High-Speed Rail in the United States:

Time to Bite the Bullet

by

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A thesis submitted in fulfillment of the requirements of the
Michigan Ross Senior Thesis Seminar (BA 480), April 22, 2020

Abstract

The continued innovation and success of High-Speed Rail in Europe and Asia calls for a deeper look into the sustainability and value of this method of transportation. Given the significant projected growth in transportation demand on a yearly basis, there is a need for improvement in infrastructure across the United States. This paper makes the case that private investment in High-Speed Rail is the fastest and most effective way to bring this technology to the United States. Current government programs hoping to increase private investment in public infrastructure are not capable of supporting a large-scale investment, and this investment does not presently have the political backing necessary to gain the proper funding. Therefore, Public-Private Partnerships present the most feasible way to construct High-Speed Rail lines in the country, with the private sector establishing their own funding and the public sector aiding in the process.

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Introduction

Transportation is a central part of the lives of citizens across the United States. From driving cars on a daily basis, riding trains to commute to work, or flying planes for vacation or business, transportation is and will remain a key element of the lives of every American going into the future. This is evidenced by the fact that the average American household spends $9,737 on transportation each year, including $705 on intercity and for-hire transportation (Bureau of Transportation Statistics, 2018). In this paper, I examine a mode of transportation that has potential to gain popularity in the United States amongst politicians, private businesses, and the public alike. High-Speed Rail ("HSR") is a widely popular method of transportation in Asia and Europe, but has not yet made its way to the United States in any significant fashion. This research identifies and outlines problems in the construction of new infrastructure and suggests a method to move forward with the investment in this technology. I make the case for investing in HSR in the U.S. and suggest the creation of Public-Private Partnerships as a method to make this investment feasible.

This research project was inspired by a semester exchange at Copenhagen Business School in the Winter of 2019. Having lived in a notoriously sustainable city that aims to have zero carbon emissions by 2025, I saw firsthand how the public and private sector could work together to create eco-friendly transportation systems that are also more operationally efficient than any system here in the United States. Major public transportation organizations in the U.S., such as the MTA in New York, are aging, inefficient, and far from eco-friendly. Massive reform is needed in the way that Americans travel, and I believe HSR is an innovative technology that needs to be considered.

Background

High-Speed Rail

High-Speed Rail ("HSR") is a method of transportation designed to operate at faster speeds than traditional rail systems for medium to long-haul distances. While there is no worldwide standard to define HSR, the European Union has outlined that a qualified line shall comprise of:

1. Specially built high-speed lines equipped for speeds generally equal to or greater than 155 mph (250 km/h),
2. Specially upgraded high-speed lines equipped for speeds of the order of 124 mph (200 km/h)
3. Specially upgraded high-speed lines which have special features as a result of topographical, relief or town-planning constraints, on which the speed must be adapted to each case.

   (Council Directive 96/48/EC of 23 July 1996 on the interoperability of the trans-European high-speed rail system, 1996).

The first full HSR system was opened in 1964, when Japanese National Railways opened the Shinkansen, whose first line ran from Tokyo to Osaka. This was originally built for the 1964 Olympics. Following this successful rollout, and continued growth in Japan, Europe started to develop their own HSR systems. Italy was the first country in Europe to establish one in 1978, when a line from Rome to Florence opened. France then followed, establishing the Train à Grande Vitesse or TGV (which in French translates to High-Speed Rail) (James, 2009). China has exploded onto the HSR scene of late, starting their planning in 2006 and now having over

16,000 mi (~26,000 km) of operational HSR lines, the most in the world and more than 8 times that of Japan (Nunno, n.d.).

The United States has made several mostly unsuccessful attempts at implementing HSR. Amtrak operates its brand of HSR as Acela Express. While the train can reach speeds of up to 150mph, it rarely does. For instance, along the Northeast Corridor, the train operates at an average speed of 85 mph. This is largely due to track congestion as well as curvy track layouts (*Next-Generation High Speed Trains*, n.d.). There have also been attempts to build an HSR system in California, since voters agreed to a plan back in 2008. However, funding trouble, gross underestimation of costs, and political conflict has plagued the project (Nagourney, 2018). In 2009, President Barack Obama, Vice President Joe Biden and Transportation Secretary Ray LaHood announced a plan for future investment in HSR outlined in the Federal Railroad Administration's "High-Speed Rail Strategic Plan." This plan, however, was to be government funded, and never moved any further than words on paper. Drastic change is necessary in the way the United States approaches investing in HSR, and this paper will offer a solution to this problem.

History of Amtrak

Amtrak, officially known as the National Railroad Passenger Corporation, was established in 1970 with the passing of the Rail Passenger Service Act. Nearly all private railways signed contracts with Amtrak, and in 1971 Amtrak assumed control of passenger service across the country. Amtrak was founded with the intention of relieving American railroads of the financial burdens of passenger service (The Editors of Encyclopaedia Britannica, 2015). From there, Amtrak continued to grow, and has not been a profitable venture for the

Federal Government, but rather serves as a public good. In the mid-1990s, Amtrak reorganized its structure, which opened it up to more federal, state, and local subsidies. In the early 2000s, Amtrak introduced its Acela service throughout the Northeast Corridor. This has helped the Northeast Corridor to become the only profitable venture that Amtrak is currently operating. (*Historic Timeline—Amtrak: History of America's Railroad*, n.d.).

Amtrak is an independent agency that is fully owned by the Federal Government. It is not formally a part of the Department of Transportation, but the Federal Railroad Administration (within the DOT) has gained increased oversight of the company due to their role in administering federal grants. (*Amtrak | FRA*, n.d.). Board members of Amtrak are appointed by the President, and confirmed by the Senate.

Environmental Impact

Emissions from transportation continue to be a major contributor and driver to climate change. The International Energy Agency estimated that in 2008, transportation accounted for 23% of CO_2 emissions worldwide. In addition, amongst all sectors measured (including industry, residential, electricity, heat, and others), the transportation sector is the only one in which emissions are continuing to rise (Jehanno, 2011). Researchers, governments, and private corporations involved in transportation markets have recognized the need for reform, as the environmental impacts of the current system have become threatening for future generations. Recently, there has been investment in research and development into electric vehicles, biofuels, and other sustainable transportation methods, indicating initial steps to finding a solution. On the flip side, there is still significant growth on a yearly basis in passengers across the transportation industry. The number of air travelers is expected to grow at a 3.5% CAGR from 2018 – 2037

(IATA, n.d.), while rail travel will grow with a 3.2% CAGR from 2015-2025[1] (*Rail passenger traffic—CAGR 2015*, n.d.). In short, there is a clear need for innovation in the transportation space in order to reduce emissions while demand for traveling is growing.

Given that HSR is proven to have lower emissions than other forms of transportation on a per-passenger basis (Jehanno, 2011), it is important to analyze whether HSR can make sustainable changes to consumers' travel patterns or, if used in conjunction with air travel and other modes of transportation (e.g. personal vehicles), would continue to add to emissions totals and inhibit progress. In the United States alone, in 2017, air travel accounted for 2.6% of total greenhouse gas emissions, while on-road vehicles accounted for nearly 24% of greenhouse gas emissions. It is worth noting that rail made up less than 1% of greenhouse gas emissions in country in that same year (US EPA, 2015).

High-Speed Rail Construction Costs

Construction costs for HSR systems vary worldwide due to terrain, population density, and political differences. It is difficult to compare the costs of different systems around the world due to these factors, along with the fact that they have been built at different times since 1964. In the United States, the California High Speed Rail Authority budget for construction has hit $80.3bn. According to Texas Central Railroads, their HSR line from Dallas to Houston will cost between $15-20bn. For an example of the cost of a successful line abroad, the Taiwanese HSR line had a total cost of $16.5bn, and was completed in 2007 (Jeng & Su, 2013). The World Bank has conducted research on construction costs of HSR on a per km basis. Analysts estimate the following costs (converted to miles):

[1] The COVID-19 Pandemic will significantly alter these projections.

