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Assessing the Economic Impact of High Speed Rail: Focus on Manufacturing

Final Report

HIGH-SPEED RAIL MARKETS, INFRASTRUCTURE INVESTMENTS AND MANUFACTURING CAPABILITIES

By

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HIGH-SPEED RAIL MARKETS, INFRASTRUCTURE INVESTMENTS AND MANUFACTURING CAPABILITIES

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1. INTRODUCTION AND BRIEF OVERVIEW OF ISSUES

Driven by increasing demand for passenger transportation and congestion in key corridors in the U.S., such as in California, the Northeast, Florida and parts of the Midwest, the U.S. has embarked on various initiatives to examine alternative solutions to this important problem. One of the initiatives relates to the possibility of either introducing or considerably upgrading high-speed rail (HSR) services. In this report, I focus on this initiative and conduct a detailed study of the HSR industry to provide guidance for policy.

The need for new transportation-related infrastructure investments is compelling due to the increasing volume of passenger traffic, and the highly congested state of roads and airports in the key business and passenger corridors in the U.S. One of the contentious issues with HSR investments has been its considerable costs. Given this, any HSR investments call for a careful assessment of its benefits and costs. While the costs are relatively high and transparent, opinions differ considerably on the benefits that HSR investments and service will bring to the U.S. economy as a whole and to the specific corridors in question. Unfortunately there is no simple answer to the calculation of benefits. This is because of the fact that the benefits that may accrue to the domestic economy from HSR investments depend on a wide range of factors such as: the exact route and end-points of service; the distance covered; the presence of local mass-transit systems at the end-points of service as well as at intermediate stops; the specific HSR speeds chosen and the average speed en route; the number of stops; whether the various components can largely be manufactured in the U.S. or do they have to be imported; the existing conditions on road and air traffic; the local and regional business and economic development that may occur due to the introduction of HSR; among others. About the only thing that is clear from this list is that it is extensive. This explains the widely divergent views on the actual benefits that HSR may bring to specific U.S. routes. Overall, the calculations of the net benefits of HSR are complex.

A somewhat different way of looking at the problem is to ask whether the rail service by itself needs to be profitable? Many ardent supporters of rail (and HSR) tend to argue that rail service by itself does not have to be held to a profit-making standard. This is because of the significant external benefits that may result from HSR-related infrastructure investments and the service. Some of these external benefits may accrue from the economic and business development, and growth, that may result. The critics, in effect, take a profitability standard for the rail investment and service alone. They question the assessment of benefits, arguing that they may tend to be low and highly uncertain, and this is traded-off against almost certain high costs. The critics, therefore, advise against HSR due to its potential loss-making characteristic.

The objective of this report is not to attempt to directly answer the questions or resolve the complex disagreements. The objective here instead is to gain a deeper understanding of the HSR industry which is dominated by prominent global players, and one where the U.S. currently has little or no comparative advantage due to the lack of this industry in the past. This however does not imply that the U.S. firms cannot develop expertise in specific areas, spur growth, and form profitable alliances and partnerships with the global heavyweights to meet the U.S. investments and services needs. To understand the core issues and potentially provide an answer to the overall HSR investment feasibility question, we need to study the international trainset suppliers, examine the components' supply-chain, the nature of contracts that have been observed in the recent past, the types of partnerships that have formed, do case studies of the economic and business development that have occurred in other countries, and then make an assessment of potential benefits that may accrue to the U.S. As noted above, the costs are somewhat clearer. Since the benefits picture is more uncertain and complex, I primarily focus on making an attempt to clarify some of the complexities that lie at the heart of the potential benefits question. This deeper understanding of the HSR industry may help formulation of appropriate HSR investment policies.

This report is organized as follows. In section 2 I take a quick look at the history of U.S passenger train industry. In section 3 I examine the potential need for new passenger HSR investments to meet growing demand for transportation and to alleviate congestion in several key corridors in the U.S. Next, in section 4, I describe the various high-speed rail categories, followed by a description of the specific types of investments needed for HSR. In sections 6 and 7, I turn to analyzing the complex and widely dispersed international HSR supply-chain, and examining the multiproduct nature of the firms in the HSR Industry.

The above-mentioned sections set the stage for examining various aspects of investments that the Government may need to make. With this in mind, in section 8 I examine the foreign firms' capabilities in the U.S., by taking a look at the major global players that have operations in the U.S. and their existing contracts in the U.S. In the next two sections I examine the nature of contracts and partnerships (section 9), including public-private partnerships (section 10), in international HSR markets.

The final four sections review some of the studies that shed light on the longer-run dynamic Effects of HSR Investments (section 11), the Buy America requirement for investing in the U.S. (section 12), obtain additional insights from the industry based on questionnaires and survey (section 13), and note some implications for U.S. HSR investments and manufacturing capabilities (section 14).

2. U.S. PASSENGER TRAIN HISTORY

In this section I briefly discuss the history of US passenger car builders, some of the newer foreign companies that have set up facilities in the US, US locomotive manufacturers, and a quick look at some areas where the US may have competencies in components manufacturing.

2.1 U.S. passenger car builders

Historically, the *American Car and Foundry Company* (ACF) built passenger and freight cars. One of the largest customers was Union Pacific, whose armour-yellow carbon steel lightweight passenger rolling stock was mostly built by ACF. The famous dome-observation car, Native Son, was an ACF product. Today, the American passenger car market is erratic in production, and is mostly handled by specialty manufacturers. Competitors such as Budd, Pullman-Standard, and St. Louis Car have all either exited the market or gone out of business. Currently, ACF builds mostly covered hopper cars for hauling items like corn or other grains. Other products are mainly miscellaneous steel products. ACF's manufacturing facilities are located in Huntington (West Virginia) and Milton (Pennsylvania).

The *St. Louis Car Company* was a major United States manufacturer of railroad passenger cars, streetcars, trolleybuses and locomotives, based in St. Louis, Missouri. The St. Louis Car Company was formed in April 1887, to manufacture and sell streetcars and other kinds of rolling stock of street and steam railways. St. Louis Car continued manufacturing until 1968 and finally ceased operations in 1973.

The *Budd Company* (now ThyssenKrupp Budd) was a metal fabricator and major supplier of body components to the automobile industry, and was formerly a manufacturer of stainless steel passenger rail cars during the 20th century. From the 1930s until 1987 the Budd

Company was a leading manufacturer of stainless steel streamlined passenger rolling stock for a number of railroads. The new name did not save the company, and on April 3, 1987, Budd ended all railcar production at its Red Lion plant in Northeast Philadelphia and sold its rail designs to Bombardier Transportation. Many of its engineers joined the staff of the Philadelphia office of Louis T. Klauder and Associates, a local railway vehicles and systems engineering consulting firm. When Thyssen merged with Krupp in 1999, Budd Thyssen became ThyssenKrupp Budd Co. in North America and ThyssenKrupp Automotive Systems GmbH in Europe. Late in 2006, its body and chassis operations were sold to Martinrea International Inc.[1]

The *Pullman Company*, founded by George Pullman, manufactured railroad cars in the mid-to-late 19th century through the early decades of the 20th century, during the boom of railroads in the United States. Pullman established his company in 1862 and built luxury sleeping cars which featured carpeting, draperies, upholstered chairs, libraries and card tables and an unparalleled level of customer service. Pullman developed the sleeping car which carried his name into the 1980s. Pullman purchased the Standard Steel Car Company in 1930 amid the Great Depression, and the merged entity was known as Pullman-Standard Car Manufacturing Company. The company ceased production after the Amtrak Superliner cars in 1982 and its remaining designs were purchased in 1987 when it was absorbed by Bombardier.[2]

Morrison-Knudsen was involved in the construction of rail projects such as the BART extension (M-K also built 80 C2 cars for BART) and the single track Apoera-Bakhuys railway in Suriname (1976–1977). It built the California Cars as well as other rail passenger cars and light rail. It also built locomotives, originally under its own name and later under subsidiary MK Rail from 1994–1996. M-K also rebuilt locomotives. In 1996, the

[1] http://en.wikipedia.org/wiki/Budd_Company
[2] http://en.wikipedia.org/wiki/Pullman_Company

Washington Group acquired Morrison-Knudsen Co., which was acquired by URS Corporation in May 2007.[3]

Turning to some of the foreign companies that have set up production facilities in the US, *Talgo* (Spain) has been successful in designing the trains, including many amenities, such as individual electric outlets for laptops, wheelchair lifts on ADA cars and individual audio-video outlets. Talgo's integral maintenance system also ensures high quality of the ride and reliability. In October of 1994, showcase runs of the Talgo rolling stock were performed for railway authorities and technical experts in Oregon, California, Missouri, Ohio, Pennsylvania, Massachusetts, New Haven and Maine. The contract with WSDOT was also renewed to continue the lease of the Talgo TP 200 trainset in the Pacific Northwest corridor. As the project proved to be very successful, in July of 1996 WSDOT and Amtrak placed an order to buy three new Talgo TPU™ trains (two WSDOT and one Amtrak) and to lease one additional train (Amtrak). A fifth trainset was manufactured at the same time as the four previously mentioned. This trainset was scheduled to enter service between Los Angeles, CA and Las Vegas, NV in early 2001, but was sold to WSDOT in 2003 and is currently in use on the Eugene to Portland, Oregon Corridor. So far, the operation of these trainsets has been a success. Ridership has continued to increase, travelling times have been significantly reduced, and the entire corridor has been revitalized.[4]

Bombardier Transportation (in cooperation with GEC Alstom, now Alstom, 25%) manufactured and designed the high-speed rail - the Acela Express - in North America for Amtrak from 1996 to 2000. Bombardier Transportation built the Horizontal Fleet coaches in Barre, Vermont, in 1989. Bombardier also supplies multilevel coaches that are in service in

[3] http://en.wikipedia.org/wiki/Washington_Group_International#Morrison-Knudsen_Co.
[4] http://www.talgoamerica.com/series6-amtracCascades.aspx

2006. Today, over 400 multilevel coaches are in operation at or on order with NJ TRANSIT and the Agence Metropolitaine de Transport of Montréal.[5]

2.2 Examples of U.S. locomotive manufacturers

General Electric provides locomotives for some old trains as well as new trains in the United States. GE-Transportation is the world's leading manufacturer of diesel-electric locomotives with more than 15,000 locomotives operating around the globe. At the same time, it is a chief provider of on-board and wayside signaling, communications, control and information systems. They are also the industry leader in service, maintaining an installed base of more than 8,000 locomotives worldwide.[6]

Electro-Motive Diesel, Inc. (EMD) is a wholly owned subsidiary of Progress Rail Services Corporation, a wholly owned subsidiary of Caterpillar Inc., that designs, manufactures and sells diesel-electric locomotives and diesel power engines worldwide under the Electro-Motive Diesel brand. EMD holds approximately 30 percent of the market for diesel-electric locomotives in North America, second to its only competitor GE Transportation Systems which holds the remaining 70 percent share of the North American market.[7] [8]

Wabtec (Westinghouse Air Brake Company merged with Motive Power Industries, Inc.) manufactures a broad range of products for locomotives, freight cars and passenger transit vehicles. The company also builds new locomotives up to 4,000 horsepower and provides aftermarket services.

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[5] http://us.bombardier.com/us/products_bt_projects.htm
[6] http://www.ge.com/products_services/rail.html
[7] http://www.webcitation.org/5stRTocRX
[8] http://en.wikipedia.org/wiki/Electro-Motive_Diesel

2.3 Examples of U.S. component makers

In this section we very briefly detail selected US component makers, including those that are in the area of electrical & electronic component. This will provide us with insights into some of the core items which could be produced in the US as it seeks to expand on rail transportation infrastructure and services. We return to this issue again in Section 13.

ITT Enidine Inc. manufactures the mechanical part for the rail system. The company offers the railway dampers, suspension damping and rail transportation products for each unique rail system. Supplying standard railway products such as friction snubbers, rebuildable dampers, rotary shock absorbers and more, customer specific applications are also available.[9]

ORX Rail produces wheel set for a wide range of rail transportation customers since 1979. From freight cars, locomotives, and light rail and heavy rail transit vehicles to industrial and historic cars, the ORX team crafts products with the same unwavering commitment and devoted work ethic, regardless of the size of the order. ORX is famous for providing the wheel set for the only America's high-speed trains, Acela Express.[10]

Besides offering the full trainset and locomotive, Wabtec also provides a wide range of components for railroad systems. For the trainset subsidies, Wabtec's production lines include pneumatic, hydraulic and electro-pneumatic brake equipment, car couplers and current collectors. Through the railroad subsidies, the company manufactures a broad range of components for locomotives and freight cars, including state-of-the-art electronic train-control systems. Wabtec also builds new environmentally friendly locomotives and provides aftermarket

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[9] http://www.enidine.com/
[10] http://www.orxrail.com/

services, such as locomotive overhaul and remanufacturing, and locomotive and freight car fleet maintenance.[11]

[11] http://www.wabtec.com/railroad/railroad_home.asp

3. POTENTIAL NEED FOR NEW PASSENGER HSR INVESTMENTS

In this section I briefly examine demand for transportation by taking a look at some data and information on existing and emerging patterns of congestion, and note how HSR investments may provide an alternative to congested roads and airports.

Urban areas worldwide are becoming increasingly larger and highly congested. The twentieth century witnessed the rapid urbanization of the world's population. As displayed in figure 3-1, the urban population increased dramatically from 1950 to 2010. The global proportion of urban population increased from a mere 13% in 1900 to 29% in 1950 and, according to the 2007 Revision of World Urbanization Prospects, reached 49% in 2007. Based on the projections, the proportion will reach almost 70% by 2050. During this process, cities are reaching unprecedented sizes and the number of megacities is rising across the globe.

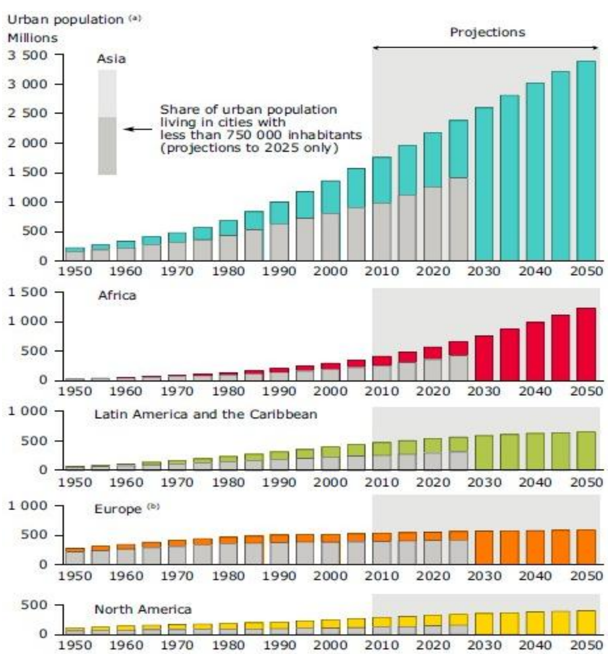

Figure 3-1: Urban population trends[12]

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[12] Source: UN population division (2010).

The growth of population and businesses during the urbanization process generates significant demand for transportation. According to figure 3-2, traffic congestion is positively correlated with the urban population size. Depending on the locations, passenger transit between urban areas depends on road, air and rail travel. Within a country, for cities which are relatively far apart from each other, such as Atlanta and New York or Beijing and Shanghai, air transportation is the more efficient and preferred mode of travel. For metropolitan areas that are not too far away, such as Washington D.C.-NYC or San Diego-Los Angeles, multiple modes of travel are feasible. Therefore, depending on proximity, we can get greater demand for all three modes of transportation or specific ones such as road or air. Due to growing urban populations and high demand for transportation, transportation by air and roads is increasingly suffering from severe congestion and delays.

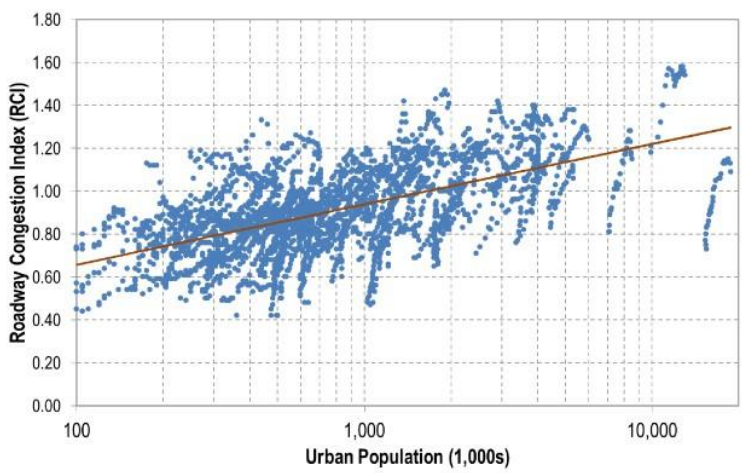

Figure 3-2: Population size and Roadway Congestion Index[13]

[13] Source: Texas Transport Institute, "The Urban Mobility Report." The Roadway Congestion Index (RCI) is a congestion measure developed by the Texas Transportation Institute and applied to a sample of 101 American cities on a yearly basis since 1982. The RCI measures the density of traffic across an urban area in relation to the overall capacity of the transport system to support it. A value around and above 1 is indicative of recurring congestion levels.

Road congestion is a worldwide problem due to traffic growing at a faster rate than road capacity. Road congestion results in significant costs due to wasted time and fuel costs. According to TTI (1999), more than 31% of urban freeways in the US are congested and is becoming worse every year. Figure 3-3 shows that 63% of travel during peak hours is congested. As expected, traffic congestion is worse in very large urban areas – 75% of travel in very large urban areas experienced congestion in 2005, compared to 28% in small urban areas. Many European (figure 3-4) and Asian countries are also experiencing severe traffic congestion. Besides congestion, air pollution and fuel prices may impose constraints on future car use and necessitate development of alternative modes of transportation.

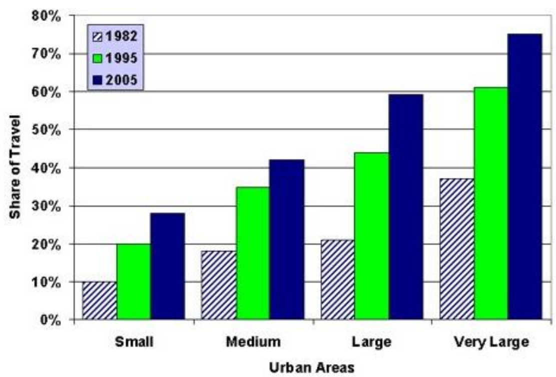

Figure 3-3: Share of travel in congested area[14]

[14] Source: Texas Transportation Institute (1999). The area definitions are as follows: Small Urban Areas – Less than 500,000 population; Medium Urban Areas – Over 500,000 but less than 1 million population; Large Urban Areas – Over 1 million and less than 3 million population; and Very Large Urban Areas – Over 3 million population.

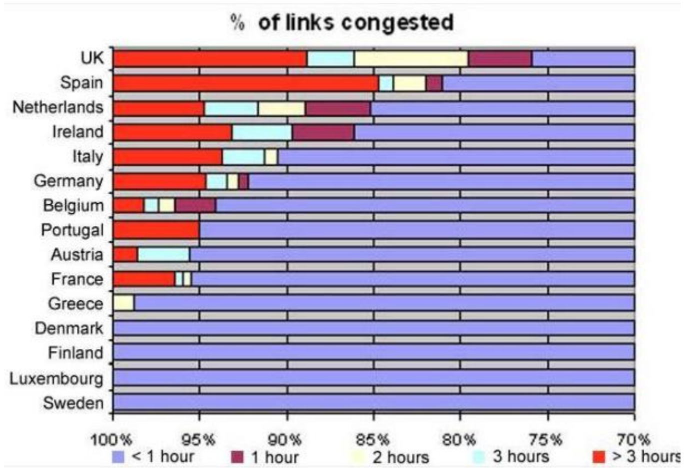

Figure 3-4: Road congestion worldwide[15]

Air traffic has become increasingly popular because of the maturation of the air travel industry, better hub-and-spoke networks, and the decline in prices in real terms since the 1970s (US Department of Transportation, 1997). As with roads, the expansion of air traffic has far outpaced the growth in airport infrastructure capacity and this imbalance between demand and capacity has led to significant air traffic congestion and flight delays. As demonstrated in figure 3-5, there are significant delays caused by the congestion in many U.S. airports. Lee et al. (1997) predicted an increase of 78 million minutes of delay for U.S. air travel between 1996 and 2005, and another 33 million minutes by 2010. The air-traffic capacity is limited due to the constraints on runway (spacing between the planes for safety), gate availability and air-traffic control. For most cities, like London, which is already highly congested with very little scope for airport expanding, continued expansion of airports is expensive and sometimes infeasible.

[15] Source: UN population division (2010).

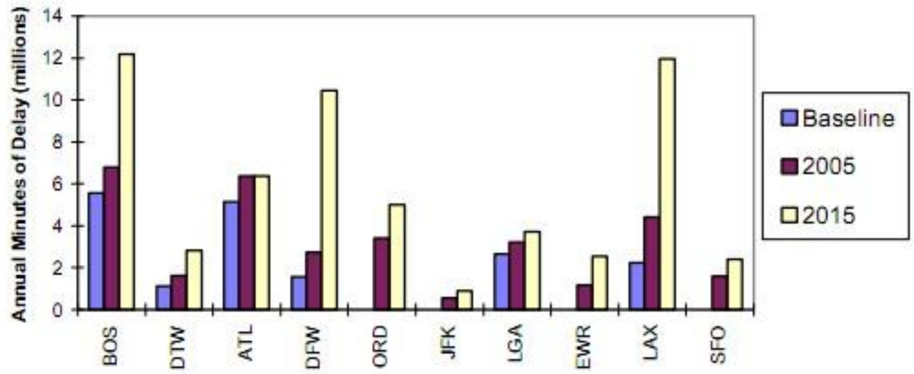

Figure 3-5: Airport delay forecast for several of the busiest US airports[16]

As has been noted in many studies, congestion can produce significant costs and negative externalities. Congestion results in queuing, slower speeds and increased travel times, which impose costs on the economy and generate multiple impacts on urban regions and their inhabitants. Congestion also has a range of indirect impacts including the environmental and resource impacts of congestion, impacts on quality of life, stress, safety as well as impacts on non-vehicular users such as the users of sidewalks and road frontage properties.

The significant projected increase in urbanization, marked increases on road and air traffic congestion, and resulting direct and indirect congestion costs calls for infrastructure investment in complementary and efficient modes of transportation such as high-speed rail.

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[16] Source: Kostiuk, Gaier and Long (1998).

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4. HIGH-SPEED RAIL CATEGORIES

In this section I discuss the various high-speed train categories, examine benefit and cost aspects of the investments, and provide a perspective of some of the U.S. markets where the services either exist or were/are planned.

4.1 Definition

There is no single definition for high speed in the context of rail services. Usually, HSR can be subdivided into the following categories in terms of overall speed:

1. High-speed Rail (HSR), with speeds of 125-155 mph on upgraded track;
2. Very High-speed Rail (VHSR), with speeds of 155-220 mph on dedicated track; and
3. Maglev, with speeds of 200-300+ mph in German or Japanese versions.

The HSR and VHSR trains use steel wheel on steel rail technology, while the Maglev uses the magnetic levitation technology. In this section, we only study the first two types and don’t discuss the Maglev.

HSR presents a challenging tradeoff: while the increased speed makes the HSR more competitive (e.g., against air travel), this comes at the expense of significantly greater investment and construction costs. As a result, the chosen speeds of HSR and the investments incurred tend to be based on a mix of budgetary constraints faced by Governments and the distance of the trip. For example, for trip distances above 300 miles, maximum speed above 185 mph may be needed to maintain competitive times relative to air transport. However, for shorter distances a maximum speed in the range of 125-155 mph may be adequate to win sufficient market share without the additional costs of attaining very high speeds.

HSR is designed for different purpose. HSR with top speed of at least 150 mph on completely grade-separated, dedicated rights-of-ways (with the possible exception of some shared track in terminal areas) is called HSR-Express. It is designed for the frequent, express, service between major population centers 200-600 miles apart with few intermediate stops. It is ideal for relieving air and highway capacity constraints.

HSR with top speeds of 110-150 mph, grade separated, with some dedicated and some shared track (using positive train control technology) is called HSR-Regional. It is designed for relatively frequent service between major and moderate population centers that are about 100-500 miles apart, with some intermediate stops. This is ideal for relieving highway congestion and, to some extent, air capacity constraints.

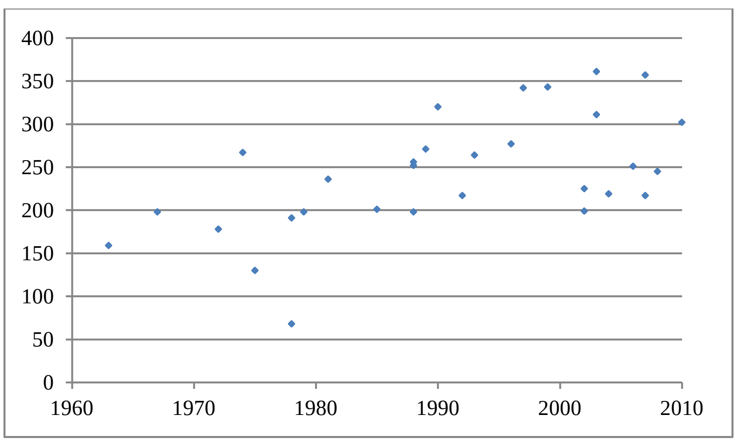

Figure 4-1: Records Speed (mph) in trial runs[17]

Figure 4-1 is the record speed of the high speed rail in different countries. From the figure, we can see that there is an increasing trend in speed over the past 50 years. The speed tends to be constant during 2000 to 2010 because it is very difficult to achieve higher feasible speed

[17] Source: (Givoni, 2006) and industry sources.

considering the noise problem, high operating cost and some other technical problems (Givoni, 2006).

4.2 HSR models

Based on the relationship between HSR service and conventional rail service, HSR models can be divided into four types. Figure 4-2 shows the four types of HSR models. In this section, we introduce the various types of HSR models and analyze the advantage and disadvantage of each model.

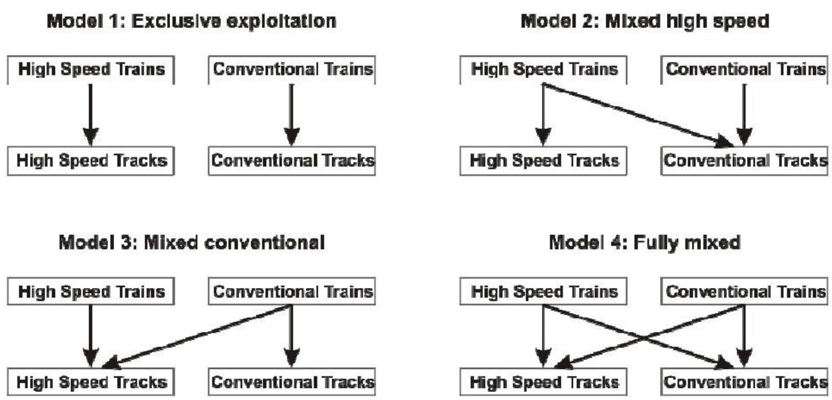

Figure 4-2: HSR models[18]

In the exclusive exploitation model, the high-speed trains and conventional trains use separate tracks and each one uses its own infrastructure. Japan used this model when building Shinkansen in 1964. Such a HSR model makes the market organization of both HSR and conventional services fully independent, which proved to be a valuable asset in the case of Japan.

[18] Source: Campos, De Rus and Barrons (2006).

However, since we need to build new infrastructure for HSR, which is not compatible for the conventional rail, the cost is also substantially higher compared to other models.

In the mixed high-speed model, high-speed trains can use both the conventional tracks and the dedicated high-speed tracks, while conventional trains can only use the conventional tracks. This model corresponds with the French TGV design, which can reach secondary destinations or city centers without building new tracks all the way to the station. This design significantly reduces the investment cost.

In the mixed conventional model, conventional trains can run on both high-speed tracks and the conventional tracks, while high-speed trains can only run on the dedicated tracks. This model is adopted by Spain's AVE. On the one hand, since the high-speed trains can only be operated on the standard gauge, it is difficult for Spain's AVE to run on the conventional tracks, which are narrow gauge such as the Japanese lines. On the other hand, adaptive technologies are used in their conventional trains, which make it possible to run on the dedicated high-speed tracks. The advantage of this model is the saving of rolling stock acquisition and maintenance costs and the flexibility for providing 'intermediate high-speed services' on specific routes.

In the fully mixed model, the rail system is completely flexible. This is the case of German ICE and the Rome-Florence line in Italy, where high-speed trains occasionally use upgraded conventional lines (as in France), and freight services use the spare capacity of high-speed lines during the night.

4.3 Investment costs

Figure 4-3 shows the compatibility with the conventional rails, maximum operating speed and construction cost of difference groups of HSR networks.

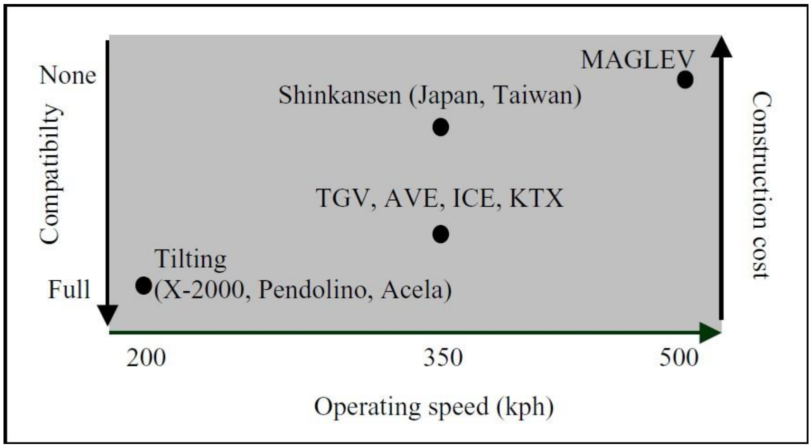

Figure 4-3: Characteristics of HSR networks[19]

To better analyze the costs of different HSR networks, we divide the cost of HSR project into costs associated with the infrastructure and costs associated with the rolling stock. Infrastructure costs include investments in construction and maintenance of the guideways (tracks), energy supply and line signaling systems, train control and traffic management systems, and equipment, among others.[20] Construction costs are incurred prior to starting commercial operations (except in the case of line extensions or upgrades of the existing network).

Maintenance costs include those related to the overhauling of infrastructure, including labor costs, materials, spare parts, and among others. These costs are incurred periodically, according to planned schedules calculated according to the assets' depreciation (Compos, de Rus and Barron, 2008). Figure 4-4 shows the infrastructure costs of HSR lines in several countries. We can see the infrastructure costs are slightly lower in France and higher in Italy. The difference can be explained by characteristics of the territories and the construction procedures.

[19] Source: Givoni (2006).
[20] The guideways part includes the sidings along the line, terminals and stations at the ends of the line and along the line, respectively

Spain and France are similar in terms of geographical characteristics. They both built the HSR lines in less populated areas outside the major centers, which significantly reduced the average infrastructure costs (Compos, De Rus and Barron, 2006). The HSR lines per kilometer are more expensive to build in Italy than any other country due to geography – narrow long country with uneven terrain. Due to this the HSR lines had to be built through more densely populated areas, without economies of space, dense urbanization and urban structure, mountainous terrain and high seismic risk areas (Albalate and Bel, 2010). From construction procedures, Spain and Japan adopted HSR models which need new rail infrastructure construction. This results in increase in the average infrastructure costs.

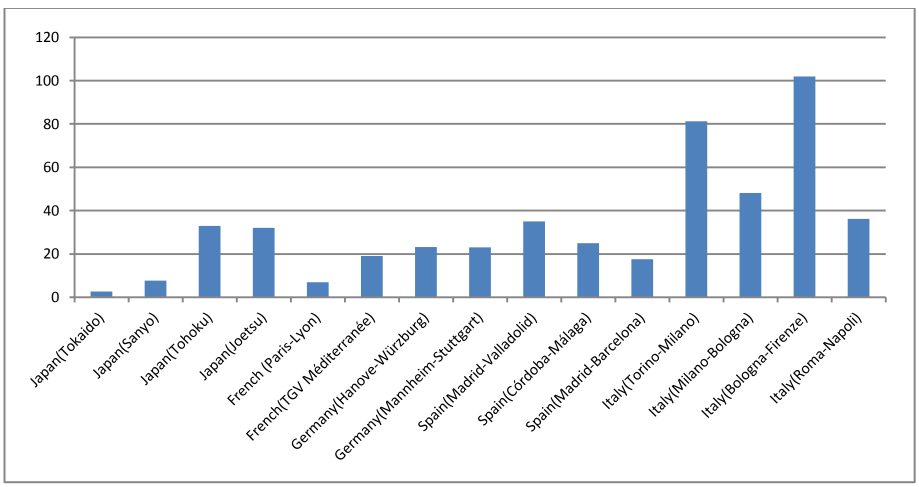

Figure 4-4: Infrastructure costs per kilometer of HSR lines by country[21]

Rolling stock costs include three main subcategories: acquisition, operation and maintenance. With regard to the first one, the price of a HSR trainset is determined by its technical specifications, such as capacity (number of seats), the contractual relationship between

[21] Source: Albalate and Bel (2010). (Data reorganized by Author.) The values are expressed in US dollar millions. The exchange rate used is 1Euro=1.5 $.

the manufacturer and the rail operator, the delivery and payment conditions and the specific internal configuration demanded by the operator. The operation costs mainly include the costs of the labor, energy consumed for the running of the trains, and in-train passenger services (food, drinks, etc). These costs usually depend on the number of trains (fleet) operated on a particular line, which in turn is indirectly determined by the demand. The maintenance costs of the rolling stock include again labor, materials and spare parts and are mainly affected by the train usage and indirectly affected by the demand via the fleet size (Campos, de Rus and Barron, 2007). Figure 4-5 and figure 4-6 show the operating and maintenance costs of different types of HSR rolling stocks. On average, the cost per seat exhibits little dispersion for all types of HSR rolling stocks, which means the cost of rolling stock are positively related to capacity. When considering the operation of the train, the cost per seat, kilometers and year shows that French HSR technology is between 10-20% cheaper compared to others (Compos, Rus and Barron, 2007). In terms of maintenance costs, the lowest is German ICE, whereas the highest is Italy's ETR500.

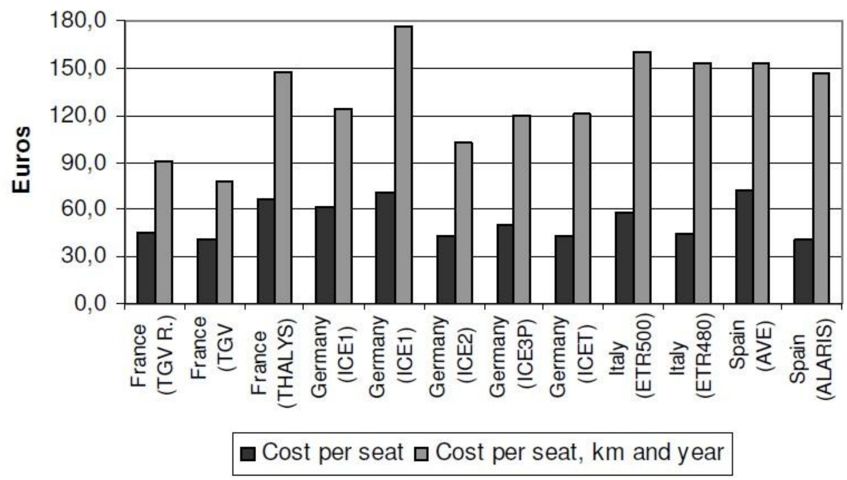

Figure 4-5: Rolling stock operating costs by train type and country[22]

[22] Source: Compos, De Rus and Barron (2006).

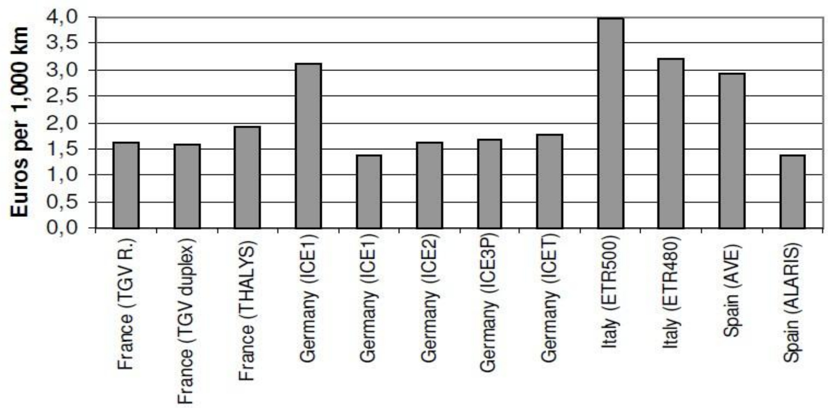

Figure 4-6: Rolling stock maintenance cost by train type and country[23]

4.4 US cost-benefit analysis

Travel time is a critical factor for HSR in competing against airlines. If the actual travel times are higher than projected, ridership is likely to be lower than projected. From a cost perspective, on the one hand, higher speed requires more advanced technologies, thus more investment. On the other hand, higher speeds would save operating and capital costs, because additional trainsets and labor hours would be required to fulfill the timetable if the speed is slow.

Several factors can slow the speed of the HSR. First, the topography may influence the speed. Higher mountain passes and greater elevation changes can slow the speed. Second, Political considerations could also reduce speed as local citizens seek to slow train speeds to reduce noise levels and as communities seek to obtain stations that are not in the current plan.

[23] Source: Compos, De Rus and Barron (2006).

Additional stations would require slower operations through built-up areas. In this section, we briefly discuss the speed issue from a cost-benefit standpoint in the US context.

4.4.1 Northeast Corridor (NEC): Acela Express

The Acela Express is Amtrak's high-speed rail service along the Northeast Corridor (NEC) in the Northeast United States between Washington, D.C., and Boston via Baltimore, Philadelphia, and New York, which is the business US corridor. Acela Express trains are the only true high-speed trainsets in North America; the highest speed they attain is 150 mph, though their average is less than half that speed. The Acela achieves an average speed (including stops) of 80 mph between Washington and New York; highest speed is 150 mph on two sections of track in Rhode Island and Massachusetts. There are also many miles of track, especially east of New Haven, that have been upgraded to allow maximum speeds in excess of 110 mph. South of New York, Acela Express service travels at 135 mph.

The limiting factor is stated to be the overhead catenary support system which was constructed prior to 1935 and lacks the constant-tension features of the new catenary east of New Haven, although in the late 1960s the Pennsylvania Railroad did run Metroliner test trains as fast as 164 mph and briefly intended to run the Metroliner service at speeds reaching 150 mph. The Acela Express project involved a series of improvements to existing stations, including major railheads in New York, Wilmington and Baltimore, with a new station, Route 128, built outside Boston, which is lower in cost compared with building the dedicated tracks and stations. However, a major problem was keeping the Acela project on schedule: the NEC is a notoriously twisting route, a major influence in opting for tilting trains to allow accelerated services with the least passenger discomfort.[24] Since the Acela shared the tracks with freight and slower passenger trains, though the Acela Express trainsets are capable of 165 mph operation, the FRA regulations do not permit any speeds above 150 mph on shared tracks.

