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Comparative Study of High-Speed Passenger Rail Deployment in Megaregion Corridors: Current Experiences and Future Opportunities

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COMPARATIVE STUDY OF HIGH-SPEED PASSENGER RAIL DEPLOYMENT IN MEGAREGION CORRIDORS: CURRENT EXPERIENCES AND FUTURE OPPORTUNITIES

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ABSTRACT

Deployment of high-speed passenger rail services has occurred around the world in densely-populated corridors, often with the effect of either creating or enhancing a unified economic “megaregion” agglomeration. This paper will review the technical characteristics of a variety of megaregion corridors, including Japan (Tokyo-Osaka), France (Paris-Lyon), and Germany (Frankfurt-Cologne), and their economic impacts. There are many lessons to be drawn from the deployment and ongoing operation of high-speed passenger rail service in these corridors for other countries now considering similar projects, such as the US and parts of the European Union.

First, we will review three international cases, describing the physical development of each corridor as well as its measured impacts on economic development. In each case, the travel time reductions of the high-speed service transformed the economic boundaries of the urban agglomerations, integrating labor and consumer markets, while often simultaneously raising concerns about the balance of growth within the region. Moreover, high-speed travel within the regions has had important implications for the modes and patterns of travel beyond the region, particularly with respect to long-distance air travel. An example is the code-shared rail-air service between DeutscheBahn and Lufthansa in the Frankfurt-Cologne corridor.

Next, we will examine the implications of these international experiences for high-speed rail deployment elsewhere in the world, particularly the US and Portugal, one

of the EU countries investing in high-speed rail. Issues considered include the suitability of high-speed passenger rail service in existing megaregions as well as the potential for formation of megaregions in other corridors. By understanding the impact of high-speed passenger service on economic growth, labor markets, urban form, and the regional distribution of economic activity, planners can better anticipate and prepare countermeasures for any negative effects of high-speed rail. Examples of countermeasures include complementary investments in urban and regional transit connections and cooperation with airlines and other transportation service operators.

High-speed passenger rail represents a substantial investment whose implementation and ultimate success depends on a wide range of factors. Among them is the ability of planners and decision-makers to make a strong case for the sharing of benefits across a broad geography, both within and beyond the megaregion (and potential megaregion) corridors where service is most likely to be provided. This paper provides some useful lessons based on international experiences.

INTRODUCTION

HSR is becoming an increasingly important and popular form of passenger transportation infrastructure, as roads and airports become more congested and greenhouse gas levels increase. Since the introduction of the first high-speed rail (HSR) line in Japan in 1964, HSR has been gaining acceptance worldwide, with new lines in operation or under construction

in several EU countries, China, South Korea, and Taiwan, as well as lines under serious consideration in other countries.

The implementation of high-speed rail lines plays an important role in reshaping the travel patterns and activities of people and consequently changing the ways cities develop. Apart from the goals of increasing transportation infrastructure capacity and providing a “green” transport alternative, the motivation to develop HSR system for many countries has also been promotion of economic growth and regional development. Traditionally, the direct economic impacts of HSR and other transport investments are assessed through a benefit-cost analysis (BCA). However, there are also indirect or wider development impacts that the traditional BCA may not capture.

These impacts are the main focus of the paper—specifically, the potential for *megaregion* or *megalopolis* formation - an integrated economic urban complex - created by fusion of multiple cities connected at *high-speed* of 200-300 km/h (124-186 mi/h).¹ Megalopolises can have many positive economic impacts stemming from larger labor markets, larger commercial markets, expanded individual daily activity zones, and so forth. Ross (2009) presents a megaregion as a geography that can be more effective than cities alone in meeting “economic and social challenges.”² Prud'homme (1997) links the size of the city's labor market to the city's productivity. The larger the labor market, both the firm and the employees have higher probabilities of getting what they want. A larger labor market also justifies and facilitates specialization of workers and jobs thus increasing productivity. Considering this theory, the megalopolis may offer a larger labor market relative to the existing labor markets of city pairs where service is being considered, and therefore contribute to increased productivity.

The development impacts from HSR may also be negative. For example, HSR can disadvantage the smaller urban areas located between the main HSR stations. Puga (2001) notes that “a better connection between two regions not only gives firms in a less developed region better access to the inputs and markets of more developed regions,” but also can harm them by reallocating economic activity to the richer regions. This is also true for cities. Therefore, we draw upon international experiences to understand what the improved accessibility from the HSR means for the economic activity, labor markets and distribution of development impacts in small- and medium-sized cities and regions.

These impacts are directly relevant to the U.S. and Portugal. For example, the US government is making investments in HSR connections for major city pairs in Florida, California, and the Midwest, among other places. Meanwhile, the Portugal government intends to deploy HSR

on the 297 km (185 mile) corridor between Lisbon and Porto, the country's two largest cities, in 75 minutes, with intermediate stops in 4 smaller cities.

First, we review transportation literature on economic development effects of HSR investments (including economic geography and megacities). Next, we present case studies of international HSR corridor experiences, specifically Tokyo-Osaka in Japan, Paris-Lyon in France, and Frankfurt-Cologne in Germany. The case studies explore the phenomenon of “megalopolis” formation along the selected corridors as a result of the HSR link and to find evidence of economic development effects on urban areas along the corridors, both positive and negative. The findings are then applied to analyze the planned Lisbon-Porto HSR corridor in Portugal; and the possible emergences of megalopolis forms and the associated implications for HSR deployment elsewhere in the world are discussed.

METHODOLOGY

The case study approach is largely qualitative and descriptive, supported where appropriate with syntheses of quantitative analyses of empirical evidence. Cases were selected to include countries with sufficient experience operating HSR systems to allow for the development effects of HSR to occur. Empirical evidence was collected through review of available data as well as existing literature from Japan, France, and Germany, both before and after deployment of HSR. Key indicators for measuring economic effects of transportation investments were identified.

LITERATURE REVIEW

The existing theoretical literature identifies a number of potential economic development impacts of HSR investment, many of which go beyond traditional impacts such as travel time savings and transport cost reductions. These include changes to the spatial location of economic activity, reductions in regional inequalities, larger labor and consumer markets, and increased productivity levels. Some of the potential negative impacts include a loss of economic activity in less developed and/or less accessible regions, and thus uneven allocation of growth.

A number of existing studies assess the economic development implications of transportation in general. Banister et al. (2001) examines whether transportation investments yield any “additional development benefits” at the regional and local levels besides the direct gains from travel-time savings. Puga (2001) and Krugman explore the effect of “reduction in transport costs” on “the spatial location of economic activities.” Puga also notes that transport infrastructure improvements are one of the main instruments for “reducing regional inequalities.”

Studies assessing the development impacts of HSR find that HSR contributes to further centralization and concentration of most economic activity in already developed

¹ Gottman, J. 1961; Pickard, J.P. 1962; Hall, P. 2006 and 2009; Lang, R. and Knox, P. 2009; and Blum et al. 1997.

² Ross, C.L. 2009, p. 5.

areas. For instance, HSR line in Spain induced spreading of economic growth and reduced disparities on a corridor level but not on a national level, according to Gutierrez (2001). While HSR “improves competitiveness and cohesion dimensions by shrinking the size of geographical space” by increasing accessibility and proximity, the biggest gains have still accrued to the major access points, per Vickerman (1997).

The reduced travel time and lower transport costs resulting from the HSR connection may play two roles in the development of urban regions, according to Pol (2003): the effects of HSR may play “catalyzing” or “facilitating” roles, depending on the level of economic potential of an urban region. “Catalysts” draw “new activities” which lead to economic growth. Meanwhile, typically in “cities with a prosperous local economy, which need new infrastructure to accommodate their economic growth,” HSR acts as a “facilitator.” Most such cities are major metropolitan centers or capitals that already have “high economic potential” and are often “the first to be connected to the HSR-network.” Thus, the growth of these cities drives the demand for HSR investments to facilitate this growth but not create new growth.³

Most researchers also agree that no economic growth can be achieved without the necessary set of conditions in place, such as appropriate development at the station level and effective public policy frameworks. The authors also doubt that public infrastructure investment alone can cause substantial increases in new employment as potential savings are realized through increase in productivity of the existing labor force. This also raises a “causality” question of whether transport investment promotes economic growth or growth encourages more demand for transport and thus further investment.⁴ Nevertheless, the available literature has not yet provided robust results explaining the relationship between HSR investment and economic growth because of the complexity of this relationship and long period of time needed for the growth effects to realize, during which other factors are at play.

Role of HSR in “Megalopolis” Formation

The literature offers many characterizations and definitions for large agglomerations, including megacities, megalopolises, megaregions, megaplexes, megapolitan regions and others (Gottmann (1961), Pickard (1962), Ross (2009), and Lang and Knox (2009)). For consistency we will use the term megalopolis and apply the definition of such an “extended functional region” offered by Blum et al. (2009) as “a geographical area that shares a common labor market and a common market for household and business services.”

The literature on the relationship between megalopolis and HSR has been emerging in the last several decades, as HSR networks have grown. Many authors agree on the

importance of agglomeration externalities especially those created by HSR investments. The role of HSR deployment in fusing urban areas into a single integrated economic zone (megalopolis) are studied by Hall (2006, 2009), Blum et al. (1997) and Ishii (2007). Hall predicts that in the 21st century, these HSR systems would accomplish “what motorways failed to do: *to shrink geographical space, and thus tie not only half of Britain, but also much of Europe, into a single polycentric Megalopolis*”.⁵ Building on the many definitions of megalopolis and related concepts and the attempts to build frameworks for understanding and explaining the relationships between megalopolises and HSR, we now present several empirical cases of HSR deployment and examine their observed impacts on regional development.

TOKYO-OSAKA (TOKAIDO) SHINKANSEN CORRIDOR

Japan was the first country to build a high-speed rail line in the world. Its first Shinkansen bullet train connecting the 515.4 km (320 miles) distance between Tokyo and Osaka in 4 hours was launched on October 1, 1964. Today, the travel time is just under 2.5 hours, and Japan remains a world leader in HSR technology with a total Shinkansen network of 2,452 km (1,524 miles) connecting major metropolitan areas and carrying over 300 million passengers per year at top speed of 300 km/h (186 mi/h).⁶ Having had the longest history with HSR, Japan provides a valuable example of the long-term development impacts of HSR services on urban areas.

