before the project becomes operational with a reliable and healthy income stream. As pioneered in the North American transcontinental railway projects, these may take the form of land grants, concessional rights-of-way, and ancillary revenue opportunities through the diversification of business such as commercial property development or minor businesses such as the exploitation of trackside lumber and minerals or leasing of advertisement space.

Some public sector support for or subsidization of part of the costs of raising or enhancing the financing package seems unavoidable, except for the most fortunate projects with strong prospects. This usually takes the form of tax holidays and incentives, generous credit, favorable profit sharing, government advancing the payment of interest due during construction, transfers in kind, and a variety of guarantees (including implicit) of the loan and bond indebtedness. Governments and markets need to be both realistic and sympathetic to special accommodations and even bailouts in the final years of a project when delays and cost overruns can strain the original financing plan (OECD 2016).

Future tax revenues can also be tapped for sharing with the private financiers and investors participating in infrastructure projects. Economic corridors along transit routes can be conveniently widened by band multiples of 500 meters to 1 kilometer either side of the line into economic and tax zones that capture growing neighboring wealth, increased business activities, and future taxes; rather than increasing current imposts or imposing betterment fees on present residents. The economic boundaries of such a zone may not always correspond to official city limits, geographical or political borders, or subnational municipal and state lines and traditional tax districts (Day 2016). Indeed, the sprawling expansion in Asia of so-called “natural” cities and agglomeration regions beyond their administrative boundaries raises many of the same questions we have identified for the proper coordination of planning, deliverability, and governance (Abiad, Farrin, and Hale 2019).

A thorough menu of potential types of taxes existing or to be created that could conceivably be designated for catchment to fund back-end participation is given in Table 25.1 segregated as to immovability in relation to land and the level of taxing authority.

A responsible tax-collecting authority will put aside an agreed share specified in the loan or debenture of attributable new taxes in a project specific trust fund to assure back-end participants that their money will be safe and locked away when interest payments come due. There are many models and approaches to tax-sharing arrangements among central and subnational governments or with specially created districts or development agencies (Yoshino and Morgan 2017). In the

Table 25.1: Menu of Potential Types of Taxes That Could be Designated for Catchment as Categorized by Mobility

Immovable (and invariably fixed or related to land and/or building; so predictably remaining inside a tax catchment area)	Sharing characteristics of both (and to a certain extent movable outside a tax catchment area over the long to medium term)	Movable (highly footloose and dependent on the current domicile of personal taxpayers)
Property tax/land rates/fixed assets tax (residential and commercial division)	Business/corporate tax (as businesses can move out but at slower pace than people)	Personal income tax (collected at central, province, and/or city level/s)
Hotel room tax/surcharge	Value-added tax/(local) consumption/sales tax	Vehicle license fee tax increment
Parcel tax/flat rate assessment on property regardless of value or size	Payroll tax/fee	Vehicle registration fee Truck tonnage tax
Betterment levies/assessment	Special tax/assessment	Other taxes on vehicles, including motorcycles
On- and off-street parking fees	Developers' fee	
Naming rights of fixed infrastructure (one-time fee) ^a	Local commercial garage fee Estate/wealth transfer tax	Gasoline, diesel, and light oil taxes
Sports stadium seating fees (seat licenses)	Amusement taxes (from cinemas and theatres)	
Heating oil for premises tax Local/urban roads taxes	Commercial advertisement space/billboard fees	
Cordon/congestion pricing/peak use surcharges	Other sundry regulatory fees and user charges	
Registration and license of land tax		
Real estate acquisition tax		
Urban/city planning tax		
Street lighting tax		
PILOT payments (i.e., direct payments by landowners in lieu of real property taxes they would otherwise have had to pay)		

continued on next page

Table 25.1 *continued*

Immovable (and invariably fixed or related to land and/or building; so predictably remaining inside a tax catchment area)	Sharing characteristics of both (and to a certain extent movable outside a tax catchment area over the long to medium term)	Movable (highly footloose and dependent on the current domicile of personal taxpayers)
Environment/nature reserve or national park tax		
Tourism tax		
Departure tax (at air/seaports)		

PILOT = payment in lieu of taxes, which may be hypothecated (pledged or earmarked) for specific purposes and paid to entities other than tax collection agency.

^a The Ginza subway line in Tokyo, built by a private company in the mid-1920s, solicited financing help through the innovation of tie-ups with major department stores along its route whereby stations would be named after the retailer rather than the neighborhood of the stop (namely, Mitsukoshimae-eki, meaning, in front of (“mae”) the original Mitsukoshi Limited main branch store in the Nihonbashi district) (Hornyak, 2017).

Note: The potential types of taxes described are illustrative and not meant to be definitive. Other names (e.g., goods and services taxes) may be used in various jurisdictions to refer to the same or a similar tax.

Source: Stillman (2018, revised).

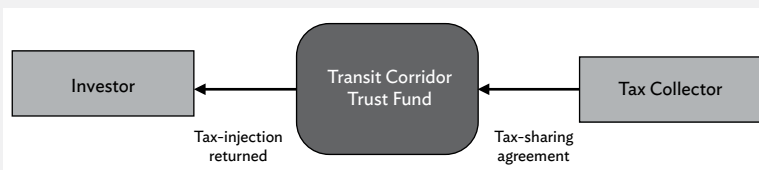
future, we may even see equitable tax sharing arrangements across international borders. In certain cases, tax laws may have to be amended or modernized to permit such innovative arrangements.⁷

Trust fund proceeds can then be used to close gaps in projects’ viability and profitability and help finance them, or the new revenue might simply be segregated for financing any availability payments agreed by the government in a project’s concession, which could also be indexed to keep pace with growth (or inflation).⁸ Private investors should be attracted to projects that offer them this new option of enjoying back-end participation in future tax revenues from affected zones (Box 25.2). The back-end share can be simply transferred to

⁷ Statutory or constitutional impediments to the sharing of internal revenues might be overcome by outright amendments where possible, or the use of proxy credits passing through the general fund and fungible payments directly correlated and arising out of the calculated tax participations due (see, further, discussion on foregone revenues and contractual credits in Stillman, Appendix 2018).

⁸ Governments, public authorities, and even financiers of private projects have indexed securities to inflation or consumer price rises in several jurisdictions; for example, the Sydney Harbor Tunnel Company issued its own indexed bonds (Deacon, Derry, and Mirfendereski 2004).

Box 25.2: Potential Ways to Transfer Back-End Tax Participation to Original Investors



- (1) Rebate check/electronic bank transfer (either to the issuer or directly to the bondholder)
- (2) Segregated revenue for backing any (gross domestic product-indexed) availability payments (unfettered or with collars in band)
- (3) Tax-injected into an open-ended viability gap fund for general purposes (but risks of dilution, raiding for other purposes, or underfunding)
- (4) Deduction or tax credit for infrastructure developers on future years' tax returns (may not be useful for overseas investors who are not taxpayers in the host country)
- (5) Payment by infra-advantaged beneficiary directly to issuer, constructor, or investor in lieu of real property tax or betterment levy they would have to pay to government tax collector (PILOT payment)
- (6) "Tax-kicker" (back-end future-tax-participating) bond

Source: Stillman (2017, revised).

the beneficiaries by something as basic as a bank cheque or bank-wire transfer. However, a more beneficial form could be realized in the form of compensating tax credits, deductions, or rebates on present and future tax return filings.

Structured finance projects or traditional bank loan project syndicates can easily mandate such transfers among the known and fewer parties in their bespoke documentation and have been quietly doing so in many diverse deals, business sectors, and legal jurisdictions. It is worth mentioning though that overseas financiers without domestic taxpaying obligations or local subsidiaries in a project-site jurisdiction might not be able to use any tax credit or rebate mechanism offered.

A more sophisticated global-standard instrument with securitization, registration, and negotiability has been proposed, which could draw on existing prototypes of tax-increment revenue bonds and social or development impact finance bonds with payouts contingent on achievable targets—we have styled them tax-kicker

bonds for infrastructure (Yoshino and Stillman 2017b). If the implanted project is modestly successful in the long term and starts generating regional growth above the national gross domestic product, these tax-kicker bonds would be able to offer higher rates of return than traditional revenue (and toll only) bonds or (availability-payment) project bonds.

In theory, tax-kicker bonds should be issuable at all levels and by any entities—assuming that legal capacities to issue securities exist or are legislated for—including central and subnational governments, regional development areas, public authorities, state-owned enterprises, and even large and creditworthy private construction companies. Of course, some of the risks inherent in the tax collection and transference aspects could be minimized if the ultimate owner of any type of issuer were the government or a public municipal entity (either owned or partially controlled by the state).

The principles of subsidiarity and efficiency require any borrower or bond issuer to be as close as possible to the grassroots of the project itself, and at the longest arm's length from the government as the market will tolerate without always relying on automatic and legally binding guarantees. Central or subnational governments are eager to keep project costs off their budgets as much as possible; this is their main reason for attracting private investment in the first place. A standing, continuing authority and some generic entities that we anticipate as possible issuers and their relationship to, or degree of separation from, the central government or sovereign are laid out in Table 25.2.

In developing Asia there is a strong presumption of what are known as implicit guarantees, meaning that the local market participants understand that the issuer has the unofficial or tacit backing of the relevant government level (although this is not formally given in the loan documentation).⁹ As a credit enhancement wrap-around supplied by a multilateral development bank can always be expected to lift the rating of an issuer to some extent, these are listed in the last column as “Preferable” across the board, except for investment-grade sovereigns and possibly some exceptional emerging countries that are market favorites. Due to their venerable operating histories and prudent operations-to-interest ratios, popular issuers like the Tennessee Valley Authority and Snowy Hydro Limited are usually rated highly by investor services agency,

⁹ For instance, informal or irregular promises to guarantee a certain level of return or profit or to protect against losses and make whole private investors in certain social projects or public-private partnerships (PPPs) have been reported in the People's Republic of China (PRC) (Xu 2017).

**Table 25.2: Subsidiarity of the Issuer and Arm's Length
from the Government or Guarantee**

Investment Grade	Issuer	LG Implicit Guarantee	LG Explicit Guarantee	CG Implicit Guarantee	CG Explicit Guarantee	MDB's Guarantee
Investment- grade sovereign nations	Central government	Capable of raising funds directly in the capital market				Not necessary
	Local government backed by central government	Capable of raising funds directly in the capital market				Not necessary
Non- investment grade sovereign nations	Central government					Optional
	Local government					Preferable
	Regional infra and development authority/ Large national companies with good financial record	Support				Preferable
	Large national companies	Support	Support			Preferable
	Local companies with good financial records	Support	Support	Support		Preferable
	Local companies	Support	Support	Support	Support	Preferable
	Local companies with poor or no financial records	Minimum chance to raise funds in capital market				

CG = central government, LG = local government, MDB = multilateral development bank.

Source: Stillman (2018, revised).