Cost Analysis

The Acela Express was envisioned and designed as an incremental improvement over existing conventional tracks and trains, which limit the speed to 150 mph. In contrast to Europe and Japan, this choice was made out of necessity driven by cost considerations. Even if money was available, the process of building a new right-of-way through the most populated region of US would require acquisition of billions of dollars. Consequently, the Acela Express would have to be able to operate over 19th century alignment that couldn't support the dedicated tracks. Nonetheless, the tracks, signaling system and power supply has to be upgraded and well maintained (Black, 2005).

The Acela trainset is a unique train designed specifically to satisfy very specific U.S. governmental rolling stock requirements. These requirements are significantly different from anywhere else in the world, including countries that have a highly functional high-speed rail network. Most manufacturers who bid on the Acela were unable to meet these requirements, bringing up cost and complication for the manufacture of the trains, and requiring manufacturers to make significant engineering changes to its standard designs (Black, 2005).

Benefits

The Acela Express carried 3.2 million passengers in fiscal year 2010; the busiest Amtrak route is the somewhat slower Northeast Regional, which had 7.1 million riders in 2010 due to its

[24] http://www.railway-technology.com/projects/amtrak/

lower fares and greater number of stops. The Acela Express is one of the few Amtrak lines to operate at a profit; the two train lines generate more than half of Amtrak's total revenue. In 2010, the Acela Express had total revenue of US$440 million up from $409 million in 2009.[25]

Many factors can be attributed to the success of Acela Express. For example, the NEC has been a historically strong intercity rail market. The NEC has been a historically strong intercity rail market, which provides Acela a ready pool of train riders that have transferred from the slower, conventional services to the high-speed services (Cox and Vranich, 2008). Also, the metropolitan areas from Washington through New York to Boston have a population of 44 million and four of the six largest downtowns (central business districts) in the United States are on the Acela HSR line (New York, Washington, Boston and Philadelphia). Central business district (CBD) employment is a strong generator of ridership, because there are HSR stations in the CBD that are easily accessed by short cab rides, transit rides or walking. In this regard, the NEC is more favorable to HSR than the California corridor. Finally, despite not being as comprehensive as European transit systems, the transit systems of the NEC metropolitan areas are generally stronger. New York's transit network is by far the largest in the nation and has the largest rapid transit system with an urban-area transit market share of approximately 10 percent. Boston, Washington and Philadelphia have some of the most extensive rapid transit systems in the nation, as is evidenced by their strong ridership (Cox and Vranich, 2008).

4.4.2 California

California proposed the HSR project from San Francisco Bay Area to Los Angeles and San Diego via the San Joaquin Valley. A National Academy of Sciences report on the potential

[25] See ATK-12-030: http://www.amtrak.com/servlet/BlobServer?blobcol=urldata&blobtable=MungoBlobs&blobkey=id&blobwhere=1249239875207&blobheader=application%2Fpdf&blobhead

for HSR in the United States indicates that a system with top speeds of 200 mph would average a maximum of 150 mph in rural areas, which belongs to HSR (not VHSR). Based upon an examination of operating conditions and the international HSR experience, it appears that the CHSRA average speed and travel time objectives cannot be met. As a result, HSR will likely be less attractive as an alternative to airline travel and is likely to have fewer passengers. However, since the planned HSR routes are generally longer than highway mileage between the urban areas, the trains still have competitive advantage despite their speeds. (Cox and Vranich, 2008)

The California HSR speed challenges are generally greater than those faced by other HSR systems. This conclusion results from an analysis of topography, route length, share of length in built-up (urban) areas and projected speed estimates as contained in project documents.

First, the California line would encounter more challenging typography. The line would begin at near sea level in Los Angeles, reach approximately 4,000 feet between Sylmar and Bakersfield, drop back to near sea level in the San Joaquin Valley, return to more than 1,000 feet in the Pacheco Pass, and then drop again to near sea level in the San Francisco Bay Area. These operating conditions would tend to reduce speeds relative to, for example, the Paris–Marseille line. (Cox and Vranich, 2008)

Second, on the California route, approximately one-third of the operation will be in urban areas (built-up areas), while in France, less than one-tenth of the operation is in urban areas. Planned operating speeds through urban areas could be reduced further because of public displeasure about noise (Cox and Vranich, 2008). Also, construction costs can be especially high in urban areas, where housing has to be acquired and work undertaken to reduce the physical intrusion of the line and trains. These costs are much lower when land corridors have previously been safeguarded. In contrast to the California HSR proposal, French high-speed rail trains generally have only their terminal stations in urban cores (such as Paris and Marseille on the Paris–Marseille line), with intermediate stations located outside urban areas or in very low density suburban areas. This allows higher speeds for longer distances.

Finally, there are additional challenges to meeting the aggressive travel times required by state statute and proposed by the CHSRA. The use of shared rights-of-way between San Francisco and Gilroy and Los Angeles and Anaheim could make schedule adherence less reliable. High-speed trains would encounter interference from the existing commuter trains along such routes, and freight trains may cross the HSR/commuter tracks or even share them. Freight service operates much slower than commuter rail and could slow HSR trains. (Cox and Vranich, 2008).

Cost Analysis

As mentioned earlier, high-speed rail involves construction of new lines, stations, purchase of new rolling stock, and additional train operating cost and external cost which includes accidents, congestion, noise and air pollution (De Rus and Nash, 2007). We examine the cost for each section of the HSR in California.

The CHSRA indicates that the HSR trains will share tracks with other types of trains over certain urban links. While shared service would reduce the speed, flexibility and capacity of HSR service because of the need to coordinate schedules and slower speed limits, it would also result in fewer environmental impacts and a lower construction cost. Dedicated high-speed rail has high up-front costs Nash (1991) has noted that, to justify the construction of new lines, at least 6 million passenger trips per annum are needed ‘in the most favorable conditions’ and more commonly at least 12 million trips will be required (in the next part, we will analyze the projected ridership of California HSR networks, which cannot reach such a higher level).

Also, as mentioned above, one-third of the operation area will be in urban area, which requires more construction cost. Urban areas lack the extensive local transit infrastructure that connects with HSR systems found in dense Asian and European urban areas. The HSR system will experience disadvantages and higher investment in infrastructure construction (Cox and Vranich, 2008).

At the same time, the California HSR project could be at particular risk of additional cost escalation because of the unique circumstances of its environment. In particular, it will be necessary to build the system in one of the world's most active geologic zones. This requires compensating for geologic risk in designing the high-speed rail system to withstand major earthquakes (Cox and Vranich, 2008).

Considering the above three points, the infrastructure cost is higher, which limit the speed to a higher degree. Table 4-1 shows the infrastructure cost of California HSR project in different segments.

Table 4-1: Los Angeles-San Francisco high-speed line infrastructure cost[26]

Segment	Distance (km)	Cost (US $)	Cost per km (US $)	Travel time (min)	Travel speed (kph)
Los Angeles Basin	38.8	$ 742,000,000	$ 19,100,000	17.2	135
Techachapi Mnt. via Palmdale	136 2	$ 2,760,000,000	$ 20,260,000	27.6	296
Central Valley	324.7	$ 2,010,000,000	$ 6,190,000	61.5	317
Pacheco Pass-Gilroy	53.8	$ 1,590,000,000	$ 29,550,000	10.3	313
Gilroy-San Jose	45.9	$ 531,000,000	$ 11,570,000	18.0	153
San Jose-San Francisco	77.6	$ 1,964,000,000	$ 25,310,000	38 5	121
Total	677.0	$ 9,597,000,000	$ 14,180,000	173.1	234

[26] Source: Leavitt et al. (1994)

Considering the rolling stock investment, the CHSRA's intention to share tracks with commuter and freight trains complicates the designing of high-speed train to meet Federal Railroad Administration (FRA) safety and crashworthiness standards that are considered the toughest in the world. The necessary regulatory approvals of an overseas train are unlikely to be achieved without substantial changes in design and weight (Cox and Vranich, 2008).

The projected capital costs of HSR have risen strongly during the planning process, even after adjustment for inflation. The 1999 CHSRA Business Plan estimated that the entire system would be built for $30.3 billion ($25 billion in 1999$). The 2005 EIS/EIR raised the estimate to $40.5 billion. By 2008, documents prepared for a meeting for potential investors indicated that the costs had risen to $45.4 billion. This figure included $30.7 billion for Phase I (Anaheim to San Francisco) and $14.7 billion for Phase II (Sacramento and San Diego extensions) (Cox and Vranich, 2008). Besides the capital cost, the operating cost are also considered. The projected operating cost of California HSR appears to be low compared with other countries experience because of the slower of the speed (figure 4-7).

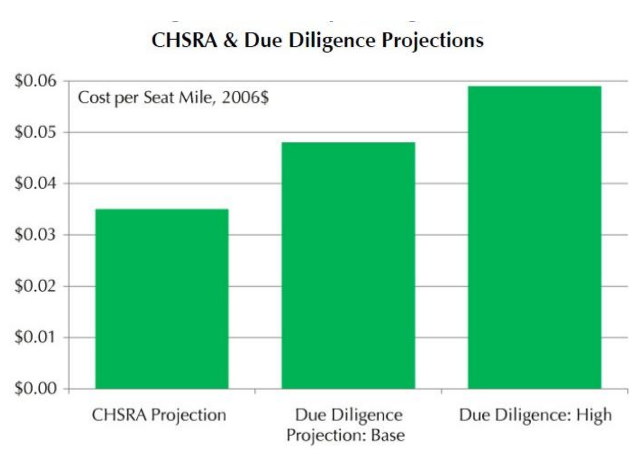

Figure 4-7: HSR operating costs with different projections[27]

[27] Source: Cox and Vranich (2008)

Benefits

The overall performance depends especially on the capacity for sustained high speed in intercity service. New dedicated high-speed railways generally provide the highest practical train speeds, making reliable train travel attractive relative to other modes -at least when the train journey is less than 3 hours (as a rule of thumb). Thus, if large population centers/demand is in appropriate proximity to each other, they may generate high traffic/revenue volumes. New dedicated lines also provide a big increase in track capacity, enabling frequent services on the new lines and releasing capacity on the existing lines for expanded local passenger services and without impinging on freight operations.

Cox and Vranich (2008) listed the disadvantages of HSR in California compared with that in Japan and Europe, including population densities in urban areas, size of central business districts, extent of connecting transit systems, distances between urban areas, and the degree to which a train-riding market existed prior to HSR service. Both Europe and Japan has more population density in urban areas, larger current train market existed prior to HSR service and more comprehensive transit system. Also, compared with Japan, the automobile ownership rate is considerably higher in California, the driving cost is much cheaper and it has a small market potential in diverting traffic from traditional rail service. Compared with Europe, large urban areas are usually not closer together to each other and metropolitan area of California can become a central hub, like Paris in France because most travel in California is point to point.

Due to the disadvantages mentioned above, it is not clear that the system in California can cover the operating and construction cost. Figure 4-8 is the California HSR revenue compared with Japan and Acela HSR system. It shows that, the revenue per passenger mile is the lowest among the three systems.

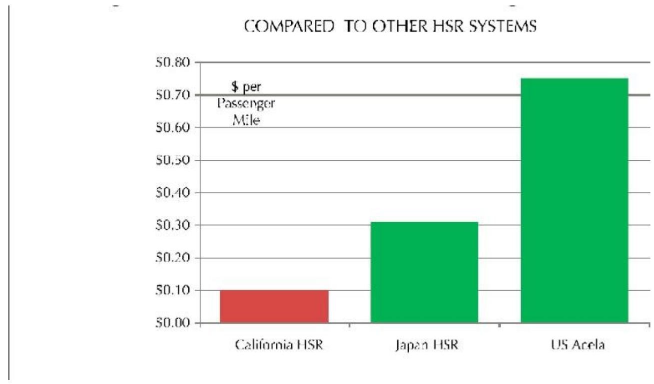

Figure 4-8: California HSR revenue/passenger mile in context[28]

Overall, the higher construction cost and the lower potential benefit of California HSR project will prohibit the government to invest more in increasing the speed. As a result, the CHSRA speed and travel objectives are unlikely to be met.

4.4.3 Florida

Florida HSR was a proposed HSR project in the US. Capital cost escalation, revenue shortfalls and higher than projected operating costs are common in high-speed rail projects. The potential cost and benefit issues while constructing the HSR project in Florida made the State government re-evaluate the project.

Initial service was expected to run between the cities of Tampa and Orlando, with plans to then extend service to South Florida, terminating in Miami. Trains with a top speed of 168 mph to 186 mph would run on dedicated rail lines alongside the state's existing highway

[28] See Cox and Vranich (2008)

network, which is faster than Amtrak's Acela Express and California high-speed train. Express trains from Tampa to Orlando International Airport would operate at between 48 and 50 minutes over the 84-mile route, according to Florida Rail Enterprise. If the trip takes 48 minutes, the average speed would be about 105 mph, while the average speed would be 101 mph at 50 minutes, At these average speeds, the Tampa to Orlando high-speed rail line would operate either slightly faster or at the same speed as the 101 mph (fastest) Acela Express service between Baltimore and Wilmington (Delaware). A Tampa to Orlando train making all three intermediate stops would average 91 miles per hour, less than 10 percent faster than the 84 miles per hour of the fastest Baltimore to New York Acela train, which makes three intermediate stops (Cox, 2011). The proposed journey times for some routes are shown in table 4-2 as follows.

Table 4-2: Proposed journey times[29]

Route	Distance (Miles)	Current Avg. Travel Time (2000 uncongested)	Current Avg. Travel Time (2000 Congested)	Proposed Avg. Travel Time High-speed Rail
Convention Center – Orlando Airport	11	16 minutes	21 minutes	11 minutes
Disney – Orlando Airport	19	25 minutes	34 minutes	21 minutes
Downtown Tampa – Orlando Airport	84	1 hour 22 minutes	1 hour 31 minutes	1 hour 4 minutes
Lakeland – Downtown Tampa	31	39 minutes	40 minutes	22 minutes

The project developer, Florida Rail Enterprise (a unit of the Florida Department of Transportation), characterized the project as the nation's first true high-speed rail line. However, the proposed speeds are substantially below those of state-of-the-art high-speed rail systems in China, Japan and France, which operate from 34 to 70 percent faster on comparable segments. The reasons might be that the world-class high-speed rail systems of China, Japan and France

[29] Source: See http://www.floridahighspeedrail.org/?f

tend to have much longer distances between stops than the 21-mile average of the Tampa to Orlando high-speed rail line. Frequent stops will limit the speed. Japan's 100-mile non-stop service between Okayama and Hiroshima averages 171 mph. China's 75-mile Beijing to Tianjin non-stop service averages 149 mph. France's 63-mile non-stop express from Charles de Gaulle Airport (Paris) to Haut-Picardie (Amiens) averages 141 mph. These services thus operate from 34 percent to 70 percent faster than planned for the Tampa to Orlando express services (Cox, 2011).

Cost Analysis

Florida's HSR was projected to use existing HSR models and build on the dedicated HSR tracks to secure the speed. International experience suggests a high likelihood that the Tampa to Orlando high-speed rail project would experience substantial cost overruns. The analysis above indicates that the additional cost to Florida taxpayers, above and beyond the $280 million commitment and the right-of-way contributions, could be from $540 million to $3 billion (Cox, 2011). Because of the continuous increasing construction cost, the state legislature was compelled to address growing concerns about costs and debated prohibiting the use of sales-taxes or tax exemptions for developers to help fund the system (Cox and Vranich, 2008).

Compared with California's project, first, the Tampa to Orlando line has two terminal stations, while the California Borden to Corcoran segment has none. The least expensive terminal station for which California planning data is currently available would cost approximately $850 million. Second, The Florida project also has three genuine, four-track high-speed rail stations, rather than the two basic stations in the California segment. Genuine high-speed rail intermediate stations in California range from $40 million to nearly $450 million in planning documents. If all the other costs are the same as that of the California's project, the estimated capital cost would eventually reach 5.7 billion (Cox, 2011).

Benefit

The Florida project was predicted to carry 2.4 million riders annually, which is two-thirds the ridership on the Amtrak Acela Express service (3.2 million in 2010). This could be difficult in view of the much smaller size of the Tampa to Orlando market compared to the Boston, Philadelphia, New York, Baltimore, Washington, DC market. The Acela market has approximately eight times the population of the Tampa-Orlando market. The metropolitan areas in both markets have substantial tourist volumes (Cox, 2011). Forecasts were based upon ticket prices ranging between $15 and $30 for a one-way ticket between Tampa and Orlando International Airport (OIA) depending upon the nature of the trip and frequency of the ticket purchases. Overall, revenues are projected to be approximately $49 million in the first year of operation.[30]

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[30] See www.ideastoresults.org

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5. INVESTMENTS NEEDED FOR HSR

The primary objective of this section is to discuss the specific types of components and expenditures needed to complete HSR investments. The commecial speeds that can be achieved is of great importance to the success of HSR systems. However, to achieve higher speed, problems related to noise problems, higher operating cost and other technicial problems have to be dealt with. Simply using more power to propel the conventional train can help to reach higher speed in test, but the speed is not available for the commerical use since fast moving vehicles damage the tracks severely (Raoul, 1997).

The main technical challenges in the development of commercial HSRs were to develop a train and track that could maintain stability and the comfort of passengers (while the train is running at high speed), maintain the ability to stop safely, avoid a sharp increase in (train) operating costs and (track) maintenance costs, and avoid an increase in noise and vibration to areas adjacent to the line. The solution included, in most cases, building tracks that avoid tight curves; increasing the distance between axles in the bogies to help maintain stability and placing the bogies between carriages (and not at the ends of each carriage) to reduce weight by halving the number of bogies required to carry the carriages; improving stability by preventing the cars from pivoting away from one another on curves; designing aerodynamic trains to reduce drag and shaping the train in a way that reduces the noise and vibration it induces; and using lighter and stronger materials (Raoul, 1997). In addition, the higher speeds required improvements to the signalling systems, the introduction of automatic braking/decelerating systems to improve safety, and changes in the operation of trains, e.g. the need to replace roadside signals with signals inside the driver's cab since at high speeds the trains passed the roadside signals too fast for the driver to see them (Givoni, 2006). As is clear, higher speeds come with significantly higher investment costs, and challenges related to safety and various technical aspects.

5.1 Locomotive and multiple units

Locomotive and individual motors in self-propelled multiple units (MUs) provide propulsion for the train. Locomotive has several advantages including easy replacing, flexible and safe, while MU is largely used in HSR since it offers high acceleration and deceleration and reduces the damage to the track when the speed is very high due to the lighter vehicles. From the 1910s onwards, the steam locomotives began to be replaced by less labor-intensive and cleaner (but more complex and expensive) diesel locomotives and electric locomotives, while at about the same time self-propelled MU vehicles of either power system became much more common in passenger service. Locomotive-hauled passenger trains are used for speeds up to 160 mph, while Electric Multiple Units (EMU) are used for higher-speed services.[31]

A locomotive is a railway vehicle that provides the motive power for a train. Considering several advantage of locomotives, many earlier trains are still locomotive-hauled. Locomotive can be classified as, by their source of energy, steam locomotive, gasoline locomotive, diesel locomotive, electric locomotive, hybrid locomotive, steam-diesel hybrid locomotive, gas turbine-electric locomotive, fuel cell-electric locomotive, slug or drone locomotive. Earlier high-speed trains used the gas-turbine electric locomotive. For example, the earliest French high-speed train TGV 001, which is also the world's second high-speed train followed by the Japanese Shinkansen, is a gas-turbine-electric locomotive-hauled train and keeps the speed record of gas-

[31] See http://en.wikipedia.org/wiki/Locomotive

turbine powered train. In 1972, the Advanced Passenger Train, an experimental tilting train developed by British Rail, is also gas-turbine powered. Due to the steep oil price, later models are gradually replaced by electric locomotives after the 1973 oil crisis and the subsequent rise in fuel costs.

The electric locomotive is supplied externally with electric power, either through an overhead pickup or through a third rail. Electric locomotives can easily be constructed with greater power output than most diesel locomotives. For passenger operation it is possible to provide enough power with diesel engines but, at higher speeds, this proves costly and impractical. Therefore, almost all high-speed trains are electric. Electric locomotives, because they tend to be less technically complex than diesel-electric locomotives, are both easier and cheaper to maintain and have extremely long working lives, usually 40 to 50 years. Although the capital cost of electrifying tracks are high, electric locomotives are capable of higher performance and lower operational costs than steam or diesel power.[32] Electric locomotives are used on high-speed lines, such as ICE in Germany, Acela in the US, CRH in China and TGV in France.

The advent of modern power electronics and AC asynchronous traction motors has considerably reduced the volume of traction equipment. This, along with other technological developments, has facilitated the development of trains with decentralized traction, which is so-called multiple units (MUs).[33]

MUs are used to describe a self-propelled carriage capable of coupling with other units of the same or similar type and still being controlled from one driving cab. MUs don't need the

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[32] See http://en.wikipedia.org/wiki/Electric_locomotive

[33] See http://www.railway-energy.org/tfee/index.php?ID=220&TECHNOLOGYID=23&SEL=100&EXPANDALL=3

separate locomotives to provide the motive power. MUs are used for higher-speed services for its higher acceleration rate. According to their power source, MUs can be classified into two main types: electric multiple units (EMUs) and diesel multiple units (DMUs). Most high-speed trains, such as the most recent Chinese CRH, German ICE 3 and Japanese Shinkansen, use the electric power because it is much quieter and energy efficient.[34]

In most countries, the locomotive-hauled high-speed trains are being gradually replaced by the MUs. For example, all the CRH trains in China, which previously were locomotive-hauled, become EMUs after the 6th speed-up campaign of China in 2007. In Japan, most long-distance trains had been operated by locomotives until the 1950s, but by utilizing and enhancing the technology of short-distance urban MU trains, long-distance MU vehicles were developed and widely introduced in the mid-1950s. This work resulted in the original Bullet Train development in EMU-type vehicle and the Tokaido-Shinkansen operated in 1964 by just EMUs. By the 1970s, locomotive type trains were regarded as slow and inefficient, and their use is now mostly limited to freight. Japan's high population density with a large number of railway passengers in relatively small urban areas, requires frequent operation of short-distance trains. Therefore, the high acceleration ability and quick turnaround times of MU have advantages in Japan. Additionally, the mountainous terrain in Japan gives the MU's advantage on grade more significance than in most countries, particularly on small private lines many of which run from coastal cities to small towns in the mountains.[35]

[34] See http://en.wikipedia.org/wiki/Electric_multiple_unit
[35] http://en.wikipedia.org/wiki/Multiple_unit

The construction costs for EMUs are lower than those of locomotive-hauled trains since EMUs don't need to build separate locomotive to provide the motive power. However, compared with a locomotive-hauled passenger trains, EMUs are much more expensive to maintain.

The cost of the train locomotive and train cars themselves includes the construction cost and the repair cost. For example, as calculated, the French TGV Reseau's total construction cost is $16.5 million per train. As for the maintenance cost part, according to Railway Technical, current state-of-art trains can run for up to 90 days between repairs. A train used at maximum capacity is likely to need repairs more often (such as the heavy-use Channel Shuttle Trains are repaired every 7 days). Taking the French TGV Reseau as an example again; based on this, the average maintenance cost per repair is approximately $10,935 (Teague et al., 2012).

5.2 Railway electrification system

Since most HSR networks use electricity to provide the motive power, an electrification system is necessary. A railway electrification system supplies electrical energy to railway locomotives or multiple units as well as trams so that they can operate without having an on-board prime mover. Railway electrification has many advantages but requires significant capital expenditure for installation.

Electrification systems are classified by three main parameters: voltage, current and contact system. Countries that earlier used the low-voltage (3KV/1.5kv) direct current (DC) are increasingly beginning to change their electrification system to 25kv alternating current (AC) to achieve higher speeds.[36] The 25kv AC powered electrification system is ideal for railways that cover long distances and require higher speed. For example, the first generation of ETR, a series of Italy's HSR which uses the 3kv DC, only has a maximum speed of 155 mph. Later, Ferrovie dello Stato chose to electrify the lines at 25kv AC for the second generation ETR and the trains can now achieve a top speed of 186 mph.[37]

Though achieving higher speed, the high voltage requires higher investment. The initial costs are higher because high voltage leads to a requirement for a slightly higher clearance in tunnels and under overbridges. The ongoing maintenance costs are also higher. For example, to avoid short circuits, the high voltage must be protected from moisture. Various weather events, such as the wrong type of snow, have caused moisture accumulation and resulted in failures in the past. This increases the maintenance cost.[38]

5.3 Track

The history of high-speed train operation follows two primary paths:

1. Trains getting higher speed on dedicated new high-specification track. For example, Shinkansen routes are completely separate from conventional rail lines (except Mini-Shinkansen which goes through to conventional lines). The lines have been built without road crossings at grade. Tracks are strictly off-limits with penalties against trespassing strictly regulated by law. It uses tunnels and viaducts to go through and over

[36] Most recent high-speed trains use the overhead lines, 25 kV Alternating current (25KV, AC) and 50HZ railway electrification system, except countries like Austria, Germany, Sweden, Switzerland and Norway use 15kv AC, 16.7 HZ system, and some old lines in Southern France and Italy use the direct current (DC) systems.

[37] See http://en.wikipedia.org/wiki/Railway_electrification_system

[38] See http://en.wikipedia.org/wiki/25_kV_AC_railway_electrification

obstacles rather than around them, with a minimum curve radius of 4,000 meters (2,500 meters on the oldest Tōkaidō Shinkansen); and

2. Trains getting higher speed on existing track. Most high-speed trains in Europe are in this category like French TGV. TGV track construction is similar to that of normal railway lines, but with a few key differences. The radii of curves are larger so that trains can traverse them at higher speeds without increasing the centripetal acceleration felt by passengers. The radii of LGV curves have historically been greater than 4 km (2.5 miles).

The two paths lead to two methods in building the tracks for HSR. The first one is upgrading the existing tracks. This allows the trains to reach secondary destinations or city centers without building new tracks all the way to the station, reducing costs compared to high-speed networks with a different gauge than the surrounding conventional network. However, there are two major difficulties if new trains are to drive fast on existing tracks. First, the train has to be adapted in order to be able to run through relative sharp curves. While tilting technology on routes has been used to solve this problem, only few of the projects using the tilting technology lead to commercial services and most of them were deemed as failures. Second, the trains have to mix with slower services on tracks which restricted the speed. As a result, the trains on the existing tracks cannot exceed 155 mph.

Increasing threshold train speeds above 155 mph involves the second method; that is, building separate tracks to a very high standard which avoids conflicts with slower local or freight trains and attain the capacity to operate many high-speed trains punctually. Besides increasing the speed, the incompatibility of the HSR track and conventional rail track also requires building the dedicated tracks for HSR. For example, all the high-speed lines have to be built to standard gauge. As a result, in Japan and Spain, whose conventional rails are built on the narrow-gauge tracks, need to build the separate standard gauge tracks to meet such requirement. For this solution, the construction costs will be higher compared with the first method.

For much of the 20th century, rail tracks used softwood timber ties and jointed rails (figure 5-1). The rails were typically of flat bottom section fastened to the ties with dogspikes through a flat tieplate in North America and Australia, and typically of bullhead section carried in cast iron chairs in British and Irish practice. The intrinsic weakness of jointed rails in resisting vertical loading results in the ballast support becoming depressed and a heavy maintenance workload is imposed to prevent unacceptable geometrical defects at the joints. The joints require lubrication, and wear at the fishplate (joint bar) mating surfaces needed to be rectified by shimming, which makes the jointed track not financially appropriate for heavily operated railroads. Also, because of the small gaps left between the rails, when trains pass over jointed tracks, they make a "clickety-clack" sound. Unless it is well-maintained, jointed tracks do not have the ride quality of welded rail and is less desirable for high-speed trains.[39]

Figure 5-1: Railroad tracks on traditional wooden sleepers[40]

[39] See http://en.wikipedia.org/wiki/Track_(rail_transport)
[40] Source: http://en.wikipedia.org/wiki/Track_(rail_transport)

The use of ballastless track (figure 5-2 and figure 5-3) can overcome such heavy maintenance costs. In its simplest form this consists of a continuous slab of concrete (like a highway structure) with the rails supported directly on its upper surface (using a resilient pad). Ballastless track allows for smoother train rides at high speeds and can reduce warping.

The ballastless track is very expensive, and in the case of existing railroads requires closure of the route for a somewhat long period. However, its entire life cost can be lower because of the significant reduction in maintenance requirements. In effect, the fixed, or overhead, costs are higher, but the marginal, or operating, costs are lower. Ballastless tracks are usually considered for new very high-speed or very high loading routes, in short extensions that require additional strength (i.e. rail station), or for localized replacement in the case of exceptional maintenance difficulties.

Figure 5-2: Japanese HSR ballastless tracks[41]

[41] Source: http://en.wikipedia.org/wiki/Track_(rail_transport)

Figure 5-3: Chinese HSR ballastless tracks[42]

Teague et al. (2012) assumes all rail track cost the same, ignoring the factors like topography, geographical features and urban areas. As a result, the cost of laying track is completely dependent on the length of track required. The estimated total track cost including the track construction and track maintenance for each region is shown in table 5-1.

Table 5-1: Total track cost for each region[43]

Region	Total track distance cost (km)	Track construction cost	Track maintenance cost (per year)	Total track cost (over 20 years)
Pacific NW	0,595.13	$3,326,761,280.34	$13,866,464.73	$3,604,090,574.91
California	1,794.00	$10,028,466,495.73	$41,800,227.08	$10,864,471,037.24
South Central	1,357.18	$7,586,619,355.59	$31,622,223.79	$8,219,063,831.39
Gulf Coast	19,657.46	$109,885,184,702.53	$458,018,748.40	$119,045,559,670.58
SE	0,834.58	$4,665,274,599.81	$19,445,598.96	$5,054,186,578.97
Keystone	0,775.70	$4,336,189,451.14	$18,073,920.25	$4,697,667,856.19
Empire	2,640.27	$14,759,092,068.85	$61,518,219.18	$15,989,456,452.41
NE	4,361.23	$24,379,285,447.04	$101,616,699.63	$26,411,619,439.58
Chicago	3,251.82	$18,177,676,969.32	$75,767,419.21	$19,693,025,353.53
Florida	0,448.67	$2,508,045,461.24	$10,453,928.31	$2,717,124,027.42

[42] Source: http://en.wikipedia.org/wiki/Track_(rail_transport)
[43] Source: Teague et. Al (2012)

5.4 Passenger car

A passenger car is a component of railway rolling stock that is designed to carry passengers. The rolling stock technology is related to the tracks. Usually, the more sophisticated the track is, the less sophisticated the rolling stock itself needs to be (Boersma, 1996). In other words, running on the same tracks, the more sophisticated technology would bring higher speed to the rolling stock. For example, tilting technologies enable the trains to increase the speed on regular rails and counteract the passengers' discomfort caused by the centrifugal force when the trains rounds at a curve with very high speed. Acela express is a good example of using the tilting technologies. The North East Corridor has a notoriously twisting route, a major influence in opting for tilting trains to allow accelerated services with the least passenger discomfort. [44]

Several construction technologies characterize the passenger equipment and allow the trains to run at higher speed. One of the passenger cart technology is articulated cars, which are becoming increasingly common in Europe and U.S. Articulated cars are rail vehicles which consist of a number of smaller, lighter cars which are semi-permanently attached to each other and which share common trucks. This technology can save on the total number of wheels and trucks, reducing initial cost, weight, noise, vibration and maintenance expenses. Further, movement between passenger cars is safer and easier than with traditional designs. Finally, it is easier to implement tilting schemes such as the Talgo design which allow the train to lean into curves.[45]

[44] http://www.railway-technology.com/projects/amtrak/
[45] http://en.wikipedia.org/wiki/Articulated_car

5.5 Signaling and control system

Railway signaling and control systems are designed to control railway traffic safely and prevent trains from colliding. The conventional track side signaling systems, shown in figure 5-4, are insufficient for high-speed rail, because the higher speed makes it impossible for the engineer/drivers to reliably read signals placed at trackside. The required vigilance cannot be expected of a human, especially for long periods and in adverse weather conditions. To increase the speed and capabilities, more advanced and complex signaling and control systems are needed.

Figure 5-4: Conventional track side signaling system[46]

There are various options for improving the signaling and control systems to increase the speed of the train including increasing the distance between distant and home signals, adding additional aspects, and cab signaling. Increasing the distance between the home and distant signals would decrease capacity. Adding an additional aspect would make the signals harder to

[46] This asset represents trackside train traffic control signals of a type built by Union Switch and Signal Company.

recognize. In either case, changes to the conventional signals would not solve the problem of the difficulty of seeing and reacting to the signals at higher speeds. To overcome all of these problems, cab signaling, a system by which signaling information is transmitted through the rails as electrical signals which are picked up by antennas placed under the train, was developed to increase the speed of the train and capacities of the system.[47]

Several major forms of cab signaling systems have been designed to make the trains run better including the European Train Control System (ETCS), the German Indusi, German LZB, British TPWS, and the French TVM.

ETCS is the train control component of the European Rail Traffic Management System (ERTMS)[48] and a functional specification that incorporates the former national standards of several European countries. The development of ETCS has matured to a point that cross-border traffic is possible and some countries have announced a date for the end of life of older systems. France will drop the usage of KVB on high-speed lines by 2017 in favor of ETCS Level 2. Switzerland will switch from ZUB/Signum to ETCS Level 1 for conventional rail in 2018. Germany will start replacing all PZB and LZB systems in 2015 to be finished by 2027. Additionally a number of non-European countries are starting to deploy ERTMS/ETCS on new tracks including China, Korea, New Zealand, India, Kazakhstan, Saudi Arabia, Libya, Algeria and Mexico. Australia will switch to ETCS on some dedicated lines starting in 2013.

The ETCS is divided into three levels and the definition of the level depends on how the route is equipped and the way in which information is transmitted to the train.

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[47] See http://en.wikipedia.org/wiki/Linienzugbeeinflussung

[48] ERTMS is a multinational standard that is being developed in Europe with an aim to improve interoperability

ETCS level 1 is a cab signaling system that can be superimposed on the existing signaling system. As shown in Figure 5-5, the train position is still detected by traditional trackside occupancy controlling devices which are linked with the interlockings. Line-side signaling is kept in general. Fixed or variable data is transmitted from track to trains by means of Eurobalises. The drawback of the Level 1 is that the speed is restricted to 100 mph only; the distance between the signals does not allow speeds higher than this.

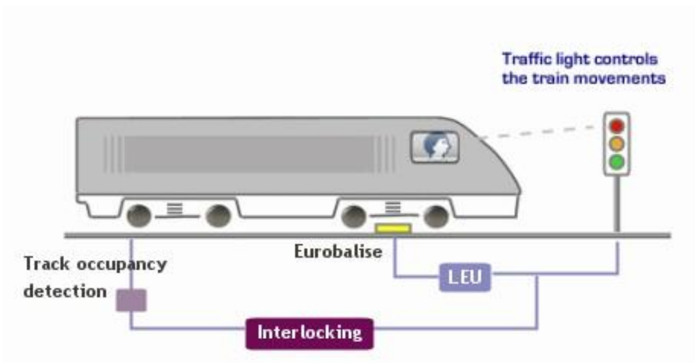

Figure 5-5: ETCS level 1[49]

ETCS Level 2 (figure 5-6) is a digital radio-based signal and train protection system. In application level 2, ETCS uses a GSM-R radio channel to exchange data between the trackside Radio Block Centre and the trains. The interlocking reports the status of the objects controlling the routes of the trains to the RBC which, in turn, generates the correct movement authorities for the different trains in the section. In normal operation, lineside signals are no longer strictly necessary. The traditional control of track-occupancy with fix block sections is still kept.

[49] Sources: http://ertms.uic.asso.fr/2_etcs.html

Nevertheless, trains report their position to the radio block centre via the GSM-R communication channel. The ETCS level 2 was installed in Turkey's high-speed line, designed for speeds of 155mph. In October 2011, it was also commissioned on the high-speed rail line of Spain, allowing the speed of the fastest trains to be increased to 193mph.

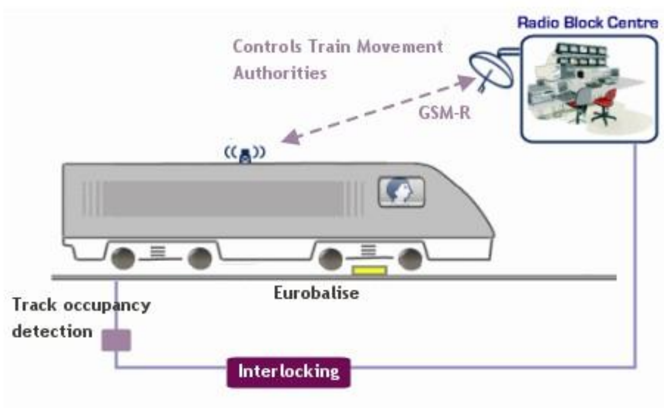

Figure 5-6: ETCS level 2[50]

ETCS Level 3 (figure 5-7) definition with low cost specifications (compared to ERTMS Regional) and the integration of GPRS into the radio protocol to increase the signaling bandwidth as required in shunting stations is now under development. In application level 3, ETCS replaces the line-side signals as well as the trackside occupancy checking devices as shown in the figure. The location of the train is determined by the train-side odometer and reported to the trackside radio block centre via the GSM-R radio transmission. In this configuration, train spacing is no longer controlled by the interlocking. However, the latter has to exchange information about the route setting with the radio block centre. This configuration

[50] Sources: http://ertms.uic.asso.fr/2_etcs.html

offers a great simplification with cost reduction of the equipment in the track and an independence from rigidly structured fixed block sections. For this reason, ETCS level 3 has the potential to become the final universal optimal configuration of ETCS.[51]

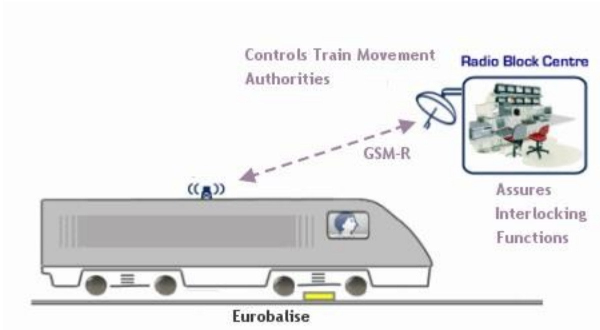

Figure 5-7: ETCS level 3[52]

TVM is another form of cab signaling system designed as part of the French TGV project. TGV lines are divided into fixed blocks about 1500 meters (1 mile) long. (The earlier TVM 300 system uses longer blocks.) Blocks are shorter than a train's braking distance, so a braking sequence takes place over several blocks, nominally four. This relatively frequent subdivision allows running trains on shorter headways, which increases the capacity of a high-speed line without placing additional requirements on the braking performance of the trains. TVM 300 is the first generation and applied on the South East High-speed Line in France. It supports a commercial headway of 5 minutes between trains. TVM 430 is the second generation of TVM and the design headway performance is 3 minutes and can be achieved under

[51] See http://en.wikipedia.org/wiki/European_Train_Control_System
[52] Sources: http://ertms.uic.asso.fr/2_etcs.html

commercial conditions at 320 kmh. This system can be delivered in an integrated configuration using the SEI interlocking platform to support both ATC and interlocking functions, thus reducing the cost.[53]

Linienzugbeeinflussung (LZB) is also a cab signaling and train protection system used on selected German and Austrian railway lines as well as the AVE in Spain. The LZB cab signaling system was first demonstrated in 1965, enabling daily trains to the International Transport Exhibition in Munich to run at 125 mph. The system was further developed through the 1970s, released on various lines in Germany in the early 1980s and in German, Spanish, and Austrian high-speed lines in the 1990s with trains running up to 185 mph. Meanwhile, additional capabilities were added to the system.[54]

5.6 U.S. High-speed rail technologies

While the Acela Express is designed to operate at or above 125 mph (which is the U.S. Department of Transportation's official rating for "high-speed rail") it rarely achieves this status out along the Northeast Corridor. Overall the train averages about 80 mph between Washington and New York and ironically, its top speed of 150 mph is achieved through the smallest states along the NEC, Massachusetts and Rhode Island.

