Where High-Speed Rail Works Best

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Executive Summary

Defining the corridors in America that are most appropriate for high-speed rail service is critical to the long-term success of America's high-speed rail program. This paper offers one mechanism for assessing which potential high-speed rail corridors will have the greatest ridership demand based on population size, economic activity, transit connections, existing travel markets and urban spatial form and density.

The authors evaluate 27,000 city pairs in the nation to create an index of city pairs with the greatest demand for high-speed rail service. The paper provides a list of the top 50 city pairs, which are primarily concentrated in the Northeast, California, and the Midwest, and provides recommendations for phasing corridor development in the nation's megaregions.

On February 17, 2009 President Obama signed into law the American Recovery and Reinvestment Act (ARRA). As part of this legislation, the Federal Railroad Administration (FRA) has been charged with the distribution of $8 billion for intercity and high-speed rail projects. On July 10th, the FRA received pre-applications from 40 states totaling $103 billion for this funding. The FRA will inevitably experience intense political pressure to spread the funding around the country. In keeping with the transparency and accountability goals set forth by the President, however, the FRA has pledged to employ impartial evaluation criteria to judge these applications and distribute this funding to only the most worthy projects. They have outlined specific transportation, job recovery, project readiness, and other public benefit criteria on which these applications will be judged. These project specific criteria are critical to successfully screening the hundreds of applications received by the FRA and distributing federal funds in a timely manner consistent with the goals of the ARRA legislation.

While these project specific criteria are necessary, they are not sufficient to identify appropriate corridors for federal high speed rail funding over the long term. The majority of the applications for the ARRA high-speed rail funding will likely be able to demonstrate at least some level of transportation and economic recovery benefits to qualify for these federal funds; however, the FRA should also develop metrics to compare the scale of these benefits across regions. Specifically, the FRA should develop a mechanism for judging which corridors across the nation have the greatest potential demand for high-speed rail and thus will provide the greatest transportation, economic, and societal benefits.

Defining which corridors are most appropriate for high-speed rail development is critical for the long term success of this nascent federal program. The $8 billion appropriated for high-speed rail in the ARRA legislation[1] is only a small fraction of what will be necessary to fully construct an American high-speed rail network. To maintain public support for a continued federal commitment to high-speed rail, the initial investments must be viewed as a success. Although there are many promising projects in smaller travel markets that should be part of a fully constructed network, these will be better positioned for success if the initial $8 billion are invested in projects that can achieve the greatest travel benefits for the largest numbers in the shortest period of time. For this to be true, they need to fund projects in corridors with the appropriate density, economic activity, and existing travel markets to support strong ridership on these new services. There are large potential financial risks inherent in any large scale transportation infrastructure project. However, investing in corridors with the maximum potential to support such systems reduces this risk, increasing the probability of success and long term public support.

The FRA Vision for High-Speed Rail

Given the wide range of definitions of high-speed rail, it is helpful to clarify exactly what may be funded under this new program. Not all projects eligible for ARRA funding meet the definition of what our international competitors consider high-speed rail. The FRA 2009 High-Speed Rail Strategic Plan provides three definitions of high-speed service, based on distance between markets, top speeds of

service, and existence of dedicated right of way.[2] The FRA defines "HSR Express" as service operating in corridors 200-600 miles in length with top speed of over 150 mph on primarily dedicated tracks. These services are expected to be very competitive with air and auto trips in these markets. The planned California high-speed rail system would qualify as HSR Express under this definition.

