M^3 Challenge Third Place (Cum Laude Team Prize) - $10,000
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High Speed Rails

A New Train of Thought

Summary

In 2009, President Obama declared a goal to provide 80% of Americans with access to high-speed rail in the next 25 years. This led to the creation of the High-Speed Intercity Passenger Rail Program (HSIPR), a costly plan to create a high-speed rail network in the US. The HSIPR-designated rail corridors contain over 44% of the nation's population. These areas are primarily centered around metropolitan centers, where travel by personal automobile is inefficient due to high traffic congestion. Yet because of the exorbitant prices advocated by the plan, the initiative was killed by a bill in November 2011.[3] Now though, most members of Congress are interested in another attempt to make high-speed rail work for America, but only if the price would be reasonable and commuters would utilize the trains.

The predicted ridership rates for each corridor were modeled based on regional population and GDP per capita. The most cost-effective and therefore highest ranked region is Florida, while the Chicago Hub is projected to be the least worthy of having a high-speed rail system. However, values predicted with these methods were extrapolated from forecasts from known data, so this is analogous to making a prediction on a prediction, which leads to an elevated level of uncertainty. To lessen the uncertainty and strengthen our predictions, feasibility data of each reason was considered. These considerations included environmental clearance, precedents for high-speed rail, private sector involvement, market share increase, and former funding from state and federal sources. One of the main motivations to switch to high-speed rail would be the faster commute times for distances of 100 to 500 miles.[18]

It is difficult to determine with great certainty what the cost of installing high-speed railroads would be. A typical track would cost about $39.3 million per mile. However, many factors can raise or lower the price of railroads. Tracks in mountainous areas or areas with abundant seismic activity cost more to lay, and cutting-edge magnetic levitation trains are far more expensive. Conversely, trains built on existing tracks can be built relatively cost-effectively. Maintenance would be about $200,000 per mile per year for high-speed rail.

Investors will be compensated for these expenses, however, as the new high-speed rails will not only provide quicker transport for Americans, but it will also reduce our dependence on foreign energy. Thanks to a transfer of travelers from less energy-efficient passenger vehicles to the more energy-efficient high-speed rails, we reduce the total amount of gasoline we need. This results in a savings of over 10 million barrels of crude oil annually, which means 10 million fewer barrels imported from foreign nations, such as volatile OPEC nations in the Middle East.

Ultimately, our team believes that the US should continue its efforts to spread high-speed rail, but only to select rail corridors of the US.

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Introduction

The Passenger Rail Investment and Improvement Act (PRIIA), passed in 2008, created a framework to build a high-speed railroad network connecting US cities. To this end, it organized Amtrak, the U.S. Department of Transportation (US DOT), the Federal Railroad Administration (FRA), and other associations to develop high-speed rail corridors nationwide.[2]

In 2009, the Obama Administration worked with Congress to pass the American Recovery and Reinvestment Act (ARRA), a $10.1 billion initiative (comprised of $8 billion initially, followed by $2.1 billion in subsequent annual funding) to “ensure America is equipped to win the future with the fastest, safest, and most efficient transportation network in the world.”[3]

