M^3 Challenge Runner Up (Magna Cum Laude Team Prize) - $15,000
North Carolina School of Science and Mathematics – Team # 808, Durham, North Carolina
Coach: Dan Teague
Students: Connor Davis; Mia de los Reyes; Alyssa Ferris; Sam Magura; Vitchyr Pong

Catching up to High Speed Trains

Team #808

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Contents

1 Summary Page

The High-Speed Intercity Passenger Rail Program (HSIPR) was a $53 billion initiative to bring high-speed rail travel to several regions of the United States. Though funding for the program was cut by Congress last November, legislators said that a smaller-scale version of HSIPR could receive funding in the future. Our goal was to build a mathematical model that could be used to identify the metropolitan regions that would be best suited for high-speed rail travel in order to revise HSIPR.

The metropolitan regions and high-speed rail networks we considered were those originally proposed by HSIPR. To determine the fraction of people who commute from city A to city B that would take a high-speed railway, we compared the net benefit $Q(A, B)$ of riding a high-speed train rather than driving in a car. Our function for $Q(A, B)$ accounted for the difference in travel times and the difference in monetary cost between the two modes of transport. We then created a function $P(Q)$ that gives the chance that a person who receives a benefit Q of travelling by high-speed rail will actually make the decision to switch. To determine the total number of commuters who would use the high-speed rail system each commute, we summed the number of commuters who would travel from A to B over all possible ordered pairs of cities A and B. We considered the ticket sales from these commuters as revenue.

Then, to calculate the costs of a regional high-speed rail network, we divided costs into locomotive and infrastructural costs. Monetary locomotive costs accounted for initial construction costs as well as continuing maintenance costs of the trains. Costs varied depending on whether the train was being used or not. To calculate infrastructure costs, we considered separately the prices of tracks and of stations. Track prices were largely dependent on the length of track needed to connect cities in a regional network, while station prices were dependent on the number of cities in the network. Total infrastructure combined with fiscal locomotive costs, therefore, yielded the total monetary cost of the regional rail network.

Environmental effects were measured by calculating the amount of diesel fuel saved for each person who switched from driving to riding the high-speed railway. We found that, on average, 107 gallons of foreign diesel were saved per person per year, potentially helping wean the United Statess dependence on foreign oil. These consistent fuel savings also added to the revenue incurred by developing rail networks.

We then prioritized the geographic regions based on the difference between benefit and cost. Despite ticket sales and oil savings, none of the regions made an estimated net profit from the proposed high-speed rail network. We ranked the regions in order from least to greatest net loss: Southeast, Florida, Pacific Northwest, Keystone, California, South Central, Chicago Hub Network, Empire, Northern New England, and Gulf Coast.

2 Introduction

High speed trains (HSTs) have long been touted as a potentially energy-efficient, cost-effective alternative to current transportation methods, particularly automobiles and air transportation. Despite these promises, phasing in the new infrastructure would be an expensive long-term venture, prompting the creation of the High-Speed Intercity Passenger Rail Program (HSIPR), a $53 billion plan intended to develop railway systems in ten identified metropolitan areas. However, with the current economic downturn, Congress recently cut off funding for HSIPR, with the caveat that a revised version could pass in the future.

Our mathematical consulting firm has therefore been hired to prioritize the ten HSIPR-identified regions in order of ability and need to support a high-speed rail line. In particular, we are investigating ridership numbers over the next 20 years to predict the demand for HSTs, as well as the financial costs of HSTs, including construction, maintenance, and environmental costs.

3 Plan of Attack

We divide the problem between the demand and the cost of establishing an HST system in a specific region. We incorporated the revenue a region would produce based off of the demand over 20 years. We then used these values to prioritize which regions deserve HSTs.

To establish the demand for a high-speed rail line, we first predicted the number of commuters between each city proposed in a given region. We then examined a passenger's benefit of riding an HST to predict what fraction of these commuters would travel via HSTs.

The demand will then be used to calculate the expected revenue from creating a high-speed rail line in a region.

The cost of the establishing a high-speed rail line in each region is divided into locomotive and infrastructure costs. We further subdivide locomotive costs into environmental costs and monetary (fiscal) costs, and we subdivide infrastructure costs into track costs and station costs. We consider maintenance costs as well as costs for initial construction.

