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# THE ASIAN JOURNAL

Journal of Transport and Infrastructure

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Special Issue

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## HIGH SPEED RAIL SERVICES IN ASIA

(A Joint Publication of ADBI and AITD)

### High-Speed Rail and Station Area Development

*Shreyas P Bharule*

### Illustrating Spillover Effects of Infrastructure

*Naoyuki Yoshino, Nuobu Renzhi and Umid Abidhadjaev*

### Modeling Spatiotemporal Urban Spillover Effect of HSR Infrastructure Development

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### Japan: HSR's Agglomeration Impact

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### Development of HSR in People's Republic of China

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### HSR Effect on Urban Spatial Correlation: A Big Data Analysis of People's Republic of China's Largest Urban Agglomeration

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### Japan: Integrated Land Development and Passenger Railway Operation

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ASIAN INSTITUTE OF  
TRANSPORT DEVELOPMENT

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# THE ASIAN JOURNAL

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## CONTENTS

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|  |     |
|--|-----|
| Preface  | i   |
| High-Speed Rail and Station Area Development<br><i>Shreyas P Bharule</i>   | 1   |
| Illustrating Spillover Effects of Infrastructure<br><i>Naoyuki Yoshino, Nuobu Renzhi and Umid Abidhadjaev</i>                                      | 11  |
| Modeling Spatiotemporal Urban Spillover Effect of<br>HSR Infrastructure Development<br><i>Satoshi Miyazawa, K E Seetha Ram and Jetpan Wetwitoo</i> | 17  |
| Japan: HSR's Agglomeration Impact<br><i>Jetpan Wetwitoo</i>  | 26  |
| Development of HSR in People's Republic of China<br><i>Haixiao Pan and Gao Ya</i>  | 52  |
| HSR Effect on Urban Spatial Correlation:<br>A Big Data Analysis of People's Republic of China's<br>Largest Urban Agglomeration<br><i>Ji Han</i>    | 85  |
| Japan: Integrated Land Development and<br>Passenger Railway Operation<br><i>Fumio Kurosaki</i>   | 98  |
| Spill-Over and Straw Effects of HSR<br><i>K E Seetha Ram and Shreyas P Bharule</i>   | 114 |
| High Speed Rail in India: The Stepping Stone to<br>Enhanced Mobility<br><i>Anjali Goyal</i>  | 123 |



## Preface

High-Speed Rail (HSR) has been in operation for over 50 years in many countries. It has always been controversial because of its high cost and downplayed potential. In this context, it is worth reminding readers that when it was decided to construct the Shinkansen between Tokyo and Osaka in 1964, a structural shift had begun in Europe where traffic had begun shifting to cars and aviation. The received wisdom in Europe, therefore, was that such huge investment in HSR was unwise.

But Japan went ahead with the project and thanks to the pattern of urbanization in Japan and population densities, the Shinkansen turned out to be a huge success. This eventually spurred the development of HSR in many other countries. In Asia, in the past two decades, People's Republic of China alone has constructed nearly 27,000 km of HSR and India, Indonesia, Thailand, Malaysia, Singapore and Vietnam are also planning and constructing HSR.

Even so, the doubts HSR have not yet been fully dispelled. The issue of alternative uses of financial and other resources that are needed to build has continued to worry economists, investors, activists and governments. It is our hope that this issue of the Journal will help in mitigating these concerns.

This hope is based on global experience which shows that investment in HSR brings considerable socio-economic benefits which are not, and cannot be, captured by internal rate of return (IRR) criteria alone. Quite apart from the long term benefits of the higher technology platform that HSR brings, the immediate effect is the significant reduction in the travel time between the travel origin and destination. The change in travel times affects the travel mode choice of the passengers. The importance of this in an increasingly environment unfriendly world cannot be underemphasized.

The positive impacts are slow to arrive and can take about a decade. But after that the spillover development effects become manifest, the most important of which is urban development in the proximity of the HSR station areas. Sensible planning changes urban dynamics and thus the economic dynamics of its service region. Simultaneously, the integration of the HSR system with the

existing transport infrastructure radically increases the above-mentioned spillover effects, expanding the market access area of any services. The increased accessibility to services and convenience of traveling thereby enhances the overall quality of life in the city. This has been the experience in all countries that have introduced HSR.

India has also initiated the process for starting HSR operations. This initiative has received a mixed response. It is in this overall context that this special issue of *The Asian Journal* has been undertaken. It comprises a compilation of important studies undertaken by researchers at the Asian Development Bank Institute (ADBI), Tokyo; the University of Tokyo, Japan and the Asian Institute of Transport Development (AITD), New Delhi, India.

It aims to highlight the various aspects attached to the implementation of advanced transport infrastructure. This special issue provides a worldview of experiences from countries that have managed running a successful HSR service and draws messages from the lessons learned by these countries while implementing their HSR service.

In the paper 'High-Speed Rail and Station Area Development', Shreyas Bharule highlights the importance of station area development in the context of high-speed rail development. The chapter highlights the complexities involved in the station area development projects. Reviewing the literature, the author emphasizes that the developments in station area are a crucial phenomenon in triggering and driving the opportunities for economic development in the near future.

In the paper 'Illustrating Spillover Effects of Infrastructure', Naoyuki Yoshino analyzes the changes in tax revenues before and after the introduction of the HSR in Uzbekistan. He introduces the concept of spillover effects. He shows how regional tax revenues increase during the construction period and after the line becomes fully operational.

In the paper 'Modeling Spatiotemporal Urban Spillover Effect of HSR Infrastructure Development', Satoshi Miyazawa, Jetpan Wetwitoo and K E Seetha Ram carry out the study on spillover effects of high-speed rail

infrastructure development in urban areas. They identify the elements that support as well as obstruct the spillover effects in an urban setting.

In the paper 'Japan: HSR's Agglomeration Impact', Jetpan Wetwitoo presents the agglomeration industrial, temporal and geographical impacts from HSR in Japan. He demonstrates the positive agglomeration effects of HSR.

In the paper 'Development of HSR in People's Republic of China', Haixiao Pan and Gao Ya study the development of HSR in People's Republic of China. The study presents the development effects of HSR and suggests that to enhance the effectiveness of HSR in People's Republic of China, the stations should be located near the city centres.

In the paper 'HSR Effect on Urban Spatial Correlation: A Big Data Analysis of People's Republic of China's Largest Urban Agglomeration', Ji Han suggests that high-income levels and enlarged job opportunities are the major driving factors attracting passenger inflows. He presents a study on the HSR's effects on urban spatial correlation. The study is conducted in the Yangtze River Delta, the largest urban agglomeration in PRC. The results of the study indicate that HSR significantly improves the correlation intensity between cities compared to road transport.

In the paper 'Japan: Integrated Land Development and Passenger Railway Operation', Fumio Kurosaki elaborates on the integrated rail and land development model in Japan and describes the historical evolution of the integrated land development process, the formulation of the development model and presents a case of integrated development of the Tsukuba express railway line in Japan.

In the paper 'Spill-Over and Straw Effects of HSR', K E Seetha Ram and Shreyas Bharule draw policy implications for countries implementing and planning to implement HSR. They emphasize that since the complete process of declaring HSR project a success takes over a decade a robust development strategy and long-term vision is a must since the beginning of the project. For this a policy framework involving and engaging all the members, stakeholders and actors should be given equal importance.

In the paper 'High Speed Rail in India: The Stepping Stone to Enhanced Mobility', Anjali Goyal points out the importance of adopting a strategic approach to the indigenization of these new technologies in India. She highlights the technologies associated with futuristic mobility in today's fast-changing world and provides a worldview of the ongoing technological advancement in high-speed mobility and debates on the need of a road map for HSR policy formulation in India.

I would like to thank Mr. Shreyas Bharule and Dr. K E Seetha Ram for their contributions in coordinating this issue of the Journal. I am confident that it will significantly increase our understanding of the benefits of HSR.

K. L. Thapar  
Chairman, AITD

# High-Speed Rail and Station Area Development

Shreyas P Bharule\*

## INTRODUCTION

Extensive case studies have helped build empirical research on the local impacts on urban development by HSR station. Existing literature has made a comprehensive evaluation on the before and after effects of HSR operation; compared cities with and without HSR station or services and among cities in various countries and regions.

This chapter reviews the topic of Station Area Development. Station area planning is a critical component for a successful operation of high-speed rail (HSR) stations. A station area is crucial in triggering and driving the opportunities for economic development in and around the station.

Another relevant concept in the context of station area development is Transit Oriented Development (TOD). Most of the literature emphasising on the concept of TOD discusses how to capture the land value generated around the transit stations or nodes with the use of urban planning and urban design strategies. However, TOD type of developments are urban context sensitive and associated with one urban setting at a time. The present chapter reviews and summarises the literature related to High-Speed Rail and Station Area Development.

Scholars term station area development as one of the most complex urban development project. The chapter tries to unveil this complexity and highlights the necessity of station area development. The chapter is divided into three sections. The first section highlights the characteristics of HSR station area development projects. The second part discusses the factors that trigger the station area development projects. The third section draws lessons for developing a good station area plan.

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## **CHARACTERISTICS OF HSR STATION AREA DEVELOPMENT PROJECTS**

HSR station areas have been described in various texts using various characteristics and indicators. Jean-Jack Terrin in his book *Railway Stations and Urban Dynamics: High-Speed Issues* highlights the characteristics of HSR development projects in European cities of Barcelona, Lillie, Lyon, Marseille, Rotterdam, and Turin. He argues that HSR stations may be on their way to becoming a new architectural typology, 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. The highlighted characteristics described primarily based on two models: transport infrastructure-led economic development and a network model connecting local and global hubs while producing mobility-induced services.

Reviewing the urban development impacts induced by HSR, Sands (1993) presents empirical evidence from Shinkansen in Japan, Train à Grande Vitesse (TGV) in France, and Inter-City Express (ICE) in Germany. He focused on the change in travel time and urban economic impacts such as demographic changes as well as station area development and redevelopment. At the local level, his analysis categorised the station in two types: first, HSR introduced in existing conventional rail stations and, second, new stations exclusively built for HSR. At a regional level, he compared stations by stations where only express HST stopped and those served by slow HSTs which stopped at all the stations.

Peter Pol proposes two groups of cities in the European context: International Service Cities and Cities in Transition. He points that International Service Cities such as London, Paris, Barcelona, Amsterdam, Lyon have a competitive edge in the international service and knowledge economy and, because of their international facilities, attractiveness and accessibility, they compete to be global players. The Cities in Transition such as Lille, Liverpool, Marseilles, Rotterdam, Turin are often old port or industrial cities seeking to transform and boost their economy by attracting new economic activities and inhabitants through investments. Both the groups of cities see the HSR station as an opportunity to attract more business activity, commercial and real estate land development in and around the station area. However, not all the station area developments observed as same. For instance, Peters and Novy analyse cases in Europe and identify four distinct categories of Train Station Area Development:

**Station Renaissance Projects:** Focused on the redevelopment of station facilities, such as the restoration and expansion of historic stations. Some stations also enhance the shopping and entertainment facilities within the station premises.

**Transport Development Projects:** The primary goal of these projects is to enhance the transportation infrastructure and improve the transfers between different modes available at the station.

**Strategic Mega-projects:** They involve significant and large-scale development in the vicinity of a railway station; require active involvement of the stakeholders in both public and private investment.

**Urban Development Projects:** Redevelopment of railway station and its surroundings must be done in one integrated master plan. Complementarity in land-use while master planning the station surroundings helps in balancing the pressures on infrastructure.

Comparing the case of California HSR with Japanese Shinkansen, Murakami, and Cervero (2010) examined the locational characteristics of job and labour markets around the planned HSR stations. They applied cluster analysis to build a typology of 26 proposed stations in California and 17 existing stations in Japan. The purpose of categorization was to assess how different factors would influence the impact of HSR on urban development. On the basis of variables based on city characteristics, the authors categorised 26 proposed stations in the following five categories:

- (i) Global and regional business centers,
- (ii) Edge cities,
- (iii) Aerotropolis,
- (iv) Leisure cities, and
- (v) Small intermediate cities.

Hall (2009) stresses the edge city stations having a locational advantage of maximum potential for future development, especially when the HSR services directly connect to airports. Kasarda (2011) proposed the concept of Aerotropolis, a city based on aviation-linked businesses with outlying HSR corridors stretching the clusters of these business and associated residential developments to a 30-

40 km radius from an international airport. Empirical findings suggest that new HSR projects are more likely to induce benefits in knowledge and service-based industries along the corridor, but they tend to agglomerate in large globally connected cities. Growth may also shift from small intermediate cities to edge cities because of enhanced accessibility.

Carmen Bellet identifies inter-related strategies cities adopted on the advent of an HSR in Spanish cities:

**Ciudad Real:** HSR station was placed in the city periphery at the same time conventional line tracks were removed from the city center. This strategy provided the city with an opportunity to strengthen the core by consequently redeveloping the city center. The new HSR station at the periphery is an opportunity to create a secondary center in the city.

**Zaragoza:** Building the HSR station on a central location by relocating the existing railway activities in the periphery of the city. The relocation of railway yards, freight facilities and workshops, etc. provides a significant amount of land in the core-city area, making it possible to be redeveloped for commercial establishments.

**Lleida:** Integrating the new HSR services within the existing conventional rail station by expanding the station building and simultaneously redeveloping the area around the station to accommodate more commercial activity.

Loukaitou-Sideris discusses six variables that intervene and influence the type of urban design strategy and station area development:

- **Geographic context:** Large metro centre, small metro centre, suburban employment centre, suburban dormitory, and exurban dormitory, rural, airport-related
- **Ridership:** Origin, destination
- **Station location:** Central or peripheral
- **Network type:** Shared with conventional line or dedicated tracks
- **Guideway track:** Elevated, surface tunnel, type of parking
- **Type of parking:** Structure or surface; concentrated or distributed.



Loukaitou-Sideris argues that the geographic context, ridership count and station location directly influence the mix of land-use as well as the type and scale of development in the station area. The type of rail network will drive the type of development on the adjacent land, whether it is shared with the conventional rail or dedicated tracks. The arrangement of the guideway tracks also defines the morphology of the surroundings, for instance, stations located underground or elevated provide more land for development adjacent to the station in comparison to stations on the surface. This aspect along with the type of parking would together define the level of integration of the station into its surroundings.

#### **FACTORS THAT TRIGGER STATION AREA DEVELOPMENT**

Several factors must be considered while investing in infrastructure like High-Speed Rail. Some authors have traced the driving forces behind the proliferation of station area development and redevelopment projects in Europe during the last two decades. Luca Bertolini and Tejo Spit in their book 'Cities on Rails' identify several innovations and changes that were responsible for redevelopment projects near HSR railway stations across Europe. These include technological innovations, institutional changes, innovative public policies, and shifts in the spatial dynamics of the region.

Technological innovations, particularly the HSR development helped in minimizing the distances and improved accessibility of the cities served by HSR. This enhanced accessibility worked as a boon for many multi-branch firms. This demand generated by relocation of firms triggered new developments around stations. One of the most reviewed case studies is of Lille, which became a critical crossroads between London, Paris, and Brussels after the opening of its HSR station on the Channel Tunnel link, triggering significant development in the station area known as Euralille.

Privatization of railway operating companies is one of the common institution changes found across rail operators in Europe. Privatization helps companies capture the locational advantage of a railway station to its maximum potential, attracting investments to develop land above and around the station. Not only the railway operators but the city municipal corporations were seen updating their policies in order to improve the city's competitive image taking

advantage of the HSR investment. This resulted in some large-scale station-city redevelopment plans. In the case of the Netherlands, such redevelopment plans are part of national policies; the country's HSR stations are part of a sizeable nation-wide government funded urban development projects, called the New Key Projects.

In addition to the vision to gain increasing economic competitiveness, such urban development policies are often motivated by the desire for more sustainable, dense and compact urban forms, which are desirable as they can easily be served by alternative modes of city-level transportation and promote walkability. The development of dense urban nodes around the HSR stations has been promoted to achieve the desired form as some of the Central European cities are currently shrinking. These developments are enabled by the public as well as private sectors willing to invest, and the availability of large parcels of developable land near many station areas. Although a significant driver has been the brown field sites, left empty in the wake of de-industrialisation and their shift to a service economy, resulting in structural transformation of the whole region.

Understanding and measuring the forces behind station area development around Dutch railway stations, Bertolini (1998) brings forth the node-place dynamics of the station area. He describes a model in which different station areas vary regarding their value as a node and as a place, and gives examples of different station areas that fall into different categories. In the Node-Place model, the value of a station as a node is a function of the accessibility of the HSR station. However, value as a place is a function of the intensity and diversity of activities in the station area.

Nevertheless, the model clarifies the tremendous need of urban design considerations to be given to each station type - node or place, or both. The binary nature of station areas having to become nodes, catering both transport and non-transport networks, and as places hosting diverse uses, generates a series of challenges. Bertolini and Spit (1998) identify five types of challenges:

*Spatial challenges* arise because of the compressed nature of most of the station sites. These challenges may paralyse the fluidity required for passengers' intermodal transfers as well as other users including railway staff. The cumbersome nature of railway infrastructure often creates a barrier effect

dissecting the station from its surroundings. However, unlike airports, railway stations can be integrated into dense urban contexts.

*Temporal challenges* arise because, usually, transport investments do not have the same time horizons as urban redevelopment plans. This, combined with the generally a decade-long time frame of station area development, generates uncertainty. Such uncertainty is extremely puzzling for urban authorities as well as private developers, delaying subsequent investments in the surroundings. Unexpected fluctuations in the real estate markets can indirectly affect planning.

*Functional challenges* arise in setting up multifunctional environ as HSR railway stations act as both transit nodes and places for passengers and non-travelers to move, and or assemble. The complexity thus created by the mélange of activities within a relatively tight area is challenging to address.

*Financial challenges* become a burden in case of addressing technical difficulties and including incompatible design requirements. Hence, the public sector often relies on private sector instruments like the use of higher floor-area ratios (FARs) or floor-space index (FSI) and transfer of development rights (TDR) for intensifying the land use. Revenue from the tax is essential this creates more demand for commercial land use than other land-uses in the proximity of the station.

*Management challenges* give rise to 'not in my backyard' issues and arguments. Due to the presence of public, private and public-private investments and properties in and around the station, many stakeholders are involved and are responsible for maintenance. Hence, the need for stakeholder coordination is of paramount importance for operation and future planning of the station as well as the station area.

#### **THE GOOD STATION AREA PLAN**

The previous section elaborated on the fact how development within an HSR station and surrounding areas is crucial and challenging in interdisciplinary ways too. What contributes to proper HSR station area planning?

As the previous sections highlighted, HSR station areas should be both transportation nodes and connector place. A third dimension towards the sophisticated setting of a good station area is of planning and policy factors.

Planning and policy factors result in an envisioned blend of facilities around the station. Compatible planning and urban development policies can achieve good intermodal connections, better door-to-door services and compact urban form by the concentration of business, cultural and entertainment activities.

Japan after the introduction of the first HSR has the longest history of station – adjacent developments. Learning from the station area development cases in Japan, Morichi brings forth a decision-making process for station area development. He suggests a four-step guideline for achieving positive impacts of high-speed rail on urban development in the form of station area development projects.

Developing a strategy for future urban structures based on the potential of the impact on the region and formulating a master plan of the station area:

- Select the target zone to be developed and decide on the types of incentives and regulation mechanism available or required.
- Establish an institution for the development, to be responsible for implementing the zoning and land-use changes as per the target zone requirements.
- Implement the project as per by the master plan.

The above points demand an uncluttered understanding amongst the stakeholders. Moreover, the timing of the land development around the station overrides all other decisions taken during the project. Timing is critical for driving the relationship between the demand of land and its price as soon as an HSR project is announced. Land prices are expected to be lower soon after the completion of the HSR project, even though they might be higher without the HSR project. This means that the cost of land development can be less expensive compared to delayed development in the station area.

According to Jaheok Oh, the Korean Express Train (KTX) stations are emerging as the core of the regional development in the Republic of Korea. Station area development plans were prepared for KTX stations. A hub-spoke model was adopted to increase the station accessibility from the surrounding areas. The plans embedded intermodal transport center complexes (ITCCs) which combine both intermodal transfer and integrate business and commercial

activities within the station area, although, the station development projects have had some difficulties which resulted in inadequate returns from investment. Firstly, there was a delay in construction of the feeder transport system. Secondly, there was a delay in development due to lack of capability of the project executing agencies. Thirdly, there were no rules or guidelines for the station area development. The integrated coordination of all the stakeholders is very complicated and is very difficult to be adjusted, if not established beforehand.

In a survey of HSR experts, Loukaitou-Sideris found the most important preconditions for station area development. The experts highlighted some important pre-conditions for the policymakers and other stakeholders, to develop the HSR station areas: these include central station location, integration of the station with its surroundings, connectivity to the station, level of service, and strong political will and vision of the stakeholders.

## **CONCLUSION**

The review draws attention to the importance of station area planning and its importance in the case of HSR stations. The discussion in this chapter brings forth the multiple characteristics and overlapping factors which collectively impart form to a station area. There is no doubt that any urban development project involves various stakeholders, but the level of complexity in case of station area developments is exceptional.

Railway operators, city local authorities, implementation agencies and other stakeholders are all equally responsible for developing a vision for the station areas. It is essential for the city authorities to carefully consider and include the local resources as well as regional potentials while designing the station area master plans. A station-city master plan should identify the areas that can be boosted, using the HSR and avoid repetitive development.

From the proposal to completion, a station area project is subjected to multiple complexities which are induced due to political, economic, urban, social and many other externalities. A general implication suggests that a non-dynamic plan does not consider these externalities. Such plan and fiscal instruments are usually too dependent on a particular type of property market or a transport policy context, and could easily and rapidly become outdated.

Lastly, an HSR station area is beneficial to both the city and the railways. To the city, it serves in the form of an urban amenity crucial for its economic growth. For the railways, station areas provide an important opportunity to harness revenue through non-railway businesses. Realising the full development effects of an HSR project may take decades. Hence, careful planning of the project and coordination amongst the stakeholders must be established to accomplish a set of phased goals to optimize the development of an envisioned HSR station area.

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# Illustrating Spillover Effects of Infrastructure

Naoyuki Yoshino\*, Nuobu Renzi<sup>@</sup> and Umid Abidhadjaev<sup>α</sup>

## INTRODUCTION

Infrastructure means basic physical and organisational facilities and services that make the operation in a society possible. Definition of infrastructure can be categorised into two types –hard infrastructure and soft infrastructure.

Hard infrastructure is based on facilities and structures like water supply, sewers, power grids and telecommunications as well as transport infrastructures such as roads, railways, tunnels and bridges. Soft infrastructure mainly refers to institutions, like healthcare, education or financial systems. Here, when illustrating the spillover effects of infrastructure, we use the definition of hard infrastructure, especially transport infrastructure, electricity and telecommunications.

Infrastructure investment has been widely believed to be a great tool to boost and promote efficiency of a country's economy, which stems from its spillover effects on wider society. The spillover effects of infrastructure are usually far bigger than the actual investment in infrastructure.

In addition to the direct impact of infrastructure investment, the effect through marginal increases in productivity of capital and labour, better proximity to markets and lower costs greatly contribute to the regional or neighbouring economic growth. This spillover effects can be illustrated by a production function represented by

$$Y = F(K, L, I)$$

where Y is the production outcome or economic outcome, K is capital input, L refers to labour supply, and I is the infrastructure investment. By taking first differencing with respect to I, we have

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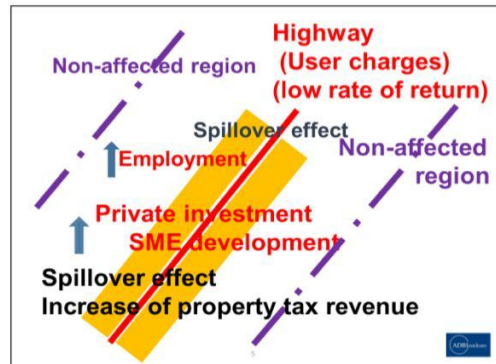
$$\frac{\partial Y}{\partial I} = \frac{\partial F}{\partial K} \cdot \frac{\partial K}{\partial I} + \frac{\partial F}{\partial L} \cdot \frac{\partial L}{\partial I} + \frac{\partial F}{\partial I}$$

|                 |   |   |   |   |   |                                 |
|-----------------|---|---|---|---|---|---------------------------------|
| Total<br>Effect | = | $\frac{\partial F}{\partial K} \cdot \frac{\partial K}{\partial I}$ | + | $\frac{\partial F}{\partial L} \cdot \frac{\partial L}{\partial I}$ | + | $\frac{\partial F}{\partial I}$ |
|                 |   | Spillover<br>Effect   |   |   |   | Direct<br>Effect                |

which shows that total impact of infrastructure investment on the economic outcomes consist of direct effects from the infrastructure investment itself and spillover effects caused by improving the capital and labour productivities.

Figure 1 shows an example of the spillover effects of a highway investment project. This positive spillover effect (highlighted in yellow) is possible if this new highway generates more employment opportunity through an increase in private business and private investment along both sides of the highway.

**Figure 1: Expansion of Infrastructure Investment:  
Capturing Spillover Tax Revenues**



Source: (Yoshino, Helble, and Abidhadjaev, 2018), ADBI.

**A. The spillover effects on economic outcomes:**

Examples from Uzbekistan and Japan

**Uzbekistan:** The connection of the Tashguzar-Baysun-Kumkurgan (TBK) railway in southern Uzbekistan was completed in 2007. By employing the difference-in-difference (DiD) estimation method, this analysis aims to examine whether such transportation infrastructure investment would yield economic



spillover effects on neighbouring regions. The estimation is based on the DiD regression equation:

$$\Delta Y_{it} = \alpha_i + \phi t + X_{it}' * \beta + \delta * D + \epsilon_{it}$$

where  $\Delta Y$  is the growth rate of economic outcomes (GDP and sectoral value-added out-comes (industry, agriculture and services));  $X$  is a vector of time-varying control variables;  $D$  is the binary variable indicating whether or not the observation belongs to the affected group after the provision of the railway line;  $\alpha_i$  is the sum of autonomous and time-invariant unobserved regional-specific growth effect;  $\phi t$  is the year-specific growth effect; and  $\epsilon$  is the error term.

The estimation result of the equation is shown by Table 1. DiD coefficient  $\delta$  capturing the spillover effects on economic outcomes for neighbouring regions, can be checked by three time periods – short-term (from pre-railway to 2008), mid-term (from pre-railway to 2009-2010), and long-term (from pre-railway to 2011-2012). Table 1 shows a significant positive spillover effect on GDP growth only in the long term for which the growth rate is augmented by 2.06 percentage points (significant at one per cent). The DiD coefficient estimate for the short term is negative but statistically insignificant. On the other hand, DiD co-efficients for contributions to sectoral value-added growth are wide-ranging and generally not statistically significant, the one exception being a negative short-term impact for agriculture (significant at 10 per cent). It could be the result that the business decisions in the agriculture sector may have been affected by the connection from the railway neighbouring regions to the country's centre.

**Table 1: Spillover Effects of TBK Railway on Economic Growth**

| Independent variable | GDP growth rate | Industry growth rate | Agriculture growth rate | Service growth rate |
|----------------------|-----------------|----------------------|-------------------------|---------------------|
| Short-term           | -2.34           | 5.31                 | -3.17*                  | -5.46               |
| Mid-term             | 1.68            | 5.72                 | -0.89                   | 0.84                |
| Long-term            | 2.06***         | 4.11                 | -1.62                   | 3.48                |

Note: Significance levels: \*  $p < 0.10$ ; \*\*  $p < 0.05$ ; \*\*\*  $p < 0.01$ .

Source: Yoshino and Abidhadjaev (2017)

**Japan:** The other analysis is based on the estimation result of the spillover effects of the Kyushu high-speed rail (Shinkansen) line in Japan on regional tax revenues. Since the data of local GDP is unavailable, using the tax revenues is a

substitution to examine the spillover effects on regional economic outcomes. The Kyushu Shinkansen was launched in 1991 and completed in 2003. The Shinkansen line started operations from Kumamoto to Kagoshima in 2004 and the entire line was opened in 2011. The analysis employs a similar DiD method to compare tax revenues of regions along the Shinkansen line with others that were not affected.

Table 2 shows the estimation results, which suggest the total tax revenues of the prefectures affected by the Kyushu Shinkansen increased during construction (see construction period column in Table 2) and subsequently decreased while it was operating (see operation phase 1 column in Table 2) as an autonomous branch (not being connected to the Sanyo line in Honshu). But once the line was connected to a wider system of railines through linkage with the Sanyo line, the tax revenues dramatically increased again (see the operation phase 2 column in Table 2).

**Table 2: Spillover Effects of the Kyushu HSR Line on Regional Tax Revenues**

| Scale of focus                   | Affected Group of Prefectures | Construction Period (1991-2003) | Operation Phase 1 (2004-2010) | Operation Phase 2 (2011-2013) |
|----------------------------------|-------------------------------|---------------------------------|-------------------------------|-------------------------------|
| Spillover effect by region       | Group 1                       | 99,949***                       | 60,884***                     | 168,586***                    |
|                                  | Group 2                       | 181,098***                      | 117,907**                     | 281,933**                     |
| Spillover effect by adjacency    | Group 3                       | 134,498***                      | 97,210***                     | 229,224***                    |
|                                  | Group 4                       | 109,557***                      | 76,310***                     | 200,704***                    |
| Spillover effect by connectivity | Group 5                       | 193,639***                      | 99,830**                      | 352,718***                    |

Note: Significance levels: \*  $p < 0.10$ ; \*\*  $p < 0.05$ ; \*\*\*  $p < 0.01$ . The unit of the tax revenues is one million Japanese Yen. Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. Source: Yoshino and Abidhadjaev (2016).

This analysis reveals that the Kyushu Shinkansen has positive spillover effects on the region it was located in (Spillover effects by region), adjacent prefectures (Spillover effects by adjacency), and prefectures along the Sanyo line

(Spillover effects by connectivity). On the other hand, results also reveal that tax revenues increased more in the located region of the rail line than in adjacent prefectures, but less than in the prefectures along the Sanyo line.

To conduct a cost-benefit analysis, Table 3 presents the discounted present values of tax revenues growth by the Kyushu Shinkansen project and the discounted present value of construction cost. The discounted present tax revenues and construction cost are calculated from the average yearly tax revenues and construction cost, by adopting the social discount rate (SDR) of 2 per cent with 1991 as base year. The Kyushu Shinkansen project has a 13-year construction period, a 7-year first operation period and a 3-year second period (on the other hand, the construction cost exists in both construction period and first operation period). From the discounted value of tax revenues and the construction cost, the expected net present values (ENPV) can be calculated, which are also presented in Table 3.

ENPV of the spillover effects of Kyushu Shinkansen had been negative for 20 years from the construction period to the first operation period, and turned positive from the second period. By calculating the ratio of total discounted revenues to total discounted costs for each group, we find the prefectures along the Sanyo line (Group 5) have the highest ratio of 0.40.

## **B. Definition of Terms**

The spillover effect: The economic impact in one region that occurs because of seemingly unrelated events in other regions.

Difference-in-difference (DiD) method: A statistical methodology used in quantitative research in the social sciences that try to capture the differential effect of a treatment (like infrastructure investment) on a 'treatment group' (affected by the treatment) versus a 'control group' (not affected by the treatment). It calculates the effect of a treatment on an outcome (like economic growth and tax revenues) by comparing average change over time in the outcome variable for the treatment group, compared with average change over time for the control group.

Table 3: Cost-Benefit Analysis

| Discounted Present Revenue                           | Affected Group of Prefectures | Year      |           |         | Total     |
|--|-------------------------------|-----------|-----------|---------|-----------|
|  |                               | 0-12      | 13-19     | 20-22   |           |
| Revenues by region                                   | Group 1                       | 87,251    | 43,515    | 109,062 | 239,828   |
|  | Group 2                       | 158,090   | 84,271    | 182,389 | 424,750   |
| Revenues by adjacency                                | Group 3                       | 117,410   | 69,478    | 148,291 | 335,179   |
|  | Group 4                       | 95,638    | 54,540    | 129,841 | 280,019   |
| Revenues by connectivity                             | Group 5                       | 169,038   | 71,350    | 228,182 | 468,570   |
| <b>Discounted Construction Cost</b>                  |                               |           |           |         |           |
| Cost   |                               | 549,087   | 628,527   | 0       | 1,177,614 |
| <b>ENPV</b>  |                               |           |           |         |           |
| ENVP by region                                       | Group 1                       | (461,836) | (585,012) | 109,062 | (937,786) |
|  | Group 2                       | (390,997) | (431,676) | 182,389 | (752,864) |
| ENVP by adjacency                                    | Group 3                       | (431,676) | (559,049) | 148,290 | (842,435) |
|  | Group 4                       | (453,449) | (573,987) | 129,840 | (897,595) |
| ENVP by connectivity                                 | Group 5                       | (380,049) | (557,176) | 228,182 | (709,044) |
| Ratio of total benefit to total cost by region       | Group 1                       | 0.20      |           |         |           |
|  | Group 2                       | 0.36      |           |         |           |
| Ratio of total benefit to total cost by adjacency    | Group 3                       | 0.28      |           |         |           |
|  | Group 4                       | 0.24      |           |         |           |
| Ratio of total benefit to total cost by connectivity | Group 5                       | 0.40      |           |         |           |

Note: The unit of the tax revenues is one million Japanese Yen.

