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UNDERSTANDING THE URBANIZATION IMPACTS OF HIGH-SPEED RAIL IN CHINA

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Abstract:

Advances in transport technology have been shown to play a vital role in urban development over millennia. From the engineering and pavement innovations of the Roman road network to the aerospace breakthroughs that enabled jet aircraft, cities have been reshaped by the mobility changes resulting from new designs for moving people and goods. This article explores the urbanization impacts of High-Speed Rail's introduction in China, which has built the world's largest High-Speed Rail network in record time. Since High-Speed Rail was launched in Japan in 1964, this technology has worked to reshape intercity travel as a revolutionary transportation alternative. High-Speed Rail has developed steadily across Japan, France, Germany, Italy, Switzerland during the 1970s and 1980s. It expanded to Russia, Spain, the United Kingdom, and Sweden in the 1990s. In the 21st century, China began developing High-Speed Rail on an unprecedented scale, and now has a national network that is longer than the totality of the rest of the world's High-Speed Rail operations combined. China's High-Speed Rail operation is exerting a transformative influence on urban form and function. This article synthesizes secondary research results to analyse the impacts of HSR on urbanization. These effects include population redistribution, urban spatial expansion and industrial development. We offer a typology that considers the urban effects of High-Speed Rail at three spatial levels: the station area, the urban jurisdiction, and the regional agglomeration. When organized through our typology, research findings demonstrate that High-Speed Rail influences urban population size, urban spatial layout and industrial development by changing the accessibility of cities. We highlight the processes by which High-Speed Rail ultimately affects the urbanization process for people, land use, and industrial development. However, High-Speed Rail's impacts on urbanization are not always positive. While leveraging the development opportunity enabled by High-Speed Rail, governments around the world should also avoid potential negative impacts by drawing lessons from the experience of High-Speed Rail's rapid deployment in China.

Keywords: *high-speed rail, China, urbanization, population, land; industry*

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1. Introduction

Urbanization is a multifaceted process, encompassing three interdependent dynamics that are each enabled by transportation. First, rural populations take advantage of transport capacity to migrate to urban areas, thus fuelling urbanization. Next, rural areas get transformed as cities expand their spatial footprint, and build urban mobility infrastructure in what was previously undeveloped land. And finally, the share of non-agricultural economic output grows in and around cities, facilitated by the mobility means that support supply chains and the face to face interaction of high value added services. Over the long run, the trajectory of a city's urban development is thus highly influenced by its position within a transport network, especially its relationship to, or function as, a transport hub (Banister and Berechman, 2000). An improved transport network can accelerate the flow of production factors (labour, capital, technology) between regions, enable enterprises to develop new markets, reduce the cost of production, and expand regional trade (Wessel, 2019; Deng et al, 2014). And at the micro-level, transport infrastructure can influence the layout of urban development by intensifying land use and function around nodes in the network (e.g., airports and train stations) (Díez‐Pisonero, 2019).

High-speed rail's (HSR) rapid expansion in China thus offers an opportunity to explore the impacts of this transport mode on urban development. Economic geography provides tools and techniques to reveal how these new transport services can influence location decisions (Krugman, 1991; Krugman and Venables, 1995). China's HSR development stands in a class by itself among this mode's global history which began in 1964, with Japan's launch of the Shinkansen. As of 2018, HSR operates in 16 countries, and is under construction or planning in more than 20 countries (see Table 1 for global HSR development highlights). HSR's advantages such as central city access and travel times equal to or faster than aviation for journeys of up to 500 miles, have yielded demonstrable urban impacts. Studies have revealed urban impacts that include: improved levels accessibility (Cao et al., 2013); increased urban housing values (Wu et al., 2020; Zheng and Kahn, 2013; Diao et al., 2016); expanding tourism (Gao et al., 2019), and, accelerating regional economic growth (Jia et al., 2017).

However, while the positive economic effects of HSR on cities have been widely appreciated, its negative effects should not be ignored. One such effect is the instigation of zero-sum economic competition between cities. Vickerman (2015) found that the build out of European HSR networks did not improve accessibility evenly across the network. The main beneficiaries from HSR turned out to be cities with previously established accessibility advantages. While HSR increases the population in these favored cities, it can also facilitate population loss in other places, thus aggravating the phenomenon of imbalanced regional development (Deng et al., 2018).