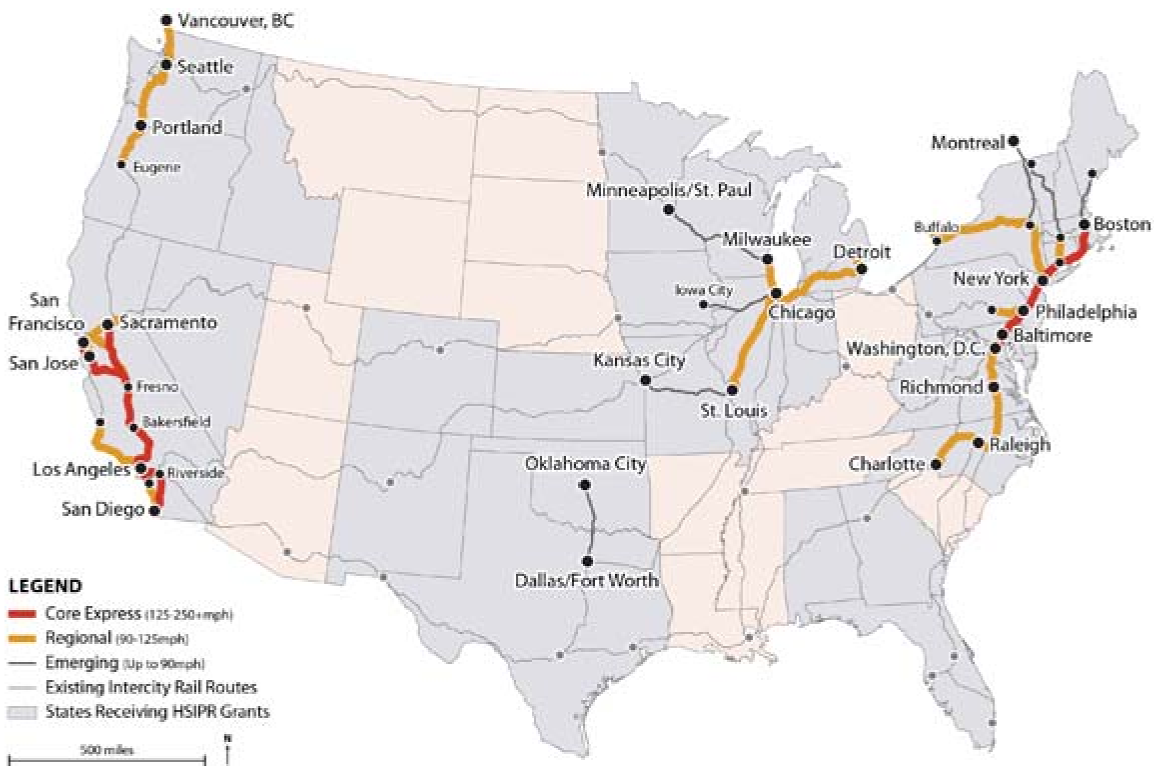
Additionally, the High-Speed Intercity Passenger Rail Program (HSIPR) was launched by the FRA in 2009. Its main objectives were as follows:

1.) Develop new high-speed rail corridors to speed and enhance commuter transport.

2.) Improve existing intercity rail service, focusing on reliability, speed, and frequency.

3.) Preparing for future high-speed rail services through corridor and state planning efforts.[1]

Figure 1: High-Speed Intercity Passenger Rail Program Map



On November 1, 2011, the California High Speed Rail Authority announced that their rail project would likely cost $98.5 billion, a 129% increase from the original expected price of $43 billion. Furthermore, the project would take 14 years longer than originally projected.[4] This announcement convinced Republicans in Congress to rise up in opposition to President Barack Obama's high-speed rail initiative, passing a bill that would eliminate any funds specifically for high-speed rail,[5] a death sentence for HSIPR.

More recently though, legislatures have become receptive to the possibility of reopening HSIPR. Now they are attempting to determine whether a high-speed rail network is an economically practical option for America.

Restatement of the Problem

Our consulting firm has been asked to analyze the benefits of high-speed rail. Factors to consider include:

1) Ridership Rates: How many commuters will switch to rail travel over the next 20 years? Will changes in rail travel times influence potential riders' chosen mode of transportation?

2) Cost: How much will it cost for the government to build and maintain high-speed rail lines?

3) Foreign Energy: How will a high-speed rail network influence our dependence on foreign energy?

4) Rail Corridors: Which geographic areas are most deserving of funding?

Assumptions

1.) The data used in our models, which was accumulated from outside sources, is accurate.

2.) Percent annual change in GDP is +4.7% (based on the average percent change in GDP from 1990 to 2011).[6]

3.) GDP growth is constant for all geographic areas.

4.) Trends in ridership of the Acela Express in the Northeast hold true throughout other regions.

5.) The four assumptions required for multiple regression models: variables are normally distributed, there is a linear relationship between independent and dependent variables, there is relatively low error in measurements, and there is homoscedasticity.[19]

6.) As people transition into using the high-speed rails, there is a decrease in usage for alternative forms of transportation that is proportional to the amount for which they were previous being used (in passenger miles).[17]

Modeling Ridership Rates

Building a model to predict rates in the different regions, we began by selecting variables that would impact ridership. The most critical variables were decided to be population and GDP per capita. Secondary values which were considered but rejected from the model include rail distance between cities, competition from other trains, population density, and auto congestion. The variables that were excluded were based on the premise that they would add unnecessary complexity, their impact would be relatively minimal on ridership, and they would be difficult to accurately quantify or compare between regions. Too much interaction was also a prime motivator in discarding them. We then researched each region's population data from 2000 and 2010, and predictions on its population in 2025 and 2050.[7-8] Due to very similar social, economic, and topographic situation data, the Keystone corridor, the Empire corridor, and the Northern New England Corridor were combined to form the North East Corridor. Using these four data points, we determined that each region required an exponential graph, which we calculated. We formed an exponential model predicting the population of each region over the next 20 years. Recorded GDP's from 2005 for each region, combined with the average growth rate of +4.7%, gave us GDP data from each year. Assuming that this rate is constant among all regions, we calculated each year's yielded GDP per capita (by dividing by population), the second variable deemed necessary for the multiple regression.