The base year for the calculation of discounted value of tax revenues and construction cost is 1991.

( ) = negative

Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka;

Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. Source: Yoshino and Abidhadjaev (2016)

# Modeling Spatiotemporal Urban Spillover Effect of HSR Infrastructure Development

Satoshi Miyazawa<sup>\*</sup>, KE Seetha Ram<sup>@</sup> and Jetpan Wetwitoo<sup>α</sup>

The concept of spillover effects has been introduced and applied to HSR development to formulate the economic impact in increasing regional tax revenue (Yoshino and Abidhadjaev, 2017). The previous study covered development of Kyushu Shinkansen (Kagoshima route) in the Kyushu region, Japan, by JR-Kyushu. Construction started in 1991 and operations in 2004. It became fully operational in 2011. This study aims to extend the idea to spatiotemporal modeling and analysis by developing the spillover effect extent estimation model. We use spatiotemporal land cover, land price panel and municipality tax revenue data to first conduct preliminary analysis to understand the regional trend. The preliminary analysis suggests the land price and the property tax revenue increased in municipalities around HSR stations during construction of Kyushu Shinkansen. But the trend around each station varied during operation. Our model takes those input data and estimates the spillover extent observed in 1km grid land cover to highlight characteristics of the spillover effect around each station. The extent is optimised based on the compound annual growth rate in each target phase of HSR development. The result suggests some features around stations promote the spillover effect, while some others may obstruct.

## 1. INTRODUCTION

### Background

HSR development stimulates local and regional economy due to connectivity to other markets. Typically, regional governments cover the construction cost as the governments would benefit from residential or corporate income tax and increasing tourist inflow. An infrastructure development like HSR project creates spillover effect on incremental tax revenues, which would

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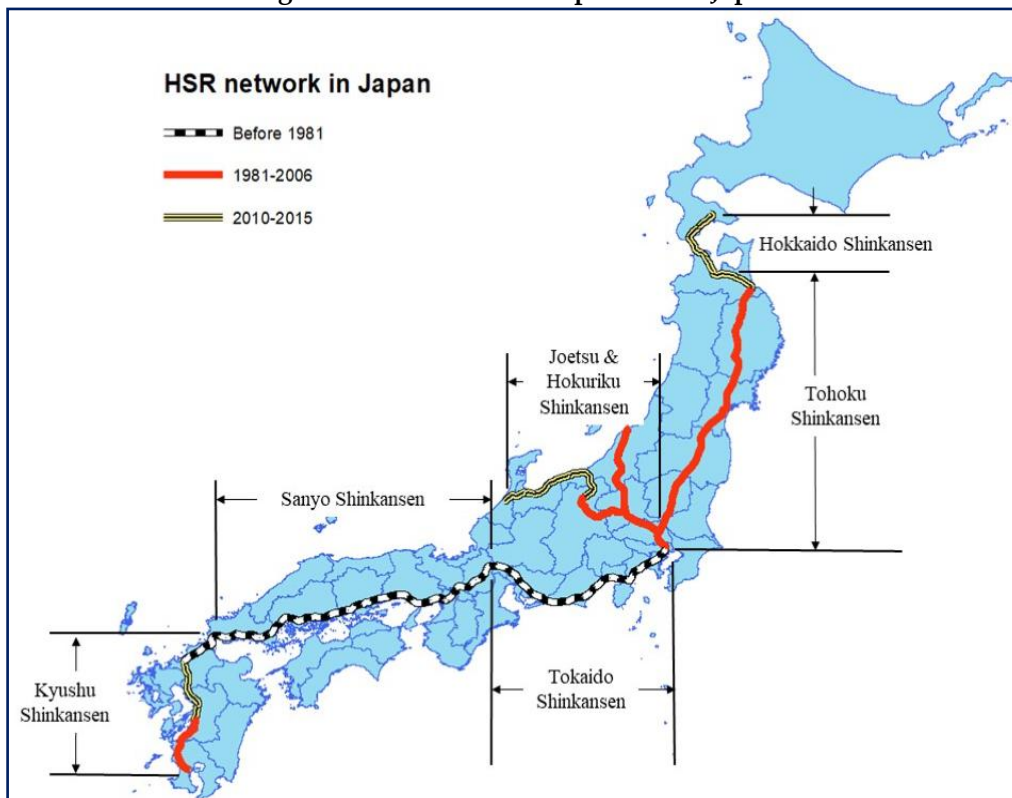
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improve performance of private investors (Yoshino and Abidhadjaev, 2017). But the development also needs planning intervention to assure improvement in quality of life like safety and amenity to station areas for the greater transit ridership.

According to the study, regional tax revenue increased especially during construction and after the line became fully operational. In other study area, Hernández and Jiménez incorporated spatial analysis to the difference-in-difference (DiD) method in Spain by using multiple distance buffer for empirical analysis, arguing the growth in public revenues and fiscal gap are most significant in municipalities located within 5 km radius of HSR stations (Hernández and Jiménez, 2014). For a potential impact of HSR project on the land market, Kanasugi and Ushijima investigate change on the balanced panel data of land price (Kanasugi and Ushijima, 2017).

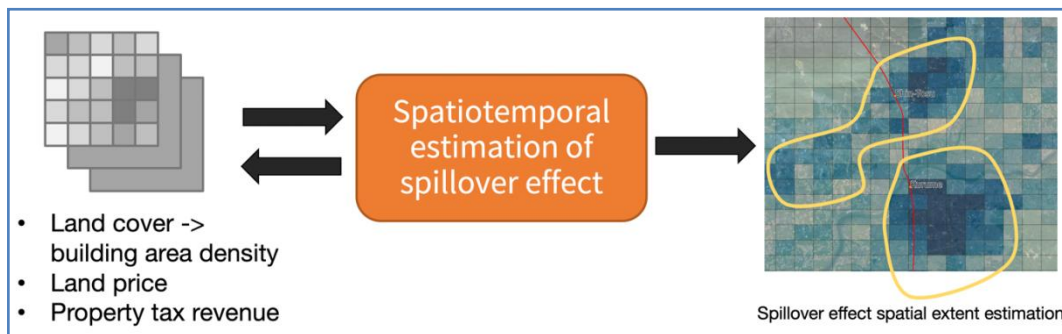
**Figure 1: HSR Network Expansion in Japan**



### Key Idea

The key idea of this work is summarized in Figure 2. Our target case is Kyushu Shinkansen in the Kyushu region in Japan, developed by the Kyushu Railway Company (JR-Kyushu). This study aims to extend the idea to the spatiotemporal modeling by developing the 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 the local development and the land market.

Figure 2: Key Idea



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

*Spatial extension of spillover effect:* The study extends the concept of spillover effect to urban development and the land market to investigate how development of the railway propagate spatially. But this work has following limitations:

- This paper only includes preliminary analysis of the model and leaves statistical evaluation as future work.
- The property tax revenue estimation is conducted at the municipality level.

The rest of this paper is organised as follows. The data are introduced in Section 2 and the method is summarised in Sections 3. In Section 4, we present the preliminary results and discuss the implications, and finally Section 5 concludes the paper.

## 2. DATA

### Infrastructure Development Time Line

The construction of the railway started in 1991. The southern part (Shin-Yatsushiro station to Kagoshima-chuo station) started operating in 2004. The northern part (Hakata station to Shin-Yatsushiro station) started operations in 2011, connecting the whole line to existing Sanyo Shinkansen. We adopt the timeframe from Yoshino and Abidhadjaev (2017) and adjust slightly due to the limited availability of data (Table 1).

**Table 1: Timeframe for the Study**

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

### Land Cover

We assume different land uses have made an economic impact on the area. We downloaded the land use class data from the National Land Numerical Download Service<sup>1</sup> by the National Land Information Division, National Spatial Planning and Regional Policy Bureau, Japan.

The data are produced in every few years (in 1976, 1987, 1991, 1997, 2006, 2009, and 2014) using multiple satellite imagery for each year. It is the 1km grid-based dataset that each grid contains area values (in m<sup>2</sup>) of different land cover class (Table 2) based on manual classification.

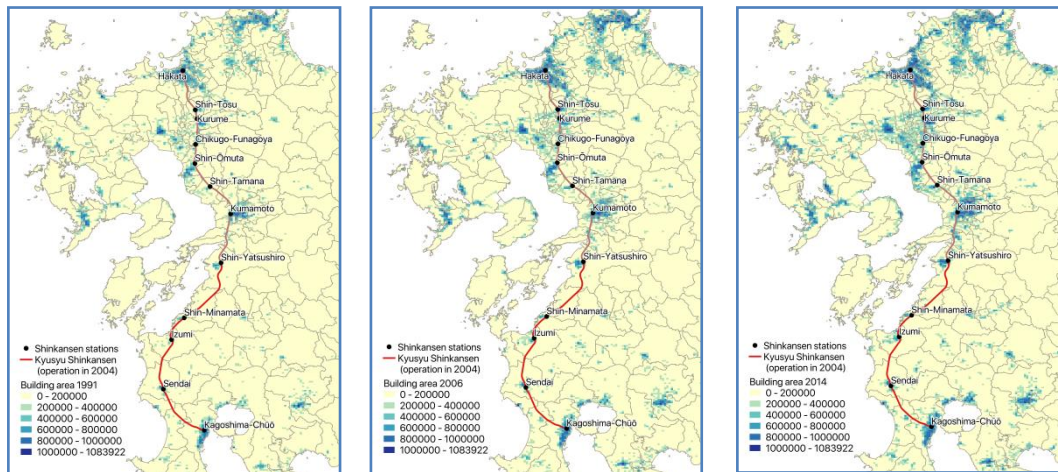
1. <http://nlftp.mlit.go.jp/ksj-e/index.html>



**Table 2: Land Cover Class**

| Code | Corresponding Details     |
|------|---------------------------|
| 1    | Paddy fields              |
| 2    | Other agricultural land   |
| 5    | Forest                    |
| 6    | Wasteland                 |
| 7    | Land for building         |
| 9    | Trunk transportation land |
| A    | Other land                |
| B    | Rivers and lakes          |
| E    | Beach                     |
| F    | Body of seawater          |
| G    | Golf course               |

**Figure 3: Building Area Density in 1991, 2004 and 2014**



### Land Price

As one proxy for the property tax revenue, we use publication of land price data also from the National Land Numerical Download Service. This is the annual sample panel data by the national government to regulate the property value and resulting property tax revenue for municipalities. Each year, there is new or discontinued point for the panel data. But we only use points available in 2014 data and the historical values for those points.

### Property Tax Revenue

We used the annual reporting of property tax ‘settlement’ revenue data of municipalities from e-Stat<sup>2</sup>. The settlement revenue represents ideal value of revenue, which excludes any delinquency or overdue payment from previous year. Some municipalities have been merged into neighbouring municipalities over years. To aggregate tax revenues of those merged municipalities, we used the administration boundary of 2014 and performed spatial join to summarise revenues to merged municipalities.

## 3. METHOD

### Compound Annual Growth Rate (CAGR)

Since each time period in the timeframe is different, each input value is converted to the compound annual growth rate (CAGR) defined as:

$$\text{CAGR}(t_1, t_2) = \left( \frac{V_{(t_2)}}{V_{(t_1)}} \right)^{\frac{1}{t_2 - t_1}} - 1 \quad (1)$$

where  $t_1$  and  $t_2$  are the start year and the end year, respectively. After each aggregation, CAGR is calculated from the aggregated values.

### Aggregation to Municipality Boundary

To show the broad spatial trend, we aggregate building density, land price and property tax revenue to the municipality boundary.

### Aggregation to Station Buffer

Then we conducted a buffer analysis on areas around each station to compare the trend of station areas. To start, we created 5 km buffers around each station and aggregated values that intersect those with the buffer. By comparing trends, we can identify characteristics of each station areas.

## 4. PRELIMINARY RESULT

### Construction Phase

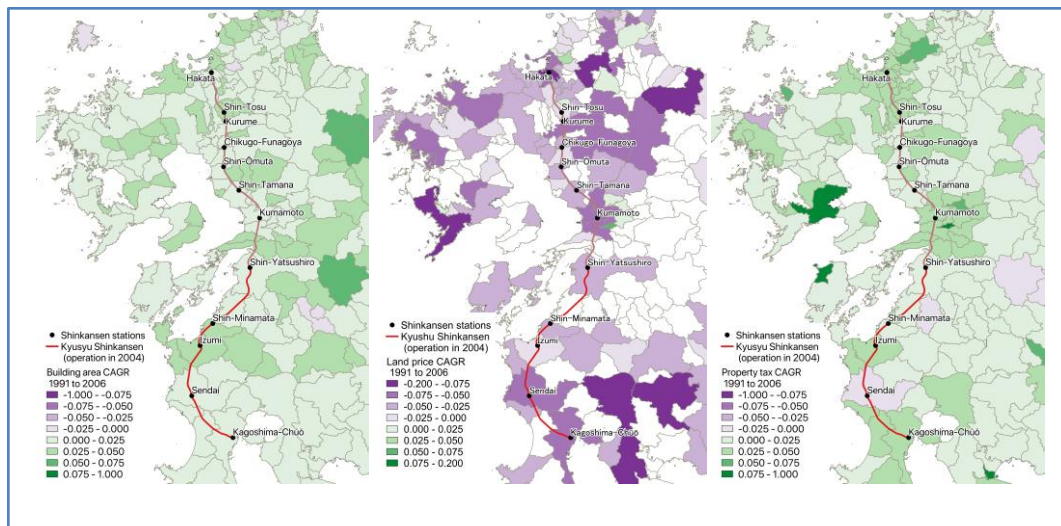
Figure 4 shows CAGR of each values during the construction phase (1991-2006). Though there is no clear connection between building area and land price

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

changes, some significant increases in building area and the property tax revenue are observed around HSR stations.

**Figure 4: CAGR of Building Area, Land Price Estimate and Property Tax Revenue during Construction Phase (1991-2006)**



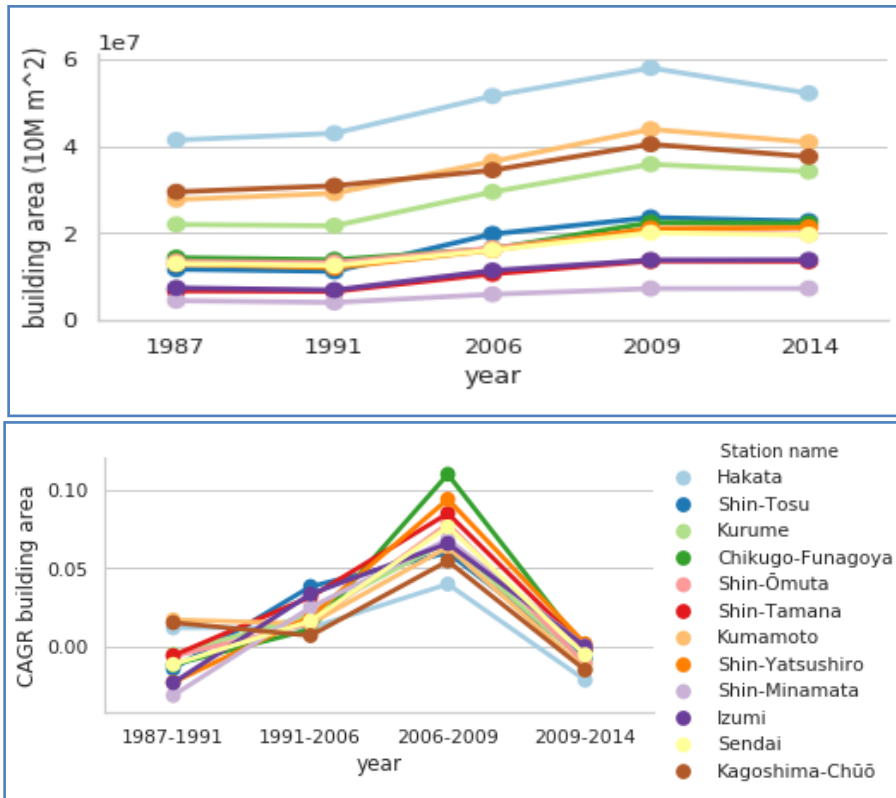
### Station Buffer Analysis

Figure 5 shows aggregated building area and CAGR of building area within 5 km around each station. Large stations like Hakata, Kumamoto and Kagoshima-Chuo have more building area than other stations throughout the period. But CAGR around most small stations (like Shin-Tosu) surpassed large stations during construction (1992-2006) and stayed higher after the operation phase.

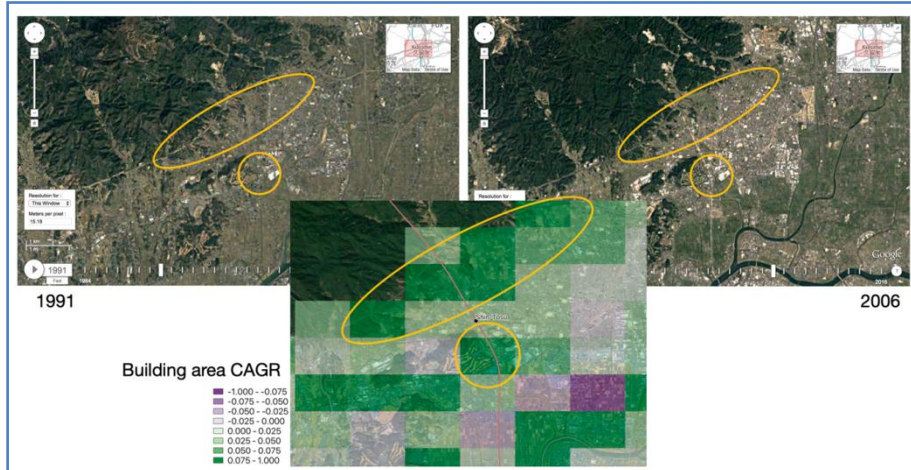
Figures 6 and 7 show the building area CAGR in 1 km grid and historical satellite imagery from Google Earth Engine Time Lapse<sup>3</sup>. The yellow shapes indicate the same locations. Some significant development can be observed in areas with high building area CAGR during the period. It suggests the potential validity of the method, even though it would require more extensive statistical modeling for comprehensive evaluation.

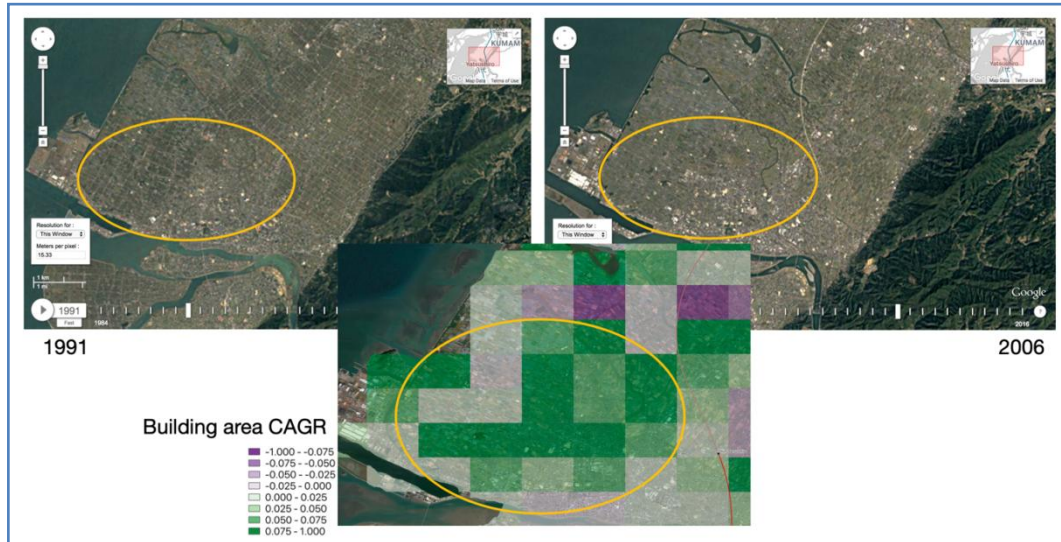
3. <https://earthengine.google.com/timelapse/>

**Figure 5: Aggregated Building Area and CAGR of Building Area within 5 km Around Stations**



**Figure 6: Building Area CAGR around Shin-Tosu Station during 1991 and 2006**



**Figure 7: Building Area CAGR around Shin-Yatsushiro Station in 1991 and 2006**

## 5. CONCLUSION

In this paper, we introduced the spatial extension of spillover model and demonstrated the potential contribution of our method with spatial analyses. The study extends the concept of spillover effect to urban development and land market to investigate how development of railway affects propagate spatially. But the paper only includes preliminary analysis of the model and leaves statistical evaluation as future work.

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3. Yoshino, N., and U. Abidhadjaev. 2017. Impact of Infrastructure on Tax Revenue: Case Study of High-Speed Train in Japan. *Journal of Infrastructure, Policy and Development* 1:1-20.



# Japan: HSR's Agglomeration Impact

Jetpan Wetwitoo\*

## INTRODUCTION

An agglomeration economy is defined as benefits that firms gain by staying close together. The concept of the industrial scale of economies in Marshall (1890) has been further formulated into three factors leading to agglomeration economies, all related to transportation. First, agglomeration creates clusters of firms wherein producers, suppliers and customers are located together. It reduces the cost of goods, materials and even services. Better transportation services can create more opportunities for firms to access better and cheaper inputs.

Second, this effect is observed in the case of workers as well. A larger pool of workers enables better matching between firms and workers. It improves productivity because skilled workers can better match their work with skills. Since better accessibility inspires workers to work away from home, larger agglomeration can be attained in labour pooling through better transportation.

Third, the so-called knowledge spillover can be expected in agglomerated areas. One of the most famous examples is the Silicon Valley. Many firms, including semiconductor manufacturers and IT companies, are located together, leading to an environment of mutual learning and assistance. Once again, better transportation encourages more meetings, discussions, or even workshops between firms, and this hastens the learning process, accelerates firms' technology development and results in better productivity.

To understand the mechanism of Marshall's economies of scale from an empirical perspective, studies have categorised agglomeration in different ways. Rosenthal and Strange (2004) provided four types of categorisation – industrial scope, temporal scope, geographical scope and organisational scope. As for organisational scope, Thabet (2015) provides a study between agglomeration and organisation-related variables like competition, firm size and foreign investment

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in a case of Tunisia. But this study would like to focus on agglomeration with regard to the other three scopes. As for temporal scope, the key issue is to investigate whether the effect of agglomeration is static or dynamic. In other words, the agglomeration effect might require an accumulation of knowledge and its effect might develop over a period of years. By using the time lag of a number of plants in the area, Henderson (2003) concluded that high-tech firms also benefitted from the agglomeration level. In a case study of Japan, Fukao, *et al.* (2011) highlights the dynamic change of the manufacturing industry's structure into a technologically-oriented one in Japan during the 1990s. As for geographical scope, the key issue is to investigate whether an agglomeration spillover effect exists across the geographical border or not. I provide an index to measure agglomeration by considering the transportation service to capture the spatial lag effects. For industrial scope, the focus of this study, agglomeration is categorised into localisation and urbanisation agglomeration.

In localisation agglomeration, I can expect better productivity, if same sector firms are located close to each other. From Marshall's economy of scale, firms benefit from supplier-sharing or even technology transfer through localisation. The concept of localised industries was proposed by Marshall (1890) and expanded into a growth model by Arrow (1962) and Romer (1986); the accumulation of knowledge spillover within the same industry is now known as the Marshall-Arrow-Romer externalities. On the other hand, in urbanisation agglomeration, the firms' productivity increases as the total market expands through urbanisation, leading to larger labour pooling and cross-industry activities and further to productivity improvement. The benefits of urbanisation agglomeration, as described in Jacobs (1969), emerge from different sectors' knowledge spillovers supporting one another. Moreover, innovation growth is believed to be stimulated by a variety of industrialisation approaches, because different ideas and information can be synthesised through variety rather than specialisation. Glaeser, *et al.* (1992) showed the economic growth of cities could be developed through cross-fertilisation of ideas in urbanisation agglomeration. In other words, firms in large cities benefit from a variety of economies compared with those in small towns.

Geographical distribution, as well as transportation services, can shape agglomeration activities. Agglomeration benefit from HSR is expected to be

higher than other types of transportation project because of the characteristics of HSR, which links the city centres. It was estimated in the HS2 project as ex-ante analysis that agglomeration benefit could be large up to 44 per cent of direct benefit (Kernohan and Rognlien, 2011). Transportation studies such as Graham (2007), Graham,*et. al.*(2009), and Melo,*et. al.*(2013, 2016) examined contribution of transportation to productivity. They considered transportation as one of the factors for agglomeration economies and showed that improvement in accessibility to transportation in term of “effective density” can create a better agglomeration environment. A significant contribution from agglomeration in the context of an urban rail project has been shown in Hensher,*et. al.*(2012) in a city scale as well. But most of these studies investigate the firm- or urban-level effect of agglomeration and ignore the possibility that the spillover effect can spread across the region. Therefore, this study analyses agglomeration in the regional scale.

The case study of Japan can be one of the ideal regional scale case studies for two reasons. First, the firm- or urban-level data could be applied in other countries where the built-up area is distinctly separated and the cross-border effect is unlikely to be expected. But the built-up area in Japan is highly connected, especially in the coastal areas, and so the agglomeration effect can be expected to overflow across the region. Second, since Japan is an island nation, agglomeration across the national border is unlikely to occur. In other words, regional agglomeration can be fully observed without interfering with the agglomeration effect of other countries.

#### **ASSUMPTION FOR AGGLOMERATION: EFFECTIVE DENSITY**

In researches related to the agglomeration economy, many variables have been applied to explain agglomeration level. Raw data like a number of firms or population is also used to determine agglomeration level in studies such as Nakamura (1985), Beeson (1987), and Henderson (2003). Furthermore, several indices have been proposed to capture the effect of agglomeration as well. The Ellison and Glaeser agglomeration index (Ellison and Glaeser, 1997) can be regarded as the most widely used index to measure agglomeration in view of its simplicity and unbiased estimation. Further to the Ellison and Glaeser agglomeration index, other discrete agglomeration indices have been proposed, like the weighted agglomeration index by Maurel and Sédillot (1999) or the



probability-based index by Mori, *et. al.* (2005). But these indices compare the agglomeration activity in the zone with other activity outside the zone discretely without actual spatial consideration. Based on Ellison and Glaeser index, Duranton and Overman (2005) proposed an agglomeration index incorporating the distance between firms.

In a comparison of the proposed index with the Ellison and Glaeser agglomeration index, Duranton and Overman (2005) concluded that the degree of agglomeration could be remarkably different when the spatial distribution is considered. By considering the distance between sources of activity, the gravity model-based index as applied in Beeson (1987) is also one of the useful indices from its capability to consider the decay parameter along with the size of agglomeration. The agglomeration index in this study will be explained by effective density, one of the gravity model-based indices proposed by the Department for Transport (DfT), Wider Impact Guideline (Department for Transport, 2014), for incorporating transportation into agglomeration.

For the selection of a suitable index for our study, two conditions need to be satisfied. First, our main objective is to investigate the impact of agglomeration through localisation agglomeration and urbanisation agglomeration. Therefore, the index used in this study must be applicable to these two types of agglomeration unbiasedly, while the Ellison and Glaeser agglomeration index and other earlier mentioned ones may satisfy only localisation agglomeration. Second, I would like to consider the accessibility effect because Duranton and Overman (2005) pointed out the importance of the geographical distribution of activities. The gravity model-based index can satisfy both our conditions since the mass, which represents an activity, can be applied to both localisation and urbanisation agglomeration while the distance in this index can be represented by the accessibility factor. Thus, I can apply the effective density index to our study. The effective density of zone  $i$  is defined as the sum of the mass of employment in another zone  $j$  and the travel time between zone  $i$  and zone  $j$ . This formulation depicts agglomeration in two ways: the mass of employment gives a number of activities generated by a particular zone  $j$ , and travel time represents the attractiveness of zone  $j$ 's activities from the viewpoint of zone  $i$ . This study assumes three types of effective densities to represent agglomeration. The first follows the concept of urbanization agglomeration. The economic scale in zone  $j$

will be explained by the total employment in zone j. The effective density under urbanisation agglomeration can be formulated as

$$A_{nit} = \sum_j \frac{E_{jt}}{g_{ijt}}, \quad (1)$$

where  $A_{nit}$  represents the effective density of zone i in any industry n,  $E_{jt}$  represents the total employment in zone j, and  $g_{ijt}$  represents the travel time between zone i and zone j, all at time t. This formulation is also used to explain the regional agglomeration in general in the next section.

The second type of effective density follows the concept of localization agglomeration. For regional productivity-level in industry n, the economic scale of each zone j will be explained only by the employment of industry n in zone j. Effective density under localization agglomeration can be formulated as

$$A_{nit} = \sum_j \frac{E_{njt}}{g_{ijt}}, \quad (2)$$

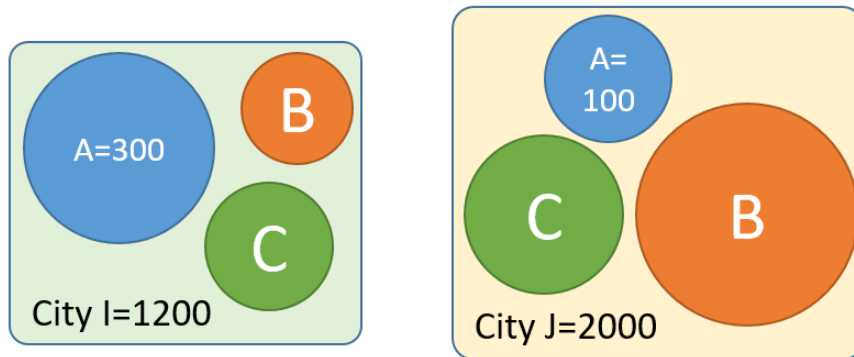
where  $A_{nit}$  represents the effective density, and  $E_{njt}$ , the employment of zone j in industry n, at time t.

## DEFINITIONS AND ASSUMPTIONS OF AGGLOMERATION

In the next two sections, agglomeration impact from HSR will be discussed from two points of view. As mentioned in the discussion regarding agglomeration, there are four scopes to be discussed. But here I would like to dedicate the discussion on the industrial scope as it is the most debated issue in terms of agglomeration effect. First, I aim to find whether “urbanisation agglomeration” or “localisation agglomeration” is more productive. Later, I aim to find whether “specialisation agglomeration” or “diversity agglomeration” is more productive for the economy. To give a better understanding of definitions, Figures 1 and 2 depict the situation of the four sub-scopes in the next two sections.

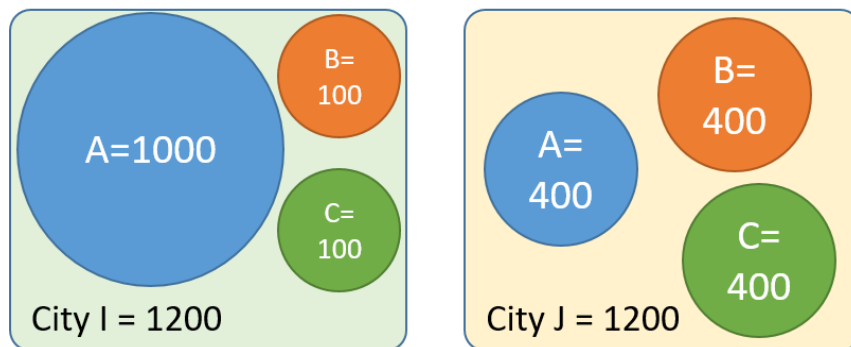
**Figure 1: Example of Two Cities with Different Industrial Scale of Agglomeration**

*Focusing on industry A's productivity*



**Figure 2: Example of Two Cities with Different Industrial Diversity**

*Focusing on whole city's productivity*



In Figure 1, let us consider two cities  $i$  and  $j$ . City  $i$  has 1,200 workers and industry A 300 workers. City  $j$  is larger than city  $i$  but the number of workers in industry A is only 100. Consider that productivity in industry A is higher. The concept of localisation agglomeration explains that agglomeration in the same industry is more important. Thus productivity of A in city I is higher. On the contrary, the concept of urbanisation agglomeration explains that agglomeration of the whole economy is more important, thus productivity of A in  $j$  is higher. But each industry may have a different effect from localisation agglomeration or urbanisation agglomeration. For example, the manufacturing industry may benefit more from agglomeration in the same industry rather than the total economy while the situation could be different in other industries. Thus, the

analysis in the next section will give an answer to how localisation agglomeration and urbanisation agglomeration benefit each industry.

In Figure 2, let us consider two cities of the same size, yet in city *i*, industry *A* is dominant, while in city *j*, there is no dominant industry. Consider the productivity of the whole city, the concept of specialisation agglomeration explains that city with one or few specialized industries is more productive. Thus following this concept, productivity in city *i* is higher. On the contrary, the concept of diversity agglomeration explains that city with a more diverse mix of industries is better. Thus, in this case, productivity in city *j* is higher. But there is still insufficient evidence to confirm whether specialisation or diversity is more productive, especially when incorporating the regional agglomeration into account. Thus, the analysis in next section will give an answer whether specialisation or diversity is more productive.

