

**Feasibility of the implementation of a high speed
rail system
– Phasing out regional air travel**



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Introduction

Aviation activities influence the environment in two major ways. One is a local effect, and the other is a global effect. Aircrafts emit six major pollutant species. These include volatile organic compounds (VOCs), carbon monoxide (CO), carbon dioxide (CO₂), nitrogen oxide (NO_x), particulate matter (PM) and sulfur dioxides. The emissions of VOCs and CO is highest when engines operate at a lower power, such as during taxi and idling. NO_x emissions are greatest when an aircraft needs high power to take-off and climb out.

In general, aircraft emissions can alter the climate by changing the amount of energy either reaching or leaving the surface of the earth. Many aircraft emissions are greenhouse gases and are capable of trapping energy in the atmosphere. The other emissions alter atmospheric concentrations of aerosols. A useful measure of evaluating the influence of emissions on the atmosphere is the concept of radiative forcing. Radiative forcing expresses the energy balance of the earth-atmosphere system in watts per square meter (Wm⁻²). A positive forcing implies a net warming of the earth, while negative value implies cooling.

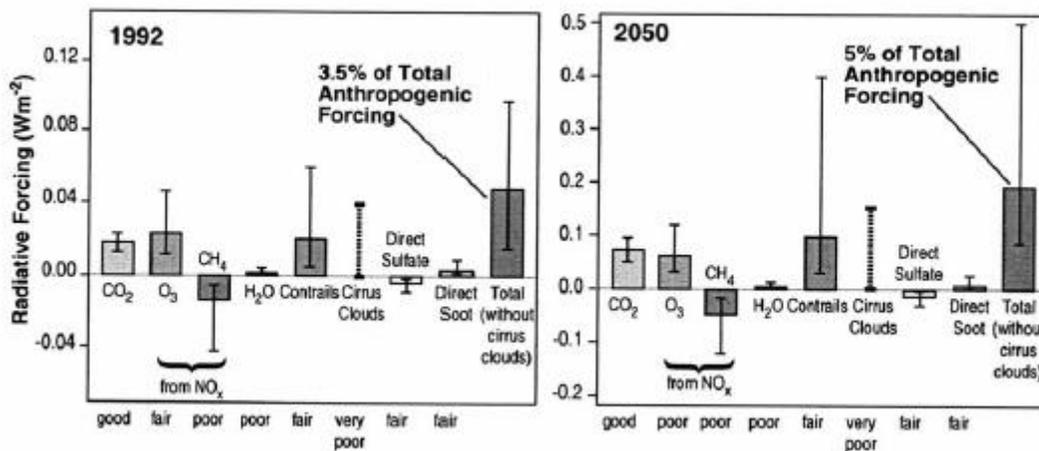


Figure 1: Radiative forcing from aircraft emissions

In 1992, the total radiative forcing of aviation was 0.05 Wm⁻², or 3.5% of the total radiative forcing from all anthropogenic activities. This is expected to increase to between 0.13 Wm⁻² and 0.56 Wm⁻² by 2050. In addition, aviation-related radiative forcing is two to four times higher than for CO₂ alone. In addition, the forcing of all human activities is 1.5 times higher than CO₂ alone. This suggests that the impact of aviation emissions at a higher altitude is more severe than those emitted at the surface of the earth¹.

The scope of our project is to determine and evaluate the feasibility of phasing out regional, short haul aircrafts in the north east of the United States and the implementation of an alternative high speed rail system. Figure 2 below evaluates today's modes of transport.

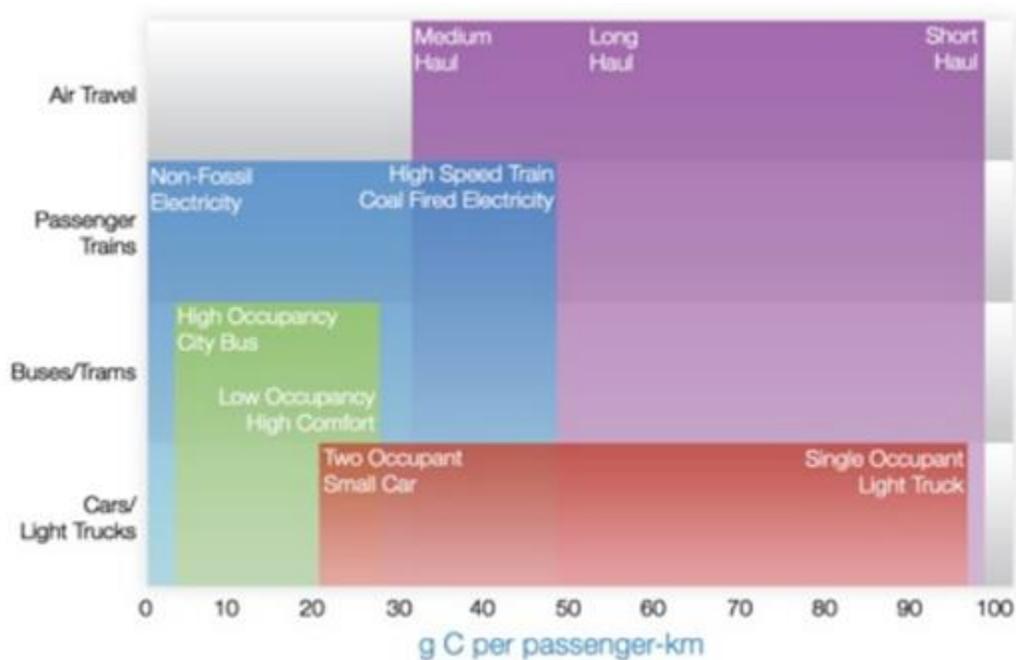


Figure 2: Carbon intensity of passenger transport

As the figure conveys, short haul air travel has the highest per passenger energy inefficiency. High speed trains as an alternative can significantly reduce energy consumption and emissions.