- China → $10-13mm per mi ($17-21mm per km)
- Europe → $15-24mm per mi ($25-39mm per km)
- United States (California) → $35mm per mi ($56mm per km)[2] (Ollivier, 2014)

Government Programs

The arm of the United States Government that would be tasked with investment in HSR, outside of Amtrak, is the Department of Transportation, which houses the Federal Railroad Administration and the Building America Bureau. These organizations have worked in tandem to kickstart investment in rail from the private sector, while also allocating money to Amtrak in the form of grants and yearly allocations.

The Build America Bureau was created in 2014 after President Barack Obama instructed the heads of all executive departments and agencies to expand Public-Private collaboration on infrastructure development and financing. Obama stated that this organization should "help interested State, local, tribal and territorial governments, and private project sponsors, understand, navigate, and use Federal transportation infrastructure financing programs in order to facilitate the use of innovative approaches to finance projects, including Public-Private Partnerships" (Obama, 2014). The Bureau now acts as a hub of information for different government programs, specifically:

1. Public-Private Partnerships (P3)
2. Transportation Infrastructure Finance and Innovation Act (TIFIA)
3. Railroad Rehabilitation & Improvement Financing (RRIF)

[2] This estimate is based on 2014 World Bank Research, when the budget for California High Speed Rail was $67.6bn. The budget has since gone up to $80.3bn, as per the CHSRA.

4. Private Activity Bonds (PAB)
5. INFRA Grants

While Public-Private Partnerships ("P3s") operate on a case-by-case basis, the other four programs are vital for the Department's initiative to build and improve infrastructure around the country with private cooperation. The TIFIA program looks to leverage Federal funds to attract private investment and other non-federal investment to improve critical infrastructure. TIFIA offers either a secured (direct) loan with a low interest rate, a loan guarantee to a non-federal lender, or a standby line of credit. This has been a widely used program in order to finance infrastructure projects of all types (US Department of Transportation, n.d.).

The RRIF program is a loan program that established across multiple acts since 2002. These acts allowed the Department of Transportation to authorize up to $35bn in loans or guarantees for the development of railroad infrastructure. These loans can have terms up to 35 years and offer low interest rates. This program has been significantly underutilized, with only $6.2bn in loans executed since the inception of the program. Many of the loans were used for smaller infrastructure improvements instead of a widespread investment in new rail (US Department of Transportation, n.d.).

Private Activity Bonds are part of a bond program through the Department of Transportation that allows for tax-exempt bonds to be purchased by private investors for privately funded infrastructure projects. The total amount of the bonds was not to exceed $15bn, and to date, over $12bn in these PABs have been issued for infrastructure projects. This has been a relatively successful program to allow private investment in this public infrastructure (US Department of Transportation, n.d.).

Lastly, there are INFRA grants. This program, established in the FAST Act of 2015, allowed the Secretary of Transportation to allocate $900mm in infrastructure investment across the country. This has been used for smaller projects across the country, and was not meant for significant investment in new technology (US Department of Transportation, n.d.).

Overall, there are significant funding programs that the Federal Government has offered in order to spur private investment into public infrastructure. However, there is no far-reaching, large program that aims to invest in massive projects to fundamentally change the way Americans travel. This is simply not in the budget, and these programs largely look to maintain and improve existing infrastructure.

Northeast Corridor

For the data portion of this research, it is important to have background information on the Northeast Corridor ("NEC"). The NEC is a 457 mile stretch from Boston, MA to Washington D.C. It runs through eight states, is used by passenger, intercity, and freight rail operators, and has four different right-of-way owners (See Appendix G). The NEC serves over 800,000 railroad trips per day (*The Northeast Corridor*, n.d.). The following is a list of operators on the corridor:

- Amtrak
- Massachusetts Bay Transportation Authority
- CTrail
- Metro-North Railroad
- Long Island Rail Road
- New Jersey Transit
- Southeastern Pennsylvania Transportation Authority

- Maryland Area Regional Commuter
- Virginia Railway Express

The sheer number of operators and Right-of-Way owners makes this a very difficult corridor to operate and maintain. However, it is particularly important to the American economy. The corridor is home to 17% of the U.S. population according to the 2010 Census, four of the ten largest metropolitan areas of the country, and is responsible for $3 trillion of economic output on a yearly basis. All of this occurs on just 2% of U.S. land (Northeast Corridor Commission, 2014). Because of this significant activity in such a small region of the country, having smooth transportation systems between these areas is vitally important to the economy.

High-Speed Rail and Private Rail in the U.S.

The California High Speed Rail Authority ("CHSRA") has been tasked with planning, designing, building and soon operating an HSR system throughout California. The project is designed to run from San Francisco to Los Angeles in under three hours. Future extensions are planned to reach Sacramento and San Diego. The train is supposed to reach speeds upwards of 200 mph. However, budgets have ballooned for the project and they have faced significant political pressure for that reason. In February of 2020, the CHSRA announced that the budget was being increased $1.3bn to $80.3bn. This publicly funded project was approved by taxpayers in 2008, and while construction has started, it has faced numerous delays. The first phase of the project is now expected to be completed in 2033, 25 years after the 2008 vote (Thompson, 2020). Public perception around this project is a huge problem due to ballooning budgets and elongated timelines, but the first phase is still being planned and constructed.

Texas Central is a very interesting company that is constructing an HSR line

between Dallas and Houston. This company is entirely privately funded, and plans to use the same technology as the Japanese Shinkansen system. Texas Central is currently in the planning process, and is buying up land and getting government permits. They have also signed a ticketing agreement with Amtrak, so that customers can buy tickets on the Amtrak website once the line becomes operational. Current estimates have the project operational around 2027, and assuming completion, would make Texas Central the first privatized HSR line in the United States.

Brightline Trains in Florida is another significant example of privatized rail in the United States. Although not currently High-Speed, Brightline is the only fully private operational passenger railroad in the United States. Soon to be renamed Virgin Trains USA due to a naming rights contract, Brightline runs a train between West Palm Beach and Miami, with construction underway to expand to Orlando. The West Palm-Orlando trip will be able to reach high speeds. Brightline is known for making their money on real estate surrounding their stations, as that is the root of their investment in the train line.

Problem Statement

The purpose of this research is to make the case for building HSR in the United States, and finding a feasible method to fund the necessary investment in this technology. The United States is currently facing a few issues in relation to this research. From an actual transportation perspective, the U.S. needs a more sustainable form of transportation going forward. Sustainable can take on two meanings here; First, there is an aging transportation system throughout the U.S. that needs to be modernized. Second, and increasingly more vital, is the environmental aspect. Transportation emissions continue to grow**,** with no sign of slowing (Jehanno, 2011).

The second set of problems revolves around the feasibility of investing in this technology for the future. Building an HSR line is an undoubtedly expensive endeavor, and the expense seems to have been amplified in the United States due to stringent government regulation and contracting policies. There is a very active private infrastructure investing market that would be willing to inject money into the public infrastructure system, with coordination and cooperation from federal, state and local governments. The question here is – how should these projects be funded, and by who? And once this is decided, a structure of this agreement must be further coordinated.

I make the case that a Public-Private Partnership is the most effective method of investing in HSR for the long term. This would include private investment paired with government support in the form of creating a stable legal environment, helping with the planning and design phase, safety oversight, and possibly administering grants, loans, subsidies, or tax credits. This will take significant investment and commitment from the government, but is necessary in order to build more sustainable transportation systems.

Literature Review

On the whole, advanced research into the benefits of HSR is just starting to emerge given the period of growth that the technology is in. There is research on the demand for HSR in comparison to air travel, as well as the sustainability of HSR. However, I have not found research that compares the two directly, in order to show that the reduction in air travel has resulted in a reduction of overall emissions. Yet, the published research on demand and the implementation of HSR is certainly helpful in establishing a case for the sustainability of it.