Next is "HSR Regional", which operates at top speed of 110-150 mph on a mix of dedicated tracks and tracks shared with slower passenger and freight trains. Acela service in the Northeast Corridor is the only intercity rail service in the country to currently qualify for this category. HSR Regional service provides relief for highway and air operating in these markets, as demonstrated by Amtrak's current 64 percent market share for air and rail trips that begin and end in New York and Washington, D.C.[3]

The third level of HSR defined by the FRA is "Emerging HSR." These are corridors of 100-500 miles in length with service operating at top speeds of 90 - 110 mph on tracks shared with freight and/or commuter services. This service is intended to build a market for intercity rail and is only expected to have a limited effect on shifting passengers from other modes. This service would not be defined as high-speed in any country but the United States. The FRA is positioning these corridors as having potential to someday achieve high-speed service through incremental investments and service improvements that could build a market over time.

A subsequent document, the High-Speed Rail Intercity Passenger Rail Program Notice, published in the Federal Register, provides insight into how the FRA will make decisions about awarding the ARRA funding. The FRA will use three categories of criteria to make decisions. The first category assesses the public return on investment, using criteria such as: transportation benefits, promotion of network integration between modes, safety improvements, preserving and creating jobs, environmental quality benefits, energy efficiency gains, and promotion of livable communities.[4]

The second category of evaluation criteria will be used to assess project readiness and sustainability of benefits. These will include organizational capacity, project engineering, environmental studies, and financial plans.[5] In addition to these two categories of project specific evaluation criteria, the FRA will employ cross-cutting "selection criteria" intended to balance projects against national priorities. These additional criteria will consider geography, economic conditions, innovation and technology, and existence of multi-state agreements.[6]

Many of the pre-applications received by the FRA only qualify under the Emerging HSR category. These applications are to improve top speeds of intercity rail service from top speeds of 60-80 mph to 80 -110 mph through specific projects along a corridor that would reduce conflicts with freight rail, address grade crossings, replace bridges or tunnels, and repair and improve track infrastructure.

Determining Potential Market Demand for High-Speed Rail

Given the long lead time and inherent risk in high-speed rail investments, it is essential that the FRA select corridors where the conditions exist to support strong passenger demand for high-speed services. In addition to the FRA's criteria described above, it is critical to identify the corridors across the country with the maximum potential to support high-speed rail in order to minimize this investment risk. To do so, America 2050 has developed a ranking system based on an index of six criteria to judge the extent of demand for high-speed rail between any two city pairs. Each city pair consists of two cities, each with a population of at least 50,000 that are separated by a distance of 100 to 500 miles. These criteria were weighted and then calculated into an index that scored the city pairs. The largest index score represented the best potential market for high-speed rail. Nearly thirty thousand city pairs were analyzed to determine their suitability for high-speed rail investment. The criteria and the results of the index are described below.

The city pairs were evaluated on the basis of the following criteria:

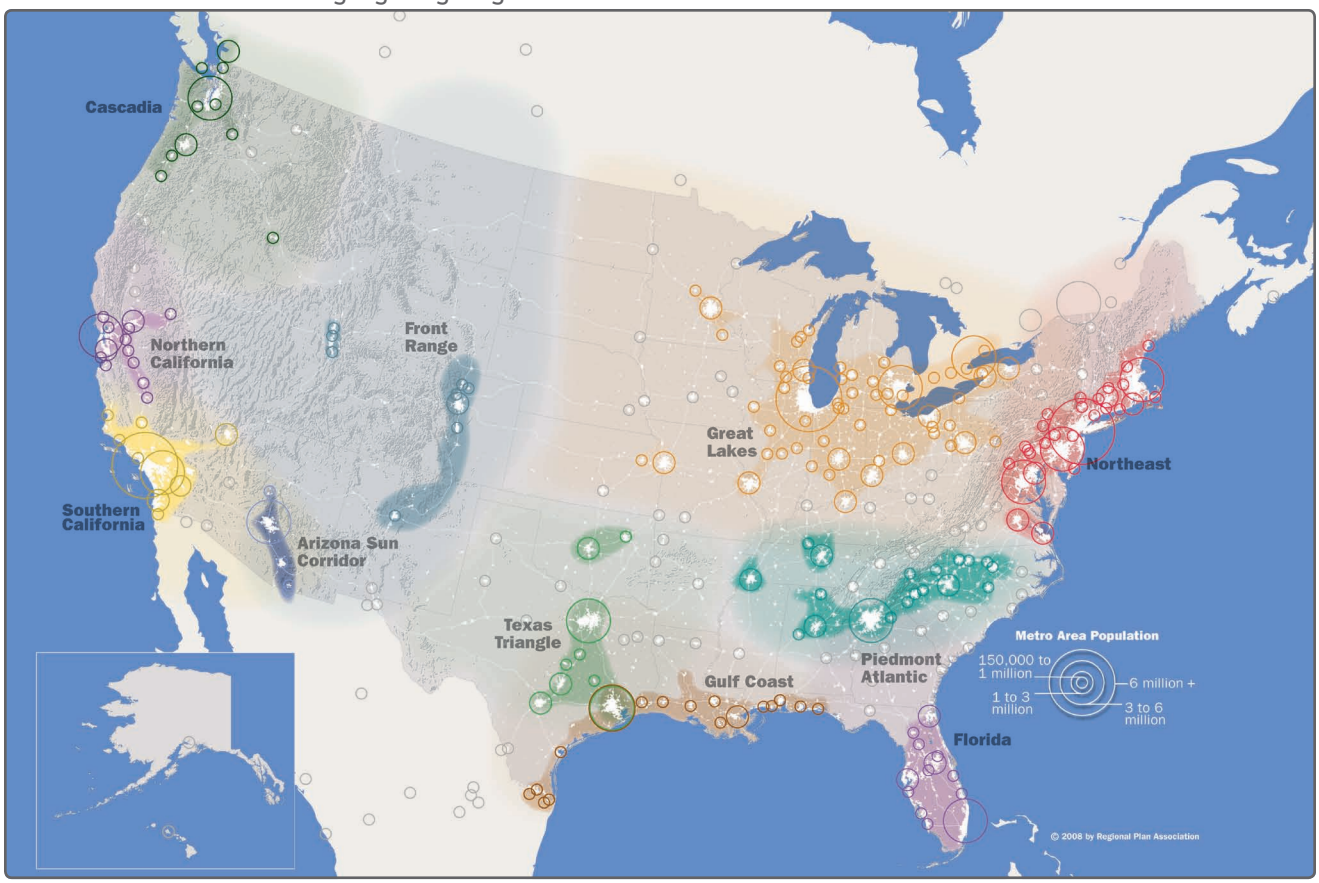
- City and metropolitan area population, favoring cities with larger populations in large metropolitan areas.
- Distance between city pairs, confined to distances between 100-500 miles, with 250 miles receiving the highest value.
- Metropolitan regions with existing transit systems including regional rail, commuter rail and local transit networks.
- Metropolitan GDP, awarding value based on the combined per-capita GDP.
- Metropolitan regions with high levels of auto congestion as measured by the Texas Transportation Institute's Travel Time Index.
- Metropolitan regions that are located within a megaregion.

The rationale for each of these criteria is described below.

Criterion 1: Metropolitan Size

To ensure sufficient travel demand for high-speed rail service, it is best to locate stations in major metropolitan areas. There are 21 metro regions in the nation with a population of at least 2.5 million; all are located within one of the 11 emerging megaregions across the country. Megaregions are networks of metropolitan regions with shared economies, infrastructure and natural resource systems. The Northeast Megaregion alone contains four of the top ten most populous metro regions in the nation – New York, Philadelphia,

FIGURE 1: America's Emerging Megaregions.



source: Regional Plan Association

Washington, D.C., and Boston. The Great Lakes and Texas Triangle megaregions each contain two metro areas in the top ten.

Metropolitan area size is a necessary prerequisite for high-speed rail, but not a sufficient indicator on its own of a successful corridor. Distance to other major metropolitan centers, richness of local transit service, economic activity, and existing travel demand are all important factors in identifying optimal corridors. These criteria will each be discussed in turn.