The NEC electrification that must be accommodated are:

1. 12kV 25Hz from Washington to New York City;
2. 12kV 60Hz from New York City to Shell, phase breaks at 7.5 mi. intervals;

[53] See http://www.trainweb.org/tgvpages/signals.html
[54] See http://en.wikipedia.org/wiki/Linienzugbeeinflussung

3. 12kV 60Hz from Shell to New Haven, phase breaks at 12 mi. intervals; and
4. 25kV 60Hz from New Haven to Boston, phase breaks at 20 mi. intervals.

Changes in traction supply must be accommodated automatically while travelling at maximum speed, without interruptions in HEP (head end power, or "hotel power" for lights, air conditioning, etc). Changes in the overhead supply are signaled to the train by wayside transponders that are part of Amtrak's ACSES system; this allows the tap changer on the main transformer to reconfigure the primary windings in time for the phase break.[55]

The Acela Express uses the latest in electric locomotive technology such as silicone oil-cooled transformers and the ability to operate under different voltages, such as is found on the NEC (anywhere between 11,000 to 25,000 volts). Other features of the Acela include a three-phase propulsion system that allows the train to accelerate incredibly quickly while requiring fewer motors than what has traditionally been used employing direct current (DC). The power cars use the newest TGV (3rd generation) traction technology.[56] Overall, the Acela Express can provide over 12,000 horsepower with each power car at either end providing over 6,000 hp.[57]

The vehicle structures are built from stainless steel and are designed to survive major impacts. Crash energy management techniques based on 3rd generation TGV technology control the structural deformations in the event of an accident, to increase the safety of the passengers. Under floor equipment is specially reinforced to withstand the rigors of operating in urban areas, where shopping carts, tires and other debris frequently find their way onto the tracks. (The Northeast Corridor is only partially fenced in, as opposed to European high-speed lines.) The Acela Express is the first train to comply with the Federal Railroad Administration's Tier II

[55] http://www.trainweb.org/tgvpages/acela.html
[56] http://www.trainweb.org/tgvpages/acela.html
[57] http://www.american-rails.com/acela-express.html

crashworthiness standards, touted to be the toughest in the world. The downside of the heavy emphasis on passive safety is the significantly higher weight of the trainset, compared to worldwide high-speed rail practice. The Acela Express is built about 45% heavier than a typical TGV.[58]

In terms of signaling system, for operation at 150 mph, the Acela express are fitted with a two frequency, nine aspect cab signal system to supplement wayside signaling. (In a cab signal system, signaling information is transmitted through the rails in the form of electrical signals, decoded by the train and displayed to the engineer directly in the cab). An ATC (Automatic Train Control) system watches over the engineer, who is in full control of the train at all times. In addition, Amtrak's ACSES system (Amtrak Civil Speed Enforcement System) ensures observance of all speed limits.[59]

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[58] http://www.trainweb.org/tgvpages/acela.html
[59] http://www.trainweb.org/tgvpages/acela.html

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6. INTERNATIONAL SUPPLY CHAIN

In this section I detail the HSR final product, and provide taxonomy of the complex international supply chain. This allows us to examine in detail the characteristics of the components, technologies and firms, and their diverse global locations.

6.1 Taxonomy of the supply chain

Given the diversity and complexity of the various components that go into a HSR, it is useful to form a taxonomy of the key components. Appendix C displays the supply-chain diagram of the international high-speed rail industry. On the top right of the diagram appear the names of the major trainset manufacturing companies around the world. The composition of the HSR is highly complex, which is shown in figure 6-1. To keep the supply-chain taxonomy tractable, we categorize the high-speed rail system into five broad component categories: (1) Mechanical Group; (2) Electronic Group; (3) Locomotive and Power Group; (4) Passenger Cart Group; and (5) Others. As itemized in the supply-chain diagram, each category contains several major component and sub-component areas and some of the leading international companies are listed in each part. Below we briefly describe each major component area (as noted in the supply-chain diagram) and some of the characteristics of the products and technologies.

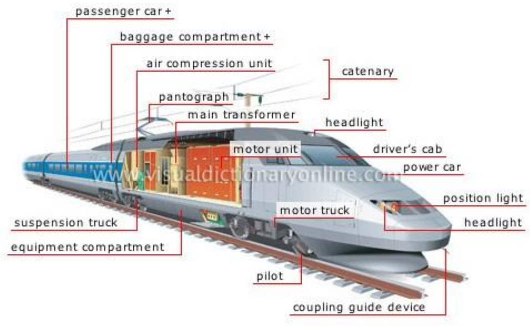


Figure 6-1: High-speed trains components

6.1.1 Mechanical group

The Mechanical Group includes physical components to manage and support the train while running on the existing or dedicated tracks. The mechanical category is used as actuator input to generate the output forces and motive power for the train. This input is shaped by mechanisms consisting of gears and gear trains, belt and chain drives, cam and follower mechanisms, and linkages as well as friction devices such as brakes and clutches.

The M1 sub-category (in the supply-chain diagram) is the wheelset related component. A wheel set is wheel-axle assembly of a rail car. Suspension is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels. Damper is a mechanical device designed to smooth out or damp shock impulse, and dissipate kinetic energy. The bogie is a frame assembly beneath each end of a railcar or locomotive that holds the wheelsets and serve to: (1) support the train's body weight; (2) ensure stability when trains run on straight and curved tracks; and (3) absorb vibrations generated by the track and reducing the effect of centrifugal forces that pull on persons when the train negotiates a curve at high speeds. To meet the requirement, the bogies usually comprise a high comfort suspension system for superior riding qualities. Figure 6-2 relates to the French TGV bogies.

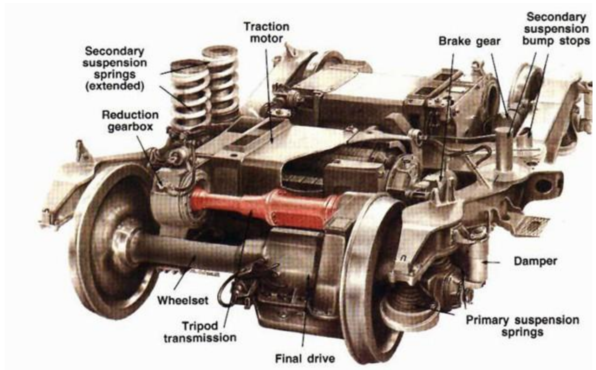


Figure 6-2: French TGV bogies

The M2 sub-category includes some connection components. Coupler is a mechanism for connecting rolling stock in a train. Gear is used to connect the coupler to the rolling stock. Brakes are used on the cars of railway trains to enable deceleration, control acceleration (downhill) or to keep them standing when parked. The higher the achievable braking rate, the longer the train can travel at a higher speed. Furthermore, a higher maximum braking rate increases the level of safety.

6.1.2 Locomotive and power group

Locomotive and Power Group provides the input forces or power of the train. This category includes the locomotive, electric motors and hydraulic system. A locomotive is a railway vehicle that provides the motive power for a train. It is the power pack of the train. Nowadays, electric locomotive are common used in the HSR industry. A locomotive involves highly complex technologies and includes several components, which is shown in figure 6-3.

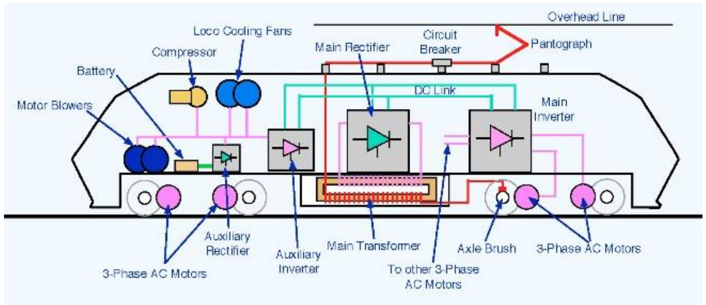


Figure 6-3: Electric locomotive parts

The L2 sub-category is the railway electrification system. Electric locomotives unlike diesels do not produce their own power. They need electric power supplied by a central power plant that may be miles away. Even the popularity forms EMUs, which don't contain separate locomotives need the electrification system to supply the power. A railway electrification system supplies electrical energy to railway locomotives and multiple units as well as trams so that they can operate without having an on-board prime mover. Transmission of the power is always along the track by means of an overhead wire or at ground level, using an extra third rail laid close to the running rail. The mechanics of the power supply wiring are not very simple. The wire must be able to carry the current (several thousand amps), remain in line with the route, withstand wind, extreme cold, heat and other hostile weather conditions. Overhead catenary systems have a complex geometry, nowadays usually designed by a computer.[60]

The L3 component area, called hydraulic system, refers to the system that transfers the energy from fluid and pressure. A hydraulic system consists of three parts: The generator (e.g., a hydraulic pump), driven by an electric motor, a combustion engine or a windmill; valves, filters, piping etc. (to guide and control the system); the motor (e.g., a hydraulic motor or hydraulic cylinder) to drive the machinery. For tilting trains, besides using the

[60] See http://edu.dvgups.ru/METDOC/CGU/INOSTR/ANGL/METOD/U_P/frame/6.htm

electrical system electrical actuation to perform carbody tilting to reduce centrifugal force in curves, hydraulic system also plays an important role in raising, lowering and relocation of the shuttering.

6.1.3 Electronic group

The Electronic Groups enable the rail service to operate safely over a given set of tracks including communications, signaling and train protection system and embedded computer system. The category contains several complex and fascinating subjects. The quality and technology of the signaling and control will determine the safety speed of the high-speed rail. The more sophisticated the signaling control system is, the higher speed the high-speed train can arrive.

6.1.4 Passenger cart group

The Passenger Cart Group includes the accessories of passenger coaches, head end power components and other design and maintenance services relating to the passenger cars. A locomotive has no payload capacity of its own, and its sole purpose is to move the train along the tracks, while the passenger cart can be used for carrying the passengers. Figure 6-4 shows the standard names used in the UK for passenger coach parts. According to this, we divide this category into seven sub-categories, which can be seen in the supply-chain diagram (Appendix C).

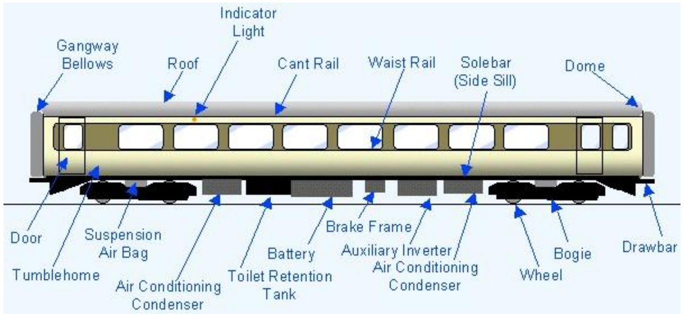


Figure 6-4: Passenger coach parts

6.1.5 Others

Others categories are infrastructure-related equipment and some aftermarket service including the maintenance and refurbishing service. Besides the trainset, the rail system needs several other components for support, such as the slab track and inverted soundproof wall.

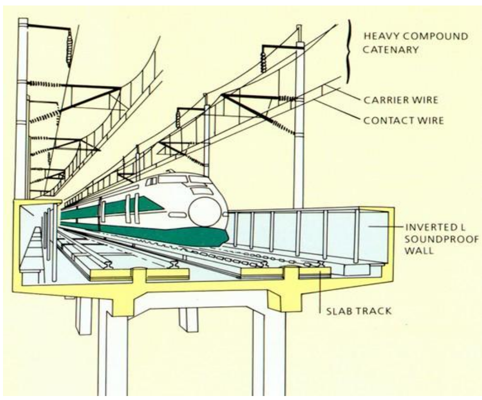


Figure 6-5: High-speed rail networks

6.2 HSR market

The HSR industry is a complex market with a large number of firms involved in the supply chain. On the one hand, there are several sophisticated companies who currently manufacture some components and deliver the final HSR product, such as the Alstom's TGV, Siemens' ICE and Bombardier's Regina. The emergence of some Chinese and South Korean companies is making the market even more complex and competitive. On the other hand, HSR is composed of numerous components involving a wide range of advanced technologies. This means even though the main trainset (or aggregator) companies like Siemens, Alstom and Bombardier have mature technologies and manufacturing and assembly capabilities, it is not possible for them to produce all the components. This results in a wide and diverse set of component manufacturers in the HSR industry supply-chain.

Below we focus on examining the complex HSR market in terms of the major trainset suppliers, as well as the components suppliers. We first identify the distribution and activity of the major trainset suppliers and the evolving of their market share in the recent 10 years. Then, we identify the development of the business and find possible reasons for this development.

6.2.1 Major trainset suppliers

Appendix C notes the nine major trainset suppliers, who can assemble the components and provide the final high-speed trainsets. Bombardier Transportation (Germany), Alstom (France) and Siemens (Germany) have been the leading international aggregators of rail and trainset vehicles, but they are increasingly challenged by China's CSR and CNR, as well South Korea's Hyundai Rotem. Other companies such as Kawasaki (Japan), CAF and Talgo (both from Spain) and Ansaldo-Breda (Italy) also play important roles internationally.

Several of the major trainset suppliers noted above are multiproduct firms and the production structures are highly complex in these companies. Most of them have competences in selected areas of HSR components manufacturing. Global companies like Bombardier, Alstom, Talgo, Kawasaki and Siemens are involved in many of the categories in the supply chain. Bombardier, for example, manufactures the entire electrical equipment, propulsion system and the power head (Locomotive and Power Group), bogies (Mechanical Group), the train control, signaling and communication system (Electronic Group), and the whole carbody (Passenger Cart Group). Some new trainset companies in the supply chain like CNR, CSR and Hyundai Rotem are not shown in many categories of the supply chain. Though involved in different categories production, all of these companies are involved in the production of signaling systems and locomotives, since these involve a lot of new technologies and high value-added. To maintain the competitiveness, the companies may choose to develop their own products in these two categories from a long-term perspective. The multiproduct nature of these major trainset and other component making firms will be discussed later.

While production of various components typically occurs in different manufacture sites, the final assembly generally occurs in the country of final sale apart from specific instances where due to a small order size or a few initial trainsets of a bigger order are assembled elsewhere and delivered in knock-down versions. Later, we discuss the details of the global production and assembly sites.

6.2.2 Market share

In this section, we study the market shares of the major trainset suppliers by examining the international contracts from 2001 to 2011. The database we compiled contains 47 international contracts between 2001 and 2011. The details of these contracts are provided in Appendix A.[61] Given our focus on international markets, we eliminated the contracts signed by

[61] The table includes 3 contracts from an earlier time period.

the trainset aggregators for their own countries.[62] Also, we only focus on studying the steel-wheel HSR networks, not the maglev.

From figure 6-6, we can see that Alstom, Bombardier and Siemens signed more contracts than the other companies during the ten years. Though Bombardier won a larger number of international contracts, their contracts were of lower than average value. This is probably because Bombardier is a smaller company (as we show later) with less resources, which may have restricted their capability to bid for the large valued contracts.[63]

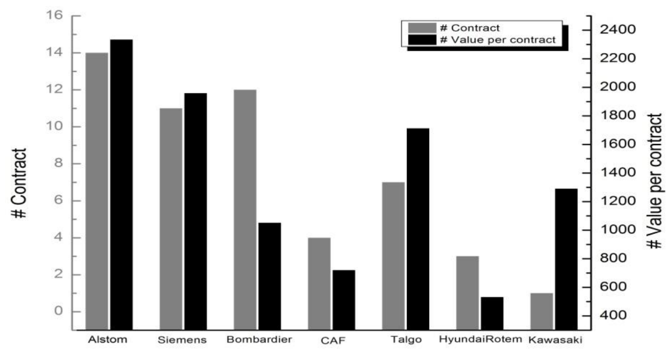
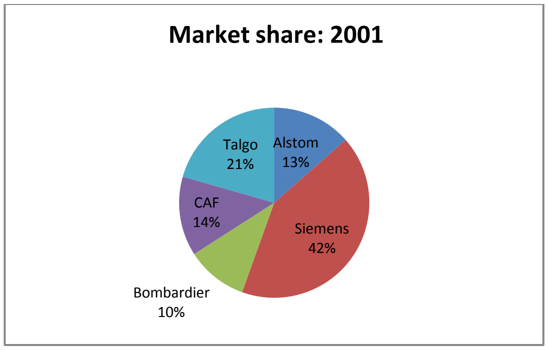
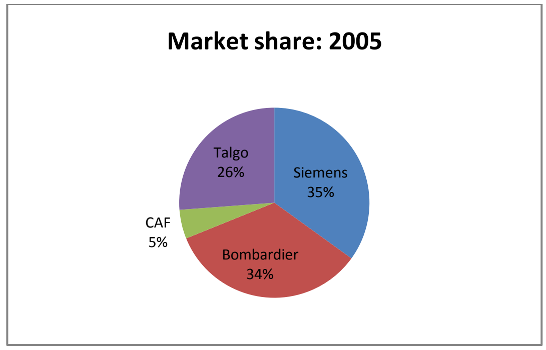
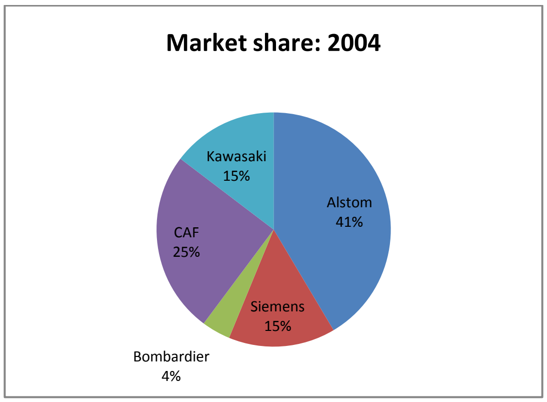


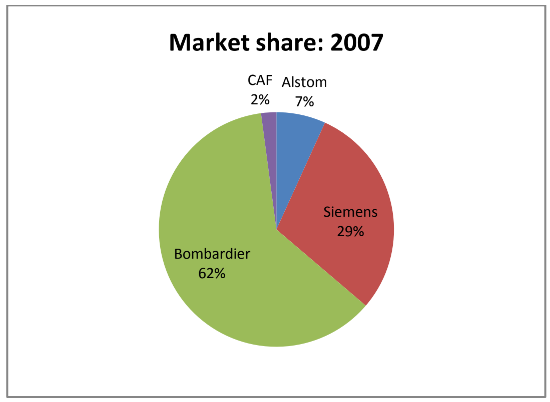
Figure 6-6: Contract number and value by company: 2001-2011[64]

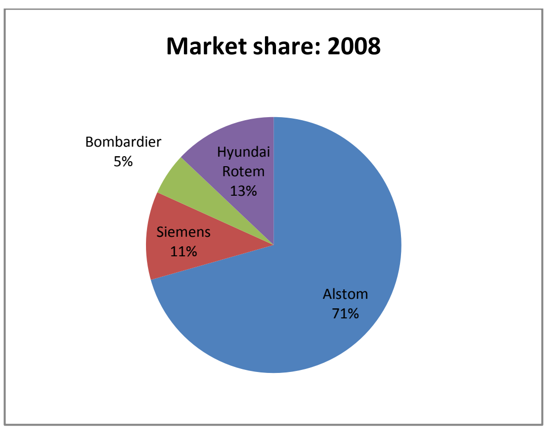
[62] Later I will provide comment here as to what this means for sample selection issues.
[63] Later we will examine the data and discuss the nature of partnerships that various trainset aggregators engaged in.
[64] Source: Appendix A.

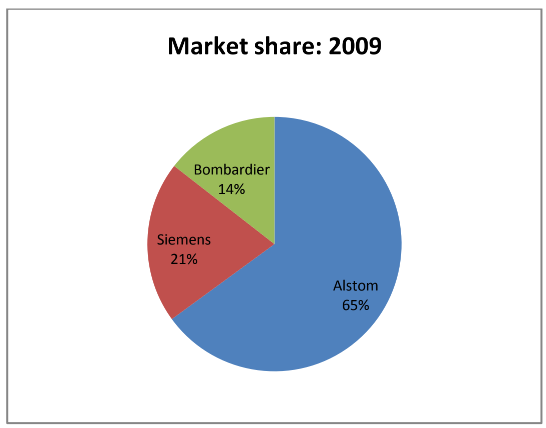

Market share: 2001
Talgo 21%
Alstom 13%
CAF 14%
Siemens 42%
Bombardier 10%

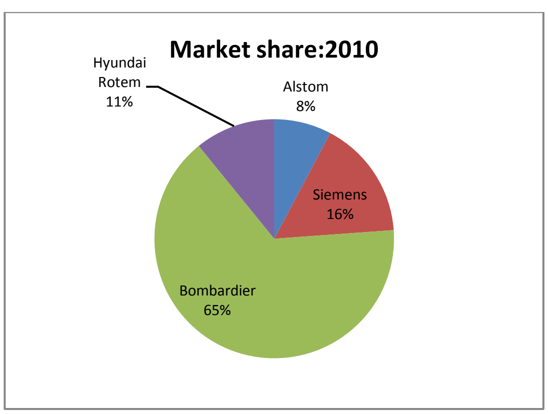

Market share: 2005
Talgo 26%
Siemens 35%
CAF 5%
Bombardier 34%


Market share: 2004
Kawasaki 15%
Alstom 41%
CAF 25%
Siemens 15%
Bombardier 4%


Market share: 2007
CAF 2%
Alstom 7%
Siemens 29%
Bombardier 62%


Market share: 2008
Bombardier 5%
Hyundai Rotem 13%
Siemens 11%
Alstom 71%


Market share: 2009
Bombardier 14%
Siemens 21%
Alstom 65%


Market share:2010
Hyundai Rotem 11%
Alstom 8%
Siemens 16%
Bombardier 65%

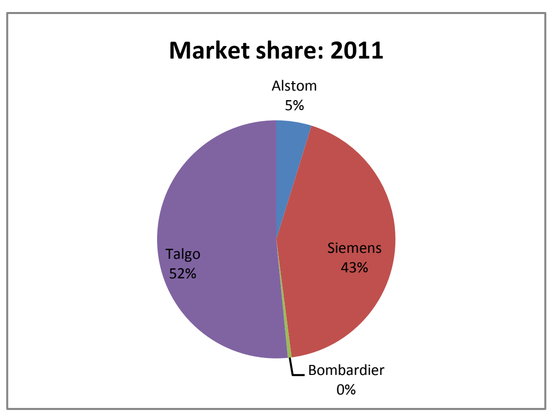
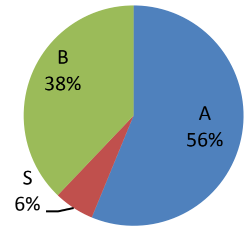
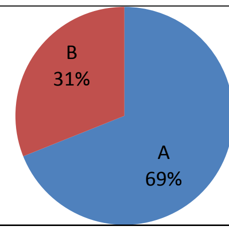
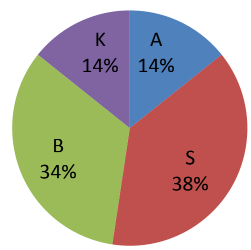

Market share: 2011
Alstom 5%
Siemens 43%
Talgo 52%
Bombardier 0%

Figure 6-7 (previous page): Market share (total contract value) by year[65]

We also examine the HSR market in different countries. Table 6-1 summarizes the contracts information by country. From table 6-1, we can see that Spain, Italy, Turkey and China are quite active in new HSR investments over the 2000-2011 period and many different companies are involved in these projects. In countries with large order size and sustained demand, the trainset companies would obviously like to bid and participate in the projects. Given the high fixed costs of development and investments needed to stay competitive in this industry, a higher order volume translates to reaping economies of scale (and scope) and potential for higher profits. It is also true that where there is need for large investments, those countries usually develop their own HSR trains via cooperation and technology transfer agreements with the leading global companies, who have already mastered the HSR and related technologies. In the Spain, the projects before 2005 are completed via cooperation between Bombardier, Alstom or Siemens and local companies. However, from 2005 onwards the Spanish companies Talgo and CAF became very proficient in completing projects on their own and set out to win international contracts independently, At home, the Spanish government subsequently began to award the contracts to local companies given their competencies and ability to meet the contractual investment requirements. In similar vein, Italian firm AnsaldoBreda and Chinese firms CNR and CSR established their own product and technological portfolios and began serving their respective home markets as well as entered into competitive bidding in the international markets. After the initial phase, most of the HSR products in Italy and China were manufactured domestically.

[65] Source: Appendix A.

Table 6-1: Contracts information[66]

Country	Company	Year	#Train	Value	Market share (Train #)
Spain	Alstom (A)	2001	20	377	
		2004	75	2210	
	Siemens (S)	2004	10	Na	
	Bombardier (B)	2001	16	304	
		2005	30	786	
		2005	18	403	
UK	Alstom	2002	52	1702	
Italy	Alstom	2002	60	312	
		2004	12	299	
		2004	14	365	
		2008	25	957	
	Bombardier	2010	50	2100	
China	Alstom	2004	60	771	
	Siemens	2005	60	1587	
		2009	100	5700	
	Bombardier	2005	20	350	
		2009	80	4010	
		2010	40	761	
	Kawasaki	2004	60	1290	
Argentine	Alstom	2008	8	3700	
Morocco	Alstom	2010	14	530	
Poland	Alstom	2011	20	941	
Uzbekistan	Talgo	2005	2	56	
Australia	Siemens	2006	23	346	
		2007	44	717	
Turkey	CAF	2005	10	224	
	Hyundai Rotem	2008	440	854	
		2010	80	438	

6.2.3 Firms in the supply-chain diagram

A large numbers of firms are involved in the supply chain of HSR industry. In this section we describe some key characteristics of these firms.

[66] Source: Appendix B.

Multinational firms

Firms in the HSR supply chain are usually multinational. For example, Alstom has manufacturing sites in nearly 19 countries and has a presence in nearly one hundred countries.

Companies set their manufacturing sites internationally for several reasons. First, companies set the site in some countries to meet the local requirements, which is often necessary for them to enter the market. For example, most of the big companies have US transportation manufacture sites. They all aim to be important suppliers for the U.S. market, which includes various rail components as well as other forms of urban transit. According to the Buy America Regulation, the U.S. Secretary of Transportation (authority delegated to the Federal Railroad Administrator) may obligate an amount to carry out a PRIIA funded project only if the steel, iron, and manufactured goods used in the project are produced in the United States. Too meet this regulation, companies build their manufacture sites in the United States. Siemens provides energy management solutions and seamless rail automation for railway systems in several US sites. Bombardier supplies passenger rail vehicles, propulsion and control equipment, rail control and signaling systems, and complete transportation systems to major transit and airport authorities across the United States. The vast majority of this equipment is built in their three manufacturing facilities in Plattsburgh (New York), Pittsburgh (Pennsylvania), and West Mifflin (Pennsylvania). Alstom offers a full range of products and services for the U.S. energy and rail transportation markets with a focus on delivering the right mix of products to support the construction of new systems utilizing the latest technology, while maximizing the lifecycle and operational efficiency of existing power plant and railway assets. CAF USA is one of the U.S. rail transportation market leaders in the design, manufacture, maintenance and supply of equipment and components for railway systems.

Elmira (New York) is home to CAF USA's American railcar production facility. All the other companies all have their US manufacture sites for the important components of rail in the US.

Another reason to establish an international manufacturing network is to make full use of the local resources. For example, through Alstom has it's headquarter of the transportation sector in France, the company finishes most of the HSR projects in its Italian facilities. After Alstom acquired the Italian company Fiat Ferroviaria, who own the tilting technology, most of the technology and facilities are in Italy. Labor and materials in Italy are also much cheaper than in France, enabling it to operate and compete efficiently in global markets.

Multiproduct firms

Appendix C lists the core products of selected components manufacturers. As it shows, firms in the supply chain are, in most cases, multiproduct firms, which provide more than one types of products. The term multiproduct covers a complex array of products and services that can be provided by a firm.

We consider the following examples from the HSR industry:

1. A firm produces one core product which has several different applications. The Czech Republic company, Bonatrans, for example, simultaneously produces wheelsets for passenger transport, locomotive, urban transport and freight transport. Though Bonatrans produces wheelset only, they are totally different products which are produced to meet the demand for different applications;
2. A firm produces only one core product for single use, however, in different types. For example, Germany Company Satek manufactures the small toilet cubicle and large toilet cubicle. The small toilet cubicle and large toilet cubicle are both specialized sanitary

cabins for the railway vehicle but in different size. So this can be viewed as another kind of multiproduct; and

3. A firm produces several kinds of core products. American company Westinghouse Air Brake Technologies Corporation (Wabtec) produces several products for the railway industry such as brake equipment, freight car truck component, rail door assemblies and signaling design. This is a more complex example as the firm is obviously a multiproduct firm, but also diversified in the sense that it produces different categories of products.

For most big companies, they do not fall into one single category, and the categorization of for these companies is complex.

Knorr-Bremse, for example, produces different types of brake systems which can be applied to the rail as well as a wide range of commercial vehicles. This company also produces other products such as automatic door systems, rail vehicle air conditioning systems and torsional vibration dampers for internal combustion engines. For Konrr-Bremse, it has several core products and some of the products can be used for multiple applications. Similarly, Kolowag produces wheelsets as well as wagons. For wagons, it produces a diverse array of passenger and freight wagons. Ansaldo STS produces signaling and automation system for rail companies and for transit operators. It also produces Automatic Train Control System (TVM) and European Railway Traffic Management System (ERTM) systems for the high-speed rail industry.

Kontron, for example, has a rather complex product portfolio. The company’s production of embedded computer system demands different technology for global and local application in rail industry. For the same application, Kontron’s embedded computer systems are different across project. Furthermore, the computer systems can be applied to energy, medical and military uses. The embedded computer systems of Kontron are both in different type for the same application and also have different kind of applications. That is, a mix of product diversification and multiple products within each category.

The product portfolio for word leading companies like ABB is even more complex. ABB is a Swiss-Swedish multinational corporation, operating mainly in the power and automation technology areas. The company offers power system for rail industry as well as the marine industry. The power systems supplied can be totally different even in the same industry. For example, the power system applied to Alstom's high-speed rail is not exactly same with that of Siemens, though both of them are power system for high-speed rail. Besides the power system, it can produce industrial robots which are used in a broad spectrum of railway applications as well as the automotive manufacture. The power systems and the robot are totally different products.

Many companies in HSR industry link economies of scale and scope to current technology and methods of production. The multi-product nature will influence the cost structure of the firms, and thus influence their R&D strategy. We discuss this in section 7.

6.2.4 Growth of HSR related businesses

From figure 6-8 and table 6-2, we can see that most of firms in the supply-chain diagram are located in Europe (especially in France, Spain and German) and Asia (such as China, Korea and Japan). Also, as we see in Appendix A, the world famous large companies are also centered in these countries. The number of firms can reflect the development of the business and the more firms a country has, the more developed the HSR business in this country.

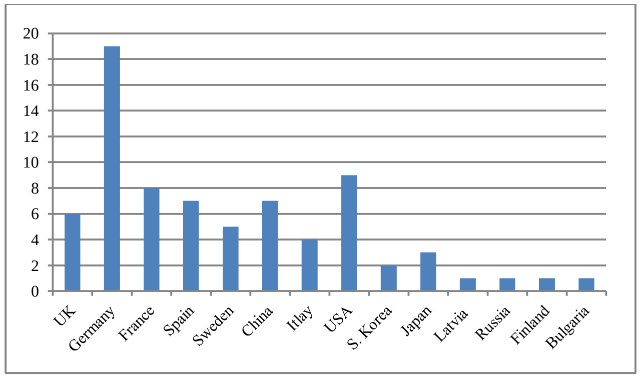


Figure 6-8: Number of firms in supply-chain diagram by country

Tabel 6-2: Number of firms in each categories of selected countries

	UK	Germany	France	Spain	Sweden	China	Italy	USA	S. Korea	Japan
Mechanical	1	9	3	2	2	2	1	4	1	
Electronic	2	6	4	2	2	2	1	2		2
Locomotive		6	1	3	1	2		5	1	1
Passenger cart	2	5	2	1	2				1	
Other Category	1	5	2			1	1	2		

Several factors will determine the development of related business for each country. First of all, in terms of the supply chain, the growth of firms in this industry typically follows the demand in the home country. Table 6-3 shows the HSR networks worldwide by country. France and Germany have had sustained demand for HSR investments over a long period. Correspondingly, France and Germany have had highly developed and sophisticated firms in the HSR supply-chain; their companies can be seen almost everywhere in the supply chain. China and Korea, the relatively new countries in HSR industry, are also developing a lot of local companies in this industry. China's case is more obvious due to its very high domestic demand for HSR. South Korea does not have high home demand as it is a relatively small country, but along the lines of other industries where they have attained significant global competitive advantage (e.g., shipbuilding, and broad based electrical and electronics) they have managed to establish significant strengths in HSR via Hyundai Rotem.

Table 6-3: High-speed rail in 2011 by country[67]

Country	Region	In operation (km)	Under construction (km)	Total Country (km)
Belgium	Europe	209	0	209
China	Asia/East	6158	14160	20318
Japan	Asia/East	2388	423	2811
France	Europe	1872	730	2602
Germany	Europe	1032	378	1410
Italy[4][5]	Europe	1296	92	1388
Netherlands	Europe	120	0	120
Russia	Europe	780	400	1180
Saudi Arabia	Asia/West	0	440	440
South Korea	Asia/East	412	186	647
Spain	Europe	2665	1781	3744
Switzerland	Europe	35	72	107
Turkey	Asia/West and Europe	457	1416	1873
Taiwan	Asia/East	345	0	345
United Kingdom	Europe	113	0	113
Uzbekistan	Asia/West	344	0	344

The second factor that has influenced the growth of HSR industry and firms is government investment. In earlier periods, Governments in Japan, Germany and France, and later Italy and Spain, for example, embarked on significant investments in mass transit systems, including HSR. This generated a high level of domestic demand, and facilitated and incentivized the growth of firms in this industry. In more recent years the Chinese government has made massive investments in rail in general, and HSR in particular due to the need to modernize the economy and facilitate growth and development of businesses. In China, the

67 http://www.uic.org/spip.php?article573. The high-speed here is defined as speeds greater than 150 mph.

total investment in new rail lines grew from $14 billion in 2004 to $22.7 and $26.2 billion in 2006 and 2007. Total investments in new rail lines including HSR reached $49.4 billion in 2008 and $88 billion in 2009. In all, the state plans to spend $300 billion to build a 25,000 km (16,000 miles) HSR network by 2020. Spurred by these public investments, companies like CNR and CSR have grown into formidable global competitors and are already selling light rail, commuter, and subway vehicles to a broad range of countries, and are increasingly active in bidding for HSR projects.

Similar to China, the investments were a major boon to Spain's manufacturing and construction industries. Nearly 600 companies generated products or provided services for Spanish rail sector. Spanish firms are competitive in every aspect of rail, from design and construction to manufacture of rolling stock to signaling, ticketing, operations and equivalent provision.

In contrast to countries like China and Spain, the US federal government has made very little investment in HSR. The United States once had a thriving intercity rail and urban transit network. So there are many big companies in the locomotive category, who mainly manufacture locomotive for the traditional trainset. By the 1950s, however, the federal government shifted its infrastructure spending decisively to highways and airports. As a result the public transportation systems atrophied, and America's technological leadership in the manufacturing of everything from subway cars to trams to various types of trains passed to companies in Japan, France, Germany, and a few other European countries. By the 1970s and 1980s, the domestically owned passenger rail manufacturing industry had vanished. Today, the U.S. passenger rail industry remains underdeveloped. Due to this lack of domestic investments and demand, the U.S has little or no competencies in the manufacturing of the sophisticated components needed for HSR.

The local rail development is the third factor that influences the growth of firms in the HSR industry. Germany is one of the largest rail and transit markets in the world. Its rail manufacturing industry remains a global technology leader, underpinned by strong internal demand and even larger export sales. We can see a large number of German firms in the supply chain diagram. Besides Siemens and Bombardier, whose transportation headquarter is in Germany can provide the full trainset and some other important components, Germany also has companies such as ContiTech, Vossloh, Knorr-Bremse in the mechanic group, Telefunken, AF Friedrichshafen in the Electronics groups, AEG power Solution in the power Group, Hubner and Satek in the passenger cart group, and Thyssenkrupp for the rail station motility system. These companies not only provide the components for the local rail companies Siemens and Bombardier, but also export their components to other countries.

Long a world leader in rail industry, Japan developed the world's first HSR network. As the most experienced HSR nation in the world, with service dating back to 1964, Japan has developed a strong technological and managerial capacity for manufacture and operation of HSR service. Japan has long been self-sufficient in providing all dimensions of rail service, including manufacture of rolling stock, which creates many world famous firms in the supply chain diagram, such as Kawasaki and Hitachi Transport System.

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7. MULTIPRODUCT FIRMS AND THE HSR INDUSTRY

As indicated in our earlier discussion of the firms in the supply-chain, the internal product structure of firms in the HSR industry is highly complex, more so than is apparent at a cursory glance. For example, the degree of product differentiation and diversification is much higher in some firms than in others. Some firms produce different products in the same industry, while others offer an array of related products but for several different industries. In this section, we discuss these aspects and comment on the business strategies that may influence the production decision-making process of the multiproduct firms in this industry's supply-chain. Among the important factors that result in firms pursuing a multiproduct strategy are production costs and synergies in technologies possessed by the firms. In this section we briefly examine some issues related to multiproduct firms as applied to the HSR industry.

7.1 Cost structure of multiproduct firms

The multiproduct strategy can be analyzed from a cost perspective. One of the important issues to consider in multiproduct setup is economies of scope and scale. This can be seen from two aspects in HSR industry (Cantos and Campos, 2005). First, is it more efficient for a single firm, rather than several separate firms, to supply different HSR components? Second, if different components are separated, will the supply of these components be more efficient within the context of a monopoly, or should two or more firms participate?

Cost function in multiproduct firms is different from that in single product firms. In this section, we will first review existing theoretical literature in economies scale and scope and then relate it to the high speed rail industry.

7.1.1 Economies of scale and scope: theoretical considerations

Economies of scale are common in single product firms, while economies of scope are new concept for the multiproduct firms. Whether exist or not in single product firms, the measurement and sources may be different when applied to the multiproduct setup. In this section, we will review the definition and measurement of economies of scale and scope theoretically.

Scale economies are often defined to be present when k-fold proportionate increase in every input quantity yields a k′-fold increase in output, where k′>k>1. Baumol (1976) define strict economies of scale as in the production of outputs in N are present if for any initial input-output vector $(x_1, \dots, x_r, y_1, \dots, y_n)$ and for w>1, there is a feasible input-output vector $(wx_1, \dots, wx_r, v_1y_1, \dots, v_ny_n)$ where all $v_i \geq w + \sigma$, $\sigma > 0$.

