University Transportation Research Center - Region 2

Final Report

Foreign Involvement in U.S. High Speed Rail Projects: Risks, Problems, Opportunities

Performing Organization: The City University of New York (CUNY)

July 2018

Sponsor:
University Transportation Research Center - Region 2

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The Region 2 University Transportation Research Center (UTRC) is one of ten original University Transportation Centers established in 1987 by the U.S. Congress. These Centers were established with the recognition that transportation plays a key role in the nation's economy and the quality of life of its citizens. University faculty members provide a critical link in resolving our national and regional transportation problems while training the professionals who address our transportation systems and their customers on a daily basis.

The UTRC was established in order to support research, education and the transfer of technology in the field of transportation. The theme of the Center is "Planning and Managing Regional Transportation Systems in a Changing World." Presently, under the direction of Dr. Camille Kamga, the UTRC represents USDOT Region II, including New York, New Jersey, Puerto Rico and the U.S. Virgin Islands. Functioning as a consortium of twelve major Universities throughout the region, UTRC is located at the CUNY Institute for Transportation Systems at The City College of New York, the lead institution of the consortium. The Center, through its consortium, an Agency-Industry Council and its Director and Staff, supports research, education, and technology transfer under its theme. UTRC's three main goals are:

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The research program objectives are (1) to develop a theme based transportation research program that is responsive to the needs of regional transportation organizations and stakeholders, and (2) to conduct that program in cooperation with the partners. The program includes both studies that are identified with research partners of projects targeted to the theme, and targeted, short-term projects. The program develops competitive proposals, which are evaluated to insure the mostresponsive UTRC team conducts the work. The research program is responsive to the UTRC theme: "Planning and Managing Regional Transportation Systems in a Changing World." The complex transportation system of transit and infrastructure, and the rapidly changing environment impacts the nation's largest city and metropolitan area. The New York/New Jersey Metropolitan has over 19 million people, 600,000 businesses and 9 million workers. The Region's intermodal and multimodal systems must serve all customers and stakeholders within the region and globally.Under the current grant, the new research projects and the ongoing research projects concentrate the program efforts on the categories of Transportation Systems Performance and Information Infrastructure to provide needed services to the New Jersey Department of Transportation, New York City Department of Transportation, New York Metropolitan Transportation Council , New York State Department of Transportation, and the New York State Energy and Research Development Authorityand others, all while enhancing the center's theme.

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Principal Investigator(s):
James K. Cohen, Ph.D.
Associate Professor
John Jay College of Criminal Justice
524 West 59th. Street
New York, NY, 10019
Tel: (212) 237-8094
Email: jcohen@jay.cuny.edu

Performing Organization(s):
The City University of New York (CUNY)

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University Transportation Research Center (UTRC)

To request a hard copy of our final reports, please send us an email at utrc@utrc2.org

Mailing Address:

University Transportation Reserch Center
The City College of New York
Marshak Hall, Suite 910
160 Convent Avenue
New York, NY 10031
Tel: 212-650-8051
Fax: 212-650-8374
Web: www.utrc2.org

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Patricio Vicuna*: Research Assistant*
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16. Abstract

In the early 1980's, promoters who wanted to build new, very high speed, rail lines in states such as California, Florida, and Texas, were obliged to rely on foreign rail technology and expertise. This research Report explains how, when, and why that dependence developed, and assesses the problems associated with importing foreign technology. The research disputes the oversimplified notion that the decline of American passenger railroads in the 1950's and 1960's led directly to reliance on Japanese, French, and other foreign technology. In fact, starting in the 1930's, American railroads and manufacturers were leading innovators in high speed technology, and Japan's *Bullet Train,* which startled the world when launched in 1964, was based, in significant measure, on U.S. technology. Furthermore, as late as the mid-1970's, the U.S. rail and aerospace sector was capable of developing very high speed, steel-wheeled trains and frictionless ground transport. Soon thereafter, however, the federal government withdrew support for research and development of new high speed technology. This, combined with the broader decline of the passenger rail market, caused American manufacturers to withdraw from that business sector. Thus, promoters of very high speed projects in the U.S. became dependent on foreign technology. They discovered, however, that transfer of technology from abroad was not a simple process, needing to overcome obstacles such as Tier 3 safety requirements and organizational protectiveness with regard to patents and licenses. This Report identifies the main problems associated with technology transfer, and in so doing also shows that further research is needed on how the U.S. might reclaim its historic status as a leading innovator in high speed ground transport.

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FOREIGN INVOLVEMENT IN U.S. HIGH SPEED RAIL PROJECTS: RISKS, PROBLEMS,OPPORTUNITIES

INTRODUCTION

In the autumn of 1964, less than 20 years after World War 2 had destroyed most of that nation's rail infrastructure, Japan National Railways startled the world by introducing very high speed *Bullet Trains*, which ran at maximum speed of over 150 miles per hour, and average speed of 98.5 mph, a world record for passenger railroads.[1] Soon thereafter, French, German, Spanish, and Italian National Railway Companies moved to emulate Japan, as did promoters of very high speed rail in the United States who, starting in the early-1980's, proposed building high speed lines in California, Florida, Texas, and other States. However, because the U.S. lacked high speed train manufacturing capability at this time, promoters planned to import either Japanese, French, or other foreign technology and expertise. This reliance on foreign technology is surprising, since the U.S. was the world's leading innovator of train technology as recently as the 1930's, and maintained an advanced, technological capability through the mid-1970's. Why, then, were American promoters obliged to rely on foreign technology starting in the 1980's? And did that dependence cause problems?