So, after eliminating several variables, our final model predicted a region's ridership (per year) using its population and its GDP per capita as predictors. Since reliable and substantial data was only found for the Northeast Region (because it is the only region with a considerably large enough high-speed rail system, the Amtrak Acela), we first used a multiple regression analysis on the said data from this region. This produced the equation: ridership = 0.01357 * Population + 47.0956 * (GDP per capita) - 493082, where ridership is measured in high-speed train riders per year. Since the significance of the F-value was less than 5% (1.8%), the test showed that there is some relationship between the population or GDP per capita and the ridership, therefore this model is applicable. Even though we only had a few data points, the standard error associated with the ridership is only 61,025 which is relatively small for a value that is projected to be in the millions. All data is shown on pages 14 - 18 and note that all Year values are given in the number of years after 2000.

Using this general equation that relates population and GDP per capita to ridership, we calculated the ridership in every region by assuming that these are the only two considerable effects on ridership and therefore the model can be applied to any region. Thus, we calculated the predicted ridership values for each region in 2032 by using the predicted populations and GDP per capitas of each region.

Changes in Travel Choices due to Improved Rail Travel Times

As train travel times are improved with the transition from commuter to high-speed rail, more people will begin to choose railroads their primary mode of transportation. This concept and the projected numbers associated with it are explored in the previous section.

By using the projected numbers, along with the percentage passenger miles for each form of major transportation, it can be determined how much each alternative mode of transportation will suffer as more and more people transition into using the high-speed railroads. Therefore, since 82.18% of all passenger miles traveled in 2005 were by passenger vehicles, it is assumed that the same proportion of newly travelled passenger miles would be ex-passenger vehicle passenger miles. This holds true as well for the percentages of miles traveled by plane (10.61%), by trucks (4.05%), by buses (2.96%), as well as by the older and slower rails (~0.60%).[17]

Cost to Build High-Speed Railroads

The fundamental difficulty in building a high-speed rail system is that it's a relatively new technology. The first modern high-speed rail line was opened in Japan in 1964.[11] Therefore, exact data on the price of building high-speed rail lines is scanty at best. In pioneering a new field, many such values are based on vague and uncertain conjectures. That is why when the California High Speed Rail Authority estimated that constructing a high-speed rail corridor would cost around $43 billion they were so cataclysmically wrong. Later assessments set the price at a staggering $98.5 billion.[4]

Furthermore, there are many factors that influence construction cost per mile. For instance, most of the prices per mile in European routes hover around $40 million. However, the Madrid to Valladolid route was $53 million per mile.[9] This makes sense when one considers that this route must scale the Sistema Central, a spine of mountains that runs through the middle of Spain.[12] The average cost per mile of non-mountainous European rail is $39.3 million.

Likewise, Japan's Takasaki to Nagano route is 75% more expensive than its Yatsushiro to Kagoshima route.[9] This can be explained by Mikuni-sanmyaku, a Japanese mountain range between Takasaki and Nagano.[13] Because passenger lines cannot exceed gradients of 3.5%, traversing mountain ranges is complicated, and may require tunnels, viaducts, and switchbacks.[11]

Additionally, Japan's routes are far more expensive than Europe's routes. Japan's cheapest route cost $83 million per mile, whereas Europe's most expensive route cost only $53 billion per mile.[9] This discrepancy is due to Japan's propensity toward earthquakes.[14]

Table 1:

Estimated Construction Costs for High-Speed Rail Projects in France, Japan, and Spain

High-Speed Rail Project	**Approximate Construction Cost (in billions of dollars per route mile)**
Europe:	
Cordoba-Malaga (Spain)	37
Madrid-Barcelona-Figueras (Spain)	39

Paris-Strasbourg (France)	42
Madrid-Valladolid (Spain)	53
Japan:	
Yatsushiro-Kagoshima	82
Takasaki-Nagano	143

Source: GAO analysis of data provided by French, Japanese, and Spanish officials.