Another problematic result from HSR development is the sprawl that has been generated in second-tier and third-tier urban regions across China. Many of these cities have chosen to build HSR stations in a peripheral location, aiming to expand and intensify suburban development. However, suburban redevelopment has proven to be slow and incomplete. In some cases, large amounts of agricultural land have been expropriated to build new towns centred around HSR.

The development effects associated with HSR have attracted attention from both academia and governments around the world, e.g. Germany (Heuermann and Schmieder, 2019), France (Crozet, 2013), United Kingdom (Brunello, 2018), Poland (Mikulski and Gorzelak, 2017), Spain (Monzon et al., 2019), China (Jia et al., 2017), and India (Verma et al., 2013). Previous impact assessment has been conducted at multiple scales including the regional level (Chen and Haynes, 2017; Brunello, 2018), the urban level (Deng and Wang, 2018) and the station area (Li and Huang, 2020). These studies typically adopt a singular assessment focus, e.g., accessibility changes (Wang, L. et al., 2019; Jiao et al., 2014; Shaw et al., 2014), population mobility (Wang, F. et al., 2019), economic growth (Li et al., 2018), land use change (Long et al., 2018), and industrial agglomeration (Deng et al., 2017). However, population, land use and industrial agglomeration, are inter-related dimensions of urbanization Therefore, a multi-level analysis is required in order to obtain a full understanding of the relationship between HSR and urbanization.

The development influences of HSR can be seen more clearly if they are examined at three spatial scales: regional, urban, and the station area. These three levels are interrelated and combine to influence urban development. At the station area, HSR accessibility can directly influence the surrounding land uses, and expand the scope of that area's influence by increasing the accessibility of development there compared to the rest of the city. At the urban level, HSR tends to reshape spatial layout by focusing urban population and enterprise distribution around station areas. And at the regional level, HSR can transform the connectivity and accessibility among different cities across a region, thus reshaping that region's economic geography.

Relationships between the three spatial dimensions of HSR impact are shown in Figure 1 below. First, the implementation of HSR has greatly shortened the time required to travel between cities and improved the accessibility of those cities served by HSR. Second, the implementation of HSR has contributed to the expansion of urban space and affected urban spatial restructuring through farmland being consumed by urban development. Third, the HSR affects industrial location and industrial structure by promoting an agglomeration of economic activities in the cities served by HSR.

In the following sections, we will integrate findings on the urbanization impacts of HSR at each level of scale (station area, urban, and regional levels), thus providing a solid foundation for further efforts at holistic analysis. A synopsis of these effects on population distribution, spatial configuration, and land development is presented in Table 2, Table 3 and Table 4, with the supporting secondary research identified for easy reference. Once we have examined each of these impacts in Sections 2, 3 and 4, we then discuss the positive and negative effects of HSR on urbanization in Section 5 and go on to consider how decision makers could improve on the mix of future outcomes in Section 6.

2. HSR Impacts on urban population

As a high speed and high capacity mode of inter-city transport, the immediate effect of HSR is to shorten the travel time between cities, thus reducing travel costs especially for those who value their time highly (Shaw et al., 2014). One consequence of urban economic development is to increase the value of time for travellers, who have growing incomes (Wang et al., 2012). Where HSR gains a significant share of the intercity passenger travel market, it exerts an important influence on population migration, business travel, and other activities. Compared with short-haul air transport, HSR offers a high punctuality rate and relatively low cost, leading to high market share in short-to-medium distance markets (Kamga, 2015; Wan et al., 2016; Chai et al., 2018； Zhang et al., 2017). The introduction of HSR has been shown to stimulate travel demand (Givoni and Dobruszkes, 2013), and thus greater use of mobility is often induced (Ren et al., 2019). The lower time cost created by HSR will tend to accelerate population mobility, thus increasing urban size by bringing more people to and from the city.