There have been multiple research papers analyzing demand for HSR in comparison to air travel. One paper specifically looked at the London-Paris/Brussels market, and found that there was a decrease in air passengers when rail was introduced. Air travel between London and Paris/Brussels had just over 5 million passengers in 1994 when Eurostar, the HSR line, was founded. 16 years later, in 2010, air travel had just over 2 million passengers, and the HSR line had over 9 million. Researchers analyzed each method of transportation from 2003-2009, and found that passengers were most likely to make their travel decisions based on frequency and travel time (Behrens & Pels, 2012). While there was some variation across leisure and business travelers, the previous generally holds true. In the later years of the study, Eurostar had the highest frequency of any alternative, and the highest on-time percentage of all competitors. Analysis here was done purely using empirical travel data, so passenger sentiment on climate change was not measured here. The conclusion of the study noted that competition on the route is expected to continue to decrease, with HSR holding firm control (Behrens & Pels, 2012).

A similar report has also been written analyzing domestic air travel in Taiwan following the introduction of HSR. A line from Taipei to Kaohsiung was opened in 2007 along the Western Corridor of the country, and entirely changed air travel in the country. In the first year of

operation alone, domestic air travel dropped nearly 70%, and over 90% on certain routes. Instead of celebrating the new and efficient transformative method of transportation, however, the authors of this piece instead argue that domestic airlines will now need to focus on being low-cost carriers in order to earn their ridership back (Jeng & Su, 2013). Since the publishing of this article, domestic air travel has been completely eliminated in Taiwan, with the exception of islands off the mainland. The train line has dominated to the point where if one wanted to fly from Taipei to Kaohsiung, they would have to connect through Hong Kong or Macau. The focus on corporate profit in research such as this will continue to inhibit the reduction of emissions. Looking at the emissions savings from this HSR implementation in Taiwan is vitally important for understanding the benefits of the method.

The structure of the project in Taiwan is also noteworthy. Realizing the high cost of this project, which was around $16.5bn, the Taiwanese government contracted the privately funded Taiwan High-Speed Rail Corporation ("THSRC") in 1998 to build this line. The Build-Operate-Transfer model that the government offered allowed THSRC to finance, construct, and operate the line for thirty-five years, after which ownership would be transferred back to the government (Jeng & Su, 2013). Essentially, the government gave THSRC thirty-five years to recoup and profit off their investment in the country's infrastructure.

While the aforementioned research on Taiwan would make one believe that emissions reduction is a no-brainer, it is not always the case. Researchers have looked not only at the demand side, but also the supply side in analyzing this problem. In analysis of the Paris-Marseilles route, it was concluded that a decline in market share of air travel, measured by passengers, does not necessitate a decline in air supply in terms of number of flights (Dobruszkes, 2011). What this means is that airlines were reducing the number of seats while

keeping the supply of flights the same, by shifting to smaller aircraft. This is key to understanding why this research is important. In order for the environmental effect of switching to HSR to be felt, a modal shift must occur in society that draws enough passengers away from air travel and to rail, resulting in flight reductions instead of just seat reductions.

It is well documented that HSR is a far more efficient form of transportation than any alternative, including air, car, bus, or normal rail travel, from an emissions perspective. The challenge in transportation is figuring out how to actually implement changes to reduce emissions. The International Union of Railways (UIC) outlined three primary strategies to reduce the impact of transportation:

1. Avoid – transport is reduced or avoided altogether
2. Shift – journeys made by lower emitting modes such as public transport, walking, biking
3. Improve – improve technology in current modes of transportation

These strategies are all relevant when it comes to HSR, and should be considered when thinking about transforming transportation on the whole (Jehanno, 2011).

While I did not find research that explicitly proved a connection with existing HSR and a reduction in emissions, there is research about the potential for emissions reductions with the construction of an HSR line in Sweden called the Europanaban. It is estimated that overall, once modal shifts occur, 550,000 tons of CO_2 per year could be saved with the introduction of this line by 2025/2030, with 60% of the savings coming from truck to rail freight and 40% coming from air/road travel to HSR (Åkerman, 2011). This study considered the manufacturing and maintenance of vehicles, as well as the construction of infrastructure and transportation of fuels. These indirect sources of emissions are certainly hard to measure. In comparison of the two

methods, you could go to great lengths to include extraneous factors in the emissions count. For example, you could argue that with air travel, emissions come not only from the operation of the planes, but the operation of vehicles at the airport, the emissions from the airport itself, all the emissions from employees of the airport, etc. Because of this never-ending trail, I have decided to only focus on emissions from the operation of each transportation method in my research. However, this is certainly something to be aware of.

Rail policy has been rapidly changing as well over the last few decades. Especially in Europe, there has been significant investment in infrastructure, as well as privatization of the operation of rail lines (Preston, 2009). The way in which these companies behave is also vitally important to how HSR is viewed in terms of its sustainability. In this heavily regulated industry, often with government owned lines with private operators in Europe, all stakeholders have a responsibility to ensure they are working to preserve the environment and reduce emissions across the board.

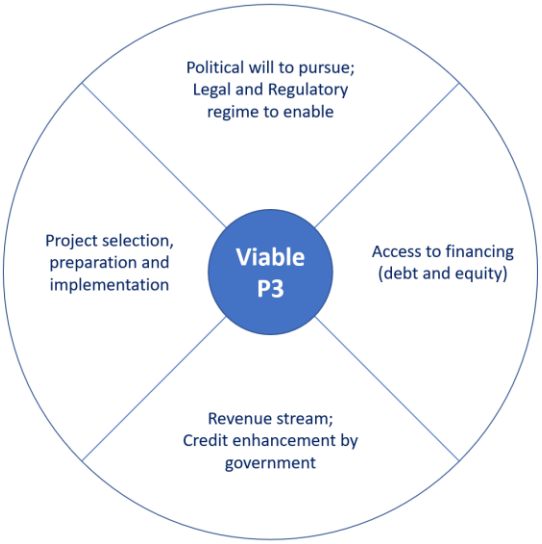
To transition to what is happening in the United States, researchers have found that enthusiasm for driving has decreased, and younger generations are looking for new ways to travel. A survey from the Office of Transportation Policy Studies, a Department of Transportation office, found that there is increasing enthusiasm for train and transit use, even in the absence of new transportation infrastructure improvements (Kamga, 2015). Additionally, since September 11, 2001, Amtrak has gained significant market share in the Northeast Corridor when compared to air travel, owning over 50% of the NY/Boston market and over 75% of the NY/DC market (See Appendix F). There are a number of reasons for this trend, including the inconvenience of airports, travel time, and congested traffic patterns (Kamga, 2015). However, it

is clear that there is demand and excitement for rail along the Northeast Corridor in the United States.

Framework

The overall framework that is relevant to this project is a Public-Private Partnership ("P3"). The World Bank has published materials regarding the formation of Public-Private Partnerships for infrastructure construction worldwide. Numerous projects around the world have used frameworks similar to this to outline the viability and steps necessary for successful completion of the work. The World Bank produced the chart shown in Figure 1 (reproduced for clarity) to show what a viable Public-Private Partnership could look like:

Figure 1: P3 Viability Framework



In addition to the framework in Figure 1, the World Bank lists five key elements of a Public-Private Partnership Framework (Delmon, 2015). First, the government must create both a clear and stable legal environment for Public-Private Partnership projects to exist. While the World Bank does not say what is right or wrong in the formation of a P3, they note that a clear policy must be written that includes a definition of a P3, identification of responsibilities, specifically for government entities, stages at which government approval will be required, and conditions for government support. Setting these legal guidelines early could help speed up projects (and therefore reduce costs), while making the process less political and more flexible to