We plan to analyze existing rail service in Europe in countries such as Spain and France as a means of comparison to determine the likely environmental impact as well as possible obstacles of a high speed rail implementation in the United States. In particular, we will be focusing on the Boston-New York Route, an area of high economic density and a significant amount of infrastructure investment. We have also looked into Amtrak's existing plans to develop a high speed rail network by 2040.

How regional jets impact the environment

When determining the energy consumption and emissions of an aircraft, most airlines and policy makers assess the energy usage (E_u) and specific intensity (E_I) of the aircraft. This is measured in gallons of fuel used per available seat mile (gal/ASM). The E_u indicates how much energy is required to perform a unit of potential output – moving a single seat one mile. The E_I is a measure of how much energy is required to perform a unit of actual output. Therefore, this incorporates an additional efficiency related to how efficiently the aircraft is being used.

Regional jets usually have a high E_I , meaning that fuel consumption is very high per person. This also means that the emissions are much higher per person. The high inefficiency is due to lesser

number of seats and similar power required to fly the altitudes at the same speeds as the larger jets. The figure below helps demonstrate how much more inefficient regional jets are as compared to long haul aircrafts.

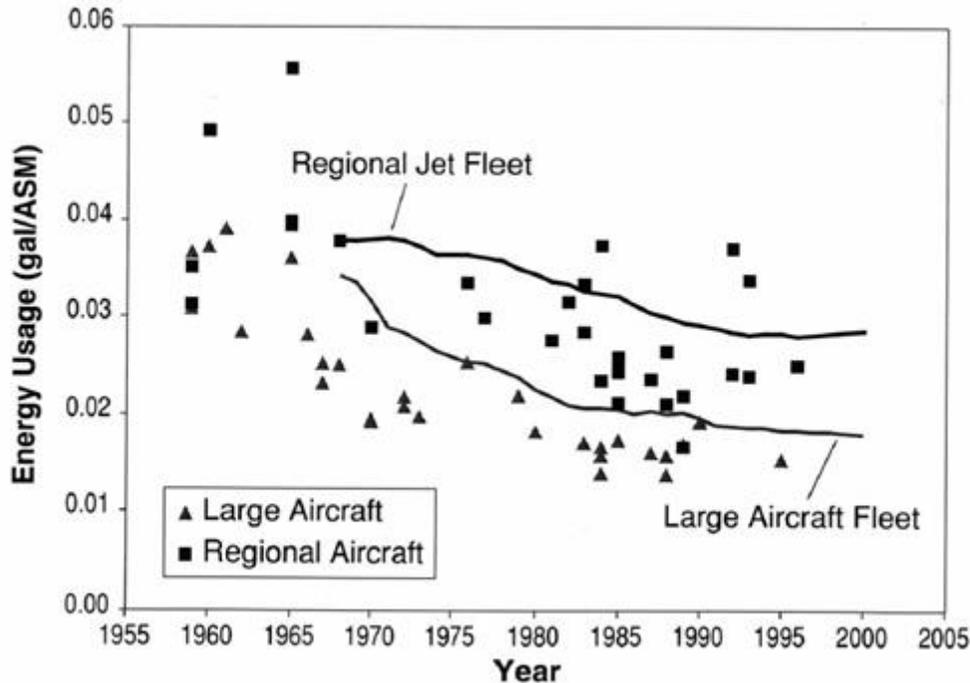


Figure 3: Energy usage for the two types of aircraft

Although the energy usage has reduced over the years due to technological development, the larger aircrafts still have much lower gal/ASM consumption as compared to regional fleets. Therefore, it is safe to conclude that the reduction of regional air travel, and the implementation of a clean, efficient alternative will positively impact the environment

Current Model in the United States

Air travel in the United States has increased by five times since 1970. This success was spurred by increased competition introduced by the Airline Deregulation Act of 1978, which phased out the role of the Civil Aeronautics Board in determining routes and fares. Since the United States is a large country, this deregulation permitted airlines to provide service where and whenever they found demand. This is what led to an increase in demand for regional jets.

This led to point to point services to operating hub and spoke systems. The hub and spoke system was set such that airlines maintain a hub airport, where a group of flights, referred to as ‘banks’ all arrive within a certain interval of time. This allows for connections and also helps passengers travel to their respective ‘spoke’ cities. The figure below shows the current model being used in the United States.

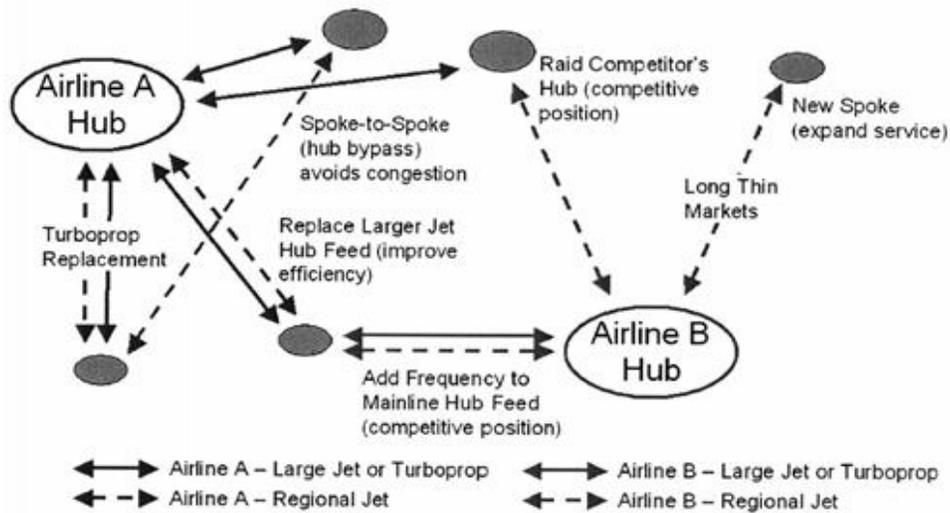


Figure 4: Current Hub and Spoke Model used in the US

Turboprops and regional aircrafts use point to point services to the Hubs of major airlines which makes connections convenient for travelers. The goal for policymakers will be to try and eliminate the use of regional aircrafts and implement efficient, convenient, environment-friendly and economical rail service that will phase out the demand to utilize regional jets.