Table 1. Parameters of the World top five high speed lines (UIC, 2019)

Operation date			Distance		
Country	**Max. Speed (km/h)**	**Date**	**Country**	**Distance (km)**	**Under construction (km)**
Japan	285	1964	China	31,043	7207
Italy	250	1977	Japan	3,041	402
France	300	1981	Spain	2,852	904
Austria	200	1990	France	2,734	-
Germany	280	1991	Germany	1,571	147

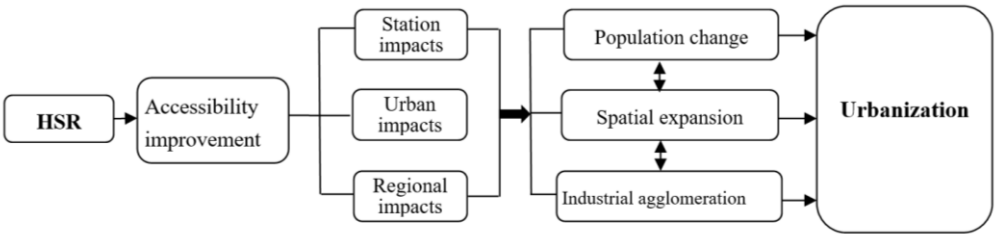

Fig.1. Relationship between HSR mobility and urbanization

Table 2. Effects of HSR implementation on population, urban expansion, and urban development (population effects).

HSR Location	Population effects	Source
China	HSR dramatically shortens the travel time between cities, reducing travel costs for travelers with a high value of time.	Shaw et al. (2014)
Multiple locations	The introduction of HSR has been shown to stimulate travel demand.	Givoni and Dobruszkes (2013)
China	The national network of HSR in China has increased urban passenger flows by 10% and employment by 7%.	Lin (2017)
Spain	HSR has stimulated interregional labor mobility. It can promote migration toward areas with greater job opportunities, especially when there is an inter-regional difference in the unemployment rate.	Guirao et al. (2018)
China	The mobility growth among the core nodes of HSR networks can have adverse effects on marginal areas and may even produce polarization effects by siphoning people and jobs away to core nodes.	Xu and Sun (2020)
South Korea	After HSR opened between Seoul and Busan, the population (density and total amount) concentrated in and around Seoul, rather than other communities along the HSR line.	Kim and Sultana (2015)
Japan	Japan's HSR increased the productivity in regional centres within 200 km of Japan's mega cities, but without a siphoning effect from the economic activity in those large urban centres. HSR did not solve Japan's social and spatial challenges from excessive concentration of population and economic activities.	Wetwitoo and Kato (2017)
Japan	HSR has not dispersed Japan's population and economic activities to smaller communities along its route. The effect of new HSR on promoting concentration of population into large cities or diffusion of economic activities to smaller communities may depend on the structure of urban networks that are being linked by HSR.	Cheng et al. (2015)

Table 3. Effects of HSR implementation on population, urban expansion, and urban development (development effects).

HSR Location	Development effects	Source
Netherlands	HSR has a demonstrated impact on the development of tertiary industry, including the service sector, through facilitating passenger travel. A high level of accessibility makes a location more attractive for commercial office development.	Willigers and van Wee (2011)
China	HSR introduction was positively correlated with the agglomeration of industries surrounding station areas.	Wang et al. (2017)
China	The level of industrial agglomeration in cities served by HSR has increased faster than comparable cities without HSR.	Pan et al. (2020) Deng et al. (2017)
China	HSR has demonstrated a great impact on office location selection for automotive industry start-up firms in Guangdong Province, China.	Xiao et al. (2020)
France	HSR can promote the growth of employment in tertiary service sector at a greater rate than retail, trade or manufacturing sectors by facilitating the free	Charnoz et al. (2018)

	flow of knowledge workers and the accumulation of corporate headquarters in station areas along in routes.	
Spain & England	HSR can encourage large cities to pursue a more decentralized development strategy by linking economic activity among multiple locations.	Garmendia et al. (2012)
Spain	HSR can promote the development of some specific industries, especially the service sector.	Campa et al. (2016)
Italy	HSR has a positive impact on the development of regional tourism.	Pagliara et al. (2017)
China	HSR played a significant role in promoting producer service industry agglomeration along its routes through the Yangtze River Delta, while the consumer and public service sectors did not experience greater agglomeration.	Shao et al. (2017)

Table 4. Effects of HSR implementation on population, urban expansion, and urban development (spatial effects).