#### **INDUSTRIAL SCALE OF AGGLOMERATION**

In this section, the goal is to investigate the industrial agglomeration. The questions of what industry should be agglomerated together with HSR and, under what circumstances, will be clarified in this chapter. Under Marshall's proposal, more interaction between industries can lead to better returns for both parties. But localisation considers only the interaction between the same types of industry and ignores the interaction between different types of industries.

On the contrary, urbanization considers the whole economy and ignores the economic structure. I use the inter-regional transportation data of Japan for our empirical analysis. Since inter-regional transportation connects one region with another, its impact on region-wide economic productivity can be felt across regions rather than within a region. Thus, I obtain data at the prefectural level (first-level administrative division in Japan<sup>1</sup>, approximately equivalent to

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1. The administrative structure of Japan can be divided into two levels. The upper tier, called "Prefecture" consists of 47 prefecture. The lower tier is called "Municipality"; there are several municipalities in a prefecture. Presently (2017), there are 1,742 municipalities in Japan; this could be decreased due to depopulation in Japan. However, each prefecture and municipality may have different levels of autonomy based on its sub-classification. For example, Tokyo Prefecture, Osaka Prefecture, and Hokkaido Prefecture may have higher levels of autonomy than other prefectures. At the municipality level, a large municipality specified as "Designated City" has a higher level of autonomy than the other municipality sub-classifications.

NUTS2<sup>2</sup> in the European Union) for dataset. Although, in reality, urbanisation in the prefectural context might vary across prefectures. For instance, the built-up areas in mega-cities like Tokyo and Osaka can cover multiple prefectures whereas the built-up areas in less urbanised prefectures might cover only small towns in a single prefecture. Thus, agglomeration in our data may be regarded as a macroscopic approximation at the regional level. Our dataset covers 11 industries (agriculture, mining, manufacturing, construction, electricity, gas and water, retail, finance/insurance, real estate, transportation/communication, service, and government service) based on the classification of the Japanese Ministry of Economy, Trade, and Industry (METI). This classification reasonably distinguishes each industry so that localisation agglomeration within the industry could be analysed properly.

The dataset covers 47 Japanese prefectures for six timeframes at five-year intervals – 1981, 1986, 1991, 1996, 2001 and 2006. Socio-demographic and socio-economic data, such as prefectural population, GDP, employees, wage, capital, and investment stock data by industry, were derived from the Statistic Bureau and Cabinet office of Japan. Note that all economic data were adjusted to the year 2000. As for transportation data, the travel time between each prefecture pair was estimated as the shortest travel time for the six travel modes HSR, conventional rail, air, ferry, intercity bus and private car. I used the National Integrated Transport Analysis System (NITAS) software developed by the Japanese Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) to search for the shortest path. Also, the transportation network has over six variations across six time periods since the transportation infrastructure was developed over time.

I estimate three models in regression processes, the prefectural fixed-effect model (prefecture controlled), the time period fixed-effect model (time-controlled) and the prefectural and time period fixed-effect model (two-way controlled). Refer to Wetwitoo and Kato (2017) for the estimation methodology. Tables 1 and 2 give the estimation results, highlighting the elasticities of effective density for each model.

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2. NUTS, or Nomenclature of Territorial Units for Statistics, is a subdivision code used in EU. The NUTS2 level indicates a population range of 800,000–3,000,000. The prefecture-level population of Japan has a range of 600,000–12,000,000.

**Table 1: Estimated Elasticities of Regional Productivity with respect to Effective Density (A) and Labour Input (l) based on Urbanisation Agglomeration**

| Prefecture Control |                       |     |             |     |                             |     |              |     |                      |     |         |     |
|--------------------|-----------------------|-----|-------------|-----|-----------------------------|-----|--------------|-----|----------------------|-----|---------|-----|
|                    | Agriculture           |     | Mining      |     | Manufacturing               |     | Construction |     | Power, gas and water |     | Retail  |     |
| A                  | 0.090                 |     | 1.267       | *** | -0.032                      |     | -0.011       |     | 0.175                |     | -0.055  |     |
|                    | (0.155)               |     | (0.178)     |     | (0.155)                     |     | (0.184)      |     | (0.148)              |     | (0.113) |     |
| l                  | 0.195                 | *** | 0.286       | *** | 0.411                       | *** | 0.574        | *** | -0.123               |     | 0.269   | *** |
|                    | (0.041)               |     | (0.033)     |     | (0.123)                     |     | (0.050)      |     | (0.076)              |     | (0.025) |     |
| Adj. R2            | 0.429                 |     | 0.510       |     | 0.727                       |     | 0.642        |     | 0.706                |     | 0.745   |     |
|                    | Finance and insurance |     | Real estate |     | Transport and communication |     | Service      |     | Govt. service        |     |         |     |
| A                  | 0.935                 | *** | -0.417      | **  | -0.051                      |     | 0.066        |     | -0.195               | *** |         |     |
|                    | (0.198)               |     | (0.138)     |     | (0.155)                     |     | (0.083)      |     | (0.054)              |     |         |     |
| l                  | 0.548                 | *** | 0.636       | *** | 0.220                       | *** | 0.080        | *   | 0.549                | *** |         |     |
|                    | (0.063)               |     | (0.075)     |     | (0.064)                     |     | (0.036)      |     | (0.056)              |     |         |     |
| Adj. R2            | 0.699                 |     | 0.730       |     | 0.721                       |     | 0.771        |     | 0.747                |     |         |     |
| Time Control       |                       |     |             |     |                             |     |              |     |                      |     |         |     |
|                    | Agriculture           |     | Mining      |     | Manufacturing               |     | Construction |     | Power, gas and water |     | Retail  |     |
| A                  | -0.296                | *** | 0.011       |     | 0.095                       | *   | -0.101       | *   | 0.002                |     | 0.033   |     |
|                    | (0.059)               |     | (0.053)     |     | (0.047)                     |     | (0.045)      |     | (0.030)              |     | (0.037) |     |
| l                  | 0.331                 | *** | 0.053       |     | 0.574                       | *** | 0.253        | *** | 0.111                | *** | 0.212   | *** |
|                    | (0.038)               |     | (0.038)     |     | (0.027)                     |     | (0.060)      |     | (0.027)              |     | (0.043) |     |
| Adj. R2            | 0.777                 |     | 0.885       |     | 0.928                       |     | 0.915        |     | 0.927                |     | 0.930   |     |
|                    | Finance and insurance |     | Real estate |     | Transport and communication |     | Service      |     | Govt. service        |     |         |     |
| A                  | 0.062                 |     | 0.292       | *** | 0.016                       |     | 0.021        |     | 0.001                |     |         |     |
|                    | (0.041)               |     | (0.072)     |     | (0.031)                     |     | (0.019)      |     | (0.027)              |     |         |     |
| l                  | 0.194                 | *** | 0.090       |     | 0.009                       |     | 0.159        | *** | 0.963                | *** |         |     |
|                    | (0.058)               |     | (0.181)     |     | (0.046)                     |     | (0.032)      |     | (0.040)              |     |         |     |
| Adj. R2            | 0.926                 |     | 0.893       |     | 0.930                       |     | 0.936        |     | 0.929                |     |         |     |

| Two-way Control |                       |     |             |     |                             |     |              |   |                      |     |         |  |
|-----------------|-----------------------|-----|-------------|-----|-----------------------------|-----|--------------|---|----------------------|-----|---------|--|
|                 | Agriculture           |     | Mining      |     | Manufacturing               |     | Construction |   | Power, gas and water |     | Retail  |  |
| A               | -0.199                |     | 0.460       |     | 0.097                       |     | -0.298       |   | 0.062                |     | 0.057   |  |
|                 | (0.230)               |     | (0.286)     |     | (0.201)                     |     | (0.191)      |   | (0.149)              |     | (0.115) |  |
| l               | 0.206                 | *** | 0.158       | *** | 0.376                       | *** | 0.172        | * | 0.073                |     | 0.064   |  |
|                 | (0.037)               |     | (0.046)     |     | (0.112)                     |     | (0.074)      |   | (0.047)              |     | (0.038) |  |
| Adj. R2         | 0.185                 |     | 0.611       |     | 0.330                       |     | 0.295        |   | 0.617                |     | 0.557   |  |
|                 | Finance and insurance |     | Real estate |     | Transport and communication |     | Service      |   | Govt. service        |     |         |  |
| A               | 0.064                 |     | 0.164       |     | 0.222                       |     | 0.005        |   | 0.095                |     |         |  |
|                 | (0.116)               |     | (0.188)     |     | (0.118)                     |     | (0.076)      |   | (0.068)              |     |         |  |
| l               | 0.062                 |     | 0.585       | *** | 0.098                       | *   | 0.060        | * | 0.710                | *** |         |  |
|                 | (0.044)               |     | (0.119)     |     | (0.043)                     |     | (0.029)      |   | (0.063)              |     |         |  |
| Adj. R2         | 0.537                 |     | 0.284       |     | 0.490                       |     | 0.630        |   | 0.372                |     |         |  |

Note: The estimates in parenthesis represent standard errors;

\* significance at 5 per cent; for every model, number of observation = 282.

\*\* significance at 1 per cent

\*\*\* significance at 0.1 per cent

**Table 2 Estimated Elasticities of Regional Productivity with respect to Effective Density (A) and Labour Input (l) based on Localisation Agglomeration**

| Prefecture Control |                       |     |             |     |                             |     |              |     |                      |     |         |     |
|--------------------|-----------------------|-----|-------------|-----|-----------------------------|-----|--------------|-----|----------------------|-----|---------|-----|
|                    | Agriculture           |     | Mining      |     | Manufacturing               |     | Construction |     | Power, gas and water |     | Retail  |     |
| A                  | -0.121                |     | 0.060       |     | -0.274                      | *** | 0.532        | *** | -1.324               | *** | 0.203   | *** |
|                    | (0.212)               |     | (0.091)     |     | (0.067)                     |     | (0.107)      |     | (0.151)              |     | (0.058) |     |
| l                  | 0.209                 | *** | 0.180       | *   | 0.570                       | *** | 0.321        | *** | 0.117                |     | 0.131   | **  |
|                    | (0.050)               |     | (0.078)     |     | (0.112)                     |     | (0.069)      |     | (0.072)              |     | (0.043) |     |
| Adj. R2            | 0.429                 |     | 0.447       |     | 0.732                       |     | 0.657        |     | 0.728                |     | 0.747   |     |
|                    | Finance and insurance |     | Real estate |     | Transport and communication |     | Service      |     | Govt service         |     |         |     |
| A                  | 0.750                 | *** | 0.153       |     | 0.520                       | *** | -0.478       | *** | -0.207               | **  |         |     |
|                    | (0.106)               |     | (0.121)     |     | (0.055)                     |     | (0.057)      |     | (0.073)              |     |         |     |
| l                  | 0.256                 | **  | 0.647       | *** | 0.141                       | *   | 0.152        | *** | 0.563                | *** |         |     |
|                    | (0.082)               |     | (0.076)     |     | (0.055)                     |     | (0.031)      |     | (0.063)              |     |         |     |
| Adj. R2            | 0.709                 |     | 0.728       |     | 0.742                       |     | 0.776        |     | 0.745                |     |         |     |

| Time Control    |                       |     |             |     |                             |     |              |     |                      |     |         |
|-----------------|-----------------------|-----|-------------|-----|-----------------------------|-----|--------------|-----|----------------------|-----|---------|
|                 | Agriculture           |     | Mining      |     | Manufacturing               |     | Construction |     | Power, Gas and Water |     | Retail  |
| A               | -0.470                | *** | 0.142       |     | 0.109                       | *   | -0.106       | *   | 0.008                |     | 0.024   |
|                 | (0.108)               |     | (0.090)     |     | (0.044)                     |     | (0.053)      |     | (0.032)              |     | (0.036) |
| l               | 0.401                 | *** | 0.045       |     | 0.567                       | *** | 0.262        | *** | 0.111                | *** | 0.217   |
|                 | (0.036)               |     | (0.038)     |     | (0.027)                     |     | (0.059)      |     | (0.027)              |     | (0.043) |
| Adj. R2         | 0.773                 |     | 0.886       |     | 0.928                       |     | 0.915        |     | 0.927                |     | 0.930   |
|                 | Finance and Insurance |     | Real Estate |     | Transport and communication |     | Service      |     | Gov. Service         |     |         |
| A               | 0.061                 |     | 0.244       | *** | 0.013                       |     | 0.018        |     | -0.007               |     |         |
|                 | (0.040)               |     | (0.066)     |     | (0.031)                     |     | (0.020)      |     | (0.029)              |     |         |
| l               | 0.190                 | **  | 0.083       |     | 0.007                       |     | 0.161        | *** | 0.964                | *** |         |
|                 | (0.057)               |     | (0.182)     |     | (0.046)                     |     | (0.032)      |     | (0.040)              |     |         |
| Adj. R2         | 0.926                 |     | 0.892       |     | 0.930                       |     | 0.936        |     | 0.929                |     |         |
| Two-way Control |                       |     |             |     |                             |     |              |     |                      |     |         |
|                 | Agriculture           |     | Mining      |     | Manufacturing               |     | Construction |     | Power, gas and water |     | Retail  |
| A               | -0.575                | *   | 1.073       | *** | 0.274                       |     | -0.254       |     | 0.155                |     | 0.029   |
|                 | (0.253)               |     | (0.209)     |     | (0.195)                     |     | (0.207)      |     | (0.155)              |     | (0.111) |
| l               | 0.267                 | *** | 0.014       |     | 0.364                       | **  | 0.177        | *   | 0.057                |     | 0.066   |
|                 | (0.045)               |     | (0.052)     |     | (0.112)                     |     | (0.074)      |     | (0.050)              |     | (0.038) |
| Adj. R2         | 0.197                 |     | 0.627       |     | 0.333                       |     | 0.293        |     | 0.618                |     | 0.557   |
|                 | Finance and insurance |     | Real estate |     | Transport and communication |     | Service      |     | Govt. service        |     |         |
| A               | 0.060                 |     | 0.292       |     | 0.221                       | *   | 0.026        |     | 0.054                |     |         |
|                 | (0.104)               |     | (0.187)     |     | (0.097)                     |     | (0.075)      |     | (0.074)              |     |         |
| l               | 0.060                 |     | 0.570       | *** | 0.071                       |     | 0.060        | *   | 0.711                | *** |         |
|                 | (0.044)               |     | (0.118)     |     | (0.045)                     |     | (0.029)      |     | (0.063)              |     |         |
| Adj. R2         | 0.537                 |     | 0.287       |     | 0.492                       |     | 0.630        |     | 0.370                |     |         |

Note: The estimates in parenthesis represent standard errors.

\* significance at 5 per cent; for every model, number of observation = 282.

\*\* significance at 1 per cent,

\*\*\* significance at 0.1 per cent.

Table 1 summarises the estimation results of the three regression models using urbanisation agglomeration in 11 industries. For all industries, model fitness is the highest in the time-controlled model, followed by the prefecture-



controlled model and the two-way-controlled model. First, the prefecture-controlled model shows that effective density has significant positive impacts on mining and finance/insurance and negative impacts on real estate and government service industries. Next, the time-controlled model shows that effective density has a significantly positive impact on real estate and a negative impact on the agriculture industry. Finally, the two-way-controlled model shows that effective density has no impact on any industry.

Table 2 summarises the estimation results of the three regression models using localisation agglomeration. First, the prefecture-controlled model shows that effective density has significant positive impacts on construction, retailing, finance/insurance, and transportation/communication industries and negative impacts on manufacturing, electricity/gas/water, and service industries. Next, the time-controlled model shows effective density has a significant positive impact on real estate and a negative impact on the agriculture industry. Finally, the two-way-controlled model shows that effective density has a significantly positive impact on the mining industry.

From the results, the fitness of the estimated models assuming localisation agglomeration tends to be higher than that for urbanisation agglomeration in any industries. The number of industries with significant estimates for agglomeration is also largest in the localisation models. This could imply that localisation agglomeration has a higher influence on economic production than urbanisation agglomeration. But the results also show agglomeration has different effects for each industry.

First, the positive impacts of both urbanisation and localisation agglomeration on regional productivity in finance/insurance and real estate (FIRE industry), may be explained reasonably using Marshall's theory. Since the FIRE industry should have customers from many other industries, a higher density of potential customers from various industries can give more business opportunities to them; this may be one of the sources of external benefit from urbanisation agglomeration. Because the FIRE industry particularly needs the latest information about local/regional/global markets, the social network of workers in the same industry can effectively contribute by sharing knowledge through meetings. Communication opportunities like seminars and informal

meetings attract business people from across regions, and so a higher density of colleagues in the FIRE industry can provide more knowledge spillover through communication; this is one of the sources of external benefit from localisation agglomeration. Localisation agglomeration also affects the labour pool as well as the procurement of high-standard service, because the FIRE industry requires skilled labour and efficient business environment for attaining higher productivity. A significant impact can be found in the finance/insurance industry only with the prefecture-controlled model, probably because its impact considerably varies across prefectures. Similarly, a significant impact can be found in the real estate industry with the time-controlled model, probably because the real estate market in Japan was influenced by conditions in the national economic market rather than by each prefecture's unique condition, although the significance in the prefecture-controlled model is relatively strong as well.

Second, the positive impact of urbanisation agglomeration on regional productivity in mining may be explained from the market perspective. Although the intuition is, localisation should be vital in the mining sector since mine products usually come directly from natural resources, which are typically located in limited areas based on geographical conditions of resource availability. By controlling the natural resources effect by the prefecture-fixed effect, I observed the significant impact in urbanisation agglomeration effect. This could be due to the fact that the mining company is not only in the mine ore area, but our data reveal that company also established its office in the urban area to sell its product. Especially in Japan where there is higher share in the rare metal and precious ore market and the demand in this market is usually higher in the more urbanised area.

Third, the positive impact of localisation agglomeration on regional productivity in transportation/communication may reflect regional market characteristics. For instance, when transportation firms are located closely, trucks/vans or drivers can be easily shared among them, thus reducing the potential business risk due to demand fluctuation in the transportation market. The network economy may also work in transportation/communication businesses that particularly use the physical network. In the case of Japan, multiple public transit operators working closely can form a wider transportation

network covering vast areas and thus enhance accessibility and the mobility of passengers. It could improve the productivity of public transit operators from the complementarity of services. A significant impact of agglomeration was found in the transportation/communication industry only with the prefecture-controlled model because its impact considerably varies over prefectures from the geographically uneven availability of natural resources.

Fourth, localisation agglomeration negatively influences regional productivity in the service industry. Generally, negative elasticities of agglomeration to productivity are found when the centrifugal forces stemming from agglomeration are stronger than the centripetal forces (Fujita,*et. al.*, 2001). The centrifugal force, or diseconomies from agglomeration, may arise from higher land rent, increased living expenses, or more congestion from a denser population. One possible reason for negative elasticity in the service industry is that agglomeration of the same service firms can cause serious market competition among them and lose the additional benefit of the imperfect competition. Agglomeration can even lead to over competition, generating negative external effects like weaker position in business contracts with their clients or customers, while less agglomerated firms can enjoy higher market power. The negative impact on some industries is supported by Combes,*et. al.*(2012), where the firm selection process<sup>3</sup> has no impact on spatial productivity difference.

Fifth, both urbanisation and localisation agglomerations have a negative influence on regional productivity in the agriculture sector. One possible explanation is the economy of geographical scale works well in agricultural business because it typically requires larger land for better production. A larger area of land decreases the average cost of production, resulting in better productivity, and leads to less agglomeration. Another possible reason, particularly for the poor impact of localisation agglomeration, is the negative external effect of agglomeration. For example, densely agglomerated agricultural businesses consume excessive natural resources like water and wood, and thus reduce the performance of agriculture.

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3. The firm selection approach explains better productivity from agglomeration resulting from the intensive competition in larger markets. Only the best firms can survive competition, resulting in better overall productivity in a large market compared to a smaller market.

Finally, industries other than FIRE, transportation/communication, service and agriculture may not have notable impacts from agglomeration. In particular, the poor significance of agglomeration in electricity/gas/water, retail and government service industries could be explained by characteristics of such services and/or goods. Because these are essential goods/services for people's daily life, the industries producing such commodities are required to be distributed evenly. The government service is a typical case, and retail and electricity/gas/water industries have to run businesses even if profit is near zero. More positively, these industries themselves distribute evenly based on distribution of population, and so regional agglomeration may make less sense in these industries.

#### INDUSTRIAL DIVERSITY

Literature regarding agglomeration on specialisation and diversity remains ambiguous. Local specialisation could favour the original idea of Marshall (1920) where better productivity from agglomeration can be expected in the area where firms in a similar sector located close to each other. On the other hand, industrial diversity could fulfill the idea proposed by Jacobs (1969) where innovation growth is believed to be stimulated by a variety of industrialisation since different ideas and information can be synthesised through variety rather than specialisation. Although empirical analysis of the literature might suggest the importance of diversity rather than specialisation, the concept of specialisation is still intriguing and could not be ignored. It is also interesting to understand why the effects of industrial diversity benefit local productivity where industrial specialisation was rarely suggested in the past empirical study.

Specialisation/diversity agglomeration is usually discussed on the basis of the spatial interaction between activities (like firms or workers). By taking spatial consideration into account, it is certain that transportation improvement could enhance the performance of spatial interaction between activities. Better transportation reduces cost of travel, encourages more meetings, discussions, or even workshops between firms. This hastens the learning process, accelerates firms' technology development and results in better productivity. Transportation literature like Graham (2007), Graham,*et. al.* (2009), Melo,*et. al.* (2013,2016) considered transportation as one of the factors for agglomeration economies and showed that improvement in accessibility from transportation in term of

“effective density” could create a better agglomeration environment. But in these studies, only the size of agglomeration has been considered by transportation effect. Considering specialisation/diversity effect from transportation from the viewpoint of theory, one of the facts could be extracted from New Economic Geography (NEG); less trade cost, a result of better transportation, leads to more variety of goods in the economy (Krugman, 1991). Yet, there is a lack of empirical study to support the idea given by NEG. Especially in the case of HSR where the effect could be different from what has been proposed in NEG since HSR mainly serves passenger transport and not freight transport assumed in NEG.

This chapter will be divided into two sections, where the relationship between industrial specialisation/diversity and productivity will be discussed in the first section, and how HSR affects local industrial specialisation/diversity will be empirically analysed in the second.

Although earlier literature favours effect from diversity agglomeration rather than specialisation agglomeration, one important issue is how the indexes are selected to explain characteristics of diversity/specialisation. As mentioned, the ideal index should be the index that can best capture characteristics of Marshall’s economy or Jacob’s economy. Since Marshall’s concept of industrial scale of economies does not mention about the interaction of scale of economies between industries and vice versa, Jacob’s concept does not restrict any industrial specialization. Thus, it is also possible to consider diversity and specialisation in the separate framework. For instance, Batisse (2002) and Thabet (2015) consider specialisation as a ratio between a share of the industry within the zone and a share of the industry from the whole country, while diversity is separately defined as an inverse of normalised HHI of industrial concentration.

Paci and Usai (1999) and Van Der Panne (2004) measure industrial diversity by an index based on reciprocal of Gini index. Although past studies usually consider specialisation/diversity in separate variables, yet, both could be intuitively considered together with the same index as they can be considered as an opposing factor to each other. As shown in the index used in Batisse (2002) and Thabet (2015), diversity is defined as an index of industrial concentration and it can also be considered as specialisation.

For this analysis, one of the issues regarding index selection is industrial distribution whether agglomeration only in its own zone or the whole study area should be considered. For example, specialisation index used in Glaeser, *et. al.* (1992), Paci and Usai (1999) and Batisse (2002) considers agglomeration of the whole study area as a ratio of regional specialisation and the ratio of global specialisation. On the other hand, index applied from HHI and Gini index can be considered as an index, which considered an agglomeration only in its zone since the share of industry is considered only within its own region. From these two concepts, I propose two indexes based on coefficient of variation. The first case where only agglomeration in its own zone is considered:

$$CV_{A_i} = \frac{\sigma_{A_i}}{\mu_{A_i}} = \frac{\sqrt{\frac{1}{n} \sum_{k=1}^n (A_{i,k} - \mu_{A_i})^2}}{\frac{1}{n} \sum_{k=1}^n A_{i,k}} \quad (3)$$

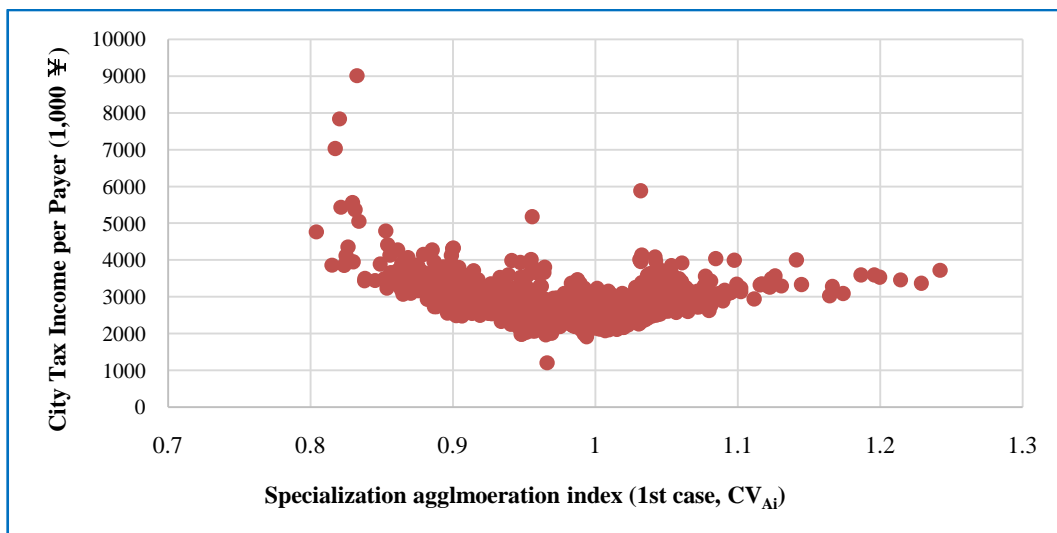
where  $CV_{A_i}$  represents the specialisation/diversity agglomeration index of zone  $i$  in the first case,  $\sigma_{A_i}$  represents the standard deviation of agglomeration across every  $n$  industries in zone  $i$ , and  $\mu_{A_i}$  represents the mean of agglomeration across every  $n$  industries in zone  $i$ . This index ranges the case of perfect diversified zone and perfect specialised zone from 0 to  $\infty$ , where the perfect diversified zone is the case where agglomeration level of every industry is uniformly distributed and the perfect specialised zone is the case where there is only one industry agglomerated in the zone.

I investigated the effect of specialisation/diversity agglomeration to local productivity in the case study in the Japanese municipality (city) level. I measured the agglomeration level from the number of employees across 17 industrial categorisations from 1,907 Japanese municipalities and the distance between each municipality. Local productivity is measured by municipality corporate tax income per taxpayer. The cross-sectional data is based on the 2014 Economic Census for Business Frame from the Japanese Ministry of Economy, Trade, and Industry (METI). Figure 3 shows the relationship between specialisation/diversity agglomeration index and local productivity in the first case where only agglomeration of in its own zone is considered.

Considering the relationship between index and productivity from agglomeration index, I found the U-shape relationship between these two

variables. By assuming a uniform distribution of the agglomeration size across industries is the perfect diversity case, I could explain the U-shape relationship through both Marshall's economy and Jacob's economy at the same time. Plots on the half left could follow the explanation of Jacob's economy where cities with more diversity (although not perfectly diversified or  $CVA_i = 0$ ) have more opportunity to obtain the spillover effect from different businesses. While Marshall's economy could explain the situation of cities in the plot on the half right, where benefit from specialisation agglomeration within the few industries become significant. But cities situated along the middle of the plot will be the loser; the diversity of industry is not large enough nor the specialisation of any dominant industry strong enough to enjoy agglomeration benefit. Thus, according to this plot, the temporal shift of level of specialisation ( $CVA_i$ ) should be planned carefully. As for example for the city on the right half plot, if the city wishes to increase its productivity in the next 10 years, changing its industrial distribution to be more specialised (at least more than the global average trend in the next 10 years) should guarantee better productivity. Otherwise, it should direct a huge change to promote more diversity in the city to shift the position from the half right to half left plot.

**Figure 3: City Productivity and its Specialisation Agglomeration Index (First Case)**



Next, I would like to investigate the relationship between HSR and level of specialisation agglomeration to link the effect of HSR to productivity through

specialisation/diversity agglomeration. In the first part, I present the situation of specialisation/diversity agglomeration in Japan. In the latter part, I further analyse the effect of HSR and specialisation/diversity agglomeration through regression analysis. CVAi used in both parts are based on the data presented in the earlier section.

**Figure 4: Situation of Specialisation Agglomeration in Japan (2014) Lines and Dots represent HSR Routes and Stations**

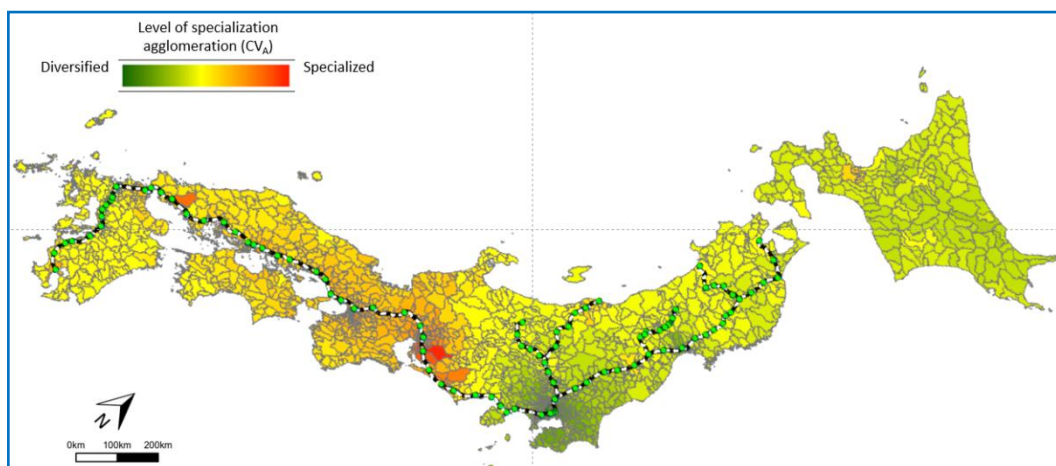


Figure 4 shows the plot of CVAi across cities (municipality) in Japan. Several findings can be drawn from it. In a comparison, the west side tends to be more specialised than the east side. The main reason behind this is high industrial diversity in Tokyo Metropolitan area. To be precise, specialised industrial workers, with a lower share of workers in finance and IT sectors, are concentrated in Tokyo. This makes our index more diversified as the share of small industry became larger in Tokyo than other regions. It is also possible to say Tokyo area is a highly specialised area for such industries. But the index used in the study defines the term of specialisation for the whole economy and not in any specific industry. Another reason is that this index considers the neighbouring effect. So regions close to Tokyo are highly affected by the agglomeration especially when the agglomeration within the regions is significantly smaller than Tokyo. Along with the distinction between west and east, the difference between regions along HSR and those located further away can also be observed. The regions along HSR lines tend to be more specialised though there might be some exceptions. Nevertheless, additional analysis is



needed to explain the relationship between HSR and level of specialisation agglomeration.