The policymakers will have to target a specific route to make in order to see if this strategy could significantly reduce carbon emissions. Ideally, the figure below shows a prospective model that could eliminate regional jets by the implementation of a high speed rail and reduce the carbon emissions.

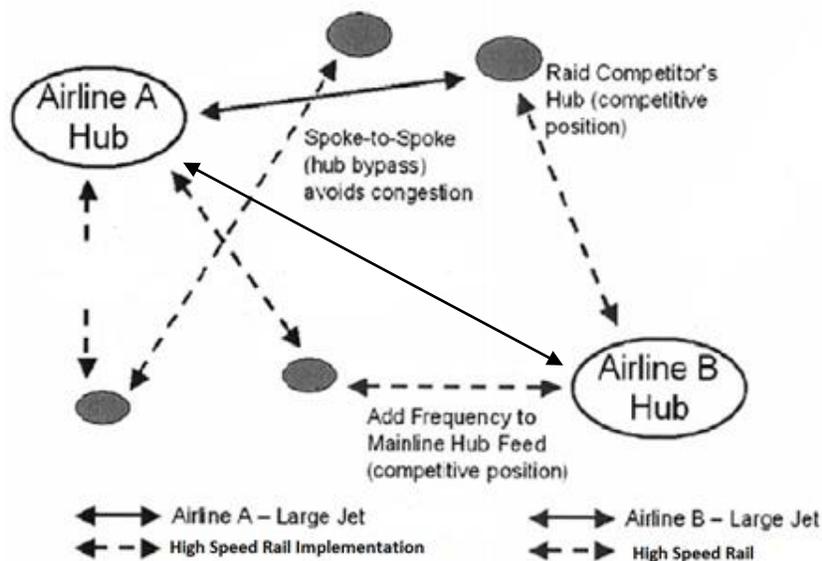


Figure 5: Possible high speed rail implementation

Rail services will be a new means of connection in terms of spoke to hub. This rail service could possible connect between airports to make connections as easy for traveler. There are many factors to be considered in order for a system like this to work in the Northeast of the United States. These, including with possible policies are discussed later in this paper. It is important to note that this model is very long term to implement through the country. In this project, we focus on the first steps of implementing a high speed rail in the United States.

Regional Jet Emissions for NYC – Boston

We calculated the regional jet emissions (CO₂ in particular) for one type of aircraft for the NYC – Boston route in a day. The methodology employed to compute the emissions is shown below.

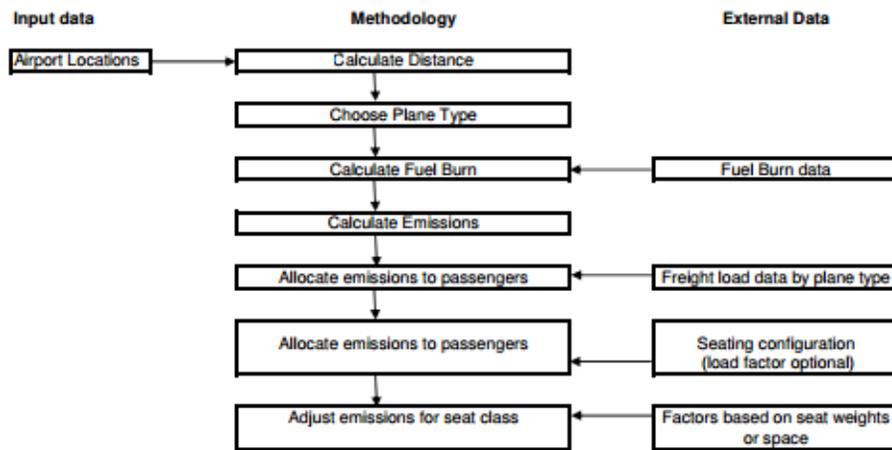


Figure 6: Emission Calculation Methodology

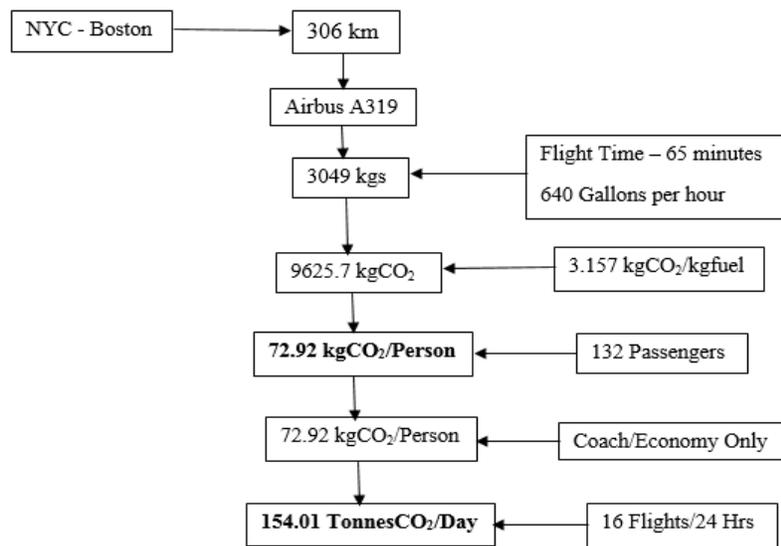


Figure 7: Emission Calculation for NYC-Boston route (One Way)

Train Emission Statistics

In the previous analysis we quantified the emissions from Boston to New York as 72.92 kg of CO₂ per passenger trip. This featured assumptions of load factor, jet fuel heating values and emission rates as well as average time of trip.