Intermediate Stations and Shinkansen Frequency

The service on Tokaido Shinkansen has maintained its reliability (with an average delay of 0.6 minutes) despite an increase in daily trains from 60 to 323.⁷

There are total of 15 intermediate stations on the Tokyo-Osaka Shinkansen corridor.⁸ In 1964, the line served 12 stations only, three of which were newly built. All the new stations were built in the peripheries of the cities and were connected to HSR line only. The remaining stations were existing conventional rail stations located in the city centers.⁹ Currently, three types of trains operate on the Tokaido Shinkansen route with varying speeds and patterns of intermediate stops. Nozomi, the fastest, operates up to up to 300 km/h (186 mi/h) and serves only major cities, with a frequency of 9 trains per hour. Hikari trains stop at some of the medium-sized cities, while Kodama trains serve all 15 intermediate stations.^{10 11}

⁵ Hall, P. 2009, p. 808.

⁶ Central Japan Railway Company. 2009. *Data Book 2009*.

⁷ United States Government Accountability Office. 2009.

⁸ Central Japan Railway Company Official Website. About.

⁹ Sands, B. 1993.

¹⁰ Central Japan Railway Company. 2009. *Data Book 2009*.

¹¹ Central Japan Railway Company. Annual Report 2009.

³ Pol, P. 2003.

⁴ Banister, D. and Berechman, J. 2001.

After the Shinkansen

The HSR corridor between Tokyo and Osaka in Japan is a unique case as it passes through one of the most populous regions in the world, with multiple urban areas of several million inhabitants located along the corridor. This corridor attracts the highest number of riders of any high-speed rail line in the world (over 150 million riders annually¹²). This explains the corridor's financial and commercial success beyond the forecasts. Tokaido Shinkansen is one of only two HSR routes in the world (along with the French Paris-Lyon TGV line) that "have broken even".¹³

Kamel et al. (2008) mentions that overall economic and social development impacts of Japan's Tokaido Shinkansen railway are mainly the products of the travel time reductions between Tokyo and Osaka from 4 hours to 2 hours 25 minutes. The high speed is what has created "more opportunities for business and economic development".¹⁴

Evidence of Megalopolis Formation and Development Impacts

The Japanese HSR has changed the people's lives and activities along the Tokaido corridor in a revolutionary way. Specifically, the ground-breaking speed and associated travel time savings have attracted significant new travel demand, illustrated by large annual ridership figures. The reduction in travel time and high service frequencies of Tokaido Shinkansen have provided opportunities never offered by any mode before. Figure 1 (see Annex A) presents a time-space diagram with the major cities along the Tokyo-Osaka corridor brought closer by the high-speed Shinkansen. Relative to other modes, the HSR's reach has expanded the commute zone to the cities that are over 200 km (124 miles) away from Tokyo. The increase in "intra-organizational" business trips in the services sector and decrease of the overnight stays attest to the enlargement of the people's daily activity zones in terms of physical distance, but within the acceptable temporal distance limits.¹⁵

Furthermore, the "concept of formation of Extra Huge Economic Zones (EHEZ)" introduced by Japan's Chubu Economic Federation (CEF) provides an evidence of a megalopolis or megaregion creation between the cities on Tokaido Shinkansen corridor in Japan.¹⁶ The EHEZ concept was developed by the CEF to make a case for implementation of Maglev trains on the Tokyo-Osaka corridor, which provides

even more dramatic reduction of the temporal distance by amalgamating Japan's major urban centers together.

Economic Development Impacts

According to Givoni (2006), HSR creates "network effect" by bringing the cities closer and increasing their connectivity because of the travel time reductions it offers. The "network effect" is in turn "the driver for the social-economic impacts."¹⁷ In the transportation literature, the Shinkansen in Japan is often used as a model for discussing the regional development impacts of the HSR. Sands (1993) concludes that "the Shinkansen has had strong development effects in Japan at the regional, urban and station levels".¹⁸ The impacts have been mainly observed in the average annual population growth, increased employment in the "information exchange industries" such as "banking, real estate, education and political institutes", and increase in business and tourism travel between the cities.

Brotchie (1991), Amano and Nakagawa (1990) and Nakamura and Ueda (1989) found positive correlations between the proximity of a Shinkansen station and regional development, but could not determine the causality of this relationship.¹⁹ Although these empirical studies are often used in discussing the impacts of HSR in Japan, "the real impact of high-speed rail on regional-economic development is still difficult to assess".²⁰ More recently, Sasaki et al. (1997) found that HSR lines in Japan led "to regional dispersion of economic activity from developed regions to less developed regions to some extent," but increasing the density of the HSR network did not necessarily contribute to long-term regional dispersion.²¹ Furthermore, Haynes (1997) and Sands (1993) argue that along the Tokyo-Osaka corridor "although growth parallels the high-speed train route, most of the route was selected on the basis of expected growth independent of the high-speed trains (HST)".²² Hence, the question remains about the direction of causation between HSR construction and regional growth.

Impacts on population growth. Overall, the cities with the Shinkansen railway stations along the Tokyo-Osaka corridor grew in population size.²³ In a study by Brotchie (1991), cities connected to the Tokaido Shinkansen registered a 22% higher growth in population size than the cities with no stations but located along the corridor.²⁴ These differences, on the other hand, may simply be a function of the smaller base size of the cities without stations.²⁵ Also, the HSR aimed to connect the cities that already were predisposed for potential population

¹² Central Japan Railway Company. 2009. *Data Book 2009*.

¹³ Cited by Iñaki Barrón de Angoitia, director of high-speed rail at the International Union of Railways, in Victoria Burnett, "Spain's High-Speed Rail Offers Guideposts for U.S.," *The New York Times On the Web*, May 30, 2009. Retrieved in 03/25/2010 from <http://www.nytimes.com/2009/05/30/business/energy-environment/30trains.html>

¹⁴ Kamel, K. and Matthewman, R. 2008.

¹⁵ Shin, D. 2005.

¹⁶ Ishii, M. 2007.

¹⁷ Givoni, M. 2006.

¹⁸ Sands, B. 1993.

¹⁹ Willigers, J. 2003.

²⁰ Willigers, J., Floor, H. and van Wee, B. 2005.

²¹ Sasaki, K., Ohashi, T. and Nado, A. 1997.

²² Haynes, K. 1997.

²³ Alabate, D. and Bel, G. 2010.

²⁴ Haynes, K. 1997; Sands, B. 1993.

²⁵ Sands, B. 1993.

growth due to other factors (e.g., other transportation linkages, demographics, physical location, etc.).

Impacts on employment and businesses. Japan's Tokaido Shinkansen HSR link has mainly "promoted the centralization of economic activities in big cities and favored intra-organizational business trips".²⁶ Alabate et al. (2010) reviews a study by Plaud (1977) claiming that the service industries became highly concentrated in the cities of Tokyo and Osaka, resulting in the centralization of this sector in the country's major cities. This trend can be supported by the fall in employment in Nagoya following the inauguration of the HST line, "estimated at around 30% down from 1955 to 1970". During the same period, Osaka and Kyoto registered an employment increase of 35%.²⁷ And Osaka became a new regional center of growth with the expansion of the Shinkansen network to other corridors. In the retail industry, Tokyo has gained the most benefits. Also, since "intra-organizational journeys" have become easier, business travel has increased significantly; however, the number of business overnight stays in hotels in Tokyo and Osaka has decreased.²⁸

Regions with good accessibility to the Shinkansen stations also have registered higher growth in employment relative to regions with no direct HSR connection. This trend is observable mainly in the locations like Tokyo and Osaka dominated by "information exchange industries" (business services, banking services, real estate), and with higher education institutes, which registered the highest increase of employees. And on the contrary, presence of large number of manufacturing industries in Nagoya has limited its regional growth even with presence of the HSR station. In addition, "the combination of expressway and the Shinkansen" had a stronger effect on growth rates".²⁹

In cities with HSR stations "employment growth in retail, industrial, construction and wholesaling was 16–34% higher" than in those without. Amano and Nakagawa (1990) found independently that growth in employment was 26% greater in cities with Shinkansen stations than that in cities with no stations ("1.8% to 1.3% respectively").³⁰ According to Brotchie (1991), "food and accommodation sectors" grew significantly at "both intermediate and termination stations".³¹ However, this growth in the cities may be a result of "displacement of activity from elsewhere and should not be interpreted as being indicative of net growth".³²

Impacts on near station development. The Shinkansen stations that were newly built in 1964 became city centers with transit terminals, hotels, offices, retail, dining and cultural

facilities, and parking, and had on average greater effects on the "redevelopment of surrounding areas" than the expanded existing stations at the time.³⁴ At first, the development around Shin-Osaka station in Osaka was low because it was separated from the city by a river, but eventually, the development was stimulated by initiation of "large-scale development projects", and opening of additional "transportation linkages" between the station and the city center.³⁵

In Yokohama, in addition to being a part of residential urban sprawl of the metropolitan Tokyo area, the area around the Shin-Yokohama station had a major inflow of mid-size companies, mainly in the computer software sector. Heavy development of the area around the entrance of the station led to the formation of a new city center in Yokohama.