For single product firms we use the following expression to measure the degree of scale economies:

$$(1)\ S = \frac{C(y)}{yC'(y)} = \frac{AC(y)}{C'(y)} = \frac{\text{average cost}}{\text{marginal cost}}.$$

Returns to scale are increasing, decreasing or constant as S is greater, less or equal than unity. However, S cannot be applied to measure the degree of scale economies in multiproduct cases for the reason that a multiproduct cost function possesses no natural scalar quantity over which costs may be "averaged". For the multiproduct firm, Baumol (1976) and Panzar and Willig (1977) generate two basic measures in the set of multiproduct firms: Product-Specific Economies of Scale and Ray Economies of Scale. In such two frames of defining economies of scale, the main point is the definition of the average cost.

Ray economies of scale is a straightforward extension of the concept of single-product economies of scale. In defining the degree of scale economies over the entire product set, Baumol, Panzar and Willig (1982) first define the Ray Average Cost (RAC) to measure the average cost of the composite good defined as $\mathrm{RAC} = \frac{C(ty^0)}{t}$; where y^0 is the unit bundle for a particular mixture of outputs-the arbitrary bundle assigned the value 1, and t is the number of units in the bundle $y = ty^0$. So the degree of scale economies defined over the entire product set, $N = \{1, \ldots, n\}$ at y is given by(2)

$$(2)\ S_N(y) = \frac{C(y)}{y \cdot \nabla C(y)} \equiv \frac{C(y)}{\sum_{i=1}^{n} y_i C_i(y)},$$

where $C_i(y) \equiv \partial C(y)/\,\partial y_i$. Return to scale are said to be increasing, constant or decreasing as S_N is greater than, equal to or less than unity, respectively.

The measure of multiproduct economies of scale by ray economies scale can only describe the behavior of costs as output expands or contracts along a given ray. It doesn't describe the full behavior of costs as output bundles change. So Panzar and Willig (1977) propose another dimension of economies scale that is product-specific economies of scale.

For product-specific economies of scale, instead of defining average cost as the single product, we use the concept of Average Incremental Cost (AIC) as part of the measurement of product-specific economies of scale.

The average incremental cost of product i is defined as $AIC_i(y) \equiv \frac{IC_i(y)}{y_i}$, where the incremental cost of the product $i \subseteq N$ ($IC_i(y)$) is given as $IC_i(y) \equiv C(y) - C(y_{N-i})$ and y_{N-i} is a vector with a zero component in place of y_i and components equal to those of y for the remaining products. Then, we can use the (3) to measure the degree of scale economies specific to product i at output vector y.

$$(3) \quad S_i(y) = \frac{IC_i(y)}{y_i C_i} \equiv \frac{AIC_i}{\frac{\partial C}{\partial y_i}}.$$

Returns to the scale of product i at y are said to be increasing, decreasing or constant as $S_i(y)$ is greater than, less than, or equal to unity, respectively.

When we extend the definition to a product set, the degree of scale economies specific to the product set $T \subseteq N$ at y is given by (4)

$$(4) \quad S_T(y) \equiv \frac{IC_T(y)}{\sum_{j \in T} y_i C_j(y)} \equiv \frac{1}{1+e_T},$$

$IC_T(y)$ is defined as the incremental cost of the product set $T \subseteq N$ at y which is given by (5):

$$(5) \quad IC_T(y) = C(y) - C(y_{N-T}),$$

where y_{N-T} is a vector with zero components associated with the products in T and components equal in value to those of y for product N-T, and e_T is the elasticity of average incremental cost of T at y.

After dividing the product set N into two disjoint subsets, T and $N - T$, one can define the multiproduct degree of scale economies as $S_N(y)$ which is denoted by (6)

$$(6) \quad S_N = \frac{\alpha_T S_T + (1-\alpha_T) S_{N-T}}{(IC_T + IC_{N-T})/C},$$

where $\alpha_T = \frac{\sum_{j \in T} y_i C_j}{\sum_{j \in N} y_i C_j}$.

Economies of scope relates to a different characteristic for the multiproduct firms. Economies of scope happen when the cost of producing output (products) 1 and 2 jointly is less than the total cost of separate production. The existence of economies of scope creates incentives for specialty firms to merge and become multiproduct firms.

Panzar and Willig (1981) define economies of scale as follows. Let $N = \{1,2,\ldots,n\}$ denote the set of products under consideration, with respective quantitiesy $= (y_1, \ldots, y_n)$. Let y_s denote the n-vector whose elements are set equal to those of y for $i \in S \subset N$ and 0 for $i \notin S$. The function $C(y_s,w)$ denotes the cost of producing only the products in the subset S, at the quantities indicated by the vector y. Here, C(y ,w) is the usual multiproduct minimum cost function and w is the vector of factor prices. Let T= $\{T_1, \ldots, T_l\}$ denote a non-trival partition of S⊂N. That is $\cup_i T_i = S$, $T_i \cap T_j = \phi$ for $i \neq j$; $T_i \neq \phi$, and l>1. There are economies of scope at y_s and at factor price w with respect to the partition Tif $\sum_{i=1}^{l} C(y_T, w) > C(y_S, w)$. The economies of scope are weak if the inequality is weak (rather than strict), and diseconomies of scope if the inequality is reversed.

The degree of economies of scope at y relative to the product set T can be measured by:

$$(7) \quad SC_T(y) \equiv \frac{[C(y_T)+C(y_{N-T})-C(y)]}{C(y)},$$

The degree of economies of scope measures the relative increase in cost that would result from a splintering of production of y into production lines T and $N - T$. Such a fragmentation of the firm increases, decreases, or leaves unchanged the total cost as SC_T is greater than, less than, or equal to zero, respectively.

Panzar and Willig (1981) obtain the multiproduct cost function, which embodies the least costly way of producing y_s by solving (8):

$$(8) \quad C(y_s) \equiv \min_k \sum_{i \in S} V^i(y_i, k_i) + \Psi(k, \beta),$$

Where V^i represents the minimum variable cost of producing the output y_i using k_i units of capital services. The quasi-public input cost function, $\Psi(k, \beta)$ represents the cost of acquiring the requisite vector k of capital services, where β represents relevant factor prices.

Panzar and Willig (1981) demonstrate that for any nontrivial partition of N, there are economies of scope if and only if Ψ is strictly subadditive in the relevant range, which illustrates the equivalence between the existence of economic of scope and the shared input.

Squires (1987) points out two sources of sharable inputs and therefore economies of scope exist: the interdependent production process and allocatable (quasi-) fixed factors. An interdependent production process leads to economies of scope through local cost complementarities. If the multiproduct cost function can be represented as $C(Q_1, Q_2)$, where Q_1, Q_2 are two different products, cost complementary is $\Delta MC_1/\Delta Q_2<0$, which means the marginal cost of producing good 1 declines as more of good 2 is produced. Risk minimization, the quasi-public nature and lumpiness of capital, the reuse of input by more than one product, economies of network and the high cost of achieving information and the organizational and strategic impediments to its market transfer are all considered as reasons for local cost complementarities (Bailey and Friedlaender, 1982).

Another possible source for shareable inputs relates to allocatable fixed factors which generate "jointness" and hence economies of scope. The existence of the allocatable fixed factors will make the marginal allocation of variable inputs depend upon the allocation of the fixed input, and generate product-specific fixed costs. For example, when we use the sheep to jointly produce mutton and wool, the cost would be less than we use part of sheep produce mutton and the others for wool. The shared factor, sheep, does lead to economies of scale, though conventionally, mutton and wool don't seems have any relationship with each other.

7.1.2 Economies scale and scope in the HSR industry

There is a significant empirical literature which reveals the presence of economies of scale and scope, in varying degrees, in many industries. Considering the production procedure of the rail industry, the economies scale and scope are likely to exist in HSR industry. In this section, we discuss the possible existence of economies scale and scope of the firms in the HSR supply-chain diagram.

The fixed factors used to produce a single product can lead directly to economies of scale. For example, many firms use assembly line production with human labor that is economical for single product in large scale, which can best lead to the economies of scale. This is one of the important reasons why the major trainset suppliers are usually large in size. If the fixed factors exist in producing multiple products, the economies of scope will come up in production. For example, Czech Republic's company Bonatrans can use the same assembly line to produce bearing systems, brake disks on wheels and axles, noise absorbers, etc, while producing the wheelset. Also, the heating facilities are flexible to handle different kinds of wheelsets like regular rail wheelsets and the high speed rail wheelsets. Suppose that, if the company only produce single product, these shared factors cannot be fully used and will lead to less profit compared with the multiproduct production.

Besides sharing the tangible assets, some intangible shared factors like research activities and other forms of economies of knowhow are also a key source for economies of scale and scope. If the company has mature technology for a specific product, the company will invest only less proportion of R&D to produce similar products for industries, since a lot of the technology may be similar. Furthermore, the production of different products required similar knowledge may create high transaction cost while produced by different companies separately, which makes the transfer difficult. As a result, internal trading within a single firm is less costly compared with trading between different firms. For example, Kontron offers a variety of Box PCs which are used in a variety of industries including medical, security, gaming and transportation. The Box PCs are designed to meet the configuration requirements of all OEM solutions, thereby reducing development costs. Similarly, ABB has the engineering capability, experience and its own technologies to deliver "turnkey" system integration of electrical Balance of Plant specifically tailored to different power plant types, such as oil & gas fired combined cycle power plants, coal fired boiler power plants and hydro power plants as well as industrial sized turbine and boiler power applications. The R&D strategy of multiproduct firms will be discussed in section 7.2.

The products jointly produced by a single firm correlate with each other. Some intermediate products may become the input for other product. In this case, economies of scope will arise because such intermediate products manufactured by the firms are freely available for use in provision of a second product. Take Bonatrans as an example again. Bonatrans develops, manufactures and delivers a complete range of wheelsets, wheels, axles and tires for all types of railway vehicles. The wheels, axles and tires can be aggregated to form the wheelsets. So the cost will be reduced since Bonatrans can get the intermediate component of the wheelsets flexibly.

7.2 R&D in multiproduct firms

HSR industry involves a lot of advanced technologies, which requires large number of R&D investment while firms developing these technologies. The R&D strategy of the multiproduct firms will determine the product structure within firms and influence the economies of scale and scope. Firms need to make several decisions on R&D investment. First, they need to decide the composition of two types of R&D, which are product R&D and process R&D. The product R&D refers to the R&D used to improve the quality of existing products and create the new products, while the process R&D is R&D aiming at lowering the cost of making existing products.[68] Firms are different in choosing the composition of these two types of R&D due to the cost and other issues. Second, since firms are multiproduct, they will need to decide the distribution of the R&D among products. In this section, we review the literature to examine the factors that may affect the R&D strategies within the firms and use the theoretical foundation to explain the R&D strategy of firms in HSR industry.

[68] See https://editorialexpress.com/cgi-bin/conference/download.cgi?db_name=esam06&paper_id=272

7.2.1 Theoretical considerations

Firms are different in the degree of process and product innovation in which they engage. For example, in petroleum refining firms, almost three-quarters of total R&D is dedicated to process innovation. However, in the pharmaceutical industries, only one-quarters of total R&D go to process innovation. Also, American firms are always criticized for not devoting a greater share of R&D to improve their manufacture process and focusing more on short term R&D project. In contrast, Japanese firms are not conducting enough basic research and focusing more on process innovation. The existence of such differences has long been studied.

Link (1982) found the property of the product will influence the choice of the R&D portfolio and proposed that the greater product complexity increases the effort dedicated to process innovation. However, Cohen and Klepper (1994) believe there may be more at work in determining the composition of R&D than only exogenous industry-level conditions. Most theoretical and empirical research suggest that firm size, market structure and industry concentration may influence the composition of R&D.

Cohen and Klepper (1994) proposed theory to show how firms size conditions influence the relative amount of process and product innovation undertaken by firms. In the paper, the profit for the firms that conducting the process R&D can be represented as:

(22) $\pi_1 = a_1 q p c_1(r_1) - r_1,$

where $a_1$denotes the length of time before process cost saving are matched. q is the firm's output when it conducts process innovation. $r_1$is the firm's spending on process R&D , and $pc_1(r_1)$ represent the decrease in the firm's average cost from its process R&D.[69]

The profit function for firms with product R&D can be represented as

$$(23)\quad \pi_2 = a_2(hq + K)pc_2(r_2) - r_2,$$

where a_2 reflects the length of time before the new product variant is imitated.r_2 is the firms spending on product R&D, and $pc_2(r_2)$ is the price-cost margin earned on the new product variant. h denotes the fraction of firm's existing buyers that purchase the firm's new product and K is the additional output from which the firm earns rents through licensing and sales to new product.

The two profit function preliminarily indicates the share of process R&D share tends to increase with firm size. From π_1, the returns to process R&D are directly proportional to the firms' output, while in π_2 the returns to product R&D do not rise in proportion to q. The relationship between p and q further demonstrates the trends further. The basic idea is that the returns to innovative activity are generally tied to firm size because firms typically expect to exploit their innovations chiefly through their own output and to grow slowly over time due to innovation. Product innovations may be expected to yield greater returns from licensing and to spawn more rapid growth in output than process innovation. Consequently, the returns to product

[69] To reflect the idea that more process R&D yields greater manufacturing cost reductions but at a declining rate, they assume that $pc'(r_1) > 0$ and $pc''(r_1) < 0$ for all $r_1 \geq 0$. Similarly, $pc(r_2)$ has the same property

innovation should depend less on the returns to process innovation, causing large firms' R&D cost spreading advantage is particular pronounced for process relative to product R&D.

Cohen and Klepper (1994) only focus on the firm size within a given product market and not on the overall size of a multiproduct firm. Yin and Zuscovitch (1997) incorporate product innovation and process innovation into a duopoly model of multiproduct firms to study the relationship between the firm size and the incentive for product and process innovation. As most R&D literature, they assume that firms participated in the duopoly model would play two-state game: they first determine their process and product innovation strategies x^i and y^i simultaneously. Then based on the R&D strategies, they will engage in Cournot competition in the second stage game. The equilibrium can be got from the standard subgame-perfect Nash equilibrium.

In their models, demand is in linear form and the large firms are defined as the firms with low marginal cost. When the new product is introduced to the market, the inverse demand for both commodities becomes:

$$(24) \quad p^i = l - m(q^{a1} + q^{a2}) - n(q^{b1} + q^{b2}),$$

where $m > n > 0$; that is, commodity a and b are substitute the effect of a commodity's quantity on the price is greater than the effect of the substitute.

Once innovation takes place, firm i′s profit in the second stage subgame is

$$(25)\quad \pi^{i}(\vec{q}, C^{i}) = (p^{a} - C^{i})q^{ai} + (p^{b} - c)q^{bi},$$

where $\vec{q} = (q^{a1};\ q^{a2};\ q^{b1};\ q^{b2})$ is the output vector; $C^{i} = c^{i} - y^{i}$ is firm i′s post-innovation unit cost of good a; and c is the unit cost of the new product b, which is assumed to be the same for both firms.

In the first stage the payoff for firm i is [70]

$$(26)\quad V^{i}(x^{i}, x^{j}, y^{i}, y^{j}, c^{1}, c^{2}) = x^{i}\left[x^{j}\pi^{i}(\overrightarrow{q_1}, C^{i}) + (1 - x^{j})\pi^{i}(\overrightarrow{q_2}, C^{i})\right] + (1 - x^{i})\left[x^{j}\pi_{i}(\overrightarrow{q_3}, C^{i}) + (1 - x^{j})\pi^{i}(\overrightarrow{q_4}, C^{i})\right] - f(x^{i}) - g(y^{i})$$

Besides the static model, they also make dynamic adjustment based on the real world situation that innovation activities need time to produce outcomes. By taking the other ways of R&D as exogenous while studying one type R&D, they derived the existence of a unique equilibrium where large firms invests less in product innovation and more in process innovation than the small firm. Also, the increasing of one type R&D for one firm leads to the reduction of the rival's marginal benefit from investing in this type of R&D. They also propose that the effect of market power on innovation strategy depends on the extent to which a new technology

[70] $\overrightarrow{q_k}\ k = 1, 2, 3, 4$ characterize the equilibrium output vectors of four cases as follows: (i) both firms succeed in introducing the new product; (ii) firm i succeeds, but its rival fails; (iii) firm i fails, but its rival succeeds; (iv) both firms fail.

replaces the existing one. Finally, they prove that in the post-innovation market, the large firm is the leader for the old good while the small firm is the leader for the new good in the sense of expected output.

Intuitively, firm's initial market share will influence the composition of R&D in terms of product and process R&D. Large firms possessing more market share will benefit more from the cost reducing process innovation than the small firms. However, they will bear more profit less in terms of the old products when a new substitute comes up. Also, for the small firms, product innovation will help them overcome the competitive disadvantage, which provides them incentive to invest more on product R&D. In other world, large firms rely on a cost gap to generate efficiency gains, while small firms prefer to seek transitory profits from a shift in demand structure.

Petsas and Giannikos (2005) develop a differentiated-goods duopoly model in which firms engage in Cournot-Nash quantity competition to study the same question. In their model, labor is assumed to be the only primary factor of production. Firm size is measured by the firm's sales and the firm's sales are proportional to the number of goods produced. Moreover, instead of studying the static case, the paper focuses more on the evolution of the technological progressive industries from birth through maturity. Firms are assumed not to attend the production process until product innovation has slowed sufficiently.[71]

Based on the assumptions above, the model shows that the number of goods produced by a firm is a decreasing function of its in R&D cost from product innovation and increasing function for the process innovation. The results support the product life cycle (PLC) theorem that

[71] To some degree, this assumption is reasonable. However, some industries like automobile, tires and antibiotics contradicts the assumption: history of these industries indicates that great improvements were made in the production process well before the emergence of any key dominant design.

the firm starting with product R&D increases the incentive to switch from product to process innovation as the number of goods produced increases and thus its size increases. Once the firm is in the process R&D, it will continue to perform process R&D indefinitely, which means large firms have no incentive to do product R&D.

There are also several papers studying the R&D investment of monopoly market. Lambertini (2003) study the monopolist R&D portfolio to determine the incentive for the multiproduct monopolist to choose between process and product innovation. In this paper, total cost of the firm is given by:

$$(27) \quad C(Q, k) = c(k) \sum_{i=1}^{n} q_i + \xi k^2 + \theta n F,$$

where $Q \equiv (q_1 q_2, \dots, q_n)$ and $F > 0$ is the fixed cost of introducing a product; θ is scope economies parameter in production with $\theta \in [0,1]$ for $n > 1$ and $n = 1$. Variable k represents the level of process R&D.[72] By maximizing the monopoly the profit, the first order result is

$$(28) \quad c'(k) = -\frac{4\xi[1+\gamma(n-1)]}{n[\alpha - c(k)]},$$

which indicates the that the monopolist's incentive towards process innovation is decreasing in the number of products supplied in equilibrium.

[72] Note that k pertains to the (common) marginal cost of production for each product, $c(k)$. It is assumed that $c' < 0$, $c'' \geq 0$ and there is no uncertainty in R&D

Lin (2004) pointed out that Lambertini (2003) didn't take into account the effects of a change in n on k. Considering that, Lin (2004) discuss a special case which assume the cost function form as $C(k) = \bar{c} - k$. The first order condition becomes as

$$(29) \quad 1 = -\frac{4\xi[1+\gamma(n-1)]}{n[\alpha-c(k)]},$$

which provides the result as

$$(30) \quad k(n) = \frac{a-\bar{c}}{4\xi[((1-\gamma)/n)+r]-1},$$

In this case, $k(n)$ is an increase function of n which contradicts Lambertini (2003) and shows that the incentive toward process innovation is increasing in the number of product supplied. The paper also gives the explanation for such result. The idea is that since cost reducing R&D lowers the unit cost of R&D, a firms' incentive to invest in process R&D is positive to the level it produces. In the model, the monopolist output is obviously with n and thus the incentive is also positive related to the number of varieties.

Lambertini and Mantovani (2005) model the optimal behavior of a multiproduct monopolist investing both in process and product R&D in a dynamic setting. The finding of the paper includes: first, they find the incentive of investing in process and product R&D will increase as the number of varieties increase; secondly, if the reservation price is sufficient low, firms will devote a larger amount of resources to process innovation rather than the product innovation irrespectively of the product range and associated level of differentiation.

Some literatures focus on solve the other strategies in R&D investment. Lin (2009) attempts to investigate the incentive for multiproduct firms to investment in non-drastic[73] cost-reducing R&D. The paper considers the decision about which product firms' R&D investment should target and how much these investment should be.

In the multiproduct monopoly model, the paper assumes the monopoly produces two products and defines the product which involved low initial level of the unit cost while producing as the core product. With the assumption of the linear demand and quadratic R&D cost function, the model shows that a multiproduct monopoly conducts more on process R&D in its core product than in its non-core products. Also, if the products are closer substitutes, the firm will invest less in R&D for both product and the monopolist tends to choose a more specialized R&D portfolio. In this case, the firms will have a simple product structure.

In the multiproduct duopoly model, it seems that all the three effects including direct effect, business-stealing effect and cross market effect[74] is more beneficial for a firm's core product than for its non-core product. If the total R&D cost is given as the quadratic form as the monopoly model, the pattern of R&D portfolio found for a multiproduct monopoly also holds for

[73] An innovation is drastic if the patentee is unconstrained by outside competition and can therefore engage in monopoly pricing.

[74] Direct effect of R&D investment states the cost-reducing R&D investment in a product raises the level of a firm's profit from that product. Business-stealing effect of R&D investment presents a firm's cost-reducing R&D investment in a product forces its rival firm to lower its Cournot output. Cross market effect means a firm's R&D investment in a product leads to an output adjustment by a rival firm in a competing product, which is unique for the multiproduct firms.

a multiproduct duopoly that each firm in the duopoly model would like to invest more in its core product and the degree of R&D specialization increases as the products becomes more similar.

However, the model also shows some differences to the monopoly model. In the duopoly model, the degree of R&D specialization is higher than that of the monopoly model, which means the market competition will lead to a more specialized R&D portfolio. Firms' R&D investment are strategic substitutes in the same product and strategic complements[75] across the products, which indicates that a multiproduct firm can adjust its R&D portfolio to avoid competition in the same product market but fights back in other competing products. A firm will cut its R&D investment in a product if its rival increases its R&D effort in that product, but will increase its R&D investment in another competing product.

Unlike the single product firms, the multiproduct firm can internalize the negative externalities that their R&D investment generate for each other by reducing their R&D efforts for all products and refocusing such efforts on different R&D projects.

7.2.2 R&D in HSR industry

The theoretical literature shows that the size of the firm will influence the composition of R&D in terms of process and product R&D. The theoretical literature tends to show that large firms will tend to conduct more on process R&D, while smaller firms tend to invest more on product R&D. This can explain one of the common strategic partnerships in HSR industry. While working on HSR project, one big company providing engineering, manufacturing or

[75] The decisions of two or more players are called strategic complements if they mutually reinforce one another, and they are called strategic substitutes if they mutually offset one another.

product development services, will partner with a smaller, entrepreneurial firm or inventor to create a specialized new product.[76] For example, while building the German ICE, Siemens cooperated with several local components manufactures. Siemens supplies capital, and the necessary product development, marketing, manufacturing, and distribution capabilities, but not in charge of supplying many specialized technical or creative expertise, which is done by the small local component suppliers.

Many small size components suppliers in the supply-chain diagram focus more on product innovation. For example, the share of Bonatrans design products is growing significantly. While in the mid 1990s Bonatrans' designs represented only approximately 4% of total deliveries from Bonatrans, in 2009 the share exceeded 47%. This documents the shift from mere manufacturer towards provider of comprehensive services. The Bonatrans research team is engaged in development of new materials, products and technologies that improve the utility value of our products for our customers and that respond to current and future needs of customers.

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[76] See http://en.wikipedia.org/wiki/Strategic_partnership

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8. FOREIGN FIRMS' CAPABILITIES IN THE U.S.

To provide a perspective, this section describes the various trainset firms' operations and capabilities in the U.S. I also comment on the implications for U.S. HSR investments.

8.1 Siemens

Siemens is a major player in global markets and has a considerable presence in the U.S. Siemens has the Sacramento (California) facility where they manufacture light rail vehicles for Denver, Calgary, Edmonton, Portland, Hampton Roads, Charlotte, and Salt Lake City. Siemens provides energy management solutions and seamless rail automation for railway systems. They supply traction sub-stations, OCS lines and energy storage systems for dozens of cities across the U.S. Siemens is the primary contractor responsible for providing state-of-the-art security, information and communication rail technology and network upgrades to make New York City's subway more efficient, faster and safer.[77]

The Sacramento facility[78] has 5 production areas, including warehouse/sub-assembly, carshell welding, carbody painting/cladding, light rail vehicle final assembly/bogie assembly and testing. The facility including the following four structures:

1. 75,000 sq.ft., which includes 15,000 sq.ft. sub-assembly shop, 37,500 sq. ft stockroom and warehouse space and 15,000 sq.ft. for engineering, purchasing and aftermarket departments;
2. 103,000 sq. ft. of carshell manufacturing and vehicle assembly space including 24,000 sq.ft office space for production management, project management, accounting, human resources, business development, and marketing;

[77] http://www.mobility.siemens.com/usa/en/pub/home.htm
[78] http://www.mobility.siemens.com/usa/en/pub/services_and_solutions/manufacturing.htm

3. 21,500 sq. ft. newly added carshell paint and final finish space; and
4. 2 cladding booths.

8.2 Bombardier

Bombardier supplies passenger rail vehicles, propulsion and control equipment, rail control and signaling systems, and complete transportation systems to major transit and airport authorities globally and across the United States.

Bombardier entered the U.S. rail transportation market in 1976 and won its first major U.S. contract for 825 subway cars in New York City in 1982. In the mid-1980s, Bombardier significantly strengthened the engineering resources and ability to serve the North American market by acquiring Pullman Technology of Chicago and the assets and designs of Philadelphia-based Transit America, the mass transit equipment division of the Budd Company. Bombardier also installed the first and only U.S high-speed trains, the Acela Express. The vast majority of this equipment is built in their four manufacturing facilities in Plattsburgh, Pittsburgh, West Mifflin and Kanona.[79]

The Plattsburgh (New York) facility is Bombardier's final assembly and test center for rail cars being delivered in the U.S. marketplace. Opened in 1995 to support projects for the Metropolitan Transportation Authority (MTA) of New York, Plattsburgh now delivers rail cars to customers across the nation. They have recently broadened the skill set and capabilities at Plattsburgh through the transfer of stainless steel welding technology and equipment, thus expanding the facility's mandate to include building car shells. Other capabilities recently added at the site are assembly of trucks and door systems. Since 1995, Bombardier's capital investment in the Plattsburgh site has totaled more than $25 million.

[79] http://us.bombardier.com/us/about_bombardier_in_country.html

The Pittsburgh (Pennsylvania) plant is the global production facility of their fully Automated People Mover (APM), monorail and rubber-tired rapid transit technologies. The products they build at this plant include the INNOVIA APM 100, INNOVIA APM 200, the INNOVIA APM 256, and the INNOVIA Monorail. The plant is also responsible for the development and implementation of CITYFLO 550 fixed block automatic train control (ATC) solution and CITYFLO 650 communications-based ATC, as well as SEKURFLO transit security family of products.

At their West Mifflin (Pennsylvania) facility, Bombardier produces the Propulsion and Control equipment for heavy rail/metro lines and APM systems. This equipment is currently in use in many American cities, including Baltimore, Boston, Miami, Atlanta, San Francisco, Pittsburgh, Philadelphia, Chicago, Los Angeles, New York, and Washington. In addition to the projects in the United States, the West Mifflin facility also provides product for international projects, including Toronto and Vancouver in Canada, Sao Paulo in Brazil, Hong Kong, Taipei, Kuala Lumpur, and Beijing.

At their Kanona (New York) facility, they provide rail vehicle overhaul for all types of rail cars as well as refurbishment of components and systems at our facility in Kanona, New York. The Kanona site has served a wide range of customers in the United States, including the Greater Cleveland Regional Transit Authority (light rail vehicles), MTA/Metro-North Railroad and the Maryland Mass Transit Administration (commuter coaches), and the Massachusetts Bay Transportation Authority (truck overhaul).[80]

[80] http://us.bombardier.com/us/products_bt_projects.htm

8.3 Alstom

Alstom, a top-tier global company, offers a full range of products and services for the U.S. energy and rail transportation markets with a focus on delivering the right mix of products to support the construction of new systems utilizing the latest technology, while maximizing the lifecycle and operational efficiency of existing power plant and railway assets. One in five metropolitan subway systems in the U.S. rolled off Alstom Transport production lines, and the company currently operates the country's largest rail manufacturing facility. Alstom Transport is a proud partner of Amtrak's Acela - the only true high-speed rail line in the U.S. - which operates along the Northeast corridor

As the U.S. works to address problems associated with pollution and urban congestion, Alstom offers decades of experience, including delivery of the world's fastest high-speed train, to potentially the U.S. realize the full benefits of advanced rail transportation technology. Alstom Transport provides a full range of rail transport products and services for the U.S. market, including the rolling stock, high-speed and very-high-speed trains, below ground metro and subway systems, above ground tramways, infrastructure, signaling and control systems and service and maintenance for existing fleets and rail networks.

Alstom's presence in the U.S. comprises as many as 10,000 employees in locations that span 47 states and the District of Columbia. Those locations range from major manufacturing sites, like our newly-opened, state-of-the-art systems manufacturing facility in Chattanooga, Tennessee (pictured above), to on-site service sites across the country. The major U.S. locations and their activities are shown in table 8-1.

Table 8-1: Alstom U.S. sites[81]

	Locations	Activities
Corporate	Washington, D.C.	U.S. Country Headquarters
Grid	Canton, OH	Grid Engineering procurement & construction services
	Charleroi, PA	High voltage switchgear (Worldwide Center of Excellence), disconnect switches
	Philadelphia, PA	US headquarters & power electronics
	Phoenix, AZ	Digital instrument transformers
	Redmond, WA	Network management solutions (Worldwide Center of Excellence
	Rockledge, FL	Grid service center
	Stow, OH	Power transformer services
	Waynesboro, GA	Instrument transformers
Power	Amarillo, TX	Wind turbine offices and nacelle assembly facility
	Chattanooga, TN	Turbine engineering and manufacturing; boiler engineering and manufacturing
	Concordia, KS	Environmental manufacturing
	Danville, IL	Turbine services
	Denver, CO	Boiler service center
	Erlanger, KY	Boiler service center
	Harrisburg, PA	Boiler service center
	Houston, TX	Boiler services
	Jupiter, FL	OOEM gas turbine services, engineering, manufacturing and R&D
	Knoxville, TN	Environmental control systems, engineering, Carbine Capture System
	Littleton, CO	Environmental engineering & manufacturing; Hydro U.S. headquarters-large hydro, hydro services & project office
	Melville, NY	Plant advisory services and design engineering
	Monroe, WA	Hydro controls & governors, engineering, sales and project management
	Richmond, VA	Turbine engineering, manufacturing and service center; power automation & controls, excitation systems, monitoring and diagnostics
	Schofield, WI	Hydro controls & governors, sales, engineering, project management & manufacturing
	Suwannee, GA	Boiler service center
	Tyler, TX	Boiler service center

[81] http://www.mikemitchellonline.com/samples/alstomusa/frameset/fr_td.htm

	Wellsville, NY	Environmental engineering and manufacturing
	Wexford, PA	Environmental engineering and manufacturing
	Windsor, CT	Boiler engineering, services and R&D
Transport	Chicago, IL	Train life services
	Hornell, NY	Rolling Stock
	Mare Island, CA	Train life services
	New Castle, Delaware	Train life services
	New York City	U.S. headquarters
	Rochester, NY	Transport Information Solutions

8.4 CAF

CAF is one of the global market leaders in the design, manufacture, maintenance and supply of equipment and components for railway systems.

Elmira (New York) is home to CAF USA's American railcar production facility. The Elmira facility, which was purchased in 2000, comes from an extensive history in the rail vehicle manufacturing, and its purchase represented the consolidation of CAF USA in the US rail transportation manufacturing.

Known mostly for final assembly of rail cars since the mid-1980's, Elmira has the facility spanning across 38 acres and has more than 400,000 sq. ft. of covered space. It houses CAF USA's Engineering, Production, Testing, and Human Resources. CAF USA has gradually increased its activities in Elmira over the years and has completed important upgrades to the plant. One of the most notable features of the Elmira facility is its test track, which covers 2,700 ft. in distance, allowing CAF USA to conduct many critical vehicle tests before the railcar is shipped to CAF USA's customers. As part of CAF USA strategic plan and commitment to the Buy America program, CAF USA is establishing a stainless steel car shell manufacturing facility within the Elmira plant. This significant investment will allow us manufacture 100% in the US with an American workforce.[82]

8.5 Nippon Sharyo

Nippon Sharyo U.S.A. was launched in 1982 with a contract to supply 44 single-level EMU cars to the Northern Indiana Commuter Transportation District (NICTD), and has been a consistent and steady presence in North America ever since.

In their traditional business model in North America, Nippon Sharyo have manufactured carbody shells in Japan, and contracted with a local North-American company for final assembly, with Nippon Sharyo retaining responsibility for overall project management and quality control. Recently, Nippon Sharyo significantly increased their commitment in North America with their decision to build a factory in Rochelle, IL. The first car, a Gallery-Type EMU for Metra, will roll out of this facility at the end of 2012.[83] The supply record of Nippon Sharyo in the U.S. is shown in table 8-2.

Table 8-2: Supply record in the U.S.[84]

Year	Car Type	Customer	Maximum Speed (Mph)	QTY
1982-1983	EMU	Northern Indiana Commuter Transportation District (NICTD)	79	44
1984-1987	PC	California Department of Transportation (CATRANS)	79	72
1985-1993	PC	Maryland Department of Transportation (MDOT)	120	63
1989-1990	LRV	Los Angeles Country	55	54

[82] http://www.cafusa.com/ingles/compania/oficinas.php
[83] http://www.nipponsharyousa.com/aboutus.html
[84] http://www.nipponsharyousa.com/products.htm

		Metropolitan Transportation Authority (LACMTA)		
1994	LRV	LACMTA	55	15
1993	EMU	NICTD	79	17
1994-1996	PC	Northeast Illinois Regional Commuter Railroad Corporation (METRA)	79	177
1999	PC	Peninsula Corridor Joint Power Board (PCJPB)	79	20
2000	EMU	NICTD	79	10
2002-2008	PC	METRA	79	302
2005	EMU	METRA	79	26
2006-2009	PC	Virginia Railway Express (VRE)	79	71
2009	EMU	NICTD	79	10

8.6 Talgo

Talgo is a Spanish multinational firm with many innovations and attractive designs to their credit. The main offices of Talgo, Inc. and the maintenance facility for the Talgo trains (property of Amtrak and the Washington State Department of Transport (WSDOT)), are located in the city of Seattle, Washington. Talgo trains in the U.S perform daily passenger services under the name of Amtrak Cascades covering the route between Vancouver, British Columbia, and Eugene, Oregon.[85]

Talgo integration allows the company to be involved in all phases of each project in U.S., including design, manufacture, and maintenance of the trains. It has also allowed Talgo to develop techniques of preventive maintenance similar to those used in the aerospace industry. Talgo is responsible for the complete maintenance of the trains carried out in Seattle. Talgo's

[85] http://www.talgoamerica.com/about-us.aspx

outstanding maintenance practices have produced noteworthy results such as greater than 99% availability in service.[86]

In October of 1994, showcase runs of the Talgo rolling stock were performed for railway authorities and technical experts in Oregon, California, Missouri, Ohio, Pennsylvania, Massachusetts, New Haven and Maine. The contract with WSDOT was also renewed to continue the lease of the Talgo TP 200 trainset in the Pacific Northwest corridor. As the project proved to be successful, in July of 1996, WSDOT and Amtrak placed an order to buy three new Talgo TPU™ trains (two WSDOT and one Amtrak) and to lease one additional train (Amtrak). These were assembled in Seattle using American workers. The new Talgo trains started service in January 1999 and were operated by Amtrak under the Amtrak Cascades brand name. A fifth trainset was manufactured at the same time as the four previously mentioned. This trainset was scheduled to enter service between Los Angeles and Las Vegas in early 2001, but was sold to WSDOT in 2003 and is currently in use on the Eugene to Portland Corridor.

So far, the operation of these trainsets has been a success. Ridership has continued to increase, travelling times have been significantly reduced, and the entire corridor has been revitalized. From Talgo's perspective, the key for success has been the design of the trains, including the many amenities, such a individual electric outlets for laptops, wheelchair lifts on ADA cars, individual audio-video outlets; the quality of the ride and reliability that is assured by the application of Talgo's integral maintenance system.[87]

[86] http://www.talgoamerica.com/about-us.aspx
[87] http://www.talgoamerica.com/series6-amtracCascades.aspx

8.7 General Remarks

The above discussion of the various global trainset manufacturers provides a fairly comprehensive summary of their manufacturing, logistics and supply-chain capabilities in the U.S. All of the trainset suppliers noted above have extensive global supply chains, new investment capabilities and experience of fulfilling contracts in many countries. These characteristics imply that if the trainset suppliers need to expand their operations in the U.S., they will be able to do so within short time frames. From a U.S. HSR investment policy perspective, this is encouraging as when multiple-suppliers are available to meet project demands, a more competitive bidding results which benefits the U.S. consumers and taxpayers.

9. INTERNATIONAL HSR CONTRACTS AND PARTNERSHIPS

In this section I take a look at information on orders and contracts in international HSR markets. The data we compile cover the period 2000-2011 and includes information on the size of the trainset orders, the type of train by speed categories, details on collaboration among firms, competition among bidders for the particular investment, among other aspects. This allows us to gain insights into the functioning of this complex industry, and potentially provide guidance for policymakers contemplating investments in this area.

The data and information we examine were compiled from information on orders and various contract details available from the Companies' websites, newspaper stories, railway technology and industry portals, information documented by various organizations, and internet search. Due to the commercial confidentiality issues, information for some aspects of the contracts are not in the public domain and therefore not available for our study. The details we were able to compile after an extensive search are presented in the table in Appendix A. Below we note some observations related to partnerships between HSR companies that emerge from the contracts table.

9.1 Partnerships between HSR firms

Based on the observations in the contracts table (Appendix A), it is clear that there are a number of orders where different HSR trainset suppliers form partnerships and collaborative agreements. Here we briefly discuss this issue.

As we have noted before, HSR is a complex industry and involves numerous advanced technologies, products and services. Consequently, an individual company often needs to form partnerships and alliances with other companies in the industry to bid for and complete projects.

Thus, partnerships and alliances have become one of the important business strategies in bidding for the international HSR contracts. In addition to the major trainset suppliers themselves wanting to form partnerships to compete and complete projects, there is also evidence that in some of the more recent projects the involved Governments themselves wanted collaborative bidding. In this section we examine issues related to such collaborations and study contracts and partnerships in international HSR contracts.

9.1.1 Partnerships: forms, determinants and effects

Partnership, or consortium, is defined as purposive strategic relationships between independent firms, who share compatible goals, strive for mutual benefits, and acknowledge a high level mutual interdependence (Mohr and Spekman, 1994). The cooperative behaviors characteristic of partnerships include long-term purchasing agreements, joint marketing programs, shared research and development programs, and equity-based relationships. Partnerships may be horizontal (between suppliers) or vertical (between suppliers and buyers) (Vlosky and Wilson, 1997).