This Report describes the results of a 15 month study on the history and consequences of America's dependence on foreign rail technology. The study focuses primarily on Japan because it was the first nation in the world to implement a very high speed rail line; because the Japanese case typifies problems caused by reliance on any foreign technology; and because American rail

[1] "Very high speed" trains run at greater than 150 miles per hour, usually, though not necessarily, on grade separated, dedicated infrastructure and track.

promoters continue, at present, to rely on both Japanese and other foreign technology and expertise.[2]

Most studies of high speed assert that the U.S. became dependent on foreign technology as a result of the long term decline of American passenger railways, which began in the 1920's and, except for a brief period in the 1930's and 40's, proceeded more or less unabated into the 1950's as intercity travelers chose cars, buses, and airplanes instead of trains. By the late 1950's and early 1960's, barely 20 percent of intercity passenger miles of travel was by train, and that percentage each year. As a result, railroads began withdrawing from passenger service as quickly as regulatory agencies allowed,[i] leading, in 1970, to nationalization of passenger service under the auspices of Amtrak.[ii] According to this interpretation, American dependence on foreign rail technology, in the 1980's and beyond, is a direct result of the earlier decline of U.S. passenger railroads. The research reported here suggests that this is an oversimplification, showing instead that American railroads and rail manufacturers were leaders in the development of high speed train technology from the 1930's to the 1970's, and that Japan relied on American innovations in developing its own very high speed technology in the 1950's and 1960's. Furthermore, even after American railroads began abandoning passenger lines in the late 1950's, the U.S. government, in cooperation with the Pennsylvania Railroad and other rail manufacturers, carried out significant initiatives to develop very high speed trains, including *Metroliners*, *Turbotrains*, and frictionless ground transport, such as tracked air cushion and magnetically levitated (maglev) vehicles. A major finding of this study is that, as of the early to mid-1970's, the U.S. had as much capability for developing its own very high speed rail lines as did Japan and France. Thus, reliance on foreign technology in the 1980's was not pre-ordained, but resulted instead primarily from the withdrawal of federal support for high speed research and development in the mid-1970's, which undermined public-private partnerships with U.S. rail companies that were producing promising high speed technologies with commercial potential.

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[2] Some information specifically about France is also included in the Report for reasons that will soon become apparent. In general, American promoters relied more on Japanese and French railway manufacturing firms and operating companies than those of other nations, such as Sweden and Germany.

TECHNOLOGY, TECHNOLOGY TRANSFER, AND FOREIGN INVOLVEMENT

In everyday discourse, people tend to think of technology in its concrete form, as a functional product, such as a cellphone or driver-less vehicle. But, technology is rarely a single product, mechanism, or process. Instead, it is usually a complex, inter-related combination of processes and products, which develop based on advances in both scientific knowledge and the ability to transform that knowledge into something concrete, an actual product.[iii] Thus, high speed trains are a complex agglomeration of thousands of mechanisms, components, parts, and techniques that are contained in the final product, a train.

Innovation drive technological change and development.[iv] A large number of innovations contributed to the development of high speed ground transport technology. Many of those innovations were originally developed within the American railroad industry, which for many decades was the leader in high speed rail science and technological development.

Once developed, new ideas, processes, and products tend to diffuse within and between firms, corporations, public entities, and ultimately across national borders, in a process called "technology transfer." America's reliance on Japanese and French very high speed rail technology, which started in the 1980's, is just a recent manifestation of a much longer process of technology transfer that began in the 1930's, and one that proceeded in both directions—back and forth between the U.S. and foreign countries.

U.S. HIGH SPEED RAIL INNOVATIONS, 1930-1960

Originally developed in Britain in the 1820's, steam locomotive technology quickly spread throughout the world. Some passenger trains in the 19th century were powerful enough to move at over 100 mph, which was considered high speed at that time, but mostly they ran at lower maximum speed, and much lower average speed, because the rolling stock was extremely heavy. Then, in the 1920's, diesel power started to replace steam, and when combined with lightweight railcars, this new technology allowed trains to run for long periods at top speeds of over 100 mph, with average speeds in excess of 60 mph.[v] The leading innovator in high speed diesel train technology was the Budd Company. Founded in 1912 by Edward G. Budd, it specialized in metal fabrication for the auto, rail, and airline industry.[vi] In the 1920's, the Chicago, Burlington and Quincy Railroad (CBQRR) asked Budd to manufacture a railcar body lighter than the wood and steel car bodies prevalent on most railroads up to that time. "(Budd) was intrigued by a new type of alloy steel (that was)…18 percent chromium and 8 percent nickel…(It) was three times stronger than regular carbon steel, yet…could be pressed into…graceful shapes."[vii] It was also stainless and did not rust. Budd Company invented a new technique, called shotwelding, that joined pieces of 18-8 stainless steel into an integrated railcar body, "without damaging its anti-corrosion properties."[viii] The Electro-Motive Company, a division of General Motors, saved additional weight through another important innovation, the 2-stroke diesel engine, which was significantly lighter than its 4-stroke predecessor.[ix] The joining of lightweight railcars and 2-stroke diesel engines allowed for the manufacture of trains which could run at faster commercial speed than their predecessors.[3]

Other American high speed innovations followed. One of the most important was the strain gauge, invented by Edward Simmons and Arthur Ruge late in the 1930's,[x] which maintained the correct dynamic properties of the rails on which high speed trains operated. With built-in sensors, strain gauges are placed on the top, bottom, and sides of rails to measure different forces. The train goes over the rails and triggers the sensors. The data is measured and appropriate action is taken to fix the rails if needed.[xi] Since imperfections and misalignments on rails can cause serious accidents when trains are running at high speed, strain gauges were an extremely important innovation.