Impacts on Tourism. Tourism has also showed significant growth following opening of the Shinkansen: rising from 15 to 25% between 1964 and 1975. However, this increase has had mixed effects across the cities on the corridor. The overnight stays decreases due to shorter travel times by HSR affected more the intermediate stops rather than the terminal points.³⁶ The six prefectures of Tokyo experienced the largest increase in the number of tourists.³⁷

PARIS-LYON TGV SUD-EST CORRIDOR

France was the second country to initiate the development of a HSR system following Japan and the first in Europe. Its first Train à Grande Vitesse (TGV) high-speed train connecting Paris and Lyon (425 km) in 2 hours was first launched in 1981. Since then, France has been gradually developing its TGV network and has become one of the leaders in HSR technology. Today, France has 1,896 km (1,178 miles) of dedicated TGV lines connecting major cities to Paris and carrying 128 million passengers per year (in 2008)³⁸ at top speed of 320 km/h (199 mi/h).³⁹

After the TGV

Several empirical studies have been done to assess the impacts of the TGV line on the regional and economic development of Paris and Lyon, with emphasis on business location and development, and tourism. Overall, the line connecting the two strongest economic regions in France, was fully successful technically, commercially and financially, generating traffic demand and net revenues beyond the estimated forecasts. The line has paid off its construction costs within 11 years and still remains profitable for SNCF.⁴⁰

²⁶ Alabate, D. and Bel, G. 2010.

²⁷ Ibid

²⁸ Ibid

²⁹ Sands, B. 1993.

³⁰ Haynes, K. 1997.

³¹ Ibid

³² Sands, B. 1993.

³³ Ibid

³⁴ Shin, D. 2005.

³⁵ Sands, B. 1993.

³⁶ Haynes, K. 1997.

³⁷ ARUP – TMG. 2001.

³⁸ Le Journal du Net. Retrieved on 05/11/2010.

³⁹ International Union of Railways (UIC) High Speed Department. 2009.

⁴⁰ Midwest High Speed Rail Association. 2009.

Evidence of Megalopolis Formation and Development Impacts

In the 30 years since its implementation, the HSR Sud-Est link has gradually brought the two largest urban centers in France closer by reducing the “temporal distances” between them (see Figure 2). The distance is no longer quoted in kilometers but in hours and minutes, with Lyon being “2 hours away from Paris.” Roth (1990) discusses that the perception of transportation users has evolved and “travel time or ‘temporal distances’ matter more than the distance traveled,” creating “a certain psychological impression of the weight of the trip made.” He asserts that “the TGV modifies the spatio-temporal relationships between cities... and as a consequence influences the behavior of potential and actual users”, which in turn eventually leads to changes in the “social and economic relationships between” these cities.⁴¹ The author also observes that the “psychological weight of a trip” is determined not only by the “temporal distances” but also the quality of the service such as frequency, “comfort”, “ease of access”, and other factors that “ease” the trip.⁴²

One of the fundamental impacts of the Paris-Lyon HSR on the users’ behavior is the significant levels of induced traffic it generated, attesting mainly to the increase in business trips made related to the buying/selling of services. Total business travel on the corridor increased 56%, and those made for sale/purchase of services by 112%.⁴³ Table 1 (see Annex B) shows the growth of business travel by mode originating in Paris and Lyon between 1980 and 1985. Round trips originating in Paris have increased much less than round trips originating in Lyons. In addition, surveys⁴⁴ showed that the number of overnight stays by TGV passengers fell after the introduction of HSR from 74 to 46% (between 1981 and 1985).

Thus, the reduced “temporal distance” between Paris and Lyons due to HSR link has led to changes in the mobility patterns of users, and generated new travel with a high number of one-day roundtrips. These factors provide an evidence of a formation of a megalopolis or megaregion between cities of Lyon and Paris. However, despite the connection to the TGV, the intermediate cities, Le Creusot and Macon, have not experienced the same levels of interaction with Paris or Lyon. This can be explained by the very low frequencies of HSR services provided in these cities (8 vs. 30 trains/day in Paris).

Economic Development Impacts

Most benefits of the HSR service supply between Paris and Lyon have been absorbed by the Paris region, “mainly due to the spatial concentration of population”. Some positive effects from the HSR connection are also observed in Lyon, mainly

“in the form of an increase in economic cooperation and exchanges with Paris”.⁴⁵

An empirical study undertaken by Bonnafous (1987) discusses the regional impact of the TGV HSR between Paris and Lyon based on the surveys conducted before and after HSR inauguration with an emphasis on the tourism and services industries. Before TGV deployment, TGV created fears among the service enterprises in the Rhone-Alps province (around Lyon) that their Parisian competitors would expand and displace them. However, in reality the opposite occurred: the Lyon region companies were able to access and expand to the Parisian market mainly in the areas of market research, advertising, and consulting, thus benefiting from the TGV connection. The fears that Lyon might lose its company headquarters to Paris also did not materialize: specialized enterprises, whose markets are outside the regional boundaries or are international, no longer needed to relocate to Paris as it became easily accessible with TGV. So, there is an emerging trend to look for clients in Paris but carry out work in the province with a distinct quality of life. The survey showed that Parisians increased their business journeys to the Rhone-Alps province by 52% for service trade, while the residents of Rhone-Alps increased their trips to Paris by 144% for the same purposes.⁴⁶ It should be noted that these surveys were conducted two-three years after the inauguration of Paris-Lyon TGV line, and the effects may have evolved further by now.

In case of Macon, some development occurred, which was partially spurred by the HSR connection. Macon registered a 13.5% increase in employment between 1999 and 2006, compared to surrounding cities which have actually lost jobs. This growth can be attributed to the availability of high speed linkages resulting in proximity to the large neighboring economic centers of Paris and Lyon. The decrease in employment in the adjacent cities attests that the relocation of some businesses took place within the province to near the HSR station in Macon. Macon has always been one of the Saône-et-Loire department’s major employment areas and attractive for the regional companies, and the HSR link helped to reinforce Macon’s already attractive location. On the negative side, the growth in Macon appears to have occurred at the expense of the neighboring cities from where the companies relocated.

The development impacts on the former coal producing town of Le Creusot were not as expected. The town hoped to attract a large pool of companies by its new HSR station and 85 minute time distance to Paris; however, six years after the opening only two companies were situated around the TGV-station.⁴⁷ Also, a new TGV station “had almost no local economic impact in terms of new jobs, firms or commercial

⁴¹ Roth, D. 1990.

⁴² Ibid

⁴³ Pidea (Planning, Economic and Development Consultants). 1991.

⁴⁴ Bonnafous, A. 1987.

⁴⁵ Alabate, D. and Bel, G. 2010.

⁴⁶ Bonnafous, A. 1987.

⁴⁷ TYCO Engenharia / Holland Railconsult. 2006.

expansion. This was due in part to its isolated station, poor road access and historical image”.⁴⁸

The opening of HSR connection in Lyon helped to attract companies from cities not connected to the TGV HSR network such as Grenoble and Genève. A number of high-tech companies originating from Paris also opened their “back-offices” in Lyon. The companies concentrated mostly close to Lyon’s TGV station Gare Part Dieu, which has developed into one of the most important business parks of France. The amount of its office space has increased by 43% between 1983 and 1990. Due to the local authorities’ efforts to promote Part-Dieu station development, the area around this TGV station has become “the most sought-after location for office space in Lyon” with “almost 40 percent of the city’s total office space”, and planned for more. Between 1983 and 1990, the office space around the station increased 43%.⁴⁹

However, it should be noted that “these measures may reflect displacement of activity from elsewhere and should not be interpreted as being indicative of net growth.”⁵⁰ The development of businesses around HSR station in Lyon has happened at the cost of a lower development in the city’s traditional downtown, which became deserted by companies relocating to near the TGV station. Other negative effects are the experiences by the cities without HSR such as Grenoble and Geneva, who lost their businesses to Lyon.

While the business growth in Lyon can be attributed mainly to the introduction of the HSR link, many argue that Lyon’s location was already attractive before the TGV started operations, and the TGV was only part of the decision process for businesses to locate themselves at the city’s station area. Sands (1993) and Haynes (1997) conclude that the TGV plays a minor role in location decisions of most firms. In a survey of businesses near the Lyon’s Part-Dieu Station, only 33% responded that HSR was one of the factors in their location.⁵¹ These companies have indicated that “the HSR station was an important factor, but not the decisive one for setting-up offices in Lyon. Plans did already exist and the TGV subsequently acted as an incentive”.⁵² Other factors include market proximity, accessibility to the rest of the transport network (road and rail links), and public assistance.

Lyon also experienced a strong growth in tourism business after the introduction of HSR, which has had a major impact on the city’s economy, but the effects were two-fold. On one hand, while business trips increased, the TGV allowed making these trips in a day, thus reducing the number of overnight stays to the detriment of hotel businesses (length of stay decreased from 2.3 days in 1980 to 1.7 days in 1992). On the other hand, the overall number of visitors for conferences has increased, forcing the restructuring of the hospitality

businesses to adapt to new groups of customers. The HSR along with the hospitality infrastructure development and Lyon’s “aggressive promotion and communication strategy” have put Lyon “on the tourist map and increased tourist awareness of the city.”⁵³

COLOGNE (KÖLN) -FRANKFURT ICE CORRIDOR

Germany started developing its HSR network shortly after France. Its first two Inter-City Express (ICE) high-speed lines were inaugurated in 1991, with upgraded links between Hannover and Würzburg and between Mannheim and Stuttgart. In 2002, Germany opened its first newly built passenger dedicated ICE line serving the 177 km (110 miles) distance between the cities of Cologne (Köln) and Frankfurt am Main. With trains running at a speed of 320 km/h (199 mi/h), this new ICE has reduced the rail journey times from 2hr 15min to just over an hour for non-stop service.⁵⁴ Today, Germany has an established network of 1,285 km (798 miles) of ICE lines, serving the major German cities as well as destinations in neighboring countries at top speed of 330 km/h (205 mi/h).

After ICE

The new ICE line effectively links two of Germany’s most active economic regions, the Rhine-Main area (population 3 million) and the Rhine-Ruhr region (population 10 million). Direct economic and socio-economic impacts are evaluated regularly such as impacts on pollution, congestion, environment, etc., however, there seem to be no official studies assessing the indirect impacts of this particular corridor such as on regional development, labor markets, etc.

“The city pair Cologne-Frankfurt seems to be a perfect example of the benefits from a shift from short distance air services to high-speed railway.”⁵⁵ This ICE route not only supports air travel as a feeder to long distance flights, but also has raised the competitiveness of rail against short haul flights and cars. The ridership on the Cologne-Frankfurt line has been growing, and the DB expects passenger numbers to more than double by 2010 to around 20–25 million from current 9 million. Limburg accounts for about 2,500 people using its ICE station daily, and between 2003 and 2005 this number grew by 32% and is expected to grow further. In Siegburg, since the commissioning of the station, the number of passengers has also been increasing steadily.