The regions are prioritized by the difference between the benefit and the cost of making a high-speed rail line in each region.

4 Assumptions

- In considering an individual person's choice between taking a railway and another mode of transportation, we chose to ignore current railway usage–that is, we assumed that individuals would choose the most cost-effective method of transportation, regardless of what other people do. We reasoned that a rational individual would not treat a mode of transportation as a status symbol, so the popularity of the railway is unlikely to affect a personal decision to ride or not ride.

- We assumed that the tracks are laid in the shortest distance between the stations and that the cost of track is \$9 million per km [18], and that it costs the same amount everywhere regardless of topography.

- As noted in the problem description, Amtrak's Acela Express is the only existing high-speed rail in North America. Since the Acela Express runs on electric power, we decided that all rail systems would similarly.

- The weight of a passenger is insignificant compared to the overall weight of a train, making it negligible in calculating the environmental costs of a railway.

- We assume all locomotives are diesel powered since diesel is the most likely technology to be used to power the trains initially, while other sources of energy would be phased in later [2].

- All passenger cars and train stations, regardless of power source, are essentially the same in design and therefore cost the same amount to build. Once an initial fleet of trains has been built, no more trains are constructed; the initial fleet is merely upgraded as needed.

- On average, trains are filled to maximum capacity; we assumed that this would be the most cost-effective method of transporting passengers. Given that HSIPR was rejected because of economic difficulties, we thought choosing the most cost-effective method would not be that unreasonable.

- Percent growth per state is constant, growth given by US Census Bureau.

5 Ridership

NOTE: The term "cite" refers to the metropolitan area around the respective city.

To determine the number of riders from some initial city to a final city, we need three numbers: the number of long-distance commuters in the first city, the proportion of those commuters who travel to the final city, and the proportion of these commuters that use the high-speed rail line. The first number is determined using the population of the initial and the fraction of the total population that are intercity commuters. The second number is determined by analyzing the structure of the rail networks, and the third is determined by analyzing a person's time and money savings by switching to the high-speed rail line.

5.1 Number of Commuters in a City

Examine city A with a population of size $|A|$. The proportion of long-distance commuters in a given population is c. So, $c \cdot |A|$ is the number of long-distance commuters from city A.

The proportion c of intercity commuters is assumed to be constant throughout the nation. According to the U.S. Department of Labor, 242 million of the 311 million Americans were workers in 2012 [8]. According the U.S. Census Bureau, 2.3% of workers travelled for more than 90 minutes in 2009 [9]. If we assume that these statistics do not vary from year to year, and that the national fraction is similar to the fraction for individual cities, we can find c by multiplying the two proportions:

$$c = 0.023 \cdot \frac{242 \text{ million people}}{311 \text{ million people}} = 0.018\,. \tag{1}$$

The population $|A|$ of the city will vary from year to year. Assuming that these populations grow exponentially, a function for each city population can be written as

$$|A(t)| = |A|_0(1 + r)^{t}, \tag{2}$$

where $\mathbf{r}$ is the growth rate in number of people per decade, and $\mathbf{t}$ is time in decades. 2000 and 2010 populations from the U.S. Census Bureau are used to determine the growth rate [11]. In these cases,

$$\mathbf{r} = \frac{\text{change in population}}{\text{population in 2000}}$$

and $|A|_0$ = population in 2000. For Vancouver and Montreal, Statistics Canada is used to define these constants [12]. Using this approach, we can predict the number of long-distance commuters from each city over the next twenty years by $c \cdot |A|(t)$.

5.2 Proportion of City Commuters Travelling a Specific Path

Examine city B in the the hypothetical rail network below.

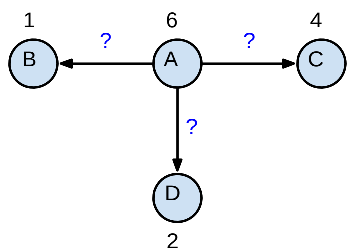

Figure 1: An example HST rail network, where A, B, C, and D are different cities. The numbers represents the number of intercity commuters from the city.