To make better understanding of the impact from HSR to the level of specialisation agglomeration,  $CV_{Ai}$  is applied as the dependent variable for regression analysis. Independent variables comprise HSR-related variable and other socio-economic variables. The general model specification can be defined as follows:

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

Where:

$CV_{Ai}$  : Specialisation/diversity index of city  $i$

$\alpha(HSR)$  : Function of HSR-related variables

$\gamma(\phi)$  : Function of other socio-economics related variables(4)

Here, HSR's impact is determined by the distance from such city  $i$  to the nearest HSR station. Furthermore, I assume the effect of HSR to specialization in a quadratic function. This assumption is based on the three cases of trade cost proposed in Ottaviano, *et. al.* (2002). Furthermore, the technique of spatial lag and time lag are applied to this estimation. Spatial lag term incorporates the effect of specialization agglomeration level in neighboring cities weighted by distance. Time lag includes the level of specialization agglomeration in the year 2012 into consideration. In summary, to be estimated function is structured as follows:

$$CV_{A_i} = \beta_0 + \beta_1 HSR_i + \beta_2 HSR_i^2 + \beta_3 WCV_A + \beta_4 CV_{A_i,2012} + \beta_5 U_i + \beta_6 U_i^2 + \beta_7 DID_i + \beta_8 DID_i^2 + \beta_9 PD_i^2 + \beta_{10} OH_i + \beta_{11} TW_i + \beta_{12} DC_i + \beta_{13} MF_i \quad (5)$$

Where:

$HSR_i$  : Distance from city  $i$  to the nearest HSR station (km)

$WCV_A$  : A matrix of product between reciprocal of distance between city  $i$  to other cities and specialisation index of other cities

$CV_{A_i,2012}$  : Specialisation agglomeration of city  $i$  in 2012

$U_i$  : Unemployment rate in city  $i$

$DID_i$  : Percentage of densely inhabited district of prefecture in which city  $i$  is located

$PD_i$  : Population density of city  $i$  (person/km<sup>2</sup>)

$OH_i$  : Rate of owned house in city  $i$

$TW_i$  : Percentage of worker in tertiary industry in city  $i$

$DC_i$  : Designated city dummy; equals to 1 if city  $i$  is designated city, 0 if not

$MF_i$  : Male to female population ratio in city  $i$

Table 3: Estimation Result

|                     | Estimates | SE       | t-stat   | p-value |
|---------------------|-----------|----------|----------|---------|
| Constant            | -0.9747   | 0.0028   | -343.735 | 0.000   |
| HSR                 | 2.16E-05  | 4.48E-06 | 4.814    | 0.000   |
| HSR2                | -3.94E-08 | 7.59E-09 | -5.194   | 0.000   |
| WCV <sub>A</sub>    | 0.9979    | 0.0015   | 673.697  | 0.000   |
| CV <sub>A2012</sub> | 0.9894    | 0.0033   | 300.525  | 0.000   |
| U                   | 0.0155    | 0.0023   | 6.621    | 0.000   |
| U2                  | -0.0017   | 0.0003   | -5.113   | 0.000   |
| DID                 | 4.11E-04  | 8.08E-05 | 5.085    | 0.000   |
| DID2                | -4.26E-06 | 6.53E-07 | -6.523   | 0.000   |
| PD2                 | -73.9864  | 6.8397   | -10.817  | 0.000   |
| OH                  | -1.76E-06 | 1.64E-07 | -10.740  | 0.000   |
| TW                  | -7.73E-05 | 2.12E-05 | -3.649   | 0.000   |
| DC                  | 0.0060    | 0.0009   | 6.435    | 0.000   |
| MF                  | -2.87E-04 | 3.02E-05 | -9.519   | 0.000   |
| R2                  | 0.9913    |          |          |         |

Table 3 shows the estimation result based on equation 5. The estimates of HSR parameter show positive value in  $\beta_1$  and negative in  $\beta_2$ . In other words, the inverse U-shape parabolic curve is found if distance to HSR station is plotted in X axis and specialisation index in Y-axis. From this relationship, the result could be interpreted into three cases. First, cities along HSR lines receive agglomeration benefit, which is further strengthened by HSR. This agglomeration benefit attracts firms in industries with positive agglomeration impact from other regions in order to enjoy the agglomeration benefit. Thus, cities along HSR lines tend to be more diversified as various types of businesses relocate to the city. But cities located away from HSR lines (those on the apex of the inverse U-shape parabolic, according to the estimation, those located around 270 km from HSR lines) tend to be more specialised because of many businesses relocated to cities along HSR lines. Only businesses that are not affected by positive agglomeration impact, remain in the city. This industry eventually becomes a dominant industry and makes the index more specialised.

In the case where cities are located very far from HSR (according to the estimation, those located around 540 km from HSR lines), firms may decide not to relocate because agglomeration benefit could be less than the trade cost. If firms relocate, premium from agglomeration could be less than the cost to transport their products from the city along HSR lines to cities very far from HSR. In other words, by not relocating to HSR service area, it is more productive to produce and sell in the same area. It makes cities very far from HSR remain diversified due to little relocation, although in our dataset the level of diversity in these regions is still smaller compared with regions along HSR lines.

## CONCLUSION

As for the analysis of industrial scale of agglomeration in previous section, two conclusions can be drawn. First, the relationship between transportation investment and the economy through agglomeration can be positive/negative or not related. As discussed earlier, this relationship depends on the type and distribution of industrial activities. Many agglomeration-related studies focus only on the manufacturing sector. But the effect of inter-industrial agglomeration should be further investigated to reveal the real mechanism behind the cross-fertilisation process proposed in urbanisation agglomeration.

Second, it can be concluded that transportation improvement, including HSR, significantly promotes the economy through agglomeration from better accessibility in many industries. Here, I want to emphasise the interest gain from the coordination between land use and transportation service. Many practices can be explained using the results obtained in the case study of Japan. For example, results show the agglomeration productivity premium found in the real estate industry and in the transportation and communication industry is positively significant in several models. These results concur with the real situation in Japan, where transit-oriented development has been effectively established in large urban areas from the late 20th century. But these results can be unique for Japan, where limited habitable land is the main issue, forcing economic activities to agglomerate together.

One policy implication drawn from the first conclusion is the agglomeration effect should be treated on the basis of industry. For example, our result shows a negative impact of localisation agglomeration in the service

industry. While I continuously observed an increasing trend of employment in the service industry in Japan, I believe the service industry should be expanded to regions where an agglomeration of the service sector is still lagging in order to reduce the over-competition effect.

As for the second conclusion, I believe to maximise regional productivity from agglomeration, land-use and transportation planning should consider whether, which and where each sector should be allocated and transportation infrastructure developed. In Japan, huge infrastructure investment is criticised because the expected benefit might not be sufficient due to declining population. But I agree with the transportation project linking major cities like the Chuo Shinkansen Maglev project. Despite its huge investment cost, it will be able to generate sufficient indirect benefits through agglomeration along the most populated corridor.

As for the analysis of industrial diversity in previous section, I intend to find answers for two questions related to specialisation/diversity agglomeration – how does industrial specialisation agglomeration affect city's productivity, and how does HSR affect industrial specialisation agglomeration. The answers to questions can be drawn from the analyses in this study as follows:

Specialisation agglomeration benefits productivity, but diversity agglomeration also benefits productivity. The city that has neither large diversification of industry nor specialisation of any dominant industry to enjoy agglomeration benefit will be the loser in this productivity competition.

Introduction of HSR could shape the spatial distribution of specialisation agglomeration, where the city is diversified, specialised as well as diversified. It depends on the distance to HSR service ranging from 0, 270 and 540 km, respectively.

This empirical result from Japan could be one of the evidences of how HSRs shape the new spatial distribution of industrial agglomeration. For countries that wish to introduce the HSR service, one of the possible policy implications is that the city should be prepared for the change of industrial distribution into a diversified city or specialised city according to the HSR service. A case study of Japan could be one of the cases where there is little intervention from the

government policy since the change of industrial distribution is supervised mainly by the private sector. But for other countries, the central/local government could indicate the change of industrial distribution to capture the best agglomeration benefit along HSR investment. Thus, this result could be one of the possible references for the public sector to guide the private sector to the best direction.

Within the scope of this analysis, two further issues are suggested. First, agglomeration is assumed to be enhanced by HSR. But other modes of transportation as well as telecommunication factors could also enhance agglomeration. Second, as mentioned, that analyses attempted in this study are from the case study in Japan, some bias toward the result could be expected due to Japan's unique characteristics. International comparative analysis between different case studies could be beneficial to the discussion of HSR's impact.

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# Development of HSR in People's Republic of China

Haixiao Pan\* and Gao Ya@

The high-speed rail (HSR) construction is continuing at a rapid pace in People's Republic of China (PRC) to improve rail competitiveness in the passenger market and facilitate inter-city accessibility. To take advantage of spillover effects, bring economic cohesion at local level and recover the local matching investment in infrastructure, all cities have planned new towns around HSR stations. To speed up HSR construction, many standardized technologies and processes have been developed. HSR stations have been planned in suburbs, far from city centres, to reduce cost of property right-of-way relating to removal of housing or industry as well as to lower complexities in negotiations. But city centres remain the main starting and destination terminals for most HSR passengers, especially businessmen who use HSR more. Besides, large railway stations in suburbs, being built to provide comfortable waiting space for passengers, have lowered travel time for HSR users. A reliable and high-quality public transit service, connecting HSR station and city centre at the launch of HSR operations, is essential to curb increase in car/taxi use. It's also suggested instead of building one big HSR station in the suburb of metropolis, constructing multiple stations in the vicinity of city centres will greatly reduce the access/egress time, thereby enhancing the travel efficiency.

## INTRODUCTION

PRC is a large country and, with recent rapid economic growth, there is a huge demand for land transport between regions. Rail transportation plays an important role in this. Since the 1990s, the proportion of rail transit in the inter-city passenger sector has declined because of development of highways and civil aviation. But too much reliance, it's being felt, on highway transport would cause several environmental, energy and safety problems. Weather factors like fog and road congestion can reduce efficiency and reliability of highway transport as well (Maria, 2014). Thus, to provide fast and reliable inter-regional transportation, rail service has become important.

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This chapter reviews development of different modes of inter-city transport in PRC since 1978. The use of rail, measured in rail passenger-km, has grown far less than other modes, especially highways. To provide better rail option, PRC began experimenting with HSR in the late 1990s. Speed of HSR has increased from initial 200 km per hour to 350 km per hour.

The Chinese government has updated the national railway networks plan with 8 'vertical' (north-south) and 8 'horizontal' (east-west) passenger corridors and, upon their completion, the national HSR system will be over 30,000 km in 2020 and 38,000 km in 2025 (NDRC, 2016). Meanwhile, regional HSR will also be developed.

Many researchers believe HSR can bring economic, environmental and social benefits to regions and cities it serves (Xiao, 2011; Feng, 2009). 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 et al., 1996). US researchers have argued in addition, HSR can enable big cities to connect further into the hinterland where housing and commercial space is more affordable (Sean, 2012). But capturing these benefits also requires attention to station location and design (Yu, et al., 2014).

Chen and Peter found that PRC's HSR services have substantial and demonstrable effects in aiding the economic transition of cities that are within 2-hour travel from major urban regions, helping generate renewed economic growth (Chen and Peter, 2011). To accelerate the HSR network construction, work processes have been standardized. To reduce difficulty of land acquisition, new HSR stations are mostly located in suburbs, away from large urban centres. It means access to stations can require a long trip from the city centre. The improvement in accessibility by HSR has realized the expected development around suburban stations.

In this study, the authors also investigated and analyzed HSR passenger travel behaviour and mode choices, using the Shanghai Hongqiao and Shaoxing Station as case study.

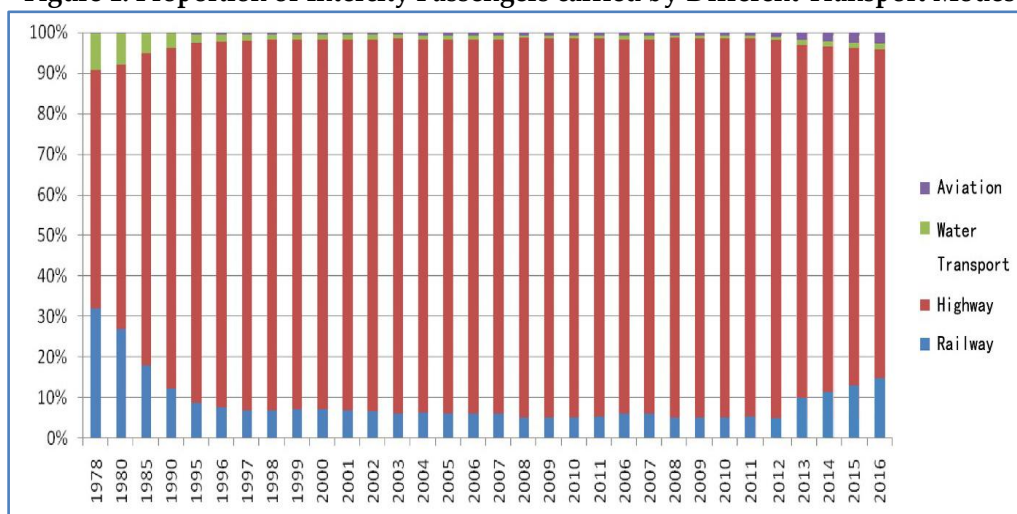
## 1. MULTIMODAL INTERCITY TRANSPORT IN PRC

PRC's railway mileage 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. It's 278.40 per cent increase in passengers over 1978 with an average annual growth rate of 3.47 per cent. Over the last decades, average annual growth rate of passengers has been even higher, reaching the 10 per cent rate in recent years. Moreover, rail passenger intensity (number of passengers carried per km) has grown fast since 2007, to 22,694 passengers per km in 2016. It is almost 7 times the highway passenger intensity. The passenger-km of railway transportation grew from 1,093 billion in 1978 to 12,579 billion in 2016, which is an increase of 1,051 per cent. Passenger-km is growing 12.52 per cent per year (Fan, 2011). As more HSRs come to service, the passenger-km volume of rail transportation is expected to keep growing.

However, despite the growth in rail service and its use, the rail share of inter-city travel had been dropping 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. PRC's highway mileage grew from 890,200 km in 1978 to 4,770,000 km in 2017. Civil aviation also attracted substantial share of the inter-city passenger growth in these decades. Consequently, the railway's share in the inter-city passenger market dropped dramatically from over 30 per cent in 1978 to around 5 per cent in 2001 and remained constant at around 5 per cent for the following decade (Figure 1).

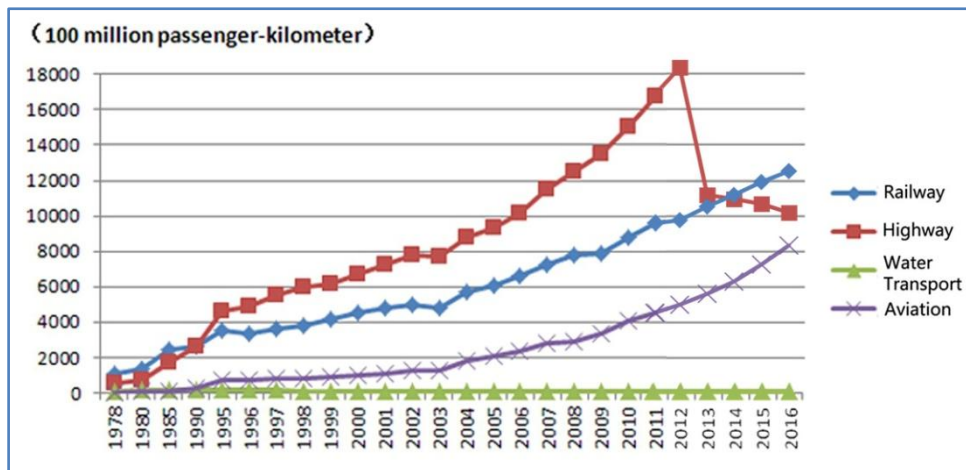
**Figure 1: Proportion of Intercity Passengers carried by Different Transport Modes**



Source: Annual China Statistical Year Book.

This changed after 2011. Measured by passenger-km, number of rail passenger-km and aviation passenger-km volumes have reported a fairly steady climb in recent years. But the shrinking of growth in the highway sector is notable (Figure 2). Since 2014, rail has become the dominant sector for the inter-city travel in terms of passenger-km.

**Figure 2: Passenger-km by Different Transport Modes, 1978-2016, PRC**



Source: Annual China Statistical Year Book

Today, in the intercity passenger transport market, rail transport has displaced highways as the dominant means of travel. This is true even for travel distances over 300 km, where rail should be highly competitive. The proportion of civil aviation is also increasing analogous to rail.

Thus, HSR is viewed as a substitute for other inter-city transportation modes by many researchers, like traditional rail (Givoni, 2006; Givoni Dobruszkes, 2013), aircraft (Dobruszkes, et al., 2014; Bergantino, et al., 2015) and automobile (Campo & De Rus, 2009). In PRC, the HSR's launch also changed the mode share for inter-city travel. For instance, the Wuhan-Guangzhou Corridor is an HSR line, connecting two mega cities with a total distance of 1,069 km. A survey conducted Wu, et al. (2014) shows before the Wuhan-Guangzhou HSR (started in 2009), conventional rail was the dominant mode of transport along this corridor. But since then HSR has become a significant alternative to traditional rail and aviation (Figure 3). For passengers using HSR, 42 per cent shifted from road, 52 per cent from conventional rail and 6 per cent from civil aviation.

**Figure 3: Rail and Air Share in Wuhan-Guangzhou Transport Corridor, PRC**

Source: Wu J, et al., 2014

Besides, our analysis and comparisons of data obtained from a survey in Shaoxing allow us to address HSR's role for inter-city leisure travel. The rise of domestic tourism in PRC has been impressive with an annual growth rate of over 10 per cent for the past 5 years, according to the Ministry of Culture and Tourism of PRC. The traffic congestion has drawn attention of academia and government (Cuccia & Rizzo, 2011; Wu et al., 2012). In particular, severe congestion on highways during national holidays has been a frequent headline with rapid motorization. Construction of HSR has extended the tourist market. For example, number of tourists visiting famous historical city Shaoxing with three world heritage sites hit 100 million in 2017. Our survey shows the average distance of visitors to Shaoxing city has increased from 304 km to 473 km, reflecting the much enlarged tourist market after launch of HSR in 2013. Moreover, 30 per cent of tourists took HSR to Shaoxing. Despite sharp rise in motorization, opening of HSR resulted into 6.7 per cent reduction in use of cars to travel to Shaoxing. Improvement in ticketing system for family and other tourist service package may further increase use of HSR.

According to previous studies, rail allows more efficient use of land for transportation than highways and helps cut pollution compared with automobiles (Wee et al., 2005). Because of scarce land and high population density, PRC seeks to make efficient use of land and reduce pollution by promoting the rail use. Since early signs suggested rail could become more

attractive compared with civil aviation or automobiles with rise in income and growth of economy, PRC has been planning HSR construction since the 1990s.

## 2. HSR NETWORK PLANNING AND CONSTRUCTION

In PRC the construction of HSR started at 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 rail development, the state council executive passed the “Mid-term and long-term railway network plan” in January 2004. It was revised in 2016, expanding the national railway programme to create over 150,000 km of national railway by 2020, with over 30,000 km of HSR. It also decided that the inter-city HSR should cover main cities in economically developed and densely populated areas, like the Yangtze River Delta, the Pearl River Delta and the Shandong Peninsula. (Figure 4) By January 2018, HSR development had reached 25,000 km.

**Figure 4: China HSR Network Plan (2016-2030)**

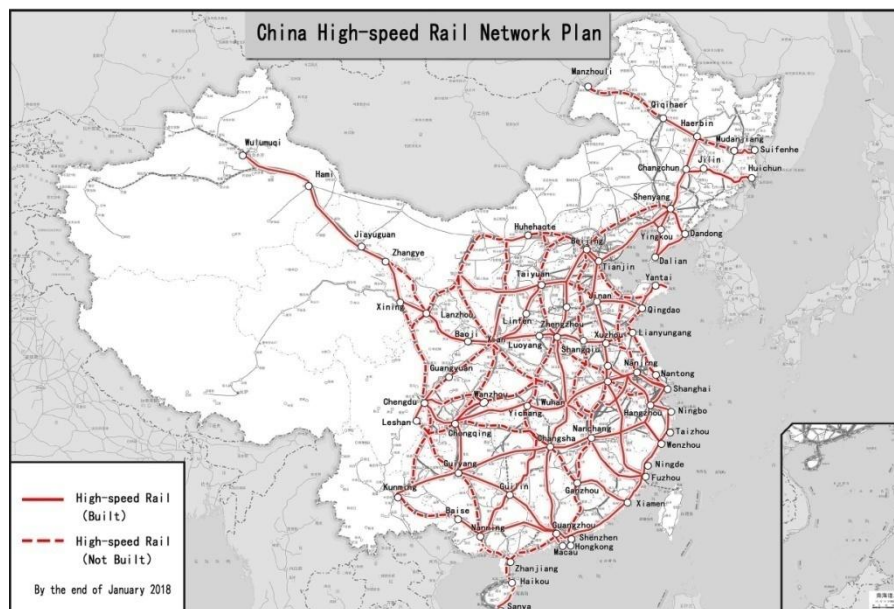
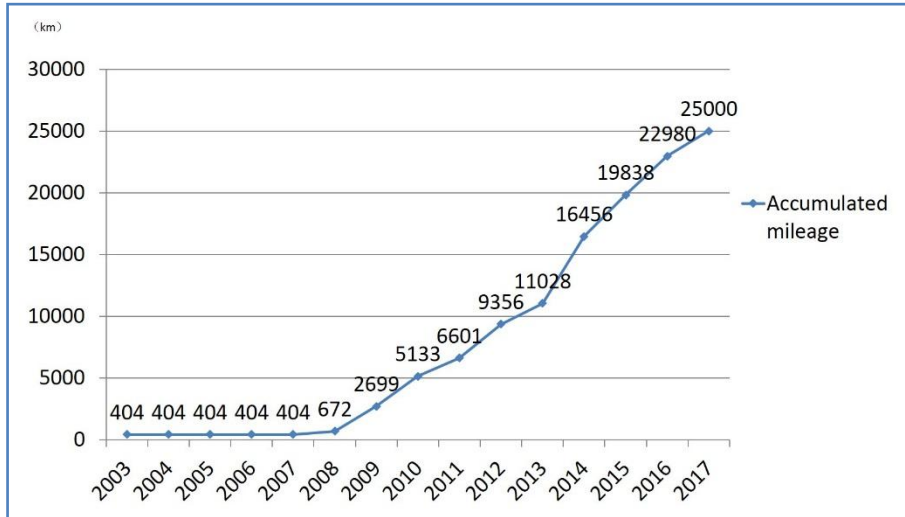


Figure 5 illustrates how fast the HSR system expanded. The 109,600 square km Yangtze River Delta is one of the most developed areas in PRC with 20 per cent of national GDP output and a high urbanization rate. The construction of HSR network will cover four city centres – Shanghai, Nanjing, Hangzhou and Hefei (Figure 6).

Figure 5: Expansion of HSR in China



Source: Annual China Railway Statistical Report

Figure 6: HSR Network Plan for the Yangtze River Delta



Source: NDRC, 2010

The system is designed for one-two hour ‘traffic circle’ between major cities and their adjacent cities, with transfers allowing passengers to arrive at all other cities in the delta within three hours. Such a network could allow these four cities and their smaller counterparts to function as a single integrated urban mega region. During last decades, 16 railway lines have been constructed, including the Hefei-Nanjing line, the Zhengzhou-Xuzhou line and the Quzhou-Jiujiang line, et. al. (Table 1) To allow for fast construction of HSR, many HSR stations, like Quzhou Railway Station, Xuzhou East Railway Station, are planned for suburban locations away from city centres.

**Table 1: HSR Line in Yangtze River Delta**

| No. | Names of HSR Way Line    | Number of Stations Passed | Designed speed                      | Length | Operation Start from |
|-----|--------------------------|---------------------------|-------------------------------------|--------|----------------------|
| 1.  | Quzhou-Jiujiang          | 10                        | 200km/h                             | 334km  | Dec, 2017            |
| 2.  | Zhengzhou-Xuzhou         | 9                         | 350km/h                             | 362km  | Sep, 2016            |
| 3.  | Jinhua-Wenzhou           | 7                         | <u>200km/h</u> ,<br>Highest 250km/h | 189km  | Dec, 2015            |
| 4.  | Nanjing-Anqing           | 14                        | 250km/h                             | 257km  | Dec, 2015            |
| 5.  | Hefei-Fuzhou             | 21                        | 350km/h                             | 813km  | June, 2015           |
| 6.  | Hangzhou-Changsha        | 21                        | 350km/h                             | 921km  | Sep, 2014            |
| 7.  | Nanjing-Hangzhou         | 11                        | 350km/h                             | 249km  | July, 2013           |
| 8.  | Hangzhou-Ningbo          | 7                         | <u>300km/h</u><br>Highest 350km/h   | 152km  | July, 2013           |
| 9.  | Hefei-Bengbu             | 9                         | 350km/h                             | 131km  | Oct, 2012            |
| 10. | Beijing-Shanghai         | 24                        | 380km/h                             | 1318km | June, 2011           |
| 11. | Shanghai-Hangzhou        | 9                         | 300km/h                             | 165km  | Oct, 2010            |
| 12. | Shanghai-Nanjing         | 22                        | 300km/h                             | 301km  | July, 2010           |
| 13. | Ningbo-Taizhou-Wenzhou   | 12                        | 250km/h                             | 275km  | Sep, 2009            |
| 14. | Wenzhou-Fuzhou           | 13                        | 250km/h                             | 298km  | Sep, 2009            |
| 15. | Hefei-Wuhan<br>(planned) | 13                        | <u>250km/h</u><br>highest 300km/h   | 360km  | Apr, 2009            |
| 16. | Hefei-Nanjing            | 7                         | 250km/h                             | 156km  | Apr, 2008            |

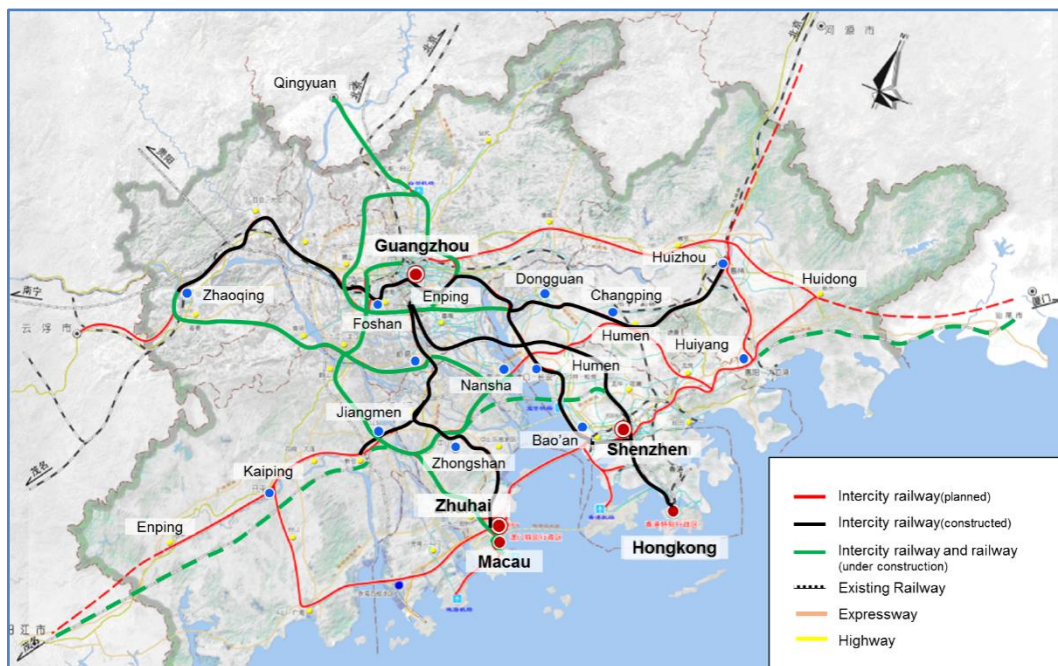
Source: By authors

In 2009, the National Development and Reform Commission also passed the “Inter-city rail transportation network plan for the Pearl River Delta Region (Revision)”. The rail network proposed in the plan comprised 23 lines with 1,890



km total length, reaching a network density of 4.8 km of rail per million sq km of land by 2030. Among the 23 lines, 15 will be constructed 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, and Macao (Figure 7). By February 2018, the total rail length in Guangzhou reached 4,510 km. Of this, 1,542 km could allow HSR with the speed of 200 km per hour and higher.

**Figure 7: HSR Network Planning of the Pearl River Delta**



Source: NDRC, 2009

### 3. HSR STATION LOCATION

In PRC, the 'HSR new town' model has been dominant in 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 large urban centres. It's hoped that HRS stations will trigger development of new towns. (In Western terms, these would be major metropolitan sub-centres or districts.) The plan is to stimulate local economic development offering an attractive alternative location to the crowded city centres.



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 included lower costs, capturing rising land values and relieving pressure on the central areas of the cities. Since there is less densely developed land in suburbs, the cost of land acquisition can be reduced compared with city centres. Suburban station development may also generate land value increment profits due to positive spillover effects. Finally, many cities are interested in promoting transformation of urban spatial structure from a single centre to polycentric to alleviate 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 project construction as well as 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.

Also, the location of HSR stations varies according to the influence of the local government in cities through which it passes or provides a station. Because of PRC's hierarchical administrative system, large cities are more influential in controlling negotiations between the local government and the railway authority than are smaller cities. Thus, in mega cities most HSR sites are located in suburbs, while in most medium and small cities new stations are located in the exurban fringe (shown in Table 2), where it's difficult to provide good public transport service. So, smaller cities have greater local car traffic associated with stations.

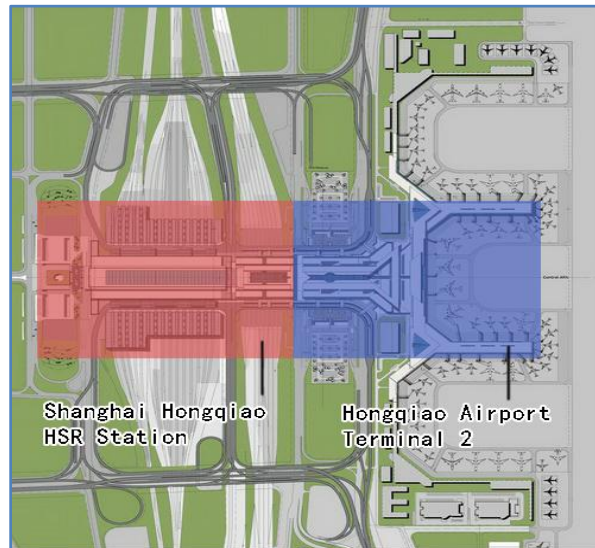
Shanghai Hongqiao HSR station is a typical example. The station is part of Hongqiao Integrated Transport Hub (Figure 8), which includes an international airport and Hongqiao business zone. Hongqiao area plan is intended to guide development in the vicinity of the transport hub. The station is located 15 km from Shanghai city centre (Figure 9) and links the Beijing-Shanghai HSR with the Beijing-Shanghai railway and the Shanghai-Nanjing intercity railway to the north, and the Shanghai-Kunming railway, Shanghai-Hangzhou-Ningbo passenger dedicated line and Shanghai-Hangzhou inter-city railway to the south. It started on July 1, 2010 with a predicted yearly dispatch passenger traffic of 120-140 million in 2020. The daily passenger dispatch volume reached 169,800 in 2017, double the number in 2011 (68,800 passengers per day).

Table 2: PRC's Major HSR Station Site Locations and Rail Line Plans

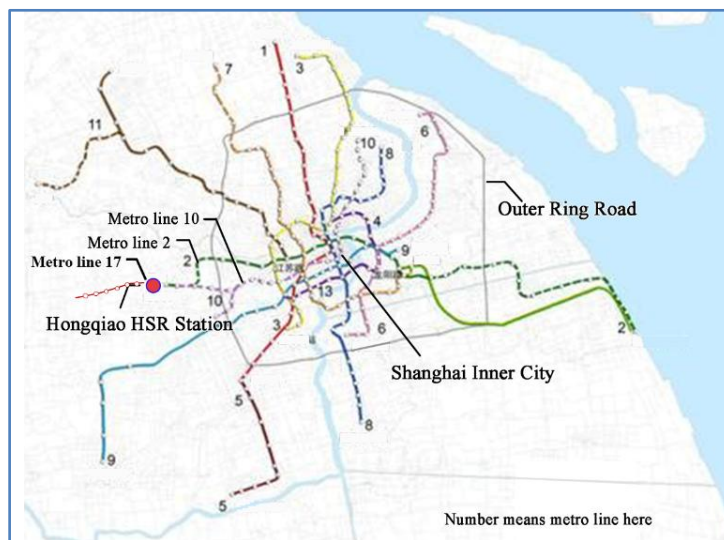
| Names of HSR Way Stations | Start from | Number of metro lines (at present) | Location of station | Linear distance from the city centre | Operation Situation of Metro Lines  |
|---------------------------|------------|------------------------------------|---------------------|--------------------------------------|---|
| North Xian Station        | Jan, 2011  | 0                                  | Suburban            | 13 km                                | Line 4: not opened<br>Line 13: not opened   |
| East Zhengzhou Station    | Sep, 2012  | 1                                  | Suburban            | 8 km                                 | Line 1: 2013.12<br>Line 5: not opened   |
| East Hangzhou Station     | June, 2013 | 2                                  | Suburban            | 13 km                                | Line 1: 2012.11<br>Line 4: 2018.01<br>Line 6: not opened  |
| Shanghai Hongqiao Station | July, 2010 | 3                                  | Suburban            | 15 km                                | Line 2: 2000.6<br>Line 10: 2010.4<br>Line 17: 2017.12   |
| South Guangzhou Station   | Jan, 2010  | 2                                  | Suburban            | 18 km                                | Line 2: 2010.9<br>Line 7: 2016.12<br>Line 22: not opened<br>Foshan Line 2: not opened           |
| South Nanjing Station     | June, 2011 | 4                                  | Suburban            | 10 km                                | Line 1: 2011.6<br>Line 3: 2015.04<br>Line S1: 2014.07<br>Line S3: 2017.12<br>Line 6: not opened |
| South Beijing Station     | Aug, 2008  | 2                                  | Near City centre    | 6 km                                 | Line 4: 2009.9<br>Line 14: 2015.12  |
| West Jinan Station        | June, 2011 | 1                                  | Suburban            | 12.5 km                              | Line 1: 2019.1<br>Line 3: not opened<br>Line R1: not opened                                     |
| Wuhan Station             | Dec, 2009  | 1                                  | Suburban            | 10 km (to sub-center)                | Line 4: 2014.12<br>Line 5: not opened   |
| Tianjin Station           | Aug, 2008  | 3                                  | City centre         | 1 km                                 | Line 2: 2012.7<br>Line 3: 2012.10<br>Line 9: 2012.10  |
| South Changsha Station    | Dec, 2009  | 2                                  | Suburban            | 10 km                                | Line 2: 2016.5<br>Maglev Line: 2016.05<br>Line 4: not opened                                    |

Source: Collected by authors

**Figure 8: Hongqiao Integrated Transport Hub Project**

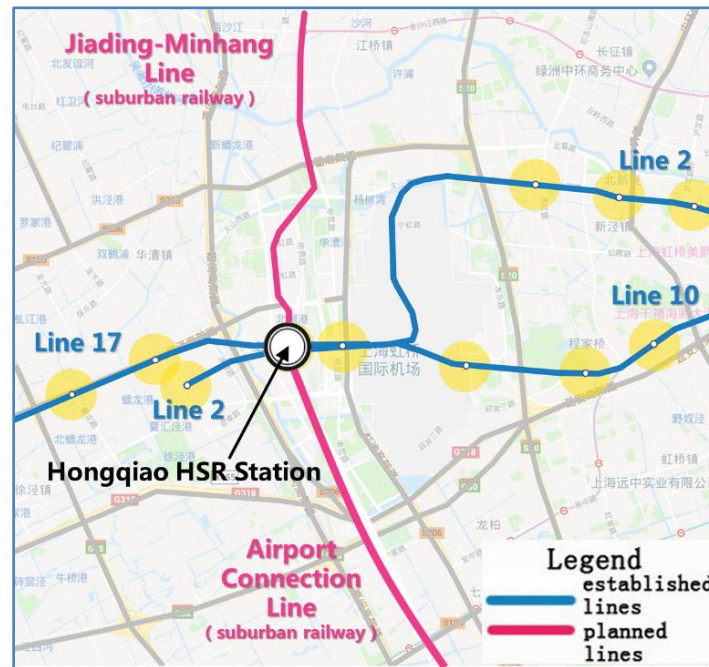


**Figure 9: Location of Hongqiao HSR Station and its Transport Connections**



To enhance connection between Shanghai city centre and the Yangtze River Delta region through the station, expressway networks and rail transit networks have been constructed. So far, rail transit lines (including line 2, line 10 and line 17) that provide seamless transfer from the Shanghai city centre have been extended to the station (Figure 10).