	Intercity train	High speed train	Air (500km)	Diesel car on motorway
Seating capacity	434	377	99	5
Load factor	44%	49%	70%	0.36
Primary energy (MJ per seat km)	0.22	0.53	1.8	0.34
(MJ per passenger km)	0.5	1.08 (0.76*)	2.57	0.94

*At 70% load factor

Table 1. ⁸

In order to quantify how much CO₂ emissions would be saved with a hypothetical modal shift to a High Speed Rail alternative, we require an energy density metric for HSR. In a 2010 study conducted by CE Delft, a Dutch Consultancy, identified the energy expenditure of a high speed rail at 1.08 MJ per passenger kilometer at a 49% load factor⁸

Since electrical grids are made up of a variety of energy inputs, all releasing pollutants at specific rates, we need to take into account the specific features of the grid of each respective region. Therefore, we sought grid profiles for the Northeastern Corridor, the United States as a whole and the country of Spain. Shown in Figure 8-9, the Spanish electrical grid is shown to operate with a greater percentage of renewables and with lower proportion of fuels with a high kgCO₂/MJ rating (such as coal). The Northeastern Corridor as a whole utilizes more Nuclear power and less coal. We assumed that Coal released .096 Kg CO₂ per Mega joule released, natural gas released .056 and the other emissions were negligible³. This of course only factors in CO₂ and does not consider the release of precursors of other greenhouse gases or even potential methane leakage associated with natural gas.

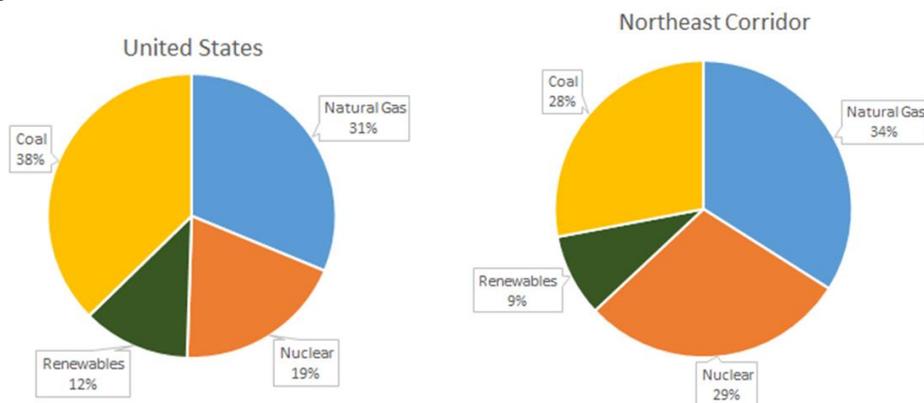


Figure 8.

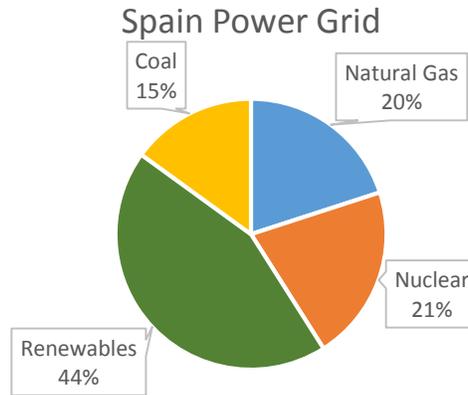


Figure 9.

We then assumed that the hypothetical high speed rails would draw evenly from the entire regional grid (though the Spanish HSR is known to operate on entirely renewable energy)¹. The emission rates for each respective mode are shown in Figure 10, with the automobile emission calculation derived from assumptions of a future fuel economy of 45 miles per gallon and a load factor of 2.2⁶. Then, assuming the train distance between New York and Boston is basically equivalent to the driving distance, we completed the dimensional analysis and determined a rate kg CO₂ released per passenger trip.

$$\frac{\text{MJ}}{\text{passengerkm}} * (\text{percentage}(\text{coal}) * \text{kgCO}_2/\text{MJ}(\text{coal}) + \text{percentage}(\text{natural gas}) * \text{kgCO}_2/\text{MJ}(\text{naturalgas})) * \text{km}/\text{trip} = \left[\frac{\text{kg CO}_2}{\text{passengertrip}} \right]$$

Assuming current grid is allocated in similar proportions in the future, and considering a conservative load factor, the emission rates for HSR in the Northeast corridor is 23% of that regional jets and 41% of a car.

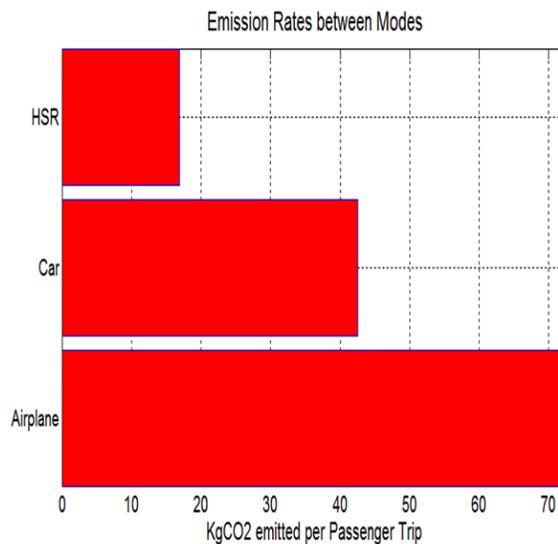


Figure 10.

This analysis suggests that every modal shift from Plane to Train will save $(73-17) = 56$ kg CO₂. In order to effectively scale potential savings we must predict how much of a mode shift is likely to take place. Because of the availability of alternative transportation, price elasticities for short-haul flights are known to have a greater magnitude than for long-haul flights. However, these elasticities do not take into account such a disruption of the system as a 94 minute train alternative, like the journey time Amtrak is currently proposing. However, according to multiple studies, rail market share increases more rapidly once the journey times have decreased below four hours for each additionally unit of time saved² and when the time decreases below three hours rail has the potential to drive air out of the marketplace.