HSR Location	Spatial effects	Source
China	In Beijing, the impact of a HSR station on house prices did not stand out when other factors were controlled for.	Geng et al. (2015)
Spain	In Madrid, differences in land use around HSR Atocha railway station show that travel time savings have a significant stimulus on urbanization.	Shen et al. (2014)
Multiple locations	When population is growing, land close to the HSR station becomes attractive for residential development. At the same time, land adjacent to the road network becomes more attractive for industrial development because of its relatively lower price.	Kasraian et al. (2016)
China	The introduction of HSR has the potential to reshape urban spatial structure by optimizing the flow of production factors, thus leading to physical expansion of the urban area.	Long et al. (2018)
Spain & France	HSR not only changes the development dynamics of newly served areas, but also works to intensify development in the urban centre affecting the spatial dynamics of the entire city	Ureña et al. (2009)
Spain & England	Peripheral HSR stations strengthen the integration effects of HSR on the metropolitan area as a whole. Over time this distributed development around HSR stations, can lead to a multi-polar urban spatial layout.	Garmendia et al. (2012)
China	An unmanaged stimulus of opening HSR stations in suburbs can lead to empty station areas that await future development, resulting in a waste of agricultural land and triggering a series of social problems, such as employment loss and social insecurity among landless farmers.	Yue et al. (2016)
China	HSR implementation has intensified China's urban sprawl.	Deng and Wang (2018)
India	The reduced travel times enabled by HSR stimulate travel volume, promote the development of trade, logistics and other industries, and eventually help to shape an interconnected metropolitan network structure.	Verma et al. (2013)
France	The TGV has created a HSR mobility network centered on Paris and radiating out to French cities and surrounding countries. The HSR system is regarded as an important factor in promoting European integration	Stephenson (2010)

HSR's ability to boost population agglomeration is fits directly into Krugman's (1991) two-sector theory of urban economic development. Here, the return to scale from agriculture remains constant and overall output is only determined by endogenous land supply. But in the manufacturing sector, economic growth works differently. When transport costs go down, labour mobility increases the market size in growing cities. Manufacturers are then be drawn to produce in regions with a growing population, and correspondingly greater demand for manufactured goods. Manufactured products will tend to cost less in these growing urban regions, in part because of lower delivery costs from nearby production sites. When wages are the same, lower prices of industrial goods raise people's purchasing power and encourage further concentration in the places near production. These effects have a cyclical and cumulative effect, in which manufacturing tends to be concentrated close to large markets, and large markets lead to further economic concentration.

The service sector typically expands following industrialization in the dynamics of economic development. Compared with the manufacturing industry, the service industry has the characteristics of short-lived output that cannot be stored, and simultaneous production and consumption. Therefore, among the factors that influence service industry development, travel time replaces the geographical distance as a key factor influencing the location of service providers. Areas with high accessibility from transport infrastructure are typically preferred locations for the service sector. The introduction of HSR thus creates an important stimulus for service industry agglomeration.

The opening of HSR can also reduce migration costs, expanding the scope and scale of labour market opportunities. Over time, labour moves to areas with higher wages and lower living costs. By expanding both the size of markets and workforce opportunities, HSR intensifies the growth of cities. This includes the labour market for talent in services. The development of an urban service sector needs a large highly skilled workforce. On the one hand, the opening of HSR has promoted the development of an urban service sector and expanded the demand for skilled labour. On the other hand, the opening of HSR has accelerated the flow of population, prompting rural population to move to cities in search of better employment opportunities.

This stimulus of the labour market has created more jobs and lowered the unemployment rate. Guirao et al. (2018), believe that when there is an inter-regional difference in the unemployment rate, the improvement of transport infrastructure can promote labour mobility toward areas with more job opportunities. Under the dual influences of both higher wage levels and lower unemployment rates, population agglomeration in cities is thus promoted. Previous studies have shown how the introduction of HSR stimulates migration and increases urban population over time. HSR's effects on population accumulate at each of the three spatial scales influencing urbanization: the station area-level; the city level; and, the regional level. Around the station area, HSR delivers and collects a large number of passengers, with the HSR station functioning as a hub for multiple modes. This travel flow, including the connection between local and intercity mobility, makes the HSR station a desirable focus for urban development. At the urban level, HSR can accelerate the population flow between cities and expand the scale of a city's floating population, i.e., those who live as some distance but are economically connected to the city. For example, using the Difference-in-Differences (DID) method Lin (2017) found that the opening of HSR in China has increased urban passenger flows by 10% and employment by 7%.