Figure 10: Hongqiao HSR Station and Metro Connection



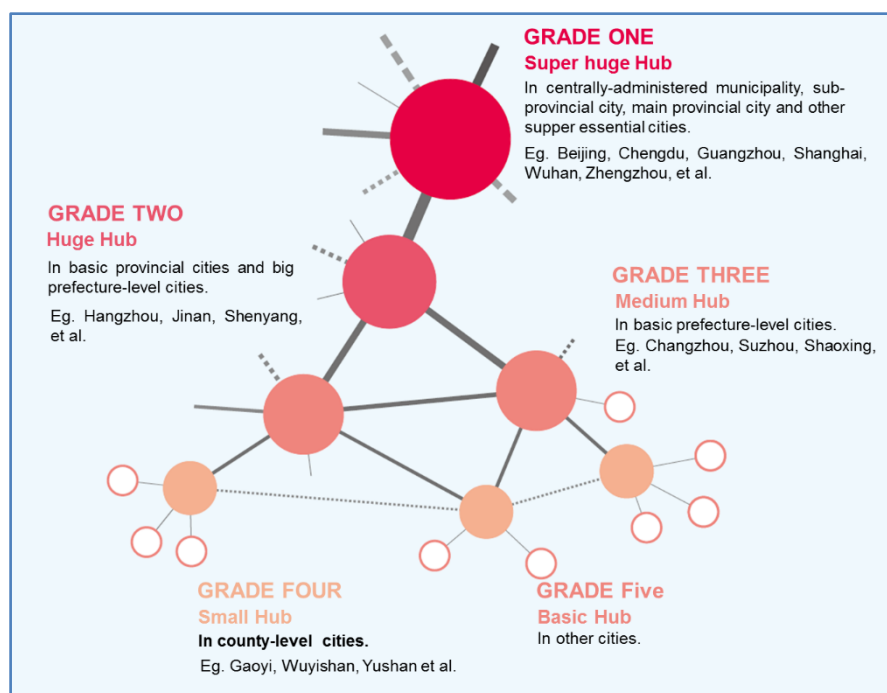
#### 4. HSR STATION DESIGN AND SERVICES

With the development of HSR, a large number of stations have been constructed. Stadium-sized stations are built to be city landmarks, with well-designed exterior, high-standard construction and latest facilities. According to Asian Development Bank (2015), the rail stations in PRC can be divided into 5 types – super, large, medium, small and basic hubs – based on the local governments' plans and their roles. For hubs with different grade and role, the facilities and services can be different. For instance, Guangzhou South Railway station, 17 km south of downtown area, is 500 meters long and 450 meters wide with covered area 486,000 sq meters.

Also, multi modes of transport like car, public transit, metros, taxis and inter-city buses can be integrated into the station through multi-level infrastructure. Since the traffic volume is high on national holidays, a large square is designed in front of the railway station. For example, Shanghai Hongqiao Railway station is connected to the city centre through two rail transit lines, an elevated motorway and several bus lanes.

Large parking lots are also built at HSR stations. According to Code for Urban Parking Plan, (GB/T 51149-2016 – the standard of parking plan in PRC), all rail stations should provide one parking space for per hundred peak passenger volume. 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 11: The Grade of HSR Station in PRC**

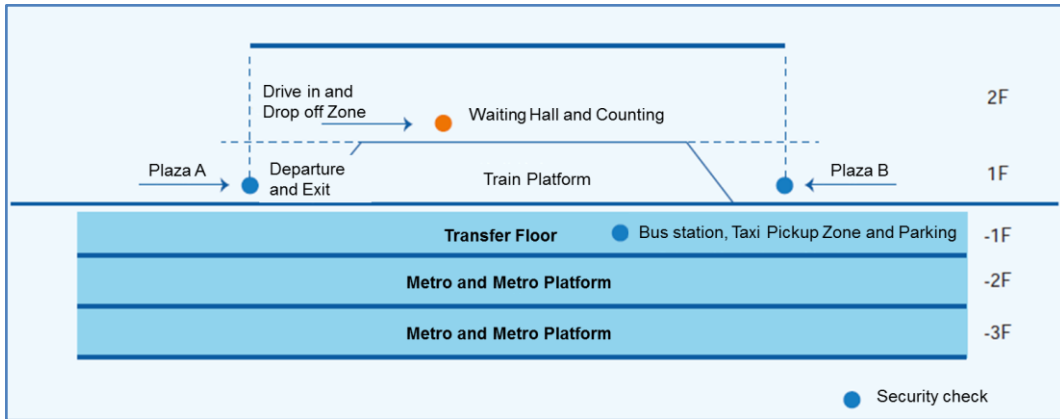


Source: Asian Development Bank, 2015

As taxis play an essential role in the passenger flow, layout of pickup zones is designed to make them convenient for passengers. Usually the pickup areas are located on both sides of HSR station halls. Inside the station hall, different modes of transport are integrated through various floors, called multi-dimensional traffic organization as shown in Figure 12. With waiting hall located on the second floor, passengers arriving by car can directly enter the station from the second floor through an overpass ramp as shown in Figure 13. But the exit/arrival for passengers are usually located on the same floor of the train platform, while parking lots, taxi pickup zones and the public transit stations

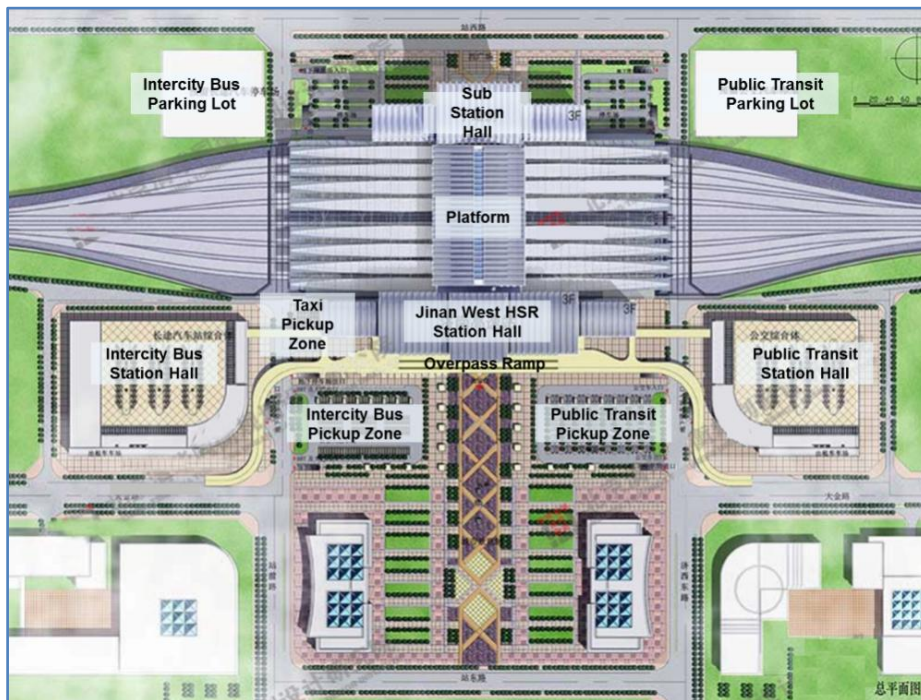
underground. Metro is located on the second and third floors. A plenty of escalators help carry streams of passengers.

**Figure 12: Integrated Modes of Transport in an HSR Station Hall in PRC**



Source: Asian Development Bank, 2015

**Figure 13: The 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.



In terms of HSR service, the departure process is relatively complex, since a passenger needs to take reserved ticket, go through security check before entering the waiting hall for the train. Tickets are also checked 15 minutes before departure of the train. Most waiting halls are huge to accommodate super-peak period rush and are enclosed buildings with proper air conditioning. Online booking now allows passengers to pay for ticket through mobile, internet and telephone. HSR stations on certain corridors even allow passengers to get on train with their personal ID card directly, easing ticket checking process. But there is only flat fare without other package choices (such as family ticket, weekend ticket, advanced ticket) for passengers.

**Figure 14: The Waiting Hall at Guangzhou South HSR Station**



Source: Asian Development Bank, 2015

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 Spring Festival, a peak passenger volume period, the on-time rate is close to 100 per cent. Any delay is displayed on the huge electronic display screen at station hall or conveyed through messages on mobile phones. Passengers are also informed about gate numbers to the train and reserved seats. Even for business travel, HSRs are cost-effective. Compared with other countries, ticket price of Chinese HSR is relatively low, with only 42RMB per 100 km for the second-class. Therefore, a lot of people living in surrounding cities to metropolis use HSR to commute. In the city cluster regions like the Pearl River Delta, the Yangtze River Delta and the Beijing-Tianjin-Hebei, where economic interaction between cities is strong, an HSR corridor is extremely busy. For example, the departure interval of

HSR from Suzhou to Shanghai during morning peak hours is just 5 minutes, serving like urban public transit system. But there are some stations where HSR service frequency is quite low like Xianlin Railway Station (in Nanjing), where there is only one train to Shanghai a day.

##### 5. HSR AND ACCESS MODE

Since HSR station is far from the city centre, where there is a high demand for travel, much effort has been made to improve transport between station and city centre, like providing public transit services (bus, metro or both) simultaneously. In Jiaxing, where HSR station is 8 km away from the city centre, only bus connects the both. According to the survey and analysis by Ye et al. (2017), passengers using taxis and public transit account for over 90 per cent as in big cities. Passengers value time more than expenses.

Figure 15 shows the modal split that we observed in a survey at Shanghai Hongqiao station. We found 60.4 per cent of passengers accessed HSR by urban rail transit and an additional 7.9 per cent used the conventional bus system, bringing the total users of public transport to access HSR to 74.9 per cent. This is far in excess of the planning forecast share for transit, which was 50 per cent. Of the private transit modes, only 7.6 per cent of passengers take cars to Hongqiao station, while 14.5 per cent take a taxi. The forecasts for the project predicted considerably higher private transport access.

Figure 15: Modal Split of Transit to Hongqiao HSR station

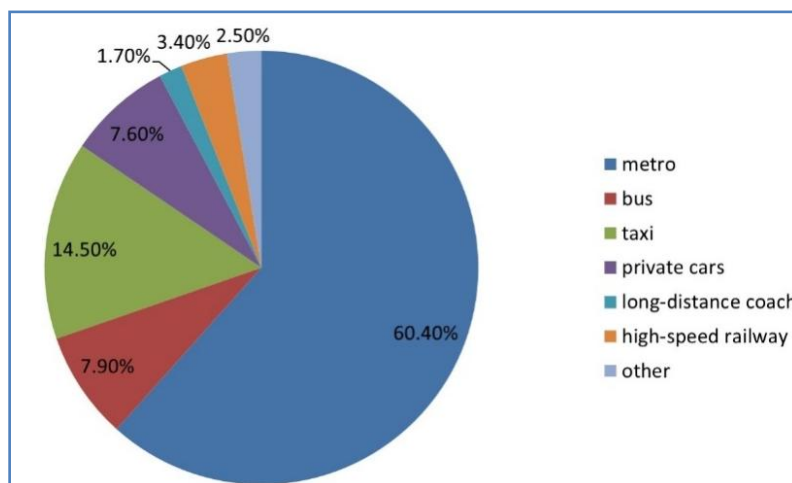
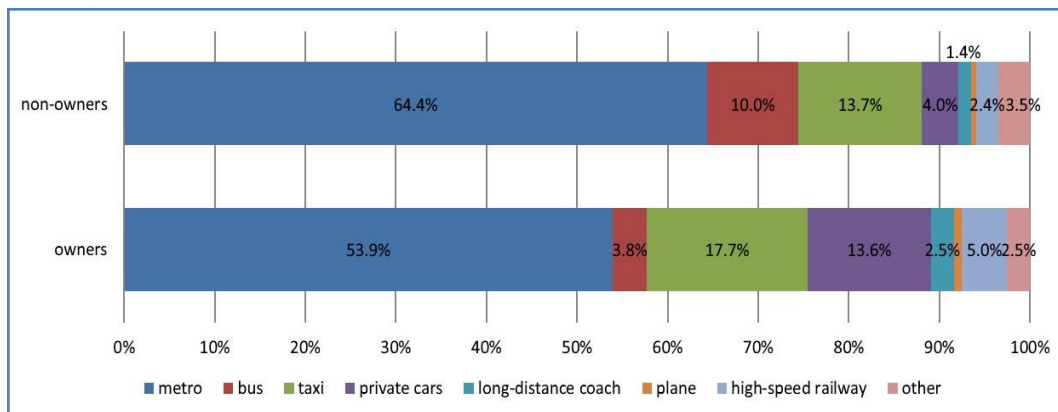




Figure 16 shows mode of access to HSR station by car owners and those without a car. Even among HSR users who possess a car, only 13.6 per cent drove to the station. These private car-owning passengers showed a preference for the metro, with 53.9 per cent preferring metro to get to the station. Private car-owning passengers use bus transit much less than passengers who don't own car. These results show the importance of provision of high quality public transport in connecting city centres and HSR stations to reduce the demand for car travel. The investment in metro to HSR stations undoubtedly reduced car mileage to stations located far away from city centres – a boon from traffic and air pollution perspective.

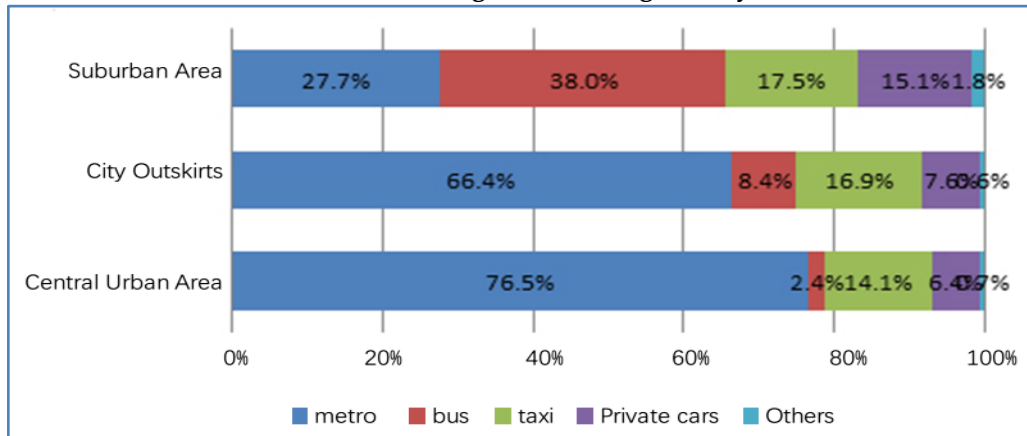
**Figure 16: Access Mode Choice to the Station by Car Owners and Non-owners**



Comparing modal choice to HSR station from various districts of Shanghai, we find that 76.5 per cent passengers from the central urban area take urban rail to HSR station, while only 7 per cent use cars. For passengers from suburban areas, less well served by urban rail network, people rely more on conventional bus transit, with 38 per cent taking buses to the station and only 27.7 per cent using urban rail. From suburban areas, demand for travel to HSR station by car is 15.1 per cent, double that of the central urban area (Figure 17).

To provide better high-speed train service, now HSRs also connect Shanghai railway station, located closer to Shanghai city centre. People could take public transport like metro line 1 and metro line 3, 4, as well as normal bus to the station. Among HSR passengers, 44.6 per cent use metro, which normal bus accounts for 15.7 per cent, and taxis 27.4 per cent.

**Figure 17: Modal Split of Transit to HSR Station from Different Regions of Shanghai City**



The survey from Wuchang railway station in Wuhan shows 92 per cent passengers take other transportation than rail, 20 per cent intercity buses, 26 per cent metros and 23 per cent city buses. To improve interconnection to public transit systems, the distance is shortened to 70 meter, while the walking distance to other private cars 166 meters (Chang & Ye, 2009).

These results indicate that people who take high-speed train are more sensitive to time, reliability and flexibility. There is need to upgrade urban public transport services along with construction of HSRs, metro or other facilities to prevent congestion around HSR stations.

## 6. HSR NEW TOWN PLAN

Chinese cities' local governments expect HSR to boost city economy and development. There are several plans like station area master plan and urban design plan to guide construction in the vicinity of HSR stations. For cities like Nanjing and Shanghai, HSR stations provide a prospective zone, a sub city centre, even a new town, which is called 'HSR new town'. Take Nanjing as an example, the catchments area of Nanjing HSR South New Town is 184 sq km with a projected population of 1600,000,

**Table 3: HSR 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 & Ye, 2009

which will be one of the three sub-centres of the city as per the master plan. Changsha HSR New Town with 500,000 people occupies 46.9 sq km. Jinan West New Town is planned with the same population but with an area of 55 sq km.

Usually, new clusters of high rise buildings for business, office and commercial activities surround HSR stations. Sometimes, public facilities like museums, exhibition centres and libraries are also located near the station. Figure 18 shows the master plan of the Tianjin West HSR station area, with an exhibition centre, a sports centre and clusters of office and commercial buildings on the north of the station, and hotels on the south. It's designed to be a mixed-used area to attract people to live, work and entertain.

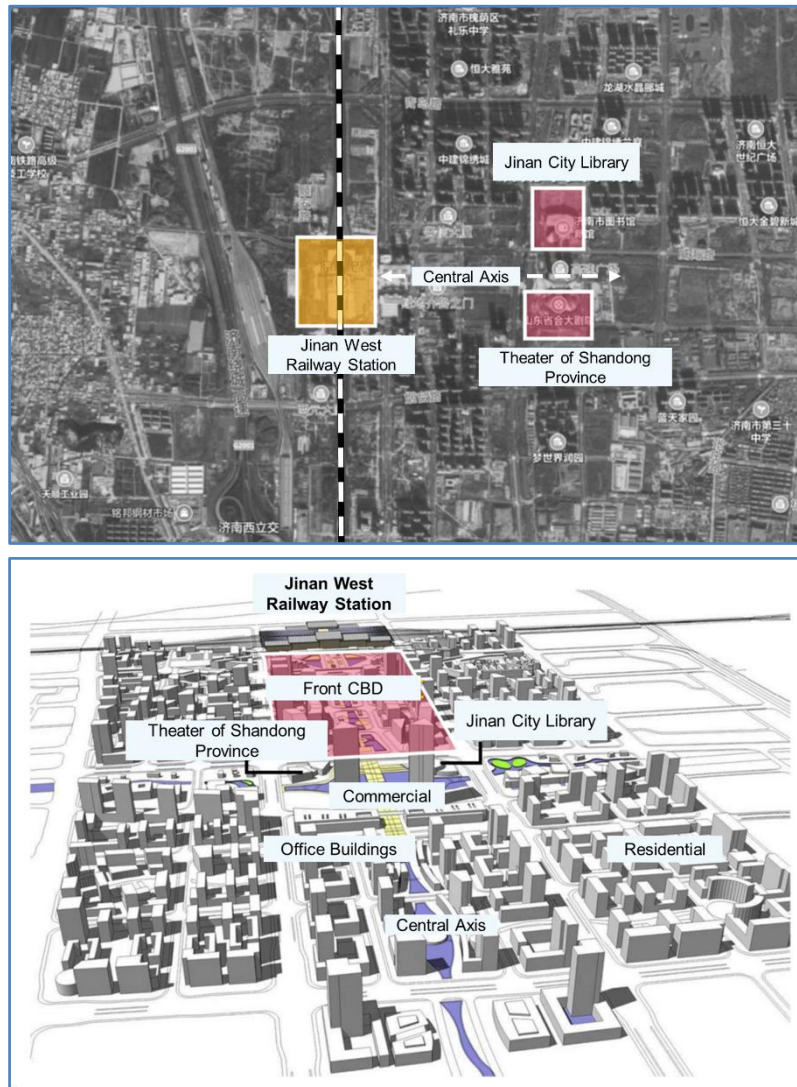
**Figure 18: Master Plan of the Tianjin West HSR Station Area**



Source: The 29th of Ideal Space, 2008

In Jinan, the West Station is built on green fields. There is an axis in front of station, with city library and theatre on its two sides. The public facilities are aimed at promoting development of peripheral regions (Figure 19). These aims are rarely realized in terms of functions defined in the plan as, except HSR station nearby areas, many supportive elements do not exist.

Figure 19: Planned Model of the Jinan West HSR Station Area



Source: The Road Network Design in the Vicinity of Jinan West Station.  
(<http://www.thupdi.com>)

## 7. HSR STATION LOCATION AND TRAVEL EFFICIENCY

As many HSR stations are located far away from city centres, empirical data is needed to analyze their impact on travel characteristics of passengers and urban spatial structure, including 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 inter-city HSR service through station location or connecting transport service options, as well as the design of stations.

We conducted a survey of 1,834 respondents from February 27, 2012 to March 3, 2012 at Hongqiao HSR station. Passengers in the waiting hall were selected randomly for face-to-face interviews and asked about trip origin and destination, on-board HSR travel time, mode of travel to the HSR station and time to station, and demographic characteristics.

From this survey, we came to know about social and economic attributes of passengers. We also collected information for each segment of their travel – from origin to destination – and travel characteristics before and after the opening of the HSR station. Based on these data, we can analyze impact of location of HSR stations and the connecting transport system on the travel efficiency for HSR passengers in terms of time and cost. We also can compare actual findings to forecasts made by transit planners in preparing for development of HSR service and station. The following research questions are explored in this study:

- (i) How far will the passenger travel by HSR and what factors influence passenger volume between Shanghai and a destination city?
- (ii) Where do the passengers come from to Shanghai? As the location of the station is closer to neighbouring 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?

PRC covers a vast geographical territory and construction of a national HSR network will facilitate inter-regional connections. How are passengers distributed from Hongqiao station to their destinations? Conducting a regression analysis based on variables of passenger number, the population of the destination city and distance between Shanghai and that city, we find that the number of passengers is in direct proportion to the destination city's population, while in inverse proportion to distance between Shanghai and the city (Table 4). In other words, larger the population of the destination city, more the passengers

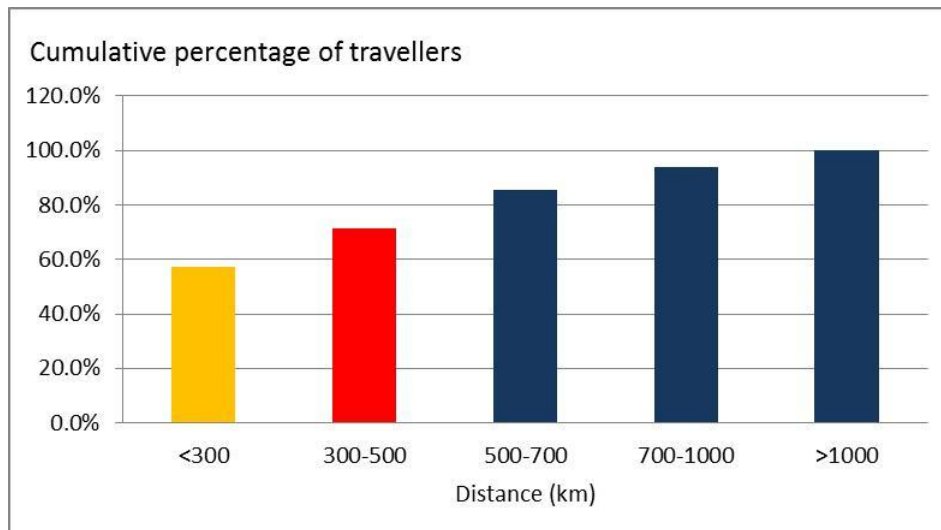
travel from Shanghai to the destination city, and shorter the distance to the destination city, the more the passengers travel via HSR.

**Table 4: Number of Passengers as a Function of City Population and Distance**

| Model                   | B      | t     | Sig. |
|-------------------------|--------|-------|------|
| (constant)              | 1      | 2.71  | .015 |
| City Population (0,000) | .086   | 2.76  | .013 |
| Distance(km)            | -0.125 | -3.01 | .008 |

The research reveals that average passenger travel distance is 377.4 km, which is not as far as was expected before the opening of HSR. It can be concluded from the travel distance distribution that short and medium-distance passengers still comprise a majority of HSR travel, with 57 per cent of them travelling less than 300 km and 71 per cent travelling less than 500 km (Figure 20).

**Figure 20: Cumulative Percentage of Travellers**



From Table 5, we see that 88 per cent of passengers surveyed are from different districts in Shanghai, 4.1 per cent transferring from the nearby Hongqiao airport and 7.8 per cent from outside of Shanghai.



To analyze the geographic location of passengers from Shanghai, we divided 16 districts and one county in Shanghai into three major categories –central urban area, city outskirts and outer suburban districts (Table 6 and Figure 21).

**Table 5: The Origin of Surveyed Passengers in Hongqiao HSR Station**

|                           | Passengers | Percentage |
|---------------------------|------------|------------|
| Hongqiao airport transfer | 75         | 4.1%       |
| Within Shanghai           | 1595       | 88.1%      |
| Outside of Shanghai       | 141        | 7.8%       |

**Table 6: Administrative Districts Distribution in Shanghai**

| Location                 | District Name      |                    |
|--------------------------|--------------------|--------------------|
| The central urban area   | Huangpu district   | Hongkou district   |
|                          | Zhabei district    | Changning district |
|                          | Jing'an district   | Yangpu district    |
|                          | Xuhui district     | Putuo district     |
| The city outskirts       | Baoshan district   | Pudong new area    |
|                          | Jiading district   | Minhang district   |
| Outer suburban districts | Chongming district | Songjiang district |
|                          | Fengxian district  | Qingpu district    |
|                          | Jinshan district   |                    |

**Figure 21: Shanghai District and County Administrative Divisions**

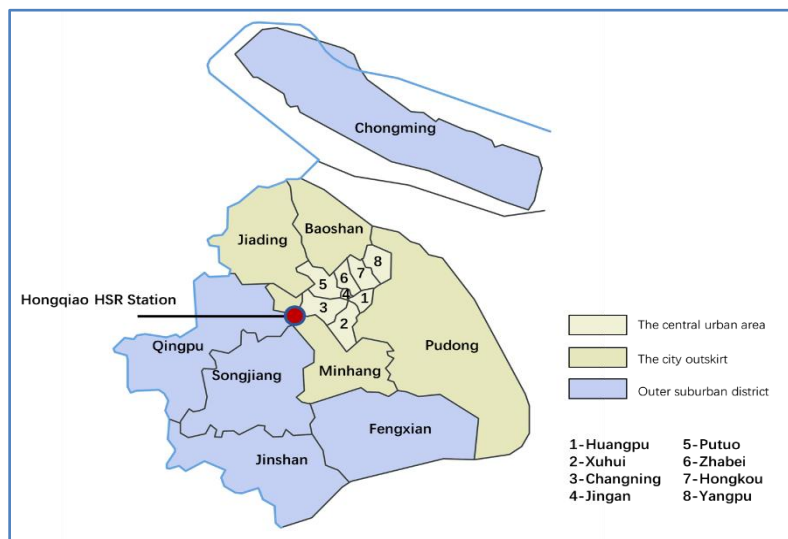
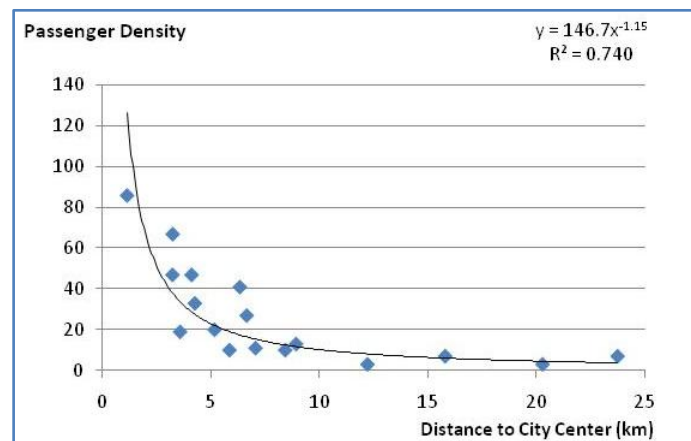


Table 5 reveals that approximately half of HSR passengers come from the central urban area of Shanghai, 40 per cent from the city outskirts and only 10 per cent from the outer suburban areas. Further analysis of passenger intensity from

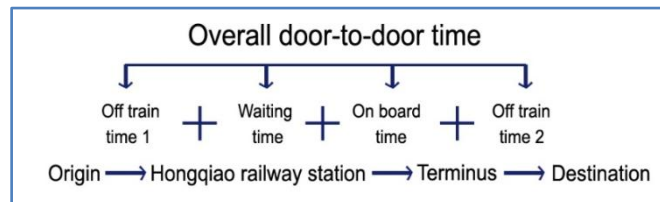
various administrative districts of Shanghai (where intensity is the number of passengers divided by the population of the district) shows that passenger intensity is in inverse proportion to distance to central urban area. In other words, majority of passengers come primarily from the dense central urban areas and adjacent districts. Thus, an HSR station located in suburbs will require a majority of passengers to travel extra distance.

**Figure 22: The Relationship between Density of HSR Passengers and Distance to City Centre**



As illustrated in Figure 23, the total door-to-door travel time for HSR is comprises four parts –time from origin to Hongqiao HSR station, waiting time at the station, travel time on board HSR, and time from the destination HSR station to the point of destination.

**Figure 23: The Segments of Door-to-Door Travel Time Consumption**



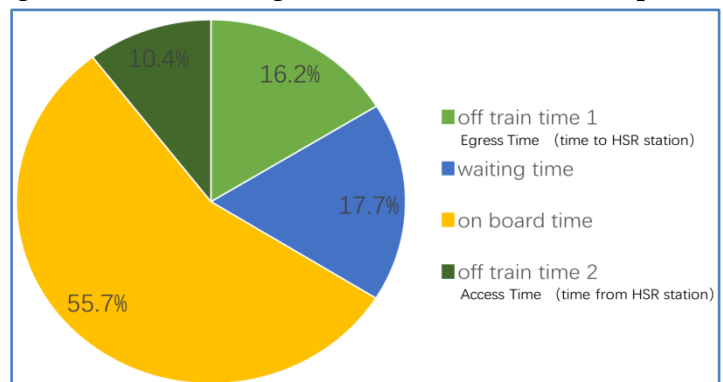
As the speed of HSR is high, the on-board time between two stations is greatly reduced compared with traditional rail or highway transit. But if people travel a relatively short distance, the on-board time may comprise only a small portion of total travel time. In this sense, during the planning and construction of HSR, we have to pay attention to access modes serving HSR stations. Large



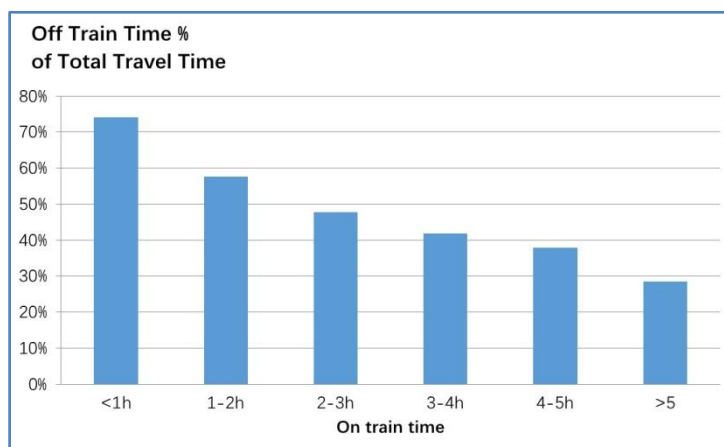
improvement in travel efficiency through HSR can only be realized when the connecting travel time from origin to HSR station and the egress time to the travel end point can be kept down in proportion to overall travel time. If this is not done, increasing train speed may make a limited contribution to total travel efficiency.