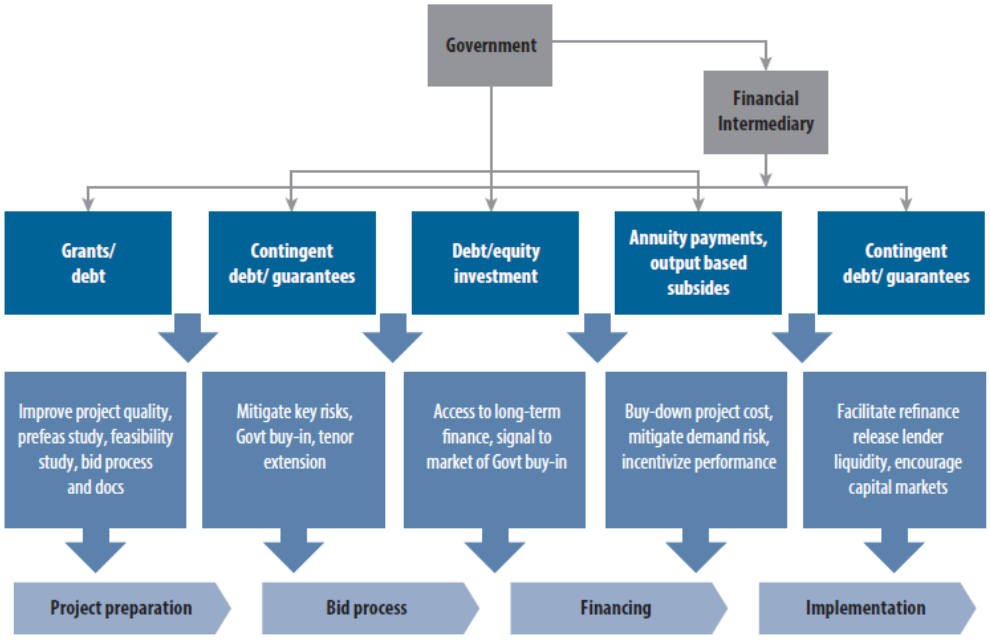
different types of projects. Common legal issues in Public-Private Partnerships include creation of LLCs, land acquisition, government obligation, collecting tariffs, and taxes.

Next, there must be an institutional framework in place to facilitate P3s. The World Bank suggests empowering a government institution that can organize and coordinate these projects, with political backing, in order to help the process move along smoothly. This institution would be tasked on helping with project selection, project preparation (including approvals inspections), and fiscal support. Having a centralized P3 organization, whether on the federal, state, or more local levels, that can be the sole organizer of this process would allow for a more organized and speedy process. In the U.S. currently, a P3 can be between multiple different governmental organizations, and is surely confusing and time consuming.

Following that recommendation, the World Bank goes on to give a few methods that would allow a government to support the procurement and implementation of these transactions. This includes feasibility studies, as well as fair and competitive procurement process. They suggest a bidding and negotiations process in order to find the right partner and terms before signing any agreement. Once that agreement is signed, the government side should continue to follow up on the progress of the project and monitor performance once complete.

After all of these procedural recommendations on how to approach P3s, the World Bank then lays out ways for the government to use public support for P3 projects in monetary form. Figure 2 (see below) nicely illustrates the many ways that governments can provide monetary assistance to these projects. Ultimately, governments, and any agencies created for P3s, will be tasked with figuring out which projects should be offered more significant monetary support than others, including decisions on who should get grants vs. a debt guarantee.

Figure 2: Government Options in P3 Financing



(Delmon, 2015)

The final element of the Public-Private Partnership guidelines set by the World Bank has to do with financing. Given the typical long-term nature of infrastructure debt, private companies may have a hard time accessing financing for their investments. While this is more of an issue in developing countries, a USD-backed project would still benefit with government help in gaining access to this long-term capital.

The U.S. Government's Build America Bureau is a start at organizing P3s. However, there are not overly clear guidelines to work with, as P3s are generally handled on a case by case basis. A clearer and more open process could spur innovation and investment in much needed areas.

Methodology

This research was conducted in two parts. First, I looked at air vs. rail travel emissions on the Northeast Corridor. The purpose of this was to simulate a potential emissions reduction by moving away from air travel to either existing rail travel or to HSR. One simulation looked at a shift from air travel to Amtrak's existing rail infrastructure. The second set of simulations looked at the potential introduction of an HSR system on the Northeast Corridor, and what emissions reductions would look like with different levels of demand for the system.

In order to conduct these simulations, I first had to find the total aircraft emissions from all flights between Boston, New York, and DC. The airports included in this study were:

- Boston Logan International Airport (BOS)
- John F. Kennedy International Airport (JFK)
- LaGuardia Airport (LGA)
- Newark Liberty International Airport (EWR)
- Washington Dulles International Airport (IAD)
- Ronald Reagan Washington International Airport (DCA)

The process of finding a total emissions number took multiple steps. First, I used the International Civil Aviation Organization's Carbon Emissions Calculator to collect data. This calculator gave not only the per-passenger CO_2 emissions numbers for each individual route, but also the types of aircraft used to fly on each route. Airlines fly multiple different Boeing, Airbus, Embraer, and Bombardier aircrafts with varying passenger capacities along this route. See Table 1 for a chart of different aircrafts with their capacities, gathered as averages from individual airline seat layouts and manufacturer capacity listings:

Table 1: Aircraft Capacities

Type	Avg Passengers
Airbus	
319	140
320	168
321	211
32B	102
Boeing	
717	100
738	176
739	180
73G	126
752	163
757	248
763	214
764	240
Embraer	
E70	112
E75	76
E7W	76
ERD	44
E90	100
ERJ	50
Bombardier	
CRJ	45
CR7	70
CR9	76

Source: Manufacturer Standards/Airline Configurations

After compiling emissions and flight capacity data, I used Bureau of Transportation Statistics Origin/Destination reports, which broke out individual airlines, distances, and other important data, to find the total number of flights on each route in 2019. Additionally, the St. Louis Federal Reserve publishes the average load factor for domestic carriers, sitting at 81.78% for 2019. See Table 2 for the total CO_2 emissions on each individual route.

Table 2: Total Route Flight Emissions on NEC

Origin	Destination	2019 Flights	Avg Passengers	Emissions/Flight	Total Emissions
LGA	BOS	9,564	110	6,430.67 KG of CO2	61,502,881.54 KG of CO2
JFK	BOS	5,065	124	7,157.92 KG of CO2	36,254,850.47 KG of CO2
EWR	BOS	5,164	137	7,409.33 KG of CO2	38,261,794.28 KG of CO2
BOS	LGA	9,561	110	6,430.67 KG of CO2	61,483,589.54 KG of CO2
BOS	JFK	5,011	124	7,157.92 KG of CO2	35,868,322.94 KG of CO2
BOS	EWR	5,171	137	7,375.81 KG of CO2	38,140,294.64 KG of CO2
LGA	DCA	6,244	107	7,122.87 KG of CO2	44,475,228.00 KG of CO2
JFK	DCA	2,197	112	6,838.48 KG of CO2	15,024,150.42 KG of CO2
EWR	DCA	2,439	103	7,828.41 KG of CO2	19,093,494.29 KG of CO2
LGA	IAD	1,234	76	4,935.46 KG of CO2	6,090,352.35 KG of CO2
JFK	IAD	1,212	61	3,092.31 KG of CO2	3,747,875.18 KG of CO2
EWR	IAD	2,084	149	9,180.88 KG of CO2	19,132,949.86 KG of CO2
DCA	LGA	6,245	107	7,105.37 KG of CO2	44,373,057.63 KG of CO2
DCA	JFK	2,209	115	6,850.43 KG of CO2	15,132,597.47 KG of CO2
DCA	EWR	2,436	103	7,845.32 KG of CO2	19,111,196.99 KG of CO2
IAD	LGA	1,234	83	5,359.70 KG of CO2	6,613,866.89 KG of CO2
IAD	JFK	1,212	61	3,092.31 KG of CO2	3,747,875.18 KG of CO2
IAD	EWR	1,948	132	8,036.41 KG of CO2	15,654,923.82 KG of CO2
BOS	DCA	8,047	119	10,381.81 KG of CO2	83,542,404.47 KG of CO2
BOS	IAD	1,337	134	9,348.21 KG of CO2	12,498,558.40 KG of CO2
DCA	BOS	8,062	119	10,381.81 KG of CO2	83,698,131.58 KG of CO2
IAD	BOS	1,336	134	9,326.22 KG of CO2	12,459,823.82 KG of CO2

Amtrak Northeast Corridor ridership data was necessary for both simulations as well (see Table 3). The Acela is Amtrak's higher speed option when compared to the Northeast Regional trains, which have significantly more stops.