And at the regional level, the reduction of travel time expands labour mobility, which means that a larger labour market can extend well beyond the city (Shi et al., 2020). Using panel data of Spanish interregional labour mobility (2002-2014), Guirao et al., (2018) confirmed that HSR has an important impact on interregional labour mobility. In sum, at all three scales, HSR accelerates the increase of the number and productivity of population in and around cities.

While HSR speeds up the flow of people in and out of cities, it also contributes to a non-equilibrium in "time and space convergence", by bringing distant places closer together in terms of the travel time between them. Xu and Sun (2020) have shown that mobility growth among the core nodes of HSR networks, especially central cities, can have adverse effects on marginal areas, and may even produce polarization effects. Labour migration from lower wage regions to higher wage cities creates simultaneous challenges of keeping up with increasing population in some cities, while coping with the problem of depopulation in smaller communities. Using population and employment data, Kim and Sultana (2015) observed spatial changes in population and employment in various regions after HSR opened on the Korean peninsula between Seoul and Busan. They found that the population (density and total amount) concentrated in and around Seoul, rather than other communities along the HSR line. Wetwitoo and Kato (2017), evaluated the impact of the Japanese Shinkansen on economic activity, finding that Japan's HSR increased the productivity in regional centres within 200 kilometres of Japan's mega cities, but without a siphoning effect from the economic activity in those urban centres. Thus, HSR did not solve Japan's problem of excessive concentration of population and economic activities. The Shinkansen has not effectively dispersed Japan's population and economic activities to smaller communities along its route. These findings suggest that whether a new

HSR line promotes further concentration of population into large cities or works to spread economic activities to smaller communities may depend on the urban structure (Cheng et al., 2015), which we consider in the following section.

3. HSR impacts on urban expansion

3.1. Land use around the HSR station area

HSR can increase the accessibility advantages of the space that surrounds railway stations, therefore a HSR station area often attracts more capital, technology and skilled labour than other urban spaces. The HSR station exhibits a rapid assembly and dispersal of people coinciding with the arrival and departure of trains which offer rapid circulation across large areas. As a result, the flow of people in and around the HSR area is both spatially and temporally dynamic. This sizable floating population increases the demand for services, such as catering and accommodation. Thus, the creation of a HSR station and supporting service sector activities increases the demand for land and can create new commercial centres.

Several studies have analyzed land use patterns around HSR stations. In Beijing, for example, Geng et al. (2015), found that the impact of a HSR station on house prices did not stand out, when other factors were controlled for. But Shen et al. (2014), examined the land use within a 20 kilometre radius of the Atocha railway station in central Madrid, Spain. They found that travel time saving has a significant stimulus on urbanization. These contrasting findings suggest that the ways in which HSR is implemented can affect the subsequent land uses around its station. When population is growing, land close to the HSR station becomes attractive for residential development. At the same time, land adjacent to the road network becomes more attractive for industrial development because of its relatively lower price (Kasraian et al., 2016).

3.2. The urban development impact of HSR

In order to stimulate the economic development, many growing cities tend to locate HSR stations on the edge of town or in outer suburbs. There are two reasons that could explain this. First, land acquisition costs in the city centre are much higher than that in the suburban areas, thus limiting the range of economic activities that can be viable in the established core. Second, with proper planning, newly built suburban HSR stations in the areas may evolve into an additional economic growth node beyond the core, thus further stimulating development of the overall urban economy. Long et al. (2018), suggest that the introduction of HSR has the potential to reshape urban spatial structure and optimize the flow path of production factors, thus leading to physical expansion of the city. Over the long run, locating the HSR station in the suburbs and proper planning of station area development could encourage a multicentric development of the city. HSR not only changes the development dynamics of newly created areas, but also works to redevelop and intensify the urban core (Ureña et al., 2009), affecting the spatial dynamics of the whole city. Some local governments plan HSR stations to become future sub-centres, hopping that urban development will cluster around the new HSR station. Peripheral HSR stations strengthen the integration of HSR with the larger metropolitan area (Garmendia et al., 2012). Over time this distributed development of HSR stations, can lead to a multi-polar urban spatial layout.