Building on these innovations, the CBQRR added a modernistic, streamlined design to its new train, called the *Zephyr.* Running at high speed on the line between Kansas City, Missouri, and Lincoln, Nebraska, the *Zephyr* was instantly successful, and led many other American railroads, including the New York Central, Santa Fe, Reading, and Rock Island Line, to invest in manufacturing their own lightweight, streamlined trains. "By 1939…the ten fastest passenger trains in the world were U.S. *streamliners*."[xii] Large numbers of riders flocked to these innovative trains, and it appeared possible that they could halt the decline of American passenger

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[3] Commercial speed means the average train speed between two cities, including time lost for station stops.

railways. After a hiatus during the war years, when relatively slow transport of high volumes of war munitions, cargo, and troops took precedence over high speed passenger trains. American railroads They renewed their infrastructure and rolling stock, and in conjunction with manufacturers such as Electro-Motive Corporation (EMC), Baldwin-Lima-Hamilton, and American Car and Foundry (ACF), developed new *streamliners.*[xiii] The most prominent were the *Aerotrain*, *Xplorer*, and *Talgo.*[4] But, this did stop intercity travelers from increasingly choosing highway and air transport over rail in the decade after the end of World War 2.[xiv] As a result, rail passenger revenues declined steeply and, later in the 1950's, rail corporations began withdrawing trains from passenger service.[xv] By the early 1960's passenger rail service in the U.S. had diminished to a point that its very survival as a mode of intercity transport seemed in peril.

U.S. – JAPAN TECHNOLOGY TRANSFER[5]

At the same time as American passenger rail was declining, Japan was renewing their rail system and laying the technological foundation for very high speed trains. After World War 2 ended, Japanese military personnel, including aeronautical engineers who designed advanced aircraft, found jobs in the rail industry, and immediately began innovating changes in rail car design and locomotion. For example, they developed secondary air suspension for a railcar chassis, first tested in 1950,[xvi] and improved traffic control systems, such as Automatic Traffic Control (ATC), a type of autopilot used to ensure maximum running speed.[xvii] Other important Japanese technological advances in the 1950s included continuously welded track, which reduced the number of joints, allowing for smoother and safer travel at high speeds; and concrete support structures, such as sleepers, viaducts, and "slab track," which improved stability. Perhaps most

[4] While the first two of these were withdrawn from high speed service after less than two years of troubled operations, the *Talgo*, developed for the Spanish National Railway Company, went on to long and illustrious intercity service. See: "ACF's 1949 Talgo Train," in *http://streamlinermemories.info*

[5] Parts of this section are based upon the research of Steven Pieragastini, Research Assistant on this Project from May through December, 2017.

importantly, Japan fully electrified their rail infrastructure, a critical step pre-requisite for running very high speed trains.

In 1955, the Japanese National Railway Company (JNR) hired Shinji Sogo as its President. Sogo's main priority was to introduce very high speed trains on the Shinkansen line between Tokyo and Osaka. While most accounts of the development of this line emphasize the indigenous nature of Japan's technology, Japan also relied significantly on foreign technology, particularly from the U.S. For example, the Budd Company entered into licensing agreements with Tokyu Car Company to construct the first stainless steel cars in Japan in 1962 (for the Tokyo Electric Express Railway) and later contributed cars for the Shinkansen, in 1967.[xviii] Most likely, Japanese engineers learned the advantages of lightweight, shotwelded, stainless steel technology from Budd. In addition, JNR imported American-made Bendix computers to manage traffic on the Shinkansen line.[xix] And the concept of building track dedicated solely to very high speed trains, which allowed for safe operations with very short headways, was derived ultimately from American practices.[6] Finally, Japan imported American strain gauge technology and utilized it, with modifications, on the Shinkansen line.[xx] In brief, Japanese National Railways was able to build and operate very high speed *Bullet Trains* by combining American innovations with indigenous technology. First introduced in October, 1964, *Bullet Trains* ran at 140 mph maximum speed, but soon thereafter increased to over 150 mph, or very high speed, a world record for a commercial passenger train.[xxi]

1965-1975: A WATERSHED PERIOD FOR U.S. VERY HIGH SPEED TECHNOLOGY

While many studies assert that *Bullet Train* technology left the rest of the world far behind, the research reported here concludes otherwise. In the U.S., even as passenger rail services deteriorated in the late 1950's and 1960's, American manufacturers, such as the Budd Company, Pullman-Standard, Westinghouse, General Electric, St. Louis Car Company, and EMC, continued to innovate. They learned from and adapted Japanese technology to fit their needs, just

[6] Headway is the amount of time separating two trains. Shorter headways provide greater capacity on a line; that is to say, more trains per hour or day.

as Japan had adopted American innovations in the 1930's, 40's and 50's. Thus, technology transfer between the U.S. and Japan moved in both directions during these decades. For example, Budd's contract with Tokyu Car Company, described in previous section, allowed engineers and managers to learn about Shinkansen high speed technology,[xxii] some of which was adapted to the American rail market. Similarly, in 1961, the World Bank loaned Japanese National Railways $80 million to support development of the Shinkansen line.[xxiii] In assessing whether to make the loan, American rail professionals visited Japan in 1960 to familiarize themselves with Japanese high speed technology.[xxiv] As a result of these cross-national interchanges, as of the early-to-mid 1960's the U.S. rail industry possessed the scientific knowledge needed to develop their own very high speed technology.