Continuing onto American estimated construction prices, we find that high-speed trains are much cheaper if the railroad tracks already exist. In almost all cases, if the tracks already exist, the trains will cost less than $10 million per mile. The median price of these trains was $3.4 million per mile.[9]

The most expensive American train is a magnetic levitation train from Baltimore, Maryland to Washington, D.C. Not only is this a more complex technology, but also it is through a densely populated area and would thus cost more to simply purchase the land on which to construct the train.[9]

Table 2: Estimated Construction Costs for High-Speed Rail Projects in the United States

Rail Line Corridor	**Estimated Cost to Build**	**Technology**	**Distance (mi)**	**Estimated Construction cost per mile (in millions)**
Washington, D.C. - New York - Boston	$3800 million	Electrified Locomotives on Existing Railroad Right-of-way	458	$8.3
New York City - Albany / Schenectady	$97.2 million	Diesel Locomotives on Existing Railroad Right-of-way	158	$0.6
Harrisburg - Philadelphia	$145.5 million	Electrified Locomotives on Existing Railroad Right-of-way	104	$1.4

Chicago - Detroit	$39 million	Positive train control and Diesel Locomotives on Existing Railroad Right-of-way	304	$0.1
Baltimore - Washington	$5150 million	Magnetic Levitation	40	$128.8
Anaheim, California - Las Vegas, Nevada	$12000 million	Magnetic Levitation	269	$44.6
Victorville, California - Las Vegas, Nevada	$3500 million	Dedicated right-of-way, steel-wheel on steel-rail system	183	$19.1
Los Angeles, California - San Francisco, California	$33600 million	Dedicated right-of-way, steel-wheel on steel-rail system	520	$64.6
Eugene, Oregon - Vancouver, Canada	$6800 million	Nonelectric locomotives on Existing Railroad Right-of-way	310	$21.9
Scranton, Pennsylvania - New York City	$551 million	Diesel Locomotives on Existing Railroad Right-of-way	133	$4.1
Chicago, Illinois - Minneapolis/St. Paul, Minnesota	$1500 million	Diesel electric on Existing Railroad Right-of-way	441	$3.4
Chicago, Illinois - St. Louis, Missouri	$125 million	Diesel Locomotives on Existing Railroad Right-of-way	284	$0.4
Washington, D.C. - Chalotte, North Carolina	$5300 million	Diesel Locomotives on Existing Railroad Right-of-way	452	$11.7

Source: Analysis of GAO data from information provided by project sponsors

In summary, we would expect a typical construction project that includes laying railroad track to cost about $39.3 million. If the track already exists, it would probably only cost about $3.4 million per mile. However, in areas that are prone to seismographic activity or in areas that are more mountainous, those prices will be much greater.

Seismic activity is common in the Pacific Northwest and Californian rail corridors.[16] The Appalachian Mountains interrupt the Northeast corridor.[15] Those three corridors would experience higher construction costs.

Cost to Maintain High-Speed Railroads

Cost of maintenance will be higher for the higher-speed railroads. In fact, railroads are separated into classes (going up to class 9). In the United States, most high-speed railroads would be classified as either class 7 or class 8, meaning that maintenance costs will generally be around $200,000 per mile per year to maintain.[15]

Lower Dependence on Foreign Energy

With more efficient high-speed railroads being utilized, energy is being saved. How much energy exactly is dependent on not only how much more efficient high-speed railroads are, but also the composition of a barrel of crude oil. A barrel of crude oil contains 42 gallons of oil, only 19.5 of which can be turned into gasoline. Gasoline is therefore the limiting factor.[20] This is because, as previously mentioned, just over 80% of the transportation in passenger miles being replaced is by passenger vehicles, which run on gasoline. Therefore, the number of barrels of crude-oil being saved is dependent on this factor.

Our calculations show that with a sum total of 34,747,432 projected passengers utilizing the high-speed rail in 20 years, as well as an average of 2580 passenger miles per year travelled via high-speed train per passenger, then the total annual amount of passenger miles being 'saved' from passenger car use is = to 43,747,432 passengers x 2580 passenger miles per passenger per year x 82.18% of these being done via train instead of car = 3.15 x 10^{10} passenger miles per year[21 22].

The energy savings from these passenger miles is calculated by understanding that because the average BTU per passenger mile for passenger vehicles is 3,538 BTU, which is 391 BTU higher than the 2,435 BTU per passenger mile for high-speed trains, there is a total savings of 391BTU / passenger mile x 3.15 x 10^{10} passenger miles / year = 2.23 x 10^{13} BTU's saved per year of gasoline.

Now, because there are ~111,400 BTU's of energy per gallon of gasoline[23] that means that there are (2.23 x 10^{13} / 111,400) a total of 195,614,035 gallons of gasoline being saved. At ~19.5 gallons of gas produced per barrel (42 gallons) of crude oil, that means that 195,614,035 gallons of gasoline saved / 19.5 gallons per barrel = 10,031,489 barrels of crude oil being saved annually.