Evidence of Megalopolis Formation and Development Impacts

According to Blum et al. (1997), the HSR link serves two purposes: to “potentially substitute for an air connection between two major cities (or rather central business districts -

⁴⁸ Haynes, K. 1997.

⁴⁹ Sands, B. 1993.

⁵⁰ Kamel, K. and Matthewman, R. 2008.

⁵¹ Ibid

⁵² TYCO Engenharia / Holland Railconsult. 2006.

⁵³ Masson, A. and Petiot, R. 2009.

⁵⁴ A.T. Kearney. 2003.

⁵⁵ Ibid

CBDs) at long distance with a direct train connection”; or to link “together many cities and CBD’s, hence, creating a new type of region with a high intra-regional accessibility”. In the latter case, the HSR “binds together cities in a band, where each pair of cities is at a time distance of between 20 and 40 min, i.e. a time distance that allows daily commuting.” Blum and Haynes (1997) argue that such a connection “gives rise to a band of cities and, hence, creates an extended functional region formed like a string of pearls”. Germany is an example where “a number of cities are connected in exactly this manner by a high-speed train”. “In the German case we could speak not only of bands of cities but rather of a network of cities connected by high-speed trains.”⁵⁶

The cities of Montabaur and Limburg are located exactly between two major agglomerations – the Rhine-Main area and the Rhine-Ruhr conurbations – and have become more reachable to the traditional employment center-cities in these conurbations such as Cologne, Frankfurt, and Wiesbaden (another large city in the state of Hesse) since the deployment of the connection to the ICE high speed services. The ICE line has moved the cities closer in space-time thus integrating them into a large megaregion or megalopolis. Frankfurt has been a large commuting destination for work and business trips by road and conventional railway modes but from much closer distances given the lower speeds of these modes. With the high-speed service, within the same travel time of up to one hour, the vicinity of reach has been expanded and now Montabaur, Limburg and Siegburg are within an acceptable time-space “zone” of reach to Frankfurt. Figure 3 (see Annex A) demonstrates time-space chart for the ICE trains and other modes for travel from the cities on the corridor to Frankfurt.

Economic Development Impacts

Montabaur and Limburg have always been the central points of commuter trips from the Westerwald and the Limburg regions. Despite their proximity to large metropolitan areas, the regions around Montabaur and Limburg have preserved a rural character, with a high quality of living and affordable land prices and rents that make them attractive for migration inflow.⁵⁷ The ICE connection has reinforced and accelerated this migration process and showed its effect already a few months after the opening of the stations. This statement can be supported by the results of the survey of commuters in Montabaur and Limburg carried out by Nina Demuth (2004) with the support of the Westerwaldkreis mbH Economic Development Corporation in 2004.⁵⁸ The survey infers that the ICE train stations in Limburg and Montabaur are used primarily by commuters to travel daily to work places in Frankfurt, and that “the attractiveness of the ICE has triggered

the increase in urbanization development around the ICE stations.”

Frankfurt as a major employment market, and, therefore, is an important hub for commuters from Montabaur, Limburg, and surrounding area. Being one of the largest job centers throughout Germany, Frankfurt attracts 80% of daily commuters on the ICE line from Limburg and about 60% of commuters from Montabaur⁵⁹. This can be explained by the fact that the ICE services have higher frequency and better connectivity options offered in direction of Frankfurt from the Montabaur and Limburg ICE stations, especially during rush hours.

The increase in the commuting patterns from these small towns may be a result of the inflow of new residents stimulated by the availability of a high speed access to the large centers. About 20% of the Montabaur ICE commuters and about 15% of the Limburg ICE commuters responded to the survey saying that they moved to these towns from the neighboring large metropolitan areas such as Rhine-Ruhr conurbations and Cologne/Bonn because of the ICE and the improved speed and accessibility it offers.

Experts in the city planning and housing industries believe that the ICE connection in Montabaur “acts as an amplifier of a trend” that has already started, i.e. people relocating from the core of the metropolitan areas out to Montabaur city and adjacent residential areas seeking higher quality and lower land costs.⁶⁰ The main factors in residential choice, per the experts, are distance to the ICE station by road, rent and home costs.

In terms of development effects due to high-speed line connection, Montabaur and Limburg have been affected positively. The population gains, triggered by the ICE railway station, are considered very important for the region’s future development. The induced migration is expected to offset the expected loss of population caused by the demographic changes such as decline in natural population growth, and stabilize the population size of Montabaur region and the Westerwald district.⁶¹ In the case of Limburg, however, the extent of urbanization development has been moderate. After ICE station inauguration, the municipalities in Limburg region have imposed some restrictive settlement policies to prevent from turning the area into pure “residential bedroom communities.”

The history of the ICE train stations is still young; therefore, an economic boom in the cities is not yet observable, except that another “residential suburbanization”⁶² is emerging from the nearby metropolitan areas that are now spreading to the regions Montabaur and Limburg as a result of improved accessibility. By becoming part of high quality ICE network,

⁵⁶ Blum, U., Haynes, K.E. and Karlsson C. 1997.

⁵⁷ Demuth, N. 2004.

⁵⁸ Ibid

⁵⁹ Ibid

⁶⁰ Ibid

⁶¹ Ibid

⁶² Ibid.

the cities gained new opportunities, which can be used for their development.

Concerning the impacts of the ICE on Siegburg, investigations of the Geographical Institute of Bonn University have shown that 90% of passengers travel to and from Frankfurt, and about three quarters of the passengers use the train for business or commuting.⁶³ The economic development of the Rheine-Sieg region is linked to the increases in real estate investments that are in turn triggered in part by the new ICE connection. Studies at the University of Bonn showed that almost 3% of the ICE-users from Siegburg have chosen to reside in this town because of the ICE connection.

CROSS-CASE COMPARISON: APPLICATION TO PORTUGAL AND LESSONS LEARNED

Before the deployment of HSR lines, all the studied corridors were served by three modes of transport – air, conventional rail and road – and connected two major metropolitan areas at two ends of the line. In Tokyo-Osaka and Paris-Lyon, air was emerging as the biggest competitor to rail, offering the fastest travel times. But in the German case the biggest competitor appears to be road (57% traffic was carried by road before HSR). All the corridors, except Cologne-Frankfurt, pass through the most densely populated regions of the respective countries and include capital cities, and the pre-HSR service in all corridors faced (or are facing) capacity constraints.

Emergence of Megalopolises

Among the expected impacts of high-speed rail investment are changes in *accessibility* through travel time cuts and increases in mobility options. Gutierrez (2001) defines the “daily accessibility indicator” as the number of possible business contacts (for business trips) and the market potential (for tourist trips). It “measures how much population can be reached from a place (or can reach a place) in a certain travel time limit and the changes in accessible population brought about by a new infrastructure.”⁶⁴ Since HSR allows reaching more population and more places at a reduced travel time relative to other modes of transportation, we can say that it contributes to the increase of the “daily accessibility indicator.” This in turn expands the area of reach and thus access to new and greater markets located within a shorter temporal distance than before (Figure 4 lays out this chain of HSR impacts through megalopolis formation).

However, there is no straight-forward way for determining when a megalopolis is indeed formed as a result of HSR deployment, leading to a question of how one would know that a megalopolis emerges. There is no precise process for measuring and identifying the emergence of megalopolis, however, there are certain parameters that could guide us to

conclude that megalopolis is formed. Some of these parameters observed in the travel patterns between the cities connected by a HSR line include:

- significant increases in one-day round trips between a pair or group of cities,
- high levels of newly generated induced demand overall,
- induced demand for business trips,
- increase in the number of daily commuters,
- decrease in overnight hotel stays.

It is important to note that these parameters may be affected by factors other than the HSR infrastructure, making the causal relationship difficult to verify.

Further, HSR by changing the relative accessibility and effectively creating “a different social and economic space”⁶⁵ through the megalopolis/megaregion formation contributes to *economic development*. A larger labor market also justifies and facilitates specialization of workers and jobs thus increasing productivity and contributing to economic growth.⁶⁶ However, the spatial distribution of this growth may not be equitable or uniform. “A better connection between two regions not only gives firms in a less developed region better access to the inputs and markets of more developed regions,” but also can harm them by reallocating economic activity to the richer regions.⁶⁷ Thus, development in one place may occur at the expense of another place, and there may be those who will *lose* and those who will *win* from HSR. HSR may also contribute to *economic shifts* through relocation of economic activity from one region to another rather than economic growth, leading to zero sum growth (no growth) or modest economic development (Figure 4). For example, if a country experiences positive growth, but individually a city not connected to HSR experiences negative growth due to loss of economic activity to the cities with HSR stations, modest development occurs but through economic shifts. There could also be absolute growth observed within the cities that lose economic activity, while relative growth may be negative.

In the case studies for Japan, France and Germany, the implemented HSR routes have changed the relative accessibility and economic space of the urban areas linked to the HSR corridors. The time-space diagrams for each corridor shown in Annex A illustrate this impact by cities becoming closer to each other and fusing into a *megalopolis*. Based on the case studies, the emergence of the megalopolis appears in two different ways: (1) as a megalopolis formed between one (or both) of the large cities and several small intermediate cities along the HSR corridor (as observed in the German and Japanese cases); and (2) as a megalopolis formed between the

⁶³ Wikipedia. Siegburg/Bonn.

⁶⁴ Gutierrez, J. 2001.

⁶⁵ Givoni, M. 2006.

⁶⁶ Prud'homme, R. and Lee, C. 1999.

⁶⁷ Puga, D. 2001.

two large cities connected at two ends by a high-speed train, while the smaller intermediate urban areas are excluded (similar to the French Paris-Lyon connection). Both of these megalopolis forms could potentially emerge simultaneously, creating a “hybrid megalopolis,” although this has not been observed in our case studies.