However, locating HSR stations in the suburbs is not without risk. If local governments overestimate the development stimulus of HSR, this can lead to empty station areas that await future development. This rapid increase in empty urban space, or vacant development, results in a waste of previously cultivated agricultural land and can trigger a series of social problems, such as employment loss and social insecurity among landless farmers (Yue et al., 2016). Deng and Wang (2018) present evidence that the rate of physical expansion in Chinese cities has often exceeded the population growth rate, concluding that HSR implementation has intensified China's urban sprawl.

3.3. The regional development impact of HSR

The reduced travel times enabled by HSR tend to stimulate travel volume, promote the development of trade, logistics and other industries, and eventually help to shape a unique and interconnected metropolitan network structure (Verma et al., 2013). For example, the TGV in France has created a high-speed mobility network centred on Paris and radiating out to French cities and surrounding countries. The HSR system is regarded as an important factor in promoting European integration (Stephenson, 2010).

French experience shows how stations in the HSR network may gradually develop from serving just a single mode into a hub that becomes an important multimodal transfer centre. Local public transport systems support connections that enable HSR to meet mobility needs beyond the city and across the metropolitan area. The city's formal political boundary becomes gradually blurred and the region exhibits an increasing level of integration. However, HSR may concentrate regional advantages within the larger agglomeration for cities served by HSR and when this yields differential rates of accessibility for economic activities, the result can be uneven rates of regional development (Weilenmann et al.,2017).

4. HSR impacts on urban industrial development

The effect of HSR improvements on industrial development mainly depend on the transport costs of particular products. The higher this share of transport costs, the more influence that HSR could exert by, for example, augmenting the capacity of pre-existing infrastructure by attracting travel away from other modes and thus lowering shipping costs by conventional rail and road. HSR also has a significant impact on the development of tertiary industry, including the service sector, through its facilitation of passenger travel. A high level of accessibility makes a location more attractive for business offices (Willigers and Van Wee, 2011). Glaeser and Kohlhase (2004) suggest that manufacturing industry should be located in regions with low population density, while service sector workplaces should be located in regions with high population density and should be well connected with both suppliers and customers. The development of tertiary industry increases the demand for high-skilled labour. And the opening of the HSR can significantly reduce passenger transport costs, thereby promoting tertiary industry agglomeration.

Around the station area, HSR can attract concentrated commercial development. In Nanjing China, Wang et al. (2017) used micro-level real estate data to quantify changes in the spatial structure of station area development after the introduction of HSR. They found a circular pattern of industrial land uses radiating outward from the HSR station area. This development pattern revealed an agglomeration effect. Furthermore, the degree of spatial clustering for tertiary service sector land use was significantly higher than for other industries once HSR began operating. In other words, HSR introduction demonstrated a positive effect on the agglomeration of industries surrounding its station areas. Overall, the location of the HSR station, land rent costs assessed by government and the operating service characteristics (e.g., network access and frequencies) of the HSR all affect the industrial development around the station area.

In Asia, the level of industrial agglomeration in cities served by HSR has increased faster than comparable cities without HSR. Most scholars believe that introducing HSR can make economic factors flow into cities (Pan et al., 2020) and promote the agglomeration of service sector industry (Deng et al., 2017). From the perspective of urban enterprise location, Xiao et al. (2020), find that the arrival of HSR and its service levels have a great impact on office location selection for automotive industry start-up firms in Guangdong Province, China. HSR can thus change the city's established pattern of enterprise locations and layout.