These roughly 10 million barrels that we save can be taken out of our annual imports of crude oil, thereby directly decreasing our dependence on foreign energy by decreasing our demand for oil.

Ranking of HSIPR-identified Regions

Using the projected ridership in 20 years of each of the ten corridors, and the distance of the projected length of railroad for each, we compared the relative cost effectiveness of the corridors in terms of people served. Let the cost-effectiveness score of each corridor equal R/L, where R is the projected annual ridership of high-speed rails in the corridor in 2032, and L is the estimated length of railroad in the corridor. Since the length of the corridor is approximately proportional to the cost of building, we can use this score to compare the cost effectiveness of the various corridors.

From the projected ridership data, we calculate the cost-effectiveness scores:

California	Chicago Hub	Southeast	Pacific Northwest	Northeast	Gulf Coast	Florida	South Central
7064	1870	6929	11174	5972	4215	12313	4648

We note that high population areas like Chicago did worse than could be expected, because distances between cities was larger than average and and tended to be unsuited to high-speed rail, which exhibits the greatest advantage over other forms of transportation at distances between 100 and 500 miles[18]. In order of cost effectiveness, the corridors are as follows:

1.) Florida (12313)

2.) Pacific Northwest (11174)

3.) California (7064)

4.) Southeast (6929)

5.) Northeast (5972)

6.) South Central (4648)

7.) Gulf Coast (4215)

8.) Chicago Hub (1870)

Using information present in America 2050's report *Amtrak High Speed Rail – A National Perspective*,[18] we derive the following chart featuring key parameters by which to evaluate the current feasibility of high-speed rails in each of the 10 designated corridors. This, along with the benefit to commuters determined previously, will be used to rank the ten HSIPR-designated regions in order from most to least deserving of high speed rail funding.

Our first criterion is Preparations for High Speed Rail Service, which designates whether or not the region has a previous system in place where trains regularly exceed 125+ mph. This demonstrates the technical and logistic capability to support a high-speed rail system. Environmental Clearance in the form of an approved Environmental Impact Statement indicate the degree of preparation for a high-speed rail system and the immediacy with which such a plan will be implemented. Existing State and Federal Funding demonstrate the capacity of the project to obtain additional funding. Private Sector Involvement and Rail Market Share Increase indicate public interest which in turn suggests the likelihood of a successful high-speed rail line.

Table 3: Evaluation of High-Speed Rail Feasibility among Corridors

Corridor Evaluation Criteria	**California**	**Chicago Hub Network**	**Southeast**	**Pacific Northwest**	**Keystone**
Preparations for High Speed Rail Service	Yes	No	No	No	No
Environmental Clearance	EIS Complete	No EIS	EIS Underway	EIS complete	EIS not needed
State Funding	Yes	Yes	Yes	Yes	Yes
Federal Funding	Yes	Yes	Yes	Yes	Yes
Private Sector Involvement	Yes	Yes	Yes	No	No
Rail Market Share Increase	No	Yes	Yes	Yes	Yes
Corridor Evaluation Criteria	**Empire**	**Northern New England**	**Gulf Coast**	**Florida**	**South Central**
Preparations for high speed rail service	Yes	No	No	No	No

Environmental Clearance	Planning	Planning	Planning	EIS complete	No EIS
State Funding	Yes	Yes	No	Yes	No
Federal Funding	Yes	Yes	Yes	Yes	Yes
Private Sector Involvement	No	No	No	No	No
Rail Market Share Increase	Yes	Yes	No	No	No

Conclusion

The information from this table supports the previously determined rankings, but some key differences merit the adjustment of some rankings. The top three corridors in terms of cost-effectiveness all have their Environmental Impact Statement completed and approved, as well as state and federal funding. Notably, California has precedents for a high-speed rail service, as well as attained public sector involvement, so as it is more prepared than the previous regions to begin construction; it is moved to the first rank. Florida and the Pacific Northwest remain at the second and third ranks, respectively. The Southeast has obtained funding from federal, state, and private sources, and is underway with the EIS, so its position in the fourth rank is justifiable. Aside from the Keystone and Empire regions in the Northwest, ranked fifth, each corridor is missing key steps that will limit the current feasibility of a rail system. Chicago Hub Network, South Central, and Gulf Coast all lack a complete EIS, and South Central and Gulf Coast lack state funding. As such, Chicago Hub Network will be moved to 6th, and South Central and Gulf Coast take 7th and 8th. The movement of California and Chicago Hub Network up the ranks stem from the feasibility of building a high-speed rail service within the next few years. As well, the higher population of people served may justify the lower cost-effectiveness.