We want to know how many of the 6 intercity commuters from A will travel to each other city in the rail network. We assume that the number of intercity commuters from A to another city is proportional to the population size of that other city. In the figure above, workers from A are most likely to travel to C, which has more people and business opportunities than any other city in the network. Below is the distribution of the intercity

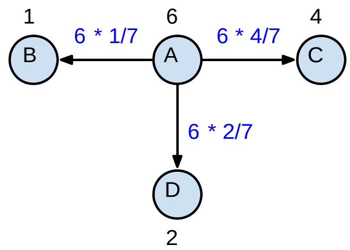

Figure 2: Figure: The distribution of the long distance commuters from B to other cities in blue. In this simplified case, 6 people in city A are intercity commuters.

commuters from A to other cities, calculated in this manner. The 7 in the denominator is a normalization coefficient, which will be defined later.

Formally, given a city A and the set of all cities in the region rail network G, the number of long-distance commuters from A and an adjacent city B is

$$L(A, B, t) = c \cdot |A(t)| \cdot \frac{|B(t)|}{\sum_{J \in G} |J(t)|} \quad ,$$

where t is the number of years that have passed since 2012.

Note that this is only the number of long-distance commuters from A to B, and not B to A. The total number of long-distance commuters between A and B at a given time is L(A, B, t) + L(B, A, t). The total number of commuters in the network (or desired sub-network) can be found by summing L for every possible ordered pair of cities in the network.

5.3 Benefit of HST commuting

We now want to see what proportion of these commuters will use an HST. We assume that people would convert to using an HST based on the amount of time and money saved. Let the function Q(A, B) represent the net benefit, in dollars, of riding the train instead of driving from city A to city B:

$$Q(A, B) = k \cdot \Delta t(A, B) + \Delta c(A, B), \tag{4}$$

where Δt is time saved from and Δc is the money saved from riding the train. Note that Δt and Δc can be negative or positive, with a positive value signifying a benefit from HST travel and a negative value signifying a loss from HST travel. Because we want to add two quantities that have different units — dollars and hours — we use a conversion factor k in our expression for Q(A, B) to convert Δt to a monetary amount. Specifically, k is the median income of the United States in dollars per year divided by the average number of work hours per year.

5.3.1 Time Difference

To find Δt, consider the difference in distance. While a car driver will typically take a direct route from one city to another, an HST rider may have to travel a longer distance to commute from one city to another. However, the difference in speed between HST trains and automobiles can still make an indirect commute by HST faster. We also must account for the number of times the train stops. Here we assume that leaving the train takes a negligible amount of time, and only account for the delay at the initial station and any intermediate stations.

$$\begin{aligned}\Delta t(A,B) &= \frac{\text{geographic distance from A to B}}{\text{car speed}} - \frac{\text{distance along tracks from A to B}}{\text{train speed}} \\ &\quad + (\text{delay per station}) \cdot (\text{number of stations}) \end{aligned} \tag{5}$$

Specifically, we used the following values: car speed = 100 km/hr [7], train speed = 250 km/hr [4], delay per station = 0.20 hr [17].

5.3.2 Cost Difference

To determine the cost benefit Δc, we made several simplifying assumptions:

- All train passengers purchase a pass that grants unlimited travel for a month. It is likely that HST commuters would purchase a monthly pass rather than buying tickets individually in order to save money.
- This monthly pass costs \$2466. [6] This is the cost for the Amtrak Acela, the existing HST corridor. Because a month for a commuter consists of two commutes per day, and each month has an average of 21 work-days, we divided the monthly cost to find the cost per commute as \$58.71.
- The only expense for a car commuter is fuel. The average highway fuel efficiency of cars used in the United States is 54.4 km per gallon. [5] Additionally, the average cost of gasoline in the United States is \$3.721. [1] Dividing the cost per gallon by the fuel efficiency, we find that the average cost of travelling by car at highway speeds is \$0.0684 / km.