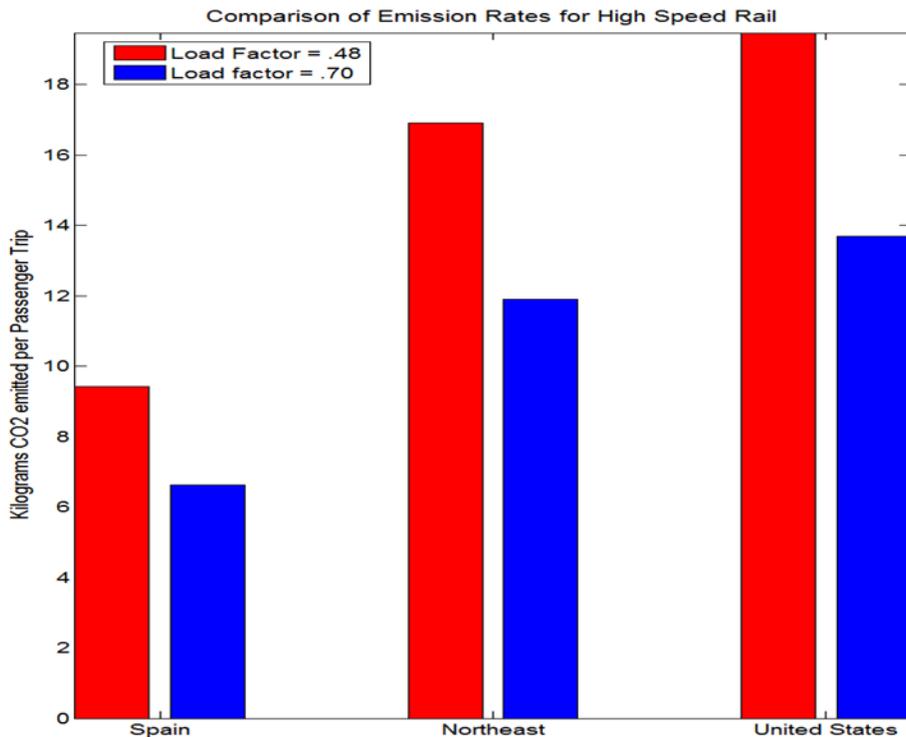


Figure 11.

This effect can be seen in numerous locations; for instance the 2 hour Paris-Lyons route in France now holds 90% of the air/rail market, up from 60% when the route took 3 hours². After the implementation of high speed rail in Spain the Madrid-Seville route took 80% of the market share. And indeed, even in the United States, the Acela market share grew from 36% to 41% between 2006 and 2007¹¹.

These observations suggest that the rail lines will experience a significant amount of growth not only by 2040 and the introduction of the 94 minute New York – Boston line, but also along the way as money is spent to more gradually improve the infrastructure and travel times. However since cross-borough transportation is not always more convenient and travel to airports or train

stations can add considerable travel time, we do not expect regional air travel to be completely phased out. Since there is an uncertain amount of generated travel and possible market reactions, we believe that around ¾ of the current airline traffic between New York to Boston will switch to rails, in order to reach the modal shifts of similar implementations.

Assuming 32 flights between the cities every day and 132 people on each flight, ¾ of the all flights would amount to about 1.2 million passenger trips per year or about 3168 passenger trips per day. Therefore, assuming the lower load factor, no change in the electrical grid, the high speed rail implementation will save about 177 metric tons of CO₂ per day or about 65,000 Tonnes per year. The mode shift from road vehicles is expected to be much less significant. Additionally, the radiative forcing from aircraft is more complicated than total CO₂ emissions due to the potential cirrus cloud formation and ozone and methane precursor emission; the IPCC calculated that the radiative force is 2.7 times that of CO₂ alone, bringing the total reduction to about 175500 Tonnes of CO₂ equivalent per year⁴.

By itself, this number does not signify much, as it is a regional figure. However, assuming the federal government implements a carbon tax in the future, using a Social Cost of Carbon we can understand how much a difference emissions would make to the price of a single ticket. Employing a 3% discount rate, in 2040 the price of Carbon Dioxide is estimated to be about 65\$ per metric ton¹³. Applying this price to the CO₂ saved with each mode shift of 56 Kg CO₂, one receives around 36 cents of a ticket projected to cost around 163 dollars, assuming the lower bound load factor.

How we can alter the model – Possible policies

There are several policies that could help the government phase out regional air travel, and implement a high speed rail to reduce emissions. These policies are modeled and analyzed by researching the current European policies. However, there may be several challenges in implementing these in the United States.

Tax fuel for regional jets

Implementing a target tax on Jet-A fuel for regional jets will discourage frequent operation of regional jets. Airlines would be forced to levy the burden of the tax on the consumer, making ticket prices more expensive. A hike in ticket prices will cause a shift in demand, and elastic consumers would start looking at alternate modes of transport. The tax amount collected by the government could be used to fund the high speed rail and develop a cleaner, efficient transportation system. However, this policy will not be able to completely phase out the use of regional jets as there will be a more inelastic demand (such as business travelers).

Cap-and-trade for the emissions

This emission policy has already been implemented in the EU. The policy states that each company has the license to emit a certain quota of emissions. Excess emissions amounts could be sold to

other companies. This provides incentives for companies to reduce carbon emissions and keeps the total emissions in check. Most experts think the cap-and-trade for the emissions is still the best way to control the GHG emission from aviation. From 1990 to 2002, the GHG emissions by aircraft in Europe had reduce 3%, but the total GHG emissions by aircraft in the world had increase 70%.

Even though it is a good way to control the GHG emissions, the aviation companies in Europe face a big problem. They ended up losing their revenue when compared with other companies that don't have this kind of limit. This sort of policy would be much harder to implement in the north eastern part of the United States.