Table 3: Amtrak NEC Ridership

Northeast Corridor Spine	2018	2019	% Change
Northeast Regional	8,686,930	8,940,745	2.9%
Acela	3,428,338	3,577,455	4.3%
NEC Special Trains	8,375	7,402	-11.6%
Total Passengers	12,123,643	12,525,602	3.3%

Source: Amtrak

The last key part of conducting this research was to find comparative efficiency statistics for CO_2 emissions. According to the Bureau of Transportation Statistics, Amtrak is, on average, 27% more efficient than air travel. One would expect this number to be higher, but this number uses real data, considering Amtrak's frequent delays and stops. Also, according to the International Union of Railways, a true HSR line is, on average, 89% more efficient than air travel. The passenger data also showed that Amtrak currently has a 59.79% market share, while air travel has the remaining 40.21%.

With all of this data at hand, I ran simulations to forecast CO_2 emissions based on multiple different scenarios. A baseline assumption that was made in this model was that travel demand on the NEC was going to grow at an annual rate of 2.50% (a conservative estimate against the projected demand numbers referenced on pg. 4 of a 3.5% CAGR from 2018-2037 for air travel and 3.2% CAGR from 2015-2025 for rail travel). First, in a more realistic and feasible demonstration, I projected out emissions if Amtrak were able to steal 1%, 2%, and 4% of Airline market share consistently each year, without any HSR intervention (other than the already existing Acela service). Next, I ran simulations based on the hypothetical introduction of HSR

onto the Northeast Corridor. In each of the scenarios, HSR stole market share in a gradual fashion. These simulations were run with the full understanding that it is not possible to introduce a true HSR line on the Northeast Corridor this year or within the next 10 years, but are rather intended to show the drastic reduction in CO_2 emissions that this technology could bring with it.

The second half of my research was centered on the feasibility of HSR on the Northeast Corridor and throughout the United States. In specific, I focused on potential methods of funding, and methods to go about effectively prompting investment in this technology. In order to do this, I reached out to professionals across the rail and HSR industries to get a better view of what is actually going on. For the purpose of their own anonymity, below are vague descriptions of professionals I had the opportunity to speak with:

- A member of a government-controlled rail planning commission
- A government infrastructure investment consultant
- An executive with a privatized rail company
- A head engineer of a privatized rail company
- A private rail investor
- A leading professor who conducts rail research

I was able to conduct in-depth conversations with the above individuals about the industries as a whole, what their view on the future was, as well as what is going on in their individual organizations. In each interview, I asked the same general questions about the individual's view on HSR in the United States now and in the future. From there, I moved to more specific questions about the individual's organization. These questions touched on topics such as funding sources, government cooperation, global, federal and state policies, specific

engine models, and environmental standards. Due to privacy requests from individuals as well as a general understanding that some knowledge shared was not meant for the public, interviews were not recorded or fully transcribed. See Appendix H for general types of questions that were asked in all interviews.

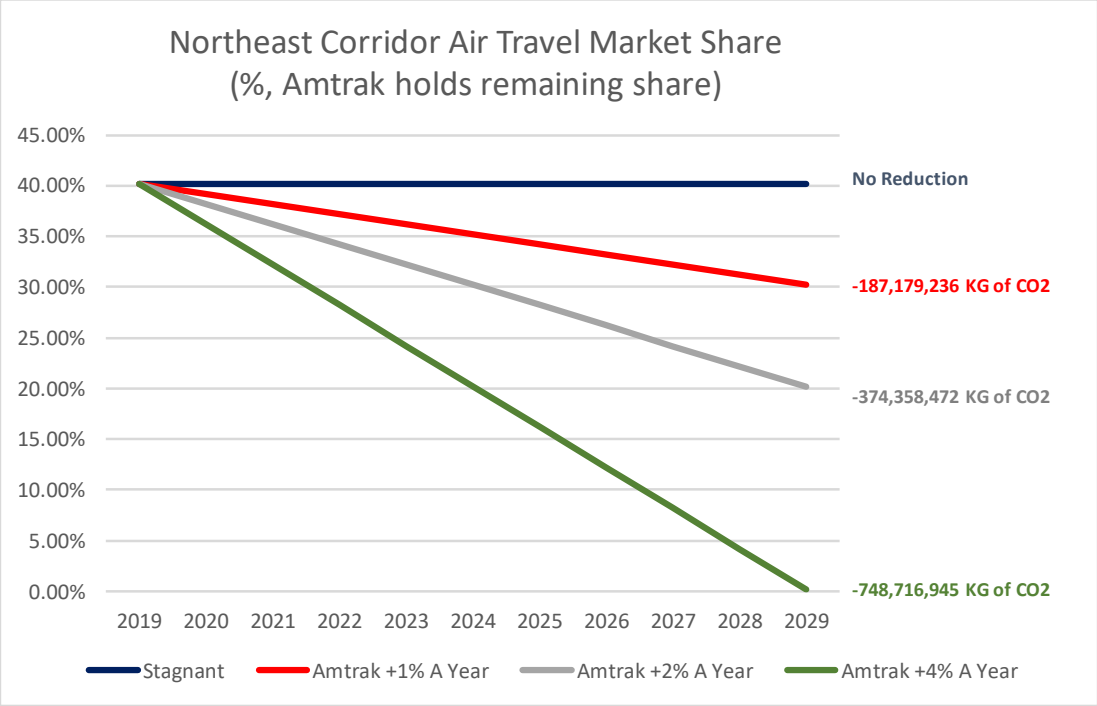
From these interviews, I was able to identify key areas of focus for completing my research, including common struggles in building new infrastructure as well as programs and ideas that seemed to be working well. Suggestions from these professionals led me to dive deeper into published government plans and policies, governmental loan and investment programs, case studies from other countries, and overall business structures. Additionally, I analyzed European and Asian policy, initiatives, and business structures in order to see what could possibly be replicated here in the United States. From all of this, I was able to draw from their experience and more concrete information from governmental entities in order to draw conclusions on whether a Public-Private Partnership is truly the best way to go about investing in HSR.

Results

The first portion of this research was intended to show the potential environmental impact of moving transportation towards rail and HSR. As a simulation, the Northeast Corridor, from Boston, through New York, and to Washington D.C., was selected, as it is Amtrak's busiest corridor and served by multiple major airports. The Northeast Corridor also has the most operationally sound version of HSR in the U.S., although it does not fit the formal European Union definition for HSR due to slower speeds. While parts of this simulation are not at all possible (e.g. introducing HSR on the NEC within the next few years), it was intended to show the dramatic effects on emissions that HSR can have.

The first simulation (see Figure 3) shows how CO_2 emissions could potentially be reduced from 2020-2030 with passengers initiating a slight modal shift towards Amtrak. As Amtrak is, on average, 27% more efficient than air travel, this demonstration showed that even a slight steal in market share could have a drastic effect on emissions. Figure 3 shows how a move towards existing Amtrak rail, away from air travel, would affect emissions. The blue line is the base case, where market share stays stagnant. The red line is a case where Amtrak is able to steal 1% of market share per year from 2020 until 2030; the gray line is a 2% steal share; the green line a 4% steal share, which would essentially eliminate air travel on the NEC. The resulting decrease in CO_2 emissions is shown below. It is important to note that this demonstration was completed assuming a 2.5% yearly growth in passenger demand as well.

Figure 3:



Clearly, a reduction in air travel could have a vast impact on travel emissions. This first demonstration was intended to show the drastic environmental impact that simply moving to existing rail infrastructure could have. The next set of demonstrations involves the introduction of a hypothetical HSR system on the NEC, and the impact is even more substantial. Below are three separate scenarios, from least intrusive to most intrusive from an HSR market share perspective, and the resulting emissions reduction from each. The first example (Figure 4) shows if HSR was able to gain 50% market share, increasing by 5% every year from 2020-2030. This would occur by evenly stealing share from Amtrak and air travel. The second example (Figure 5) shows if HSR was able to entirely steal Amtrak's share, and leave air travel untouched. The third example (Figure 5) shows total domination of HSR, where, in a case like Taiwan, HSR would completely steal all Air and Amtrak passengers over a span of 3 years. Again, this is an extreme example meant for demonstration and not a possible scenario.