Under these assumptions, the cost difference is

$$\begin{aligned}\Delta c(A,B) &= (\text{car cost per km}) \cdot (\text{geographic distance from A to B}) \\ &\quad - (\text{train cost per commute}) \end{aligned} \tag{6}$$

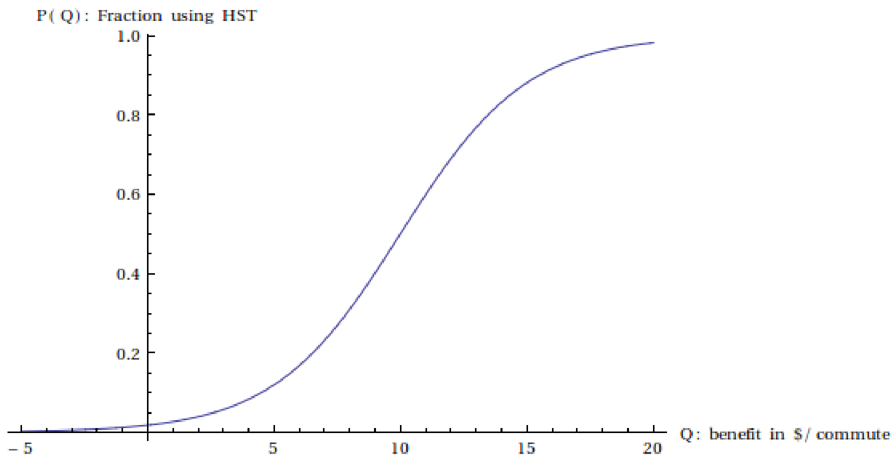

Figure 3: Plot of proposed P(Q) function.

5.4 Actual Proportion of HST Commuters

In order to convert the benefit of HST commuting Q into a probability, we created a function P (Q):

$$P(Q) = \frac{1}{1 + e^{\frac{10-Q}{2.5}}} \tag{7}$$

We made the function such that there would be a very low, but nonzero, fraction of people who decided to commute by HST even though they did not benefit from HST travel. For example, $P(0) = .017$ — that is, 1.7% percent of intercity commuters use HST when there is no net benefit or drawback to doing so. However, when $Q = \$20$ per commute, the percentage of intercity commmuters choosing HST over cars is 98.2.

5.5 Ridership Along a Specific Path

Now we use $P(Q(A, B))$ — the fraction of commuters who travel from A to B that use HST travel — along with $L(A, B, t)$ — the number of people who travel from A to B per commute with t years in the future — to find the number of commuters $R(A, B, t)$ who travel by HST from A to B in a given commute, after t years:

$$R(A, B, t) = L(A, B, t) \cdot P(Q(A, B)). \tag{8}$$

Substituting in our expressions for L and Q, we have

$$R(A, B, t) = c \cdot |A(t)| \cdot \frac{|B(t)|}{\sum_{J \in G} |J(t)|} \cdot P(Q(A, B)).$$

5.6 Total Ridership

To find the total ridership, we simply sum the ridership from A to B — $R(A, B, t)$ — over all *ordered pairs* of cities (A, B). We sum over all ordered pairs (A, B) rather than all combinations $\{A, B\}$ because $R(A, B, t)$ is the ridership from A to B, not the ridership *between* A and B. Thus, the total ridership after t years, $R(t)$ is given by

$$R(t) = \sum_{(A,B)\in G} R(A, B, t) \tag{10}$$

where G is the rail network. The nodes of the rail network are cities. Two cities are adjacent in the rail network if and only if there is a HST track between them.

5.7 Implementation

We wrote a procedure in the Python programming language to calculate $R(t)$ for each rail network for t between 0 and 20 years. We entered in proposed rail networks for each region using the following map. We used latitude and longitude data from the Wolfram—Alpha

Figure 4: Map displaying HSIPR-designated railway areas.

knowledge base (2012) to calculate the distance between cities. The Wolfram—Alpha knowledge base contains data curated by Wolfram Research.

5.8 Ridership Results

Below are the results of the Ridership numbers using the aforementioned method.