Additional tax on manufacturers of regional jets

An additional tax on manufacturers of regional jets might cause airliners to stop buying many regional jets. It can be argued that airlines should be encouraged to buy new aircrafts because they are more efficient. The scope of our project is to focus on passenger demand shift towards a cleaner, high speed rail. Therefore, we are trying to completely eliminate the use of regional jets. That is why we feel this tax policy will increase the chance of consumers opting for the high speed rail.

Trains must travel from airport-airport for easy connections

This regulation is more of a long term regulation. If policy makers can suggest that the rail network is connected from airport to airport, regional jets can be eliminated. A good example for this is if an individual were to fly from Grand Rapids, Michigan to Los Angeles. With the current model, a traveler will fly a regional jet to Detroit Metropolitan airport, and connect to Los Angeles on a much larger aircraft. If the rail system brings the traveler right into Detroit airport (rather than Detroit city), the traveler might chose to use it as the rail would be much cheaper, nearly as fast, and provide the same convenience for the traveler to make the connection.

Implementing code-share agreements between airlines and Train Company in order to share profits

If the rail company and airlines implement a code-share agreement, the airlines might be dissuaded from operating regional jets from spoke to hub routes. The code-share agreement would mean that the traveler will buy one ticket that will include the rail ticket from a spoke to hub, as well the airline ticket from hub to another hub. This would also mean that the airlines could share profits with the train company. This would eliminate competition between the spoke to hub sector for the airline and the train company.

Implementing the High speed rail⁵

Present High Speed Rail Conditions

The focus for high speed rails in this project is the Boston and New York Business Districts. As a result, we will look only at the Northeast Corridor (NEC). The NEC Main Line extends from New York to Boston to Washington D.C. with a multitude of regional, commuter lines branching off. All of these lines cater to business and freight traffic. Acela Express, a high speed rail that reaches speeds up to 150 mph, is accommodated on the Main Line and has more amenities than Regional. Acela Regional is accommodated on the regional lines. Acela Express and Regional trains provide a competitive alternative to air and auto travel, especially between NYC and Washington D.C. The NEC now handles 60% of the Boston-NY-DC air-rail travel market with 10 weekday trains serving the Boston-NY route.

City Pair	Ridership	% Total
New York - Washington	1,740,474	25.7%
New York - Philadelphia	1,548,212	22.9%
Philadelphia - Washington	701,136	10.4%
Boston - New York	663,919	9.8%
Albany - New York	623,829	9.2%
Baltimore - New York	378,961	5.6%
New York - Wilmington	308,087	4.6%
New York - Route 128	273,681	4.0%
BWI Airport - New York	266,923	3.9%
New York - Providence	263,432	3.9%
Total	6,768,654	100.0%

Source: Amtrak

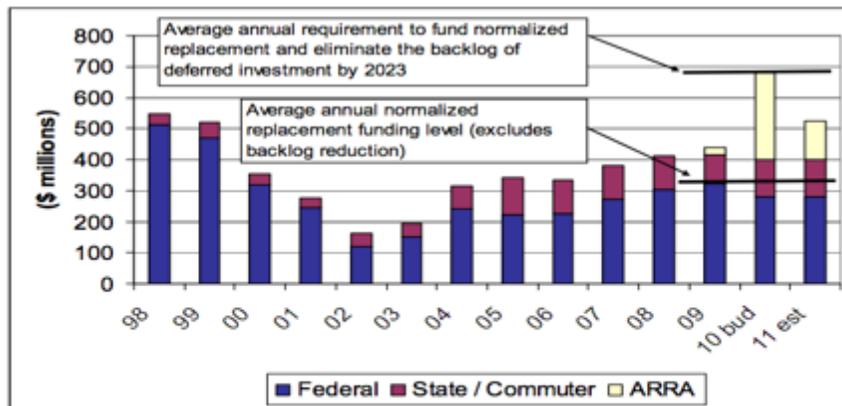
Figure 12: Ridership numbers for the most heavily used intercity Main Lines

When the NEC was conveyed to Amtrak in 1976, the condition of the rail network was not well maintained. The State of Good Repair (SGR) is a condition in which the existing physical assets, both individually and in a system, are functioning within their useful lives and sustained through regular maintenance and replacement programs. In order for the rail network to maintain SGR, Amtrak requires funding, much of which was lacking. Likewise, NEC has not been in SGR from 1976.

	Daily Trains	Thousands	
		Riders	Passenger Miles
Intercity			
Amtrak	154	13,092	2,354,556
Commuter			
MBTA / RIDOT	296	23,344	133,968
ConnDOT / Shore Line East	23	484	12,367
Metro-North	345	48,884	999,780
Long Island Rail Road	581	86,100	203,714
NJ Transit	387	57,980	850,657
SEPTA / DelDOT	374	17,830	203,810
MARC	83	8,000	159,416
Virginia Railway Express	29	3,825	72,121
Total Passenger	2,272	259,539	4,990,390
Freight	50		
(Pan Am, Conrail SA, P&W, CP, CS, NS, CSX)			

Source: Master Plan Working Group (2007-2008) Riders and passenger miles are annual figures.

Figure 13: Statistics for the current ridership population (as of 2010) in annual figures



Source: Amtrak Engineering Department, in year of expenditure dollars, except average annual amounts for Normalized Replacement and elimination of the Backlog of Deferred Investment. Higher Federal funding levels in 1998 and 1999 reflect approximately \$2.2 billion made available to Amtrak as a result of the Taxpayer Relief Act of 1997 (P.L. 105-34), a portion of which was used on the NEC. Figures represent funding required for Amtrak owned/operated portions of NEC Main Line and branch lines and exclude the New Haven Line, Hudson Line, and Washington, DC to Richmond line.

Figure 14: Capital Funding Trends from both federal and state/commuter governments

Funding for SGR has been increasing since 2004 as contributions from Northeast states and railroads have grown over the past decade and now account for about one-third of Amtrak’s NEC capital program.