There are two forms of partnerships:[88] (1) general partnership; and (2) limited partnership. In a general partnership, the partners divide responsibility for management, liability and their share of the business' profits or losses. Shares are assumed to be equal unless a written agreement states differently. Joint venture is a common general partnership, but the partnership is formed for a clearly defined or limited period of time or is formed for a single project. In a limited partnership, most of the partners (to the extent of their investment) have limited liability, along with limited input in management decisions. While this can encourage and help obtain investors for short-term projects or for investing in capital assets, this form of ownership is not

[88] See http://www.justia.com/business-formation/docs/forms-of-partnership.html

often used for operating service or retail businesses. Limited partnerships have a more complex and formal structure than general partnerships.

A formal partnership between two commercial enterprises is called strategic partnership. One common strategic partnership involves one company providing engineering, manufacturing or product development services, partnering with a smaller, entrepreneurial firm or inventor to create a specialized new product. Typically, the larger firm supplies capital, and the necessary product development, marketing, manufacturing, and distribution capabilities, while the smaller firm often supplies specialized technical or creative expertise. Another common strategic partnership involves a supplier manufacturer partnering with a distributor or wholesale consumer. Rather than approach the transactions between the companies as a simple link in the product or service supply chain, the two companies form a closer relationship where they mutually participate in advertising, marketing, branding, product development, and other business functions.[89]

Research on partnership has posited several theories to support the partnership. The formulation of the partnership is motivated primarily to gain competitive advantage in the marketplace. First, partnership can take a form to access new technologies or markets and companies can provide a wider range of products or services via certain partnership. Second, partnership can minimize the transaction costs and increase economies of scale in joint research or production. Third, partnership firms access knowledge beyond their boundaries (Powell, 1987; Jakki and Robert, 1994).

Partnerships, however, can also cause complications in business relationships. For example, partnerships may cause one company rely too much on the other and lose autonomy (Mohr and Spekman, 1994). As an example, in March 2001, Siemens won one half of RENFE's

[89] See http://en.wikipedia.org/wiki/Strategic_partnership

tender to supply 32 high-speed trains for the Madrid-Barcelona high-speed rail line, offering a modified version of the ICE 3 high-speed train used by German Railways (Deutsche Bahn) for its InterCity Express service. The ICE 3 trains were a joint production with other Germany-based train manufacturers, who refused to supply parts or sell licenses to Siemens for the AVE Class 103. This caused a delay (for which Siemens eventually paid €21 million), during which Siemens had to re-develop the missing components. Giving up the partnership finally helped Siemens build the complete high speed rail manufacturing platform.[90]

Free riding is another problem in partnerships. Some firms may bear a proportionally higher fraction of the necessary time and effort to secure collective resources while others may try to free-ride on those efforts (Mesquita and Lazzarini, 2007). Further, partnerships may increase the complexity of the project and cause the problem of information asymmetry (Provan, 1984; Williamson, 1975; Mohr and Spekman, 1994).

9.1.2 Literature review

The willingness of the partners to work for the survival of the partnership is important to the success of the partnership. Mohr and Spekman (1994) studied the attributes of partnerships and concluded that more successful partnerships**,** compared with less successful ones, exhibit higher levels of commitment, coordination, interdependence and trust. Commitment refers to the trading partners to exert effort on behalf of the relationship. Coordination is related to boundary definition and reflects the tasks each party expects the other to perform. Interdependence refers to firms joining forces to achieve mutually beneficial goals, they acknowledge that each firm is dependent on the other. Interdependence results from a relationship in which both firms perceive mutual benefits from interaction and the loss of autonomy will be equitably compensated

[90] See http://en.wikipedia.org/wiki/AVE_Class_103

through expected gains. Trust is the belief that a party's word is reliable and that a party will fulfill its obligation in an exchange which is highly related to firms' desires to collaborate.

Thomson’s (1967) categorization of interdependencies helps illustrate the multiple ways in which interfirm coordination can lead to distinct types of collective efficiencies. There are several reasons for the existence of interdependencies. First, firms depend on each other to benefit from resources which any firm alone would be unable to acquire due to scale constraints. Second, firms’ activities may be related to each other in a sequential fashion, where one’s input is another’s output. Third, activities may be related to each other in a reciprocal way, whereby each agent’s input is dependent on the others’ output and vice versa.

Mesquita and Lazzarini (2007) argue that a rationale governance is an important mechanism of interfirm coordination based on transaction cost theory. As parties integrate the above resource interdependencies to attain collective efficiencies, they must align expectations and mitigate associated trade hazards. Given the relationship-specific nature of these efforts, transaction cost logic suggests that parties will need to employ safeguarding mechanisms, such as formal contracts, to avoid opportunistic expropriation. As a result, they need rational governance mechanisms which are interfirm cooperative arrangements based on informal rules and unwritten codes of conduct that affect the behavior of firms when dealing with others. Rational governance will on the one hand help firms overcome such free riding problem by enhancing their ability to align expectations and craft common strategies to secure collective resources in the vertical cooperation, and on the other hand play an particular important role to guarantee the success of horizontal cooperation.

They follow Palay (1984) and Kaufmann & Stern (1988) by focusing on particular relational norms supporting informal agreements. First, parties engaged in relational governance should share information so as to facilitate their current interaction and promote subsequent changes in product design and schedules. Second, firms should maintain a high level of mutual assistance, for instance by helping each other during unanticipated crises, or recommending alternative courses of action when new contingencies emerge. Finally, firms should pay attention to distributive norms by sharing the costs and benefits of their joint efforts.

Vlosky and Wilson (1997) point out that with intense competition in marketplace and condensing of product life cycle, paying attention to business relationships has become imperative for firms wanting to maximize performance.

The degree of participation of horizontal partners varies in European Union. The question of who should be involved and when is largely determined by the member states in accordance with the spirit of the regulations, the institutional culture of the state and the realities on the ground. The picture is more varied in other states, but the extensiveness of horizontal partnerships is generally correlated with the length of the Member State’s experience with partnerships.

The ultimate goal of a partnership is to develop strategic advantage by pooling resources, gaining access to markets and technical information, leveraging of complementary strengths, and achieving economies of skill. It is unclear that whether or not partnership actually enhances the performance.

Some research supports partnerships’ contribution to improve performance. For example, Ellinger, Keller and Ellinger (2000) found that collaboration such as team work, sharing and the achievement of collective goals is positive associated with performance. However, Brinkerhoff (2002) argues that most evidence of inter-organizational partnerships’ contributions to performance is anecdotal, except in some private alliance, where Shah and Singh (2001) can quantify increased efficiencies.

9.1.3 Partnerships in HSR markets

In 1963, Japan became the first country to own the high speed rail network – the Shinkensan. Later in 1967 and 1985, France and Germany developed their own high speed rail networks. At that point, only some Japanese companies like Kawasaki, French company Alstom, and German company Siemens had the capability to manufacture the trainset. During that time, international collaborations were somewhat rare. Countries typically choose to develop their HSR, and components and supply-chain, using their local companies. However, due to the complex nature of the HSR projects, there were a lot of partnerships within the countries. For example, Germany's ICE was jointly produced by a large number of German-based companies besides the leader Siemens.

After this initial period, many European and Asian countries like Italy, Spain, China and Korea have subsequently built their high speed rail networks via imports, partnerships and technology transfer agreements. Most recently, Turkey, Saudi Arabia, Morocco and United States have developed plans for HSR networks. However, as these countries develop their high speed rail systems, we note that very mature high speed rail technology has already been developed in other countries and can be manufactured by the companies mentioned earlier (see, for example, the supply-chain taxonomy in Appendix C). Therefore, the best way to develop high speed rail network is likely to be based on existing platforms, possibly adapted to local use and conditions. Due to this, and other complexities of technologies and investments, more and more partnerships are being created to develop the HSR networks in various countries.

Three common ways are used to develop HSR networks in the current set of countries looking to either introduce or expand HSR services:

1. Countries choose to order the high speed trains from or outsource the HSR project to the companies who already own the mature trainset directly. Examples include United States, Morocco and Turkey. These countries often select from the existing HSR networks or high speed trainset that is best for their own needs and award the contract to the companies' manufacturing such HSR networks or high speed trainset. The companies awarded the contract then decide whether to build the partnership or not;
2. In some countries, where traditional rail is highly developed, some local companies with rich experience in rail build the consortium with the companies owning the complete platform and develop their own high speed rail brand via cooperation. Examples include Spain and Italy. Often such partnerships lead to longer-term collaborations as we see in China where the more traditional companies such as Alstom and Siemens are now collaborating with CNR to bid for projects overseas; and.
3. Countries use technology transfer to get parts or most of the HSR manufacturing technology. Examples include South Korea and China. As compared to the first type of countries noted above, these countries may have larger demand for HSR, such as China. Equally, it may emerge as an important export-oriented strategy based on initial technology transfer and/or domestic strengths in manufacturing and technology, such as South Korea. Such strategies may enable the host country to relatively quickly establish a manufacturing and technology base in an area in which it had no competencies before. In the longer run, these transferred technologies may lead to the countries developing their own versions and modifications for domestic use or exports.

If the company can achieve higher profits via working in the partnership than manufacturing by its own, the company will choose to collaborate with others. Usually, the market structure, contract characteristics and size, and the company characteristics will determine the formation of partnership.

First, a more competitive market may result in more partnerships. In the early stages of the HSR industry, only a few companies had the capability to manufacture the high speed rail. So the competition was not fierce. Companies could win the bidding without partnerships. Recently, with more companies mastering the technology to manufacture the full trainset, the market has become more competitive. When the new countries who want to invest in HSR open the project contract bidding, more companies can bid for this project, making it difficult for a given company to win the project. Especially, some emerging companies from China and Korea can manufacture cheaper HSR networks, but sometimes may not have the full range of technologies and expertise. Companies need to control time and budget and improve quality to win the bidding. Partnerships are an effective way to maintain the companies' competitiveness in the bidding process. Companies can avoid spending time and money in some processes which they are not good at, which lowers the production cost and makes the construction more efficient. Also, with the partnership, the consortium can provide high quality project if they can make the most of their competitive advantage.

Second, the contract characteristics related to value and the size of the trainset order are also important for the company to determine whether to form partnership or not. The order size and the value can reflect the complexity and working load of the project. Normally, the more complex the project is, the more difficult it may be for a single company to finish the project, and thus it is more likely for the company to form a partnership. Further, the order size of the contract also reflects the demand from the country. If the country needs more high speed trains, the country may let most parts be manufactured by the local company locally. If the local company does not have the capability to manufacture the whole trainset, partnerships will need to be formed with another company that can make up for the missing components or companies with mature high speed rail platform. In this way, the company can develop their own platform via cooperation or technology transfer.

Third, the characteristics of the company itself will determine the formation of partnership. As mentioned above, if the company needs to develop the high speed train due to the high demand but does not have the capability to manufacture the whole network, the company will automatically choose a partnership or join other consortium led by a mature HSR manufacture to bid for the contract. For some companies which own the complete platform and can manufacture the trainset independently, there are two possible reasons for them to form partnerships. On the one hand, companies want to gain access to the market with large demand for HSR. So they should sign the technology transfer agreement or cooperate with the local company to meet the requirement for the bidding. On the other hand, even though the company can manufacture the whole trainset by itself, the resources of the firm may restrict the timing and budget of the process. As a result, small firms usually form partnership to reduce the cost and increase efficiency.

9.1.4 Insights from observed partnerships in HSR contracts, 2000-2011

Here we examine international high-speed rail contracts data covering the 10-year period 2000-2011. This will enable us to learn more about the partnerships and draw inferences. Since there is very little information available about vertical partnerships, here we only focus on the horizontal partnerships.

The contracts data reveal many partnerships between companies with mature HSR platform and companies whose headquarters are located in the project country. Partnership of this type include Alstom/CAF consortium and Bombardier/Talgo consortium in Spanish project, Alstom/Hyundai Rotem consortium in South Korea project, Alstom/CNR Changchun Railways consortium, Siemens/CNR Tangshan consortium, Bombardier/CSR Sifang consortium, Kawasaki/Nanche Sifang consortium, Bombardier/AnsaldoBreda consortium in Italy project. The local companies may not have the complete platform and rich experience in the production of HSR at first. However, after the cooperation, some of them may develop their own platforms and manufacture their own brand of high speed trains.

The partnership will help the local companies gain the technology and help the foreign company gain access to the market. For example, Alstom/CAF consortium designed and manufactured the RENFE's class 120 for Spain. Based on that, CAF manufactured the TCDD HT65000 independently for the Turkish project after cooperating with Alstom. CAF is currently developing the Oaris modular platform for top speeds above 185 mph. Similarly, Talgo developed its own brand of high speed trains Talgo 250 and Talgo 350 after cooperating with Bombardier in the Spanish project and is currently developing its own train AVRIL with higher speed.

China and South Korea both used technology transfer agreements to gain the technology for manufacturing HSR. The Korea-France project was a massive bi-cultural undertaking. The project's process of technology transfer entailed sending 1,000 Korean engineers to France for training in detail drawing, process designing, key parts manufacturing and testing, and quality control. Though the technology transfer did not provide for a complete control of manufacturing processes and some parts had to be imported, this undoubtedly played an important role in the development of Hyundai Rotem in manufacturing high speed train.

Five years ago, Chinese companies did not have HSR manufacturing capabilities. Today, CSR and CNR can both manufacture HSR for China independently, as well as export HSR to some other developing countries. The giant leap of Chinese HSR is attributed to the technology transfer through the partnership between Chinese manufacturers and world leading HSR manufactures. In 2011, China had one of the largest HSR market with 6,185 km lines in operation and 14,160 km lines under construction. Siemens of Germany, Alstom of France, Bombardier based in Germany and Kawasaki of Japan all want to access the market and share the profits from these large contracts. Technology transfer is an important part of gaining access in China because to win contracts in China, all the companies had to adapt their HSR trainsets to China's own common standard and assemble units through local joint ventures (JV) or cooperate with Chinese manufacturers. Bombardier, the first foreign train-maker to form a joint venture in China, has been sharing technology for the manufacture of railway passenger cars and rolling stock since 1998. Since Bombardier transferred all the technology of manufacturing HSR to China, the partnership matured and a large number of contracts go to the BST joint venture between Bombardier and CSR Sifang. In contrast, since Japanese did not engage in technology transfer to China, Kawasaki’s cooperation with CSR did not last as long. Within two years of cooperation with Kawasaki to produce 60 CRH2A sets, CSR began in 2008 to build CRH2B, CRH2C and CRH2E models at its Sifang plant independently without assistance from Kawasaki. We can also see from the contracts table that in the technology transfer contracts, the share of the foreign companies become less and less. This is because the local company gains more technology in manufacturing HSR networks via the technology transfer and participate more in the new contract manufacture. For example, from 2004 to 2010, Bombardier was awarded five major contracts by MOR China. Bombardier's share (figure 9-1) was over 70% in the first two contracts in 2004 and 2005, while decreasing to less than 50 percent in the following three contracts from 2007 to 2010. Similarly, Siemens' share of project is decreasing in the China projects and the role it plays has become less significant.

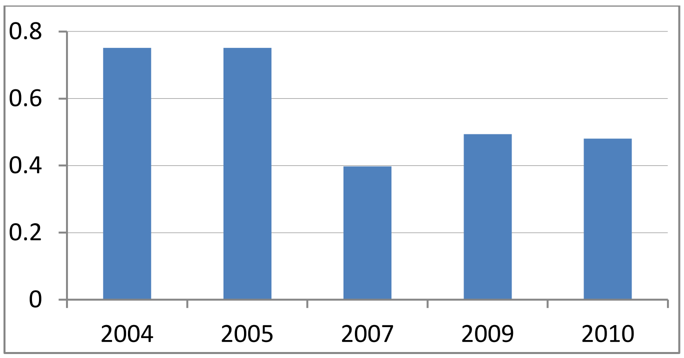

Figure 9-1: Bombardier share in Chinese projects, 2004-2010[91]

The partnerships enable companies to be able to manufacture trainsets independently and make the market more competitive. In 1994, when South Korea began to develop the HSR networks, only Alstom, Siemens and Mitsubishi bid for the project. However, in 2011, when Florida opened the bidding, 9 consortiums led by Talgo, Bechtel, Hyundai Rotem, Mitsubishi, GE and CSR Sifang, Siemens, Alstom and Bombardier participated in the bidding process. The increasing competition of the HSR market brings more challenge for the company to win the contract. To maintain the competitiveness in the market, the companies need to form partnership

[91] Source: Appendix A.

to win in the bid. From the observed contracts, most of the contracts are awarded to the partnership during these two years.

The contract value and the order number are usually higher in the projects done with partnerships. Spanish projects are most built by Alstom/CAF consortium, Bombardier/Talgo consortium and Siemens. RENFE, the Spanish national railway company awarded the contract to Alstom/CAF consortium in 2001 and 2004, ordering 50 trains totally worth €2,217mn. RENEFE also awarded Bombardier/Talgo consortium contract with the order of 64 trains worth totally €1,992mn. However, Siemens was only awarded 26 high speed trains worth €705mn. As for the Turkish project, TCDD first awarded the contract to single company CAF with the order number of trainset 10 and 2 and later to the Hyundai Rotem/Tuvasas joint venture when the contract order number increase to 440 and 80. Another example can be seen in Siemens' contracts. Siemens rarely forms partnerships. The one partnership was formed with Bombardier in the German project. The order and the amount of the contract are among the largest of all the contracts in the table. From the contracts of Alstom, projects without partnership are all small in size, like Finland and Russia's project contract which orders only 4 trains in 2007, Morocco's project valued only $400mn. The order size and project value of the two projects are much lower when compared with Argentina and Saudi Arab's project.

Often, the size of the company determines the formulation of partnerships. Siemens, Alstom, Bombardier all have the complete HSR manufacturing platform. However, the share of project with the partnership is totally different among these three firms. Siemens forms partnership only in two contract of the 12 contract, while Bombardier forms a partnership nearly in all the project besides 3 contracts with Sweden. Table 9-1 gives us a perspective on the revenues (size) of Siemens, Alstom and Bombardier. Siemens is the biggest company and

Bombardier is the smallest one. This appears to indicate that small companies are more likely to form partnerships than the bigger ones.

Table 9-1: Revenues of Siemens, Alstom and Bombardier[92]

(in € million)	2011	2010
Siemens	73,515	68,978
Alstom	20,923	19,650
Bombardier	13,391	13,360

9.1.5 Summary of findings

Overall, we can draw the following suggestive conclusions from the partnerships in the HSR industry:

1. Companies tend to form partnership to increase their competitiveness when markets are more competitive;
2. Companies tend to form partnerships when they are awarded large contract in terms of the order numbers of trainset and the total value;
3. Companies will form partnership with local firms through Technology Transfer Agreements or simply cooperation to gain market access, if the market demand is sufficiently high;
4. If the firms don't have a rich experience in HSR, they will tend to cooperate with another firm which has a lot of experience and technology in building HSR;

[92] Source: Siemens, Alstom and Bombardier's annual reports.

5. Even in the country with mature HSR manufacturing platform, companies will build partnership to meet the requirements for bidding; and
6. Small companies, restricted by their technological and financial resources, are more likely to form partnerships than the bigger companies.

10. PUBLIC-PRIVATE PARTNERSHIPS IN HSR INVESTMENTS

The term "public-private partnership" (**PPP**) has a broad connotation. In the most commonly used sense, PPPs are arrangements in which government and private sector firms share in a project's risks, responsibilities and rewards. PPPs have come to play an important role in the construction of high-speed rail lines around the world (Dutzik et al., 2011).

Government budgets are often limited and private investors may be discouraged by the high-cost and high-risk features of HSR infrastructure investments. PPP, however, may allow for solving some of these problems (Roll and Verbeke, 1998). In this section I detail the different kinds of PPP models, the principles directing its implementation, and review some case studies of PPP in global HSR contracts.

10.1 Models of Public-Private Partnership

The term "public-private partnership" (PPP) is distinguished from traditional government contracting in that the private sector partner is more integrally involved in a project's development and execution than as a "contractor for hire". Private-sector firms might be involved in helping to design a piece of infrastructure, finance it, or operate it once construction is complete. In the most commonly used sense, PPPs are arrangements in which government and private sector firms share in a project's risks, investments, responsibilities and rewards. As noted by Dutzik et al. (2011), PPPs have come to play an important role in the construction of high-speed rail lines around the world.

The "public" and "private" sectors are the two players in the PPP models. The potential players include: (1) the government agency (e.g., European Union and individual nations in Europe, and state and federal governments in the United States); (2) government-owned corporations or state-owned enterprise (e.g., Amtrak[93], many state-owned railways in France, Spain and Germany); (3) non-profit corporations (e.g., Great Britain's Network Rail); (4) private corporations (e.g., Japan National Railways has been privatized, with six large, regional privately-owned companies); and (5) joint ventures (e.g., high-speed rail alliance, the joint venture for Netherlands HSL-Zuid HSR, who 90 percent is owned by state-owned Dutch national railways and 10 percent is owned by Air France-KLM).

The necessary steps in the construction of HSR include finance, design, construction, maintenance and operation. Based on the proportion of the work shared between public and private, we divide the models into the traditional and the more contemporary models.

10.1.1 Traditional models

Definitions

In the traditional models, the government has played the major role in construction of the HSR projects. Government entities will pay more than half costs of the projects. Based on Davies and Eustice (2005), the traditional government procurement models should include the following characteristics:

1. The public sector procures assets, not services, from the private sector.
2. The private sector is responsible for delivering assets, not for their long-term performance beyond standard warranty periods.
3. The project management of procurement typically remains with the public sector, including the risk of successfully integrating multiple work contracts.

There are several examples of traditional models at work in HSR projects:[94]

[93] Extensive details about Amtrak's history and operations can be found at: http://en.wikipedia.org/wiki/Amtrak
[94] See Dutzik et al. (2011).

1. The Netherlands HSL-Zuid line - which links Amsterdam and Rotterdam in the Netherlands to Belgium - cost around 6.7 billion Euros and relied on the public sector for 86 percent of its budget.[95] This is the largest project so far that has ever been implemented in Netherlands. The HSL-Zuid was built between 2001 and 2006 and equipped under the lead management of the infraspeed consortium.[96] The turnkey HSL-Zuid project was pre-financed by Infraspeed B.V. as concessionaire on the basis of private funds and bank loans. The customer repays the investment costs over a period of 25 years. As an experienced partner in the turnkey business sector, Siemens was responsible for installation of the signaling system (ETCS), power supply with overhead lines, signaling and safety systems including tunnel equipment, and all communication equipment.
2. The Perpignan-Figueres high-speed rail connection between France and Spain benefited from a public investment of 57 percent of project costs. The contract to build the line was awarded in 2004 to the TP Ferro consortium, a joint venture of Eiffage (France) and Dragados (Spain). The group constructed the line for an estimated cost of approximately €1.1 billion, and will operate the line for 53 years. It will receive a public subsidy of €540 million, split between the European Union, France and Spain.[97]
3. The extreme example of the government-dominated PPP models can be seen in China. The Chinese government has contributed nearly 100 percent to all HSR projects. In China, both railways and rolling stocks are owned and operated by the Ministry of Railways. China Railways is a division under the Ministry that is in charge of passenger

[95] http://www.railwaypeople.com/rail-projects/hsl-zuid-project-56.html
[96] The Infraspeed Consortium comprising Siemens with its partners BAM N.V. (trackwork) and Fluor Infrastructure B.V. (project management).
[97] http://www.railway-technology.com/projects/perpignan/
http://www.railwaygazette.com/news/single-view/view/tunnel-with-no-trains.html

rail operations. In 2007 the Ministry of Railways established China Railways High Speed (CRH), a division of China Railways, for the development and operation of the country's first high-speed rail systems.

4. The Portugal's high-speed rail network is the fourth example in this category. The financial structure of the project is shown in figure 10-1. The project is financed through PPP models with the Promoters & Commercial Banks and European Investment Bank as the private sector, and the EU Grants and State Grants as the public sector. According to it, the private sector only financed 49 percent for the project, while the other 51 percent was from the public sector.

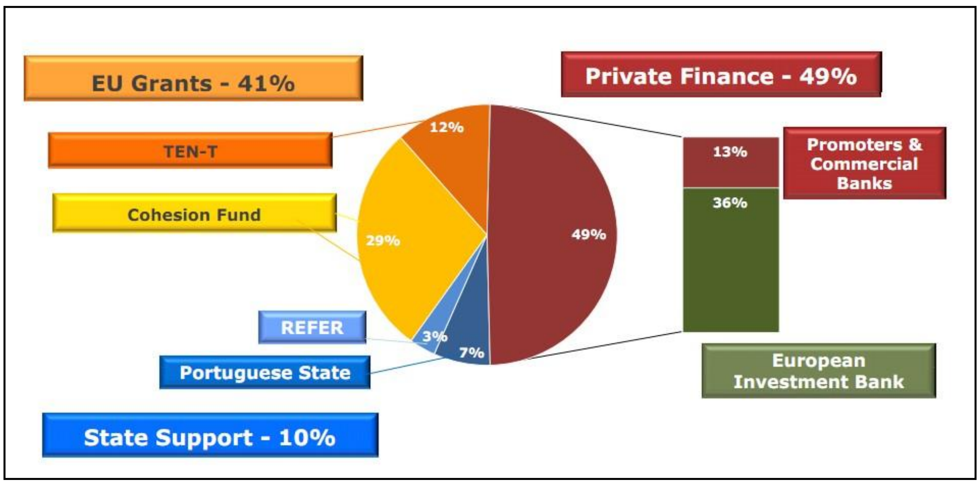

Figure 10-1: PPP financial structure[98]

Pros and Cons

The successful risk sharing is the most important advantage of the traditional PPP models. The involvement of the private sector reduces the risk to the public sector, compared with the non-PPP models. Also, a somewhat lower level of involvement makes it affordable for

[98] Source: Silva (2010)

the private partners to participate in the project. According to Rutzen and Walton (2011), the Portugal's PPP model has been successful in sharing the risks of the project, making it more affordable to the private sector participants. The risk sharing matrix of the Portugal's project is shown in figure 10-2. From the matrix we can see that the risk of political aspects and planning all went to public side, and the risk of design, expropriation, construction, environmental and maintenance were borne by the private sector. Some of the other risks were shared between the public and the private sector.

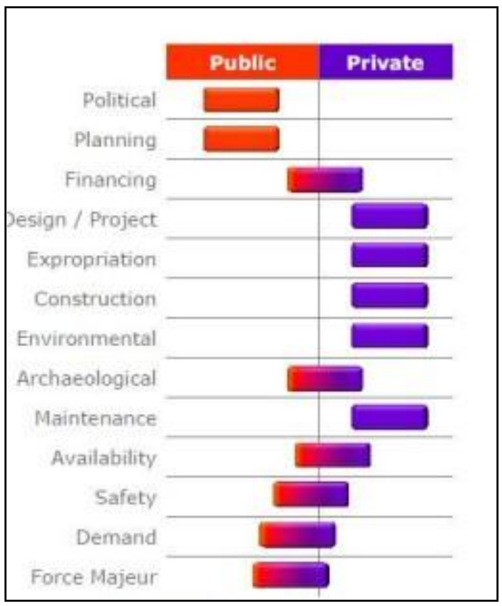

Figure 10-2: Risk sharing matrix[99]

However, large-scale public works projects may threaten efficiency and strains project delivery. The high political profile and conflicting interests often puts pressure on contractors and agency administrators to cut corners to achieve politically determined benchmarks. This inevitably increases the risks of error with potentially tragic results. A case in point is China's

[99] Source: Rutzen and Walton (2011)

high-speed rail disaster near Wenzhou last July that killed 40 and injured 200. The issue exposed the full scale of China's rail program and thrust its weaknesses embarrassingly onto an international stage. While the failure of software technology was identified as the proximate cause of China's rail disaster. The real problem may have been human error in that the dispatchers had the information they needed but failed to recognize the danger and slow the trains down; there were also reports that political pressure was on the train operators to show greater speed and increase utilization.[100]

Also, programs that grow quickly involve vast sums of money and lack accountability and transparency, which breeds corruption. Taking China as an example, the Beijing-Shanghai high-speed rail route alone nearly doubled in cost as expenses grew from an estimated 12.3 billion yuan to over 21 billion yuan. Many Chinese officials have been fired or removed from key positions, including the Minister of Railways and the chairman of a major logistics company, because of corruption that may have led to billions of dollars of waste. Obtaining lucrative construction contracts during the early 2000s appeared to be more about connections than the quality of work (and cost), and middlemen were handsomely rewarded for mediating services.

10.1.2 Contemporary models

Definitions

In their more contemporary versions, and contrary to the government-dominant traditional PPP models, the government will give more tasks to the private sector. The case of the HSR project in Taiwan is a good example of modern PPP models. The THSRC was selected to build and finance the project because its proposal did not include any request for government

[100] There have been several commentaries on this particular issue. One being: http://reason.org/news/show/chinas-hard-lessons-on-high-speed-r

support (Rutzen and Walton, 2011). The scope of work is shown in figure 10-3. According to figure 10-3, the Government was in charge of infrastructure improvement, administration and supervision, while the main design, construction, operation and maintenance works are the responsibility of the private sector. The share of the government is only 21 percent. Compared to the traditional models, the government involvement in the project is pretty small.

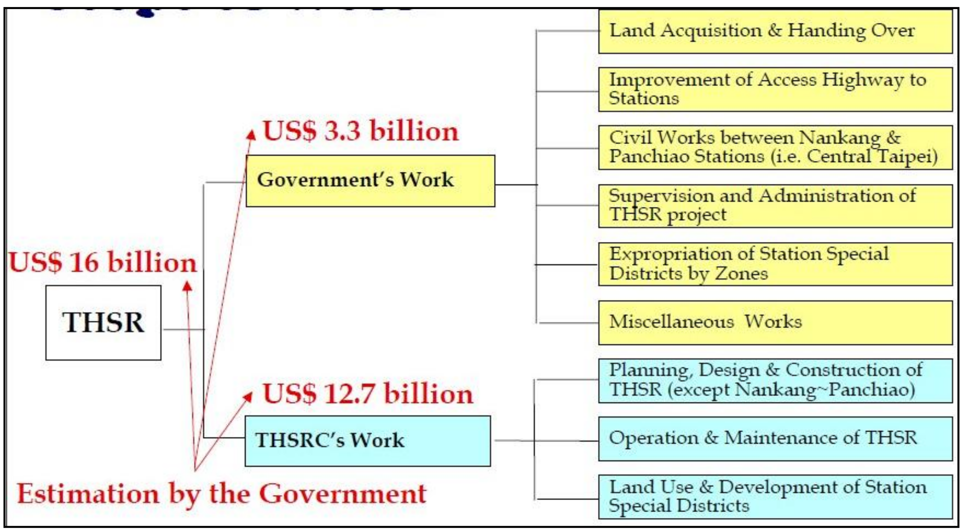

Figure 10-3: Scope of work in Taiwan's HSR project[101]

Another example is a project in Brazil. Apparently believing the claims that high-speed rail is profitable, the Brazilian government set about planning a line connecting São Paulo to Rio de Janeiro stipulating that private investors would build the infrastructure and operate a line, at their own risk. The winning bidder in Brazil would have been granted a 40 year concession and would have been required to provide substantial funding toward more than $20 billion in capital cost. If the international experience of project cost inflation holds in Brazil, the total investment cost of this HSR line could double and escalate to $40 billion. Anticipating this, and to secure the

[101] Source: Chiu (2006).

interest of the taxpayer, the government has required that any cost overruns also be paid by the winning bidders, the private sector.[102]

Private funds may come from diversified sources including the private project entrepreneurs and shareholders, or from private saving and financial institutions. Private participation could also come from companies which benefit from the expansion of HSR. For example, General Electric, the largest producer of diesel locomotives in North America, via GE Capital participates in international financing of rail infrastructure in the USA, in Canada and in Mexico. In the proposed Florida HSR project, besides some major trainset companies, many component manufacturers are involved in the PPP project as the private sector and announced to guarantee the uncovered cost.[103]

<u>Motivation</u>

PPP solutions with more private involvement can be particularly effective for new-build rail infrastructure. They encourage whole-life cost optimization and lock in incentives for responsible stewardship of the infrastructure over the long term. However, the impact of the financial crisis and credit constraints on the project finance market is making large transactions challenging. Budget constraints have become increasingly important for most national and regional governments, which has led to a reduction in public spending on transport infrastructure.

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[102] Brazil had originally planned to build the bullet train linking the country's two largest cities in time for the 2014 World Cup, alleviating an expected surge in air traffic between the cities during the world's premier soccer event. But when the government held an auction to find builders and operators for the project in 2011, no companies bid. Companies claimed that the project was too risky without numerous government guarantees and subsidies.

[103] Florida High Speed Rail is a proposed high-speed rail project in the U.S. state of Florida. Initial service would run between the cities of Tampa and Orlando, with plans to then extend service to South Florida, terminating in Miami. Until now, 8 consortiums bid for the project including Florida Mobility Partners, Bechtel-SNCF-Amtrak, Parsons-Samsung-Korail, Fluor-Balfour Beatty-FHSR/Japan Group, ASC-Dragados-Odebrecht-GE-CRCC-CSR, Florida Rail Ventures, Vinci-OHL USA-Alstom-Virgin, Bombardier-Kiewit.

Overreliance on the government often blocks the development of the project. For example, China's high-speed rail project, has run out of money and will be scaled back dramatically this year. Out of 23 current railway projects, some 70 per cent have been suspended, partly suspended, or delayed, according to the Chinese state media.[104] Due to lack of funding resources, many public entities have been promoting the use of more private-involvement PPP models to solve the constraints on public budget deficits and the current credit crisis.

Pros and Cons

The most impressive outcomes of contemporary PPP models relate to the cost reductions with more private sector involvement. Portugal's experience enabled a significant cost reduction. As shown in figure 10-4, construction and maintenance costs significantly decrease when the public sector is involved in the project, which can offset the considerable increase in design cost caused by the higher transaction cost (Silva et al., 2011). As a result, the total cost was reduced by about 40% with more private sector involvement.

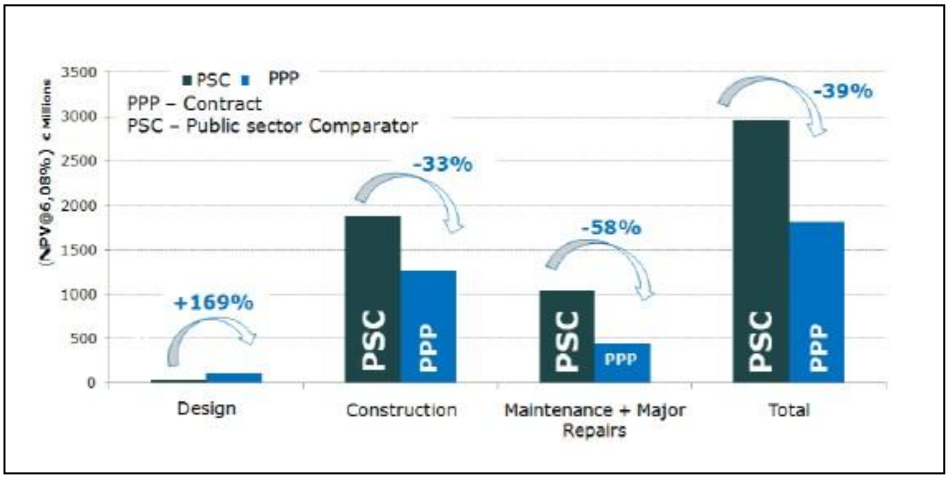

Figure 10-4: Public sector comparator[105]

[104] http://www.telegraph.co.uk/news/9095729/Chinas-high-speed-rail-project-runs-out-of-steam.html
[105] Silva et al. (2011)

Contemporary PPP models can maximize the use of private sector skills and also make the project affordable (Davies and Eustice, 2005). More extensive use of the private sector throughout a project's life gives best value, as the private sector parties have the capability to deliver projects and maintain them over lengthy periods and are repeatedly delivering projects internationally, which cannot be done by public sector. Also, in the current atmosphere of constraint public budget, access to private capital may make the difference between building necessary high-speed rail projects and leaving them on the drawing board for years to come. Because of the multi-billion dollar price tag of most high-speed rail projects, governments in both Europe and the United States have stated that private investment will be necessary to build their high-speed rail networks (Dutzik et al., 2011).

However, the capital cost may be higher and more volatile with greater private sector involvement. Private companies usually have higher long-term borrowing costs than public entities. Public sector costs in 2007 for raising capital through debt were a full 35 percent less than the lowest cost a private entity could hope to obtain (Enright, 2007). What's more, during the current credit crisis it has typically become relatively more expensive for the private sector to borrow capital compared with the public (Dutzik et al., 2011). As the cost of the credit increases, the private sector's inability to obtain the capital or to obtain the capital at the cost anticipated when the PPP was originally devised can jeopardize the entity's ability to carry out the project. In such cases, the government will be become responsible either for bailing out the private entities or take over the project midstream, which can increase the costs significantly. Such a situation occurred with the construction of Taiwan's HSR project.[106]

[106] In 1998, the Taiwan High Speed Rail Corporation (THSRC) was awarded a 35-year concession to build and operate Taiwan High Speed Rail (THSR), partially based on THSRC's promise to build the system without

Also, the recent research suggests that the HSR project cannot be funded solely by private investment. Their long-term return and the risks they carry make them unattractive to the private sector participants. For example, an auction to build a major high-speed rail link between Brazil's two main cities, Sao Paulo and Rio de Janeiro, has failed to attract any bidders so far. A high initial investment cost and long construction period are combined with a slow ramp-up period for increasing revenues, which all yields a rather low and slow cash flow time-path at a 'normal' discount rate, as depicted in figure 10-5. This cash flow profile makes it less attractive for private investors. As a result, in order to attract private investors, one will need to have an optimal degree of participation from the public sector.

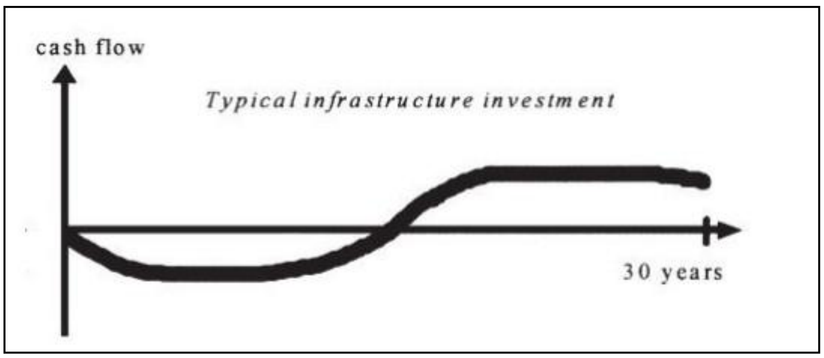

Figure 10-5: Cash flows during life cycle of an infrastructure investment[107]

Last but not least, more involvement of the private sector will change the initial purpose of the government. The HSR project is proposed by the government considering not only the profitability issues but also the social and economic development. As shown in Dutzik et al.

government capital. But the company began to run into difficulty after the Asian financial crisis in the late 1990s, when it was forced to take out loans with high interest rates in order to pay for the project. At the end, in order to keep the system operating, the government refinanced THSRC's loans and contributed hundreds of millions of dollars to the network. In order to keep the system operating, the government refinanced THSRC's loans and contributed hundreds of millions of dollars to the network (Dutzik et al., 2011).