Moody's (2005), even without full faith and credit (general) obligation or unconditional guarantees from central or subnational governments to repay their revenue bonds from consolidated and general national revenues. Nevertheless, whoever the issuer may be, it seems inescapable that governments must stand by to steady markets if necessary, by being prepared to underwrite issues or become the buyer of last resort for novel or high-profile infrastructure bond offerings.

Finally, we hope that back-end tax participation will not be seen as a present transfer payment or credit, making it possible to treat it as budget-neutral and not immediately recordable in annual national balance sheets. This should interest governments around the world who want to minimize their present debt burden to encourage much needed transport infrastructure investment.

The Appendix to ADBI's *Financing Infrastructure in Asia and The Pacific* (Yoshino et al., 2018) offers a tentative explanation of how such an instrument might work in practice (updated and expanded from the preliminary version in Stillman 2017), and includes a possible model term sheet for this new instrument to illustrate its key features and guarantees (Stillman 2018).

25.5 Some Notable Experiences of First-generation Development Authorities

Since land is constitutionally a state responsibility, urban development administration bodies are often formed under the state legislative background. Local government or an urban local body implements the urban development strategies. An urban local body is the third tier of governance, directly elected by the people of India. Planning and development for major cities and urban regions are done by urban, metropolitan, or regional development authorities. These authorities are functionaries' institutions under the state government.

In 2015, the national planning commission was replaced with a new institution. The government of India sorts guidance from a policy think tank, the National Institute for Transforming India, in order to achieve the Sustainable Development Goals (SDGs) with cooperative federalism through fostering partnerships with state governments. The rationale for "transformation" was to increase state governments' role in determining the growth and development trajectory.

The three-tier urban development process in India involves the Union government which limits itself to administration, while the state and local governments together cooperate in the implementation of the urban development plans. The overview at each tier is as follows:

- (1) At the Union government level, the Ministry of Housing and Urban Affairs is the apex body for the formulation and administration of regulations and laws relating to housing and urban development.
- (2) At the state government level, urban development is administered by the State Town Planning Act and the relevant legal framework of each state. Presently, all states have ministerial departments responsible for urban planning, urban development, housing, and governance.
- (3) At the local level, the planning and development department within a development authority is responsible for devising

various plans in large cities, as well as for issuing development permits and implementing development, among other things. The department is established under the provisions of the State Town Planning Act or an individual planning and department act drafted for a region or area.

The state government under the provision of the respective state town and regional planning acts may specify any undeveloped area as a “notified area” under two conditions:

- (i) the notified area falls under the jurisdiction of the one or more statutory urban development authorities formed under the provisions of the one state’s town and region planning act; and
- (ii) depending on the dominant land use to be allotted in the development plan the notified area will be developed by a) a regional development authority, b) a state’s industrial development corporation, or c) a special planning authority (SPA), formed under the administration of one regional development authority. However, the notified area remains under the jurisdiction of one or more urban or local development bodies. The degree of autonomy exercised by any development authority from its local government supervision varies based on provisions of the state’s town and regional planning act.

An SPA is a unique provision in India’s Spatial Planning System for plan implementation and assumes the same powers as that of any planning authority under the provision of the state’s town and region planning act. An SPA is formed for development purposes such as land acquisition in a notified area under the provision of the Land Acquisition Act 1984. Under the provision of a state’s town and regional planning act, a notified area encompasses land required for the development of a proposed infrastructure project or any land adjacent to an infrastructure project. In cases such as a port handling specialized cargo, the notified area for the port is often secluded from the urban region and provisions, services, and amenities required to serve the specialized port need to be drawn from a nearby source. In such special cases, an SPA is instrumental in development monitoring and implementation of a spatial plan. However, SPAs do not function independently of a larger regional planning authority responsible for development of the regional development plan and regional transport network.

25.5.1 Navi Mumbai International Airport and Mumbai–Pune Expressway, Maharashtra, India

The Maharashtra government on the proposal of a secondary airport, in Navi Mumbai, appointed the City and Industry Development Corporation (CIDCO) as the SPA to develop areas around the proposed airport. CIDCO was a planning authority responsible for the development of Navi Mumbai city within the larger Mumbai Metropolitan Region, formed a dedicated SPA for the development plan formulation and implementation in a notified area adjacent to the proposed airport to be developed into an aerotropolis. The notified area was known as Navi Mumbai International Airport Influence Notified Area (NAINA). CIDCO proposed a masterplan and planning regulation for the development of 270 villages under NAINA of 560 square kilometers (Bharule 2019).

The NAINA masterplan also included an existing expressway developed by the Maharashtra State Road Development Corporation (MSRDC), a government organization responsible for the implementation of road infrastructure projects. Recently, the MSRDC, appointed as the SPA for the development along the expressway, had to participate in the development of NAINA, such that the development along the expressway infrastructure was the responsibility of the MSRDC. The Maharashtra state government, acting as an arbitrator between CIDCO and the MSRDC, allotted the responsibility of 46 villages to the MSRDC leaving 224 with NAINA. However, the expressway had a vehicle count of over 50,000 per day, while having a capacity to handle 100,000 vehicles per day; banking on the potential the MSRDC proposed a masterplan for the development of the allotted area based on the expressway infrastructure. The proposed masterplan includes affordable housing, townships, and amusement nodes along the 120-kilometer (km) expressway.

25.5.2 Bengaluru–Mysore Infrastructure Corridor, Karnataka, India

The Nandi Infrastructure Corridor Enterprises Road officially called the Bengaluru–Mysuru Infrastructure Corridor was developed in a build–own–operate–transfer (BOOT) model. The state government envisioned developing an efficient infrastructure corridor between two cities, Bengaluru and Mysore, as well as to have planned and organized dispersal of population through growth centers, which will act as counter magnets to Bengaluru city's growth. The proposed Bengaluru–Mysuru Infrastructure Corridor project comprises mainly a 110-km expressway with several interchanges and five new townships along the proposed expressway.

However, the project area and its components pass through the jurisdiction of several planning authorities making it cumbersome to implement the corridor development in a comprehensive manner, as we have been recommending throughout. In order to have a single agency to facilitate a planned development of the corridor, the areas falling under different authorities were amalgamated to form a notified planning area comprising over 125 villages and covering a total of 701 square kilometers. At the end of 2019, the project was still under development and has partnered with Bengaluru's metro rail corporation to develop metro stations and lucrative car parking along the corridor, to capture much of the untapped land value along the infrastructure corridor.

25.6 Multimodal Transport Networks of Interlocking Corridors

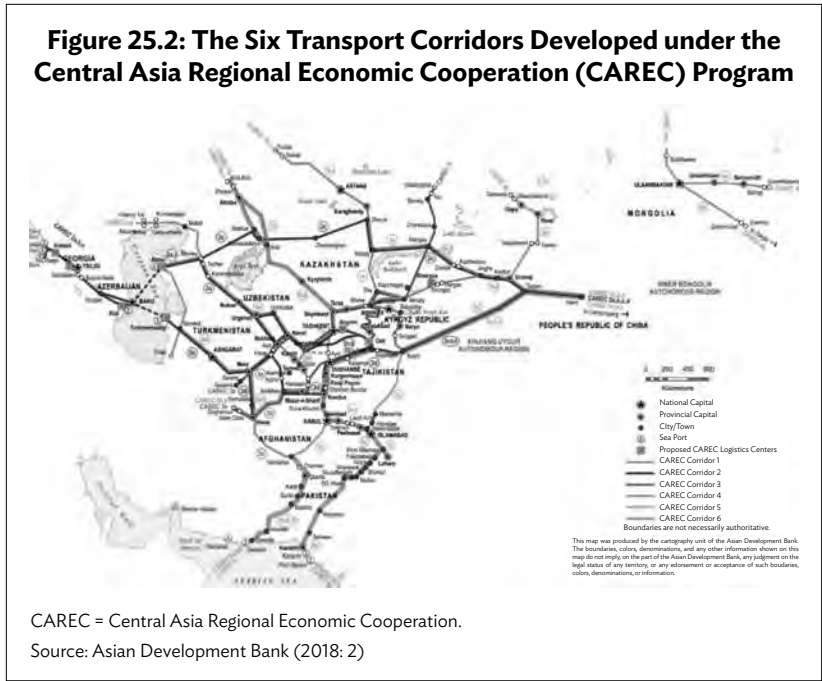
The Central Asia Regional Economic Cooperation (CAREC) program is a partnership of eleven countries¹⁰ and six multilateral institutional development partners¹¹ working together to promote development through international cooperation, leading to accelerated economic growth and poverty reduction. The CAREC program has emerged as instrumental in the interlinking of landlocked countries of Central Asia through investment transport infrastructure such as rail and road.

The program is a proactive facilitator of practical, results-based regional projects, and policy initiatives critical to sustainable economic growth and shared prosperity in the region. Since its inception in 2001, CAREC investments have helped establish multimodal transportation networks, increased energy trade and security, facilitated free movement of people and freight, and laid the groundwork for economic corridor development. A schematic network of the six CAREC transport corridors is shown in Figure 25.2.

The CAREC 2030 program envisages an even more ambitious, long-term strategic framework for the region through the coming decade. It is anchored on a broader mission to connect people, policies, and projects for shared and sustainable development, serving as the premier economic and social cooperation platform for the region.

¹⁰ The eleven countries in the CAREC program are Afghanistan, Azerbaijan, Georgia, Kazakhstan, Kyrgyz Republic, Mongolia, Pakistan, People's Republic of China, Turkmenistan, Uzbekistan, and Tajikistan.

¹¹ The six multilateral partners are Asian Development Bank (ADB) serving as the CAREC Secretariat, European Bank for Reconstruction and Development (EBRD), International Monetary Fund (IMF), Islamic Development Bank (IsDB), United Nations Development Programme (UNDP), and World Bank.



25.7 Recent Advances in Value Sharing Approaches

Lately, a few countries and economic zones in Asia have successfully used various land value capture (LVC) models which are part of the broader financial technique of present-day sharing of future value creation. Essentially, the host government already owns or fairly acquires the land which it then sells, leases, or trades¹² in various ways to fund projects (ADB 2017b, Box 5.4). Notice though these traditional forms of LVC remain primarily public sector inspired and initiated projects; although aiming to attract public–private partnership (PPP) involvement, the government must still find the money to pay for

¹² Completely free or overly generous land grants are no longer possible or popular in many countries. Reportedly, a request from PRC contractors for development rights to land along a planned rail link under negotiation was turned down by Thailand (Ono and Kotani 2017).

it but instead of using taxes or deficit financing exploits local land values.¹³

Over the last 10 years, for instance, land transfer fees paid by industrial developers in the People's Republic of China have been channeled as fiscal revenue supplying about one-third of local and provincial authorities' needs (ADB 2017a). Hong Kong, China has also been able to use LVC to improve its mass transit systems by selling subsidized public land to the transport authority at less than market value and allowing the authority to recapture the enhanced value in future resales after the new line is in place. The Republic of Korea passed a law in 1997 that requires appropriate land values to be used to finance transportation for new developments either large in scale or serving a high population density (ADB 2017b, Box 5.4).