Data

Florida		GDP 2005	$608,082,000,000		
Year	**Population**	**GDP**	**GDP per capita**	**Ridership (per year)**	
					population =
0	**14,686,285**	$483,313,292,382	$32,723.49	1,247,372.10	$14{,}758{,}310e^{0.0150*years}$
10	**17,272,595**	$765,060,106,046	$44,628.95	1,843,167.89	
12	17,661,226	$838,665,773,788	$47,486.27	1,983,009.59	
17	19,027,239	$1,055,169,739,989	$55,455.74	2,376,876.24	
22	20,498,908	$1,327,564,823,779	$64,762.70	2,835,166.82	
27	22,084,403	$1,670,279,476,886	$75,631.63	3,368,563.64	
32	23,792,528	$2,101,466,897,085	$88,324.65	3,989,531.79	

Pacific Northwest		GDP 2005	$337,405,000,000		
Year	**Population**	**GDP**	**GDP per capita**	**Ridership (per year)**	
					population =
0	**7,400,532**	$268,174,886,637.70	$36,289.05	1,316,411.40	$7{,}389{,}800e^{0.00903*years}$
10	**8,367,519**	$424,507,064,969.14	$52,483.84	2,092,238.73	
12	8,235,742	$465,348,465,182.76	$56,503.53	2,279,760.11	
17	8,616,107	$585,479,501,319.27	$67,951.74	2,824,082.84	
22	9,014,040	$736,622,707,738.88	$81,719.48	3,477,883.57	
27	9,430,352	$926,783,964,825.22	$98,276.71	4,263,306.43	
32	9,865,891	$1,166,035,893,861.73	$118,188.61	5,206,980.41	

California		2005 GDP	$1,658,507,000,000		
Year	**Population**	**GDP**	**GDP per capita**	**Ridership (per year)**	
					population =
0	**34,583,523**	$1,318,207,870,994.28	$38,298.23	1,779,963.79	$34{,}418{,}346e^{0.01123*years}$
10	**38,399,247**	$2,086,655,321,648.39	$54,184.40	2,579,919.43	
12	39,384,986	$2,287,410,343,488.86	$58,078.23	2,776,680.18	
17	41,659,719	$2,877,911,860,507.43	$69,081.40	3,325,753.86	
22	44,065,832	$3,620,853,031,650.06	$82,169.18	3,974,786.07	
27	46,610,913	$4,555,586,589,263.30	$97,736.48	4,742,479.54	
32	49,302,988	$5,731,624,286,009.23	$116,253.08	5,651,066.78	

South Central Triangle		**2005 GDP**	**$817,510,000,000**		
Year	**Population**	**GDP**	**GDP per capita**	**Ridership (per year)**	
0	**16,131,347**	$649,770,014,004.48	$39,787.88	1,599,685.94	population = $16{,}331{,}545e^{0.01698*years}$
10	**19,728,244**	$1,028,552,542,739.21	$53,146.47	2,277,633.84	
12	20,021,687	$1,127,508,554,323.60	$56,314.36	2,430,810.10	
17	21,795,772	$1,418,578,109,759.82	$65,085.01	2,867,946.93	
22	23,727,056	$1,784,788,102,735.92	$75,221.64	3,371,548.89	
27	25,829,468	$2,245,536,251,935.41	$86,936.99	3,951,824.31	
32	28,118,171	$2,825,227,852,553.77	$100,476.94	4,620,558.73	

Chicago Hub		**2005 GDP**	**$2,072,869,000,000**		
Year	**Population**	**GDP**	**GDP per capita**	**Ridership (per year)**	
0	**53,768,125**	$1,647,549,411,211.43	$31,073.34	1,699,968.88	population = $52{,}158{,}201e^{0.00511*years}$
10	**55,525,296**	$2,607,986,056,091.40	$46,429.70	2,447,031.03	
12	55,481,751	$2,858,897,786,561.89	$50,312.69	2,629,311.58	
17	56,540,328	$3,596,930,420,178.02	$61,500.91	3,170,592.43	
22	57,619,103	$4,525,488,287,274.90	$75,177.10	3,829,319.65	
27	58,718,460	$5,693,756,021,349.10	$91,894.51	4,631,554.48	
32	59,838,792	$7,163,615,409,591.67	$112,329.43	5,609,152.48	