[107] Source: Rutzen and Walton (2011)

(2011), the public faces dangers that a PPP may create a publicly subsidized piece of infrastructure that is primarily used to serve the profit-maximizing purposes of a private entity in ways that conflict with the public interest. An example of this tension arises in the setting of ticket prices. A private concession operator will tend to want higher-priced tickets as a way to recover their initial investment costs and maximize their revenues for shareholders, even if higher ticket prices depress total ridership and therefore diminish the positive public impact of the route.

10.1.4 Summary

PPP models vary from short-run simple management contracts to the long-term and very complex Build-Operate-Transfer (BOT) form. Figure 10-6 gives a simplified spectrum of PPP models used in Canada, as well as the characteristics in terms of private involvement and private sharing risks for each models. Figure 10-7 provides a more general category of PPP models. From figure 10-6, we can see that the involvement of the private sector is positively correlated to the risk shared by the private sector. Appendix B provides more detailed characteristics of selected PPP models.

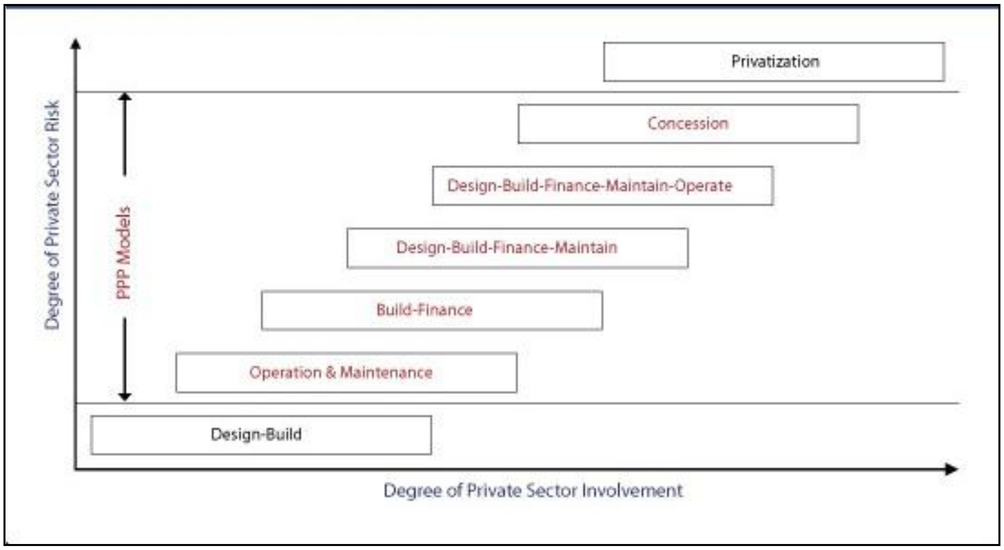

Figure 10-6: Scale of public-private partnerships: risk transfer & private sector involvement[108]

Figure 10-7: PPP models[109]

10.2 Attributes for success

Rutzen and Walton (2011) summarize the key requirements necessary for the successful implementation of PPP, which include strong government commitments, regulatory and legal framework that facilitate such structures, a fair allocation of risk involved, well prepared model tailored to specific project, and clear and transparent tender process.

[108] Source: 2005-2012 The Canadian Council for Public-Private Partnership: http://www.pppcouncil.ca/resources/about-ppp/models.html

[109] Source: Hansen (2010)

Dutzik, et al. (2011) indicate the 10 principles that should guide the use of PPPs in HSR projects as follows:

1. Government must only pursue the PPP for the right reasons;

2. PPP must deliver identifiable added value;

3. PPP contracts must align private sector incentives with public sector goals;

4. PPP must only be pursued in an atmosphere of competition;

5. PPP must only be pursued by capable and prepared governments;

6. There must be clear accountability in PPP projects;

7. The public must retain control over key transportation-system decision;

8. PPP contracts must not impose unreasonable limitations on future government action;

9. PPP contracts should be of reasonable length; and

10. PPP must be subject to extraordinary transparency.

Roll and Verbeke (1998) argue that neither private nor public means alone appear sufficient to finance the large new transport infrastructure needed in Europe. Both sources of funds are required simultaneously in the form of public–private partnerships. The public involvement of the project is good for the socio-economic development, while the private involvement will benefit the financial returns from a long-term perspective. Whether or not private-sector equity is invested in capital, previous experiences suggest that federal funds will be critical to maintaining high-quality infrastructure. Private sector involvement in Japanese HSR was generally viewed as successful while British were not. In the example of the Japanese Shinkansen HSR system, the government continued providing subsidies to maintain infrastructure, but sold the rail system to private interests thereby allowing the companies to operate lines as regulated public utilities. Most notably, the private Japanese operators retained substantial sources of revenue by capitalizing on station area redevelopment. In contrast, the British example of rail privatization highlighted the danger of ceding badly-maintained infrastructure to privately held Railtrack. The private sector was ill-equipped to invest necessary capital for maintenance, resulting in rail safety debacles. The rail was re-nationalized to facilitate national reinvestment, although improvements appear tenuous. Both the Japanese and British private-sector models illustrate that an optimal extent of public funds along with efficient project management are necessary for initial infrastructure construction as well as for long-term maintenance.

10.2 Selected PPP contract analysis

In this section, we briefly analyze the details of the selected PPP contracts in the HSR industry. The cases of the Netherland and Taiwan are selected as representative of old and traditional PPP models separately.

10.2.1 HSL-Zuid Netherland

The HSL-Zuid HSR Project is the largest PPP awarded by the Dutch Government, as well as the largest PPP rail project in Europe. The complex project can be subdivided into three major segments: the Substructure, the Superstructure (infrastructure provider project) and the Train Operating Service. The substructure contract is managed directly by the public sector, Dutch State's project company, because Dutch government believed that it was unable to transfer the risk to the private sector. Awarded in 2001, the superstructure contract was awarded in the form of turnkey to Infraspeed, the private sector firm which was responsible for designing, building, financing and maintaining the system's tracks, stations and signaling for a 25-year period. The operation contract was won by High-Speed Alliance, a consortium 90 percent owned by the Dutch state railways, NS, and 10 percent owned by Air France-KLM. In all, as mentioned above, the project is seen as a more traditional PPP model as it relied mostly on public funding, drawing the private sector investment for only 14 percent of the project cost (Dutzik et al., 2011).

Based on Wilden (2004), the project is financed based on a fairly typical private-financing initiative/PPP-type structure (i.e., a small amount of base equity with the majority of the sponsor's contribution being injected via subordinated debt as well as the use of the equity bridge facility). This resulted in the project achieving a 5% reduction compared with pure state funding. The relative cost saving achieved is crucial to demonstrating the success of PPP models in Netherland.

However, Dutzik et al. (2011) note that from the beginning of the project, designers of the project made several important mistakes that led to cost overruns, delays and government bailout. The bids for the substructure contracts were higher than expected, due largely to a lack of competition in the Dutch construction market. The consortia biding on the substructure project was later found engaged in illegal coordination (cartel). In any event, the total estimated cost of the project ballooned to 43 percent higher than budgeted. Because the Dutch government was primarily concerned with completing the project within its pre-determined budget, the higher-than-expected bids forced the government to make cutbacks in the design of the system and to pursue other strategies to induce lower bids, including the elimination of penalties for late delivery of the substructure. This left the state liable for making payments to the superstructure and operations contractors in the event that the project was delayed. Dutch government failed to transfer the risk to the private sector since the state took on almost all the responsibility for cost overruns and delays in the original contract.

In summary, the Dutch government's decision to undertake separate contracts for superstructure and substructure appears to have been a contractual mistake. The lack of effective competition among bidders prevented anticipated cost savings from being realized, while the lack of proper risk management provisions in the contract exposed the state to effects of cost overruns. Failing to establish a clear line of authority for government management of the project, and creating what was in effect a public-public partnership for operation of the line compounded the problems.

10.2.2 Taiwan High-Speed Rail

In 1998, the Taiwan High Speed Rail Corporation (THSRC) was awarded a 35-year concession to build and operate Taiwan High Speed Rail (THSR), partially based on THSRC's promise to build the system without government capital. Unfortunately, the Asian financial crisis of 1997/98 made the company run into financial problems as it was forced to take out loans with high interest rates in order to pay for the project. Because of the ongoing financial losses, "THSRC shareholders signaled reluctance to invest further in the project, which has led to difficulty for THSRC in securing financing from banks as well," Matsunori et al. (2010). Lack of financing led to problems with completing the project, and when the network opened to the public in 2007, several key stations were incomplete (Dutzik et al., 2011). To complete the project, the government had to bail out the project and refinanced THSRC's loans and contributed hundreds of millions of dollars to the network, even though the original build-operate-transfer plan stipulated that the THSRC build the system without any government capital.

From Taiwan's example, we see that overreliance of the private sector is also sub-optimal from the viewpoint of the project's success. Since the private sector participants' access to capital may be volatile and unstable, the private sector may be unable to restore themselves to financial health when facing a financial crisis. Taiwan's example also demonstrates the dangers of "lock-in" (Dutzik et al., 2011). The Taiwanese government could have allowed the THSRC to go bankrupt and operation of the high-speed rail line to cease when the company ran into financial trouble. Doing so, however, would have resulted in the abandonment of a critical public asset, leaving the government with little choice but to prop up the failed business plan of a private operator with public funds (Dutzik et al., 2011).

10.2.3 Summary

Governments tend to give more responsibility to the private sector when the project costs are high and they face significant budget constraints. As a result, the current and future trend for the rail sector has preponderantly kept in the public sphere all responsibilities regarding regulation, planning, establishment of requirements and management of overall systems, while transferring to the private sector all types of responsibilities regarding designing, construction and maintenance of infrastructure.

Table 10-1 is the benchmark analysis of rail projects, which reveals a clear international trend towards more private involvement on large projects, namely through the use of PPP. Around the1990's the projects tended to be public dominated, while more PPP models with greater private sector involvement have been used in the large rail project since the mid-2000s. Though the responsibilities regarding regulation, planning, establishing of requirements and management of the whole system are still in the public hands, the financial role and operational role have been increasingly transferred to the private sector.

	France 1980/90 Spain 1980-actual	United Kingdom Decade 90	Holland 2005	Perpignan-Figueras (France-Spain) 2005	Bordeaux-Tours (France) 2007	Brazil 2009
Strategic Role Regulation Planning Establishment of Requirements Articulation of the System	Public	Public	Public	Public	Public	Public Private(PPP)
Financial Role	Public	Private(PPP)	Public and Private	Private(PPP)	Private(PPP)	Private(PPP)
Operational Role Design Build Maintain Operate	Public	Private(PPP)	Public and Private	Public and Private	Public and Private	Private(PPP)

Trend (Reduction of Public Sector risk exposure)

Table 10-1: International procurement choices[110]

		France	Spain	Germany	Korea	Italy	The Netherlands	Portugal	Japan	Taiwan
		TGV	AVE	ICE	KTX	TAV	HSL-Zuid	RAVE	Shinkansen	THSR
Specification		State	State	State	State	State	State	State	State	State
Substructure	Design, Build	RFF	ADIF	DB Netze	KR	RFI	State	PPP	JRCC	THSRC
	Operate, Maintain								JR Group	
Superstructure	Design, Build						PPP		JRCC	
	Operate, Maintain								JR Group	
Rolling Stock	Supply	SNCF	RENFE	DB Bahn	KORAIL	NTV	Dutch Railways (NS)	State	JR Group	
	Maintain					Trenitalia				
Operations						Trenitalia	PPP	PPP		
Financing	A mix of options involving private sector funding, bank debt and capital market financing raised directly by the project vehicle of IM with strong public sector support									

Increasing Involvement of the Private Sector

Table 10-2: Public and private sector involvement in development HSR[111]

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110 Silva, et al (2011)

111 Source: Rutzen and Walton (2011)

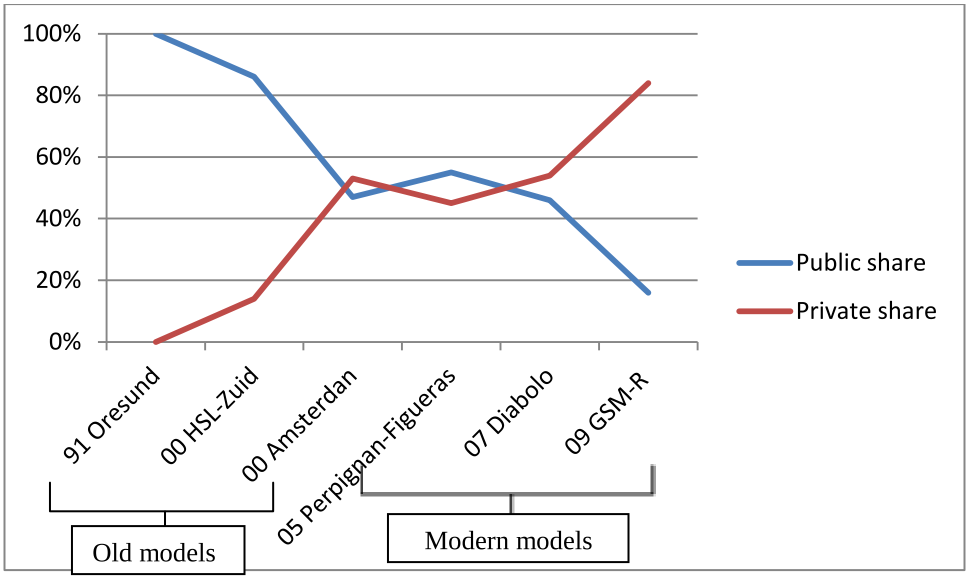

Figure 10-8: Public-private share in selected railway projects in the world[112]

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11. LONGER-RUN DYNAMIC EFFECTS OF HSR INVESTMENTS

Investing in HSR infrastructure is often associated with lower total travel time, higher reliability, reduction in the probability of accident, and in some cases the release of extra capacity which helps to alleviate congestion in other modes of transport such as highway and air travel, and reducing the net environmental impact of transport. Last but not least, it has been argued that HSR investments can boost regional economic and business development (De Rus, 2008). As the Halcrow Group (2009) report notes, the gains include both efficiency improvements with the supply and distribution of lower cost goods and services and effectiveness improvements.

In this section, we discuss the direct effects including the transportation, environmental and wider social-economic effects of the HSR investments. Cases of France, United Kingdom, Japan, United States and Russia are used to examine the direct and indirect effects of HSR system investments.

11.1 Direct effects

Some of the direct benefits of HSR services that have been noted include: passenger time savings, increase in reliability and comfort, reduction in congestion and delays in roads and airports, and lowering of negative environment externalities (Rutzen and Walton, 2011). In this part, we analyze these direct effects including the traffic effect and environment effects of the HSR investment.

11.1.1 Traffic effects

The primary motivation for early HSR construction is increasing the transportation capacity in highly congested corridors and reducing travel time. Nowadays, HSR could be used to solve two different accessibility problems. First, where a point-to-point link is dominant, they are a potential substitute for road and air travel. Second, it links together many cities and can facilitate new networks with a high intra-and-inter regional accessibility (Blum et al., 1997).

The introduction of the HSR technology, consisting of infrastructure and rolling stock that allows the movement of passenger trains capable of speeds above 180 mph, has led to a revival of rail transport in many countries and regions (De Rus, 2011). As for rail transportation, traditional rail is often too slow to compete with automobile and air transportation options. We need to increase the maximum speed to above 186 mph for trip distance above 300 miles or at least 125 mph for shorter distance trips to maintain competitive times relative to air transport. Figure 11-1 shows the rail lines speed and the corresponding market shares. As the train speeds increase, the rail market share is likely to increase with that as some passengers who earlier used road or air now travel using the higher-speed trains. Table 11-1 also shows that HSR services seem to be competitive for shorter distance routes.

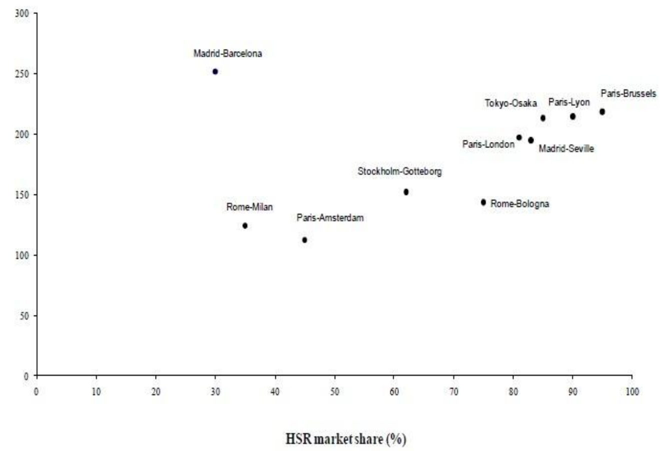

Figure 11-1: Rail market share and railway speed[113]

Table 11-1 Rail market share and railway speed[114]

City-pair route	Distance(miles)	Speed(mph)	HSR market share
Madrid-Barcelona	386	217	30%
Rome-Milan	315	115	35%
Madrid-Seville	259	168	82%
Tokyo-Oska	310	200	83%
Paris-Lyon	260	186	90%

Although adhering to sometimes divergent design principles, new HSR systems in various parts of the world have uniformly succeeded in reducing journey times and capturing increased traffic among the major cities served. According to table 11-2, Japan, Spain, Germany and Korea all successfully increased their rail market share by attracting passengers from air and auto transportation to their HSR systems. The International Union of Railways (UIC, 2008) finds that the access charges levied on train operators vary substantially, but absorb between 25% to

[113] Source: De Rus (2010).

[114] Source: Rutzen and Walton (2011) and Preston (2009).

45% of the revenue of high speed rail operators. As such, they significantly affect the competitive position of rail as opposed to other modes of transportation.

Table 11-2: Transportation impact of HSR[115]

HSR system	Impacts after HSR operation	Referred literature
Japan Shinkansen	The traffic of Japan's Sanyo Shinkansen was diverted by (1) 23% from air (2) 16% from cars and buses (3) 6% induced demand	Givoni (2006)
France TGV	After the line of TGV Sud-Est, air traffic between Paris and Lyon decreased 50%. After the line of TGV Atlantique, air carrier traffic decreased 17%.	Vickerman (1997)
	The traffic of TGV Sud-Est from Paris to Lyon is derived from as follows: (1) 24% from air (2) 37% from cars and buses	Givoni (2006)
Germany ICE	About 12% of traffic transferred from air and roads.	Vickerman (1997)
Spain AVE	The demand (Madrid–Sevilla) for air carriers decreased 60%, and the demand diverted from the other modes is as follows: (1) transferred from air 32%, (2) transferred from buses 25%, (3) transferred from conventional railway 14%.	Vickerman (1997)
	The market share of domestic air carriers decreased from 89% to 36–47% (Madrid to Barcelona).	Lopez-Pita and Robuste (2005)
South Korea KTX	(1) 28% of air passengers preferred to travel by air after the opening of KTX. (2) Air traffic dropped by 20–30% after KTX operation and the traffic of the short-distance route (less than 100 km) increased about 20%.	Park and Ha (2006)

The experience of other countries with HSR networks shows that HSR is competitive with air and automobile which relieves the congestion caused by road and air transportation. Even at the 375-500 miles range, HSR could be highly competitive given access times, frequencies and reliability. In some countries, HSR therefore started to be seen not just as a competitor to air for inter-regional journeys, but as a complement for longer international and

115 Source: Cheng (2010).

inter-continental journeys. Thus interconnection of the HSR network with airports became a core design feature (Vickerman, 2006).

In summary, HSR lines fulfill the purpose of increasing the route capacity and reducing travel time. Higher capacity and travel speed lead to changes in the modal share, increasing the share of the train at the expense of the aircraft and cars, and diverting passengers from the conventional train to the HSR. In addition, international evidence appears to indicate that the introduction of HSR services can also lead to the generation of new demand on the routes.

11.1.2 Environmental and related effects

An additional advantage of HSR is that it can deliver the above-mentioned benefits with potentially lower environmental impact. HSR's carbon footprint is lower than either road or air travel, particularly if electricity is generated from low carbon sources. Electric traction is potentially independent of oil supplies, which road transport is currently not, and air transport is unlikely to be in the foreseeable future.

Having the capacity to transport a significant proportion of freight and passengers by electric traction will make the economy potentially less vulnerable to disruption from changes in the international price/supply of oil. This greater independence from foreign oil in effect may benefit national security.

Capacity released on conventional lines will reduce overcrowding, improve reliability and enable more services to operate from local stations, and more freight services. It will also enable conventional lines to take passenger and freight traffic from the road network (Halcrow Group, 2009).

The exact environmental impact of high speed rail is, however, somewhat controversial. Many comparisons make overly simple assumptions concerning diversion between modes and load factors. The primary fuel used to generate electricity is also important. When we allow for diversion of some traffic from existing rail routes and generated traffic, as well as traffic diverted from road and air, it appears that even at high load factors such as the 70% quoted for the French TGV and for Eurostar, the benefit of high speed rail in reducing carbon emissions is somewhat marginal. At much lower load factors, however, there may be no benefits at all (de Rus and Nash, 2007).

As shown in Figure 11-2, CO2 emissions per passenger kilometer by rail are significantly lower than road or short-haul air travel, noting further that the electronic train (HSR) has even a lower carbon footprint than the average diesel train.

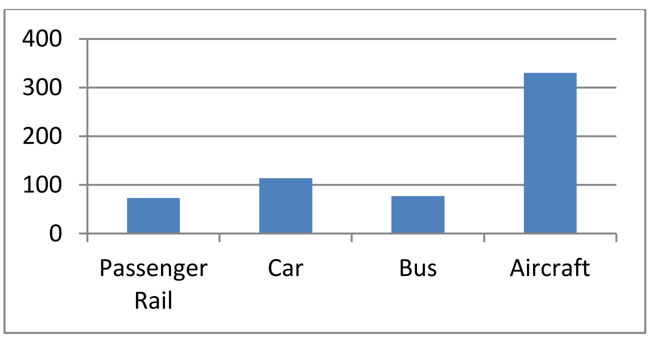

Figure 11-2: Average CO emissions/passenger kilometer[116]

11.2 Wider social and economic effects

HSR services result in additional impacts besides the ‘transport impacts’ described above. They can also be the drivers for the social-economic impacts (Givoni, 2006). Before HSR,

[116] Source: The data is from Lee (2007)

a number of economic areas could be inaccessible for many workers and organizations because transportation expenses (in terms of time and money) were too high and exceeded benefits of their activity in a destination point. The advent of the HSR can improve the relative accessibility and increase the connectivity of the regions connected with HSR services by shortening the travel time, which can lead to the regional development, expand labor markets and enhance business development. Cities from where daily commuting was unthinkable before the implementation of HSR come into reach of the next agglomeration. In this section we discuss some of the wider social and economic effects from the perspective of regional, labor markets and business development.

11.2.1 Regional development

HSR system will benefit the regional economy. Pol (2003) mentioned two effects of the HSR-connection on regional economy. One is the “catalyzing” effect, which means the HSR network draws new activities and thus enables a region’s economy to grow. The other one is a “facilitating” effect, which means the new infrastructure will accommodate economic growth that is already in progress in an urban region.

Sands (1993) shows that the development effect of high-speed rail stations are most clearly associated with a strong regional economy and good links with other transportation modes, especially rail links to the local city center and public sector support of development. The presence of these factors can help provide the formation of significant development activity around stations catering to the information-exchange sector, such as offices and hotels, the stimulation of retail activities in the area, and increases in overall land value of approximately 20 percent. At the regional and urban levels, concentrations of information-exchange sector employment and centers of higher education are associated with above-average employment and population growth rates, as well as access to high-speed rail.

Blum et al. (1997) argue that there are some HSR networks (for example, German ICE) where the train system links many cities, and therefore create a new type of region with a high-intra regional accessibility. The linked cities or regions form the corridors. The improved internal accessibility and the improved conditions for face-to-face contacts favor the economic development in the regions forming the corridor. Blum et al. (1997) also examine economic integration in a corridor economy in the short, medium and long term. First, investments in the transportation system, for example in the form of a new HSR line or substantial speed improvements on a old line, will be an instrument to better integrate partly isolated markets, potentially reducing monopoly behavior, lowering prices and broadening choice, while forcing firms with scale economies to increased production and competition with each other. Second, high speed rail networks help the regions to fully develop their comparative advantage and thus improve the productivity, because the high speed trains enable the regions to exchange their goods and services with other regions more efficiently. Third, the increased international and interregional trade brought by the economic integration may help reduce income inequality.

Investment in HSR has been defended as a way to reduce regional inequalities (De Rus, 2008). One argument about the effects of HSR investment in regional inequality can be seen in Ottaviano and Puga (1997): "Firms producing in locations with relatively many firms face stronger competition in the local product and factor markets. This tends to make activities dispersed in space. However, the combination of increasing returns to scale and trade costs encourages firms to locate close to large markets, which in turn are those with relatively many firms. This creates pecuniary externalities which favor the agglomeration of economic activities.

Another argument can be found in Vickerman (2006) who examines how transportation costs (and therefore accessibility) interact with other determinants of economic development, particular scale economies and the size of market areas, in an imperfect competitive world.

Some literatures discuss the characteristics of the regions that would be benefit from the HSR systems. The Halcrow Group (2009) notes that major development opportunities will present themselves in the city centers particularly around HSR stations and hubs. Further, land demand for office land use is set to increase significantly as the activities of the knowledge economy would cluster in city centre locations.

Pol (2003) argues that HSR can be beneficial to those cities that already hold a strong competitive position. They normally already have a relatively high economic potential and attractive location factors for new service companies and well-educated residents. Both these advantages will be further enhanced by the improving external accessibility. In weaker urban regions, the advent of the HSR can be an opportunity to improve their competitive position. The improving external accessibility may help to enhance their economic potential and location factors. However, a precondition for economic growth and renewal for these cities will be that this economic potential exceeds a certain critical (sometimes psychological) level. When it does not, the improved external accessibility may also lead to backwash effects. For instance, companies moving out of the affected urban region since their local markets will no longer be protected by transport barriers. Therefore, the advent of the HSR may stimulate these weaker regions to improve their economic attractiveness. Murakami (2011) argues that the HSR project is likely to yield regional accessibility and agglomeration benefits predominantly to major cities at the expense of small intermediate cities. If this were true, then while some locations within a country might benefit, others suffer resulting in national net benefits being uncertain.

11.2.2 Labor market development

Spatial integration due to the HSR services may result in a wider city or regional labor market and increase labor market efficiency and the level of economic activity. HSR and improved transportation can increase the labor supply since it will increase workplace accessibility and expand labor market catchment areas. Fuchte (2007) points out that the new HSR lines/networks can create new possibilities for employees working in the large agglomerations to select different residential locations. Putting HSR into operation may bring residential zones and employment zones together by force of decrease of integrated transportation expenses and efficiency of transit. As consequence, previously distant workers may become members of a city or regional labor market and the mobility of working population who can work in more remote areas will also increase.

However, such integration may not benefit all kind of labor. Haynes (1997) indicates that the spatial integration of labor markets due to transportation improvements lead to increasingly efficient utilization of highly specialized skills and a reduction in the demand for mid-level positions. Sundstrom et. al. (1993) think lower skilled and highly localized employment has marginally lower costs due to reductions in local rents and local shortages, while the impact for individual occupations are highly variable.

11.2.3 Business development

HSR can have significant impact on business efficiency through productivity improvement, agglomeration benefits and the narrowing of the international production and productivity gap (Halcrow Group, 2009). Besides, HSR may bring many opportunities to specific industries which promote their development

Productivity Growth

The advent of HSR can significantly reduce the business travel time. Since face-to-face contacts are necessary in many industries, ease of business trips and, therefore, face-to-face meetings will improve the firms' productivity. Also, many service producing firms, in particular those engaged in the provision of producer services, where the firm supplies a service to another firm, work very intimately together with its customer. These kinds of firms can gain substantial advantages from working on a large integrated market (Blum, et al, 1997).

Agglomeration Benefits

Agglomeration is one of the biggest sources of wider economic benefits. This is simply a geographical concentration or cluster of businesses and employees. The benefits derive from close interaction between businesses, and from an enlarged pool of specialist skills, talents and shared support industries within a rapid access area (Halcrow Group, 2009). Large scale investments in HSR construction bring improvements related to connection between administrative centers and remote areas which leads to the centralization of labor market and to the concentration of labor force. As is known, there is a strong correlation between the concentration of labor force, the level of labor efficiency and economic growth.[117] This can be seen from the following basic factors.

First, the HSR related investments can increase of size and depth of the labor market. The widening labor market is a starting point for business development. Firms can search for labor in

[117] http://www.eng.hsrail.ru/vsm-1/development-of-the-project/

wider circles and people in the labor force can supply their labor within a larger geographical area (Blum et al., 1997). Improvements to public transport services can help promote access to employment and services to vulnerable groups, particularly those without their own private transport. The introduction of HSR could have a profound effect on the opportunities for achieving greater participation levels, but only if the developments are integrated to ensure that need and opportunity are firmly linked. Clear opportunities would exist to reduce poverty and deprivation (Halcrow Group, 2009). Second, the investment may increase of a number of competitors and potential contractors, which create additional incentives for innovations development and efficiency improvement. Another perspective is the development of specialization in sphere of service. Third, the investment may create opportunities for the knowledge and contacts sharing (for example, in sphere of scientific research).

Murakami (2011) shows that the HSR projects are likely to induce knowledge- and service-based business agglomeration benefits, mostly to large and globally connected city. Also, the HSR projects can guide the clustering of time-sensitive manufacturing and business service activities in edge-city locations, accompanied by regional airport development plans and local transit feeder service.

Recent research (Graham, 2007) suggests that agglomeration benefits in sectors such as financial services may be greater than in manufacturing. This is relevant to the urban commuting case but arguably is important for some HSR services (e.g., the North European network which links a set of major financial centers and may be used for weekly commuting). Given these aspects, it may be erroneous to conclude that scale economies and agglomeration economies (productivity impacts) are only found in manufacturing and freight transport (De Rus, 2008).

Specific industry development

The HSR project may also make the specific industry thrive. For example, since it involves travel, the HSR project might be able to promote regional tourism, hospitality industry, and local leisure services in relatively large cities, with high-quality urban design and unique social capital (Murakami, 2011).

11.2.4 Technology development

The labor market development and the business development will induce the technology development for specific regions. The employment growth rate in some information-related industry and high education industry is higher in the regions with HSR stations, compared with those without HSR stations, which will benefit the local technology development. According to Nakamura and Ueda (1989), in Japan, the R&D and high education industries' employment growth rate of the regions with Shinkansen stations is up to 27% , while the growth rate of those without stations is only 21%.

Many high-tech companies choose to locate their business headquarters from cities to non-urban cities connected by the HSR services. This urban-nonurban interaction, exchange of commerce and specialists, may facilitate better sharing, transfer and development of technologies. For example, the Waterman Company, a producer of writing instruments sold worldwide, relocated its headquarters from Paris to Nantes, despite the fact that construction of a new headquarters in Nantes cost the equivalent of two years' rent in Paris after introducing to TGV to France (Sands, 1993).

11.2.5 Summary

HSR may bring wider social and economic development. However, there is no agreement on the precise extent to which the HSR infrastructure leads to wider socio-economic impacts and benefits in addition to its direct impact as a mode of transport. The evidence is mixed and there seems to be disagreement on whether the overall impacts, if they exist, are positive or negative. These arguments and evidence show that the introduction of HSR alone is not sufficient for social economic impacts to take place. Such impacts depend on other prevailing conditions and mainly 'the presence of a buoyant local economy that can take advantage of the new opportunities offered by the high-speed rail accessibility' (Banister and Berechman, 2000). This is in line with the conclusion that transport investment acts as a complement to other more important underlying conditions, which must also be met if further economic development is to take place (Banister and Berechman, 2000).

Further, the existing within-city transportation network is very important in determining the effects of HSR services. If the cities have extensive mass transit systems in the form of underground/subway and metro light rail transit, this would greatly enhance the benefits of connecting the two cities by HSR. Also, HSR services can only be attractive on high-demand routes (Givoni, 2006). Various studies show that a high load factor/utilization is critical to reap the projected benefits of HSR. If after reaching the destination, passengers require a long access journey to the HSR stations and are hard to travel within the city, then the time savings HSR services can offer will be cancelled and the benefits of HSR will be lower than expected. Hence, Cities with dense and dominant city centers are more attractive, unlike large cities which are more dispersed in nature.

11.4 International cases

A review of the literature on HSR's developmental effects in different countries reveals significant effects at regional, urban and station level, including changes to the following: population and employment growth rates; ridership; business behavior; real estate values and activity; business and employment location; and residential location. In this section, we will study the cases of France, United Kingdom, Japan, United States, and Russia to see how HSR networks affect the transportation and economic development.

11.4.1 France

Overall, the passenger traffic of HSR in France has increased by 62.5% between 1996 and 2004 (Lee, 2007). The first HSR line, Paris-Lyon line, has been extremely successful since its opening, securing enough revenue to offset its infrastructure debt within a decade. It has to some extent the character of a long distance commuter line. The journey time was reduced to 2hours for 275 miles and has been a particular success in terms of both trip diversion and trip generation. Total rail passengers on the corridor increased from 12.5 million in 1980 to 22.9 million in 1992, 18.9 million being TGV passengers (Vickerman, 1997). The success of this line thus led to the expansion of the country's HSR network, with new lines built in the south, west, north, and east of the country (Rutzen and Walton, 2011).

Air travel, which is the main competitor of the HSR services, has been impacted since the opening of the first TGV lines. Table 11-3 illustrates the rail share of the rail-air market in specific TGV corridors. As can be seen from the figure, in the Paris-Lyon and Paris-Nantes corridor HSR dominated the market. This high usage of the rail mode has caused the airline provider, Air France, to cease certain flight destinations and for some routes, such as Paris-Brussels, entered into a partnership with Thalys, a cross-border rail operator (Rutzen and Walton, 2011).

Table 11-3: Rail-Air market share[118]

City pair route	Length (miles)	Speed(mph)	Rail Share	Air Share
Paris-Lyon	287	150	91%	9%
Paris-Nantes	238	120	89%	11%
Paris-Bordeaux	346	115	62%	38%
Lyon-Lille	423	121	60%	40%
Paris-Marseille	482	152	60%	40%

We can detect some development effects of TGV Atlantic (Paris-Le Mans) which has only been in operation for three years. Real estate prices and transactions have risen sharply in several communities with stations, and in Nantes the network is perceived as qualifying the city for the location of businesses. Nantes has attracted a number of large businesses out of Paris (although the TGV is also used by Paris-based firms to serve customers in and around Nantes), and the presence of the TGV has spurred a major redevelopment project near the station as well as helped to produce a 20 percent rent premium on space in the redevelopment area (Sands, 1993).

The city of Lille in the north of France which is situated on the cross-way of Eurostar HSR routes London-Paris and London-Brussels is another example for regional development. Over the years this city was a fading away as an industrial and coal mining center with a high unemployment rate. Due to the introduction of the Eurostar HSR, Lille at this point is the third in order of importance trade and financial center of France. The increase of economic benefits in

[118] Source: Rutzen and Walton (2011); Year 2003.

this city most likely brought about an economic decrease in other centers. Nevertheless in such a situation the redistribution of economic activity from the most economically successful regions such as Paris is most likely and this should be considered a positive effect.[119]

The TGV also benefitted business development, has affected the behavior and location decisions of businesses and has had noticeable development effects around some stations. Introduction of the TGV Southeast (Paris-Lyon) had several discernible effects on business trips: total business trips by rail increased 50 percent with service sector business trips by rail more than doubled. For firms, the medium-size information sector firms in hinterland areas used the TGV Southeast to enter Paris markets. When making business location decisions, access to the TGV Southeast was just one of a number of factors cited in business relocation decisions. Development was inconsistent across station locations, with effects generally limited to the area around the station, but the level of development was determined by the overall economic strength of the community and the presence of service sector firms requiring access to Paris (Sands, 1993).

It is hardly surprising that the introduction of HSR affected the travel and related industry. The total tourism has increased a lot. At the same time, hotel business is characterized by two contradictory effects: first, a drop in the number of overnight stays as more day-return journeys are made possible by high-speed trains; second, the development of tourist packages using the TGV. Several "special-interest" initiatives have shown the value of such packages, notably in Burgundy, thus responding to demand from tour operators (Bonnafous,1987).

However, not all the TGV effects are beneficial. The town of Le Creusot provides an example of a new TGV station that has failed to stimulate development. The town, located in a region undergoing economic restructuring because of the closure of local coal mines,

[119] http://www.eng.hsrail.ru/vsm-1/development-of-the-project/

had hoped to capitalize on its access to Paris to stimulate industrial growth. However, in 1990, six years after the TGV began service and reduced the travel time from Paris to 85 minutes, only two firms, both marginal, had located near the isolated TGV station. The main reasons for the weak development impact of the TGV seem to be a general lack of demand for new development, the isolated station location, and the station's poor road access (Sands, 1993).

TGVs are also bad for the economic development of small towns which are not connected by the TGV services. Some medium size French companies choose to relocate their manufacturing site to small cities connected by the TGV services. This has a significantly disruptive impact on the small towns, which have come to rely on the companies as their major or only income sources (Sands, 1993).

11.4.2 United Kingdom

As of 2011, there are four "classic" main railway lines in Britain operating at up to 125mph, plus 70 mile of purpose-built high-speed line (HS1 and HS2).[120] The HS1 line was finished on time and under budget. The reduction in journey times and increase in reliability achieved through the opening of Section 1 enabled Eurostar to capture 71% of the total London-Paris market and over 80% of the leisure market and Section 2 has increased these figures further.[121]

[120] The first purpose-built high-speed rail line in Britain was the Channel Tunnel Rail Link, the first section of which opened in 2003. The building of the line (re-branded "High Speed 1" in 2006) provoked discussion in the national media and specialist rail circles on the merits of constructing further high-speed lines. A second purpose-built high-speed line is now planned by the government — High Speed 2 — which will connect London with Birmingham, and at a later phase cities in northern England (including Manchester, Sheffield and Leeds).

[121] See http://www.lcrhq.co.uk/

The HS2 scheme is expected to generate benefits of some £32 billion (present value) and net revenue of almost £15 billion over sixty years. Over 85% of benefits come from traditional transport user benefits such as time savings, crowding relief and reliability improvements. Of these transport user benefits around £2.5 billion (slightly less than 10%) are due to reliability improvements. It is estimated that HS2 generates an average benefit of £8 per trip. Of these transport user benefits, more than £20 billion accrue to HS2 passengers (mainly due to improved journey times), up to £4 billion accrue to passengers on the classic line (due to reduced overcrowding and increased frequency) and £2 billion to road users (due to reduced congestion – for example, traffic on the southern section of the M1 is forecast to fall by around 2%). It should be noted that 61% of the transport user benefits accrue to business users (who only make up 30% of passengers), reflecting the higher values of time for this group, which can be up to seven times higher than the values for leisure travelers (Preston, 2010).

Studies conducted for the British railways suggests that about 50% of the traffic on a new high-speed rail line will be diverted from other modes, mainly car and air, with the remaining being totally new trips. This diversion would lead to a reduction in congestion and delays in roads and airports since HSR offers a higher capacity of transport, about 400,000 passengers per day (Rutzen and Walton, 2011).