Under the Value Capture Finance (VCF) Policy Framework, cities in India through state urban acts and regulations have been developing and exercising some VCF mechanisms (Ministry of Housing and Urban Affairs 2017). The following are the tax instruments proposed under the VCF Policy Framework in India.¹⁴

- Land value tax: based on land records, valuation, assessment, and revenue collection and enables levy for rural and urban land.
- Tax for land use change: capturing gains from changes in land use from residential to industrial, commercial to industrial, residential to commercial, etc.
- Betterment levy: Authorities collect a "betterment levy" on a plot, assuming benefits from adjacent infrastructure development by the state or authority. For instance, if building roads, metros and other transport infrastructure leads to appreciation in land prices in the vicinity of these projects, then landowners enjoy a benefit and are required to pay a betterment levy.
- Development charges: Under the Development Charges Act 1997, municipalities in India can impose development charges against lands to be developed to pay for growth-related capital costs for the municipality such as roads, water supply lines, recreation, etc.

¹³ Complex questions raised by equitable land use and rezoning procedures from rural to urban, as well as avoiding insider unjust enrichment or fraudulent schemes remain outside the remit of this chapter, but see, generally, Tiwari, Stillman, and Yoshino 2020.

¹⁴ Value capture financing—a big ticket reform for speedy urban service delivery and resource mobilization. (Government of India blog: <https://blog.mygov.in/editorial/value-capture-financing-a-big-ticket-reform-for-speedy-urban-service-delivery-and-resource-mobilization/>)

- Transfer of development rights (TDR): Used for trading development rights and excess floor area ratio (FAR), thereby aiming to recover monetary compensation. Some state acts restrict use of TDR to special land use. For instance, FAR that would have been lost due to heritage conservation or land being utilized for social causes such as open spaces and affordable housing etc., may be traded in the form of TDR in other parts of the city. However, it must be consumed within the administrative limits of the same urban development authority.
- Premium on relaxation of FAR: TDR may be used for additional development rights beyond the permissible limits. However, the addition FAR is availed on a premium.
- Vacant land tax: The land development corporation, in case of land not extensively used for agricultural purposes and are not occupied by building impose a 0.5% vacant land tax on the estimated capital cost of the land.
- Town planning schemes and land pooling system.

States such as Tamil Nadu and Maharashtra have made land value tax applicable to urban areas, under which increase in land value is tapped through increased land revenue tax. Some states such as West Bengal have formulated a system to capture tax gains from land use conversion tax. Several states resort to area-based development charges that vary from urban to rural areas. For instance, the Mumbai Metropolitan Region Development Authority (MMRDA) and CIDCO, are responsible for the development plan implementation in the Mumbai metropolitan region. However, both authorities use different value capture financing (VCF) methods such as a betterment levy to finance infrastructure development in the urbanizing areas. States such as Karnataka, Gujarat, and Maharashtra have made provisions for enabling the transfer of development rights to buy additional FAR. However, the FAR must be consumed within the same administrative boundary.

The main message from successful legacy examples is that the planners behind earlier public and private projects fully realized that pure revenue streams from fares and tolls would never be enough to induce and complete the complicated and expensive infrastructure projects of past centuries. Governments and financiers used to take it as a given that extra sweeteners in the form of free land (including its mineral rights and sales of timber) had to be added to the financing mix, which could be turned by private constructors and investors into much needed immediate cash or mortgaged as security for loans (sometimes even becoming early forerunners of mortgage-backed

securities, such as “land-grant bonds” issued with packaged collateral from unsold land (Cox 2015). More so if the company was newly created or only in the sole business of trying to build a railroad and it did not have other corporate sources of revenues (income from finished projects) to cross-subsidize the interest servicing costs of its bonds and borrowings that fell due before project completion or customers started generating profits.

This lesson was soon forgotten when governments moved into the business of major project sponsorship and fulfillment: e.g., the Trans-Siberian railway could only be done as a completely czarist government enterprise, sometimes resorting to convict, unpaid laborers. Governments, which alone enjoyed the advantages to print money or borrow cheaply could readily cross-subsidize expensive public works until they returned future profits. These nation-forging railways also saw some of the earliest examples of bonds being subsidized or enhanced with regular interest installments being either paid or guaranteed by the deeper and more dependable pockets of federal and state governments.

Indeed, by using the public purse and future profits in expectation to pay off current project debts, governments were basically following the same concept of relying on future tax revenue streams being proposed here. When the postwar pendulum swung back during the Thatcher and Reagan privatization revolution, governments were irrationally exuberant in their expectations of the profitability of the private sector to create infrastructure out of thin air. They forgot to pass back the hidden but necessary windfalls, except for the occasional incredibly successful crown jewels of the public sector, dependable and money-spinning brownfield assets, or a foolproof sector like telecommunications.¹⁵

With the exception perhaps of undeveloped parts of Africa—i.e., the parklands or nature reserves that are not environmentally protected—or possibly the deserted stretches of Central Asia’s hinterland, very few countries have any stock of available and undeveloped public land that is not under the stewardship of traditional owners or nomadic people, which can be given away to constructors and their investors as was done in the United States and Japan. Instead of the actual land being given away or shared, or sold at a discount, perhaps the next best thing would be to look at the economic fruits or *profits a prendre*

¹⁵ Until the 1980s most airport income would come from traditional landing and passenger-handling charges; however, since then about two-fifths worldwide is in the form of so-called “non-aeronautical revenues” from shops, food and beverages, airport car parking and car rental fees, and advertising and property income (The Economist 2017).

emanating from that land in the form of increased property, business, and income taxes that grow along with the communicating railways and highways.¹⁶

25.8 Overcoming Rights-of-Way Challenges for Equitably Delivering High-Quality Infrastructure

The disappointing scale-back of California's showcase high-speed rail system between San Francisco and Anaheim has many experts asking what lessons can be learned (Slowey 2019). Similar pushbacks have occurred on other continents: witness the popular resistance to construction of a new superstation as part of Stuttgart 21 urban renewal, which escalated into violent demonstrations, delays, and stalemates. Megaprojects worldwide encounter opposition from the very people they aim to serve (See Chapter 2).

Developing countries without the open expanses of, e.g., Central Asia or parts of the People's Republic of China, often point to their difficulties in buying a right-of-way corridor through crowded cities or confusing, multiple smallholder farm plots along which a highway or rail project is planned. (Usually rail rights-of-way run at ground-level, i.e., at-grade, which for our purposes includes embankments and cuttings that permanently change the topography). There are many reasons for these difficulties, just as each country's sociopolitical and land use history is diverse and defies easy stylization (Table 25.3).

Next comes the obvious but little remarked innate endowment of basic geography. Projects in big countries like Spain, Canada, and Australia often benefit from large landowners (Table 25.4), who are

¹⁶ It is beyond the scope of this chapter to treat in depth all the complicated philosophical, social, and legal issues involved in the acquisition of land from private owners for rights-of-way, but see further Tiwari, Stillman, and Yoshino (2020). Certainly, we believe subjectively equitable, reasonably prompt, fully adequate, and effective compensation of land being subjected to eminent domain or forced acquisition with proper avenues of appeal and voluntary relocation is essential. For our part, we should like to encourage early sellers or first movers by offering them more attractive inducements to cooperate in the transfer of their land such as staying in possession, leasebacks, or offering them a larger immediate payout or future participation than those who delay the project and come along later under compulsory court order. This might be done with a sliding scale for the purchase plan rewarding the early and voluntary sellers. Also, proper channels for the unwilling landowners and customary stewards to object must be created, potentially inside of a local infrastructure and development authority or hometown trust association before an independent and trusted ombudsperson.

Table 25.3: Difficulties in Securing Rights-of-Way for Public Transport

Main problem	Reasons	Ease of Solution
Poor or no land titling, unclear, contesting undocumented owners	History, land reform, society dispossessed or war-torn	Long term, nation- or state-wide reforms are best
Indigenous/informal settlers, transients, stewardship of nature	Conflict in land use views, respect and reparations	Often intractable, politically unpalatable, losers resent
No or slow eminent domain/forced sales	Different legal tradition, weak courts, lack of trust, cultural reluctance to invoke	Usually long term, multi-generational wait, political will to invoke may never come about
Unpredictable zoning, unfair to first movers/first peoples	Religious or cultural uses, original use vs. new plans, speculators corner market in advance	Medium term, improve consultation/voice stages
Uncertain if land gets used for planned public purpose, delays depress values	Many risks of projects stalling, greater in DMCs	At pre-plan and build stages, believable guarantor helps
Suspicion of governance and process transparency, insensitive involuntary resettlement	History, stage of rule of law, distrust of elites, lack of capacity or respect for safeguards	Usually long term, nation- or state-wide level reform best, immediate role for IFIs to improve capacities

DMCs = developing member countries; IFIs = international finance institutions.

Sources: Authors; Fukuyama and Yoshino (2019).

easily able to cede a small portion of their vast holdings for a public transport purpose and keep and enjoy the remainder of their property relatively undisturbed. Understandably, if you are asking a poorer smallholder who only has that modest plot to live on and cultivate for themselves and their families, the chance of nonacceptance will always be greater. Add to that, if the smallholder is a long-time member of a nurturing village or thriving ethnic community, they are also going to be more cautious about taking the chance of being split up or relocated from their friends and neighbors.

In addition, the length of time during which the transportation technology has been in use will be another determinant. If a country has a long history of railways, chances are it will have been able to lay enough legacy tracks and obtain sufficient rights-of-way when the areas were not so built-up, or following regrettable windows of opportunity caused by natural disasters or those caused by humans, which allow a second chance for more organized easements.

Table 25.4: Comparison of Rail Tracks Laid in Select Countries by Farm Size and Population Density

Country	Average Farm Size (from largest to smallest; hectares)	Population Density (per square kilometer)*	Track Length (kilometers)**	First Railway, (year of introduction)***	Expected Commencement of Planned or Proposed HSR Project
Australia	4,331 ^a (2016)	3	33,343 (2015)	1854	2040 (Proposed)
Canada	314.84 ^b (2011)	4	77,932 (2014)	1836	2031 (Proposed)
Spain	25.4 ^c (2010)	94	15,302 (2017)	1848	1992 (In operation)
Thailand	3.15 ^d (2013)	135.8	4,127 (2017)	1893	-
Pakistan	2.58 ^e (2010)	275	11,881 (2019)	1861	-
Georgia	1.4 ^f (2014)	65.2	1,363 (2014)	1872	-
Philippines	1.29 ^g (2012)	358	77 (2017)	1891	2020 (Proposed)
India	1.08 ^h (2016)	455	68,525 (2014)	1853	2023 (Proposed)
Viet Nam	0.188 ⁱ (2014)	308	2,600 (2014)	1881	2050 (Proposed)

* Country-wise track population density (people per square kilometer of land area) up to 2018 are extracted from the respective country webpage World Bank's Data on Population density website: <https://www.data.worldbank.org/indicator/EN.POP.DNST>

** Country-wise track lengths up to the year in parenthesis are extracted from the respective country webpage of the Central Intelligence Agency's World fact book website: <https://www.cia.gov/library/publications/resources/the-world-factbook/>

*** Kakizaki, I. (2014). *Trams, Buses, and Rails: The History of Urban Transport in Bangkok, 1886–2010*. Silksworm Press.