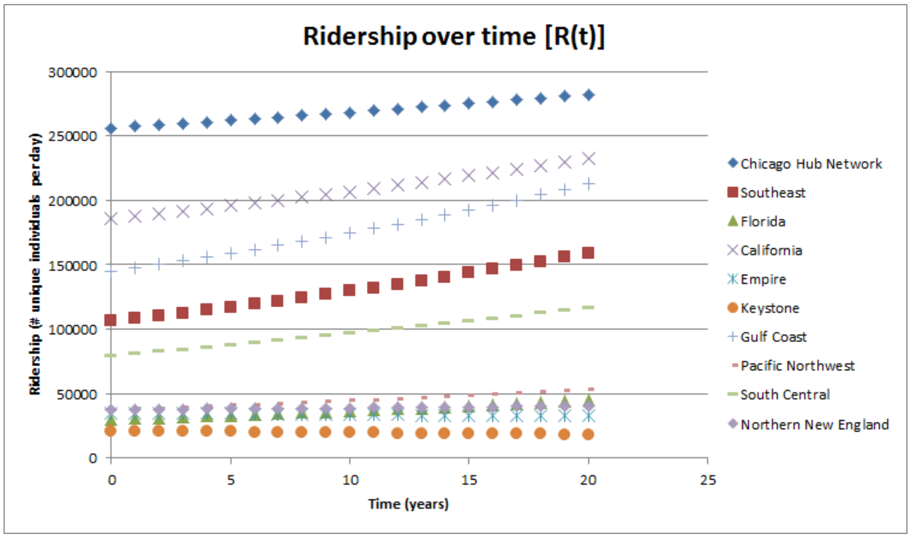

Figure 5: Plot of ridership number over 20 years for each region.

6 Environmental Benefit and Foreign Dependency

Any thorough transportation plan must account for environmental cost. To do this, we examine how many barrels of oil would be saved by having commuters switch from driving to riding high-speed trains. This change in oil consumption would also affect the dependence of the United States on foreign oil as an energy supply.

These costs measure the number of barrels of oil consumed as a function of ridership, since the total amount of diesel used depends on the number of active trains, which in turn depends on the number of passengers R(t).

We first determine a function for the number of active trains. Given that trains are, on average, filled to maximum capacity, we can write the number of active trains as

$$T_a(t) = \frac{R(t)}{24 \cdot s}, \tag{11}$$

where s is the number of available seats per train. Because t is in units of hours, we must convert R(t) from hours to days.

Because the Acela Express is similar in design to the French TGV models [23], we assume most US high-speed trains will be modeled after the TGV. The TGV Rseau has 377 seats per train, so we can set $s = 377$. Therefore:

$$T_a(t) = \frac{R(t)}{24 * 377}. \tag{12}$$

Using the number of active trains, we can calculate how many gallons of diesel fuel will be saved per year by the people who take the rail instead of driving a car. We find that the average number of gallons of diesel used by each locomotive is 215,116 gallons/locomotive every year (using data of Amtrak trains) [10]. Also, we know that the number of people who switch from driving to riding a train is equal to R(t), the ridership (because our assumption was that no one started out riding the train). Therefore, the volume of diesel used by each person per year who switches from driving to riding a train is:

$$B = (T_a(t)) \cdot \frac{215,116 \text{ gallons per locomotive}}{R(t)} \tag{13}$$

In the above equation, since $T_a(t)$ is a functions of R(t), this will cancel out with $\frac{1}{R(t)}$, making B a constant. On the other hand, the total amount of gasoline per year that the people who drove used before taking the train can be found by multiplying the number of people who switch from driving to taking the train R(t) by the liters of diesel fuel used per capita 497.9 $\frac{\text{liters per person}}{\text{year}}$ by the conversion factor of .264 gallons per liter [13]. Therefore, to find the number of gallons used we must divide this number by R(t), the number of people who drove. Once again, the R(t) cancels with $\frac{1}{R(t)}$ leaving us with a constant. This can be written out as

$$M = \frac{497.4 \text{ liters}}{\text{person}} \cdot \frac{0.264\text{gallons}}{\text{liter}}$$