Although private railroads began phasing out their passenger services in the late 1950's and early 1960's, a paradox of American rail history is that the federal government was, at the same time, taking steps to develop high speed train technology. Senator Claiborne Pell led efforts to introduce high speed trains on the Northeast Corridor between Boston, New York, and Washington, D.C. Largely as a result of his efforts, Congress passed and President Lyndon Johnson signed, in 1965, the High Speed Ground Transportation Act (HSGTA), legislation that provided funds to support "research and development in high-speed ground transportation, including but not limited to components such as materials, aerodynamics, vehicle propulsion, vehicle control, communications, and guideways."[7] A new Office of High Speed Ground Transportation (OHSGT) was established within the Department of Commerce (DOC), and $90 million, the equivalent of almost $500 million in year 2000 dollars, was authorized for the first two years.[xxv] Very soon thereafter, DOC asked the Budd Company to build high speed rail test vehicles, and contracted with three U.S. manufacturers to build 50 vehicles called *Metroliners,* trains they hoped would be able to operate at very high speed on the Northeast Corridor. Budd won the contract to build the railcars, beating out Pullman-Standard and the St. Louis Car Company, while General Electric and Westinghouse were chosen to develop the electric propulsion systems and equipment.[xxvi]

[7] Public Law 89-220, 79 Stat 893.

OHSGT's initial objective was to develop very high speed trains that could run on existing Pennsylvania Railroad (PRR) track, not on dedicated right of way, as was the case with the Shinkansen line. Track between New York City and Washington, D.C. was already electrified, which was ideal for very high speed. In addition, the PRR had upgraded "almost the entire route with 295 track-miles of welded rail;...another 310 miles of exiting track was smoothed out;...(and) heavier catenary wire…was…extended to nearly the entire length of the route."[xxvii] However, the line between New York and Boston was not electrified, so on that segment OHSGT and United Aircraft Corporation developed new technology, with gas turbine powered locomotives, called *Turbotrains*, which were also based partly on designs from the *Talgo* streamlined trains developed in the 1950's. In November of 1967, two Budd *Metroliner* cars tested at 164 mph—very high speed—on the New York to D.C. electrified track. A few weeks later a *Turbotrain* hit 171 mph on the Boston-New York route, still a world speed record for gas turbine powered trains.[xxviii] OHSGT and the PRR proved they could develop train technology that could run at very high speed.

However, technical and financial problems soon developed. The former mostly involved electrical systems on the cars, which delayed implementation of the new service.[xxix] The latter problem was that, even though *Metroliners* were very popular, and gained high levels of ridership,[xxx] the PRR was hemorrhaging money outside the Northeast Corridor. The New York Central Railroad, one of PRR's main competitors in the Northeast and Midwest, faced similar problems, which led the two companies to merge, creating the Penn Central Railroad. But, that merger failed after just over two years, and the Penn Central filed for bankruptcy in June, 1970.[xxxi] Only six years after it made a significant commitment to developing very high speed rail, the PRR (now Penn Central) was bankrupt.[8]

Soon thereafter, President Nixon signed legislation essentially nationalizing passenger rail services under the control of Amtrak, and ceded private railroads the more profitable freight sector.[9] While Penn Central continued to operate *Metroliner* service through a contract with

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[8] As a result, payments to Budd for producing *Metroliner* cars stopped, at least temporarily.

[9] The Rail Passenger Services Act of 1970 (P.L. 91-518, 84 Stat. 1327). In the enabling legislation, the National Railroad Passenger Corporation, or Amtrak, was created as a for-profit entity. However, de facto, it relies largely on public subsidies for its capital and operating budget, and only generates operating profits on the Northeast Corridor services; and even that line relies on government funding for its capital budget.

Amtrak, development of very high speed technology was no longer a priority. Parts of the Northeast Corridor, which had been upgraded in the late 1960's "(were allowed) to deteriorate because of deferred maintenance,"[xxxii] which effectively precluded operations at very high speed. These setbacks notwithstanding, the importance of OHSGT's partnerships with the PRR and United Technologies was to establish the technological foundation for future very high speed trains on the Northeast Corridor. Amtrak's *Acela* trains, which run at top speed of 150 mph for brief periods, are in fact the only very high speed trains in commercial operation in the U.S. at present.

In addition to steel-wheeled rail technology, OHSGT also supported development of frictionless ground transport. For this, they relied initially on the work of a French aeronautical engineer named Jean Bertin. In 1965, Bertin was in the early stages of designing a tracked air cushion vehicle, called the *Aerotrain* (not to be confused with the GM *Aerotrain* of the 1950's).[xxxiii] OHSGT invited Bertin to participate on an American rail advisory panel, and Department of Transportation (DOT) officials[10] travelled to France to look into developments at Bertin's test facility.[xxxiv] Following these investigations, OHSGT contracted with Grumman, a leading American aerospace-transport corporation, to "extend the technological level achieved (by Bertin) in France."[xxxv] Meanwhile, Bertin "negotiated a joint venture with Rohr Industries, (another American aerospace company),.. (which was) looking to diversify into land-based transport, to develop a commercially viable version of the *Aerotrain*."[xxxvi] OHSGT also explored linear induction propulsion technology for tracked air cushion vehicles; as well as magnetic levitation technology, another type of frictionless ground transport that both German and Japanese government agencies, rail operators, and manufacturers were experimenting with at this time, and which was originally developed by two Americans, Gordon Danby and James Powell.[xxxvii]