At the regional scale, HSR implementation can strengthen economic ties between cities as well as communications among production sectors, thus changing the regional industrial structure. Charnoz et al. (2018) point out that HSR can promote the growth of employment in tertiary service sector at a much greater rate than retail, trade or manufacturing sectors by facilitating the free flow of knowledge workers and the accumulation of corporate headquarters in station areas along in routes. The free flow of labour between regions can thus advance the regional economic integration through tertiary industry's agglomeration. HSR can encourage large cities to pursue a more decentralized development strategy and adjust economic activity among multiple locations (Garmendia et al.， 2012). In addition, HSR can promote the development of some specific industries, especially the service sector. Campa et al. (2016), present examples of such effects in Spain, while Pagliara et al. (2017) draw upon experience in Italy to demonstrate that HSR has a positive impact on the development of regional tourism.

However, some studies suggest that the influence of HSR on industrial agglomeration varies by economic subsector. Shao et al. (2017) examined a sample of 25 cities in China's Yangtze River Delta

to assess HSR impact on the agglomeration of urban service industries. Their results showed that HSR played a significant role in promoting certain kinds of service industry agglomeration along its routes through the Yangtze River Delta. They divided service industries into producer, consumer, and public service sectors. This revealed that the impact of HSR on producer service agglomeration was significant, but the consumer and public service sectors did not experience greater agglomeration.

5. Discussion

The paper has systematically identified and connected findings about HSR's impact on population, land use, industrial development and urbanization. To date, most studies have explored only a subset of factors that can influence this interdependent nexus of urbanizing forces, and paid limited attention to the synergy among the accumulation of these factors affecting urbanization. Population, land and industrial dimensions of urbanization are interconnected and can only be fully appreciated by being analysed as a holistic system, as depicted in Figure 2.

First, the intensification of human activity and industrial growth complement each other. Population growth boosts the demand for both manufacturing and services. In addition, an expanded labor force can lead to lower production costs, which further encourages industrial agglomeration. Agglomeration will further stimulate migration as people are drawn to an expanding labour market. Second, the introduction of HSR improves the accessibility level between cities, accelerates the speeds at which population and economic factors flow between those cities, and promotes the aggregation of population and industry. The agglomeration of population and industry boosts the demand for land, thus encouraging and accelerating the transformation of rural space into urbanized development, yielding spatial expansion of the city. In other words, the human and industrial impacts of HSR both work to accelerate the urbanization of land.

Finally, many HSR stations are built on the edge of cities or in the outer suburbs, partly to take advantage of lower suburban land prices and living costs. China's vast HSR network has strengthened the geographical advantages of suburban spaces creating an interesting parallel with the big boost to suburban development that followed the implementation of the U.S. Interstate Highway system. In the USA, suburban development was spread far and wide along the highway corridors, but in China, population and industrial development generally cluster around the HSR station area, forming a node that acts as an urban sub-centre. In other words, suburban development caused by HSR leads to the agglomeration of population and industry in different ways than the highway infrastructure spread suburban development around North America, and to a lesser extent in Europe. The comparison of suburban development impacts from HSR in China and metropolitan highways elsewhere thus appears ripe for further analysis.

To summarize the state of current knowledge on the HSR-urbanization nexus at three spatial scales, we have created Figure 3 below. It illustrates how HSR serves as a bridge between urban and suburban regions across growing metropolitan areas in China. HSR areas are located in specific sections of each metropolitan area, but they have wider effects throughout the metropolitan region.

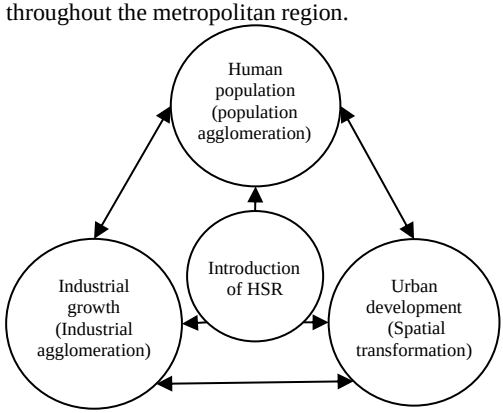

Fig. 2. Relationships between population, land development and industrial growth in urbanization