Sources:

^a Australian Bureau of Statistics. (2016). *Agricultural Commodities, Australia, 2015–16*. <https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/7121.0Main+Features12015-16?OpenDocument> (accessed 3 December 2019).

^b Statistics Canada. (2011). *Snapshot of Canadian Agriculture: Chapter 1*. <https://www150.statcan.gc.ca/n1/pub/95-640-x/2011001/p1/p1-01-eng.htm> (accessed 3 December 2019).

^c OECD Economic Surveys: Spain (2010), Organisation for Economic Co-operation and Development.

^d Podhisita, C. (2017). Household Dynamics, the Capitalist Economy, and Agricultural Change in Rural Thailand. *Southeast Asian Studies* 6(2): 247–273. https://doi.org/10.20495/seas.6.2_247

^e Government of Pakistan. (2010). *Agriculture Census Organization*. http://www.fao.org/fileadmin/templates/ess/ess_test_folder/World_Census_Agriculture/Country_info_2010/Reports/Reports_5/PAK_ENG_REP_2010.pdf (accessed 3 December 2019).

^f National Statistics Office of Georgia. (2014). *Census of Agriculture 2014*. Agricultural Statistics.

^g Philippine Statistics Authority. (2012). *Agriculture and Fisheries Statistics*. <https://psa.gov.ph/tags/agriculture-and-fisheries> (accessed 3 December 2019).

^h Government of India. (2018). *Agriculture Census 2015–16*. http://agcensus.nic.in/document/agcen1516/T1_ac_2015_16.pdf (accessed 3 December 2019).

ⁱ World Bank. (2016). *Transforming Vietnamese Agriculture: Gaining More from Less. Vietnam Development Report 2016*. <https://openknowledge.worldbank.org/handle/10986/24375>

If promoters can plan their high-speed routes to take advantage of existing freight lines or underused or abandoned tracks, then securing the guideway becomes much faster and less complicated. Other factors favoring success include linking naturally complementary cities not too far apart or separated by challenging terrain, such as Tokyo to Shin-Osaka; New York to Washington, DC; or Mumbai to Ahmedabad (although India's impressive legacy rail network is a rarity in developing countries).

Finally, cutting-edge technology is coming to the aid of getting around rights-of-way bottlenecks. Today's maglev and high-speed trains traverse elevated tracks on spanning viaducts supported by pylons with much smaller footprints on the rural landscape. Just as high-voltage transmission towers can allow planting of crops and animals to graze around their base, modern railway support columns are engineered to require smaller foundational areas, preserving the claims of farmland of smallholders' underneath (Figure. 25.1). At the other extreme, engineers in Europe, the Americas, and Asia are recognized for their experience with railway and highway tunneling. Moreover, the costs and time of tunnel boring will continue to be reduced by advancing carbon-lite technologies. Yet, even underground routes have the potential to cause nuisance (particularly during construction), are not free from technical barriers, and can therefore encounter objections by ground-dwellers or owners of the property above.¹⁷

A mixture of elevated and underground sections will also be better for climate and disaster resilience; land and water conservation; reduction of deforestation, and air, noise and visual pollution; less disruptive of animals' grazing paths and access to habitat; as well as safer and more efficient for the separation of pedestrians and car traffic from busy at-grade crossings. These criteria will be used to evaluate the life-cycle efficiency of future rail systems, such as the Asian Development Bank–Japan International Cooperation Agency supported Malolos–Clark Railway Project.

Instead of resorting to traditional confrontational compulsory acquisitions with the distress caused by relocations, new ways to package and pool smallholder lots and easements through equitable readjustments, reallocations, exchanges, or reversionary rehabilitation schemes are being tried by communities with the support of land trusts, banks, and sympathetic renewal authorities (Yoshino et al. 2019).

¹⁷ Very deep tunnels passing well beneath a building's foundations or useable subterranean levels might not even need to purchase underground rights or permissions from the surface landowner depending on limitation regimes established by local law. See further discussion on superficies in Nakamura et al. (2019, p. 257).

Box 25.3: A Long-Range Approach for Redevelopment Masterplan Implementation in the Central 23-Wards of the Tokyo Metropolitan Region

For over a quarter century or more, rights-of-way managers have been patiently waiting for owners and tenants to voluntarily sell, cease trading on retirement, or expire. Piecemeal the necessary strip of land is slowly acquired as land prices rise and replacement buildings are set back to make way for another segment of a road transit corridor. Postwar reconstruction, the 1959–1964 Olympic building boom, and the Narita airport expansion controversies have made Japan cautious and respectful about invoking its eminent domain powers of compulsory acquisitions.



Left: Mita-1 road-widening and revised property setbacks in Minato Ward, Tokyo, Japan (image courtesy of G.B. Stillman).

Right: Secured section of ring road no. 35 abutting remaining apartment that projects beyond the right-of-way, in Heiwadai, Nerima ward, Tokyo (image courtesy of M. Tanaka).

In megacities like Tokyo, individuals who occupy small houses often increase the utility of their land by consolidating their property with neighbors and erecting apartments or office buildings on it. Usually, the landowners entrust their land to a trust bank, which develops the consolidated properties to use them more effectively. Sometimes the

participating landowners can live in apartments within the building¹⁸ and receive part of the profits as dividends from the trust bank. Assuming breakeven occupation and sufficient rental revenues, individual landowners can generate greater profit by this collective method. Similarly, an agricultural trust bank can manage the rural landowners' collective properties. Another option might be a registered transfer of only certain usage rights over the land (e.g., aerial or overpasses) to the trust bank. This way, landowners can maintain ownership of the land, yet increase their profit by lending the land to other users, including railways, through trust banks (Yoshino and Paul 2019).

Using long-term leases to secure sections of guideways with options to buy at the end of 40 or 99 years is another viable option that deserves further exploration. This approach could allow landowners, first peoples, or informal settlers in the way of a development to retain their legal interest in or connection to the land, without vetoing the optimal path or placing a rent-seeking stranglehold over future operations when the lease comes up for renewal.

Therefore, the solution for quickly lining up rights-of-way in crowded places is not always at-grade, pushing aside everything in its path; nor necessarily elevated tracks on spanning viaducts or burrowing endless underground tubes. Rather, an imaginative, respectful and utilitarian amalgam of all three dimensions building on existing, repurposed track paths is preferable.

25.9 Strengthening Infrastructure Governance Should Assure More Equitable Solutions for Delivering High-Quality Transport

The final Quality Principle (QP 6) recognizes that a high degree of coordination across different levels of government and the ability to convene the private sector with public utilities is central to the success of infrastructure governance. The latest International Monetary Fund Public Investment Management Assessment estimates that as much as one-third of the economic benefits of new infrastructure could be lost

¹⁸ Reportedly, it took nearly 15 years to assemble 400 smallholders' plots into the 27 acres required for the Roppongi Hills mixed-use development connected to subways in Tokyo. Apart from the private developer offering above-market price purchases, inducements for very reluctant sellers included providing them with replacement dwellings inside the high-rise, luxury residence; effectively foregoing future floorspace from which to recover rental income (German 2010).

due to inefficiencies in governance and management. The experience of establishing “whole-of-government” one-stop-shops for foreign direct investment and public-private partnerships has been widely embraced in the fields of public service management and institutional governance reform (Bhatta 2020). Therefore, we would like to encourage countries to see the wisdom in spinning-off close control within traditional, turf-conscious departmental silos and embracing holistic regional and development authorities especially established with a mandate to (i) plan strategically and coherently, (ii) make the scientific case for change and business judgment of commercial viability, (iii) offer and appraise options using state-of-the-art social cost benefit and effectiveness analyses and (iv) after making the best multicriteria decision (PIP p.2), and (v) fairly deliver those with most chance of widespread support inside a logical region or corridor underpinned by transport infrastructure.

That is not to say that the accountability and answerability to the public and electorates will be foregone with the advent of special authorities. Independent watchdogs, transport regulators, assurers of international quality and financial sustainability, external auditors, procurement referees, service delivery inspectors, corruption investigators, civil society audits, and ultimately an administrative tribunal or court system, must be in place to provide useful checks and balances to provide oversight and discipline the powers of any regional infrastructure and development authority. Furthermore, the ultimate approving body to decide whether megaprojects go forward (PIP p.1) need not always be the integrated, standing authority, and may reside either with the appropriate government concerned or even put to the people by referendum or proposition.

As the G20 leaders concluded at the 2019 Osaka Summit, in order to achieve master planning on an integrated basis resulting in equitable project delivery that is efficient and on schedule, the involvement of, and sharing of information with, a wide sector of stakeholders, especially users, local populations, civil society organizations and the private sector, is the key element to build trust, acceptance, and success (QP 6.1 and 6.4).

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Annex I

G20 Principles for Quality Infrastructure Investment (QP)

Principles for Promoting Quality Infrastructure Investment

This document sets out a set of voluntary, non-binding principles that reflect our common strategic direction and aspiration for quality infrastructure investment.

(QP 1) Principle 1: Maximizing the positive impact of infrastructure to achieve sustainable growth and development

1.1 Setting off a virtuous circle of economic activities

- The aim of pursuing quality infrastructure investment is to maximize the positive economic, environmental, social, and development impact of infrastructure and create a virtuous circle of economic activities, while ensuring sound public finances. This virtuous circle can take various forms. New jobs are created during construction, operation and maintenance of infrastructure, while positive spillover effects of infrastructure stimulate the economy and lead to more demand for jobs. Advanced technology and know-how may be transferred voluntarily and on mutually agreed-upon terms. This can result in better allocation of resources, enhanced capacities, skills upgrade and improvement of productivity for local economies. This impetus would improve the potential for economic growth, leading to widening of the investor base, crowding-in more private investment, and resulting in further improvement in economic fundamentals. This would facilitate trade, investment, and economic development. All these expected outcomes of the investment should be considered in the project design and planning.