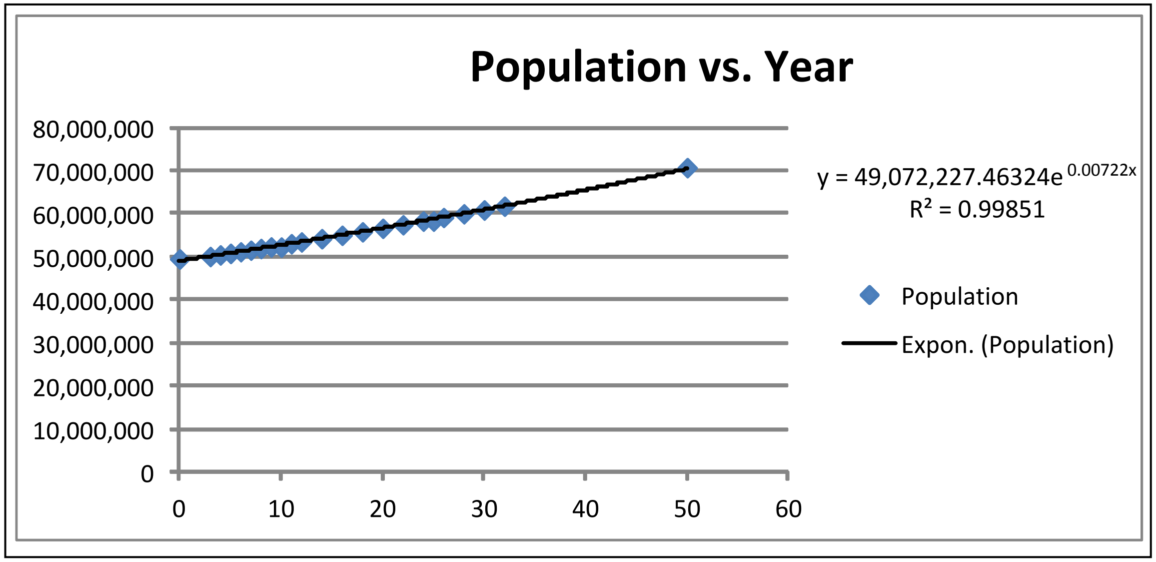
Gulf Coast		**2005 GDP**	**$524,122,000,000**		
Year	**Population**	**GDP**	**GDP per capita**	**Ridership (per year)**	
0	**11,747,587**	$416,580,542,476.61	$35,712.20	1,348,242.65	population = $11{,}664{,}737e^{0.01401*years}$
10	**13,414,934**	$659,425,592,109.65	$49,140.41	2,003,281.41	
12	13,800,537	$722,868,268,900.93	$52,379.72	2,161,072.25	
17	14,801,929	$909,478,778,294.50	$61,443.26	2,601,516.01	
22	15,875,984	$1,144,263,323,974.21	$72,075.11	3,116,806.57	
27	17,027,974	$1,439,658,171,076.67	$84,546.65	3,719,795.97	
32	18,263,554	$1,811,310,042,123.26	$99,176.21	4,425,552.94	

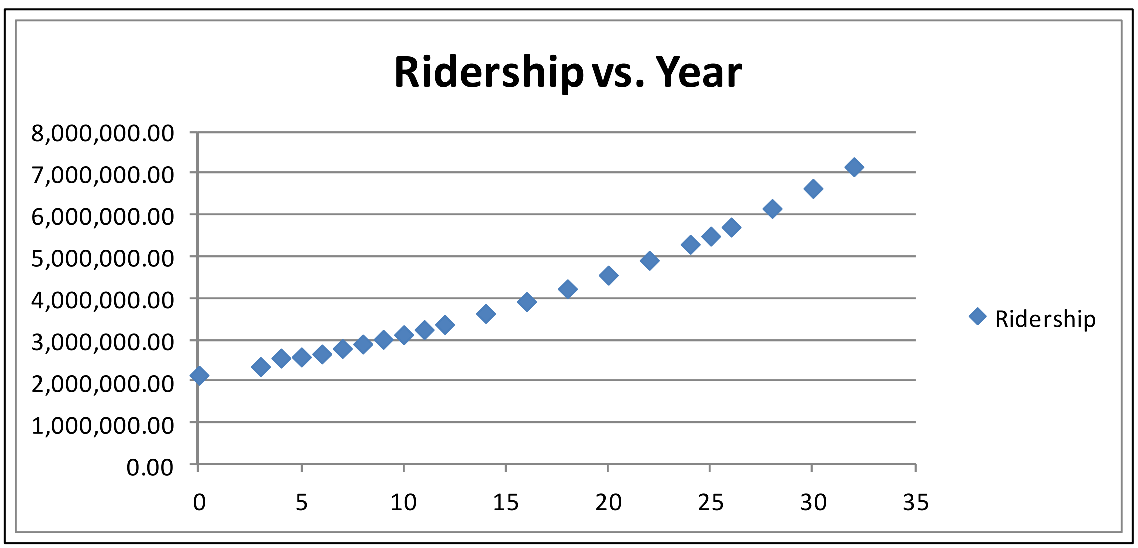
Southeast		2005 GDP	$485,753,000,000		
Year	**Population**	**GDP**	**GDP per capita**	**Ridership (per year)**	
					population =
0	**14,855,052**	$386,084,248,036.99	$25,738.78	920,712.89	15,000,025 $e^{0.01478 \cdot years}$
10	**17,611,162**	$611,151,525,110.64	$35,145.20	1,401,119.87	
12	17,911,034	$669,949,802,190.01	$37,404.31	1,511,583.82	
17	19,284,794	$842,899,258,174.41	$43,707.97	1,827,103.40	
22	20,763,921	$1,060,496,110,467.49	$51,073.98	2,194,084.68	
27	22,356,496	$1,334,266,212,017.44	$59,681.37	2,621,069.07	
32	24,071,220	$1,678,710,847,649.02	$69,739.33	3,118,027.37	