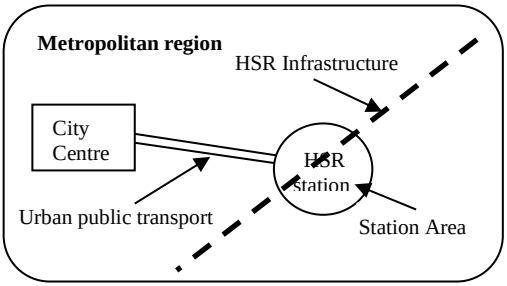

Fig. 3. Spatial relationships among the station, city, and region

Loukaitou-Sideris et al. (2013), have concluded that the economic and spatial impacts of HSR will vary based upon the configuration of a metropolitan region and the composition of its economic activity. Therefore, future research needs to examine multiple spatial levels in order to obtain an accurate assessment of the effects that HSR will exert on urbanization.

6. Conclusions

This article provided an overview of the research that has assessed a range of impacts from HSR on urbanization. A fulsome understanding of these inter-related dynamics could be particularly valuable in understanding the rapid development of both space and mobility across China that is proceeding with the build out of the world's largest HSR network. We have conducted a systematic review of studies that examine the impacts of HSR on human migration, land use and industrial development at three spatial levels (station, city and region) and can offer the following conclusions.

First, the introduction of HSR improves urban accessibility, resulting in the "time-space convergence" effect. However, the operation of HSR may polarize this accessibility effect on cities. While HSR increases the accessibility of some cities, it may simultaneously make the relative accessibility of other cities worse. Second, the initiation of HSR reduces time costs of travel and speeds up population flow. The agglomeration and diffusion effect of HSR encourages people to gather in urban areas and increase their trip making frequency by reducing travel costs, thus affecting the change in urban population size. Third, HSR infrastructure can reshape the spatial layout in and around a city. Land use surrounding the station area is affected by the change in mobility introduced by HSR. When the city is well planned, HSR can contribute to advancing polycentric metropolitan development. If the planning falls short, excessive spatial expansion – i.e., sprawl, would waste developable land resources, creating social problems such as low land use efficiency, agricultural land loss, and environmental degradation. Fourth, the arrival of HSR changes the industrial trajectory of the city. Opening HSR service accelerates the flow of production elements between regions, thus strengthening industrial agglomeration in and around cities. HSR's effects on passenger travel also exert a powerful influence on the service sector further influencing the economic restructuring of the city.

The existing literature has enriched our understanding of HSR's effects on urbanization, however, these findings also reveal research gaps that merit further investigation. First, the issue of urban depopulation and shrinkage through HSR linkage to agglomerating industrial development deserves closer examination. In the HSR era, travel time gradually replaces the traditional geographical distance as the most import dimension of accessibility. HSR has improved the city's connection with broader markets, influenced the distribution of urban population, industrial development and spatial layout. At present, most scholars recognize the agglomeration effect of HSR, that is, HSR can cause the concentration of economic factors. However, it is important to note that in some cases, cities instead experience a net outflow of population, which can cause the phenomenon of deurbanization.

The explanation behind this phenomenon of deurbanization may be the siphon effect. Large cities gain more advantages from the development process that is stimulated by HSR, and they can thus draw in the resource elements from surrounding smaller and mid-sized cities. Some urban population growth may be accompanied by the loss of population from other urban areas. Therefore, the siphon effect produced by the creating of HSR is worth further exploring. We need to understand which cities are more likely to be siphoned by HSR mobility and thus face deurbanizing effects when this mobility mode is introduced or expanded. The loss of talents and production factors in some HSR-served cities will inevitably hinder the urban economic

development. This phenomenon will further aggravate the process of unbalanced economic space, resulting in the shrinkage of some cities.

Second, what are the advantages and disadvantages of expanding urban space across a metropolitan area in the ways enabled by HSR? Since many HSR stations across China are being built on the edge of the city or in the suburbs, planning will play a crucial role in their eventual effects. What planning principles and practices facilitate the polycentric development of the urban region? Further research into the actual unfolding of HSR urban spatial expansion can help to answer this question.

Third, HSR's role in the transformation and upgrading of industrial activity calls for closer attention. Can the optimal industrial division between cities in a region be realized by introducing HSR? What would it take to ensure that economies of scale and maximum utility are realized in cities served by HSR? These avenues of exploration can help us understand more about how HSR affects urban development on multiple spatial levels.

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