In sum, for a period of 10 years after President Johnson signed the High Speed Ground Transportation Act, from 1965 to 1975, the federal government and a number of private rail and aerospace/transport corporations, such as the Pennsylvania Railroad, Budd Company, General Electric, Westinghouse, Rohr Corporation, and Grumman Aerospace/Transport, worked to

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[10] OHSGT moved from the Department of Commerce to DOT in 1967.

develop new technology for very high speed ground transportation. This included steel wheeled technology, such as *Metroliners* and *Turbotrains*; tracked air cushion vehicles, such as the *Aerotrain*; and magnetic levitation technology. The federal government and private corporations exchanged technical knowledge and expertise, and entered into contractual agreements with foreign rail corporations, such as Bertin and Company, to develop tracked air cushion vehicles. Though Bertin was the original inventor of tracked air cushion technology, American companies were equal partners in these arrangements and were not technologically dependent on foreign companies. In other words, as of the early to mid-1970's, it seemed entirely possible that one or more American companies might be able to achieve commercial operation of high speed ground transport technology in the U.S.

PROBLEMS CAUSED BY FOREIGN INVOLVEMENT IN U.S. HIGH SPEED RAIL

In the late 1970's and early 1980's, the outlook for very high speed rail in the U.S. was partly discouraging, partly hopeful. On the downside, in the early 1970's Congress began cutting funds for OHSGT research and development projects. Then, in 1975, the High Speed Ground Transportation Act was not renewed. For the better part of 10 years, federal funds had been a major incentive to private rail and aerospace corporations to innovate very high speed ground transportation technology. After federal support ended, most attempts to develop alternative forms of very high speed ground transport collapsed. Compounding the problem, rail manufacturing companies shut down their rail manufacturing divisions, unless they had customers in the freight rail sector. The Budd Company was sold to Thyssen Industries, a German company, in 1981; and Pullman Standard was sold to Bombardier, a Canadian company, in 1987. General Electric continued to manufacture passenger locomotives for Amtrak, but not high speed equipment. These changes meant that American manufacturers could not be relied upon to provide technology for new, very high speed projects.

On the other side of the ledger, promising events taking place abroad emboldened promoters of very high speed rail in the U.S. Japan's *Bullet Train* was thriving, running at full capacity in both number of trains and passenger loads, thereby generating high revenues. The French National Railway Company, SNCF, launched its equally successful *TGV* (*Train à grande vitesse;* very high speed train) in 1981, and other European, Scandanavian, and Asian nations were planning high speed projects. American promoters included Amtrak, which together with Japan Central Railways and other interested private organizations, proposed to build a dedicated, very high speed line from Los Angeles to San Diego in the early 1980's,[xxxviii] and continued to push for faster versions of the *Metroliner* on the NEC.[xxxix] Other proponents of very high speed rail included officials in State transportation agencies; engineering and construction firms, such as Skanska, Parsons Brinckerhoff, Fluor, Bechtel, and Oldebrecht; high speed rail experts, academics, advocates, and planners, most of whom were members of the newly developed High Speed Ground Transportation Association, or the venerable Transportation Research Board; and investment banks and other financial firms, such as First Boston and Merrill Lynch, and some foreign banks. All of these companies, agencies, and corporate groups wanted to promote high speed rail because the as yet untapped American market held the promise of large profits. Thus, starting in the early 1980's, organizations joined together in consortia that competed to win franchises to implement very high speed rail lines in various states. The research for this Report focused on consortia plans in California, Florida, and Texas, where the earliest and most long lasting initiatives occurred. Also, Texas and California currently have high speed projects in active development, while Florida East Coast Industries and its subsidiary, All Aboard Florida, is planning to operate moderately high speed trains between Miami and Orlando.[xl]

The consortia that formed to promote high speed rail in the U.S. were obliged to rely on foreign rail technology and expertise because of the recent collapse of U.S. passenger rail manufacturing capabilities. Although reliance upon, and transfer of foreign technology "may seem to involve nothing more complicated than the invention and commercialization of a useful technical device, (its sale)…to a second locale, and the use and absorption of that device in the second locale,"[xli] in fact the process is usually quite complex. Partly, this is because most technology, such as in high speed rail line, is multifaceted, involving rail track dynamics, propulsion systems, railcar construction, and much more, so all these components must be factored into the negotiated transfer. Partly also the processes of both transmission and reception-absorption of technology confront complex trade rules, regulatory requirements, and laws in recipient nations concerning foreign investment and intellectual property. Thus, technology transfers also bring geo-political considerations into play.[xlii] Finally, social and cultural differences between supplier and recipient nation can affect the success or failure of foreign participation in local projects.[xliii] In short, the process of transferring foreign technology can be complex and fraught with difficulty.

This raises the question: was foreign involvement helpful, or a hindrance to high speed rail projects? One of the main objectives of this study was to identify and describe the positive and negative aspects of foreign participation in American rail consortia. To accomplish this, both U.S. and foreign participants were interviewed about their experience. Interviewees included representatives of public agencies; public and private rail operators; rail manufacturers; engineering and construction companies; investment and finance companies; labor unions; and research and development institutes. Preliminary interviews took place before this project was approved for funding, and were used to develop the Project proposal. Then, during the course of the Project's 15 months of funding, the main interviews were conducted.