From our survey, the average on-board HSR travel time is 192 minutes, transit time to HSR Hongqiao station 56 minutes, and waiting time for HSR train 61 minutes. For the shorter trips under 300 km, on-board travel time for HSR only accounts for 25 per cent of total travel time. Thus for shorter trips, the higher train speed will produce less benefit to improve travel efficiency and efforts during HSR planning to reduce the off-train time are really the key.

**Figure 24: Total Passengers' Door-to-Door Time Composition**



**Figure 25: Off-train Time as % of Total Travel Time Compared with On-train Travel Time**



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 centre. Comparing passenger average access time to those two stations to average access time to newly built Hongqiao HSR station, we find that average access time increased 18 per cent, from 50 minutes to 59 minutes (Table 7). Passengers whose access time increased the most are those whose origin is the central urban district. Passengers in the suburban south part of Shanghai benefit from the location of Hongqiao HSR station in the form of reduced access time to the station. But 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 HSR connection located farther away, and it appears that the travel time increase is acceptable to most passengers.

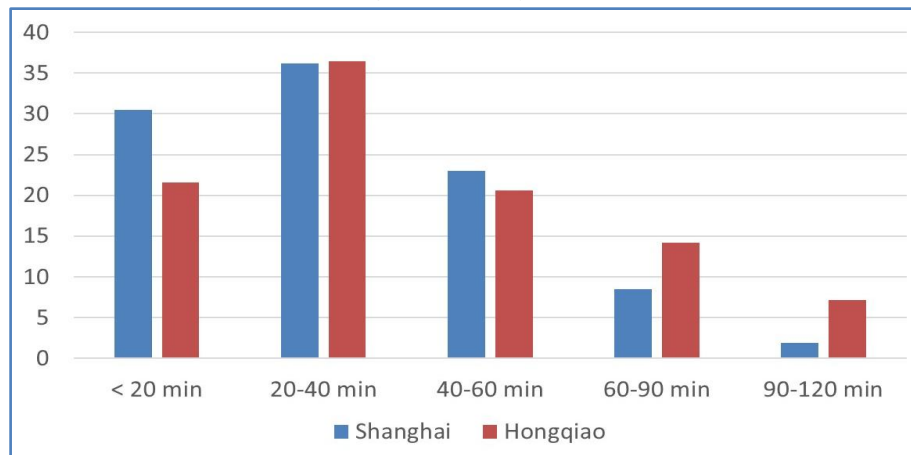
**Table 7: Access Time Changes in Different Districts of Shanghai**

|                     | District  | Average access time to Hongqiao HSR Station (min) | Average access time to Shanghai or Shanghai South Railway Stations (min) | % 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%    |
|                     | Minghang  | 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%    |

After the opening of HSR service in Shanghai, one research has compared the access time to two stations, which shows the access time to Hongqiao HSR is

longer than to Shanghai railway station. People will also pay 3RMB more to Hongqiao HSR station on average (Figure 26).

**Figure 26: Comparing the Access Time to Hongqiao HSR Station and Shanghai Railway Station**



## 9. HSR PASSENGER ANDECONOMIC IMPACT

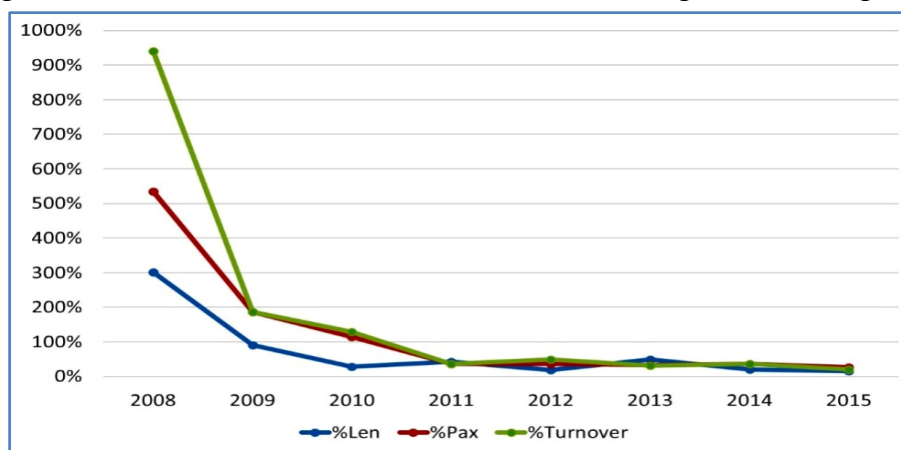
The large-scale HSR network and service attracted a large number of passengers. In 2008, passengers taking HSR was only 0.5 per cent of the total railway passengers in PRC. In 2016, 43.4 per cent of railway passengers were carried by HSR. In 2012, PRC built around 10,000 km HSR. From that year the increase in passenger and passenger-km is becoming stable in comparison with before.

The economic impact of investment in transport has been the subject of a long debate. Jia and Qin (2014) summarized that research on economic impact of HSR can be categorized into three types, including study of input-output balance, interaction intensity between cities reflected by time-space map or other ways, and the statistic models to analyze impact of accessibility on economic changes.

First, increased spending is likely to raise economic output whether it is on transport infrastructure or something else. Recent developments in economic geography place particular stress on agglomeration economies as a source of productivity growth. By improving connectivity between firms and their suppliers, competitors and customers, and existing and potential sources of

labour, specialization may be increased, economies of scale exploited and productivity and hence output may be raised. Jia and Qin (2014) suggest that HSR construction should take the passenger demand into consideration to gain the balance between input and output. Therefore, the HSR corridor has to link metropolis with high population density, serious congestion problem and limited aviation services.

**Figure 27: The Growth Rate of HSR Network Size, Passenger and Passenger-km**



Second, in terms of location of economic activity, it has been 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 be concentrated in the large business-oriented cities, mainly located in the East and the Southeast part of PRC, such as Beijing, Tianjin, Shanghai, Wuhan, Changsha, Jinan, Xuzhou, Suzhou and Guangzhou, as well as provincial capital cities. Today, much higher traffic is generated along the more economic advanced HSR corridors like Beijing-Tianjin, Wuhan-Guangzhou and Beijing-Shanghai than the corridors located in the middle and western areas of PRC. One research by Lu et al (2013) indicates the spatial distribution patterns of HSR economic zones and shows that the HSR network has replaced the evenly distributed spatial economic model by a clustered distribution, and accordingly increases the urban agglomeration effect in metropolitan areas like the Yangtze delta region. But there are significant differences in terms of the spatial economic model, 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. Another study by Jiang et al. (2017) has compared change of city accessibility on the

Harbin-Dalian railway corridor and the Zhengzhou-Xi'an railway corridor. The research shows, though accessibility of cities along HSRs has improved, degree of improvement of the Harbin-Dalian corridor is stronger. Besides, HSR also enlarges the accessibility gap of some regions, especially the marginalized ones.

HSR also affects the tourism market in a similar way. According to Yin (2012), the Zhengzhou-Xian HSR corridor has strengthened the tourism attraction of Zhengzhou, Luoyang and Xi'an and further attracted the tourism industry clustered in these three traditional tourism cities.

However, because of HSR's high cost, some researchers have argued that, in areas, especially in western part of PRC and the poverty-stricken areas in central part of PRC, building advanced conventional railways would be better. In a country as vast and diverse as PRC, it's important to take regional differences into account, rather than a single approach to rail investment.

## 10. CONCLUSION

Since 2003, the China Railway Authority has been implementing the national strategic plan for widening railway's reach, prioritizing HSR along with inter-regional cargo rail. The HSR network is now the largest in the world. HSR is an excellent mode of transport for PRC's rapidly growing demand for inter-city travel. Its high speed and capacity, and 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, PRC's HSR is faster than auto travel and is competitive with domestic air travel for majority of inter-city trips. It is even competing with air travel for over 1,000 km journey. In Shanghai and many other cities, suburban and exurban HSR station locations have been chosen because they are less expensive to build, allow straighter alignments, faster rail services, and may also stimulate sub-centre growth.

Our survey conducted at Shanghai's Hongqiao station, a typical new HSR stations, shows over 70 per cent passengers travel on HSR for distances less than 500 km. For these travellers, the time taken to access HSR station is a major consideration; higher train speed has a decreasing contribution to total travel efficiency. Therefore, the challenge is how to balance location of HSR stations with provision of improved urban centre transit connections and higher HSR

passenger intensity. The Shanghai case shows extending connections, especially rail transit connections, to the HSR station can attract many passengers. But this comes at a high cost and HSR access still takes more time for travellers than the earlier system. Also, in-city stations are required.

Instead of constructing a large HSR station in a distant suburb, planners should consider direct connection of HSR to existing traditional rail stations, where HSR train can be accessed more easily 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 service for intercity travel, we cannot neglect the improvement in high quality public transport system within a city. HSR passengers would prefer reliable and comfortable access modes to HSR station. HSR with poor urban public transport service will induce more car traffic accessing to the station, thus resulting in severe traffic congestion or parking problems. The high concentration of HSR passenger traffic in economic dense area indicates that HSR is a justified solution in capacity increasing in those areas. In less developed areas, more sophisticated operation should be designed to balance the relative traffic volume, operation/maintenance cost and political equity policy. Upgrading the normal train service is also needed in those less developed areas in PRC.

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# HSR Effect on Urban Spatial Correlation: A Big Data Analysis of People's Republic of China's Largest Urban Agglomeration

Ji Han\*

HSR is recognized as one of the most important transport modes and has been given increasingly great priority in regional development. An understanding of HSR's effect on the urban spatial correlation is important for optimizing the layout of the HSR system and promoting the competitiveness of a city region. We develop a crawler programme to compile online big data for urban spatial correlation analysis, which supplement the existing social network analytics. Differing from the previous studies, vectorial, realistic and high spatiotemporal resolution inter-city passenger flow data instead of statistical and modeled data are used for the spatial correlation analysis. Yangtze River Delta (YRD), the largest urban agglomeration in People's Republic of China (PRC), is selected as a case to test the big data approach and to gain insights to HSR's effect on the urban spatial correlation. The results indicate HSR significantly improves the correlation intensity between cities compared with road transport. Nanjing and Shanghai have become the dual cores of YRD due to the introduction of HSR. Shanghai and Suzhou are attracting passengers due to their positive net-degree centrality, but Zhenjiang and Changzhou are showing opposite trend. The high-income level and massive job opportunity are the major driving factors attracting passenger inflows.

## 1. INTRODUCTION

Due to characteristics like reliability, convenience, time saving and environment friendliness, HSR has been recognized as one of the most important transport modes and has been given great priority in regional development. It's especially true for PRC. With more HSR to be introduced or expanded, it's necessary to have a better understanding of HSR's effects on the urban spatial

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correlation and to develop appropriate strategies and policies toward a sustainable development of HSR system and city region.

The urban spatial correlation is an important driving force that determines dynamic growth and economic performance of a region<sup>1,2</sup>. A great number of studies have been done on theories and modeling of the urban spatial correlation. For example, Zipf first introduced Newton's law of gravity into urban study, and built a theoretical basis for the urban spatial correlation research<sup>3</sup>. Converse developed a breaking-point model on the basis of the Reilly's law of retail gravitation to determine the urban attractive range and classify the economic zone<sup>4</sup>. Taylor proposed a concept of 'world city network', which provided a new angle for the urban correlation study and expanded the previous single-city dominated analysis to a city-network<sup>5</sup>. Afterwards, the urban spatial correlation studies have attracted lots of attention from both scholars and policymakers. The research also covered a wide range of fields like inter-city trade, transportation, information, tourism, and logistics<sup>6-10</sup>. Among diverse methods and models, social network analytics is recognized as an effective and quantitative measurement of the hierarchical structure and the spatial correlation within a region, since it can reflect correlations between cities<sup>11</sup>. But deficiencies still exist in measuring correlations. Taking one of the widely used social network analytics, the gravity model, as an example, it uses the unit sizes (often GDP or population) and distance to estimate flows between two units to analyze correlations. But main deficiencies may include the following aspects.

First, the correlation between two cities is usually defined as a scalar rather than a vector, which means the attraction of one city to another, will not change when roles of these two cities are reversed<sup>12</sup>. Results derived from the gravity model may sometimes be contrary to reality and it's also easy to find out a counter-example that population leaving a small city for a core city in a city region will be much larger than the backward population.

Second, correlations are analyzed on the basis of modeled flows between two units rather than real flows (like population flow, trade flow and traffic flow) occurred, which may deviate from the reality.

Third, due to availability of data, the gravity model usually relies heavily on the statistical data published by the government. Both time and space resolutions are low. Taking Chinese cities as an example, all the city-level

statistical data (like GDP, population and urban population) are published and renewed once a year. But the real terrain and transport conditions between cities are neglected. As an alternative, Euclidean distance is used due to easy calculation, through it might also cause error.

Obviously, these deficiencies form an obstacle for our in-depth understanding and investigation of the correlation between cities. New methods and novel data are increasingly needed to address the challenges.

Fortunately, development of big data science and techniques offers us a possible solution to these problems. Big data on the inter-city passenger flow, including the flow direction, date and passenger number with a high-time resolution (hourly interval), is compiled from a ticket booking website to support the urban spatial correlation analysis. Several correlation measurement indices, commonly adopted in social network analytics, are employed in this study to quantitatively explore the intensity, structure, and spatial correlation of a region. Six cities in YRD have been chosen as a case study region to test the spatially explicit approach and big data set, and to gain insights into the urban spatial correlation in PRC's urban agglomeration (UA).

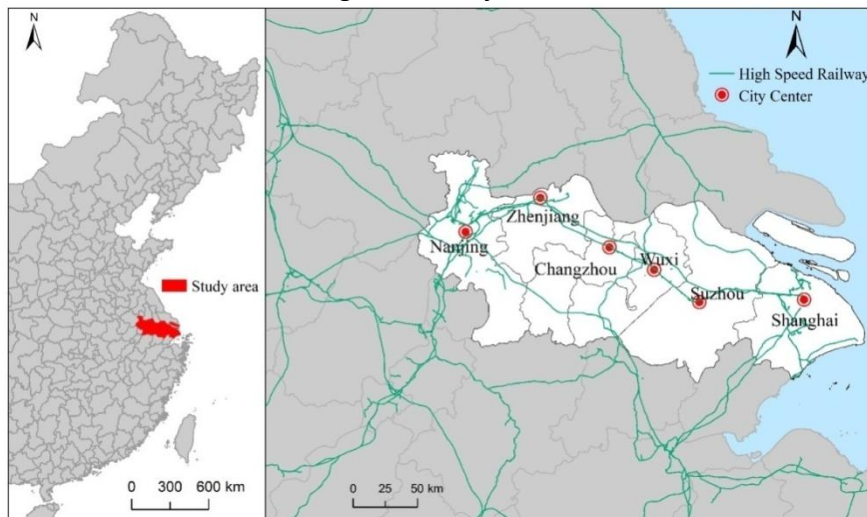
The remainder of this paper is organized as follows: Section 2 introduces the study area. Section 3 describes materials and methods for collecting HSR and bus passenger flow data and the social network analytics. Section 4 interprets results and discusses the research limitations and potential improvements. The last section summarizes the major findings.

## 2. STUDY AREA

YRD urban agglomeration (as shown in Figure 1) is located in the eastern region of PRC. In this study, we have chosen six cities (Shanghai, Suzhou, Wuxi, Changzhou, Zhenjiang, Nanjing) along the Hu-Ning Line for testing the big data approach and gaining insights to the impact of HSR on the urban spatial correlation. As one of the earliest constructed and busiest HSR lines in PRC, its annual passenger turnover volume reaches 0.4 billion. The six cities are also densely populated and economically prosperous. Moreover, YRD urban agglomeration as a whole is the sixth largest UA in the world and the largest in PRC, which plays a significant role in the national and regional development. In 2016, population and GDP of YRD UA was 159 million and 15 trillion Chinese

yuan, respectively, accounting for 11.5 per cent and 20.5 per cent of PRC's total. But it only occupies 2.3 per cent (219 thousand km) of territory. The YRD UA has an ambitious urbanization plan to raise its population share to 72 per cent by 2020 and to build world-class industrial, innovation and urban clusters with global impact. To realize goals, it's urgently needed for the YRD UA to achieve a synergic correlation among its internal cities. Thus, selection of the YRD UA as a case study could help gain insights into the urban spatial correlation in PRC's most developed region, and generate implications and experiences for other UAs for sustainable development.

**Figure 1: Study Area**



### 3. MATERIALS AND METHODS

#### Materials

In this paper, inter-city passenger flow of bus and HSR modes are adopted to measure the urban spatial correlation in UA. Instead of using the traditional statistical data, we compiled bus and HSR passenger flow data from an online ticket booking websites, Bus Steward and 12306<sup>13</sup> through R language programming. As Bus Steward is one of the strategic partners of the PRC Road Transportation Association, and 12306 is the official railway ticket booking website, it's believed that their passenger flow data are most detailed and reliable in YRD. With the help of R studio, especially its package 'httr' and 'xml2', a crawler programme has been developed to get the enormous long-term ticket

information automatically from Bus Steward and 12306 websites. In this study, over 270,000 pieces of ticket information in an hourly interval of June 2018 were obtained. It included origin and destination station names, coach types, departure times and ticket numbers of each seat class. Table 1 shows some examples of the online collected data. Bus data of Lianyungang and Taizhou could not be obtained due to website database structure problem.

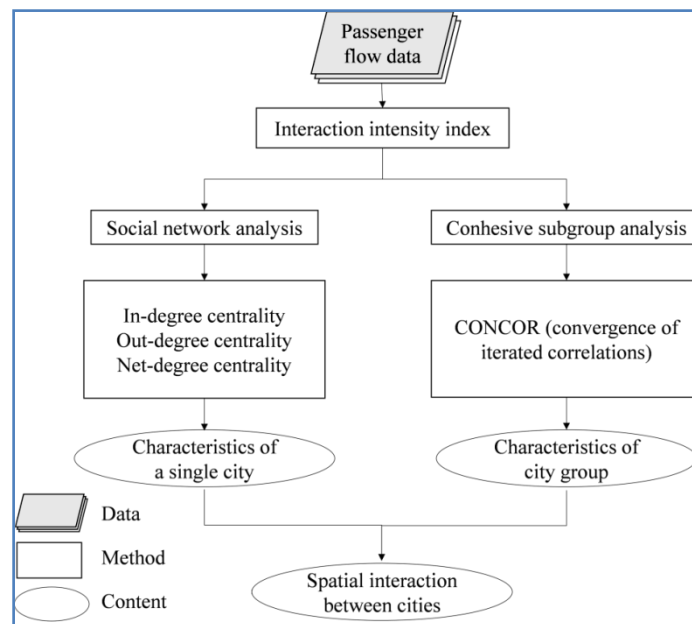
**Table 1: Examples of the Online Retrieval Bus and HSR Passenger Flow Data**

| Origin   | Destination | Coach type | Departure time | Remained Ticket |
|----------|-------------|------------|----------------|-----------------|
| Shanghai | Wuxi        | Large      | 10:00          | 10              |
| Nanjing  | Changzhou   | Large      | 15:20          | 18              |
| Suzhou   | Zhenjiang   | Medium     | 21:15          | 5               |
| ⋮        | ⋮           | ⋮          | ⋮              | ⋮               |

**Methods for Urban Spatial Correlation Analysis**

Basically, the urban spatial correlation between cities can be evaluated on the basis of two aspects – characteristics of a single city and characteristics of city group. Some widely used indices have been adopted to quantify these characteristics. The flowchart is shown in Figure 2 and details about each index are described as follows.

**Figure 2: Flowchart of the Study**



**Correlation Intensity Index**

Correlation intensity index is used to measure how strongly connected are two cities and is defined by equation (1)

$$I(i, j) = P_{ij} + P_{ji} \quad (1)$$

where  $I(i, j)$  is the correlation intensity between cities  $i$  and  $j$ ,  $P_{ij}$  is the number of passengers departed from city  $i$  for  $j$ ,  $P_{ji}$  is the number of passengers departed from city  $j$  to  $i$ .

**Degree Centrality and Betweenness Centrality Index**

The degree centrality means the number and intensity of links incident upon a node. To make better use of the vectorial passenger flow data, three more degree centrality indices are defined. They are in-degree centrality, out-degree centrality, and net-degree centrality, which are represented by the number of passengers moving into a city, leaving for other cities, and their net changes. It's easy to understand that cities with higher in-degree centrality means greater attraction than cities with lower in-degree centrality. Correspondingly, the larger value of out-degree centrality means less attraction of a city.

$$C_{Di}(i) = \sum_j^n P_{ji} \quad (2)$$

Where  $C_{Di}(i)$  is the in-degree centrality of city  $i$ ,  $P_{ji}$  is the number of passengers departing from city  $j$  for city  $i$ ,  $n$  is the total number of cities in YRD UA.

$$C_{Do}(i) = \sum_j^n P_{ij} \quad (3)$$

Where  $C_{Do}(i)$  is the out-degree centrality of city  $i$ ,  $P_{ij}$  is the number of passengers departing from city  $i$  for city  $j$ ,  $n$  is the total number of cities in YRD UA.

Net-degree centrality  $C_{Dn}(i)$  is defined in equation (4) to indicate the net change of degree centrality.

$$C_{Dn}(i) = \sum_j^n P_{ji} - \sum_j^n P_{ij} \quad (4)$$

All the above centrality indices are calculated by the software UCIENT 6, which was developed by Roberta Chase and Steve Borgatti<sup>14</sup>. All values are normalized between 0 and 1 to make them comparable.

### Cohesive Subgroup Analysis

The cohesive subgroup is described as a subgroup comprising several members, which have relatively strong, direct, close and positive relationship<sup>15</sup>. The city network cohesive subgroup analysis can reveal structure inside a UA to measure the amount of cohesive subgroups and their group members, which could describe the development state of UA from a new angle. In this study, we discuss the subgroup aggregation phenomenon in the YRD UA according to the correlation intensity between two cities to indicate relationship between different cities and reveal spatial structure of UA cities.

The convergence of iterated correlations (CONCOR) index has been used to identify the cohesive subgroup in the study. CONCOR starts from a first correlation matrix C1, as shown in equation (6).

$$C_1 = \begin{pmatrix} 1 & a_{12} & a_{13} & \cdots & a_{1j} \\ a_{21} & 1 & a_{23} & \cdots & a_{2j} \\ a_{31} & a_{32} & 1 & \cdots & \vdots \\ \vdots & \vdots & \vdots & \ddots & a_{(i-1)j} \\ a_{i1} & a_{i2} & \cdots & a_{i(j-1)} & 1 \end{pmatrix} \quad (6)$$

Here  $a_{ij}$  is normalized number of passengers departing from city  $i$  for city  $j$ .

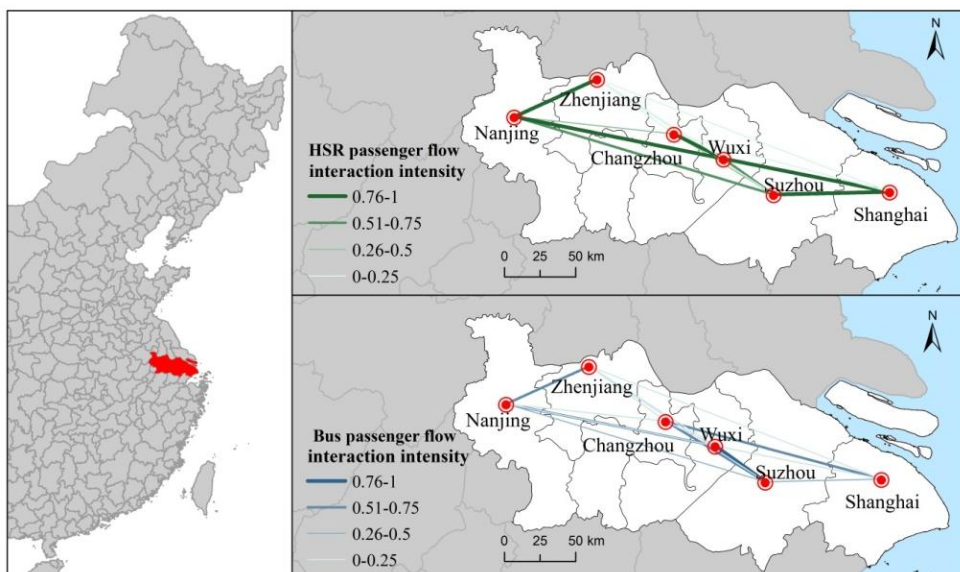
The Pearson correlation coefficient of every row and column is calculated to produce a new correlation matrix C2. Then the procedure is repeated until the result ends up with a matrix whose entries take one from two values: 1 or -1. The final matrix can be permuted to produce blocks of 1s and -1s with each block representing a group of structurally equivalent actors. Finally, tree diagram is used to reveal the structure of each subgroup and shows all the subgroup members. In addition, the progress mentioned above is also performed in UCIENT 6.

#### 4. RESULTS AND DISCUSSIONS

##### Correlation Intensity between Cities

Figure 3 presents the correlation intensity of inter-city HSR and bus passenger flows in the YRD UA. Generally, the correlation intensity of HSR flow is much higher than that of bus flow. It suggests that HSR has significantly improved the urban spatial correlation between cities compared with the road passenger transport. In addition, with the development of HSR system, Shanghai, Suzhou, Wuxi and Changzhou are more closely connected. While Nanjing, Zhenjiang and Changzhou are more spatially correlated with each other compared with situation of bus passenger flow. The six cities in the YRD UA tend to be an organic whole due to operation of the HSR system. Regarding the bus-data-based spatial correlation, Shanghai is the only core city of the YRD UA as it holds the most intensive correlations with other cities. Four of the five cities have a strong correlation with Shanghai with their values above 0.19. But when the HSR system is introduced, the HSR data-based spatial correlation tells us that there appears dual core cities in the YRD UA, namely, Nanjing and Shanghai. Notably, the correlation intensity between Nanjing and the other five cities are all above 0.33, which is even larger than that of Shanghai. It means Nanjing would become another important centre together with Shanghai.

**Figure 3: Correlation Intensity of Cities based on HSR and Bus Passenger Flow Data**

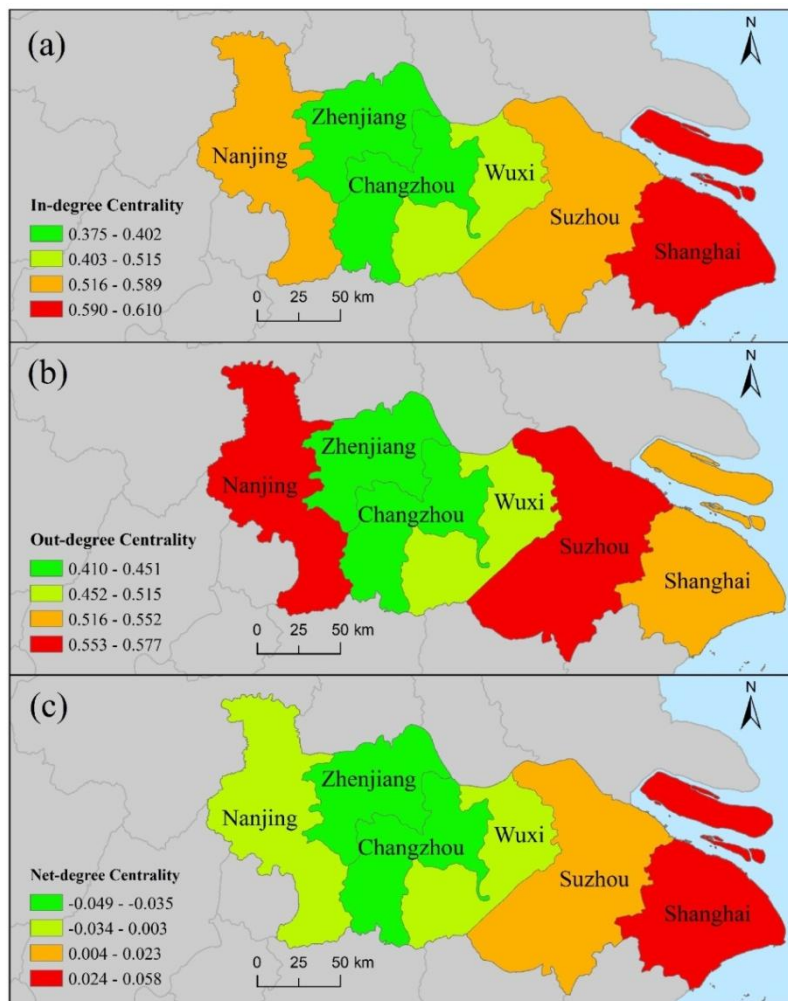




**Degree Centrality of Cities in the YRD UA**

Figure 4 shows the results of in-degree, out-degree and net-degree centrality of cities in the YRD UA based on HSR passenger flow data. Each index is classified into four grades according to the natural breaking methods<sup>16</sup>. Shanghai and Suzhou showed a positive net-degree centrality, which means they are attracting passenger flows. The situation was opposite in Nanjing, Zhenjiang, Changzhou and Wuxi that showed a negative net-degree centrality, which means they sent out passengers to other cities in YRD.

**Figure 4: In-, out- and net-degree centrality of cities in the YRD UA based on HSR flow data**

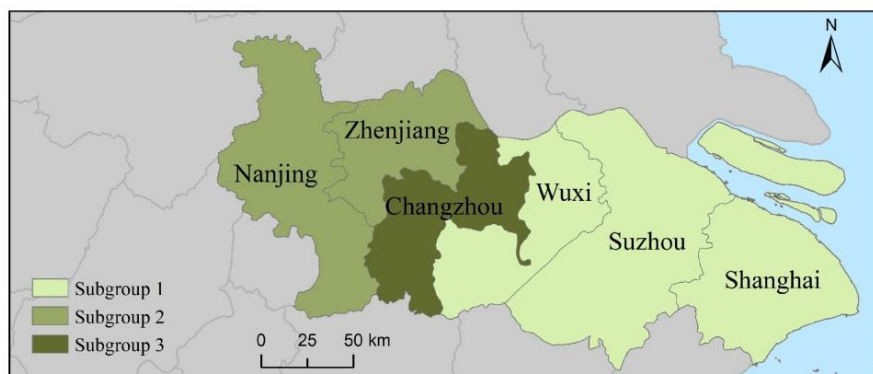


In specific, though Suzhou in Jiangsu province has a high value in both the in-degree and out-degree centrality, its net-degree centrality is positive but lower than that of Shanghai. It suggests that Suzhou may have a less attraction to HSR passengers compared with Shanghai. On the contrary, Zhenjiang and Changzhou had the largest negative net-degree centrality with values of -0.05 and -0.04, respectively. It indicates they are the biggest origin cities of HSR passenger flows in YRD. According to a survey conducted on the trip purposes of HSR passengers along the Beijing-Shanghai Line (it covers the Hu-Ning Line in our study), work, tourism and visits to friends and relatives are the top three purposes accounting for 99.3 per cent<sup>17</sup>. Due to the dominant role of Shanghai in economic performance and employment in YRD as its per capita income was 54000 RMB and provided 0.6 million new jobs in 2016, it attracts massive population inflows with the annual growth rate of net population immigration reaching 5 per cent in 2016<sup>18</sup>.

#### **Cohesive Subgroups of YRD UA**

As shown in Figure 5, cities in the YRD UA are divided into three subgroups. Generally, cities within each subgroup are geographically close to each other. Nanjing and Zhenjiang had a stronger connection. While Shanghai, Wuxi and Suzhou were more closely interacted regarding the HSR passenger flow. Changzhou is categorized as an independent group. Though the subgrouping results affected the number of sample cities, the result is consistent with the long-term layout of the YRD UA. Nanjing is planned to be the important node city to ensure the shift of manufacturing industries from east to the west YRD<sup>19</sup>.

**Figure 5: Subgroups of Cities in the YRD UA**



### Limitations

Big data provides a supplement to the traditional statistical-data-based urban spatial correlation analysis. But some limitations still remain and require further research. On one hand, the data used to measure the spatial correlation between cities in the study only covers bus and HSR passenger flows, while the passenger flows by other transport modes like conventional railway, private car and ferry are not considered due to the data limitation. This could cause a bias in the result. More endeavours should be made to fill the data gap. Data from social media, cellphone and transport card could be the possible sources to obtain the desired passenger flow information with high time and space resolutions. In addition, the study period could also be expanded to a year or even longer to avoid the impact of some accidental events on the result.

On the other hand, we only reveal characteristics of urban spatial correlations among cities in this paper. An in-depth investigation of the mechanism of the spatial correlations and its correlation with the industrial location and socio-economic development of UA is needed in the future study so that proper policy implications could be generated to promote the competitiveness and sustainability of UA.

### 5. CONCLUSIONS

The study on HSR's effects on urban spatial correlation among cities will help develop appropriate strategies and policies toward sustainable development of the HSR system and city region. We have developed a method for collecting a big data of inter-city HSR and bus passenger flows from the ticket booking website and applied this in the YRD UA as a case study. Through a series of indices, we analyzed the spatial correlation among cities in the YRD UA regarding its correlation intensity, degree centrality and subgroups. The major findings are summarized as follows.