Figure 4:

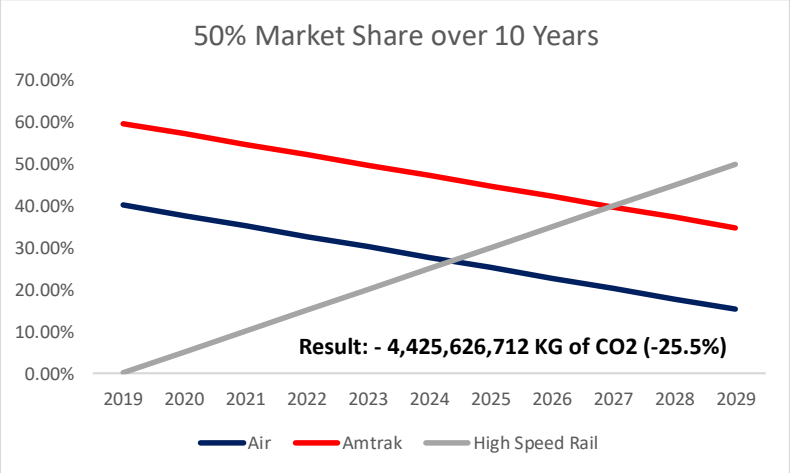


Figure 5:

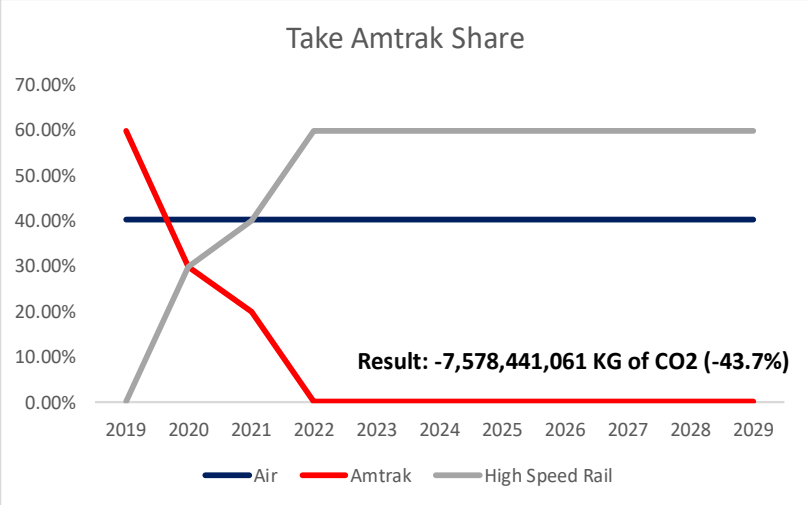
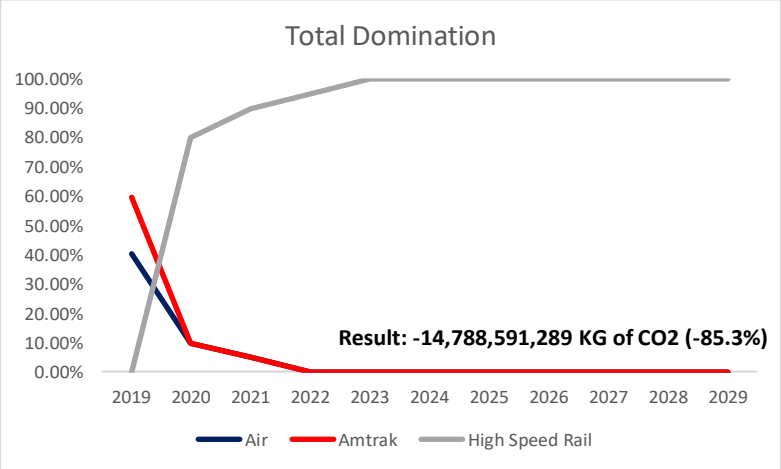


Figure 6:



The environmental impact that moving away from air and toward rail, and even more drastically HSR, is clear. The importance of this data in regard to this thesis will be discussed further in the Discussion section.

The next portion of this research involved interview-based data collection. Throughout conversations with multiple rail industry leaders, I was able to collect information about government attitude towards HSR, feasibility of the projects, funding sources, and more. An initial sit-down with a leading rail research professor opened my eyes to the many different avenues of this business, and where the future may be heading. From that conversation, I was able to narrow down my topic of research, and learn more from industry leaders.

One of the first avenues I explored with this research was whether an HSR line was feasible on the Northeast Corridor. I theorized that, given the Acela system, the NEC would be a great place to build the first operational HSR line in the United States. However, I was quickly proven to be incorrect. The Northeast Corridor, as detailed within the background information of this paper, is an incredibly complicated route. When I asked a member of a government-controlled rail planning commission about the possibility of building this line, they were frank, and said "I am going to be honest; true High-Speed Rail on the Northeast Corridor will never happen." As it turns out, the Federal Government had already explored this option over a seven-year planning period, detailed in their "NEC Future" report. The government considered three options for the future of the Northeast Corridor: Maintain, Grow, or Transform. The "Transform" option was the only option to include the construction of new tracks in order to fit a true HSR system, and was not chosen, with the government opting for the "Grow" choice (*NEC FUTURE: Tier 1 Final EIS*, 2017).

The same individual said that "Amtrak would have loved the 'Transform' result", and that commuter railroads lobbied simply for the "Maintain" option. An environmental impact study also showed that the introduction of HSR on the NEC would be negatively impactful to the environment, due to the cost of constructing new tracks so close to the ocean and other bodies of water. However, with all of this said, they noted that the Federal Government would be open to private investment in this space, and that Amtrak specifically would love to grow the rail space with private assistance.

After coming to the realization that HSR on the Northeast Corridor was not feasible in the coming years, I reached out to an executive of a privatized rail company in order to gain insight from the private sector on the future of HSR. Their initial response was to outline a few necessary considerations to building an HSR line:

1. High growth areas, from a population and economic standpoint
2. Right distance away – too long to drive, but also a short flight
3. Workable terrain, preferably flat
4. Anchored by city pairs

This executive then went on to speak about funding and government cooperation. They noted two loan programs offered by the Federal Government, specifically within the Build America Bureau (as discussed in the Background section on pg. 5), being the TIFIA and RRIF processes. Their opinion was that there could be a lot of negative press around accessing these loans, and they can be very difficult to actually obtain. Given strict conditions and a lengthy time process for these loans, this executive said they would prefer private investment, whether from American or Foreign investors, to these loan programs.

This sentiment was echoed by the Head Engineer of another privatized rail company. They noted that their company in specific had looked at the RRIF loan process and never reached the end of it, as it was a long and arduous process where they could obtain funding more easily from another source. They said that the "never-ending" due diligence process, strict provisions, and substantial requests from contractors derailed the process and made "time more important than money." They instead looked at the PAB (Private Activity Bond) process, which better fit their needs with less due diligence necessary.

While this engineer was certainly in favor of private investment and limited government intervention on the financial side, they noted that the government must be involved in the process. As safety is the top priority for the government, and hopefully operators, working with the government on engineering, operation, and general oversight of safety requirements is vital and very important for the success of any project.

Following these insights, I spoke with an infrastructure investing consultant who mostly does work for the government. When I asked about funding and Public-Private Partnerships, they said that a P3 "could be a good delivery method, but not a good funding method" for investment in HSR going forward. What this essentially means is that governments and private organizations should be working together on the development and planning of projects, but should not simply put their funds together and split a stake in a project. They noted that the California High Speed Rail Authority currently has P3s with consulting and design firms in order to plan their project. This consultant also noted that the best options for HSR in the U.S. will be projects that are complimentary to Amtrak service, just as the Texas Central project is serving a need that Amtrak currently does not fill. On that note, they said long-haul HSR in the U.S. is not very beneficial.