Appendix A lists interviewee names and their companies. Since anonymity was promised to interviewees, results are provided generically, without attribution to specifically identified persons. Transcriptions and/or notes from interviews were analyzed in the context of the history of innovation in high speed technology in the U.S rail industry, and of the nature of the technology transfer process.

Here, then, are the most salient findings from interviews. First, with regard to social and cultural factors, neither Japanese, nor French or U.S. officials indicated that they experienced difficulties working with each other due to differences in social and cultural backgrounds, norms, or language. One foreign official explained that, with their common western heritage, "stronger cultural connections exist between American and European companies than between American and Japanese companies..." but that Japanese representatives to rail consortia in Florida and California had "worked successfully to change that."[11] A French official stated that he worked "without any difficulty" with his American colleagues in Florida and Texas. "We were on the same page." Cultural differences, therefore, did not interfere with foreign involvement and technology transfer.

[11] This and all subsequent quotations are drawn from interview notes and/or transcriptions of interviews conducted by the Principal Investigator between December, 2015, and December, 2017.

Second, Japanese and French officials from rail manufacturers, operating companies, engineering-construction companies, and financial firms—all indicated that they were interested in transferring technology to the U.S. because it represented a potentially huge, new market for their products, services, and expertise. They recognized that both declining population and slow economic growth in their home countries was, as one official stated, “limiting domestic demand, so we are looking increasingly to the burgeoning global (high speed rail) market.” In addition, national governments supported their efforts because exporting technology “increased national pride and prestige.” Foreign corporations, in other words, were strongly motivated to transfer their rail technology to the United States, and their governments usually supported these efforts.

Third, some foreign companies tried to avoid legal and regulatory impediments to technology transfer by purchasing ownership of U.S. rail companies. According to one interviewee, French companies “purchased small North American companies to give them inroads into the American market.” He added that “our problems were not with whether we could sell our products (in the United States), but with how to beat out our competitors (from Spain, China, and Japan).” In this sense, transfer of technology did not confront significant American regulatory or legal problems. But, that does not tell the full story. Another interviewee indicated that the French National Railway Company, SNCF, wanted to “maintain control of its patents as proprietary technology,” and that that could have become a problem if the Americans had wanted to take over and/or license those patents. In other words, transferring high speed technology required the donor and recipient of the technology to agree, first, on which party would control the technical information and/or products; and, second, on whether or not the information and products would be licensed to the recipient organization, with recipient access to underlying technical processes and recipient ability to use the foreign technology to develop American refinements. Since implementation of high speed rail technology transfer never moved to an operational stage, foreign and American companies have yet to test whether issues involving control of technology can be worked out.

Fourth, one financial advisor to projects in Florida and Texas indicated that Japanese rail operators were less willing than their American counterparts to accept ridership and associated revenue projections, if those indicated that the projects might not be able to cover debt service expenses. He added, however, that the Japanese “were very rigorous about ridership-revenue studies," and had no choice but to either accept the data we showed them, or to commission new studies. On the other hand, U.S. companies in some consortiums were more willing than the Japanese to "massage" ridership studies to achieve a "more propitious" result; and/or to point to additional revenue sources, such as profits from real estate development, that attenuated the importance of revenues from ridership. This caused conflict between Japanese investors and their American counterparts. As this financial advisor noted, in the 1980's, "a lot of Japanese investors with capital (were) looking for a place to park their money. They were upset that ridership studies didn't show higher ridership for the proposed Dallas to Houston line." In short, conflicts arose over whether to accept or reject the most rigorous ridership and revenue projections for the Texas project, and these conflicts can be traced partly to differences in standards applied by foreign and U.S. companies.

Fifth, U.S. government regulations and standards for operating a very high speed railway were a significant hurdle to overcome when importing foreign technology. Specifically, Federal Railway Administration (FRA) Tier 3 safety standards govern trains running at greater than 160 miles per hour (mph). According to one American official, who served together with foreign representatives on the Transportation Research Board (TRB) Committee on Safety Standards, Japanese and French railcars tended to be too light to meet Tier 3 standards. Thus, either the standards and/or the foreign technology had to be changed. This official stated that foreign company representatives, who also served on the TRB committee, "used that committee as a forum to argue for standards" that made it easier for them to export their technology to the U.S. market. Regulatory standards, in other words, had the potential to negatively impact the transfer of foreign high speed rail technology.

Sixth, none of the American officials interviewed expressed concerns about the impact of using foreign technology in a U.S. high speed rail project. They were "not concerned" that accepting the transfer of foreign rail technology might "diminish the U.S. rail manufacturing sector," even though the 1980's and 1990's were a period when American manufacturing was in decline. Nor were Americans worried that technology transfer would "take jobs from U.S. workers." Further, they "did not think it would diminish the research and development capabilities of U.S. firms" and/or government agencies. Yet, those are major concerns of critics of technology transfer, whose opinions were gleaned from published reports reviewed for this project.[xliv] Thus, while loss of American rail manufacturing capacity and jobs did not cause conflict inside the high speed consortia, outside experts raised this issue in objecting to transfer of foreign technology.