Below we summarize and sketch megalopolis formations drawing from the case studies. The cities that have gained the most benefits and those that have become worse off as a result of the HSR are also listed (Figures 5, 6 and 7 in Annex A). The accompanying tables in Figures provide detailed information on the main HSR stations such as service frequency, compatibility with conventional rail, direct link to an airport and the industry focus of the station cities. Each of these megalopolises has different magnitudes of impacts on the urban areas located along the corridor.

Japan’s Tokyo-Osaka corridor. The HSR link in the Tokyo-Osaka corridor has favored the most those cities that specialize predominantly in “information exchange industries” (such as banking services, real estate, R&D, education, and/or political institutes). These cities are Tokyo and Osaka mainly, where employment levels have substantially increased since the HSR deployment. Interaction increased between the cities with the services industry and tourism focus, driven primarily by growth in business and tourism travel from nearby cities. The HSR link also contributed to further centralization of economic activity in the major metropolitan areas of Tokyo and Osaka. Nagoya, with a prevailing manufacturing industry base, experienced losses in employment levels as HSR plays a minimal role in the manufacturing sectors of the economy. While positive regional developments such as employment growth occurred in the urban areas along the corridor, the causal relationship with HSR is not clear, and it is possible that new growth came at the expense of other regions outside of the Shinkansen network. *One-day trips have increased and overnight stays decreased mainly to/from the intermediate stops rather than between the terminus points, thus leading to a conclusion that two daily activity zones or megalopolises were formed between the cities at two ends of the route, but not between Tokyo and Osaka* (see Figure 5 in Annex A).

France’s Paris-Lyon Corridor. The TGV further reinforced the existing centralization of economic activity in Paris primarily. Paris was the biggest winner from the HSR connection to Lyon, allowing some of the Paris-based companies to increase services exchanged in the Lyon markets. Lyon also benefited substantially by attracting a large pool of businesses, mostly relocated from neighboring cities and within the Rhone-Alps region, a high number of business tourists, and access to Parisian services market. Macon has experienced a small growth of businesses and increase in employment, but it was mainly due to business relocations within the Saône-et-Loire department and not from Paris or Lyon. Le Creusot gained neither jobs or commercial growth

following the opening of the connection. The significantly high levels of new trips generated by TGV have contributed to the economic development of the connected regions; however, it was mainly a result of redistribution of economic activity from cities with no HSR to the cities with HSR station. *The increase in the one-day tourism trips and decrease in overnight stays as well as the growth in intra-organizational business trips between Paris and Lyon attest to the fusion of these two cities into one daily activity zone, i.e. megalopolis* (see Figure 6 in Annex A).

Germany’s Cologne-Frankfurt Corridor. The findings and evidence from the existing studies lead us to conclude that smaller cities Montabaur and Limburg, previously not connected to conventional rail, were affected positively as a result of improved proximity to the major centers of Frankfurt and Cologne. *Daily commuting trips from Montabaur and Limburg to Frankfurt have increased since the ICE line opening, thus bringing these cities closer and integrating them into a megalopolis.* This increase is due to increased residential inflow to Montabaur and Limburg, which has been attracted partly by the new ICE access. There is no evidence of a megaregion formed between Siegburg and Cologne as the traffic increase originating in Siegburg is not significant and the trips are mostly taken in direction of Frankfurt, and not as much to Cologne. Frankfurt has benefited more than Cologne by attracting more commuters, which can be explained by its much larger labor market compared to Cologne’s. However, residences relocating from Frankfurt to Montabaur and Limburg count not as new employment and growth but rather as reallocated economic activity. There is no evidence found supporting the formation of a megalopolis between Frankfurt and Cologne. The increase in travel on this O-D pair comprises mostly those traveling to Frankfurt airport, and not to the city center. This may be explained by the limited business interactions between the two cities, given the differences in their dominating economic activities: Cologne is a cultural center while Frankfurt is a center of finance and banking (see Figure 7 in Annex A).

Role of Induced Demand

Drawing from the experiences of Japan, France and Germany, on the national level HSR may play a *catalyst role* resulting in new growth, or a *redistributive role* resulting in relocation of economic activity within the corridor, which amounts to zero-sum growth.⁶⁸ The HSR-linked areas become more attractive relative to the unconnected areas leading to relocation of residents and businesses. If the induced traffic is driven from within the relocated population or businesses, the growth it leads to would be at the expense of cities that lost its population, i.e. *relocated (or redistributed) growth*. Both the Paris-Lyon and Cologne-Frankfurt HSR corridors generated induced demand of about 50%; however, some of it has been a

⁶⁸ Pol, P. M. J. 2003.

result of an inflow of businesses and residents relocating from other parts of the country to the more attractive cities with HSR stations. Thus, on the national level the economic growth was redistributed, at least in part.

Theoretically, net growth may happen when high-speed line *induces* substantial levels of new travel demand, i.e. changing the travel patterns of people who otherwise would not have traveled the longer physical distances, but will because of the improved accessibility, mobility and lower travel time offered by HSR. Computing this net growth is difficult as there are a number of other factors that may have greater impacts on growth than HSR. The new traffic induced from within the city (excluding those who relocated to the city from other areas) creates new demand for services and hence contributes to the development of new businesses to accommodate this new demand. The development of new businesses creates new employment opportunities, which in turn contributes to creation of more new traffic.

Potential for Megalopolis Formation along Portugal's Lisbon-Porto Corridor

Portugal intends to deploy HSR on the 297 km (185 miles) Lisbon-Porto corridor in 2015 (although likely postponed in light of the financial crisis), eventually offering non-stop travel between the two cities of 1 hour 15 minutes, while also serving the four smaller intermediate cities of Oeste, Leiria, Coimbra, and Aveiro. Below we focus on analyzing the potential of megalopolis formation on the planned HSR corridor between Lisbon and Porto, the country's two biggest cities.

Lisbon-Porto corridor already has well-developed conventional rail connections. It is currently served by two types of rail services: Alfa Pendular, an upgraded to high-speed conventional line (2 hours 45 minutes) and conventional service (3 hours 15 minutes). Alfa Pendular's service frequency from Lisbon and from Porto is 11 trains per day, with only 2 making all intermediate stops.⁶⁹ This existing rail network uses non-standard 1,668 mm gauge tracks, while the new high-speed lines are planned to be built to the international standard 1,435 mm gauge to ensure high speeds and compatibility with the EU HSR network.

The temporal distances between the cities planned to be connected by the new Lisbon-Porto HSR line will be reduced significantly relative to travel times by any currently available mode of transportation. The high speed link would shrink the entire 297 km (185 miles) corridor within the limits of 90-minute travel time, making it a zone of one-day activity and potentially forming a megalopolis. Figure 8 visualizes the time-space distances by mode from Lisbon.

A megalopolis may emerge along the corridor as a result of increased interaction between the cities in two different ways as was observed in the case studies discussed earlier. Applying the same logic, we offer the three possibilities of

potential megalopolis formations along the future Lisbon-Porto HSR corridor: (1) megalopolis forming between two main end cities (Lisbon- Porto); (2) megalopolis forming at one of either ends of the HSR routes or both simultaneously (Lisbon-Oeste-Leiria and Porto-Aveiro-Coimbra); and (3) emergence of combinations of both cases in (1) and (2) simultaneously creating a "hybrid megalopolis" (see sketches of various combinations in Figure 9 of Annex A). A fourth possibility is for no megalopolis to form. Since the Lisbon-Porto corridor already has well-developed rail services, the incremental impacts from increased speed on most of the cities may be very small. With no induced traffic or no changes in the travel patterns, no increase in the interaction between the cities may take place, and thus no fusion of multiple cities and formation of a megalopolis may happen. Of course, the absence of megalopolis does not imply the absence of economic development. Growth may still occur, just without major changes in the spatial structure of cities and interaction between them (e.g., Montabaur and Limburg in Germany).

Regional Development Effects on Urban Areas

For the cities connected to HSR line, accessibility increases, and with even greater magnitude for smaller cities than for large cities, as the latter already have good accessibility levels. The question, however, is not whether accessibility improves for small cities, but rather, what does that accessibility mean for the economic activity, labor markets, and distribution of growth.

The three case studies confirm the theory of Pol (2003) that "new forms of infrastructure" such as HSR "tend to be constructed where there is already much interaction" and "the most intensive interaction occurs among economic key areas", usually capital cities.⁷⁰ In all three cases, the decisions to construct the high-speed lines were made mainly to solve limited capacity issues on the existing corridors with high demand for accessibility, and in two cases (Japan and France) capital cities were the first to be connected, while smaller urban areas were connected as intermediate stops in part due to political pressures. Germany's internal geopolitics such as reunification between East and West Germany with different capitals and the historical presence of several major urban economies led to a more dispersed network of HSR lines.

In all three cases, the cities with already "strong competitive positions"⁷¹ and consequently stronger economic potential have benefited more than smaller urban regions did. This is also in line with Pol's theory that HSR's "influence on urban areas" depends on the pre-existent "economic potential of an urban region". The same theory expects HSR will have a "catalytic" effect on cities with lower economic growth, and a "facilitating" effect on already economically prosperous cities. However, based on the case studies, the "catalyzing effect"

⁶⁹ Comboios de Portugal, Official Website. 2010.

⁷⁰ Pol, P. M. J. 2003.

⁷¹ Ibid

(i.e., development of new activities in an urban area) leads to net economic growth on a city level, but on a national level this growth usually occurs at the expense of other urban areas. Hence, the HSR may have a third type of effect on the national economy – a redistributive effect.

Minimizing Negative Effects of HSR on Small Urban Areas

Cities not connected to the HSR will be the worst off by potentially losing their businesses, labor market and population to the cities with HSR stations. The impacts of HSR on smaller cities located at intermediate stops may vary, with some benefiting, some losing, and some remaining the same. Based on the case studies discussed in this paper, the following factors and strategies for HSR deployment can lead to a higher likelihood of benefits for small urban areas not connected to the network.

Compatibility with conventional rail system.