The Halcrow Group (2009) listed the potential wider economic benefit for Scotland. It is clear that HSR provides Scotland with a major opportunity for significant economic growth and world-class business development. Edinburgh and Glasgow city centers are at the heart of these businesses, and will drive the Scottish economy forward. There is evidence however that HSR alone will not deliver these benefits, but requires the positive support of government, local government and business if the opportunities are to be fully realized. In terms of wider economic benefit, it is estimated that 10 new direct rail jobs will support, as well as14 additional induced and indirect jobs, and that the rail industry will invest £1.30 for every £1 of public investment.

11.4.3 Japan

From 1965 to 1989, annual ridership increased from 31 million to 236 million, and annual passenger kilometers increased from 11 million to 66 million (Taniguchi, 1992). The Shinkansen was designed to supplement existing intercity transportation modes, particularly from other rail lines and the airlines. By these standards, it has been very successful. In 2007, Japan's HSR mode share was 30% of the overall passenger kilometers traveled; 67% for trips between 310 and 435 miles. Most of Japan's major cities, such as Osaka, Nagoya, Kobe, and Kyoto, are located within 186 to 373 miles from Tokyo, which are ideal distances for HSR rail service. For distances above 435 53 miles, HSR has an 11% market share. Up to 23% of the passenger traffic on the Shinkansen lines is induced traffic (Lee, 2007). Rutzen and Walton (2010) show the market share between the HSR and air modes for several destinations originating in Tokyo. As is evident from the table 11-4, the HSR market share is reduced as travel distance increases.

Table 11-4: Rail-Air market share[122]

Distance to Tokyo (miles)	Rail Share	Air Share
310	81%	19%
320	65%	35%
450	57%	43%
506	9%	91%

[122] Source: Rutzen and Walton (2011); Year 2003.

Shinkansen has significantly saved leisure and business travelers transit times.. The first Shinkansen, traveling at a maximum speed of 125 mph, reduced the travel time between Tokyo and Osaka to four hours, saving 2.5 hours over the previous best time. Today, with trains traveling at a maximum speed of 170 mph, the trip takes less than 3 hours (Amano et al.,1991; Taniguchi, 1992). In the first 11 years of operation, the Shinkansen was estimated to have saved 2,246 million hours, the equivalent of one year of standard working time for 1.22 million people (Sanuki, 1979; Sands, 1993).

The Shinkansen has had strong economic development effects in Japan at the regional, urban, and station levels. Based on Lee (2007), the estimated economic impacts of 450 miles of new HSR on the national economy are 30 billion Euros and HSR can collect 6.7 billion Euros in tax revenue per year after 5 years of starting operations.

Sands (1993) argues that regions served by the Shinkansen generally have higher population and employment growth rates than those without direct Shinkansen service. The annual increase rate of population is 1.88 for cities with Shinkansen stations and 1.55 for cities without stations. The results are similar with regard to employment: average annual employment growth rate were 1.8 percent for cities with stations and 1.3 for those without stations.

Sasak et al. (1997) examined the impacts of Shinkansen on spatial dispersion of economic activities and population from the developed regions. They found that Shinkansen network expansion leads to regional dispersion from developed regions to some extent. However, building Shinkansen cannot simply resolve the problem of excessive agglomeration. In fact, the degree of dispersion cannot be increased much even when an extensive network is implemented. This is particularly true when we take ‘long-run’ effect concerning production capability into account. This is because the stock effect of existing lines works favorably to the developed regions, and construction of the lines in remote regions improves accessibility of central regions as well.

At the urban level, the Shinkansen's correlation with population and employment growth rates increases is clear. Although rates vary between studies, population and employment growth rates were consistently greater in areas with Shinkansen service than in those without. Employment growth and development activity were especially strong in the information exchange sector, as well as the hotel and food service sectors. Although there was also increased growth in the retail and wholesale sectors, there is evidence that these were merely shifts within communities, not general growth. This last observation lends further support to the theory that the Shinkansen has served to merely shift growth, not induce it (Sands, 1993).

As for the station level effects, station locations on the high-speed route generated higher population growth levels than non-station locations on the route but only marginally (Amano and Nakagawa, 1990). In another study (Brotchie, 1991), stations along the main high-speed line (Tokaido Shinkansen) had population growth 22% higher than non-station locations on the route (Haynes, 1997). Employment growth in retail, industrial, construction and wholesaling was 16–34% higher in station than non-station locations (Hirota, 1984).

The commercial value of the land near the stations increase much more than those located far from the stations (figure 11-3). This was independently corroborated by Amano and Nakagawa's (1990) finding of a 26% higher employment growth level for station versus non-station locations (1.8% to 1.3% respectively). Both intermediate station and termination stations showed significant growth in food and accommodation sectors (Brotchie, 1991; Hirota, 1984). The rise in tourism had mixed effects for station location. Overnights stays did not go up proportionately for intermediate stops due to expansion of same day travel (Obate, 1979). Some cities along the line without a station saw a decline in the number of visitors, notably Onomuchi city which experienced a decline of 9.0 percent. Specific employment sector impacts such as retailing were small and declined with distance from the stations (Okabe 1973). The wholesaling sector became more concentrated in larger centers (Okabe 1979; Haynes, 1997).

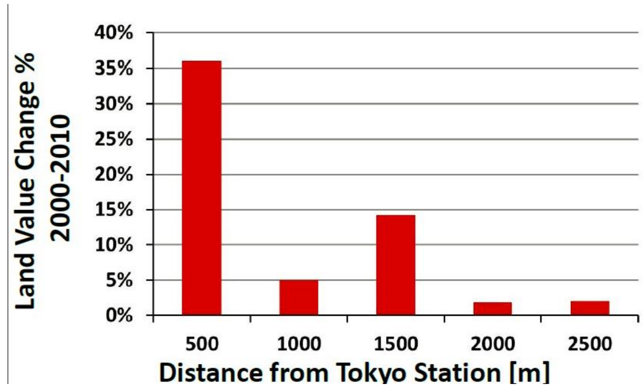

Figure 11-3: Commercial land value premiums in catchment area[123]

11.4.4 Russia

HSR 1 project was built to connect the Moscow and St. Petersburg. The total social and economic effect is expected to be Rubles 224,666 billion as estimated by The Russia Joint-Stock Company (JSC).[124] The potential effects can be itemized as follows:

1. The time economy effect due to reduction of travel time from the center of Moscow to the center of St. Peterburg to 2 hours and 30 minutes will bring about Rub. 234 bln.
2. The effect from improvement of safety in operation brought to 2010 will be Rub. 6.4 bln.
3. During building and exploration, 40 thousand vacancies will be created inclusive of related sector development. The enumerated effect from the growth of the population

[123] Source: Murakami (2011)
[124] http://www.eng.hsrail.ru/vsm-1/development-of-the-project/

income due to new job formation will be approximately Rub. 134 bln. The enumerated effect from additional income of enterprise of industrial, building and power sector is up to Rub. 113 bln.

The research conducted by the World Bank in 2007 showed that in the middle of 2000s the economies of many retarded regions of Russia had showed faster rates of growth just as the economics of some resource-abundant regions had grown considerably slower. The statistical analysis points to the hypothesis that the strong urban and regional agglomerations effect promoted the strong economic growth in the Central, Northwest and Southern regions in comparison with other parts of the country. According to expectations the improvement of the transport infrastructure will intensify the concerned effect for the retarded regions of the country including regions beyond the zone of HSR.

As for the travel industry development, the travel industry in Russia is at a lower level of development compared to the majority of European countries. This situation is related to a number of factors including the traditional insularity, intricate visa regime, and the large territory of the country which force tourists to cover enormous distances. HSR projects are expected to unite considerable number of cities having an essential development potential of the travel industry and still lesser-known outside Russia (for example, the historical center of Nizhni Novgorod). It is expected that the HSR investments will have big opportunities in the development of tourist traffic. In the course of this analysis the potential of the travel industry development has not been considered. But it is likely that the majority of foreign HSR operators pay great attention to this segment of market. Thus, the tourist stream in Malaga increased by 25% after the high-speed line launch. According to the statements of the Russian government representatives, the visa regime in Russia will be simplified during the 2018 FIFA World Cup.

There will be an active marketing campaign to develop Russian travel industry with the use of railroads the sporting events as a part of the World Cup can bring to the general increase of popularity of the tourism in Russia.[125]

11.4.5 United States

Northeast corridor (NEC)

In the USA, only one HSR line is in operation: the Acela Express tilting train running on the North East Corridor line between Boston and Washington, DC. Recently, the Next-Gen HSR 220 mph trains running on dedicated tracks between Washington, DC, and Boston, Massachusetts have been proposed and would provide tremendous mobility benefits to the traveling public and support the growth and competitive position of the region by investing in a vital transportation necessity whose time has come.

The estimated ridership is rising with continued economic growth in the Northeast; 35% more riders are projected over the 2010-2020 period and another 33% projected over the 2020-2030 period (Amtrak, 2010). The sources of the increasing riders are shown in figure 11-4.

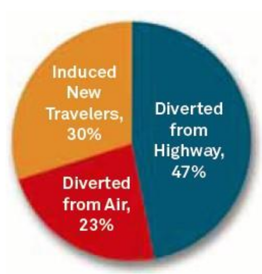

Figure 11-4: South of New NEC riders[126]

[125] http://www.eng.hsrail.ru/vsm-1/development-of-the-project/
[126] Source: Amtrak (2010)

Next-Gen High-Speed Rail service for NEC would generate an annual operating surplus of approximately $900 million. Potential positive economic impacts of the proposed Next-Gen HSR system would be generated in a number of areas (all dollar figures are in discounted 2010 dollars). The project's construction would directly increase employment and earnings along the corridor and beyond, with these workers' higher consumer expenditures generating more jobs to meet this increase in consumer demand. The project's construction would generate roughly 44,000 jobs annually and $33 billion in wages over the 25-year construction cycle. Similarly, the Next-Gen HSR system would support approximately 7,100 new permanent jobs within Amtrak, which along with indirect and induced employment result in a total of 22,100 jobs and $1.4 billion in annual wages. The estimated projected benefits of 2011 are shown in table 11-5.

Table 11-5: Projected benefits of Next-Gen HSR system[127]

Project Benefits	
Operating Surplus (Passenger Revenues – O&M Costs)	$11.0
Travel Time & Cost Savings, Accident Avoidance, Highway Delay Reduction	$16.3
Energy and Environmental Benefits	$1.3
Commuter Network Benefits (Slots, New Commuters, Reduced Delays)	$26.4
Air System Impacts (Reduced Air System/Traveler Delays)	$21.5
Market Productivity Benefits	$23.8
Total Project Benefits	**$100.2**

<u>California Corridor</u>

The Californian HSR, connecting the San Francisco Bay area with Los Angeles and San Diego, is at the most advanced planning stages (Federal Railroad Administration, 2005).

International experience suggests that the large regional air markets tied to large dynamic metropolitan areas in California will likely result in ridership levels on California's high speed

[127] Source: Amtrak (2010).

rail network well in excess of 8 to 10 million passengers for a line of 500 miles that de Rus and Nombela estimate is necessary to justify high speed rail investment (de Rus and Nombela, 2007).

Unlike many European systems in which smaller provincial towns are connected to dominant economic centers (as is the case in France) the linking of two large relatively independent metro regions in California could result in agglomerations benefits at the high end of the estimated range. The California HSR projects is likely to induce knowledge and service-based business agglomeration benefits that accrue mostly to globally connected cities and shift some service activities to edge cities, airports, and leisure-entertain hubs at the expense of small and intermediate cities (Brinckerhoff, 2011).

Proponents believe that California's HSR is seen as an economic stimulus. Catz and Christian (2010) show California HSR networks will materially reduce travel times, congestion and accidents on regional transportation systems. According to CAHSRA (2010), the California HSR Authority expects that the HSR project will generate 600,000 construction-related jobs over the course of building and induce 450,000 permanent new jobs over the next 25 years. As Murakami and Cervero (2010) note, the average number of jobs in 5km created by the HSR is 117,837 and the average number of workers in 5km is around 65,771 in 2008.

As to the business development, Brinkerhoff (2011) points out that the HSR network in California has the potential to increase business-to-business interaction between Southern and Northern California, integrate the economies of the Central Valley, and provide capacity in the congested airport hubs for higher value international connections. However, there are also literatures that doubt the benefit of the HSR services. Levinson (2010) expresses concerns about the full cost of a HSR system in comparison to those of highway and airport systems. Giuliano (2004) argues that the public spending in railway system is likely to generate smaller accessibility improvements and economic advantages as the linkage between transportation and land use has diminished in the wake of telecommunication advances.

Murakami and Cervero (2010) study the economic development effect of proposed California HSR services quantitatively by examining recent labor and job market trends in proposed California HSR stations. The results show that the direct user benefits of the new HSR and local transit systems alone will unlikely be large enough to cover full investment and operating costs. External agglomeration benefits, if leveraged by pro-active public policies that reward efficiencies and appeal to high value-added industries and labor, could help tilt the benefit-cost equation in HSR's favor. The net economic impacts of the California HSR project will likely be negative unless public policies (e.g., zoning, supportive infrastructure investments, pro-business governance) pro-actively guide market shifts to station catchments that, based on Japan's experiences, offer comparative economic advantages.

11.5 A summary of positives and negatives

In table 11.6 below we provide a summary of the pros and cons discussed above.

Table 11-6 Impacts of HSR in selected countries

France	Positive	1. Secure enough revenue to cover the cost debit. 2. Traffic passenger of HSR increase. Passengers are attracted from air service 3. Regions around the stations of TGV like Nantes and Lille experience significant economic development. 4. Companies change their decision while choosing the locations. 5. Travel industry thrive after introducing the TGV
	Negative	1. Small towns not connected by TGV faded. 2. Regions which are isolated stations and lack new development will not benefit from the TGV services.
UK	Positive	1. HS1 finished under the budget and took up more market due to reducing journey time and its reliability. 2. HS2 is expected to generate benefits of some £32 billion (present value) and net revenue of almost £15 billion over sixty years. 3. 50% of the traffic on a new high-speed rail line will be diverted from other modes, mainly car and air, with the remaining being totally new trips.

		4. HSR provides Scotland with a major opportunity for significant economic growth and world-class business development. 5. 10 direct and 14 indirect rail jobs will be created while constructing HSR networks.
	Negative	1. HSR alone will not deliver these benefits, but requires the positive support of government, local government and business if the opportunities are to be fully realized
Japan	Positive	1. Ridership increase since the operation of Shinkansen. 2. Shinkansen is successfully supplement existing intercity transportation modes, particularly from other rail lines and the airlines. 3. Shinkansen significantly saves time of travelers and business trip. 4. Shinkansen will bring 30 billion Euros economic benefits and generate 6.7 billion Euros in tax revenue per year after 5 years opening. 5. Regions with Shinkansen stations experience higher growth rate of population and employment. 6. The commercial value of the land near the stations increase much more than those located far from the stations
	Negative	1. Some cities along the line without a station saw a decline in the number of visitors. 2. Overnights visitors decline.
Russia	Positive	1. The total social and economic effect, including time economy effect, safety improvement effect, job creation effect is expected to be 224,666 bln rub. 2. The economies of many retarded regions of Russia had showed faster rates of growth.
	Negative	1. The economics of some resource-abundant regions had grown considerably slower. 2. The travel industry in Russia is at a lower level of development compared to the majority of European country

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12. BUY AMERICA REQUIREMENT FOR FRA AND FTA

In 2009, President Obama, together with Vice President Biden and Secretary of Transportation LaHood, articulated a new "Vision for High-Speed Rail in America". The High-Speed Intercity Passenger Rail (HSIPR) program implements that vision, which includes a goal to bolster American passenger rail expertise and resources. The Buy America requirements reinforce this goal, and aid in encouraging a domestic market in the rail sector.[128]

The Passenger Rail Investment and Improvement Act (PRIIA) of 2008 authorized the appropriation of funds to establish several new passenger rail grant programs, including capital investment grants to support intercity passenger rail service, high-speed corridor development, and congestion grants. FRA consolidated these and other closely related programs into the HSIPR program, as funded through the American Recovery and Reinvestment Act of 2009 (ARRA). Spending authorized under PRIIA is subject to the Buy America provision of 49 USC § 24405(a).

According to the FRA's HSIPR Interim Guidance, Buy America provision at 49 U.S.C § 24405(a) applies to projects funded under Track 1 and Track 2, to service development program and individual and to projects funded under the FY 2010 DOT Appropriations Act. However, FRA's HSIPR program also includes projects whose funds were not authorized through PRIIA and funded through FY 2008 and 2009 Department of Transportation and related Agencies Appropriations Acts in Track 3 and Track 4. Therefore, these projects are not applicable to the section 22045(a) but must comply with Buy America Act. Amtrak's direct purchases have a separate statute governs which is 49 U.S.C. § 24305(f) and the 49 USC § 24405(a) is not

[128] http://www.fra.dot.gov/Pages/251.shtml

applicable. As provided in 49 U.S.C. § 24405(a)(11), the PRIIA Buy America requirements apply only to projects for which the costs exceed $100,000. [129]

Section 24405(a) [130] provides that the Secretary of Transportation (authority delegated to the Federal Railroad Administrator) may obligate an amount to carry out a PRIIA funded project only if the steel, iron, and manufactured goods used in the project are produced in the United States.[131] The Secretary of Transportation may waive that if the secretary finds that:

1. applying that would be inconsistent with the public interest;
2. the steel, iron, and goods produced in the United States are not produced in a sufficient and reasonably available amount or are not of a satisfactory quality;
3. rolling stock or power train equipment cannot be bought and delivered in the United States within a reasonable time; or
4. including domestic material will increase the cost of the overall project by more than 25 percent.

The Secretary of Transportation may not make a waiver for goods produced in a foreign country if the secretary, in consultation with the United States Trade Representative, decides that the government of that foreign country: (A) has an agreement with the United States Government under which the Secretary has waived the requirement of this subsection; and (B) has violated

[129] http://www.fra.dot.gov/Pages/11.shtml

[130] http://www.fra.dot.gov/downloads/49USC24405a.pdf

[131] From 49 C.F.R. § 661.5(d): For a manufactured product to be considered produced in the United States, (1) All of the manufacturing processes for the product must take place in the United States; and (2) All of the components of the product must be of U.S. origin. A component is considered of U.S. origin if it is manufactured in the United States, regardless of the origin of its subcomponents. From 49 C.F.R. § 661.3: Component means any article, material, or supply, whether manufactured or unmanufactured, that is directly incorporated into the end product at the final assembly location.… End product means any vehicle, structure, product, article, material, supply, or system, which directly incorporates constituent components at the final assembly location, that is acquired for public use under a federally-funded third-party contract, and which is ready to provide its intended end function or use without any further manufacturing or assembly change(s).

the agreement by discriminating against goods to which this subsection applies that are produced in the United States and to which the agreement applies.

Amtrak is in compliance with the U.S.C. § 24305(f)[132] domestic Buying preference. According to that, Amtrak shall buy only: (A) unmanufactured articles, material, and supplies mined or produced in the United States; or (B) manufactured articles, material, and supplies manufactured in the United States substantially from articles, material, and supplies mined, produced, or manufactured in the United States. This subsection applies only when the cost of those articles, material, or supplies bought is at least $1 million. On application of Amtrak, the Secretary of Transportation may exempt Amtrak from this subsection if the Secretary decides that: (A) for particular articles, material, or suppliers (i) the requirements of this subsection are inconsistent with the public interest; (ii) the cost of imposing those requirements is unreasonable; or (iii) the articles, material, or supplies, or the articles, material, or supplies from which they are manufactured, are not mined, produced, or manufactured in the United States in sufficient and reasonably available commercial quantities and are not of a satisfactory quality; or (B) rolling stock or power train equipment cannot be bought and delivered in the United States within a reasonable time.

FRA believes that high-speed and intercity rail passenger equipment can and should be manufactured in the United States and will do everything to ensure that its grant funds are spent domestically and where there is not currently domestic production, will do what it can to encourage domestic projection. Where it is not possible for a grantee to find a fully complying bidder/offeror (and therefore a waiver from Buy America is requested), the grantee is encouraged to choose (as long as this choice is consistent with applicable procurement practices) as its

[132] http://www.fra.dot.gov/downloads/49USC24305.pdf

contract award the bidder/offeror with the proposal containing domestic manufacture and the highest domestic content.

FRA will apply the statutory Buy America provision strictly and will issue a waiver only when the bidder/offeror has demonstrated by clear evidence that it has met the requirements for a waiver. Moreover, FRA considers the need to grant waivers under these circumstances as strictly temporary because it expects that achieving domestic manufacture and 100% domestic component content can and will occur in the very near future. By encouraging grantees to use manufacturers or suppliers who maximize domestic content, FRA hopes to achieve its goal of 100% domestic content in the near future.

FTA has its own Buy America statute,[133] which in many respects is identical to FRA's statute. However, the FTA's Buy America statute, at 49 U.S.C. § 5323(j)(2)(C)(i) and (ii), includes the specific additional waiver regarding a 60% component and American assembly allowance for rolling stock[134] that 49 U.S.C. 24405(a) (FRA's HSIPR Buy America statute) does not. Except that part, the general FTA and FRA Buy America provisions regarding the steel iron and manufactured goods used in its grant-funded projects are nearly identical. FRA will not use statutory authorities it doesn't have.

The FTA, throughout the 30 years it has administered its own Buy America statute, has implemented regulations and changes to those regulations which have resulted in a very detailed set of rules, guidance documents, and enforcement strategies.

[133] http://www.fta.dot.gov/legislation_law/12921.html

[134] The FTA's Buy America exception says "when procuring rolling stock (including train control, communication, and traction power equipment) under this chapter— … the cost of components and subcomponents produced in the United States is more than 60 percent of the cost of all components of the rolling stock; and … final assembly of the rolling stock has occurred in the United States."

The definitions and provisions at 49 C.F.R. §§ 661.3, and 661.5 implement FTA’s Buy America general requirements covering steel, iron, and manufactured goods, except where 661.11 applies, which is FTA’s regulation covering the procurement of rolling stock (including train control, communication, and traction power equipment).

FRA is developing its own regulations; however, in the interim, FRA has concluded that it is reasonable and appropriate to use applicable FTA rules for purposes of providing guidance to FRA’s grantees, specifically 49 C.F.R. § 661.3 and 661.5 – and use them as guidance for both FRA-funded manufactured goods procurement generally and rolling stock, where appropriate. As explained above, FRA cannot apply § 661.11 to rolling stock procurements because of the differences in FRA and FTA statutory authority - though some of the analysis might be helpful in particular circumstances.

13. INSIGHTS FROM THE INDUSTRY

In an effort to further understand the intricacies of the industry, two questionnaires weer distributed. On conducted by me and one by FRA.[135] Below I report the findings from the two surveys. In the next section I offer a brief summary and comment on policy implications.

13.1 My questionnaire and answers regarding high speed rail

All of the questions below were specifically asked pertain to high-speed rail (<u>not</u> regular rail, light-rail or transit systems).

A. Broad Supply-Chain Aspects

A.1. How would you classify the major categories of components that go into a <u>trainset</u>? List as many as you might consider as meaningful "broad" categories.
<u>Response:</u>
Car/wagon, bogie, air conditioning, interior, cockpit

A.2. In which of the broad component segments noted above do you produce <u>directly</u>?
<u>Response:</u>
Car/wagon, bogie, air condition, interior (except seats), cockpit

A.3. Which of the broad component segments noted above do you operate in, but <u>sub-contact out</u>? (That is, you contract to deliver specific components, but then sub-contract out the production of those components.)
<u>Response:</u>
Air condition, bogie (axles and wheels), seats

B. Production and Supplies

Some countries impose domestic content and/or production clauses – for example, some or all of the production may have to take place in the country of the contract. The questions below are premised on the country requiring at least some domestic content and/or production.

B.1. If you were to consider a new contract for a specific country, how many <u>trainsets</u> would have to be ordered for you to set up production facilities in that country?

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[135] Due to confidentiality requirements, I do not know the names of the companies that FRA surveyed, and neither have I seen the original responses that were sent by the companies to FRA. I only received a synopsis of the responses. For my questionnaire, since the firm I contacted was in full confidence, the name of this company is not revealed. That is, confidentiality of the companies is maintained all around.

Response:
50 +

B.2. For the scenario stated in B.1: What fraction of the total order would be produced in that country at the start?
Response:
Pilot series will be assembled in mother factory and then transfer of production is done step by step

B.3. For the scenario stated in B.1: What fraction of the total order would be produced elsewhere and imported at the start?
Response:
Same as above - Pilot series will be assembled in mother factory and then transfer of production is done step by step

B.4. Same as item B.2 above, but by the component categories you identified in A.1?
Response:
Bogies will be manufactured in bogie factory and imported

B.5. Same as item B.3 above, but by the component categories you identified in A.1?
Response:
Bogies will be manufactured in bogie factory and imported

B.6. Following up on B.2 above: How do you expect this percentage to change over 3-5 years?
Response:
Approx. 80% local content and only import of highly sophisticated parts

B.7. Following up on B.3 above: How do you expect this percentage to change over 3-5 years?
Response:
Hardly, localization of bogie production

B.8. Following up on B.4 above: How do you expect these percentages to change over 3-5 years?
Response:
Approx. 80% local content and only import of highly sophisticated parts

B.9. Following up on B.5 above: How do you expect these percentages to change over 3-5 years?
Response:
Approx. 80% local content and only import of highly sophisticated parts

C. Partnerships

C.1. For the component categories you identified in A.1, do you envision a significant role for joint-ventures to meet production targets?
Response:
JVs with local partners in many cases; please see press releases for more details.

C.2. Following up on C.1: How would to expect this to change over 3-5 years?
Response:
Local content will be steadily increased over the years

D. Barriers to Production in Foreign Countries

D.1. In your view, what are some of the main broad impediments to production in foreign countries?

(a) For countries that are not traditionally HSR-intensive?
Response:
Quality level not sufficient; qualified suppliers not available; homologation procedures; scale effects not seen; low volumes.

(b) For countries that are traditionally HSR-intensive?
Response:
Qualified suppliers linked to competitors; homologation procedures; scale effects not seen.

D.2. Following up on D.1: In your view, what may be some of the specific impediments to production in the foreign locations by the component categories you identified in A.1?
Response:
Quality level not sufficient; qualified suppliers not available; homologation procedures; scale effects not seen; low volumes.

13.2 FRA questionnaire and responses

Below are the summary of responses to questions on Buy America provisions relative to passenger rail equipment procured under the Passenger Rail Investment and Improvement Act. As noted above, this questionnaire/survey was carried out by FRA and the summary of the responses (the table below) were made available to me.

a	What is your organization's current ability to achieve high levels of US content in the rolling stock you would build in the US?
	Carbuilders with existing manufacturing facilities in the U.S. are currently able to produce rolling stock with U.S. content in the range of 60% to 85%, determined according to the current FTA rules.
b	What are your plans or approach for increasing that level of content, now and over the next 5 years?
	Level of U.S. content is determined to a large extent on the availability of U.S. produced components and subsystems. The typical approach to increasing the level of content involves an incremental localization over a number of years as suppliers see consistency of orders and are induced to transfer technology and/or establish U.S. manufacturing facilities. Carbuilders' plans for localization, therefore, depend on the market size and require a consistent level of adequate funding. The maximum level of U.S. content that respondents felt could realistically be obtained ranged from 80% to 90%.
c	Assuming appropriately sustained demand for rail rolling stock in the US market, please provide an estimate of the design and production engineering your firm would perform in each of the following ways: (1) At your facilities in the US? (2) At your facilities outside the United States and (3) By your sub-suppliers.
	Typically, 20% to 30% of a foreign carbuilder's new vehicle design engineering is done in U.S. The balance is done in their facilities outside the U.S. Production engineering and car overhaul engineering has much higher U.S. content, typically about 90%. Again, these levels of U.S. content would be expected to increase gradually if sustained demand for rolling stock continued to exist for many years. Domestic carbuilders perform all of their vehicle design and production engineering in the U.S. Information regarding engineering content provided by sub-suppliers was not offered by most of the carbuilders surveyed. Those that did respond estimated that approximately 1/3 to 1/2 of the total design and engineering was attributable to sub-suppliers (with the balance attributable to the carbuilder). Reliance on the engineering expertise of major system suppliers was a common theme. After fully amortizing the capital costs of establishing manufacturing facilities in the U.S., the manufacturing and assembly costs account for approximately 1/3 of the total car cost, with about 2/3 going to suppliers for purchased parts and equipment.
d	What level of sustained demand for rolling stock do you believe will be needed to re-establish a US supply chain and why?

	There is quite a lot of variation in the responses to this question. Some responders considered just cars or just locomotives. Others included all types of passenger rolling stock (including inter-city, commuter, metro and light-rail). There is further inconsistency in that some manufacturers quoted volumes required for compliance with FTA Buy America rules, whereas others provided only volumes required for profitability. Required annual production for an individual carbuilder ranged from 25 to 400 vehicles; with estimates of 200 to 1000 vehicles per year needed to re-establish a U.S. supply chain and sustain the entire industry. The need for a consistent level of production over many years (5 to 20), rather than highly fluctuating levels from year to year, was also emphasized, especially for the lower average levels of annual production.
e	Can combining manufacturing, overhaul and maintenance and focusing or concentrating these activities at just a few centers nationwide help sustain the design and production capability?
	There may be some possibility for synergy by combining new car manufacturing with major overhaul or remanufacturing activities. Routine maintenance, however, must be performed locally at operator's property to avoid taking equipment out of service. Some responders expressed reservations about combining maintenance with production at all, citing different labor expertise requirements, differences in facility layout and work flow patterns, and restrictive union agreements.
f	What components does your company typically outsource?
	Carbuilders surveyed are primarily integrators and assemblers and, hence, outsource most of the components they use. Car shells and truck frames are typically built in-house.
g	Who are your major sub-suppliers and what level of responsibility have they had for design and engineering- ie- were they given detailed design and assembly drawings for parts to be fabricated or simply interface and performance requirements?
	Respondents provided extensive lists of sub-suppliers, covering a wide range of components. All respondents emphasized that suppliers of major sub-systems (such as brakes or HVAC) were responsible for the design and engineering of their own products according to the performance and interface specifications provided by the carbuilder. Many respondents also described a lower tier of suppliers that manufacture parts based on detailed design and assembly drawings provided by the carbuilder.
h	What is your view on the potential use of the FTA Buy America definition of "Components," "Subcomponents" and "Substantial Transformation" for acquisition of intercity passenger rail rolling stock? Is it appropriate? Would it facilitate your organization's ability to respond? Should it be modified in some way to have better applicability to intercity passenger rail rolling stock?

	All respondents were well acquainted with the FTA Buy America terms and conditions. 'Domestic' suppliers favored a more straightforward, "true" accounting of U.S. content. Suggestions include aggregating all content and comparing the total to a single threshold, rather than using the FTA roll-up method which encourages gamesmanship in manufacturing methodology. 'Foreign' suppliers generally felt the FTA rules to be appropriate to intercity passenger rolling stock and favored the adoption of these rules by the FRA because the rules have been established for a long time, and are well known throughout the industry. The complexity of a new and different set of rules would be an increased burden and may cause confusion among some suppliers. Having said that, a few modifications to the current implementation of FTA rules were suggested: • Increase the consistency and accuracy of Buy America audits by having FRA administer them rather than the agencies. • Revisit the division of components vs. sub-components to reflect the state of modern equipment design. • Allow neutral content (testing, training, manuals, assembly) to be included as U.S. content. • Revise rules to avoid situations where unnecessary expense is incurred simply to comply with Buy America rules (for example, prototype car is disassembled after testing outside the U.S. and then reassembled in the U.S.).
i	How does your organization view the current capacity for production of passenger rail rolling stock nationwide? Is it about right? Is there excess production capacity? Is there insufficient production capacity to meet projected demand?
	All respondents felt that there was significant excess of production capacity for passenger rail rolling stock in the U.S. Projected demand was seen as low and uncertain, especially given the contentious political climate here recently. In addition, localization without sufficient demand leads to cyclical excess capacity as orders are completed and then plants forced to close due to lack of further orders.
j	What are the primary barriers to higher levels of US content in passenger rolling stock production?
	The primary barrier to higher levels of U.S. content is the lack of a consistent level of assured, adequate demand by U.S. agencies for passenger rolling stock. Standardized equipment design can promote sustained demand, but discourages the use of new technology originating within the U.S.
k	What components or materials are currently difficult to source in the United States and why?
	Stainless steel and aluminum suitable for body shells, and electronic components were most often cited as unavailable in the U.S. Specialty castings, forged wheels, propulsion systems, transmissions, and fabricated truck frames were also mentioned as difficult to obtain in the U.S. The requirements for these products are quite stringent and unique to the passenger rail market, and the market in the U.S. is much smaller than in other areas worldwide (particularly Europe and Asia), so incentive to invest in U.S. production facilities does not exist.
l	In your view, what can or should be done by the US government and state governments, to enable rolling stock manufacturers to achieve the highest possible US content at the earliest possible time? What components, subcomponents or materials, if any, do you believe are unlikely to ever be available in the US and why?

	Federal and state governments should make long-term commitments to support the passenger rail industry with a dedicated level of funding. The FRA should be realistic in setting goals for U.S. content so as not to discourage localization or the adoption of innovative, state-of-the-art technologies. And the FRA should provide clear and consistent rules to administer the Buy America requirements. Using promised level of U.S. content as an award criterion when evaluating proposals may also be an effective strategy for inducing manufacturers to increase their domestic content. Components identified in item (k) are unlikely to be available in the U.S. in the current economic climate.
m	What investments has your organization made in US based production capabilities and what are your plans for the future?
	Most respondents have built or acquired at least one manufacturing and assembly plant in the U.S. Future plans for investment in production capability are dependent on the market demand.
n	What volumes may be necessary to justify establishing and/or expanding US based production and design capabilities?
	This question was interpreted and answered similarly to question (d) with regard to establishing production capability. Establishing design capability in the U.S. would require substantially higher volumes.
o	Does your organization believe there is any potential to build rolling stock for export from the United States? Could it be useful to allow these exports to balance the net total of imported components and subcomponents?
	With a few exceptions (notably regarding exports to other North American countries), respondents were generally very negative regarding the prospect of exporting passenger rolling stock from the U.S. Many reasons were given, including: • Lack of experience in high speed development • U.S. standards, dimensions and safety requirements are unique to U.S. • Sufficient to excess production capacity already exists in other markets. • Lack of reciprocity – all markets demand high levels of localization, but must also tolerate a reasonable level of imported technology. Respondents seemed intrigued with the notion of allowing exports to offset lack of U.S. content, but they expressed uncertainty about how it would work in practice.

14. SOME IMPLICATIONS FOR U.S. HSR INVESTMENTS

Based on several important issues and characteristics examined for the HSR industry, it is clear that it is a complex industry, and evaluating the benefits and costs of investments is a difficult task. Below I note selected aspects and draw some conclusions to aid policy.

1. U.S. manufacturing content

If the longer-run objective is to spur domestic manufacturing and establish a meaningful U.S.-based supply-chain, the size and continuity of HSR trainset orders will need to be above critical thresholds. In a survey, an important trainset supplier noted that the lower bound on orders for setting up "production" facilities in a country would be above 50 trainsets, where a trainset refers to a full train. The FRA survey responses noted orders of well above 200 vehicles per year on a sustained basis. These numbers imply that both the initial and recurring (annual) demand have to be high, above threshold levels. An important reason for the numbers being high relates to the economies of scale and scope in HSR manufacturing discussed in this report. These responses imply that unless the U.S. is planning for fairly extensive investments in HSR networks and services across the country, this level of initial and recurring (annual) demand is unlikely to be met. For example, if we were to consider just California, the Northeast corridor and maybe parts of the Midwest, this level of demand is not likely to be met.

Given the dominance of existing companies (e.g., Siemens, Alstom, Bombardier, CAF, Talgo) and the emergence of new players (Hyundai-Rotem, CNS, CSR), it seems highly unlikely that the U.S. can become an exporter of these technologies and components in the future. This effectively takes out an export-based argument that may grow and sustain a domestic U.S.-based HSR components supply-chain.

To put it differently, at plausible expected levels of initial and recurring demand, and effectively no potential of U.S.-based HSR exports, the big-picture objective of developing a healthy U.S.-based HSR supply-chain is not likely to be met.

2. Component areas

The above, more general picture, obscures some specifics. As we discussed earlier, and as evident in the supply-chain (Appendix C), the overall HSR product has an extensive array of components. If U.S. were to engage in meaningful expansion of HSR, there will inevitably be some areas where U.S.-based manufacturing will pick up, and other component areas where we will have to rely on imports.

Among the areas where US may have potential for developing a manufacturing base is in the broad electronics, and locomotives and power, areas where there are several U.S. companies that produce components for rail and other industries and could transfer those skills to producing components for HSR related. In highly advanced components such as HSR signaling systems, the U.S. may find it very difficult to develop manufacturing and compete in this highest-technology areas which are dominated by Germany, France and Japan.

Some of the U.S. companies that appear in the supply-chain examples (Appendix C) are, for example, Eaton, Wabtec, General Electric, ITT, ORX, EMD, Caterpillar and URS. Arguably, if the expansion were to take place, companies like Texas Instruments, for example, could be in play, along with a number of small and medium manufacturing companies that would diversify to provide components (see previous discussion of multiproduct firms), as well as infrastructure based construction and services companies.. Given the lack of an existing U.S. HSR industry, it is a bit difficult to spell out a wider range of U.S. firms that may diversify or enter this market. A more detailed study needs to be conducted to assess this aspect in its entirety.

Overall, an examination of U.S. HSR expansion even below the thresholds described above, appears to indicate that many U.S. firms can provide important components and spur domestic manufacturing in selected areas.

3. Minimizing policy-driven uncertainty

The literature on investment under uncertainty shows that greater uncertainty tends to retard investment.[136] The specific source of uncertainty could be diverse, such as uncertainty arising from future profitability, policy uncertainty, among others. In the HSR industry, with significant economies of scale and scope, along with technology sophistication and R&D and sunk investment requirements, this is likely to be an important factor. What this implies is that if U.S. policy is to establish adequate and reliable HSR service and upgrades, it needs to be done so with policy-certainty. Else firms in this complex industry will not enter various component markets and make the necessary, and risky, investments.

4. Standardization of components

Large initial and recurring HSR order size allows for more degrees of freedom to reap the economies of scale and scope, and potentially have differing standards for HSR investments in different parts of the country. But given the likely smaller order size of potential U.S. HSR investments, it is critically important that there be a concerted attempt to standardize technical

[136] See for example the discussions and references to the literature in: (1) Ghosal, Vivek, and Prakash Loungani. "The Differential Impact of Uncertainty on Investment in Small and Large Firms." *Review of Economics and Statistics* 82, 2000, pages 338 – 343; and (2) Ghosal, Vivek. "Small is Beautiful but Size Matters: The Asymmetric Impact of Uncertainty and Sunk Costs on Small and Large Businesses."

requirements and components. Else the HSR investment costs will balloon to unsustainable levels and lead to adverse net benefits.

5. Buy America requirements

Based on the questionnaire survey responses, it appears that the Buy America requirement can be met in important part. If the order size is large and above the earlier noted thresholds, with recurring orders over several years, the foreign manufacturers appear in good position to set up production facilities in the U.S. to deliver the investments and components. And many U.S. companies are also likely step up to the plate to deliver important components. With more modest order sizes, as appear to be the realistic projections, the percentage Buy America requirements are likely to be lower, but with careful planning, standardization of investments and components, predictability of policy and orders, and appropriate public-private partnerships, this percentage can be pushed higher.