With all of this in mind, it was important to hear from an established rail investor to see what it would take to garner significant investment into HSR. I spoke with an investor who is mostly invested in freight in the United States but has exposure to passenger rail in Europe. The first thing they noted was the difficulty in establishing strong passenger service in the United States due to right-of-way laws for freight trains. They said that "North America is the envy of the world in the freight sector, even though it is not in passenger." The reason there has been a stronger investment in freight, according to this investor, is the significant liability that it carries, as insurance for freight in the U.S. is far cheaper. This investor said they would love the opportunity in the future to be able to invest in an HSR project, and that it would likely need to have a "Brightline" aspect to it, having the profits be anchored in something else such as real estate. This investor and I, who does not work for a Private Equity ("PE") firm, also spoke about the potential negatives of PE investment in railroads. PE firms are typically looking for a 3/5/8-year investment and then to sell, and in this industry, significant capital expenditure is required to actually improve railroads. They noted that "actual partnership" is vital in this industry.

Discussion

The results of this research have led to a few recommendations for the future of HSR in the United States. In my opinion, the benefits of investing in this technology are clear. HSR is a proven safe, fast, and affordable method of transportation around the world. In the U.S., the nationwide Amtrak system is aging, and is not a profitable venture. Going forward, there needs to be an alternative mode of transportation that can keep up with increasing demand, and private investment in these projects is going to be necessary.

Overall, it seems as if the programs that the government currently offers (RRIF and TIFIA, specifically), are working for small, specific improvements on existing rail lines, but not for a widespread investment in new technology. Private investors find the process to be way too long, detailed, and restraining, and expressed that getting private finding was simply easier. Additionally, PAB allotments are nearly maximized, and will need to be expanded in order for the program to continue. However, with all of these issues in mind, the government still needs to have a role in this investment.

There are additional problems that the market has experienced in the rail industry. On the Northeast Corridor, for example, right-of-way laws and different owners of the same track in different areas causes significant delays and traffic. The Federal Railroad Administration should work to find a solution to scheduling issues that cause significant delays on railroads around the country. Precision scheduled railroading ("PSR") is a concept in freight railroading that can potentially be applied across both freight and passenger rail in order to improve on-time service. This scheduling could also open up more open lanes on tracks to allow trains to reach higher speeds and efficiencies.

The data portion of this project, showing potential decreases in emissions from HSR, was not meant to be the justification for investing in this technology. It can, though, be a used as a potential selling point to Congress, and a way to get things done. In fact, the first document in the proposed Green New Deal states that the government must invest in:

"overhauling transportation systems in the United States to remove pollution and greenhouse gas emissions from the transportation sector as much as is technologically feasible, including through investment in –

i. zero-emission vehicle infrastructure and manufacturing;

ii. clean, affordable, and accessible public transit; and

iii. high-speed rail"

(Ocasio-Cortez, 2019).

The Green New Deal has not yet taken off in Congress, and is still in its beginning stages of becoming accepted policy. However, the mere introduction of HSR in the deal is proof of the value of this research. If the more progressive wing of Congress can bring HSR to the negotiating table as a necessary investment due to emissions, the more pro-business wing of government could establish an effective way for the private sector to invest in this project.

In any new legislation regarding HSR, it will be essential for the government to establish a way, likely through the Building America Bureau and Department of Transportation, to facilitate private investment in this new technology. At the same time, while making the flow of private funds into infrastructure easier, the government will need to establish its role in this process. I believe the best way for the government to be involved here is in the planning of different routes, safety inspections, and general oversight. If the government was to provide monetary assistance, it should be in the form of grants to spur initial investment, tax credits, or

the expansion of the PAB program to allow for tax-exempt investing in this. This will require vast expansion of the Build America Bureau. In today's political climate, it would be unrealistic to expect, or hope, that the government passes an HSR package of hundreds of billions of dollars in order to make HSR in the U.S. a reality. Instead, they can position themselves to allow the private sector to make these improvements, and act as a helping hand along the way.

In the future, it is possible that the government takes an approach to rail more similar to Europe. In many European countries, tracks are owned and maintained by the government, and trains are run by private operators under government contract. However, this would require a massive buyback program by the government, similar to what happened in 1970 when Amtrak was founded, and is unrealistic to start out. If rail one day becomes a more significant form of passenger travel around the country, bringing greater competition to airlines, this could become a possibility. Most airports are government owned and shared by many airlines, and a future rail system could become similar.

If HSR is going to be a successful venture in the United States, the government and private companies are also going to have to take Amtrak into account. Texas Central Railways, for example, has a ticketing agreement with Amtrak. This means that Amtrak passengers can use a Texas Central Railway operated train with an Amtrak ticket, similar to an airline codeshare agreement. Amtrak was supportive of this since they do not run trains from Houston to Dallas directly. If Amtrak could become a partner in the development of private HSR around the country, they would certainly benefit as well.

Limitations

It is important to acknowledge the limitations in conducting this research. In terms of the data side of the research, there are several important distinctions that should be made. First, the air travel passenger numbers are projections based on the number of flights, the planes that fly on those routes, and aircraft capacities. The Federal Government and airlines do not publish official traffic numbers for individual routes. The Bureau of Transportation Statistics offers a survey that is intended to reach 10% of domestic travelers. However, the choice was made to instead project out ridership individually using aircraft capacities and flight statistics. Because of this, emission numbers will not be entirely precise, as emissions were calculated on a per-passenger basis. Additionally, in terms of capacities, the data was not weighted for aircraft flown more frequently than others, as that was not included in the Origin/Destination Reports. Therefore, any larger aircraft, like a Boeing 757, or smaller aircraft, like a CRJ-400, could skew the data in either direction.

Second, it is important to note that this research purely took the actual operation of planes and trains into account. There was no consideration in the data for the environmental impact of activities that go along with using these forms of transportation. As an example, with air travel, there is the environmental cost of running an airport (e.g. construction, airport operations, moving bags, etc.), and physically getting passengers to an airport. With rail, there is the environmental impact of building tracks, stations, crossings, and bridges, and similar costs of running stations. This study was intended to purely look at emissions based off operation, as expansion into other categories is dependent on a host of other issues. It is important to note as well that only Boston, New York, and Washington DC were included in the study. The line does

also include cities such as Hartford, CT and Philadelphia, PA, but for simplicity, were not included.

On the interviewing side of the research, there were limitations in who I was able to interview for the project. Most of the individuals who were interviewed held private sector positions, as public sector employees were harder to get in touch with. I was not able to reach anyone from Amtrak for comment. Speaking with more individuals in the public sector could have provided a different insight from the government's perspective on the future of HSR in the United States. In addition to U.S. public sector workers, input from governments in Europe and Asia would have been helpful in looking to make policy suggestions here in the United States.

Future Research

There are numerous avenues that future research could investigate relating to the introduction of HSR in the U.S. A very important area of research would be around the demand for HSR, and whether Americans would actually want to use these transportation systems. Once that more surface-level research is conducted, it could be important to know more about the attitude of Americans towards public transportation in general, and to learn what it would take to induce a modal shift. While this research looked at a direct comparison to emissions with air travel, highway traffic is another major emitter and source of transportation. There will have to be a significant improvement in public infrastructure as well as a cultural shift to get people out of their cars and onto a train, and learning more about those triggers is vital to the success of an HSR line.

Additionally, in line with current worldwide happenings, it is undoubtable that the COVID-19 pandemic will have a significant lasting impact on daily life around the world. The matter in which public transportation fits into people's lives going forward would be a great topic of research. There will surely be a general fear around mass public gatherings and crowded spaces in the coming months and years, which will require adaptation from public transport operators to ensure the safety of their riders. Learning about a shift in riders wants and needs will be key going forward to continue operating successful public transit.

Conclusion

Overall, it is my belief that investing in High-Speed Rail in the United States is a necessary endeavor to provide a more sustainable and efficient method of moving people from generations to come. This cannot be done alone by the public sector or the private sector, and requires coordination across the board. However, private investment in this technology, with strong government support could prove to be a worthwhile financial investment, and would certainly create a more sustainable travel system for the public good from a cost, safety, and emissions standpoint. If the private sector could garner necessary funding and enthusiasm for a project of this scale, and the government could cooperate with the private sector for massive transportation reform, HSR lines between the right city groupings across the country are certainly possible.