Calculating these values of M and B gives M = 131.31 gallons/person each year and B = 23.77 gallons/person each year. Now, to look at the effect of the trains on oil consumption, we can take $M - B$. If this difference is negative, that means $B > M$ and more oil is consumed when the train is used. If this difference is positive, then $M > B$ and less oil is used to take the train. Therefore, we would want $M > B$ because that would decrease the US use of oil which would also decrease the environmental impact of commuters and the US dependence on foreign oil. We can find exactly how many barrels of oil would be saved by taking the train instead of driving per year because we know how many gallons of diesel are produced from a barrel of crude oil (10 gallons), what percentage of crude oil is imported (49%) and the current average cost for a barrel of oil (\$101.97) [14][15][16]:

$$\begin{aligned}
|M - B| \frac{\text{gallons}}{\text{year}} \cdot \frac{\text{barrel}}{10 \text{ gallons}} \cdot 0.49 \cdot \$101.97 \\
= (131.31 - 23.77) \frac{\text{gallons}}{\text{year}} \cdot \frac{\text{barrel}}{10 \text{ gallons}} \cdot 0.49 \cdot \$101.97 \\
= \$537.33
\end{aligned}$$

Because this number is positive, we know that on average the US government would save \$537.33 on foreign oil per person every year. This corresponds to saving 107.53 gallons of diesel per person per year, which creates less stress on the environment and less stress on the US to obtain foreign oil. Taking the sum of all the barrels of foreign oil saved over the next 20 years gives that the US would save \$6,162,110,299.11 on foreign oil alone.

7 Costs

7.1 Locomotive Costs

We first look at the cost of the train locomotives and train cars themselves. Fiscal cost, or monetary cost of the locomotives, includes a combination of construction and maintenance costs as a single function of time.

We first consider the cost of constructing the trains, which we assume to be an initial one-time cost. The TGV Reseau costs 33,000 Euros per seat to build and acquire [4], which translates to roughly $43,600 USD. Multiplying this by the number of seats per train (377 seats), we obtain a total acquisition cost of $16,437,200 per train.

We then consider the cost of maintaining the trains as a function on ridership, since more heavily used trains are more likely to need maintenance or upgrades. According to Railway Technical, current state-of-the-art trains can run for up to 90 days between repairs [3]. We assume that this is a best-case inspection rate for a train with no passengers (and therefore in very little need of repairs). A train used at maximum capacity is likely to need repairs much more often; for instance, every 7 days, as some heavy-use Chunnel Shuttle trains are [3]. Since we assume the trains are filled to maximum capacity, we can interpolate an inspection time of about 31.9 days/repair.

The average cost of maintenance is $3.91 per mile traveled, or $2.43 per km traveled. Again using the French TGV as a model, we use the fact that TGV trains are inspected and repaired every 4500 km to estimate the average cost of each repair: $2.43/km · 4500km/repair = $10,935/repair.

We divide this average repair cost ($10935/repair) by repair time interval (31.9 days/repair = 765.6 hours/repair) to obtain the maintenance cost per time, $14.28/hour. Combining construction and maintenance costs, we can obtain fiscal cost (in dollars) as a function of time for a single active train:

$$C_{active}(t) = \$14.28t + \$16,437,200. \tag{14}$$

Multiplying this by the total number of active trains $T_a(t)$, we can determine the cost for active trains as a function of time.

We assume the total number of trains is greater than the number of active trains, so that the number of inactive trains is $T_i = T_{total} - T_a$. The number of total trains for each region can be approximated from the fact that each Acela train carries an average of 8818 passengers per day [22], so the maximum ridership/day for each region, divided by 8818 passengers/day/train, yields an approximation for the total number of trains and therefore an approximation for the number of inactive trains. We choose to work with the maximum ridership values to ensure that we have enough trains, as ridership increases with time.

For a single inactive train, which has an equivalent average repair cost ($10935/repair) but a much longer repair time interval (90 days/repair = 2160 hours/repair), the maintenance cost per time is $5.06/hour:

$$C_{inactive}(t) = \$5.06t + \$16,437,200. \tag{15}$$

Multiplying this by the total number of inactive trains ($T_i = T_{total} - T_a$), we can determine the cost for inactive trains as a function of time.

The cost functions for active and inactive trains can then be added together to determine total train cost for each region.

7.2 Infrastructure Cost

7.2.1 Track Costs

Since we assume that all rail track will cost the same, ignoring such factors as topography, geographical features, and urban areas, the cost of laying track is completely dependent on the length of track required.