Compatibility of the TGV with the conventional rail system has allowed a greater area of reach of TGV trains to the remote areas without the need to invest in high-speed track extensions. For example, TGV trains may reach some remote areas in France without traveling through Paris. Given the differences with the gauge size of conventional track, Japan's Shinkansen was integrated with the conventional rail through allowing stations to be shared by both high-speed and traditional trains. This structure ensures provision of *feeder services* to HSR stations from cities not connected to HSR, and the track does not have to be compatible. Portugal plans to integrate the Lisbon-Porto HSR line with the existing conventional rail network by designing the stations to accommodate both high-speed and conventional trains, specifically the stations in Lisbon, Leiria, Coimbra, and Porto, so that easy connection and transfer between two types of services is allowed. In addition, flexible-gauge vehicles will be purchased which can take advantage of changeovers, which are planned for installation near stations in Aveiro, Coimbra, Porto and Lisbon, to allow the circulation of high-speed and conventional trains in both networks. If Portugal implements these measures, the potential negative effects on the small urban areas may be minimized. The integration of HSR with the conventional network would also generate greater passenger traffic through a network effect.

Frequent stops at intermediate stations. The increased frequency of stops of HSR service at intermediate stations would contribute to regional development and reduction of regional disparities by more equally distributing the benefits of HSR to the smaller urban areas located in between the major centers. However, increasing frequency will lead to lower average speeds, and consequently lower capacity and longer travel times. This in turn may make HSR less competitive with other modes, especially with air, resulting in little change in accessibility and mobility, limited generation of new traffic,

especially for business purposes, and consequently suppress the overall development benefits that high-speed rail may yield. Therefore, frequency is an important factor for achieving economic development impacts and for ensuring the more equitable distribution of these impacts to smaller urban areas. The trade-off has to be made to balance these two goals.

Adequate access to other modal connections. Integrating HSR with other modal services is an important factor in improving regional access and maximizing accessibility changes driven by HSR lines: these include, for example, direct linkages with urban transit systems and airports in major cities.

According to Vickerman (1997), HSR is considered an “intermediate level” mode as it serves inter-city trips, and its impacts depend on how well it is connected to local “lower level” (e.g., parking, road, transit, other local transportation, etc.) and to international “higher level” (e.g., international airports) networks. Therefore, provision of adequate access from HSR nodes to other modal networks is critical. No matter how fast the HSR network is, “for firms and individuals in the region, the critical factor will be how easy it is to access that network”,⁷² especially, in case of peripheral station locations. Similar to conventional rail feeder services, other modes may extend the HSR's service area to cities not connected to HSR without the need to build high-speed track extensions.

CONCLUSIONS

As concerns for climate change grow and demands for fast and sustainable transport alternatives increase, high-speed rail networks will continue to expand worldwide. This will call for a need to better understand the role HSR may play in changing people's travel patterns and forming new economic geographies of cities – megalopolises or megaregions – and how economic development effects of HSR may be distributed within these new geographies.

A rich literature exists on HSR and there is a general consensus among researchers about the possible range of development impacts of HSR investment, including impacts on spatial location of economic activity, accessibility and proximity to economic mass, labor markets, and productivity. However, the question of the causality between HSR investment and economic growth still remains because of the complexity of this relationship and long period of time needed for the growth effects to realize, during which other factors are at play. Below, we present our main conclusions drawn from the case studies with respect to potential for megalopolis formation and development implications of HSR:

HSR investment is associated with potential changes in accessibility and market size, as a result of reduction in travel time and transportation costs, which in turn may lead to economic and functional integration of multiple urban areas by fusing them into a megalopolis. The emergence of a

⁷² Vickerman, R. 1997.

megalopolis or multiple megalopolises may occur in different forms as a result of accessibility and proximity to larger markets brought about by HSR. For example, in both Tokyo-Osaka Shinkansen and Cologne-Frankfurt ICE corridor case studies, a megalopolis formation is observed between one (or both) of the large cities at the two ends of the corridor and several small intermediate cities in between. In the case of Paris-Lyon TGV line in France, a megalopolis has emerged between Paris and Lyon connected at two ends of the route, while the smaller urban areas in between have not been integrated. The emergence of all these megalopolis forms simultaneously could potentially create a “hybrid megalopolis”, although it has not been observed in any of the case studies.

The economic growth stimulated by HSR is not uniformly distributed within a megalopolis, resulting in winners and losers. HSR through the megalopolis formation contributes to *economic development*. It may either spur new growth (catalytic role), or contribute to *economic shifts* through relocation of economic activity within the corridor (redistributive role), which may imply some growth, no growth or even negative growth for some. The spatial distribution of any growth is non-uniform, which may essentially lead to urban areas that win at the expense of other areas.

Role of induced traffic in the generation of economic growth is critical. The formation of a megalopolis seems to be driven mainly by the generation of more travel for commuting, business, leisure or other purposes. New growth is more likely to take place when HSR *induces* substantial levels of new demand by changing travel behavior of those who would not have traveled otherwise. However, if the induced traffic is driven from within the population and businesses that relocated from other areas, the growth it leads to could be redistributed at the expense of cities that lost economic activity and population.

The way that the urban areas are impacted by the new HSR is related to pre-existing conditions in the cities before the high speed connection. Case study findings have shown that cities with a strong economic base before the HSR construction seem to benefit from the HSR the most, while cities with smaller economies gain to a lesser extent or not at all. HSR tends to favor urban areas with service and information exchange industry foci and less manufacturing and agriculture oriented areas. Other pre-existing factors that may maximize HSR’s positive impacts are compatibility with the conventional railway, inter-modal connectivity, tourist attractions, and station location in the city center. Cities not connected to HSR line directly are the biggest losers from this development, especially if they are not linked to HSR by conventional feeder services.

Megalopolises or megaregions present the need for planning on a new spatial scale with new boundaries and linkages; and HSR links may be used to shape the direction of megalopolises within Portugal. Knowing the impacts of

HSR on development can help to shape appropriate strategies within a megalopolis, for example in Portugal and in the US. For example, “the implementation of climate change strategies and programs” can be addressed more appropriately within the megalopolis “framework”.⁷³ Moreover, since transport infrastructure investments such as HSR are essential in linking the urban areas into a megalopolis or megaregion, planning transport links may be used to shape the direction in which megalopolises are developed, specifically with respect to ensuring the development of the intermediate urban areas located in between the main stops, and urban areas not directly connected to high-speed lines. This includes the planning of station locations, inter-modal connections and frequency of HSR service that may minimize the negative or redistribute development effects of HSR within the megalopolis.

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NOMENCLATURE

A3	Autobahn 3
AF	Alfa Pendular
CB	Deutsche Bahn
CBD	Central Business District
CEF	Chubu Economic Federation of Japan
EHEZ	“Extra Huge” Economic Zones
HSR	High-speed rail
HST	High-speed trains
IC	Inter-City
ICE	Inter-City Express
LGV	Ligne à Grande Vitesse
RE	Regional Express
SNCF	Société Nationale des Chemins de fer Français
TGV	Train à Grande Vitesse

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ANNEX A

FIGURES

FIGURE 1: TIME-SPACE CHART FOR COMMUTING TIMES FROM/TO TOKYO BY MODE

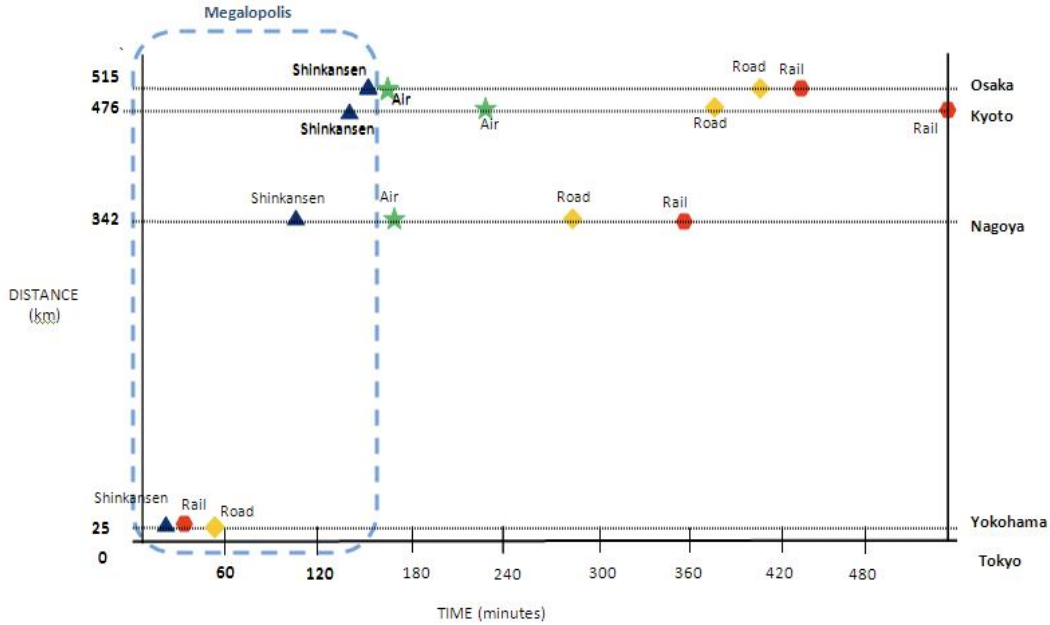
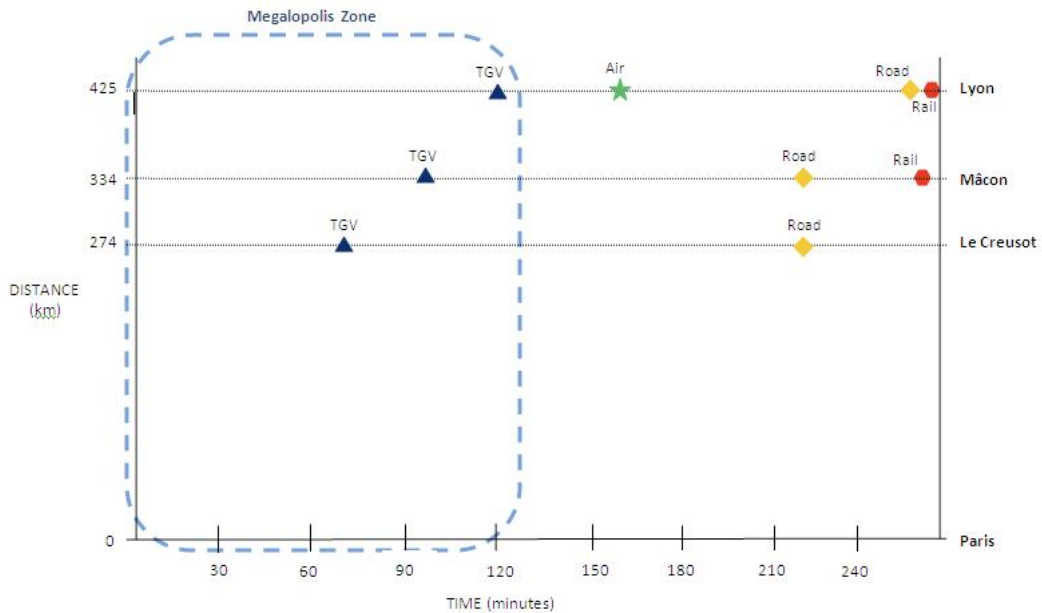