The purpose of this analysis is to project the feasibility of having an Acela Express that can complement air travel by eliminating the need for short, inefficient flights that are both costly in diesel and harmful to the environment. Easy enough, the best way to examine this feasibility is to look at a plan that is already in the works.

The NEC Master Infrastructure Plan

The NEC rail network is among the most heavily utilized rail networks in the world. The vision of this network is to facilitate sustainable economic growth with affordable and efficient rail transportation, efficiently use land and fuel to move as much freight and business traffic as possible, reduce travel times and expand mobility options, and to link core urban centers and outlying area. Similar to all other aspects in business, growth will be constrained without investment to improve the condition and capacity of the NEC infrastructure. As a result, the Northeast Corridor Infrastructure Master Plan was created in 2007 as a collaboration between 12 Northeast states, the District of Columbia, Amtrak, and the Federal Railroad Administration (FRA), eight commuter and three freight railroads operating on the Northeast Corridor. The Capital Plan for the NEC Master Plan is outlined below:

<u>Cost Category</u>	<u>Total (Millions)</u>
MASTER PLAN PROJECTS	
SAFETY / POSITIVE TRAIN CONTROL	264
SGR BACKLOG	8,786
CORE GROWTH	32,245
SPECIAL ISSUE Baltimore Freight Tunnel	2,000
SUBTOTAL MASTER PLAN	43,295
SGR NORMALIZED REPLACEMENT	9,035
TOTAL CAPITAL	\$52,330

Note: This table should be read in conjunction with the accompanying discussion of cost estimates.

Sources: NEC Master Plan Working Group and individual railroads for estimate of state of good repair requirements; Master Plan projects are detailed in Part III, Capital Program Summary by Segment. All costs shown are order-of-magnitude for planning purposes stated in 2010 dollars.

Figure 15: Capital needs for various aspects of the Master Plans. Capital Investments will be needed in areas like protective railroad mandates such as positive train control, SGR needs, actual grown of the rail network, normalized replacement costs to maintain existing assets in good condition for Main Line and the branch lines.

Potential NEC projects that are to be included in the action plan for the Master Plan are to be geared towards increasing railroad capacity efficiently. Each have been evaluated to ensure the benefits justify the cost of investment:

- Tracks: Additional tracks to allow more train traffic, including passing tracks for higher speed trains to pass slower trains
- Bridges: Bridges with additional tracks to allow more train traffic and replacement of “moveable” bridges with high-level fixed structures, where feasible, to eliminate bridge openings due to boat traffic
- Curves: Modification of curves so that train speeds are not restricted
- Track and Platform: Improved layout at certain stations to move trains through more efficiently
- Passenger: Full train length high level station platforms to speed passenger boarding and disembarkation
- Signals: Upgraded signal system to allow trains to operate at closer spacing, greater speed and with improved operating flexibility
- Main-branch junctions: Redesign of Main Line - branch junctions to allow branch line trains to wait off of the Main Line for trains coming from the other direction
- High volume junctions: Redesign of very heavily used junctions to provide grade separated movement
- Train power: Adding additional power as additional cars are added to trains so that train performance is not degraded
- Yards: Adding maintenance and storage yards to reclaim Main Line capacity consumed by deadheading trains
- Side tracks: Construction of side tracks where trains that are reversing direction can be staged off of the Main Line to set up for the return trip

The Future of High Speed Rails

NEC ridership growth is projected to be 49%-165% in the next 20 years through 2030. The lower end of the range primarily represents secular growth without improvements; the upper end of the range assumes substantial investment in new rolling stock and infrastructure improvements. Forecasts prepared for the Master Plan fall between the lower and upper ranges, and are considered to be in the conservative to moderate range - a 77% increase in ridership for the Northeast region, from approximately 13 million riders in 2009 to 23 million by 2030.

	States / Amtrak	Commuter RRs	Totals
Riders (millions)			
2010	13	246	260
2030	23	389	412
% Change	76%	58%	59%
Average Weekday Trains			
2010	154	2,207	2,361
2030	210	3,084	3,294
% Change	36%	40%	40%

Source: Master Plan Working Group; See Section 6 for additional discussion of service plans.

Figure 16.

Looking ahead to 2030 to improve regional service, Amtrak service between Boston and NYC will include 15 weekday round trip Acela Express trains by 2030, up from 10 currently, providing approximate hourly express service between the two cities.

Current safety mandates, such as Positive Train Control (PTC), accounts for approximately \$264 million of the \$43 billion budget in NEC Master Plan Projects. PTC is a technology that can automatically bring trains to a stop and prevent collisions and derailments in many situations. This is planned to be installed on all trains by December 2015.

Environmental Assessment on High Speed Rails

Amtrak analysis states that electrified passenger rail in the northeast consumes half the fuel on a per passenger mile basis than all other competing modes of transportation. Rail is also an efficient user of land resources at a time when available land to expand transportation facilities for all modes is increasingly scarce.

NEC stakeholders' goals include close collaboration among the northeast states, the FRA, the NEC Commission and Amtrak and other rail operators. One of their goals is to propose improvements and mitigate potential negative impacts of increased rail construction on the land and water resources, wildlife habitat, historic structure, and residential neighborhoods.

Preliminary Estimated Benefits	2030 Compared to Base Year (2009)
Increased Rail Psgr Miles	4.3 billion
Vehicle (Auto) Miles Avoided	2.7 billion
Gasoline Saved	104 million gallons
Greenhouse Gas Saved	926 thousand tons of CO ₂ -e
Illustrative Value of Travel Time Savings	\$34 million
	Annualized
Jobs Created / Maintained	64,400

All values are preliminary estimates. Environmental values based on estimated increase in rail passenger miles. Estimated travel time savings are illustrative only and assume that reliability and congestion on the rail network improve as other modes remain relatively constant. Greenhouse gas includes carbon dioxide or equivalents (methane and nitrous oxide). Jobs estimate includes direct and indirect jobs including supplier industries.