1. Big data provide vectorial, realistic and high spatiotemporal resolution information of urban correlation than traditional statistical data. It serves as a supplement to existing data and methods for the spatial urban correlation analysis.
2. HSR has significantly improved the urban spatial correlation between cities compared with road transport. Nanjing and Shanghai became the dual core cities in YRD due to introduction of HSR.

3. Shanghai and Suzhou are – the two largest cities – are absorbing passengers from other cities since their net-degree centrality are positive. On the contrary, Zhenjiang and Changzhou are sending passengers out as they demonstrate a negative net-degree centrality. Nanjing, Ningbo and Yangzhou are the top three largest cities absorbing passengers regarding net-degree centrality. The high-income level and massive job opportunity could be the main factors driving Shanghai to be the largest passenger inflow city in the YRD UA.
4. Cities in the YRD UA formed three subgroups. Each subgroup comprised of cities geographically close to each other.

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# Japan: Integrated Land Development and Passenger Railway Operation

Fumio Kurosaki\*

Railway construction has large external economy. For maximizing the external economy, railway construction and urban development should be integrated and coordinated. If the railway company internalizes the external economy, it can increase its revenue. Before 1970s, the Japanese private railway companies had promoted railway construction along with urban development. They earned from both railway operation and real estate businesses and extended the rail network without relying on public subsidy. As the road network has expands and population increase becomes modest, it has become essential for the public sector to take the initiative to undertake railway construction and land development. Thus, railway construction and urban development should be coordinated. For achieving the coordination, Japan formulated the integrated development law (IDL) and applied it to the Tsukuba Express project, which was commissioned in August 2005. IDL has prevented inconsistency between railway planning and regional planning, and promoted comprehensive regional development. The concept of integrated development could be applied to other projects as well.

## INTRODUCTION

### Background

Japan has rich experience of integrated development promoting construction of railway network along with development of land around stations. These experiences have attracted attention of experts and specialists. Besides engineering, the development of railway network, land development and management of railway companies have attracted interests from the railway sector professionals (Kurosaki, 2017).

Until 1970s, some private railway companies developed rail network within the metropolitan areas like Tokyo and Osaka without relying on public subsidy, which helped Japan develop dense rail network in those areas. During those

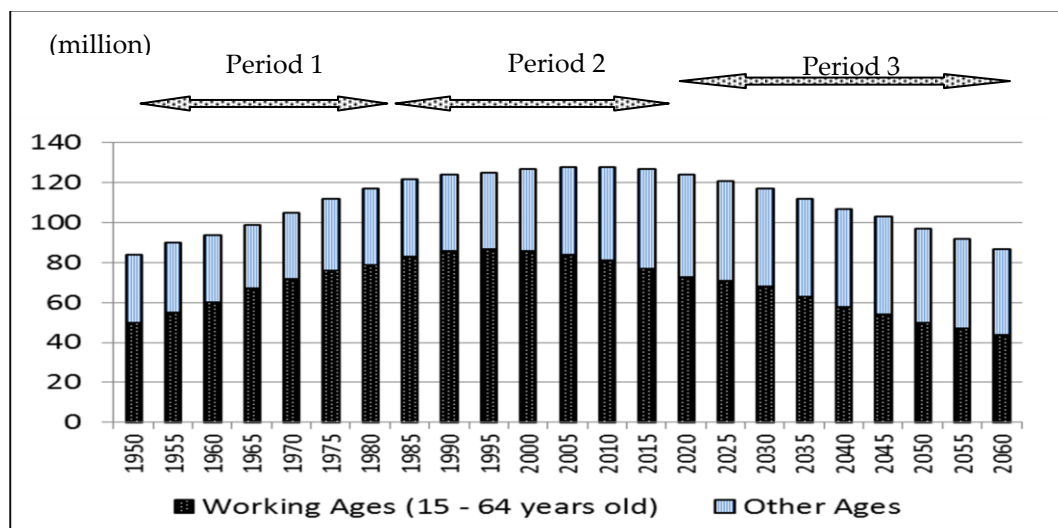
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years, private companies could earn revenues not only from passenger services but also from land development along the line.

But it has become difficult for private rail companies to promote this business model due to reasons like progress of motorization and change in population growth. Coordination between rail construction and land development is essential both for the management of companies and land development along the lines. Thus, they should be integrated. Besides the integrated development by private companies, the Japanese government has been making efforts to promote integrated development between rail construction and urban development. Interestingly, methods of the integrated development have been different depending on the time. (Figure 1.1):

**Figure 1.1: Three Periods of Population Change in Japan**



Source: Kurosaki, F. (2015)

- (i) Period 1: during rapid population increase;
- (ii) Period 2: during modest population increase; and
- (iii) Period 3: during population decrease.

This paper investigates how Japan promoted integrated development in the three stages. In particular, the investigation focuses on the Period 2 as conditions then in Japan appear relevant to other countries that are preparing to build railway systems.

### **Characteristics of Rail Construction**

For understanding the policies and experiences in Japan, this section notes two characteristics regarding railway construction and urban development.

*External economy of railways:* Operation of passenger rail services has large external economy. It can raise the value of land around stations and benefit not only passengers but also entities that own those lands. Since the rail transport services increase land value, construction of rail systems helps develop residential areas and business districts along the line. Also, the management of rail companies can be improved provided the external economy of railways can be internalized.

*Necessity of integrated development:* With the implementation of regional development plans in cooperation with railway construction, rise in real estate value can be achieved more effectively. For example, to raise the potential of railway services, other public transport modes like buses and taxis should be available at each station with proper ramps and parking for these vehicles. For comprehensive development, it's also essential to plan and build roads and other social infrastructure in coordination with stations and other railway facilities.

### **INTEGRATED DEVELOPMENT DURING RAPID POPULATION INCREASE: KOBAYASHI ICHIZO MODEL**

This chapter discusses the integrated development by Japanese private railways during the period when population increased rapidly until 1970s.

#### **Conditions during the Period**

After the Second World War and until 1970s, some Japanese large private railway companies implemented real estate development along construction of urban/suburban rail lines in metropolitan areas. This kind of integrated development could be realized because of several reasons during the period. First, the extension of rail lines was carried out when the road network was still poor. It made the rail system convenient and popular transport mode to commute from residential areas to central business district. As expansion of the urban/suburban rail network was an effective way to encourage development of suburban area, the residential areas were developed along the rail lines accordingly. Second, as shown in Figure 1.1, population increased at a rapid pace during the period, and urbanization progressed in metropolitan areas

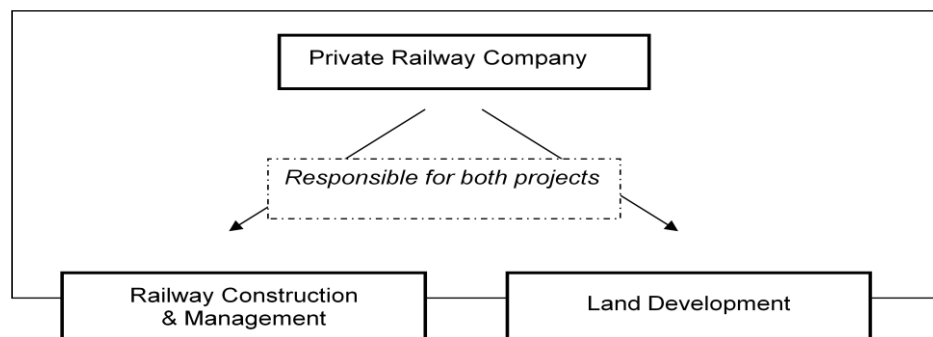


extensively. Thus, there was a shortage of residential spaces in metropolitan cities like Tokyo and Osaka. Because the price of land soared during the period, people considered purchasing real estate to be a good way of accumulating private assets. Due to these reasons, the risk for private railway companies' investment was relatively low, and some large firms actively invested in both rail construction and land development.

### Integrated Investment by Private Railways

The regional governments primarily supported the planning of integrated development. Some private rail companies invested in both rail construction and real estate development and promoted both rail and non-rail businesses (Figure 2.1).

Figure 2.1: Scheme of Integrated Development by Private Railways until 1970s



Source: Author

This kind of management and development is known as the 'Kobayashi Ichizo' model, referring to the person who first promoted this particular business model. Kobayashi Ichizo founded a private company Hankyu Corporation in 1907 and carried out integrated development promoting railway construction and land development. Under this model, private companies would construct a new line in a less populated region and develop residential areas along the track. In some cases, companies would develop other facilities like amusement parks and a baseball stadium to attract large number of passengers who would travel in the opposite direction of most commuters. They also tried to invite universities to set up campuses in the suburban areas along the line. In many cases, companies developed department stores, office buildings and hotels close to large stations to promote affiliated businesses. Kobayashi made profits from both transport services and affiliated businesses, and others followed this business

model. Nowadays, some large private railway groups earn more than half of the revenue through non-rail businesses.

People who purchased houses along the line would usually commute from a suburban area to a business district by trains. It meant that rail companies earned revenues from both passenger transport and real estate businesses. In practice, Japanese private companies increased their revenues from both businesses and invested their profits to extend their networks. As of March 2017, 15 major private railways accounted for over 2,700 km network and 1,661 stations. Along with JR lines and metro systems in the region, private railways are one of the most popular transport modes. They transported 7.6 billion passengers in FY16 (Japan Private Railway Association, 2017).

From the viewpoint of a theory in economics, it can be said the Kobayashi Ichizo model had utilized external economy of railways besides gaining revenue from rail transport business. We can also say, traditionally private railways in Japan have been very active in promoting affiliated businesses. But the Kobayashi Ichizo model requires the private sector to make huge investments in both rail facilities and land development. Also, the period of rapid population increase has ended and road network has been developed in Japan. Thus, in recent years it has become practically impossible for the private sector to promote the Kobayashi Ichizo model by taking risks to invest in both rail facilities and real estate around the line.

#### **INTEGRATED DEVELOPMENT DURING GRADUAL POPULATION INCREASE: TSUKUBA EXPRESS PROJECT**

This chapter investigates the integrated development law, which aims to solve inconsistency between railway planning and regional planning. This law was applied to construction of Tsukuba Express (TX) Line, connecting city centre of Tokyo metropolitan area and its suburb. Thus, the outcome of the project and management of the line are also investigated.

#### **Integrated Development Law (IDL)**

*Problems of inconsistent development:* Prior to enforcement of IDL, discussed in this chapter, regional development was implemented after opening of rail lines in many cases. The inconsistency between railway planning and regional planning often resulted in many serious problems, like insufficient provision of public infrastructure and unorganized development of residential

areas around stations. With proper planning and construction of roads and other infrastructure, the area around stations can be developed as a business/commercial district and wider surrounding area can be developed as residential areas. Nevertheless, this kind of regional development can't be attained without consistent planning and strict regulations. In other words, to use external economy of railways, proper planning and regulations are required in coordination with railway planning and construction.

Without proper regulations, some private companies might speculate in the land around planned stations expecting rise in land values. This kind of activities not only prevents the consistent regional development but also causes delay in rail construction works. In other words, consistent regional planning and proper regulations are required for preventing disorder in the development process.

*Aims of IDL:* To solve the problems, described earlier, a new law was enacted in June 1989. The official name of IDL is "the special measures law for coordinated development of residential areas and railways in metropolitan areas,". As the name indicates, the law aims to promote both railway construction and real estate development along the rail line in an integrated manner to supply large residential areas. The law made it possible to promote integrated regional planning in coordination with railway planning and construction.

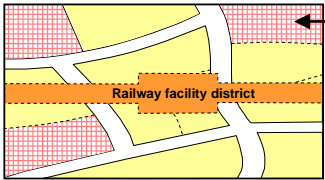
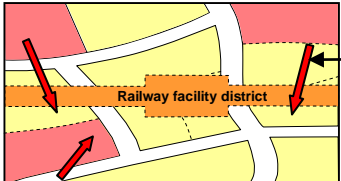
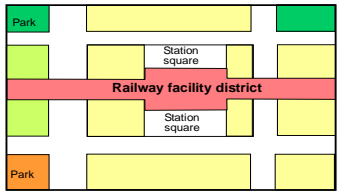
*Integrated development based on the law:* IDL promotes railway construction and urban development based on the approach called 'land readjustment'. In other words, the main characteristic of IDL is integration of railway construction and land readjustment.

The approach of land readjustment is effective for comprehensive regional development converting the land from agricultural to urban/residential area. In the process of land readjustment project, infrastructure like roads, parks and other public facilities are provided. In many cases, their funding is covered by sale of a part of the reserved area for commercial purposes.

Before the project, many inhabitants owned land of different physical shapes and sizes without sufficient infrastructure. In the project, the owner would be provided re-plotted land, which has been reshaped but reduced in size to provide the reserved area. Although the re-plotted land has less space, the value can rise as the re-plotted land is reshaped and has infrastructure. The flow

of the railway construction based on the land readjustment project is shown in Figure 3.1.

**Figure 3.1: Flow of Land Readjustment Plan**

| Step      | Explanation and Image   |
|-----------|---|
| 1st stage | <ul style="list-style-type: none"> <li>• Priority area is specified around planned stations.</li> <li>• Railway facility district* is also specified within a priority area.</li> <li>• Railway facility district covers the area of the planned station and railway route. This district is specified in the land readjustment plan.</li> <li>• A part of the land within a priority area is purchased in advance by public entities like local government, public railway company and a public urban developer.</li> </ul>  <p>(a part of priority areas)</p> |
| 2nd stage | <ul style="list-style-type: none"> <li>• The land readjustment plan is authorized and use of the land within a priority area is determined.</li> <li>• The land purchased in advance is re-plotted and consolidated into the railway facility district.</li> </ul>  <p>(a part of priority areas)</p>  |
| 3rd stage | <ul style="list-style-type: none"> <li>• Railway facilities and public facilities are constructed.</li> <li>• Public facilities like roads and parks are constructed along with development of other buildings.</li> <li>• Comprehensive urban development is completed by the land readjustment project.</li> </ul>  <p>Completion of comprehensive urban development</p> <p>(a part of priority areas)</p>   |

Source: Kurosaki and Ogura (2013)

As the flow shows, before construction works, the public entities like local governments purchase the land in the priority area. Because of the land readjustment project, to be implemented later, it's not necessary for them to directly buy land of the railway facility district. Thus, the public sector can buy the land in advance with less difficulty. Based on the authorization of the land readjustment project, they would re-plot the purchased land to the railway facility district. In this process, the law stipulates that only the public entities like public/joint venture railways, regional governments and a public developer can re-plot the purchased land to the railway facility district.

Based on IDL, the regional governments make a fundamental regional plan for:

- (i) location of stations and routes of railways;
- (ii) development of residential areas;
- (iii) priority areas for integrated development;
- (iv) schedule for development; and
- (v) other issues necessary for integrated development.

To make this fundamental regional plan, the local governments and the railway company/companies need to cooperate. IDL also stipulates that the government, the regional governments and public entities should make efforts to develop public facilities essential for development of residential area within the stipulated priority area.

#### **Tsukuba Express (TX) Line Project**

This section investigates construction and management of TX line, where IDL was applied and comprehensive development achieved.

**Background:** Construction of the TX line had an aim to develop residential complexes in the northeastern part of Tokyo Metropolitan area, from Akihabara to Tsukuba. More specifically, it has the following four main objectives (MIR, 2011).

- (i) Improvement of the transportation network in northeastern part of Tokyo Metropolitan Area
- (ii) Easing severe passenger congestion on JR Joban and other commuting lines, which connect the centre and the northeastern part of the Tokyo Metropolitan Area

- (iii) Development of new residential areas in Tokyo Metropolitan Area
- (iv) Industrial and commercial development along the line.

Based on the above-mentioned necessities, construction planning of the TX line progressed as follows (MIR, 2017).

- July 1985: The Council for Transport Policy recognizes the need to construct a new railway line to moderate congestion of commuting trains to and from Ibaraki prefecture in Tokyo Metropolitan Area.
- June 1989: IDL passes in June and takes effect in September.
- March 1991: Metropolitan Intercity Railway Company (MIR) is set up.
- January 1992: The minister of transport grants Class 1 Railway Licence to MIR.
- October 1994: Construction of Tsukuba Express Line begins.
- August 2005: Operation of Tsukuba Express Line starts.

#### **Outline of TX Line**

Total length of the TX line operating route is 58.3 km, connecting Akihabara (Tokyo) to Tsukuba (Ibaraki). The line is operated in Tokyo (13.2 km), Saitama (7.4 km), Chiba (13.5 km) and Ibaraki (24.2 km). It has 20 stations, of which 8 are underground. Average distance between stations is 3.07 km. All trains have 6-car formation, with 900-passenger capacity per train. The train runs from end to end, between Akihabara and Tsukuba, with maximum speed of 130 km/h in 45 minutes on fastest trains. The line introduced one-person operation assisted by ATO. Functional facilities like automated platform gates, elevators, escalators and multi-functional rest rooms are installed at all stations. As the above specifications show, TX has modern rail technologies and provides passengers with comfortable and competitive commuting services against private cars.

#### **Operating Company**

When the construction process of TX started, the period of rapid population increase had ended. Thus, it was difficult for the private railway to take the financial burden of both railway construction and land development. Metropolitan Intercity Railway Company (MIR), a joint-venture company, established in March 1991, operates the TX Line. Its shareholders are Tokyo

Metropolitan government, Saitama Prefecture, Chiba Prefecture, Ibaraki Prefecture, some of their municipal governments and 196 private companies.

Similar to most other railways in Japan, as a Class 1 licensed railway, MIR owns railway infrastructure and operates independently. Thus, not only rolling stock and railway systems but also the land for infrastructure belonged to MIR after completion of construction. In overseas passenger railways, the public sector invests in rail infrastructure and vertical separation is frequently introduced for railway operation. MIR keeps an integrated structure and owns all of the railway systems, including the land for them. As MIR inherited liabilities for assets, it has been repaying them using the income through railway operation. This management system can thus be regarded to be distinct, especially as compared with many overseas passenger railways.

#### **Land Development**

For promoting coordinated regional development, IDL was applied and based on the concept of the law, Tokyo Metropolitan government and three prefectures – Saitama, Chiba and Ibaraki – reached an agreement and made a fundamental principle for the regional development along TX line. The regional governments and public entities developed land readjustment plans around the future stations and executed them.

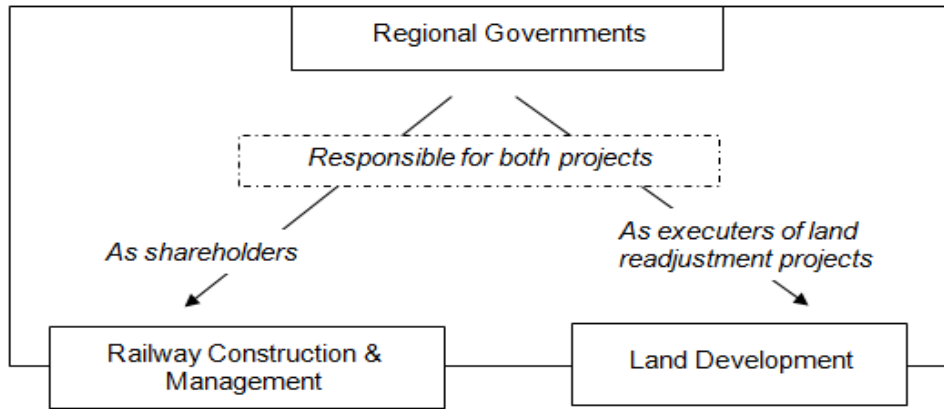
To promote the land readjustment projects, each project has its own financial account independent from their municipal account. As it could be expected that land value would increase along the line, the conditions were advantageous to reach an agreement about the land readjustment projects from the people within the district. Thus, negotiations with landowners and projects were relatively smooth, paving the way for on-schedule development. In case of the TX line, based on IDL, 20 land readjustment projects were executed especially around stations; the executed area amounted to over 3,000 hectares.

#### **The Project Scheme**

As noted above, integrated development could be attained in TX project as well. But different from the Kobayashi Ichizo model, the regional governments were responsible for construction and management of the railway company since MIR was a joint venture company mainly financed by the local governments. The regional governments were responsible for promoting land development as

executors of land readjustment projects in the region. The scheme of TX line project is shown in Figure 3.2.

**Figure 3.2: Scheme of Integrated Development in TX Project**

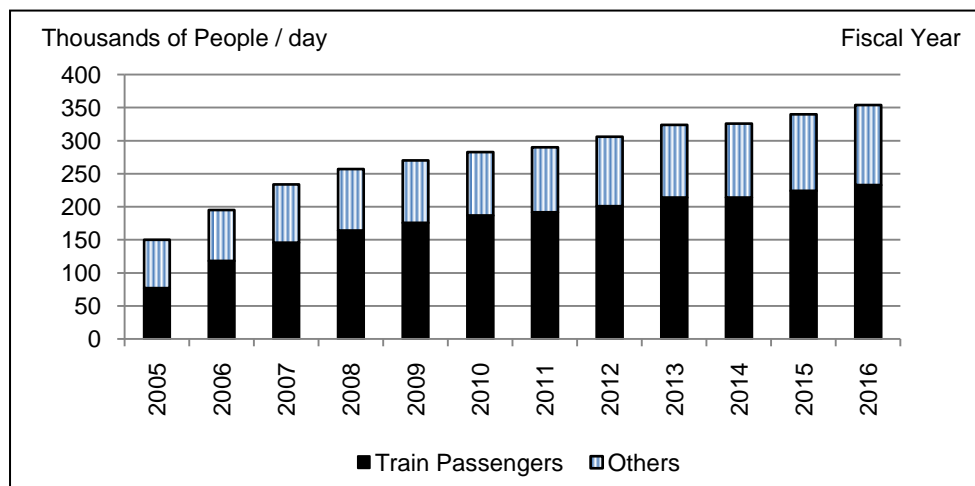


Source: Author

**Outcomes of Railway Operation**

Due to high-level of transportation services along with the regional development around the line, the number of passengers on TX line has been increasing steadily. Figure 3.3 shows the trend of daily ridership of the line since the start of its operation in August 2005.

**Figure 3.3: Trend of the Daily Ridership of TX Line**



Source: Author's revision of MIR (2017)



Along with the increase in daily passengers, the MIR management has been stable. Although the Japanese economy faced depression and conditions for the railway operation have not been favourable, as was expected originally, the outcome of MIR has been successful so far.

#### **Outcomes of Urban Development**

Due to efforts by regional governments and other public entities, purchase of land, re-plotting, and construction works have been implemented relatively smoothly. Because of some engineering works, the project was delayed by 5 years. The delay was not due to application of IDL. Although smooth coordination within a land readjustment project is required, as compared with direct purchase, it can be claimed that the land procurement and re-plotting procedures based on IDL were successful in the TX project.

The steady increase in number of passengers, based on high standard transportation services, also contributed to the favourable regional development. The regional development along the line has been promoted mainly on the basis of IDL. As apparent, disordered development could be avoided and consistent regional development was carried out based on IDL. In addition, people also enjoy inter-relationship between developed regions along the line. Establishment of new suburban cities along the railways can be regarded as one of the outcomes of the comprehensive development based on IDL as well.

Since population increase contributes to rise in taxes to the regional governments, it can be said the regional governments, which had invested into MIR, have been gaining from the external economy of TX line. They can use these taxes for developing residential areas with requisite infrastructure and public facilities. In addition, industrial and commercial activities along the rail line have also become more active since the opening of the line. Based on these outcomes, it would appear that, using IDL, the TX line project has achieved its initial objectives.

#### **INTEGRATED DEVELOPMENT DURING POPULATION DECREASE: COMPACT PLUS NETWORK**

In Japan, the period of population increase has been over, and the population has started to decline in most areas. Even in this situation, coordination between railway operation and urban development is essential both for transport operators and regional governments.

In recent years, the number of unprofitable railways has been increasing because of several factors like urban sprawl and motorization. These effects cause decrease in number of passengers and aggravate management difficulties for rail companies, in a vicious circle. Also urban sprawls increase the regional governments' expenses and decrease land value in the city-centre area, which lessens the amount of local taxes. Thus, preventing urban sprawl and revitalizing a city-centre area is required to attain sustainable management of the regional governments.

To prevent this vicious circle, integrated measures are required. The Japanese government aims to establish compact cities by integrating both transport and urban policies. To manage the financial difficulties of unprofitable passenger railways and creating compact cities, the government has enacted and revised several laws regarding public transport:

October 2007: The "Act on Revitalization and Rehabilitation of Local Public Transport Systems" was enacted. This allowed a scheme to support unprofitable public transport by entities concerned in the region.

October 2008: The Act was revised, making it possible to support unprofitable passenger railways through vertical separation.

May 2014: The Act was further revised and the "Act on Special Measures Concerning Urban Renaissance" was revised as well. The revisions meant that policies for transport and urban planning have been integrated to establish better and sustainable public transport and urban systems.

Under the current policies, the regional governments are encouraged to establish long-term plans, which cover both transport and urban planning in the region. These plans were earlier made by different divisions in many regional governments. The new Acts aim to revise the earlier status and mitigate the vicious circle by integrating transport and urban planning within each region. The concept of the current policy is named "compact plus network."

When the government admits an integrated plan, proposed by a regional government using the "Act on Revitalization and Rehabilitation of Local Public Transport Systems," it provides one-third of the investment to upgrade/replace facilities of unprofitable railways. As the current policy shows, the government and the local governments try to integrate urban planning and transport

planning under the age of population decrease. During the process, role of the regional governments is essential as they are often required to provide financial support to sustain the management of public transport, including railways.

## **DISCUSSIONS AND CONCLUSIONS**

### **Change of Stakeholders**

This paper studied that Japan has experienced different kinds of integrated development according to the change in population and showed that the concept of integrated development remained essential at every stage. On the other hand, role of public and private companies changed depending on the types of integrated development.

The private sector could lead the integrated development until 1970s during the rapid population increase and urbanization. The condition was also advantageous for railway development because road infrastructure was poor and demand for appropriate land for residential areas was high. This condition made it possible for the private sector to promote integrated development, for example, Kobayashi Ichizo model, investing both in railway system and land around the line.

Integrated development was also implemented during modest population increase since 1980s. This study showed the typical project, construction of TX line and land development around the line. Different from the Kobayashi Ichizo model, we can say, the public sector led the integrated development in the TX project since the regional governments are the major shareholders of the operating company (MIR) and also are executers of land readjustment projects along the line.

Integration of urban planning and transport planning is important even at the stage of population decrease. The Japanese government plans to establish compact cities by integrating both transport and urban policies. To attain this, role of the public sector remains important as, besides stipulating urban planning, it's necessary for the regional governments to sustain unprofitable operators, including railways in many cases.

As reviewed above, integration of urban planning and transport planning has remained essential even if the rate of population increase has changed largely in Japan. But the role of the public and private sectors changed at different stages.

Besides change in conditions and risks in large projects, the aim of the integrated development also changed. Table 5.1 summarizes the changes in the role and the background of the changes.

**Table 5.1: Roles of the Public and Private Sectors in Integrated Development and the Background of Changes**

|   | (Change of Population )                        |                  |                       |
|---|--|------------------|-----------------------|
|   | Rapid increase                                 | Gradual increase | Decrease              |
| <b>Roles of Public and Private Sectors</b>                                | Central  | →                | Supportive            |
| Role of the private sector  |  |                  |                       |
| Role of the public sector   | Supportive                                     | →                | Central               |
| <b>Background of the Changes</b>  | Relatively limited                             |                  | Large                 |
| Risk in large-scale projects  |  |                  |                       |
| Effect of the external economy of railways (e.g., increase of land value) | Large  | →                | Limited               |
| Main aim of the integrated development                                    | Provision of large volume of residential areas | →                | Making compact cities |

Source: Author's revision of Kurosaki (2015)

## CONCLUSION

This paper investigated the integrated development promoting both railway construction and land development. It's true that railways have large external economy and can raise the land value around their lines, and Japanese private rail companies could extend their network gaining revenue both from transport businesses and real estate businesses. But because of the changes like in the development of roads, it has become difficult, and too risky, for the private sector to promote integrated development, and invest both in railway construction and land development.

Similar to the recent situation in Japan, it looks the public sector should promote its essential role to boost integrated development in overseas countries as well. As the finances and abilities of the private sector are useful, it's recommended that the public sector would initiate measures to encourage the private sector to invest in parts of projects like development around stations.

Although stakeholders of an integrated development project have changed to the public sector, railway construction and land development along the line

should be coordinated for maximizing the external economy. For example, in case regional planning and development is implemented after construction of a railway line, inconsistency between railway planning and regional planning often results in problems like insufficient provision of public infrastructure and disordered regional development around stations.

To avoid such inconsistency, the regional development should be planned and carried out along with rail development. This paper highlighted the TX project promoted by IDL. Although IDL has been applied only to the TX project so far in Japan, the concept of comprehensive development can be applied to other projects as well. In particular, there are several countries where the population is increasing and the rail network is expanding to cover residential areas. In these countries, integration of railway construction and regional development is particularly essential. They should consider external economy of railways when they plan and construct railway lines. Under these circumstances, it would appear that the concept of IDL should be applied. Experiences of the TX project might be relevant to the projects. We can thus conclude that the investigation and study implemented in this research work indicated essential implications beneficial for promoting integrated development not only in Japan but also overseas.

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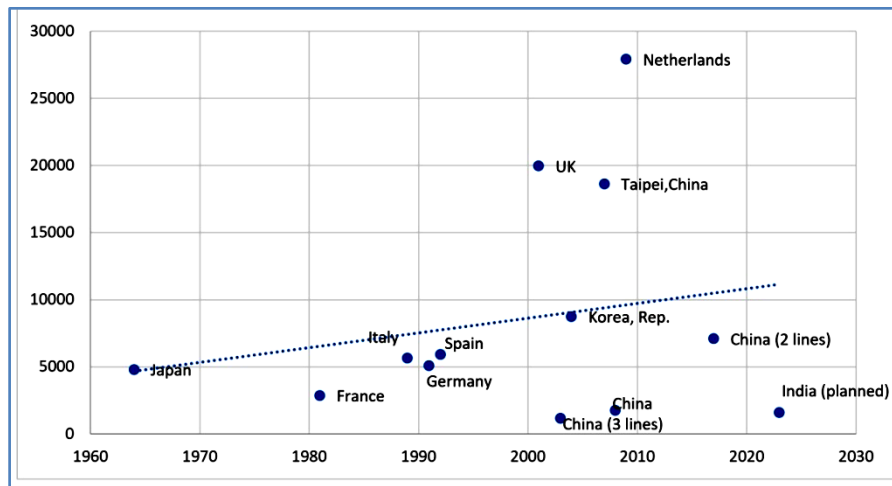
# Spill-Over and Straw Effects of HSR

K. E. Seetha Ram\* and Shreyas Bharule@

*“Introduction on the timing of HSR development, economic development (regarding GDP/per capita GDP) in countries; comparison of cost of HSR as a share of GDP.”*

The study of level of economic development of a region is vital for introduction of HSR corridor. Introduction of HSR helps commuters save time and increases value of land as the economy grows. Economic growth also demands higher level of reliability, safety and comfort, adding up to better quality of life. All HSR operating countries have experienced a rapid economic growth after introduction of high-speed rails. Experiences indicate that each nation invested in HSR when their economy was growing rapidly. The per capita gross domestic products (GDP) in the 2018-dollar terms of HSR operating countries at the time of launch of an HSR corridor are shown in Figure 1.

Figure 1: GDP Per Capita (in US \$)



Since 1964, the Tokaido Shinkansen corridor in Japan, along with major highways, has become the backbone of one of the most important regional

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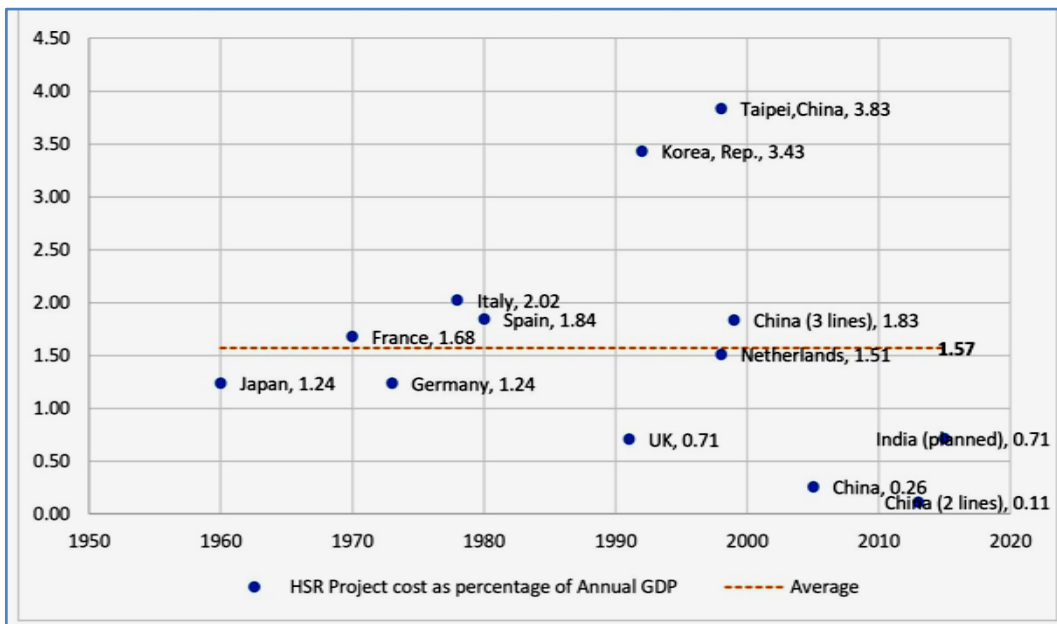
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economic belt developments in the world. The Shinkansen line’s construction started in 1960s when Japan’s GDP was \$44 billion and it stood 5th in the world. The \$548 million project cost for the Shinkansen line was about 1.24 per cent of the then Japanese GDP.