FIGURE 2: TIME-SPACE CHART FOR COMMUTING TIMES FROM/TO PARIS BY MODE



- Notes:**
- Rail is for conventional (regional and inter-city) trains.
 - No air services available to Macon and Le Creusot.
 - No direct TGV service is available between Macon and Le Creusot.
 - No direct conventional rail link available between Paris-Macon. No conventional rail service runs between Le Creusot and Paris, and between Le Creusot and Lyon. Travel by conventional rail between Paris and Macon involves at least one transfer (via Dijon). Conventional trains serve Macon Centre station in Macon, which is different from the TGV station Macon-Loche.

FIGURE 3: TIME-SPACE CHART FOR COMMUTING TIMES FROM/TO FRANKFURT BY MODE

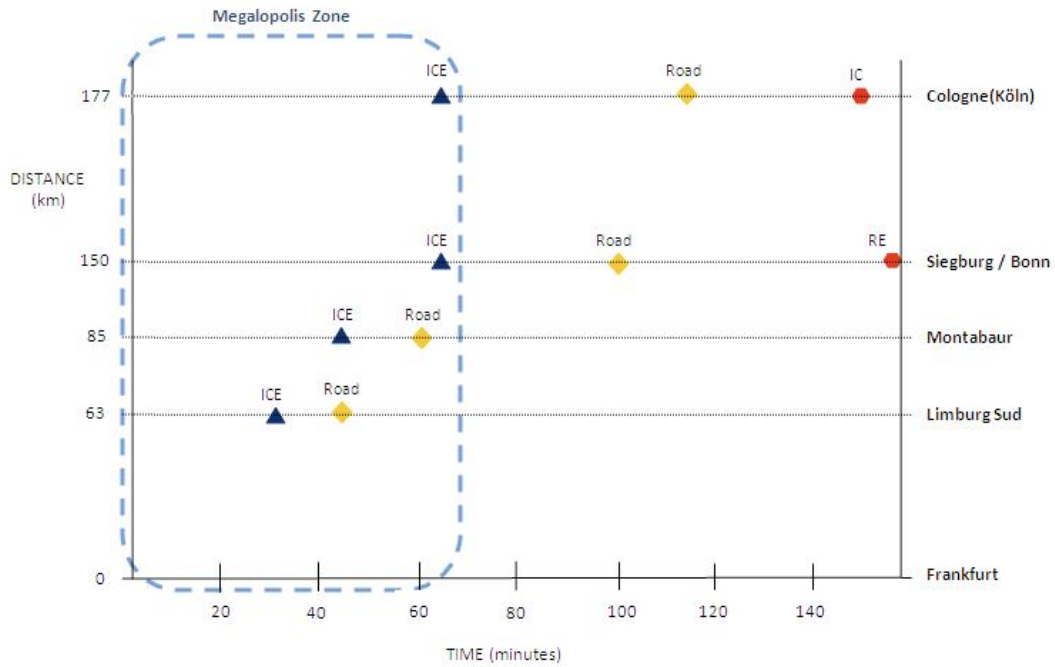


FIGURE 4: FUNDAMENTAL CHAIN OF DEVELOPMENT IMPACTS OF HSR THROUGH MEGALOPOLIS FORMATION

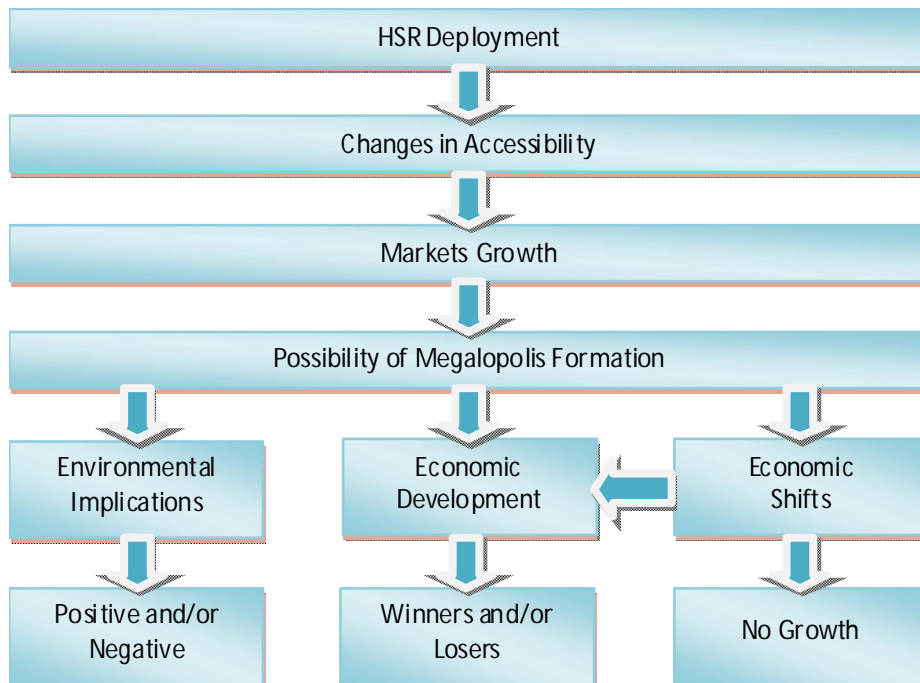
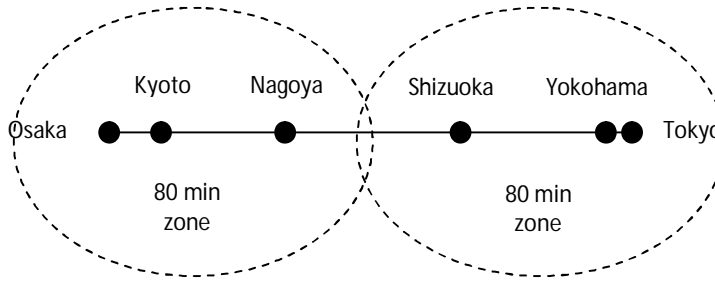


FIGURE 5: JAPAN MEGALOPOLIS FORMATIONS: TOKYO-OSAKA HSR CORRIDOR



Megalopolis 1: Tokyo-Yokohama-Shizuoka

Megalopolis 2: Osaka-Kyoto-Nagoya

Gains: Tokyo, Osaka, Yokohama, Kyoto

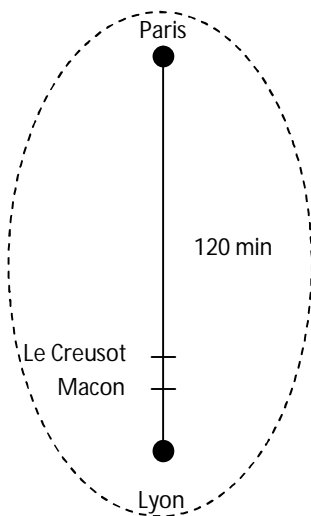
No impacts: Shizuoka (Shizuoka is served by Hikari Slower and less frequent trains)

Losses: Nagoya, cities outside of Shinkansen network

	Tokyo	Yokohama	Shizuoka	Nagoya	Kyoto	Osaka
Frequency (trains/day)	173	173	66	173	173	173
Station served by conventional rail line	Yes	No	Yes	Yes	Yes	No
Connection to airport	No	No	No	No	No	No
Primary industry sector focus	Services	Shipping, Biotech	Services	Manufacturing	IT/Tourism	Services

Source: sketched by the authors based on the case study research findings (drawn not to scale).

FIGURE 6: FRANCE MEGALOPOLIS FORMATION: PARIS-LYON HSR CORRIDOR



Megalopolis: Paris-Lyon

Gains: Paris, Lyon, Macon

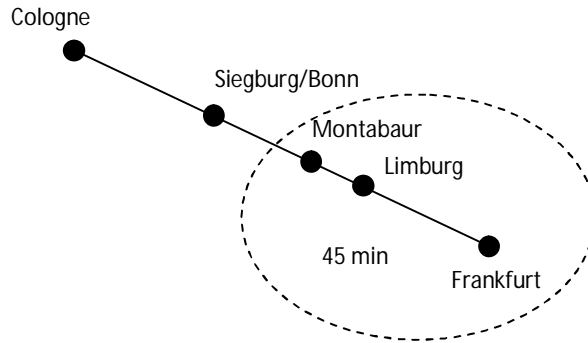
No impacts: Le Creusot

Losses: cities not connected to TGV

	Paris	Le Creusot	Macon	Lyon
Frequency (trains/day)	38-46	8-10	5-8	38-46
Station served by conventional rail line	Yes	No	No	No
Connection to airport	Yes	No	No	Yes
Primary industry sector focus	Services	Metallurgy	Shipping, Metallurgy	Services/R&D

Source: sketched by the authors based on the case study research findings (drawn not to scale).