Source: Amtrak.

Figure 17.

Federal View on the High Speed Rail Network⁷

In 2009, President Obama signed for the policy to develop America’s first nationwide program of high-speed intercity passenger rail service. It has been spurred by \$8 billion in Recovery Act grants. This policy was set to develop 13 new, large-scale high-speed rail corridors across the country.



Figure 18: High-speed rail corridors designated by the Federal Railroad Administration as of September 18, 2009

What the government should do is not only built this kind of high-speed railway, but also should consider lowering the price of ticket to take the high-speed rail. As we know, it will need a lot of money to build high-speed railway system, the price of the airplane tickets from Boston to New York is only about \$100. If the price of the tickets for high-speed railway becomes higher than an average airfare, consumers may still prefer aircraft. The purpose of the high speed rail is to complement the air travel and the environment by phasing out the need for regional air travel (trips that are under 500 miles) and replacing it with time and economic efficient rail travel. For example, if a passenger wants to travel from Detroit to New York City, the average flight requires you to fly from Detroit to Chicago O’Hare and then to Newark. In an effort to stem the massive energy sink, it is preferred to cut out that short flight from Detroit to Chicago and replace it with an efficient, environmentally friendly high speed rail.

Economic Costs and facts after implementation

We decided to make an economic cost table of the various costs involved in implementing the high speed rail systems. These are what we forecasts economic costs to be.

	Train	Aircraft
Cost of Project	\$151 Billion	-
Cost of Ticket	\$163 (adjusted PPP without subsidy)	\$220 + Fuel Tax
Travel Time	94 minutes	65 minutes
Frequency	Every 30 mins at peak	16 flights/day
Emissions Forecast (CO ₂)	17 kgCO ₂ /Passenger	79.2 kgCO ₂ /Passenger

Table 2. Economic costs and facts

The cost was forecasted based on the existing Amtrak proposal. The cost of ticket was modeled based on the current high speed rail from Barcelona to Madrid. Because of similarities in distances, we found the price of the ticket in Euros and adjusted it to the purchasing power parity (PPP) to determine the forecasted price of the ticket. The frequency and travel time was modeled based on the current capabilities of the Spanish rail service.

Consumer preferences and behavioral change

It has been shown that customers will switch to high speed rail if it can rival the speed of transport as the other alternatives⁸. Greater convenience of rail stations, less frequent delays, less intrusive security, more stable ticket prices and greater comfort generally makes for a superior traveling experience once there is no speed disadvantage.

However, there are a variety of other factors that will spur additional modal shift, not only through direct competition with air travel but through integration and cooperation between the transit modes. With rapid transit between Logan and Newark Airports for instance could conceivably be

linked by high speed rail transportation, allowing for better communication and route planning that could perhaps advance the sustainability of operations as a whole. In addition to the reduction of the travel time and streamlining a potential mode transition, additional measures to integrate infrastructure can be taken, such as improving the city mass transit to better connect transit hubs, or by offering integrated ticketing to make payment between rail, air, buses and subways more convenient.

There are many more stakeholders and operations to consider, however, it is generally observed that if there is enough demand to satisfy and sustain high frequencies for the high speed rail, the potential to both compete and cooperate with air travel is quite strong.

Conclusion and Recommendations

According to many studies looking into the solvency of High Speed Rail, researchers found that initiatives were generally successful if the current railroad in the region was in need of both added capacity and increased speed⁸. The North East Corridor, as of now at capacity with slightly less than half of the air/rail market, would benefit greatly in terms of ridership from the Amtrak planned improvements to the Acela line, and be able to more successfully compete with the current regional flight model between Boston and New York City

However, we cannot forecast enough mode switching between plane and rail to justify from an environmental and climate perspective alone. Serious environmental benefits can occur if this development is accompanied by greater renewable development in the Northeastern Grid, improvement of the load factor and perhaps the implementation of a carbon tax, or tax on regional jets to spur greater mode shift. However, these political developments, given the current climate, cannot be forecast to such a degree. Additional benefits can also manifest if the rail services reaches a high level of convenience among the mega regions of the Northeast corridor, allowing for cooperation instead of competition between the modes, meaning integrated service, smarter flight allocation and quite probably a higher load factor among both planes and trains. Unfortunately however, this effect is beyond the scope of this assignment to quantify.

What this development does is lay the foundation for a sustainable, high speed alternative network in the United States, beginning in the region both with biggest need or repair and the highest density of necessary economic activity, as well as a high growth projection. President Obama's 2009 High Speed Rail \$8 Billion stimulus package, allocated the funds across many regions in the United States (since then a few regions have refused the funding. These funds, numbering in the low billions, almost scale out of the necessary \$151 Billion necessary to complete the Amtrak Master Plan over the next 26 years; indeed, due to the high necessary funds and plethora of stakeholders who need to work together on a long time scale, a single administration will not be able to ensure construction of the High Speed Rail and the allocated funds might not be even able to stave off natural decay of the rest of the American rail system.

This makes construction of a single line, where past rail experience and economic activity can ensure success before moving on to convince separate regions, an important strategy. As people begin to observe the decreased congestion and location pollution and increased accessibility of urban areas and economic activity as well as the impact on regional aviation along the path of the rail, it may be more politically feasible to request more funding for the development of other regions.

Though Europe, with its more efficient energy grid, nationalized trains, and ability to build regional lines unilaterally before finally connecting the network, makes competition and cooperation between air and rail much more likely, the United States can still find success within High Speed Rail, if it begins with a committed development of the regions where it has a higher chance of success and lower barriers to entry from already existing lines. In conclusion, the Northeast Corridor, along with other regions of similar economic density, should be fully developed so the United States can realize the benefits of a fully integrated system in terms of accessibility, efficiency, and increased quality of life. In order to successfully prepare already congested regions for more sustainable growth, we must not shy away from these ambitious actions.

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