One important takeaway for me was to find that I was incorrect in thinking that HSR could be viable on the NEC. While I was deep into my research when I came to this realization, I found that it was easy to still make the case for HSR around the country, while also showing the potential effects that a hypothetical HSR line would have on the NEC. It serves as an important example of how drastic a switch to HSR could be for the environment. Further research is necessary to decide what other city pairs around the country could be viable for HSR, but the Pittsburgh-Cleveland-Detroit-Chicago corridor as well as expansion in Florida, Texas, and California seemingly make sense. Conducting this research throughout the year has been an incredible learning opportunity for me. I would like to offer my sincerest thank you to all who supported me throughout this process, most notably:

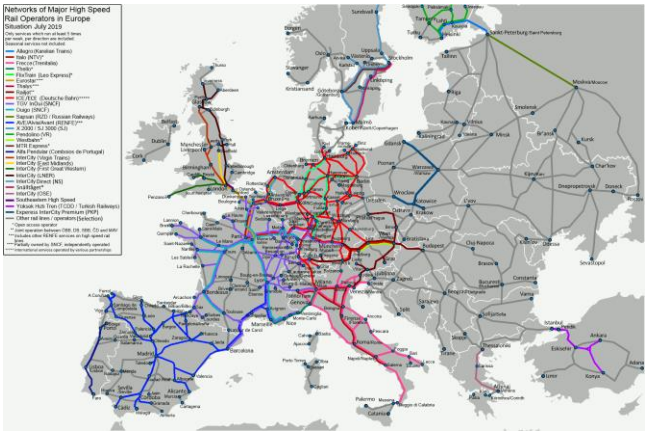
- My advisor, Professor Andrew Hoffman
- Course Coordinators Dean Francine Lafontaine and Professor Burcu Tasoluk

- My PhD mentor, Mana Heshmati
- All of the individuals who took time to speak with me over the phone and video chat, and provide me with additional resources to aid in the completion of this thesis.

I am thankful to have had the opportunity to conclude my time at the Stephen M. Ross School of Business with an experience such as this, and hope that this research can be used as a stepping stone for continued private investment in public infrastructure throughout the country.

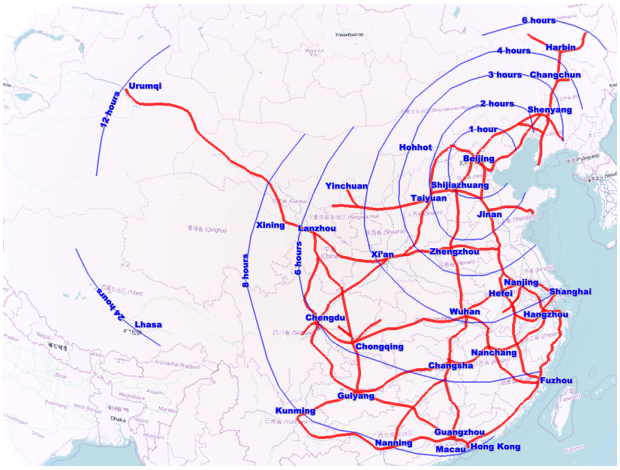
Appendices:

Appendix A: Map of Current High-Speed Rail Lines in Europe



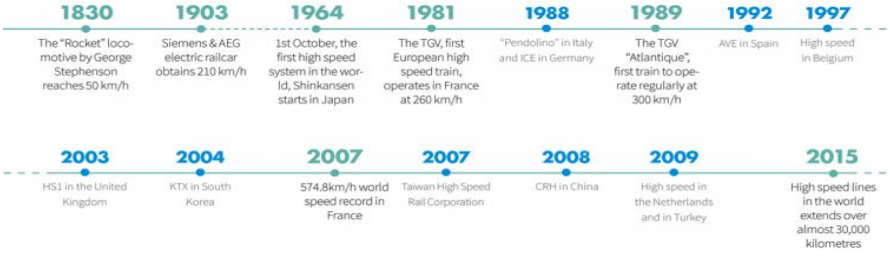
(Nunno, n.d.)

Appendix B: Map of Current High-Speed Rail Lines in China



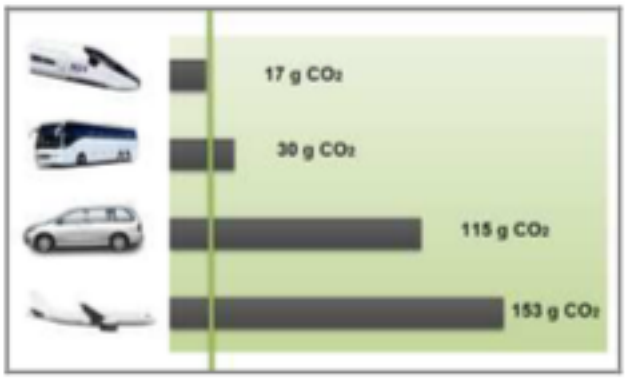
(Nunno, n.d.)

Appendix C: Brief Timeline of High-Speed Rail History



(*High-Speed Rail History*, n.d.)

Appendix D: Transportation Method Emissions Per Passenger Kilometer (ppk)



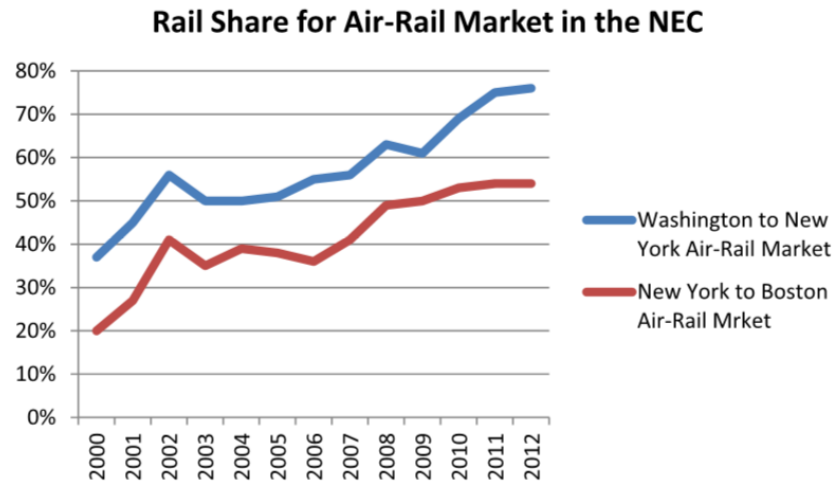
(Jehanno, 2011)

Appendix E: Top 10 High-Speed Rail Operating Countries Worldwide

Country	Lines in operation (km)	Lines under construction (km)	Approved not built	Max speed (km/h)
China	26,869	10,738	1,268	350
Spain	3,100	1,800	0	310
Japan	3,041	402	194	320
France	3,220	125	0	320
Germany	3,038	330	0	300
Sweden	1,706	11	0	205
United Kingdom	1,377	230	320	300
South Korea	1,104	376	49	305
Italy	999	116	0	300
Turkey	802	1,208	1,127	300

(Nunno, n.d.)

Appendix F: Rail Share for Air-Rail Market in the Northeast Corridor



(Kamga, 2015)

Appendix G: Northeast Corridor Right-of-Way Graph

(*The Northeast Corridor*, n.d.)

Appendix H: General Interview Questions

1. What is your view on the potential construction of HSR lines in the U.S.?
2. What is the Federal Government's attitude towards HSR?
3. Do you think that the U.S. government would allow for Public-Private Partnerships in rail? Either investment in Amtrak or new joint ventures?
4. What is your opinion on privately funding the construction of rail lines?
5. How do you think HSR in the U.S. could be financed? Can it be totally private, can the government step up and fund it, or does it have to be a middle ground?
6. What government programs are available for one to access in the funding of construction of an HSR line?
7. How realistic is it for Public-Private Partnerships to become more widespread within infrastructure development?
8. What do you think about the possibility of HSR on the Northeast Corridor that truly fits the definition of HSR, unlike Acela?

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