1.2 Promoting sustainable development and connectivity

- Infrastructure investment should take into account economic, environmental and social, and governance aspects, and be guided by a sense of shared, long-term responsibility for the planet consistent with the 2030 Agenda for Sustainable Development, national and local development strategies,

and relevant international commitments, and in the spirit of extensive consultation, joint efforts and shared benefits. The facilities and services of infrastructure should have sustainable development at their core and need to be broadly available, accessible, inclusive and beneficial to all. A virtuous circle of economic activities would be further secured through enhancing accessibility to, and national, regional, and global connectivity of, infrastructure, based on consensus among countries. Domestic resource mobilization is critical to addressing the infrastructure financing gap. Assistance for capacity building, including for project preparation, should be provided to developing countries with the participation of international organizations. Quality infrastructure investment also needs to be tailored to individual country conditions and consistent with local laws and regulations.

(QP 2) Principle 2: Raising Economic Efficiency in View of Life-Cycle Cost

Quality infrastructure investment should attain value for money and remain affordable with respect to life-cycle costs, by taking into account the total cost over its life-cycle (planning, design, finance, construction, operation and maintenance (O&M), and possible disposal), compared to the value of the asset as well as its economic, environmental and social benefits. Using this approach helps choose between repairing or upgrading an existing infrastructure or launching a new project. Project preparation, as set out in the *G20 Principles for the Infrastructure Project Preparation Phase* is crucial in this regard.

2.1 The life-cycle costs and benefits of infrastructure investments should be taken into consideration in ensuring efficiency. Construction, O&M and possible disposal costs should be estimated from the onset of the project preparation stage. The identification of mechanisms to address cost overruns and cover ongoing O&M costs is critical to ensure financial sustainability at project level. Cost-benefit analysis should be used over the life-cycle of infrastructure projects.

2.2 Infrastructure projects should include strategies to mitigate the risks of delays and cost overrun, and those in post-delivery phases. Necessary elements to achieve this objective can include: (i) broad stakeholder engagement throughout the project; (ii) expertise in planning, operations, and risk allocation/mitigation; and (iii) application of appropriate safeguards and instruments.

2.3 Innovative technologies should be leveraged through the life-cycle of infrastructure projects, where appropriate, to raise economic efficiency for existing and new infrastructure. Advanced technologies are an important component for new and existing assets and can help to improve data availability to monitor infrastructure use, performance, and safety.

(QP 3) Principle 3: Integrating Environmental Considerations in Infrastructure Investments

Both positive and negative impacts of infrastructure projects on ecosystems, biodiversity, climate, weather and the use of resources should be internalized by incorporating these environmental considerations over the entire process of infrastructure investment, including by improving disclosure of these environment related information, and thereby enabling the use of green finance instruments. Infrastructure projects should align with national strategies and nationally determined contributions for those countries determined to implement them, and with transitioning to long-term low emissions strategies, while being mindful of country circumstances.

3.1 These environmental considerations should be entrenched in the entire life-cycle of infrastructure projects. The impact on the environment of the development, operation and maintenance, and possible disposal of the infrastructure project should be continuously assessed. Ecosystem-based adaptation should be considered.

3.2 The environmental impact of infrastructure investment should be made transparent to all stakeholders. This will enhance the appreciation of sustainable infrastructure projects and increase awareness of related risks.

(QP 4) Principle 4: Building Resilience against Natural Disasters and Other Risks

Given the increasing number and heightened magnitude of natural disasters and slow onset of environmental changes, we face the urgent need to ensure long-term adaptability and build resilience of infrastructure against these risks. Infrastructure should also be resilient against human-made risks.

4.1 Sound disaster risk management should be factored in when designing infrastructure.

A comprehensive disaster risk management plan should influence the design of infrastructure, the ongoing maintenance and consider the re-establishment of essential services.

4.2 Well-designed disaster risk finance and insurance mechanisms may also help incentivize resilient infrastructure through the financing of preventive measures.

(QP 5) Principle 5: Integrating Social Considerations in Infrastructure Investment

Infrastructure should be inclusive, enabling the economic participation and social inclusion of all. Economic and social impacts should be considered as an important component when assessing the quality of infrastructure investment and should be managed systematically throughout the project life-cycle.

5.1 Open access to infrastructure services should be secured in a non-discriminatory manner for society. This is best achieved through meaningful consultation and inclusive decision-making with affected communities throughout the project life cycle, with a view to securing non-discriminatory access to users.

5.2 Practices of inclusiveness should be mainstreamed throughout the project life cycle. Design, delivery, and management of infrastructure should respect human rights and the needs of all people, especially those who may experience particular vulnerabilities, including women, children, displaced communities or individuals, those with disabilities, indigenous groups, and poor and marginalized populations.

5.3. All workers should have equal opportunity to access jobs created by infrastructure investments, develop skills, be able to work in safe and healthy conditions, be compensated and treated fairly, with dignity and without discrimination. Particular consideration should be given to how infrastructure facilitates women's economic empowerment through equal access to jobs, including well-paying jobs, and opportunities created by infrastructure investments. Women's rights should be respected in labor market participation and workplace requirements, including skills training and occupational safety and health policies.

5.4 Safe and healthy occupational conditions should be put in place, both at the infrastructure site and in the surrounding communities. Maintaining occupational safety and health conditions would also present a huge economic advantage worldwide.

(QP 6) Principle 6: Strengthening Infrastructure Governance

Sound infrastructure governance over the life cycle of the project is a key factor to ensure long-term cost-effectiveness, accountability, transparency, and integrity of infrastructure investment. Countries should put in place clear rules, robust institutions, and good governance in the public and the private sector, reflecting countries' relevant international commitments, which will mitigate various risks related to investment decision-making, thus encouraging private-sector participation. Coordination across different levels of governments is needed. Capacity building is also key in ensuring informed decision-making and effectiveness of anti-corruption efforts. In addition, improved governance can be supported by good private sector practices, including responsible business conduct practices.

6.1 Openness and transparency of procurement should be secured to ensure that infrastructure projects are value for money, safe and effective and so that investment is not diverted from its intended use. Transparent, fair, informed and inclusive decision-making, bidding and execution processes are the cornerstone of good infrastructure governance. Greater transparency, including on terms of financing and official support will help ensure equal footing in the procurement process. A wide range of stakeholders such as users, local population, civil society organizations and private sector, should be involved.

6.2 Well-designed and well-functioning governance institutions should be in place to assess financial sustainability of individual projects and prioritize among potential infrastructure projects subject to available overall financing. In addition to project-level financial sustainability, the impact of publicly funded infrastructure projects, and of possible contingent liabilities¹⁹, on macro-level debt sustainability, needs to be considered and transparent, given that infrastructure investment can have significant impact on public finance.

¹⁹ Contingent liabilities, as defined by the IMF 2019 revised Fiscal Transparency Code, are payment obligations whose timing and amount are contingent on the occurrence of a particular discrete/uncertain future event or series of future events.

This will contribute to attaining value for money that considers life-cycle cost, promoting fiscal sustainability, saving fiscal space for future potential projects, and crowding in more private investments. A functionally integrated and transparent decision-making framework for infrastructure investments that considers both O&M and new investments to ensure efficient resource allocation.

6.3 Anti-corruption efforts combined with enhanced transparency should continue to safeguard the integrity of infrastructure investments, which are potentially large-scale, complex, long-term, and with a wide range of stakeholders. Infrastructure projects should have measures in place to mitigate corruption risks at all project stages.

6.4 Access to adequate information and data is an enabling factor to support investment decision-making, project management and evaluation. Access to information and data needs to be available in-country to help undertake cost and benefit analyses, supports government decision-making and policy monitoring, and facilitates project preparation processes and management.

Annex II

G20 Principles for the Infrastructure Project Preparation Phase (PIP)

Prepared by the Infrastructure Working Group

The introduction of robust and transparent infrastructure planning and pipelines, improved business cases and project stage gate controls, and the development of business case methodologies have led to more productive infrastructure being built.

The following Principles for the Infrastructure Project Preparation Phase could be considered when preparing national and regional infrastructure projects. The Principles consist in a list of critical aspects to consider under the following dimensions:

- Project rationale
- Options appraisal
- Commercial viability
- Long-term affordability
- Deliverability

These 5 key dimensions and their respective headline questions present a way to achieve a high standard of business case development. The G20 is clear that to be effective, these Principles are expected to be more effective when supported by sound governance and public leadership, implemented in a transparent and accountable manner, and sponsored from the outset by government bodies (such as ministries, development agencies, centralised or specialised authorities, etc., according to the country framework) at different levels of administration with the capacity to move through the entire process.

The idea behind these Principles is that every infrastructure project or program will benefit from having a reasonable and structured justification (i.e., business case analysis) or proposition to explain why it is needed and how it can be taken forward. The systematic implementation of good business case analysis can help bridge the infrastructure gap by building a pipeline of projects that are bankable and that satisfy investor requirements. It helps to create delivery confidence by ensuring and demonstrating that projects have been scoped robustly and planned realistically from the outset and over the entire life-cycle, with the associated risks taken into account.

A good business case methodology provides a framework for thinking around three issues:

- where are you now?
- where do you want to get to?
- how are you going to get there?

and provides:

- a structured format to allow government authorities at all levels to develop its proposals and explain and justify any project or programme;
- a framework to enable an approving body to decide whether or not to allow the project or programme to go forward;
- a process for preparing projects for market; and
- a record of transparent decision-making.

The implementation of these Principles can be greatly supported by project preparation tools and instruments that are already operational. Given the increasingly digitalized global economy and the importance of good access and quality of infrastructure data, a multilateral online infrastructure project preparation software platform can be particularly instrumental for improving consistency, quality, transparency and accountability of business case analysis. A compendium of existing resources for project preparation support is provided in Appendix I.

Project Rationale

Underpinned by sound governance and public leadership, the Project Rationale establishes the need for the project, placing it within an overall strategic context and outlining the project scope and objectives. In short, it should present the “case for change”.

Critical Issues to address are:

- Establish the rationale for the project and place the project within an overall strategic context, e.g., national, regional and local long-term plans. This should confirm project sponsors and government parties on their role.
- Outline the project scope and objectives, and the problems the project aims to solve or the benefits it should bring.
- Define the key risks, constraints and dependencies relating to the project e.g. Have planning, external approvals and issues related to cross-border projects been taken into account.
- Define the positive and negative externalities generated by the project, as well as potential linkages and alignment with other infrastructure projects and sectors, regional planning and other programs, networks, and national and local policies.

Options Appraisal

The Options Appraisal should demonstrate that all relevant options have been considered involving the relevant stakeholders (including the private sector) at the national, regional and local level, and that social cost benefit analysis (SCBA), social cost effectiveness analysis (SCEA) or multi-criteria decision analysis (MCDA) has been conducted in an appropriate manner on a further short list (derived from all relevant options) to determine the option which offers best value for money over the entire life-cycle of the project (including its maintenance), taking externalities into account. In addition, for Public-Private Partnership (PPP) infrastructure projects, it should demonstrate that using private finance optimises value for money for the government, by comparing it to the same solution using public capital.