We calculated track costs for each region by considering the distance between cities in designated corridor regions, shown in the map earlier. For each region, we calculated total distance of the tracks displayed in the map. We then multiplied these distances by a fairly conservative construction cost estimate of $5.59 million/km [18] to obtain track construction costs. We also multiplied these distances by a maintenance construction estimate of $23,300 [19]. Adding construction and maintenance costs together yields total track costs for each region:

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

7.2.2 Station Costs

We then considered the cost of the stations in each region. Assuming each major city has its own station with a cost of $366,772 [21] and the maintenance cost per year is $36,677 [20], we obtain total station cost for each region.

Region	Number of stations	Station construction cost	Station maintenance cost (per year)	Total station cost (over 20 years)
Pacific NW	0,004.00	$1,467,088.00	$146,708.00	$1,613,796.00
California	0,005.00	$1,833,860.00	$183,385.00	$2,017,245.00
South Central	0,007.00	$2,567,404.00	$256,739.00	$2,824,143.00
Gulf Coast	0,011.00	$4,034,492.00	$403,447.00	$4,437,939.00
SE	0,004.00	$1,467,088.00	$146,708.00	$1,613,796.00
Keystone	0,005.00	$1,833,860.00	$183,385.00	$2,017,245.00
Empire	0,004.00	$1,467,088.00	$146,708.00	$1,613,796.00
NE	0,004.00	$1,467,088.00	$146,708.00	$1,613,796.00
Chicago	0,012.00	$4,401,264.00	$440,124.00	$4,841,388.00
Florida	0,003.00	$1,100,316.00	$110,031.00	$1,210,347.00

7.2.3 Total Infrastructure Costs

Finally, we can combine the total track costs and total station costs to obtain total infrastructure costs for each region.

Region	Total infrastructure cost (over 20 years)
Pacific NW	$3,605,704,370.91
California	$10,866,488,282.24
South Central	$8,221,887,974.39
Gulf Coast	$119,049,997,609.58
SE	$5,055,800,374.97
Keystone	$4,699,685,101.19
Empire	$15,991,070,248.41
NE	$26,413,233,235.58
Chicago	$19,697,866,741.53
Florida	$2,718,334,374.42

7.3 Total Costs

Combining the locomotive and infrastructure costs, we obtain the following graph of total cost for each region over time.

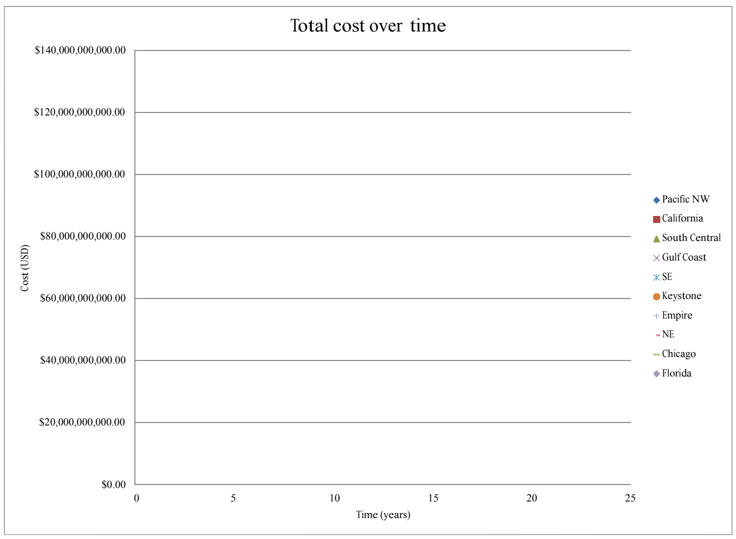

Figure 6: Total cost (locomotive and infrastructural) per region over time.

8 Cost-Benefit Analysis

In order to compare the importance of the different regions we calculated the profits and expenditures over 20 years. The profit for each year was calculated by multiplying the number of people who rode on a line by the cost of twelve rail passes. The costs per year was the sum of rail and station maintenance every year. Additionally, there was an initial infrastructure cost that includes building the track and stations. Finally, each person that rides the train saves 10.7 barrels of oil per year, so this savings was added into each region's profit. All of the regions lost money, particularly the Gulf Coast Region which built significantly more track but did not have a significantly higher number of passengers.