In sum, interviews with participants in, and observers of, consortia that were promoting very high speed rail in the U.S. indicate that, on the one hand, foreign involvement proceeded smoothly. Foreign rail manufacturers and operators purchased small U.S. rail companies to facilitate their entry into the potentially huge American market. Representatives of foreign companies serving on American consortia that were promoting high speed rail projects in various states, worked well together; social and cultural differences did not cause problems. And American promoters were not deterred by concerns that accepting foreign technology would diminish or undermine U.S. rail manufacturing and research capabilities. On the other hand, transfer or licensing of patents owned by foreign companies posed a significant obstacle to promoters, as did satisfying U.S. government, FRA Tier 3 safety standards. In addition, some U.S. promoters were more willing than their foreign counterparts to accept less-than-promising ridership and revenue projections because those promoters expected additional revenues to flow from real estate development at station stops. On balance, these results indicate that, even though American organizations welcomed foreign participation on their consortia, transfer of technology would not proceed unimpeded because legal and regulatory hurdles needed to be overcome, and because critics argued that foreign involvement was undermining American rail manufacturing, research, and development.

CONCLUSIONS

This study shows that the origins of technology transfer for very high speed ground transportation date to the 1930's, when American manufacturers, such as Budd and Electro Motive corporations, developed railcar bodies built with lightweight, shotwelded, stainless steel, pulled by lightweight two-stroke diesel engines. These innovations allowed American railroads to develop *streamliners,* trains that could run at top speeds well in excess of 100 mph, and average commercial speeds above 60 mph. Japan and France adopted much of this technology and used it to modernize their railways after the end of World War 2. By combining American and indigenous technology, Japan developed *Bullet Trains* and thereby became the first country to implement very high speed commercial service, in 1964, on its Shinkansen line between Tokyo and Osaka.

Just as Japan's success could not have been achieved without earlier American innovations, U.S. manufacturers and railroads learned from Japan. At the same time as Budd Company licensed its lightweight, shotwelding technology to Japan in 1962, it studied advances made with the *Bullet Trains* that Japan was developing. Similarly, when Japan applied for a World Bank loan in the early 1960's, to support its Shinkansen high speed project, American engineers evaluated Japan's technology. And engineers and managers from various rail manufacturing and operating companies attended international conferences where they exchanged technical knowledge. International exchanges allowed American and foreign rail companies to stay abreast of the latest developments in very high speed technology. As a result, when the U.S. government began funding research and development in high speed ground transport, under the auspices of the High Speed Ground Transportation Act (HSGTA) of 1965, U.S companies such as Budd, the Pennsylvania Railroad, Westinghouse, Rohr Technologies, and Grumman Aerospace, among others, already possessed sufficient technical grounding to be capable, soon thereafter, of developing *Metroliners* and *Turbotrains,* which tested at very high speed on the Northeast Corridor in 1967. These companies also drew upon on support from the Office of High Speed Ground Transportation to develop radical alternatives to steel-wheeled trains, including frictionless, tracked air cushion and magnetically levitated vehicles propelled by linear induction motors. In short, from the 1930's through the mid-1970s, the U.S. was a leading innovator in high speed technology. Japan and France also became major innovators as technical knowledge about high speed trains flowed back and forth across national boundaries.

But, then, in the early 1970's, Congress cut funding for high speed research and development; then 1975, decided not to continue the Office of High Speed Ground Transportation. As a result, American rail manufacturers could no longer rely on public support for research and development. Nor could they turn for support to the country's National Railway Corporation (Amtrak), which was so poorly funded in this period that it was mostly cutting passenger services. As a result, rail manufacturing companies, or divisions of those companies, such as Budd and Electro-Motive Corporation, began pulling out of the passenger rail sector. By the early 1980's, the U.S. passenger rail manufacturing industry, once a world leader in the field, was a severely diminished shadow of its former self.

Given these circumstances, when officials in states such as California, Florida, and Texas formed organizations of planners, contractors, investors, and others, to promote very high speed projects, they had no choice but to rely on foreign technology and expertise. And, of course, Japanese, French, and other foreign companies were happy to enter the untapped American high speed rail market. American and foreign rail promoters faced no significant cultural or social hurdles working together, though they did face problems involving transfer of patents and licenses; agreeing on appropriate thresholds in ridership and revenue forecasting studies; and meeting Federal Railroad Administration Tier 3 safety standards. Promoters also faced criticism that, in relying on foreign technology, they were undermining American manufacturers who might re-enter the market for producing high speed railcars and propulsion systems. These aspects of foreign participation interfered with implementation of very high speed projects proposed in the 1980's and 1990's. How much these problems contributed to the failure of promoters to actually implement their very high speed projects was not assessed in this study. The objective was to identify risks, obstacles, and problems created by foreign participation, thereby to provide useful information to planners and promoters of future projects.

POLICY CHOICES REGARDING FOREIGN PARTICIPATION

In order to increase the chances for successful implementation of future high speed rail projects, promoters can either they can try to overcome the obstacles identified in this study that are created by foreign participation in American rail projects; or they can work to rebuild America's domestic rail manufacturing capabilities, so that dependence of foreign technology and expertise is not necessary in the first place.

For the first option, the most important step to take would be adapting domestic Tier 3 safety standards to better fit with railcar technology imported from abroad. This would make it easier, for example, for lighter weight foreign high speed trains to operate on American infrastructure. Another step would be for foreign companies to loosen their stringent licensing requirements, making it easier for U.S. rail companies to rely on foreign technology. Finally, regulations from the Buy America Act of 1982, which requires that foreign technology used in publicly supported high speed rail projects be produced in this country could be loosened to make it easier for foreign companies to produce high speed railcars in the U.S.; [xlv] though, in fact, those regulations are already relatively easy for foreign companies to comply with, and are not very strictly enforced. In short, foreign participation in American projects is already relatively easy to accomplish, as was demonstrated in this study.