The European countries soon followed the technological advancement and started construction of HSR lines. Within four decades of the launch of the Shinkansen line in Japan, European countries like – France, Germany, Italy, Spain, the United Kingdom and the Netherlands – have opened national as well as trans-European HSR networks.

Japan’s neighbouring Asian countries, like Taipei,China and Republic of Korea, implemented HSR services aggressively and invested over 3 per cent of their respective annual GDP to build the first line. The People’s Republic of China (PRC) followed soon and today it operates the largest network in the world. Experiences from Japan, South Korea and PRC indicate that they invested in HSR when their economy was growing rapidly. Figure 2 indicates the HSR project cost invested as a percentage of the annual GDP for HSR operating countries.

Figure 2: HSR Project Cost as Percentage of Annual GDP



European and Asian cases in Figure 1 indicate that a certain amount of economic development is essential for investing in HSR infrastructure. The case of Japan and PRC suggests that decisions on execution of HSR projects were made in very early stages of economic development. The vital lesson for policymakers of countries that are planning to implement HSR projects is that timing and scope of investment in HSR is a key factor in a nation's economic development. Republic of Korea has built over 600 km, Japan over 3,000 km and PRC more than 27,000 km of HSR lines. The expected investment in the inaugural Mumbai-Ahmedabad HSR in India could be less than 1 per cent of its annual GDP (Figure 2).

There has been a growing awareness among countries about importance of thinking strategically to encourage growth and wellbeing. Lessons from the cases above suggest that investment in HSR emerges as a stepping stone towards reducing regional disparity, divides, and polarization while augmenting growth and quality of life of citizens.

#### **EFFECTS OF HSR**

HSR systems are built to reinforce accessibility and strengthen inter- as well as intra-regional relations. HSR corridors are set between pairs of cities, which bring a paradigm shift for inter-regional mobility, boosting national economy. 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, safety, comfort, punctuality and frequency of trains, which are significant in terms of increased business activity and productivity. With the increased accessibility to better markets, it's possible for businesses located in one region to explore national and international opportunities, which would previously be accessible only to businesses located in capital cities.

Several models of integrated land development and railway operation have been implemented in Japan since early 1900s. A consistent incremental improvement in the integrated land development practices has resulted in the better economic development of the cities served by the Shinkansen corridors, suggesting inter-dependence of implementation and planning process. Over time, services and industries agglomerated along the first Shinkansen corridor, established nodes with connecting transit facilities in cities like Tokyo, Nagoya and Osaka, which have emerged prominent hubs.



South Korea has followed a similar model of development but requires additional efforts in integrating regional public transport to the KTX corridors and stations to enhance revenue. With the fast mobility of KTX, a new form of national economy was born. International conferences could now be held at places other than Seoul. The added accessibility attracted almost 10,000 people to connected cities from the Seoul capital area. This population shift was unprecedented in the country's history. Integration of public transit with KTX is underway around hub stations.

The case of THSRC, an HSR 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 operations and sustainability of HSR. Reorganizing the company's operations management, improving stakeholder relationships and establishing station to city center bus services, which increased ridership, resulted in a steady revenue growth.

These cases suggest that establishing a successful HSR corridor takes over a decade, but the methods to achieve success can be different. The following section elaborates on impacts of HSR project.

#### **IMMEDIATE EFFECTS**

HSR contributes significantly in saving in travel time, comfort and safety. For 400-700 km distances, HSR is the preferred mode of travel over automobiles and planes. Since the inauguration of the first Shinkansen line, the intercity travel time has reduced by over 50 per cent in Japan. Technological innovations have helped in upgrading top speed and train cars' safety, assuring increased frequency and improving the ride quality. HSR competes with roadways and airlines, not just because of change in share but also the total travel time, including access and egress, with the added comfort and travel safety.

Safety is a central issue that challenges decision-makers during planning and implementation of HSR. Appropriate systems should be in place to ensure safe performance during operations. To contribute to capacity-building efforts in countries importing HSR technology, the role of top management in improving the safety culture of organizations is vital (Bugalia, Forthcoming).

**MEDIUM-TERM EFFECTS**

A city is a complex geographic setting with inter-linked functions. Urban life in a city is extremely intertwined, and interdependencies of networks of activities are endless. An HSR line is one such link connecting and creating important hubs through cities it connects. The effects of linking cities with an HSR in the case of Kyushu Shinkansen varied on spatiotemporal scale. The Shinkansen line construction started in 1991. It was partly operational till 2004 and in 2011 became fully operational. During construction, the land price and the property tax revenue increased in municipalities around HSR stations. But the trend around each station varied after inauguration of the line.

**IMPACT ON LOCAL ECONOMY**

HSR plays a leading mode of inter-city transport, enhancing service sector activities. HSR directly affects the service sector industries that function in the form of multi-city branch networks. Countries in Europe and East Asia are leading this trend through expansion of HSR networks.

Development of station area around the HSR station is a function of time. Station areas served by HSR emerge as new compact hubs of economic and cultural activities. Being the gateways where passengers from HSR meet, city and stations are important components not only for planning and designing an HSR project but also for creating opportunities of economic gain and enhancing the image of a city.

**IMPACT ON REGIONAL ECONOMY**

Empirical data shows successful operation and maintenance of HSR yield significant “spill-over effects”, particularly near station areas of HSR, that accrue in the medium-term. The spillover effects include increased tax revenues for local government, increased income for local business, and increase in land and property values. To systematically harvest the spillover effects, it’s important for regional (state-level) and local (municipal) governments to prepare master plans that consider the planning and operation of HSR.

Globally, HSR is considered among the most expensive and premium forms of infrastructure, but challenges and opportunities related to planning and implementation of infrastructure vary from country to country. Despite such local variations, almost all HSR-operating countries have reported a dynamic

change in various other urban systems associated with HSR within only a few years of its inauguration.

Academic studies about HSR and urban interactions suggest that, with the introduction of an HSR corridor, accessibility of HSR influence in the region is transformed over time. HSR service creates critical impacts on the existing network of service sector industries located in the HSR corridor region. The HSR cities over time gain functional specialization resulting in a constant economic growth through land development and the service sector concentration.

#### **SPILOVER AND STRAW EFFECTS OF HSR**

One important phenomenon of HSR impact can be described by the terms “spillover effect” and “straw effect.” On the one hand, HSR introduction has caused a spillover effect, wherein the peripheral hinterland has started receiving services originally located only in the metropolitan areas to which the railway now connects seamlessly. On the contrary, a straw effect occurs when prominent services located in peripheral hinterland relocate to metropolitan area after becoming connected by an HSR service. Although both effects involve multiple dimensions and span multiple time periods, they work in changing the dynamics of the HSR region. When talking about reducing the regional disparity between metropolitan areas and peripheral hinterland, these two common effects are observed the world over.

#### **HOW AND WHY SPILOVER AND STRAW EFFECTS MANIFEST**

In years immediately after inauguration of the Tokaido Shinkansen in 1964, Tokyo – the capital and economic center of the country – caused a straw effect, with most major firms relocating their branch offices there. In 1997, upon introduction of the Hokuriku Shinkansen connecting Nagano and Tokyo, Sakudaira station became an excellent example of the spillover effects caused by proximity of an HSR station. As an intermediate stop on the route, small town of Saku, by the following decade, had absorbed much urban development around the station area. These examples highlight two opportunities that HSR implementation offers to towns and cities – improvement of transportation services, and economic and urban development.

## **LESSONS FROM EXPERIENCES OF COUNTRIES OPERATING HSR SERVICES**

Across all HSR operating countries despite of introduction of HSR with the same speed, frequency and technical specifications, effects and impacts may vary. Strategy of regional and urban development is critical for generating a regional structure and a basic concept of direction of future growth. Understanding intentions and partnering with local government and other related urban development agencies is important to study while planning an HSR corridor.

The economic feasibility of the project should be in check with a vision of establishing an alternative financing system in the future. A common point is success of an HSR investment is heavily dependent on collaboration and cooperation among various public and private sector stakeholders. An efficient and incentive-oriented legal system is required to maintain collaboration and cooperation among stakeholders. Setting up a legal system also helps in formulating guidelines and policies for future development, expansion and consulting. Other important aspects associated with HSR implementation are gathering, sharing and analysis of data, which are crucial for ensuring that urban systems flourish.

An additional compelling point is that HSR is only a component of city infrastructure, and it must be tied to processes and policies that govern urban life. Development tools, like land acquisition and land readjustments, are subjected to various governance levels. A consensus among stakeholders can help in devising innovative financing method like setting up 'land banks' and monitoring development to attract investments.

The HSR project's planning and implementation needs a strong leadership. The implementing agency is expected to draw the vision for complete project while maintaining coordination among stakeholders. Without consensus amongst stakeholders, incremental policy formulation and meticulous planning, it's difficult to implement any development in urban areas. Building a consensus among all beneficiaries is a significant factor for successful HSR development.

## **CONCLUSIONS AND POLICY MESSAGES**

How to maximize potential positive effects and manage potential adverse effects.

The process for declaring an HSR system's success takes over a decade, and having a vision of the desired future development is essential. The meticulous planning of implementation procedure can also be termed an essential component of the vision. Also, since the implementation process involves multiple stakeholders, actors and steering members, engaging all of them in discussions is vital for maximizing HSR project's benefits.

In the light of maximizing positive effects, the following must be considered while implementing an HSR project:

- HSR is a key component of economic development; mobility improvement for a large population (frequency, time savings, safety and comfort)
- A region can take advantage of an HSR project not only by introduction of the project but only if it is contributing to the future growth of the connected cities. It is invariably important to set a vision and goals to be attained in a phased manner.
- HSR implementation entails planning for up to 50 years
- Cooperation, collaboration and consensus among planning bodies is essential to share and cooperate to envision and overcome issues that might arise over a long term. The planning systems must accommodate future growth while respecting legal and policy frameworks of the country.
- HSR is not limited to construction period of around 5-10 years.
- HSR is an advanced infrastructure and may pose compatibility issues with other urban settings. The construction period of an HSR corridor is an opportunity for the region to align other services with it: creating business opportunities around HSR station areas, developing innovative financing models like land value capture and improvement of city level public transit services that connect to HSR stations.
- HSR effects manifest in 20-40 year operation period.

Incremental planning of the envisioned development flow direction is most difficult. Undetermined changes in administrative systems, political support to the project, declining economy due to structural transformation, and fall in competitiveness of cities may adversely affect the whole region in long-term.

It should be emphasized that HSR generates significant impacts on the region it serves. For instance, the increased accessibility promotes investment in the region, adds to the growth of tourism, helps in expansion of the market for industries, and increases in-migration of firms and people. All these impacts add to the growth of the region and boost the local economy. HSR also changes people's travel patterns and promotes intercity competition, which are important factors in enhancing economic development of each HSR-connected city.

Thus HSR projects visibly affect its surrounding areas. The quantitative impacts cover effects related to the economy like change in industrial productivity, urban development and growth in tourism. At the same time, qualitative impacts like changes in people's lifestyles in terms of employment, education, shopping pattern and tourism have been observed. Cities and city regions getting connected by HSR require accurate information about these expected impacts to incorporate them into their land-use policies and urban development plans. Working together, stakeholders can shape win-win outcomes for an HSR project and the connected cities and city regions.

# **High Speed Rail in India: The Stepping Stone to Enhanced Mobility**

**Anjali Goyal\***

Rapid economic growth manifests itself in many ways. One of them is an increased demand for transportation. Indian GDP which has been growing at an average of around 7 per cent a year for the last decade is not an exception to this general rule. The demand for all forms of transport has therefore grown rapidly, not least for rail travel, both intra- and inter-city. While the former is being taken care of with enhanced investment in metro rail and augmented bus fleets, the latter has lagged behind considerably. Therefore, the time is both ripe and opportune for development of an ultra-fast, inter-city transport network in the country.

India today has the highest number (53) of big cities in the world, after China, and a large population with propensity to generate demand for travel – work as well as leisure. In the recent past, this burgeoning demand for travel, backed by measured policy interventions by the government, has led to rapid expansion of the civil aviation in the country.

These features can lead to deployment of high-speed rail (HSR) system, which would provide comfortable, fast and economical mode of inter-city transport. This ultra-fast and ultra-low carbon emitting transport can be a catalyst in turning highly populated and rapidly growing cities of India into powerful engines of growth. These characteristics give it an edge in commercial viability over other modes of transport.

The existence of a large number of inter-city dense sectors like Mumbai-Delhi, Mumbai-Bengaluru and Chennai-Bengaluru, offers enough scope to plan and develop a new time-sensitive mode of transport. For example, in the Delhi-Mumbai HSR corridor, a single HSR train can string as many as 14 big cities in a journey from the central business districts (CBDs) of NCR to CBDs of Mumbai

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(Belapur included) within a running time of 330 minutes. This corridor is comparable with Beijing-Shanghai HSR network.

As India lacks HSR technology to develop and acquire the advanced rail technology, a paradigm shift in approach towards transfer of technology is required. With financial closure, beginning of detailed planning and land acquisition, the Mumbai-Ahmadabad high-speed rail (HSR) project is an apt signal that the country is ready to travel in this direction.

However, as I have pointed out in my previous writings on HSR in India in order to adopt and turn HSR into an affordable public transport system, India needs a methodical approach and strategic road map on policy, cost, technology acquisition, localisation and upgradation,. The country also needs to focus on the indigenisation of the core technology platforms.

In a fast-changing world of technology, it is vital to weigh available as well as futuristic technologies before reaching a decision. Experts, as usual, agree to disagree on most issues. But debates help in ironing out differences of opinion, develop in-depth knowledge and understanding as well as throw open the door to newer possibilities.

Let us, therefore, look at the available and futuristic technologies, their various aspects – both known and unknown.

#### **HSR VERSUS MAGLEV VERSUS HYPERLOOP**

When the first international seminar on HSR for India was held in 2007, under the aegis of the railways ministry and the Asian Institute of Traffic Development (AITD), a view emerged that India should consider leapfrogging to futuristic technologies rather than binding itself to the available HSR.

At that time, China already had a commercial Maglev (magnetic levitation) line between Shanghai and Pudong Airport, capable of reaching 431 kmph, (whereas HSR was mostly being built for 250-350 kmph).

As the Mumbai-Ahmedabad project ushers in the HSR era in India, several transport experts and planners have suggested some other options for a higher speed transit system for the country such as the Hyperloop. Introduced by Elon



Musk as a revolutionary inter-city transit technology, the Hyperloop challenge is all about reducing air resistance and friction in travel modes to achieve extraordinary speeds, along with innovative ideas for cutting investment and operating costs.

There is thus a resurgence of concepts for faster passenger transit modes to be taken into account before committing to HSR. The Hyperloop technology, with its stated promise of lower cost, high energy efficiency and speed to beat even airplanes, has caught the imagination of many transport planners world over. India is no exception.

Virgin Hyperloop One has promised to build hyperloop connectivity between Pune and Mumbai. Hyperloop Transport Technologies (HTT) have signed an MoU with Andhra Pradesh to build hyperloop between Vijaywada and Amravati. The tag line, “lower cost and higher speed” poses a challenge to those planning the technology upgrade of surface transportation. Questions have been posed - should India wait before expanding its HSR initiative beyond the Mumbai-Ahmedabad HSR or plunge into hyperloop.

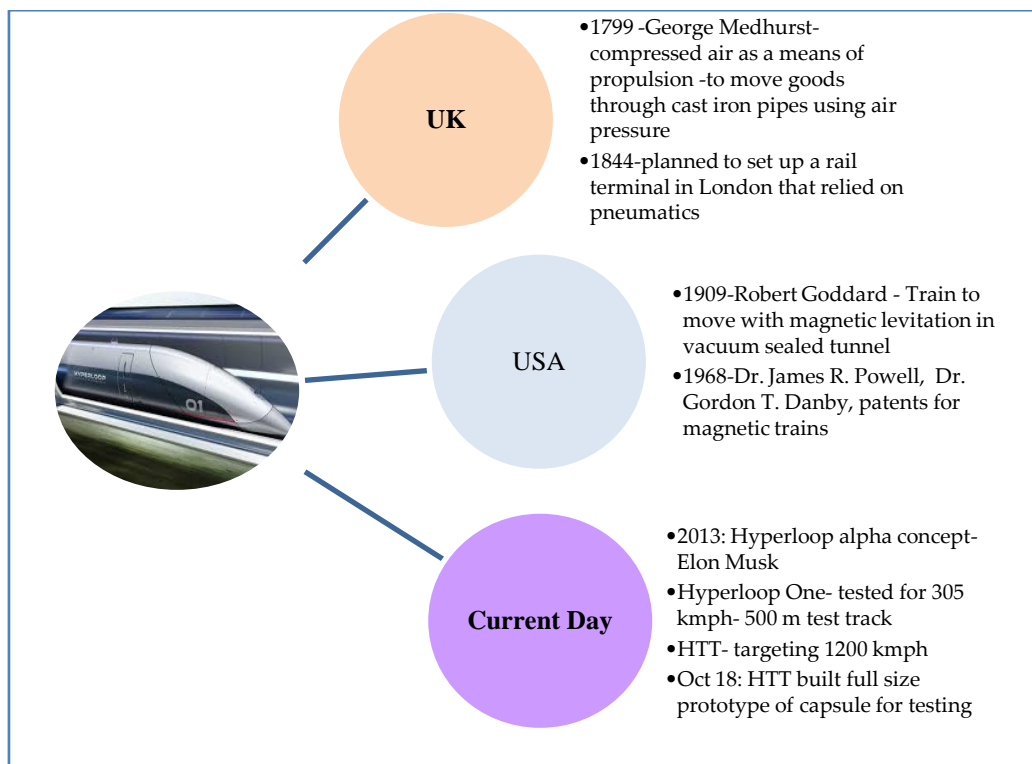
**Box 1: Timeline of Magnetic Levitation Trains – Some Milestones**

- 1968-69: James Powell and Gordon Danby designed the first Maglev train
- 1991: German government certified operation of train for public transport
- 1997: Federal parliament passed Trans-rapid Requirement Law
- 2003: Japan achieved a test run speed of 581 kmph, one year before Shanghai Maglev opened
- 2004: Shanghai Maglev line commenced commercial operation as an airport-CBD passenger connectivity line ( 30.5 km ) with a top speed of 461 kmph.
- 2013: Japan committed to build the first 286 km medium distance inter-city Maglev line between Tokyo and Nagoya; expected to open for commercial operation by 2027-2030.
- 2015: Japan achieved a top speed of 603 kmph with a 7-car Maglev train on a 43 km test track L-Zero, Yamanashi. (Shanghai Maglev route where commercial operation has been on for 14 years is shorter than the Yamanashi test track route length).

Some recent Hyperloop developments spell good news. The first full-size Hyperloop capsule, named “Quintero One” has been put on display in Spain by HTT. To build the capsule, dual layer composite material called “Vibranium” has been used. But trial runs are yet to take place. As the technology is still in the works, questions over operational safety and commercial viability had to wait.

The transition from technology ideation to viable commercial operation takes a long time for all new transport systems even in the nations with technology residency.

**Figure 1: The Ideation and Testing Timeline of Vacuum Tube Trains / Hyperloop**



Though it would be premature to make a comment on technologies that are in the process of development, some experts have expressed concerns about cost and technology for mitigating air pressure impact in the near vacuum like low-pressure tubes. They are also debating damages to the human system due to

possible leakages or failures. Also, Hyperloop is yet to cross speeds achieved by HSR and Maglev.

Compared to Maglev and Hyperloop, HSR is a technologically proven, safe and commercially viable mode of transport. Also the stated cost advantage of Hyperloop over HSR is far from evident. Investment costs per km quoted range from \$17 million to \$40 million. The carrying capacity of Hyperloop appears to be less than HSR. A US feasibility study states that Hyperloop can carry 840-3,360 passengers per hour against 12,000 per hour by HSR. Addition of more tubes to accommodate passengers would lead to higher cost.

Though India is yet to obtain HSR technology for indigenisation and localisation, but with proven credentials of developing space and satellite technology, involving PSLV and GSLV systems, the country can well emerge as a dark horse in HSR or Maglev or even Hyperloop technology systems and product development. It can rival China in driving down HSR costs for its domestic network.

The World Bank has rated HSR of China, built through aggressive localisation and standardisation of designs and manufacturing, as the most economical.

The apprehensions on the cost of HSR must be confronted through public debates. Few in India realise that it's not more expensive than a top quality expressway. Thus, the cost of the recently completed nine km section of the 14-lane expressway between Delhi and Meerut is about \$14 million per km. The completed cost of 6-lane Noida-Agra Expressway was reported as \$14 million per km. In contrast, the Chinese HSR per km cost is \$17-21 million per km.

#### **STRATEGIES ON TECHNOLOGY**

Public sector supported R&D and innovation has thrived in countries with advanced rail technology. In the 1990s, when Japan and Germany demonstrated their ability to introduce Maglev, the US administration dallied with funding research on making Maglev a reality. In 1992, Senator Moynihan argued on the need to catch up on the technology to avoid a situation where USA would end up buying it, despite having patents and original research on shore.

The countries that are active in research in advanced rail technology with public sector-supported R&D have come forward to maintain their foothold on developments taking place in the hyperloop technology. China has taken a strategic stand. Its state PSUs are investing US\$ 1 billion in Arrivo and US\$ 300 million in HTT.

If we study the history of HSR in China, its confidence rests on its R&D and innovation successes. From a newcomer in 2006, China has raced ahead to establish world's largest HSR network of over 20,000 km (and growing) with complete indigenization on the strength of its R&D institutions, research centres and public funding. China has strategically offered its country for hyperloop testing with the added promise of running trains on the One Belt One Road routes. The China Aerospace Science and Industry Corporation (CASIC) has announced plans to take hyperloop speeds to 4000 kmph, and export these trains to countries investing in the OBOR. A controlling stake in hyperloop start-ups will pave the way for eventual indigenization of the technology in China, to lower costs.

When India is on the verge of framing strategies on absorbing and assimilating HSR technology, the social actors like government departments and policymakers need to be conscious of the messages they could be sending out. Mixed signals could act as a hurdle in active participation of industry and R&D institutions. The country needs to wake up and review technology transfer and absorption strategies, if it wants to catch-up with the world in the high-speed transport infrastructure like HSR, Maglev and Hyperloop.

Susana Martins Moretto's case study suggests manufacturers in the HSR supply chain have deployed constructive technology assessment (CTA) as a strategic intelligence tool, reflecting societal embedding in technology development. It was further backed by various EU legislations, which forced manufacturers to use techniques like CTA to improve competitiveness and performance, and match customer expectations. This helps to mitigate market failure and in fructuous investment.

To be among the advance high-speed transport technology developer nation, India needs to prepare a domestic strategy, the earliest, and think and act like a strategic buyer of HSR (or Maglev or other inter-city high speed surface

transportation technologies). It should be pro-active and develop a 'benign technology transfer' policy. By benign technology transfer, I mean, joint development and avoiding partners competing with each other. Here is a suggested road map for developing such a strategy.

#### ROADMAP ON HSR TECHNOLOGY

***Building an ecosystem:*** The country must build the capacity to absorb and assimilate latest know-how. To absorb the tech knowledge, it must develop and strengthen ecosystem of scientists, engineers, faculty, students, interns, researchers and technicians across the vast network of IITs and NITs. Designs, drawings and technologies have to be shared across the ecosystem to foster organisational learning. Knowledge of atomised technology platforms will require large teams of scientists, who would specialise in understanding system integration, body shell designs and material components, traction control, network control and track systems.

***Nurturing R&D appetite:*** India has a vast pool of engineers and researchers – alumni of 16 IITs, 31 NITs and institutions like Indian Institute of Sciences and other elite tech universities. The standards and recruitment processes of IITs, IISc and NITs are no less rigorous than Gaokao national entrance examination of China, CSAT Entrance Exam of South Korea, Concours of Grande Écoles of France or the selection process of Russell's Group of Universities in the UK or the Ivy League and their rival prestigious universities like MIT and Stanford of the US.

To use and encourage this rich crop of the finest and internationally recognised talents, a talent corral should be created, which will absorb and innovate advanced rail technologies and compete with others in lowering cost.

Metro Rail encouraged development of many top quality construction firms, but the number is insufficient to meet India's requirements. They are also reluctant to acquire international skills through M&As with companies that have rich experience in advance rail infrastructure projects.

Another problem that afflicts capable and competitive enterprises as well as human resources is their inability to nurture talent. They should offer opportunities to young talents through attractive project-oriented internships, a

norm in techno-savvy and prospering societies. Like Japanese, German, Korean, French, US companies, Indian firms too should offer attractive internships to achieve project-oriented nationally beneficial outcomes. Integration between industry and academia, which could encourage innovation, is also almost missing.

***Tech procurement contracts:*** For contracts where technology transfer is involved, procurement procedures and policies must be drafted in a manner that controversies are avoided and tech transfer absorption with desired cost-efficient outcomes are achieved in a smooth manner. At present, even the most complex defence contracts are governed by the same autoschediastic purchase procedures as applicable for buying office stationery.

***Strategic negotiations:*** HSR and Maglev can be expensive. While negotiating transfer of technology and seeking to expand the in-house know-how, India has to project its capability of cheaper manufacturing costs and demonstrate benefits of a large domestic market. The terms and conditions of engagement while procuring HSR should be for joint design and product manufacturing with commitment to develop local brands. The custodians of original technologies continue to improve their products.

It should not take too long for India to come up with innovations required to weave in advance technologies for perfect harmony with the domestic conditions. This can result in increased use of locally available high quality resources to lower cost of advance technology transport systems like HSR, Maglev or Hyperloop.

***Institutional backbone:*** Strategic negotiations, absorbing technology, disseminating knowledge in academic institutions to foster future growth and well informed decision-making will all require a revisit of the institutions involved in HSR development. A framework is suggested below:

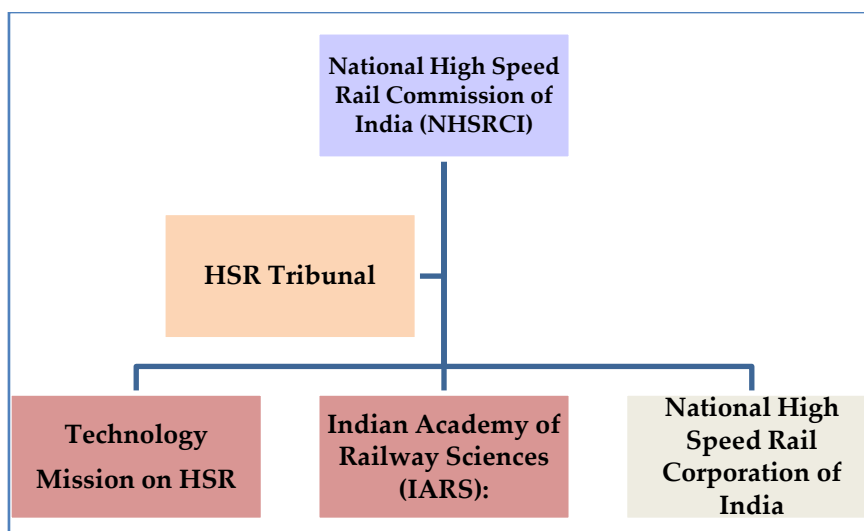
A National High Speed Rail Commission of India (NHSRCI) which will:

- (i) Draft a national high speed rail policy for approval by Parliament. Necessary for public acceptability, avoiding disputes on alignment,

economically rational decision-making, etc., without burdening public exchequer.

- (ii) Oversee acquisition of complete transfer of HSR technology from drawings, design and metallurgy to manufacturing, preventive maintenance and routine maintenance practices.
- (iii) Develop safety, operational and technical standards for HSR in India – track, rolling stock, vehicle control systems, signalling, passenger comfort, noise and vibration levels, etc.
- (iv) Decide on vendor development policies
- (v) Function as the national regulator for HSR and future technologies like Maglev and Vacuum Tube Trains or Pods.
- (vi) Draft special procurement contracts for transfer of technology, settle terms of engagement with domestic manufacturing entities, with non-disclosure conditions for selected private vendors.
- (vii) Select mentors for R&D and sharing technical knowhow across academia.

This body will be multi-ministry and multi-disciplinary with support of national and international experts.



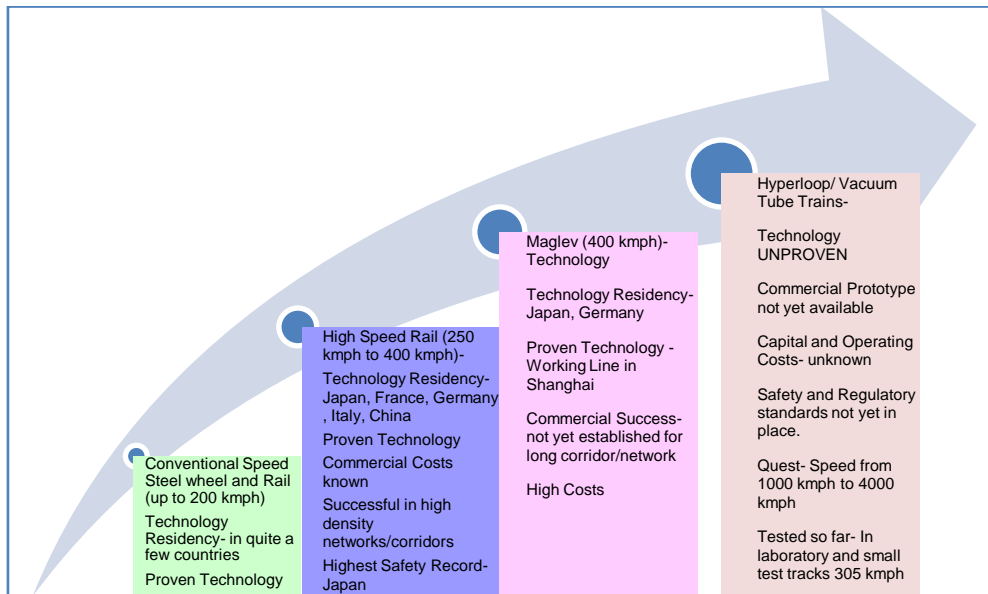
***A technology mission on HSR:*** A multi-ministerial body involving Ministry of Urban Development, Ministry of Railways, Ministry of Finance, Ministry of Commerce and Industry (DIPP), Department of Science and Technology, Department of Space, DRDO, etc., under the aegis, say, of NITI. The Mission is to be tasked to set up technology development platforms in collaboration with R&D centres in Indian Institute of Science, IITs, NITs and leading engineering colleges and manufacturing sector industries, which are willing to commit to complete localization of the HSR technology in India.

This cannot be left to market forces alone. Intensive mentoring and project specific internship in HSR industries, of IIT and NIT students under direct supervision of scientists, researchers and professors of science and technology is required in a mission mode. The target has to be an in-depth study and assimilation of technology platform of every aspect of the ART - the body design, the track resilience features, chemical processes of rail and steel structures, curing processes, traction and braking systems, system integration of all parts of the vehicle guidance and control systems, among others.

***National High Speed Rail Corporation of India:*** NHSRC will be in charge of project implementation and will function under the policy guidance and oversight of National HSR Commission. The NHSRC can outsource the programme management to internationally reputed programme management companies which have been associated with similar management of HSR and Maglev projects. The HSR Tribunal will resolve disputes in regard to procurement actions and conducting forensic audit of procurement activities and matters relating to technology transfer and all patent-related matters, on a fast track mode.

***Indian Academy of Railway Sciences (IARS):*** To set up and nurture dedicated R&D centres, testing facilities and HSR innovations. It will manage the test bed/test track as a multi-use facility, which could also earn revenues from testing metro coaches and other standard gauge rolling stock even for international companies. It will work in close collaboration with Technology Mission on HSR and report to National High Speed Rail Commission of India.





## WAY FORWARD

It's given that India needs high-speed transport system(s). What is required is to take an informed decision on the technology, which could serve as backbone for the next generation high speed network.

In the initial phase, technology outsourcing is critical for the long-term success of developing high speed networks. To inspire confidence in the technology partners, it is necessary to protect their intellectual property rights, patents and business interests.

The country also needs to develop a scientific temper, talent pool and perseverance to pursue absorption of outsourced technology as well as capability to innovate and create new technology platforms. Equally necessary is the development of an institutional framework that would promote outsourcing of relevant technologies and establish safety, operational and technical standards. This would include launching of technology mission and establishing a multi-disciplinary, multi-ministerial body.

The scope is huge, so are challenges. A nimble-footed strategic policy framework can go a long way in meeting various requirements of existing as well as emerging technologies and propel India's growth as a powerhouse in the field of newer technologies.

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