Critical Issues to address are:

- Have you established critical success factors against which you can test your options?
- Have you considered all relevant options to create a long list and short list?
- Have you subjected your short list to SCBA (if cost and benefits can be converted into monetary value) or SCEA (if benefits cannot be valued or the information required is too difficult to determine) in order to establish a preferred option? If comprehensive MCDA is instead used, does it incorporate SCBA or SCEA as an input and if not are there grounds for not performing them (lack of information, large pipeline of projects and insufficient resources to perform the analysis, etc.)?
- Are all the key modelling assumptions clearly articulated, backed up by sound sources and reflective of market conditions?
- Are cost and schedule estimates in line with the required output specifications and based on established national/international benchmarks? Are social and environmental costs monetised where possible?
- Have risks been identified and quantified and a reasonable adjustment made for “optimism bias”?
- Have you tested resilience against natural disasters and other force-majeure risks?
- Have you tried to take account of non-financial risks and benefits in your short list evaluation?
- Have all relevant stakeholders been addressed, including the private sector and affected local communities?
- Does the project help achieve universal access to basic services, such as electricity and energy, water and sanitation, waste

- removal, transport, housing, health care and education?
- How does the project improve accessibility and inclusiveness for the most disadvantaged social groups?
- Do you have a robust justification for your preferred option?
- What are the weights one should attribute to the different aspects above in order to derive the preferred option?

Commercial Viability

Showing Commercial Viability involves demonstrating that the project is feasible and deliverable for investors and contractors as well as the government and citizens, that the supplier market has been tested and that the procurement strategy and contract is well developed with an appropriate risk allocation.

Critical Issues to address are:

- Have you reviewed different contract options and chosen the one which offers best value for money? Is the contract bankable? In case it is not and the project targets low income users, carries positive social externalities or is viable from a socio-economic perspective, do these factors justify public sector support?
- Have you tested that the proposal is commercially feasible and that the supply market is likely to be interested in it?
- What is your procurement strategy?
- Do you have a risk matrix which allocates risks to the party best able to manage them? Is this risk allocation stated in the contract?

Long-Term Affordability

Long-term affordability analysis should ascertain the likely life-cycle costs, adequate and affordable maintenance funding and financing of the project. Accordingly, it should (a) demonstrate that the project is affordable and cost effective over its life, taking account of the public funding allocated to the project and allowing contingencies for unexpected occurrences; and (b) make clear what amounts are funded from public sources and what amounts are sought by way of other funding sources or are payable by users of the facility. Debt sustainability and transparency of project financing will also be taken into consideration.

Critical Issues to address are:

- Have you accurately assessed the project costs?
- Have you accurately assessed all project revenues?
- Have you identified finance and funding sources?

- Have you built relevant financial models?
- Have you performed a sensitivity analysis over the estimated financial results and rate of return?
- Are credit enhancement and risk mitigation products available to support project financing?
- Are there readily available and affordable mechanisms for interest rate and foreign currency hedging, if necessary for the project?
- Have you tested affordability from a macroeconomic/fiscal sustainability perspective?

Deliverability

Deliverability analysis should demonstrate that arrangements are in place to ensure the successful delivery and maintenance/operational management of the project, respecting existing environmental and social safeguards. It should show that the project is properly staffed and resourced over its lifetime, with appropriate governance arrangements, advisers and timetable, so that it can be procured on time and successfully operated as well as monitored.

Critical Issues to address are:

- Have you put in place project management and governance arrangements?
- Do you have a risk management plan, including an environmental and social risk assessment and its corresponding mitigation plan?
- How is responsibility assigned or delegated amongst the public sector and shared with private partners? How can each institution help with the project preparation?
- What is your assurance and approval structure?
- What advisers will you appoint and have you considered this expense in the budget?
- What project management methodology will you use?
- Do you have a detailed project plan and timetable?
- Are conflict assessment and resolution mechanisms in place?

Annex III

Extract from T20 Secretariat, T20 Summit 2019 Communique

TF4 Economic Effects of Infrastructure Investment and its Financing

There is an urgent need for G20 countries to develop high quality infrastructure that is cost efficient over the life cycle, and maximizes the contributions to economic growth, the Sustainable Development Goals and environmental outcomes including impact on and resilience to climate. High-quality infrastructure should encompass all benefits and costs including spillover effects and externalities, with equal consideration to economic, social and environmental dimensions. The positive “spillover effects” of infrastructure, if well-managed, can boost GDP and tax revenue at the municipal, regional and national levels and in turn be utilized to address the gap between infrastructure demand and availability of finance.

Maximize the Impact of Quality Infrastructure Investments Through Land Trusts and by Tapping Spill-Over Effects Boosting Long-Term Returns

- Develop an integrated approach to quality infrastructure through robust upstream policy and institutional foundations including multilevel governance; high quality standards to guide the design, build and operation of projects; project preparation platforms and facilities; and mobilization and alignment of large-scale financing. Reform the land acquisition process through measures such as land trusts to unlock investments. Connect infrastructure development, urban governance and earth system research and develop comprehensive infrastructure models to promote sustainable growth in all regions.
- Create viable revenue models by tapping spillover effects that can boost long-term returns, and which together with improved credit enhancement mechanisms, can attract private capital, pension funds and sovereign wealth funds worth trillions of dollars, reduce costs of capital and improve debt sustainability.
- Strengthen collaboration between the multilateral development banks as well as with other development partners to support the quality infrastructure agenda in emerging market and

developing countries through country, regional and global platforms to provide strategic advice to governments, build local capacity in critical areas such as planning and procurement, adopt universal standards and transparency, and mobilize private capital at scale, locally and internationally.

*Boost Quality Infrastructure Development by Integrating
Impactful Environmental Solutions*

- Promote upstream planning for quality infrastructure that fully incorporates social and environmental risks and costs into project pipeline development and considers the role and value of ecosystem services and nature-based solutions.
- Establish common financing principles, standards and frameworks that minimize ecological footprints through land and water conservation, biodiversity enhancement and healthy ecosystems.
- Promote research, policies and commitments that advance deforestation-free development models and restoration of landscapes. Develop Strategies for Enhancing Resilient Infrastructure Development
- Incorporate spatial vulnerability and impact of climate change into infrastructure planning and design through comprehensive assessments and warning systems; improve the interaction between higher education programs, policymakers and owners and operators to strengthen disaster resilient infrastructure.
- Accelerate policies for low-carbon and climate-resilient growth, including carbon pricing and elimination of fossil fuel subsidies and disclosure of climate risk.
- Develop and share national and urban strategies for promoting resilience, including resilient transport systems based on proactive, holistic resilience engineering and management processes, and rapid disaster response and post-crisis policies.

Conclusions and Policy Messages

26

Evaluation of Transport Infrastructure Impacts and their Implications for Quality of Life

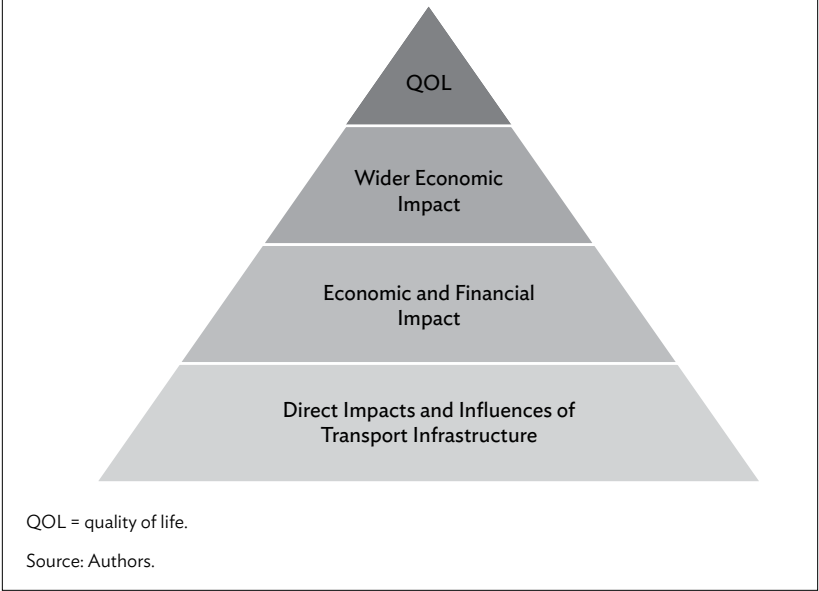
Yoshitsugu Hayashi, KE Seetha Ram, and Shreyas Bharule

Transport infrastructure is a complex ecosystem that is open to all users. As a system in society, it emanates values from human activities in different places with diverse contexts. There are numerous contributions of an efficient and effective transport infrastructure system to economic growth and social development, both directly and indirectly.

However, evaluating the impact of transport infrastructure is challenging. The difficulty lies in the identification of an exact relationship between transport infrastructure investment with social development. To fully understand the complex impacts of investment in transport infrastructure, the Asian Development Institute (ADBI) held several knowledge-sharing events in Tokyo between February 2018 and May 2019—conferences and seminars covering the broader aspects of planning, operations, and implementation of high-speed rail infrastructure. In addition, five special sessions and a high-level panel discussion on Messages for Policy Makers for Developing and Operating Transportation Infrastructure, through the platform of the World Conference on Transport Research (WCTR), were held at the Indian Institute of Technology Bombay, Mumbai in May 2019.

Participants at these events came from diverse groups such as policy makers, researchers, and experts in relevant fields. Participants discussed the significant impacts of transport infrastructure and presented their recent research based on empirical evidence from existing *ex-post* evaluation studies. This essay summarizes the viewpoints discussed during several panel discussions and sorts out the theoretical methods on transport infrastructure impact evaluation in the form of an analytical hierarchy, for further discussion and knowledge sharing.

Figure 26.1: The Pyramid of Analytical Hierarchy



As has been discussed in this handbook, it would be useful to illustrate the complex impacts of transport infrastructure in a hierarchical pyramid (Figure 26.1). From bottom to top, they are the direct transport system impact, economic and financial impact, wider economic impact (WEI), and quality of life (QOL) impact.

Direct Impacts and Influence of Transport Infrastructure

Direct impacts and influences of transport infrastructure form the base of the transport system impact hierarchy. The immediate direct effect of the introduction of transport infrastructure is the improvement in travel conditions. An investment in transport infrastructure may alter individual users' behavior in terms of mode choice, route choice, time of travel, and destination choice. Such a change in an individual's behavior is relatively easy to observe and capture. However, to measure the corresponding impacts on the economy and social welfare, a general approach of cost-benefit analysis (CBA) is instrumental.