FIGURE 7: GERMANY MEGALOPOLIS FORMATION: COLOGNE-FRANKFURT HSR CORRIDOR



Megalopolis: Frankfurt-Limburg-Montabaur

Gains: Frankfurt, Montabaur, Limburg

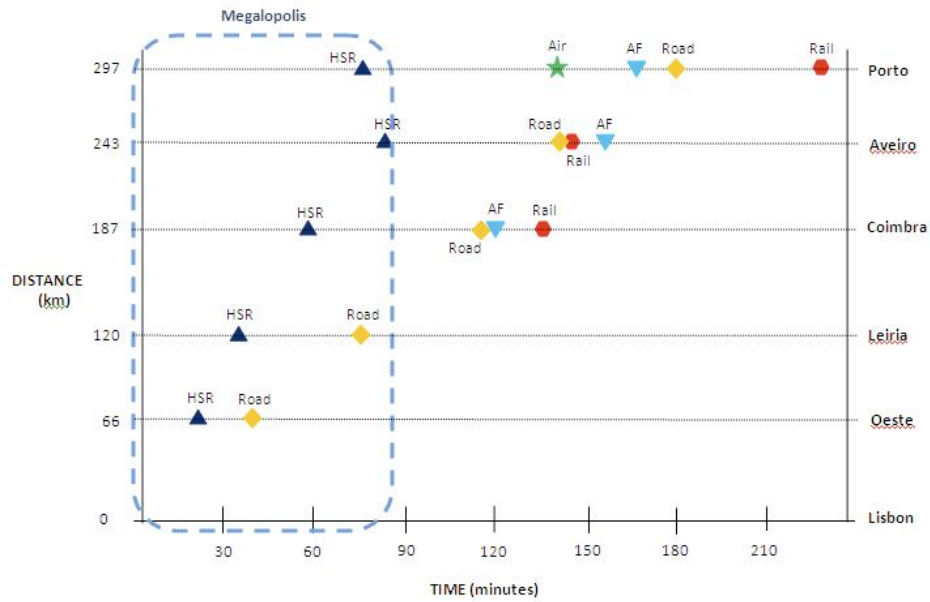
No impacts: Cologne, Siegburg

Losses: cities not connected to ICE

	Frankfurt	Limburg	Montabaur	Siegburg/Bonn	Cologne
Frequency (trains/day)	32-33	14-15	14-15	14-15	32-33
Station served by conventional rail line	Yes	No	No	Yes	Yes
Connection to airport	Yes	No	No	No	Yes
Primary industry sector focus	Services	Services	Services	Services	Arts, media, manufacturing

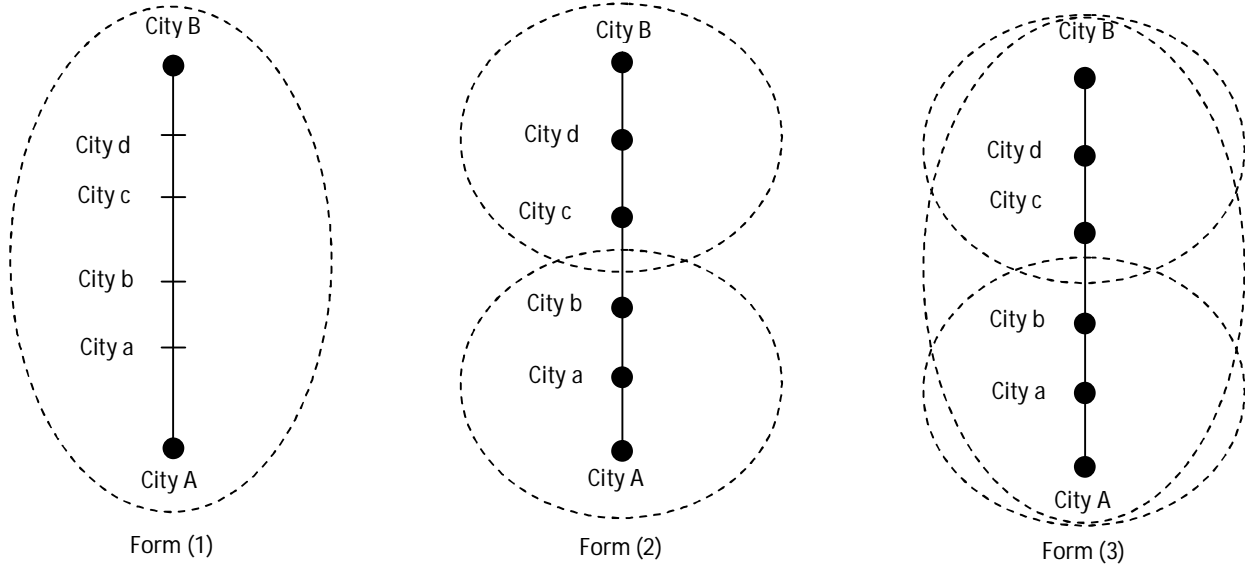
Source: sketched by the authors based on the case study research findings (drawn not to scale).

FIGURE 8: TIME-SPACE CHART FOR COMMUTING TIMES FROM/TO LISBON: EXISTING MODES AND HSR



Note: AF – Alfa Pendular; Rail – conventional intercity services.

FIGURE 9: POSSIBILITIES OF MEGALOPOLIS FORMS



ANNEX B

TABLES

TABLE 1: GROWTH OF BUSINESS TRAVEL (1980-1985)

	Mode		Trip Origin		Overall
	Train	Airplane	Paris Region	Lyon Region	
Growth Rate	151%	-46%	20%	86%	56%

Source: Roth, D. 1990. The TGV System: A Technical, Commercial, Financial and Socio-Economic Renaissance of the Rail Mode. Department of Systems, University of Pennsylvania, Philadelphia, PA.

**TABLE 2: COLOGNE-FRANKFURT CORRIDOR TRAFFIC MARKET SHARES BY MODE & TRIP PURPOSE (%):
BEFORE AND AFTER**

Before the ICE (2001)

Trip Purpose	Rail	Air	Road	Total
Business	12.7	0.7	31.3	44.7
Private	29.5	0.0	25.8	55.3
Total	42.2	0.7	57.1	100.0

After the ICE (2005)

Trip Purpose	Rail	Air	Road	Total
Business	29.4	0.0	36.5	65.9
Private	36.8	0.0	29.2	65.9
Total	66.2	0.0	65.7	131.9

Note: Percentages are presented relative to year 2001.

Source: Deutsche Bahn AG. Matrix Analysis by Martin Thust of DB AG. Provided on 04/15/2010.

TABLE 3: HSR CORRIDORS COMPARISON BY COUNTRY

	JAPAN Tokyo-Osaka Link (actual)	FRANCE Paris-Lyon Link (actual)	GERMANY Cologne-Frankfurt Link (actual)	PORTUGAL Lisbon-Porto Link (expected)^a
<i>Main Corridor Characteristics</i>				
Date of Completion	1964	1981	2002	2015
Route Length (km & miles)	515.4 km (343 miles)	425 km (264 miles)	177 km (110 miles)	297 km (185 miles)
Current top operating speed (km/h & mi/h)	270 km/h; (168 mi/h); 210 km/h (130 mi/h) initially	300 km/h (186 mi/h)	320 km/h (199 mi/h)	300 km/h (186 mi/h)
Technology type (trainsets)	Shinkansen	TGV	ICE	TGV
Travel time between route end points (direct service)	2 hours 25 min (4 hours before 1992)	2 hours	1 hour 10 min	1 hour 15 min
Newly built line or upgrade	Newly built	Newly built	Newly built ^b	Newly built
Primary motivation	Increase corridor capacity	Increase corridor capacity	Increase corridor capacity	Increase corridor capacity
Compatibility with conventional rail (track and trains)	Non-compatible (“exclusive exploitation model” ^c)	Compatible HST (“mixed high-speed model” ^c)	Non-compatible (“exclusive exploitation model” ^b)	Non-compatible (“exclusive exploitation model” ^c)
Non-mixed use dedicated track or shared with freight/conventional trains	Non-mixed use passenger dedicated	Non-mixed use passenger dedicated	Non-mixed use passenger dedicated ^b	Non-mixed use passenger dedicated
Number of intermediate stops	4 (Nozomi trains) 8 (Hikari trains)	2 (Le Creusot, Macon)	4 (Siegburg/Bonn, Montabaur, Limburg, FRA Airport)	4 (Oeste, Leiria, Coimbra, Aveiro)
Cities with stations shared with conventional trains (regional/intercity)	All except Yokohama and Osaka	Paris only	Frankfurt, Cologne, Siegburg/Bonn	Lisbon, Leiria, Coimbra, Porto
Financing sources for construction	World Bank loan and Japanese government	French government	EC initiative grant, German government	EU, EIB loan, private sector (PPP), government
Frequency of least stops service per day	173 (4 stops)	30 (0 stops)	18 (1 stops)	TBD
Frequency at intermediate stops per day	173 (4 stops) ^d	8 (1 stop only)	14-15 (4 stops)	TBD
<i>Observed Effects</i>				
Air/Rail market share	85% rail, 15% air	90% rail, 10% air	100% rail, 0% air	
Ridership per year by HSR	150 million	20 million	9 million	
Level of induced demand	High	High (49%)	High (~50%)	
Development impacts (zero sum or net growth) on national scale	Zero sum	Zero sum	Zero sum	

Notes:

^a All decisions for Portugal have been made and are not changeable, except for frequencies.

^b German strategy to HSR deployment is generally by upgrading conventional line and tracks are generally shared with freight and conventional trains (“fully mixed model” according to Campos et al., 2007); Cologne-Frankfurt line was the first newly constructed HSR link with dedicated track not shared with freight or conventional trains.

^c According to Campos et al. (2007) models.

^d Japanese fastest HSR service between Tokyo and Osaka (Nozomi trains) stops at least at four intermediate stations. The second fastest service (Hikari trains) makes eight intermediate stops, and the slowest service (Kodama trains) – 15 stops. For comparison purposes above, we are considering the fastest Nozomi train services only.