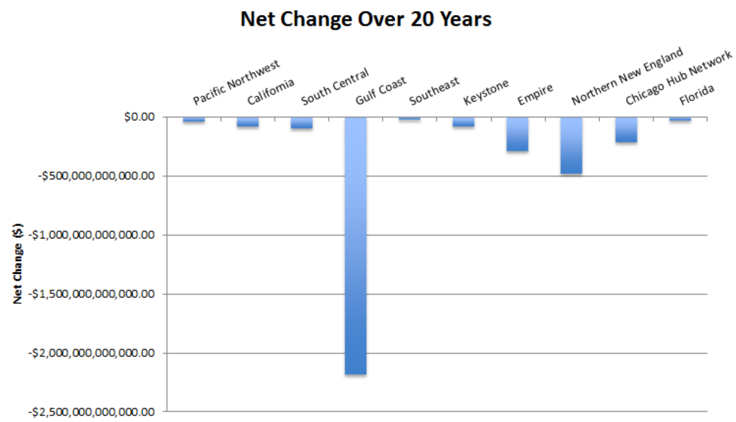

Figure 7: A plot of the net benefit of making each HST system by region. The negative values indicate that money would be lost.

We rated the regions according to the total profit that they produced, so the ranking from most profitable to least profitable was:

1. Southeast
2. Florida
3. Pacific Northwest
4. Keystone
5. California
6. South Central
7. Chicago Hub Network
8. Empire
9. Northern New England
10. Gulf Coast

9 Strengths and Weaknesses

9.1 Strengths

- Our model is fairly easy to modify and is not very sensitive to variable data. For example, if new regions were considered for the HSIPR program, it would be easy to evaluate that region's priority as long as certain values, such as population size and growth rate, are known.

- It is realistic and comprehensive in its estimation of potential costs, particularly since we used current data.

9.2 Weaknesses

- The model uses many average values such as population growth rate, maintenance costs, and employment rate. The model also assumes that these values will stay constant over the next 20 years.
- The model only takes into account commuter traffic, not leisure travel
- The model does not account for metropolitan reactions to the creation of a HST system. For example, we do not account for an increase in intercity commute that would probably accompany the establishment of an HST system.

10 Future Works

The ultimate test of the model would involve the construction of a multi-billion-dollar high-speed train system; however, that is obviously not a reasonable way to test our findings. We recommend two alternative ways to test the model. First, the model could be applied to the Amtrak Acela and European high-speed rail networks that are in current operation. If our model and assumptions are valid, the actual ridership, costs, and revenues of other high-speed rail networks should be close to those values predicted by the model. The model could also be tested on a smaller-scale transportation network. This could either be done on an existing network, or a new transportation system created to test the model. Though the model is best-suited for high-speed rail travel, it may be applicable to normal passenger trains, or even bus systems. Bus systems are similar to train systems in that there are well-defined routes. Additionally, both systems have possible environmental benefits despite high initial costs. Though applying the model to low-speed train or bus systems would require additional research, if successful, it would demonstrate the versatility of the model in addition to its validity.

11 Conclusion

Our goal was to build a mathematical model that could be used to identify the metropolitan regions that would be best suited for high-speed rail travel in order to revise the High-Speed Intercity Passenger Rail Program (HSIPR). The metropolitan regions and high-speed rail networks we considered were those originally proposed by HSIPR. To determine the fraction of people who would commute via high-speed railway, we considered the net benefit of riding a high-speed train rather than driving a car. We considered the ticket sales from these commuters as revenue. Then, to calculate the costs of a regional high-speed rail network, we divided costs into locomotive and infrastructural costs. Environmental effects, included in the locomotive costs, were measured by calculating the amount of diesel fuel saved for each person who switched from driving to riding the high-speed railway. We found that, on average, 107 gallons of foreign diesel were saved per person per year. Despite ticket sales and oil savings, none of the regions made an estimated net profit from the proposed high-speed rail network. We ranked the regions in order from least to greatest net loss: Southeast, Florida, Pacific Northwest, Keystone, California, South Central, Chicago Hub Network, Empire, Northern New England, and Gulf Coast.

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