In ADBI's special sessions at WCTR-2019, Tae Hoon Oum provided case studies of transport infrastructure's impact on individual behavior and interactions among stakeholders involved. The research utilizes the speed reduction of the People's Republic of China's (PRC) high-speed rail (HSR) as a quasi-natural experiment to empirically quantify HSR speed effects on airlines. Specifically, by using CBA, the effects of HSR speed on airline demand, equilibrium airfares, and passenger volumes were examined. The analysis of HSR speed reduction impact on airlines between short haul (500 kilometers [km]) and medium to long haul (1000 km) is carried out by comparing the treatment group (the airline routes with HSR presence) and the control group (the airline routes without HSR presence). To identify the changes of airline demand and price between the "treatment" and "control" groups both before and after the treatment—"HSR speed reduction". The paper concludes that elasticities of airline demand shift after the reduction of HSR speed, as well as the equilibrium of airline traffic and price concerning HSR speed, is nearly twice larger on the 500 km market than the 1000 km market.

A similar microeconomic CBA approach was applied in the Japanese context (Fu, Oum, and Yan 2014). The research found that HSR transit-time reduction has many fewer effects on air travel demand than a reduction in airfare. The research identifies a potentially great unrealized demand for low-cost carrier services in Japan. However, since the advent of HSR infrastructure, the nature of its direct influences has remained contextual to the physical and economic geographies on which they operate. For instance, even though the elasticities of air travel demand widen twice as much in the case of a 500 km market than a 1000 km market on lowering HSR speed in the PRC. In the absence of such a market and geography that would permit medium-haul HSR lines, a similar estimation in the case of Japan's *Shinkansen* does not present similar results, rather indicates the need for investment in alternative high-speed and cost-effective travel modes such as low-cost carriers. Such studies along with lessons drawn in Part 1 of the handbook, provide methods to quantify direct impacts and influences of investment in HSR infrastructure.

Economic and Finance Impact

Traditional CBA that is based on the maximization of social welfare can measure the direct transport system impacts, such as ticket fare and travel time. However, social welfare is not always the center of evaluation. Thus, the economic and financial impacts, which are essential for the public or private sectors in making an investment decision on transport infrastructure, cannot be justified completely. This is particularly true

for private sector enterprises that see transport infrastructure as an investment instrument and weigh the rate of returns. Therefore, to demonstrate the benefits of transport infrastructure projects, there is a need to aggregate the direct impacts of transport systems at the individual level. However, these impacts need to be quantified in economic terms as discussed in the above comparison of HSR in the PRC and Japan.

Different from the traditional CBA, the measuring of spillover effects takes a macroeconomic approach of examining the aggregate impact of investment on growth and productivity. Naoyuki Yoshino proposed the concept of the spillover effect of infrastructure at ADBI's special session at WCTR-2019. The research demonstrates the existence of spillover effects across time and regions (see Yoshino, Helble, and Abidhadjaev [2018], Chapter 3, and Chapter 5). The research on the spillover effects of infrastructure may emerge in the form of a new innovative transport infrastructure financing scheme: Land Trusts (see Chapter 1).

Tax is an aggregate indicator of economic activity. The total tax revenues disaggregated as personal and corporate income taxes, property and sales taxes, among others, such that they precisely reflect the impacts of infrastructure on different attributes. Moreover, tax revenues are directly linked to government fiscal revenues, and part of the spillover tax revenues can be transferred to the original private investors. Such a tax revenue transfer and sharing process will stimulate the willingness of private investors to participate in infrastructure investments. The finding has significant implications for new financing sources and influence on the business decisions for infrastructure. However, approaches to land development and control involve several complexities, especially in terms of land rights.

Transport infrastructure projects are substantially linear and hence create a "corridor" effect along with the linear infrastructure. A corridor-wide governance mechanism in land development is a crucial missing link in the implementation process of transport infrastructure like HSR lines (see Chapter 25). However, governance institutions such as a "land trust" would not only introduce local benefits but introduce development effects throughout the corridor ameliorating the transport infrastructure corridor through tax-based benefits for all stakeholders. Such a level of inter-territorial governance integration would enhance the quality of life of the individuals within the influence zone of the transport infrastructure.

Wider Economic Impacts

The wider economic impacts (WEI) of transport infrastructure are gaining growing awareness. The altered individual choices and business decisions have a strong influence not only on the transport

systems and economic activities but also on other potential impacts, such as environment, employment, industrial transition, social structures, and land-use patterns, on a broader sense. WEI is vital for public administrations and transportation professionals when making transportation-related policies.

The challenge is there. It is already difficult to identify the exact relationship between investment in infrastructure and economic development for traditional CBA. When taking the wider economic impacts into account, the relationship becomes much more complicated. Based on the European experiences, Werner Rothengatter talks about the WEI method and its implementation on large transport investments. The WEI evaluation framework integrates the CBA analysis and breaks down these complex relationships by the understanding of internal causality. Contrasting CBA, there is no standard procedure or agreed theoretical foundation for WEI measurement. However, with the emphasis on different attributes of socioeconomic impacts, possible quantitative approaches include spatial computed equilibrium models, the integrated regional land use and transport infrastructure models, regional simulation models, macroeconomic integrated models, and system dynamics models (Rothengatter 2019).

Such WEI evaluation methods extend the scope of traditional CBA by incorporating impacts that go beyond the direct user and business impacts. Moreover, they complement the analysis by providing both quantitative and qualitative evidence. In such a framework, those impacts which cannot either in principle or in current practice, be attributed to monetary values (as is for CBA) are identified, described, and measured. In spatial terms, WEI is thus important in linking and measuring potential gains absorbed in the vicinity of transport infrastructure.

Quality of Life Impact

On top of the pyramid is the quality of life (QOL). It is the measurement of happiness. The QOL method considers different needs for various categories of people—young and old, men and women, rich and poor that living in various places—city centers, suburbs, rural areas at different times—past, now, and the future (see Box 26.1). It not only includes attributes covered by the CBA and WEI methods, but also incorporates other values influenced by transport infrastructure. Values such as businesses connections, culture exploration, superior landscapes in towns and nature, playing sports on the beach, meeting family and friends, and other such activities directly affect the happiness of people. For instance, for the group of retired people, their use of the transport system, which is considered less valuable in

conventional CBA but very essential for their happiness, is perceived differently and captured in the QOL method. Similarly, different age groups such as children, adults, retirees, among others, would have different levels of perceived happiness and result in different results as captured in the QOL method.

The perception of happiness is different for different people with diverse backgrounds, depending on their value system (see Box 26.1). There has been substantial research to measure the social and environmental impacts such as air pollution, noise, and regional segregation, as introduced in the WEI section (Hayashi et al. 2015). However, there is no method yet to distinctly measure merits for multiple incoherent attributes in a consistent manner. Against this background, Yoshitsugu Hayashi proposes the QOL evaluation method to identify happiness. The method adopts the nonmonetary QOL indicator. Similar to the indicator of benefit–cost ratio (B/C) for CBA, the QOL indicator is based on the ratio of the sufficiency of an individual's happiness against society's burden, denoted as Q/SB (Hayashi 2018).

Multiple studies are introduced to demonstrate the QOL method and the application of the QOL indicator. In the case of urban transport network planning in Nanjing City, the QOL modeling of gross regional happiness is carried out, which is based on the individual perceived value that integrates with the accessible value (of medical resources particularly for this case). In Singapore, public surveys on the weights of QOL factors, such as education, community, recreation, and so on, are done to reflect the happiness perceptions of different population categories, visualized in the form of a QOL distribution map. Individual perception for QOL components is also estimated in the across Chubu Motorway Project in Japan (Hayashi 2018).

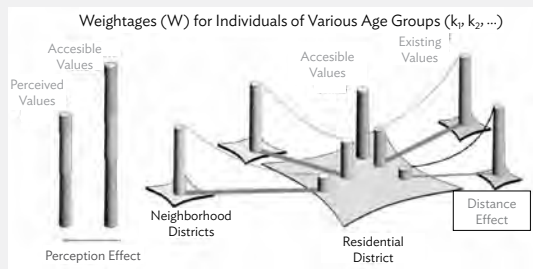
The QOL indicator facilitates the appraisal of transport infrastructure investment. This is important for national and regional transport planning and policy making to shift from a cost-benefit based evaluation system to QOL performance-based value system. Therefore, the lessons drawn from the four parts of this handbook and the concept of improving QOL for different people and uses, helps in the integration of qualitative and quantitative methods. Such an integrated method would aid in developing policies and eventually, the achievement of the Sustainable Development Goals (SDGs).

Box 26.1: Improvement of Quality of Life for Different People and Uses

The critical goal to achieve a higher quality of life (QOL) is based on nonmonetary indicators that are not motivated by GDP. However, the approach to identify happiness in urban and regional development is still scientific. Several sub-indicators are identified under five major indicators:

- A. Economic Opportunity
- B. Living and Cultural Opportunity
- C. Amenity
- D. Safety and Security
- E. Burden on Environment

Value Accessibility Theory of Quality of Life



However, on an urban–regional scale these factors are subjected to endogenous condition. For instance, a *young individual* (k_1) residing in the residential district may find a fitness center in the neighboring district more attractive and aligned with their needs and goals in improving their quality of life, compared to the fitness center located in their own residential district. Therefore, they won't mind the cost of traveling to the neighboring district. Thus, their perceived value of accessing the neighboring district would be lower than it actually is (see equation 1). However, an *old individual* (k_2) might worry more about a nearby healthcare center and not so much about a fitness center. An older individual may perceive higher value for an average healthcare center located in their residential district and rate a lower value to a good healthcare center in the neighboring district because of the costs and efforts involved in traveling to the neighboring district. Thus, the value of QOL is dynamic with respect to the subjected age group and individual preferences.

continued on next page

Box 26.1 *continued***Measuring QOL - Concept and Model****Accessibility values**

$$A_{ij}^m = V_j^m \cdot e^{-\alpha c_{ij}} \quad (1)$$

m : M type service to influence QOL

i : Mesh block with residents living in

j : Mesh block with objective value of QOL factor m

α : Impedance parameter for traveling from mesh block i to mesh block j

c_{ij} : Travel cost between mesh block i and mesh block j

V_j^m : Existing value of QOL factor m exists in mesh block j

A_{ij}^m : Accessible Value of V_j^m for residents living in mesh block i

Perceived value = QOL for individuals

$$QOL_i^k = \sum W^{mk} A_{ij}^m \quad (2)$$

k : Population group k with certain socio-economic attributes

W^{mk} : Weight of QOL factor for service type m for person k among all factors

QOL_i^k : Perceived value => Quality of life for person k living in mesh block i

Gross Regional Happiness (GRH)

$$GRH^k = \sum_i P_i^k \cdot QOL_i^k \quad (3)$$

P_i^k : Sum of population residing in mesh i that belongs to population group k

$$GRH = \sum_k GRH^k \quad (4)$$

Source: Hayashi (2018).