Northeast		2005 GDP	$2,591,075,000,000	
Year	**Population**	**GDP**	**GDP per capita**	**Ridership (per year)**
0	**49,563,296**	$2,059,427,822,334.48	$41,967.14	2,155,959.77
3	50,146,887	$2,363,668,789,437.05	$47,134.91	**2,363,454.00**
4	50,510,257	$2,474,761,222,540.59	$48,995.22	**2,568,935.00**
5	50,876,261	$2,591,075,000,000.00	$50,928.96	2,595,838.73
6	51,244,917	$2,712,855,525,000.00	$52,939.02	**2,668,174.00**
7	51,616,244	$2,840,359,734,675.00	$55,028.41	2,798,946.32
8	51,990,262	$2,973,856,642,204.72	$57,200.26	2,906,306.54
9	52,366,990	$3,113,627,904,388.35	$59,457.84	**3,019,000.00**
10	**52,332,123**	$3,259,968,415,894.60	$61,804.51	**3,129,000.00**
11	53,128,655	$3,413,186,931,441.64	$64,243.80	3,253,474.36
12	53,513,632	$3,573,606,717,219.40	$66,779.37	3,378,112.54
14	54,291,975	$3,917,419,845,876.36	$72,154.68	3,641,827.83
16	55,081,639	$4,294,310,891,828.28	$77,962.66	3,926,073.91
18	55,882,788	$4,707,462,248,420.18	$84,238.14	4,232,493.27
20	56,695,590	$5,160,362,483,878.44	$91,018.76	4,562,860.41
22	57,520,214	$5,656,835,798,089.90	$98,345.18	4,919,092.57
24	58,356,832	$6,201,074,313,388.33	$106,261.33	5,303,261.11
25	**58,353,993**	$6,492,524,806,117.58	$110,455.24	5,500,737.28
26	59,205,618	$6,797,673,472,005.11	$114,814.67	5,717,604.01
28	60,066,749	$7,451,670,839,073.25	$124,056.50	6,164,539.21
30	60,940,406	$8,168,588,638,829.64	$134,042.24	6,646,679.13

32	61,826,769	$8,954,480,383,182.80	$144,831.77	7,166,846.32
50	**70,777,591**	$20,468,247,491,319.90	$290,712.16	14,158,633.40

*Bolded values are Actual Data





Data Input into Multiple Regression for New England

Population	GDP per capita	Ridership
50,146,887	47,134.91	2,363,454.00
50,510,257	48,995.22	2,568,935.00
51,244,917	52,939.02	2,668,174.00
52,366,990	59,457.84	3,019,000.00
52,332,123	61,804.51	3,129,000.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.9907596
R Square	0.981604585
Adjusted R Square	0.963209169
Standard Error	61025.7859
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3.97451E+11	1.98726E+11	53.36137122	0.018395
Residual	2	7448293090	3724146545		
Total	4	4.04899E+11			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-493082.6574	8304507.735	-0.059375302	0.958052276	-3.6E+07	35238330.21
Population	0.013571899	0.193873116	0.070004026	0.950560212	-0.8206	0.847740589
GDP per capita	47.09555345	30.87238732	1.525491144	0.266652089	-85.7376	179.928715

*All years are in years after 2000. So a ‘5’ would correspond to 2005 and a ‘15’ means 2015

Overall Multivariable equation relating Population and GDP per capita to Ridership in a region:

Ridership = 0.01357 * Population + 47.0956 * (GDP per capita) - 49308

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