6. Public-Private partnerships

This report presented an extensive discussion, along with specific case studies, of the changing characteristics of public-private partnerships in HSR investments. In an era of tight Government budget constraints, it is inevitable that the private sector participants be more explicitly embedded into such high cost infrastructure investments. This reduces the burden on public moneys, and provides greater incentives for the private sector to be an important stakeholder to ensure successful investments and operations of the HSR projects. While some of our foreign examples were revealing, the proposed Florida HSR project also offered a glimpse of the extent to which private participants were willing to step up and contribute. While this report was somewhat exploratory in this area, more analysis needs to be done to examine creative public-private partnerships that can deliver important infrastructure projects to the country while reducing the burden on Governmental resources.

7. Evolving HSR industry characteristics

Using data and information on HSR contracts during 2000-2011 (Appendix A), we noted several interesting factors at play. The HSR industry has evolved considerably than even 10 years back, with emergence of significant new players such as Hyundai-Rotem (S. Korea) and CSR and CNR (China). Increasingly, these firms are competing head-to-head with the more traditional heavyweights such as Siemens, Bombardier, Alstom, among others. This has lead to more competitive pricing. In other words, given the enhanced competition among trainset suppliers today, the Governments can get a better deal today (relatively speaking, and in terms of lower investment costs) as opposed to, say, 10 years back.

The second characteristic we observe in the HSR contracts relates to the evolving nature of partnerships among the trainset suppliers. Far more suppliers are now engaging in partnerships, in part designed to adjust to the changing market conditions, as well as to meet complex Governmental requirements related to domestic content and technology transfer agreements. Many of these adjustments being made by the suppliers are creating a more favorable investment climate.

Overall, the ability Governments today to draw a greater number of suppliers into competitive bidding can result in a wide range of benefits, and creates a more opportune moment to undertake HSR investments.

APPENDIX A. INTERNATIONAL HIGH-SPEED RAIL CONTRACTS

Notes:
1. Information presented in this table are based on materials that were available from the various company websites, national rail administrators, and industry reports that were publicly available.
2. In column 2, 'capacity' refers to passenger capacity.
3. For the contract amounts, ***'mn'*** refers to millions and ***'bn'*** refers to billions.
4. The abbreviation TTA denotes "Technology Transfer Agreement".
5. The Saudi Partners for the Alstom (2009) contract are: Al Arrab Contracting Company Ltd, Al Suwailem Company, Saudi Consolidated Engineering Company (Khatib & Alami).
6. In instances where the contract had a partner – e.g., say Alstom was the main supplier with Bombardier as a partner – then the table below reports two rows referring to this contract, one with an entry for Alstom and another with an entry for Bombardier. While this produces some duplication (in instances where the contract had a partnership), the benefit is that this system more clearly signals the contracts for each of the major trainset suppliers the national rail authorities contract with.

1. Company/ Partnership	**2. Contract with Year/ delivery Train/ speed Trains/ cars/ capacity**	**3. Total Cost Project share Maintenance contract Competing bids**	**4. Manufacturing and other contract related information**
Alstom/ Eukorail, Hyundai Rotem	KHSRCA Korea 1994/ na KTX1/ 300 46/ 20/ 965	na Alstom's share is \$2.1bn (€1.5bn) na Compete with Siemens and Mitsubishi	Infrastructure and rolling stock were created via TTA, which paired up Korean companies with core system supplier Alstom and its European subcontractors for different subsystems. 46 trains were built - the initial twelve in France by Alstom, the remainder in South Korea by Rotem. The core system technology encompass the catenary, signaling and rolling stock. In line with the core system contract condition that over 50% of the added value has to come from South Korea after technology transfer, the remaining 34 of the 46 trainsets ordered were built under license by Rotem in South Korea itself.
Alstom/ Bombardier	Amtrak USA 1996/ 1999-2000 Acela Express/ 240 20/ 8/ na	Na Bombardier's share is 75% and Alstom 25% na Compete with Siemens (American ICE) and ABB (X2000)	The Acela Express was largely built on United States soil, as stipulated in the Amtrak contract. Bombardier's plants in Barre, Vermont, and Plattsburgh, New York, performed much of the manufacturing. Alstom also furnished some components made in France. (The funding scheme for the project is rather unusual as it puts very little burden on Amtrak.) Bombardier is financing the \$611 million to purchase the trains (including additional electric locomotives) and part of three new maintenance facilities, as well as to operate and maintain the equipment for 20 years. Amtrak's ability to repay Bombardier will come from additional revenue that the Acela Express is expected to create in service, estimated by Amtrak at \$200 million per year.
Alstom/ CAF	RENFE Spain 2001/ 2003 Alaris/ 270 20/ 4/ 237	€440mn (\$377mn) na Full maintenance of the new fleet for 14 years Na	Alstom, the consortium leader, was responsible for providing the traction system and 50% of the mechanical equipment for these high-speed regional trains. Trains will be largely built in Alstom industrial units in Spain.
Alstom/ None	Virgin Trains UK 2002/ na	€1.8b <u>Unable to get</u>	<u>Unable to get information.</u>

	Pendolino/ 225 na/ na/ na	information.	
Asltom/ Bombardier, AnsaldoBreda	Trenitalia Italy 2002/2005-2007 ETR 500/300 60/na/na	€330mn Alstom's share of the work is €60mn Na na	ALSTOM is in charge for the supply of bogies, transformers and auxiliary converters. The work will be carried out at ALSTOM's factories in Sesto and Savigliano. The other consortium members are Ansaldobreda, which will supply body shells, traction equipment and bogies; Firema, which will supply body shells and traction equipment; and Bombardier, which will supply electrical equipment.
Alstom/ None	Trenitalia Italy 2004/ 2007 Pendolino/ 250 12/ 7/ 430	€240mn na na na	Manufactured at Alstom site in Italy, with components from Alstom EU Sites.
Alstom/ None	Cisalpino Italy and Swiss 2004/ 2007-2008 Pendolino/ 249 14/7/430	$356mn na na na	Trains built at Alstom's Savigliano plant in Italy.
Alstom/ CAF	RENFE Spain 2004/ 2006-2009 Shuttle, Variable Gauge/ 250 30(Shuttle)/ na/ na; 45(variable gauge)/ na/ na	€1,777mn (Supply €937mn) Alstom leads consortium and share of the contract is €1,027mn na Alstom-CAF provide maintenance services for 14 years (€840mn)	Alstom Santa Perpetua plant and CAF's Beasain and Zaragoza plants will share the work of building body shells and assembling the trainsets. Alstom leads the consortium for the supply and maintenance of 30 trains (shuttle) and its participation in the order is €476 million. It also participates in the mechanical construction, electric equipment supply and maintenance of the 45 variable gauge units, worth €551 million. Alstom total share of these contracts, including maintenance, is €1,027 million.
Alstom/ CNR Changchun Railway	MOR China 2004/ 2007 CRH5/ 250 60/ 8/ na	€620mn na na na	First three sets manufactured at Alstom factory in Italy. Next 6 sets were delivered in complete knock down form and assembled by CNR Changchun Railway Vehicle. Remaining 51 sets built by CNR Changchun through technology transfer from Alstom.
Alstom/ None	Karelian Trains Ltd (Russia and Finland) 2007/2009-2010 Pendolino/ 220 4/na/352	€120mn na na na	An option for four future trains.
Alstom/ None	SNCF French 2007/ 2009-2014 Duplex TGV/ 320 55/ na/ na	$2.8bn na na na	Unable to get information.
Alstom/	NTV Italy	€650mn	Unable to get information.

None	2008/ na AGV/ 360 25/ 11/ 500	na 30 years maintenance contract (not included in the above amount) Na	Manufactured in Alstom Italy site
Alstom/ Isolux Corsan, Iecsa and Emepa	Argentine Railways 2008/ na double-decker TGV(Cobra)/ 250-300 8/ na/ 509	$3.7bn Alstom's share is $1.7bn na Compete with Siemens, and Spanish consortium (CAF, Obrascon Huarte Lain)	Alstom is responsible for technical studies, engineering design and construction of railway, and sourcing appropriate high speed rolling stock. High speed line is split into 2 sections. The first section will be a 250-300 line. Second section will be 160 diesel power.
Alstom/ CRCC(China) and Saudi Partners.	Saudi Arabia Govt. 2009/ na na/ na na/ na/ na	$18bn na na na	Alstom is in charge of phase I. Design and construction contract for Phase I Package 1 – Civil Works for the project was awarded in March 2009 to Al Rajhi Alliance. which comprises China Railway Construction Corporation (CRCC), Al Arrab Contracting Company Ltd, Al Suwailem Company and the French power and rolling stock company Alstom Transport. It is cooperating with the consultant Saudi Consolidated Engineering Company (Khatib & Alami - K&A). Scott Wilson Group will provide project management support.
Alstom/ None	ONCF Morocco 2010/ 2015 Double-decker/ 320 (the first 200km) 160-220 (others) 14/ 8/ 533	€400mn na na na	The 14 trainsets will be developed and built in France at Alstom Transport's La Rochelle workshops (pilot site) and its sites in Belfort (power cars), Le Creusot (Bogies), Ornans (engines) and Tarbes (traction drive), as well as Villeurbanne (electric control system), Charileroi in Belgium, Sesto in Italy and Montreal in Canada (on-board IT and passenger information). The trainsets' power cars and passenger cars will be delivered separately to the ONCF's Moghogha factory just north of Tangiers, where trainset assembly operations will be carried out. Technical tests will be carried out at the Moghogha site as well as ONCF network. The trains will run at 320 km/h and at 25 kV between Tangiers and Kenitra - the first 200 km section of Morocco's very high-speed network. Between Kenitra and Casablanca, the trainsets will run on the traditional network at speeds of 160 km/h or 220 km/h at 3 kV, depending on the running speeds set by the Moroccan operator in 2015.
Alstom/ Siemens	Eurostar French 2010/ na Velaro e320 /320 10/ na/ na	$1bn na na na	Unable to get information.
Alstom/ None	PKP Poland 2011/ 2014 na/ na 20/ na/ na	€665mn na 17 years maintenance and construction of new maintenance depot	Manufactured at Alstom site in Italy.

		na	
Alstom/ None	Iraq Govt. 2011/ na na / 250 na/ na/ na	Unable to get information.	Unable to get information.
Siemens/ Thyssen Transrapid and Transrapid international	SMTDC China 2001/ na Maglev/ 431 na/ na/ na	DM 1,293bn na na na	Trainset and tracks built by Siemens.
Siemens/ None	RENFE Spain 2001/ 2005 ICE3(Velaro E)/ 350 26/ na/ 405	€705mn na 14 years maintenance Compete with Alstom, Talgo-Adtranz	Unable to get information.
Siemens/ None	RENFE Spain 2004/ na ICE3(Velaro E)/ 350 10/8/404	na na na Compete with Alstom-CAF	Unable to get information.
Siemens/ CNR Tangshan	MOR China 2005/ na Velaro CN(CRH3)/ 300 60/ 8/ 601	RMB 1,3000mn Siemens' share is €669 mn na na na	TTA provisions require majority of components and sub-systems to be sourced in China by the end of the initial building.
Siemens/ None	Austrian Railways 2006/ na ICE trailer(Railjet)/ 230 23/ 7/ 469	€250-€300mn na na na	Railjet is the name of the high speed rail in Austria but it is based on the Siemens ICE model.
Siemens/ None	Russian Railway 2006/ na ICE3/ 250 8/ 10/ 600	€276mn na 30 years of service contract worth another €300mn Na	Development and construction is being carried out by Siemens at Erlangen and Krefeld in Germany.
Siemens/ None	Austrian Railways 2007/ na ICE trailer(Railjet)/ 230 44/ 7/ 469	Approx. €498-€548mn na na na	Unable to get information.

Siemens/ None	DB Germany 2008/ 2011-2012 ICE/ 320 15/ 8/ 485	€500mn na na na	Unable to get information.
Siemens/ CNR Tangshan, CNR Changchun Vehicle	MOR China 2009/ 2010 CRH/ 350 100/ na/ 1026	$5.7bn Siemens share is €750mn na na	In this contract, Siemens acts as a component supplier, with only 18% of the content actually made by the company. Siemens is in charge of technical assistance and the supply of electrical equipment and bogies for the new trains; Tangshan and Changchun Vehicle use the technology from the previous TTA and is currently assembling 300 km/h CHR3 Velaro trainsets under a technology transfer agreement with Siemens.
Siemens/ Alstom	Eurostar French 2010/ na Velaro e320 /320 10/ na/ na	$1bn na na na	Unable to get information.
Siemens/ Bombardier	DB Germany 2011/ 2013-2016 ICx/ 250 300/ 7(10)/ 499(724)	Total order value for the 220-train deal is approx. €6bn Bombardier's share is €1.3bn for the initial 130 trains and €3bn for the combined order for 220 na na	Bombardier will supply all of the bodyshells for the ICx fleet from its Görlitz plant, whilst the driving vehicles will be assembled at Hennigsdorf. Bombardier is also to supply Flexx Eco unpowered bogies for the trailer cars from its Siegen facility. DB also has an option to order another 80 sets 'at any time' during the validity of the framework contract, which runs to 2030.
Bombardier/ Alstom	Amtrak USA 1996/ 1999-2000 Acela Express/ 240 na/ na/ na	na Bombardier's share is 75% and Alstom 25% na Compete with Siemens (American ICE) and ABB (X2000)	The Acela Express was largely built in the US as stipulated in the Amtrak contract. Bombardier's plants in Barre, Vermont, and Plattsburgh, New York, performed much of the manufacturing. Alstom also furnished some components made in France. (The funding scheme for the project places very little burden on Amtrak.) Bombardier is financing the $611 million to purchase the trains (including additional electric locomotives) and part of three new maintenance facilities, as well as to operate and maintain the equipment for 20 years. Amtrak's ability to repay Bombardier will come from additional revenue that the Acela Express is expected to create in service, estimated by Amtrak at $200 million per year.
Bombardier/ Talgo	RENFE Spain 2001/ na Talgo/ 350 16/ na/ na	€339mn Bombardier's share is €138mn na na	Unable to get information.
Bombardier/ CSR Sifang (Bombardier Sifang Transportation)	MOR China 2004/ 2006-2007	$350mn Bombardier's share is $263mn	The trains, which can reach a maximum speed of 200 km/h, will be designed by Bombardier in Västerås, Sweden. Bombardier will manufacture the bogies in Siegen, Germany and will provide part of the

	CRH1A/ 200 20/ 8/ 670	na na	propulsion from its site in Västerås. The carbody production and final assembly will be undertaken in China under BSP's responsibility.
Bombardier/ CSR Sifang (Bombardier Sifang Transportation)	MOR China 2005/ 2006-2007 CRH1A/ 250 20/ 8/ na	$350mn Bombardier's share is $263mn na na	The trains will be designed by Bombardier in Västerås, Sweden. Bombardier will manufacture the bogies in Siegen, Germany and will provide part of the propulsion from its site in Västerås. The carbody production and final assembly will be undertaken in China under BSP's responsibility.
Bombardier/ Talgo	RENFE Spain 2005/ 2008-2010 AVE S-102/ 364 30/ na/ na	€655mn ($786mn) Bombardier's share is approximately €243mn ($290mn) In 2008, Bombardier Transportation, in consortium with Talgo, was awarded 14 years contract with RENFE, the Spanish National Rail Operator for the maintenance of 45 AVE S-130 high speed trains. Maintenance activities will be carried out until 2022 at RENFE's depots in Santa Catalina and Fuencarral, both in Madrid. Bombardier's share in this contract is about €128mn ($202 mn) na na	Bombardier will be responsible for manufacturing the running dynamics, the entire electric equipment of the powerhead including the proven and reliable MITRAC 3000 propulsion system with traction, auxiliary converter and drive system, and the very high-speed bogies. Bombardier will also carry out the final assembly and testing of its scope of work, while the production of the passenger coaches will be under Talgo's responsibility. The production of a large part of the propulsion system will be undertaken at Bombardier's plant in Trápaga (Spain). After the mechanical assembly at Talgo's workshop, the assembly of the powerheads will be completed at Bombardier's site in Kassel (Germany) and at RENFE's workshop in Málaga (Spain). The manufacture of the passenger coaches and the coupling of the complete trains will take place in Talgo's Las Matas plant and at RENFE's Malaga site.
Bombardier/ Talgo	RENFE Spain 2005/ 2007-2009 Talgo 250/ 250 18 high speed trains+10 power head/ na/ na	€338mn ($403mn) Bombardier's share of contract is €122mn ($145mn) na na	Bombardier's scope of supply will include the manufacture of the entire electrical equipment, the propulsion system, the train control and communication systems and an exhaustive signaling system. Bombardier will also participate in the final assembly and testing of the trains and the power heads. The production of a large part of the propulsion system will be undertaken at Bombardier's plant in Trápaga, Spain. Production of the mechanical components, including the variable-gauge bogies, will be under Talgo's responsibility.
Bombardier/ CSR Sifang (Bombardier Sifang Transportation)	MOR China 2007/ 2009-2010 EMU (CRH1B, CRH1E)/ 250 40/ 16/ na	€1bn ($1.5bn) Bombardier's share is €413mn ($596mn) na na	The new high-speed EMU trains will be manufactured at BSP production facilities in Qingdao, China. Bombardier MITRAC propulsion systems for the trains will be jointly produced by Bombardier CPC Propulsion System Co. Ltd., a Bombardier joint venture based in Changzhou, and Bombardier facilities in Europe. MITRAC propulsion systems are included in more than 23,000 rail vehicles worldwide.
Bombardier/ None	SJ AB Sweden 2008/ 2010 Bombardier Regina/ 210 20/ 4/ na	€221mn ($349mn) na na na	Project management and lead engineering will take place in Västerås, Sweden, where the Bombardier Mitrac propulsion system will also be designed and manufactured. In Germany the vehicles will be engineered and assembled at Bombardier Hennigsdorf site; the carbodies will be manufactured in Görlitz, and the bogies in Siegen.

			Contract includes option for 20 additional trains.
Bombardier/ CSR Sifang (Bombardier Sifang Transportation)	MOR China 2009/ 2012-2014 CRH380D/ 380 CRH380DL/ 380 20/ 8/ na 60/ 16/ na	RMB 27.4bn ($4.01bn) Bombardier's share is RMB 13.5bn na na	The Zefiro 380 trains will be manufactured at Bombardier Sifang Transportation production facilities in Qingdao, China. Engineering will take place in Qingdao and at Bombardier centers in Europe with project management and components provided from sites in Europe and China.
Bombardier/ CSR Sifang (Bombardier Sifang Transportation)	MOR China 2010/ 2010-2011 CRH1/ 250 40/ 8/ 604	RMB 5.2bn (€591mn, $761mn) Bombardier's share is RMB2.5bn (€289mn, $373mn) na na	Unable to get information.
Bombardier/ None	SBB Sweden 2010/ 2012-2019 Bombardier Twindex/ na 59/ na/ na	Swiss Fracs 1.8bn ($1.6bn or €1.3 bn) na na na	The Twindexx project will be managed from Zürich, while Villeneuve – the only rail production site in western Switzerland – will be responsible for producing the vehicles together with Görlitz. Görlitz is also taking the lead in the engineering process. The Winterthur site will design the bogies, while production will take place in Siegen, Germany. The Swedish site of Västeras will be responsible for the drive system with the super-efficient permanent magnet motors. Contract includes options for >100 additional Twindexx trains.
Bombardier/ AnsaldoBreda	Trenitalia Italy 2010/ 2013 Bombardier Zefiro (V300 Zefiro)/ 360 50/ na/ 600	€1.54bn ($2.1bn) Bombardier's share is €652mn ($889mn). €30.8mn for each train na Compete with Alstom's AGV and Pendolino, and CAF's Oaris	The work will be divided between Bombardier's Italian factory near Genoa, and Ansaldo's factory near Florence. Bombardier will have roughly 60 per cent of the work and will be responsible for the propulsion and electrical system. Ansaldo will be responsible for the train body and final assembly. Bombardier will ensure the control equipments and the propulsion system, while AnsaldoBreda the body and the final assembly at its facility in Pistoia.
Bombardier/ None	Västtrafik Sweden 2011/ 2013 Regina/ na 6/ 3/ na	$101mn na na na	The European rail traffic management system (ERTMS) will be developed and engineered by Bombardier in Stockholm, Sweden, and assembled at Bombardier's Hennigsdorf site in Germany. The car bodies will be produced in Görlitz, and the bogies in Siegen of Germany. The delivery of the trains is scheduled for 2013.
Bombardier/ Siemens	DB Germany 2011/ 2013-2016 ICx/ 250 300/ 7(10)/ 499(724)	Total order value for the 220-train deal is approx. €6bn Bombardier's share is €1.3bn for the initial 130 trains and €3bn for the combined order for 220 na na	Bombardier will supply all of the bodyshells for the ICx fleet from its Görlitz plant, whilst the driving vehicles will be assembled at Hennigsdorf. Bombardier is also to supply Flexx Eco unpowered bogies for the trailer cars from its Siegen facility. DB also has an option to order another 80 sets 'at any time' during the validity of the framework contract, which runs to 2030.
CAF/	RENFE Spain	€440mn	Alstom, as the consortium leader, will be responsible

Alstom	2001/ 2003 na/ 270 20/ na/ 237	na Includes maintenance of new fleet for 14 years Na	for providing the traction system and 50% of the mechanical equipment for these high-speed regional trains. The trains will be largely built in Alstom industrial units in Spain.
CAF/ Alstom	RENFE Spain 2004/ 2006-2009 Shuttle, Variable Gauge/ 250 30(shuttle)/ na/ na 45(variable gauge)/ na/ na	€1,777mn (Supply € 937mn) Alstom leads the consortium and total share of these contracts, including maintenance, is €1,027mn Alstom-CAF will provide maintenance services for 14 years. (Worth €840 mn) Na	Alstom Santa Perpetua plant and CAF's Beasain and Zaragoza plants will share the work of building body shells and assembling the trainsets. Alstom will lead the consortium for the supply and maintenance of 30 trains (shuttle) and its participation in the order is €476 million. It also participate in the mechanical construction, electric equipment supply and maintenance of the 45 variable gauge units, worth €551 million.
CAF/ None	TCDD Turkey 2005/ na TCDD HT65000/ 250 10/ 6/ na	€180mn na na na	Unable to get information.
CAF/ None	TCDD Turkey 2007/ na TCDD HT65000/ 250 2/ 6/ na	€37mn na na na	Unable to get information.
Talgo/ Bombardier	RENFE Spain 2001/ na Talgo/ 350 16/ na/ na	€339mn Bombardier's share is €138mn na na	Unable to get information.
Talgo/ Adtranz (Bombardier)	RENFE Spain 2001/ na Talgo/ 350/ 330 16/ na/ na	€ 660mn Split with Talgo, each in charge of building 16 trainsets na Compete with Siemens and Alstom	The trainsets consist of Talgo passenger cars modified in order to allow speeds of up to 350 km/h (220 mph) with power cars at each end which provided by the ADtranz (later Bombardier Transportation)
Talgo/ Bombardier	RENFE Spain 2005/ 2007-2009 Talgo 250/ 250 18 high speed trains+10 power head/ na/ na	€338mn ($403mn) Bombardier's share of contract is €122mn ($145mn) na na	Bombardier will provide manufacture of the entire electrical equipment, the propulsion system, the train control and communication systems and an exhaustive signaling system. Bombardier will also participate in the final assembly and testing of the trains and the power heads. The production of a large part of the propulsion system will be undertaken at Bombardier plant in Trápaga, Spain. Production of the mechanical components, including the variable-gauge bogies, will be under Talgo's responsibility.

Talgo/ Bombardier	RENFE Spain 2005/ 2008-2010 AVE S-102(Talgo 350)/ 364 30/ na/ na	€655mn ($786mn) Bombardier's share is approximately €243 mn ($290mn) na na	Bombardier will manufacture the running dynamics, the entire electric equipment of the powerhead including the proven and reliable MITRAC 3000 propulsion system with traction, auxiliary converter and drive system, and the very high-speed bogies. Bombardier will also carry out the final assembly and testing of its scope of work, while the production of the passenger coaches will be under Talgo's responsibility. The production of a large part of the propulsion system will be undertaken at Bombardier's plant in Trápaga (Spain). After the mechanical assembly at Talgo's workshop, the assembly of the powerheads will be completed at Bombardier's site in Kassel (Germany) and at RENFE's workshop in Málaga (Spain). The manufacture of the passenger coaches and the coupling of the complete trains will take place in Talgo's Las Matas plant and at RENFE's Malaga site.
Talgo/ Ingeteam	Uzbekistan Railways 2009/ 2011 Talgo 250/ 250 2/ 8/ 257	€40+ mn na Includes maintenance contract Na	Includes the supplying of the rolling stock and the equipment for maintenance.
Talgo/ RENFE, ADIF, OHL and eight other companies	Saudi Arabia Govt. 2011/ na Talgo 350/ na 33/ na/ na	€6.5mn($9.4 bn) na na Compete for more than a year with a French group made up of Alstom, and the French national operator SNCF.	Talgo in charge of phase II. Talgo would be responsible for supplying 33 trains similar to those used on Spanish high speed lines. Renfe and Adif would operate trains and manage the line for 12 years.
Talgo/ None	RZD Russia na/ na na/ 322 7/ na/ na	€100mn na na na	Unable to get information.
Hyundai Rotem/ Tüvasas	TCDD Turkey 2008/ 2011-2014 EMU/ na 440/ 5/na	€580mn na na Compete with Alstom, CAF, and a consortium of Bombardier, Siemens and Nurol (Turkish Co.)	Part of the railcar production will be carried out in the plant of Eurotem, Hyundai Rotem's Turkish joint venture.
Hyundai Rotem/ Tülomsas	TCDD Turkey 2010/ 2014 Electric Locomotive/ na 80/ na/ na	€330mn with Islamic Development Bank to provide $220mn TTA will see local content reach 35% na Compete with Bombardier,	Unable to get information.

		AnsaldoBreda, Chinese supplier, and Hyundai Rotem (the lowest bidder)	
Hyundai Rotem/ None	Ukrainian Railway 2010/ 2012 EMU/ 160 (Slower HSR) 10/ 9/ 579	$304mn na na Compete with Bombardier and Siemens	Unable to get information.
Kawasaki/ Nippon Sharyo, Hitachi	THSRC Taiwan 1999/ 2007 700 series Shinkansen (THSR 700T)/ 300 30/ na/ 989	$15bn (€11.5bn) na na Taiwan High Speed Rail Consortium (THSRC) competed with Chunghwa High Speed Rail Consortium (CHSRC). THSRC's bid was based on the high-speed technology platform of Eurotrain, a joint venture of GEC-Althom, the main manufacturer of the French TGV, and Siemens, the main maker of the German ICE. CHSRC's bid was based on Japanese Shinkansen technology supplied by Taiwan Shinkansen Consortium (TSC), a joint venture between several Japanese companies.	Unable to get information.
Kawasaki/ Nanche Sifang Locomotive	MOR China 2004/ 2006 E2-1000 Shinkansen (CRH2B)/ 200 60/ 8/ na	¥140bn Kawasaki's share will be ¥80mn na na	Kawasaki will make design changes and supply the first three finished trains and the following six as knocked-downs. The expected delivery of finished trains was February 2006. After that, Nache Sifang will build the remaining 51 trains in China by using the production technology transferred by Kawasaki.
CNR Changchun Railway/ Alstom	MOR China 2004/ 2007 CRH5/ 250 60/ 8/ na	€620mn na na na	The first three sets was manufactured by Alstom's factory in Italy, the next 6 sets were delivered in complete knock down form and assembled by CNR Changchun Railway Vehicle. The remaining 51 sets were built by CNR Changchun through technology transfer from Alstom.
CNR Tangshan/ Siemens	MOR China 2005/ na Velaro CN(CRH3)/ 300 60/ 8/ 601	RMB1,300mn na na na	TTA provisions require majority of components and subsystems to be sourced in China by the end of the initial building.
CSR Sifang/ Bombardier (Bombardier	MOR China 2004/ 2006-2007	$350mn Bombardier's share is	The trains will be designed by Bombardier in Västerås, Sweden. Bombardier will manufacture the bogies in Siegen, Germany and will provide part of

Sifang Transportation)	CRH1A/ 200 20/ 8/ 670	$263mn na na	the propulsion from its site in Västerås. The carbody production and final assembly will be undertaken in China under BSP's responsibility.
CSR Sifang/ Bombardier (Bombardier Sifang Transportation)	MOR China 2005/ 2006-2007 CRH1A/ 200 20/ 8/ na	$350mn Bombardier's share is $263mn na na	The trains will be designed by Bombardier in Västerås, Sweden. Bombardier will manufacture the bogies in Siegen, Germany and will provide part of the propulsion from its site in Västerås. The carbody production and final assembly will be undertaken in China under BSP's responsibility.
CSR Sifang/ Bombardier (Bombardier Sifang Transportation)	MOR China 2007/ 2009-2010 EMU(CRH1B,CRH1E)/ 250 40/ 16/ na	€1bn ($1.5bn) Bombardier's share is €413mn ($596mn) na na	The new high-speed EMU trains will be manufactured at BSP production facilities in Qingdao, China. BOMBARDIER MITRAC propulsion systems for the trains will be jointly produced by Bombardier CPC Propulsion System Co. Ltd., a Bombardier joint venture based in Changzhou, and Bombardier facilities in Europe. MITRAC propulsion systems are included in more than 23,000 rail vehicles worldwide.
CSR Sifang/ Bombardier (Bombardier Sifang Transportation)	MOR China 2009/ 2012-2014 CRH380D/ 380 CRH380DL /380 20/ 8/ na 60/ 16/ na	RMB 27.4bn ($4.01 bn) Bombardier's share is RMB 13.5bn na na	The ZEFIRO 380 trains will be manufactured at Bombardier Sifang Transportation production facilities in Qingdao, China. Engineering will take place in Qingdao and at Bombardier centers in Europe with project management and components provided from sites in Europe and China.
CSR Sifang/ Bombardier (Bombardier Sifang Transportation)	MOR China 2010/ 2010-2011 CRH1/ 250 40/ 8/ 604	RMB 5.2bn (€591mn, $761mn) Bombardier's share is RMB 2.5bn (€289mn, $373mn) na na	Unable to get information.
CRCC/ Alstom and Saudi Partners	Saudi Arabia Govt. 2009/ na na/ na na/ na/ na	$18bn na na na	Alstom in charge of phase I. Design and construction contract for Phase I Package 1 – Civil Works for the project was awarded in March 2009 to Al Rajhi Alliance which comprises China Railway Construction Corporation (CRCC), Al Arrab Contracting Company Ltd, Al Suwailem Company and the French power and rolling stock company Alstom Transport. It is cooperating with the consultant Saudi Consolidated Engineering Company (Khatib & Alami - K&A). Scott Wilson Group will provide project management support.
Nanche Sifang Locomotive/ Kawasaki	MOR China 2004/ 2006 E2-1000 Shinkansen (CRH2B)/ 200 60/ 8/ na	¥140bn Kawasaki's share ¥80mn na na	Kawasaki will make design changes and supply the first three finished trains and the following six as knocked-downs. The expected delivery of finished trains is February 2006. After that, Nache Sifang will build the remaining 51 trains in China by using the production technology transferred by Kawasaki.

APPENDIX B. PUBLIC-PRIVATE PARTNERSHIP MODELS

Models	Ownership	Responsibility and Payment	Types	Risks	Duration	Pros and cons
Management Contract	The public retains the ownership of facility and equipment	The private is provided specified responsibilities concerning a service. The private contractor is paid a fee which is performance based	-Supply or service contract -Maintenance management contract - Operational management contract	The private sector is generally not asked to assume commercial risks	Short period from two to five years. Longer when large and complex operation facilities.	May not offer enough incentive for efficiency improvement
Turnkey		The private contractor selected through a bidding process designs and builds a facility for a fixed fee, rate or total cost		The contractor assumes risks involved in the design and construction phases	Short-term contract	There is no strong incentive for early completion of a project
Affermage/Lease		An operator(the lease holder) is responsible for operating and maintaining the infrastructure facility and services, but generally the operator is not required to make any large investment. Under a lease the operator retains revenue collected from customers/users of the facility and makes a specified lease fee payment to the contracting authority. Under affermage, the operator and the authority share the revenue from customers/users.		The government maintains the responsibility for investment and thus bears investment risks. The operational risks are transferred to the operator.	15-30 years	The model is always applied in combination with other models. In such a case, the contract period is generally much longer and the private sector is required to make a significant level of investment.
Concessions	The government may retains the ultimate ownership of the facility and/ or right to supply services	The government defines and grants specific right to an entity (usually a private company) to build and operate a facility for a fixed period of time. The government may retain the ultimate ownership of the facility and/or right to supply service. In concessions, payments can take place both ways: concessionaire pays to government for the concession rights and the government may also pay the concessionaire, which it provides under the arrangement to meet certain specific conditions.	-Franchise -BOT type of contracts	Under Franchise, the private sector carries commercial risks and may be required to make investments. Under BOT, the private sector builds an add-on to an existing facility or completes a partially built facility and rehabilitates existing assets, then operates and maintains the facility at its own risks for the contract period	Range between 5 to 50 years	Usually, such payments by government may be necessary to make projects commercially viable and/or reduce the level of commercial risks taken by the private sectors, particularly in the initial year of a PPP programme in a country when the private sector may not have enough confidence in undertaking such a commercial venture.
Private ownership of assets	In some cases the public sector may relinquish the right of ownership of assets to the private	The private sector remains responsible for design, construction and operation of an infrastructure facility.	-Build-Own-Operate (BOO) -Private finance initiative (PFI)	PFI projects bear direct financial obligations to government in any event. In addition, explicit and implicit		As the same entity builds and operates the services, and is only paid for the successful supply of services at a pre-defined standard, it has no incentive to

	sector		-Divestiture	contingent liabilities may also arise due to loan guarantees provided to lenders and default of a public or private entity on non-guaranteed loans.		reduce the quality or quantity or the service. Compared with the traditional public sector procurement model, where design, construction and operation aspects are usually separated, this form of contractual agreement reduces the risks of cost overruns during the design and construction phase or of choosing an inefficient technology, since the operator's future earning depend on controlling costs. The public sector's main advantages lie in the relief from bearing the costs of design and construction, the transfer of certain risks to the private sector and the promise of better project design, construction and operation.

APPENDIX C. INTERNATIONAL HSR SUPPLY-CHAIN AND COMPONENTS

Examples of International Companies in Supply-Chain

Trainset

Major Trainset Suppliers
- Alstom (France)
- Siemens (Germany)
- Bombardier Transportation (Germany)
- CAF (Spain)
- Talgo (Spain)
- Hyundai Rotem (S.Korea)
- Kawasaki (Japan)
- CSR. (China)
- CNR (China)
- AnsaldoBreda (Italy)

Mechanical

M1: Bogies, Suspension, Wheels, Axles, Dampers
Bombardier Transportation (Germany)
Bonatrans (Czech Republic)
Siemens (Germany)
Firth Rixson Metals (UK)
Hutchinson Paulstra (France)
Kolowag (Bulgaria)
RVR (Latvia)
MTC (Spain)
RBC Bearings (France)
SKF Group (Sweden)
Tangshan Railway (China)
Contitech Railway (Germany)
Freudenberg Schwab (Germany)
Mediterr Shock Absorbers (Italy)
ITT/Koni Enidine (USA)
ORX Rail (USA)
Vossloh Rail Vehicles (Germany)
Talgo (Spain)
Yujin Machinery (Korea)
GHH-Valdunes (France, Germany)
ContiTech (Germany)

M2: Brakes, Coupler, Draw Gear, Connection Systems
Dellner Group (Sweden)
Knorr-Bremse (Germany)
MTZ Transmash (Russia)
Voith Turbo Scharfenberg (Germany)
Wabtec (USA)
Yujin Machinery (Korea)
Ningbo Ebong (China)

M3: Hydraulic and Related Systems
Eaton (USA)

Electronic

E1: Computer Hardware, Software, Control, Monitoring
EKE Electronics (Finland)
Esterel Technologie (France)
Kontron (Germany)
Leroy Automation (France)
Traintic, ITS (Spain)
ZTR (USA, Canada)
Henan Splendor Science & Technology (China)

E2: Signaling, Communications
Siemens Mobility (Germany)
Bombardier Transportation (Germany)
HollySys(China)
Ansaldo STS (Italy)
Alstom (France)
Eliop Seinalia ,CAF group(Spain)
Vossloh Cogifer (Germany)
Wabtec (USA)
HeNan Splendor Science & Technology (China)
Thales Group (France)
Invensys Rail Group(UK)
Nippon Signal Co. LTD. (Japan)

E3: Controls, Electromechanical Equipment, Drives
Alstom (France)
Eliop Seinalia, CAF group (Spain)
AQ Wiring System (Sweden)
ZF Friedrichshafen (Germany)
Wabtec (USA)
SKF Group (Sweden)

E4: Operation Control, Passenger Information Display, Entertainment
Alstom (France)
Hitachi Transport System (Japan)
Telefunken Racoms (Germany)
Nomad Digital (UK)

Locomotive and Power

L1: Locomotives and Related
Alstom (France)
Siemens (Germany)
Bombardier Transportation (Germany)
Kawasaki (Japan)
Hyundai Rotem (S. Korea)
CNR (China)
CSR (China)
Talgo (Spain)
CAF (Spain)
EMD (USA)
Caterpillar (USA)
Wabtec (USA)
GE (USA)

L2: Electrification, Traction, Power Supply
ABB (Switzerland)
Alstom (France)
SKF Group (Sweden)
BombardierTransportation (Germany)
AEG Power Solutions (Germany)
Schneider Electric (Germany)
GINO (Germany)
Ingeteam Traction (Spain)
EMD (USA)
Eaton (USA)

Passenger Cart

P1: Gangway System
Hubner (Germany)
Hutchinson Paulstra (France)

P2: HVAC, Cooling Systems, Compressors
Merak (Spain)
Noske-Kaeser (Germany)

P3: Passenger Coaches
Alstom (France)
Bombardier Transportation (Germany)
Isoflex (Sweden)
Kawasaki (Japan)
RVR (Latvia)

P4: Galley, Buffet Car, Restaurant Equipment
Kugel Edelstahlverarbeitung (Germany)

P5: Door System, Locks, Lighting, External Components
Pickersgill-Kaye (UK)
Traslec (UK)
Yujin Machinery (Korea)

P6: Fire Safety, Detection, Suppression
Consilium (Sweden)

P.7: Toilet Equipment
Satek (Germany)

Other Categories

O.1: Interior Design
Pininfarina (Italy)
Priestmangoode (UK)
Bombardier Transportation (Germany)
Alstom(France)
Siemens (Germany)

O.2: Rail Station Mobility Systems
Thyssenkrupp (Germany)

O.3: Aftermarket Services
EMD (USA)
Vossloh Rail Services (Germany)

O.4: Infrastructure & Planning Services
Alstom (France)
Vossloh Fastening Systems (Germany)
Eiffage (France)
URS Corporation (USA)

O.5: Concrete and related Product
China ACM (China)

Notes (to supply-chain diagram):

1. The diagram includes URLs for the underlying companies supplying the components. These were current when the diagram was configured. It is possible that for some of the companies the current URLs are different. Further, there are many M&As in this industry and some company names may have changed since the diagram was configured.