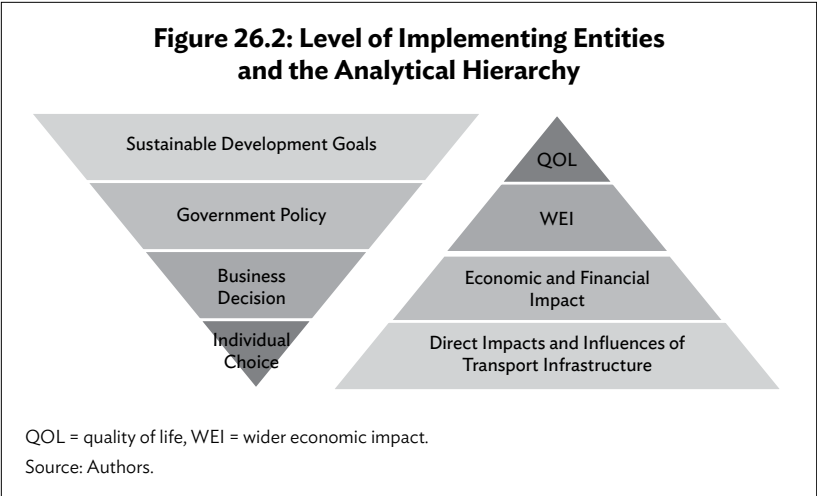
Way Forward: Implementation of Analytical Hierarchy

The analytical hierarchy currently synthesizes different methods on the evaluation of the direct and indirect impacts of transport infrastructure investment. The impacts vary greatly. From the bottom of the hierarchy, the direct impact and influences of transport infrastructure are to improve travel conditions for the individual user. The spillover effect could be captured as the new finance source for both public and private investors. WEI that are about the social impacts and other externalities need to be recognized as well, for policy making and the enhancement of the quality of life.

Various stakeholders are involved in transport infrastructure: transport users, investors, and public administrators. According to their specific focus and purposes, the evaluation methods in the analytical hierarchy are selected consistently by different levels of implementing entities in the transport-related decision-making process. Figure 26.2 shows the relationship between implementing entities with the analytical hierarchy.

The evaluation method should be able to address the entities' objectives. For instance, individual users concern more about travel fare and time, which are the direct outcomes of the transportation system. Investors see transport infrastructure investment as a business and ask how profitable it would be. Therefore, the CBA method is appropriate for them. The vertical integration of the analytical hierarchy is crucial. The evaluation methods should not be implemented in isolation. The traditional application of CBA on transport infrastructure ignores the existence of broader impacts arising from economic activity, and the evaluation by CBA solely may result in an inadequate evaluation of the total benefits. This would cause the miscarriage of an alternative infrastructure investment plan with potential wider socioeconomic benefits.

The vertical integration is especially important for a higher level of implementing entity. In general, the government has multiple roles and a wide range of responsibilities, and governmental policy making is of extreme importance for the potential long-term impact of transport



infrastructure investments. The transport policy needs to balance the tradeoff between efficiency and equity. This leads policy makers to ask how transport investments and policies can best be identified based on the measurement of the impacts.

However, to achieve a practical and comprehensive evaluation of transport infrastructure, attention should be paid to the way the analytical hierarchy is embedded into decision-making processes, according to the level at which the policies are made and implemented. The evaluation needs to reflect the extent to which spending on transportation affects different income, social, or racial groups differentially. Moreover, how the system is created helps to allow disadvantaged groups to fully partake in society. Unless an attempt is made to integrate different levels of the analytical hierarchy, inferior outcomes may result from an inefficient allocation of investment funds, and thus inequality will prevail in regional distribution of benefits.

As an ideal example of this vertical integration of analytical hierarchy, the spillover effect that incorporates the consideration of the cost and benefit (or specifically the rate of return) to business investors and general socioeconomic benefits, has received a great deal of attention and analysis over the years. Against the perceived constraints on the availability of public funds in the short term, the private sector is a new financing source for infrastructure. Governments are increasingly interested in the procurement of transport infrastructure through public-private partnerships or entirely through private funds. With the expectations of future involvement of investors, governments need to examine the robustness spillover effect as well as the wider impacts through the integrated evaluation.

Goal: Quality of Life Beyond the Sustainable Development Goals and the G20 Principles of Quality Infrastructure

The goal of infrastructure investment is to provide all its users' happiness, while minimizing societal burdens on nature and the economy of the planet. The SDGs are a collection of 17 global goals agreed on by the United Nations General Assembly in 2015; they essentially are useful to check happiness to be gained and reduce the burdens by infrastructure. Aimed at balancing socioeconomic activities and the environment, the goals are broad and interdependent, yet each has a separate list of targets to achieve. Some SDGs are directly and indirectly connected to sustainable transport and accomplishing the SDGs will rely on advances in sustainable transport.

Transport infrastructure brings a more comprehensive range of services to a diverse range of individual users. Besides, in recent years, it is understood that the final goal of transport infrastructure investment is to ameliorate the lives of all the citizens of society, such that the investment also achieves SDGs. In 2018, to set these efforts in motion, global leaders at the Group of 20 (G20) meeting endorsed a “Roadmap” and drew the G20 Principles for Quality Infrastructure Investment (see Chapter 25, Annex II). However, the G20 principles for promoting quality infrastructure investment exclude the “quality of life” aspect attached to transport infrastructure. Under ADBI’s “Making Cities more Livable” initiative, the Conference on Transport Infrastructure, Spillover Effects, and Quality of Life reveals the quality of life aspect to G20’s prelude.

Transport brings a wide range of services to a diverse range of individual users. Understanding and differentiating the concept of price, cost, and value is essential for better measurement of infrastructure impacts for various groups in different places in a consistently integrated manner (Box 26.2).

All decisions are a matter of judgment. The actual decision-making process needs to trade off diverse factors, both explicit and implicit, quantitative, and qualitative. Travel attributes, individual perceptions, and social features mediate satisfaction with travel price, economic cost, and value perceived. Different levels of implementing entities make different levels of decisions and choose the evaluation method in the analytical hierarchy that can best address the concern aligned with their position. Decisions made on transport infrastructure must have people and their quality of life at the core.

The prediction of individual behavior, as an indispensable part of transport infrastructure impact evaluation, is based on the theory of utility maximization, which assumes that individuals are entirely rational. However, in the era of changing the sense of values, subjective understanding of happiness challenges this assumption of the rational human.

The value system, which is a coherent set of values adopted by individuals, is an essential driver in transport infrastructure decision making. The QOL method is the value system-based evaluation method, and it has gained momentum recently. It questions the assumptions of the rational human and the unconstrained choices and comprehensive information that support the theory of utility maximization. Instead, it emphasizes that the value of the same transport infrastructure can be perceived differently based on the perception of utility and the quality of life at the individual level, as well as the temporal and spatial context.

Box 26.2: Concept of Price, Cost, and Value

Price is the amount of money at which a good or a service is available. It assumes a market, a seller, a buyer, and the exchange of goods or services. Price is quoted by the seller and agreed and paid by the buyer. Price has multiple forms in the transport field, such as bus fares, road tolls, and parking fees. Price is deterministic and measurable.

Cost is the sum of money incurred on the provision of goods or services. It represents the consumption of resources to create or manufacture. Cost covers more terms. Traditional cost–benefit analysis evaluates the economic cost, which is measured in monetary terms. For example, travel time is dealt as the time cost in the cost–benefit analysis.

Value is a complex and wide concept, which goes beyond price and cost. It is the worth attached to a particular good or service that motivates a person to have it. It is the reflection of a buyer’s future anticipation. Unlike cost or price, value is not deterministic in the complete sense. Value is subjective because people value different things differently.

Price, cost, and value are interconnected. The existence of the good or service in the market is the precondition of the exchange, which is contingent on the cost to the provider. The cost to the provider is primarily intended to be covered by the price offered by the buyer. Price, as the willingness to pay for the good or service, is based on the perceived value the good or service can provide the buyer. A transaction happens when the cost to the provider is lower than the price the buyer pays, and the price is lower than the value the buyer gets.

Source: Authors.

The QOL method adopts the Q/SB indicator that integrates complex and multidimensional data on an individual’s happiness and society’s burden into a single and intuitive value. Based on the evaluation objective, the indicator of Q/SB can be transformed into, for instance, QOL/CO_2 when CO_2 emissions and its impact on the quality of life are focused. These QOL indicators can capture the change of values and the impacts of transport infrastructure investment to meet the SDGs, especially Goal 11 (Sustainable Living), and Goal 16 (Inclusiveness). The most important viewpoint of SDGs is “Inclusiveness,” which means “no one left behind.” Sustainable transport infrastructure development should recognize and align a variety of needs with people and their quality of life, to make society better for everyone.

Conclusion

Transport infrastructure significantly contributes to socioeconomic development and the increased quality of life. The transport sector is large, diverse, and complex, and infrastructure decisions and investments have an especially long lifespan at both regional and national levels. This makes the decisions made today critically important for tomorrow. It is vital for decision makers of infrastructure investment to build consensus with stakeholders (Nakamura et al. 2019). The analytical hierarchy is a useful decision tool that can be incorporated for engaging the public and private sectors and all relevant stakeholders in future appraisals of transport infrastructure investment, toward achieving the SDGs.

Through the special interest group on High Speed Rail: Policy, Investment, and Impacts in WCTR, ADBI will continue to draw new insights for policy makers on the impact of transport infrastructure development from the experience of investment, implementation, and operation around the world.

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Handbook on High-Speed Rail and Quality of Life

Asia needs high-quality infrastructure development projects, such as high-speed rail (HSR), to drive economic growth and improve quality of life in the region. In addition to meeting the rapidly growing demand for high-quality infrastructure, researchers, policy makers, and all stakeholders must consider its implications and contributions to the overall enhancement of quality of life.

Handbook on High-Speed Rail and Quality of Life outlines global experiences of HSR development, including its construction, impacts, and planning, with a special focus on countries that are planning implementation in the coming decade. HSR infrastructure can bring considerable socioeconomic benefits that cannot be captured through econometric modeling alone. Thus, analysis of the true impacts requires a scalar as well as a temporal lens. The studies in this handbook discuss transport infrastructure projects of varying geographic scale and describe the underlying complexities of developing an infrastructure system while focusing on the aspects that can enhance quality of life.

The cases, concepts, and ideas presented in this handbook were discussed and refined during a conference and seminar series held at the Asian Development Bank Institute in Tokyo and special sessions on transport and quality of life at the 15th World Conference on Transport Research at the Indian Institute of Technology Bombay in Mumbai. The special sessions were jointly organized by the Asian Development Bank Institute and World Conference on Transport Research Society Special Interest Group A4, “High-Speed Rail: Policy, Investment, and Impacts” (WCTRS SIG-A4). The conference and special sessions highlighted critical issues and delivered key messages on the broad research on high-speed rail and quality of life.

About the Asian Development Bank Institute

ADB Institute, located in Tokyo, is the think tank of the Asian Development Bank, an international financial institution. ADBI aims to be an innovative center of excellence for the creation of rigorous, evidence-based knowledge that can be implemented as new actionable policies by developing and emerging economies, so as to contribute to achieving a prosperous, inclusive, resilient, and sustainable Asia and the Pacific.

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