Far more difficult would be rebuilding American high speed rail manufacturing capabilities, thereby reducing reliance on foreign technology and expertise. This could be accomplished by taking the two major steps: first, strengthen and enforce provisions of the Buy America Act. The intent of this Act is to support American manufacturing, but according to recent research provisions relating to so-called "domestic content" are sometimes manipulated by companies to avoid the requirements of the law.[xlvi] Strengthening enforcement of regulations would make it harder for foreign manufacturers to produce railcars in the U.S. and, thereby, create opportunities for American manufacturers to enter this market sector. Second, government procurement policies could be geared directly to stimulating domestic railcar manufacturing. A number of manufacturing companies, such as Wabtech, which currently operate largely in the freight market, might be willing to expand into passenger railcar manufacturing, if sufficient market opportunities and government incentives became available.[12] A recent report details the robustness of the "emerging U.S. rail industry," and makes numerous recommendations for ways companies could capture market share and profits in this growing economic sector.[xlvii] An intermediate step would be for American companies to put provisions into licensing agreements to allow foreign technology to be adapted for future production within the U.S. This has been done for centuries by companies and countries wishing to build up industrial sectors, most recently to great effect by China in its high speed rail manufacturing. Since the mid-to-late 1970's, the U.S. government and private companies have ceded the manufacture of high speed technology to foreign companies in Japan, France, Spain, Germany, Italy, China, and Korea. The policy recommendations identified here could change this situation and put the U.S. on a path to reclaiming the leadership it exercised in high speed rail as recently as the mid-1970's.

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[12] General Electric sold its locomotive manufacturing division to Wabtech in 2018.

FUTURE RESEARCH

The research for this study produced original findings concerning, first, the history of American leadership in developing very high speed rail technology from the 1930's to the 1970's; second, the reasons why the U.S. became dependent on foreign technology after the 1970's; and, third, the problems dependence on foreign technology and expertise created for new high speed rail projects in the 1980's and beyond. The research raises an important question for further research; specifically, is it feasible for the federal government and private companies to consider rebuilding America's high speed rail manufacturing, research, and development capabilities? A study of the ways in which federal cooperation with private corporations, in the period 1965 to 1975, affected technological innovation would help answer that question, since great strides were made in that period towards development and commercialization of very high speed ground transport technologies. Analyzing the initiatives of that period would provide information on both the generic factors involved in developing new technologies as well as the specific problems that renewed efforts to rebuild U.S. manufacturing capabilities would confront. Fortunately, the U.S. Department of Transportation (DOT) and its Office of High Speed Ground Transportation, as well as the companies whose research and development activities were funded by DOT, such as Rohr Technologies, Grumman Aerospace, United Technologies, the Pennsylvania Railroad, Westinghouse, General Electric, and Bertin Technologies--all produced reports and company documents pertaining to innovation. These provide a strong resource base for further research. Both the government reports and company documents are held at the National Archives in College Spring, Maryland. An in-depth study of this material would contribute greatly to understanding how the U.S. could escape its current dependence on foreign rail technology and expertise.

APPENDIX A: INTERVIEWEES

Arduin, Jean-Pierre. Senior Transportation Economist, TRED/Transportation and Real Estate Development Company. Paris, France.

Borrell, Jaime. Market and Portfolio Director, Alstom, Inc. Paris, France. (Alstom is a major international corporation that manufactures rail vehicles and propulsion systems.)

Brand, Daniel. Senior Consultant, Charles River Associates. Boston, Massachusetts.

Coindreau, Pierre. Investment Advisor, Meridiam Instrastructure; formerly Project Manager for Banque Nationale de Paris (BNP). Paris, France.

Doll, Claus. Researcher, Project Director, Fraunhofer Institute for Systems and Innovation Research, Germany.

Huffman, B. Keith. Counsel to President and Chairman of the Board, Skanska Construction Company, Stockholm, Sweden and Great Falls, Virginia.

Leray, Alain. President, French National Railways/SNCF America. Washington, D.C.

Lupo, Pascal. President, SNCF Consulting Worldwide. Paris, France.

Medevielle, Jean-Pierre. Director (retired), INRETS, the French Institute of Science and Technology for Transport, Development and Networks. Liaison to U.S. Transport Research Board. Lyon, France.

Morshed, Mehdi. Executive Director (retired), California High Speed Rail Authority.

Rainey, Ian. Senior Vice President, The Northeast Maglev Company, affiliated with Japan Central Railways. Washington, D.C.

Sol-Rolland, Bruno. Vice President, Transport Operations, Alstom, Inc. Paris, France.

Thinnieres, André. Manager (retired), Alstom, Inc. Paris, France.

Turro, Marco. Manager, CXS Railroad, USA.

Vautherin, Loys. Line Manager, Operations Division, SNCF/French National Railways. Paris, France.

Verna, Vincent. Director of Regulatory Affairs, Brotherhood of Locomotive Trainmen and Engineers. Washington, D.C.

White, Richard. Professor of History, Stanford University. Palo Alto, California.

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Region 2 - University Transportation Research Center
The City College of New York
Marshak Hall, Suite 910
160 Convent Avenue
New York, NY 10031
Tel: (212) 650-8050
Fax: (212) 650-8374
Website: www.utrc2.org