Metropolitan Region	Population
New York, NY	18,815,988
Los Angeles	12,875,587
Chicago	9,524,673
Dallas-Fort Worth, TX	6,145,037
Philadelphia, PA	5,827,962
Houston, TX	5,628,101
Miami, FL	5,413,212
Washington, D.C.	5,306,565
Boston, MA	4,482,857
Detroit, MI	4,467,592

Source: U.S. Census 2000

Criterion 2: Distance

The competitive advantage of high-speed rail over other modes of travel is maximized at distances between 100 to 500 miles. Distances below 100 miles are better suited for auto and commuter rail networks whereas distances greater than 500 miles are more efficiently travelled by air. There are significant barriers to air travel causing it to be inefficient at short distances. These barriers include accessing airports located outside the metropolitan core, onerous security processes, long check-in times, and airport delays and congestion. These time barriers to air travel result in significant time advantages to efficient rail service. This time advantage drops off sharply at distances beyond 500 miles when the superior in-flight speed of air travel overwhelms the initial time costs of travelling to and checking in at the airport. This index weighted the distance criteria such that it peaked between 200 and 300 miles and decreased to zero after 500 miles, replicating performance of existing systems in Europe and Asia.

Criterion 3: Transit Connections

Two additional competitive advantages of rail over air are rail's ability to bring passengers directly into the city center and attract riders through connecting local and regional transit networks, which act as feeder services. High-speed rail systems will attract greater numbers of riders if they begin and end in central locations within the metro region and tie seamlessly into existing commuter rail and transit systems. These commuter and local transit systems support intercity ridership by offering passengers options to transfer to final destinations. Without access to transit systems, intercity passengers are dependant on autos to begin or end their trip, significantly decreasing rail's competitive

advantage. The presence and use of transit and regional rail systems within a metropolitan region also may indicate a willingness of the people in that region to leave their cars at home and the land use patterns that support that choice—making use of high-speed rail a more likely option.

There are only a handful of American cities with sufficiently large transit systems capable of providing the connections to make high-speed rail an attractive option. Of the nine American cities with commuter rail systems and rail transit systems, five are located in the Northeast. Of the remaining four, two are in California, one is in the Midwest (Chicago) and one is in Florida (Miami).

There are eight commuter rail systems operating in the Northeast Megaregion carrying approximately 350 million annual riders. New York has by far the most robust of these systems with a commuter rail network of more than 1,000 route miles. In terms of annual ridership, the New York metro region has three of the top four commuter rail services in the nation, with each carrying approximately 300,000 daily passengers. The Metra system in Chicago carries passenger volumes similar to one of these systems. Boston and Philadelphia are the only other cities with commuter rail systems that carry more than 100,000 average weekday riders.

With heavy rail transit systems, New York again is in a class of its own. New York's subway system is more than twice as large as the next closest in terms of route miles, and eight times larger than the next closest in terms of passenger volume. The system carries nearly eight million passengers on an average weekday. The second busiest heavy rail transit system in the nation is also located in the Northeast. Washington, D.C.'s metro system has an average weekday ridership of nearly one million passengers. These supporting transit systems are one reason that the New York to Washington, D.C. market currently has the highest intercity rail ridership in the nation. These two cities are followed by Chicago, Boston, and San Francisco in terms of ridership.[7]

Total Track Miles in Transit Systems

Metropolitan Region	Commuter Rail	Heavy Rail Transit	Light Rail Transit
New York, NY	1,082	233	14
Washington, DC	277	105	0
Chicago, IL	541	103	0
San Francisco, CA	160	91	25
Philadelphia, PA	215	38	55
Boston, MA	388	38	25
Baltimore, MD	197	29	15
Miami, FL	71	23	5
Los Angeles, CA	386	16	56

Source: Federal Transit Administration 2004

Criterion 4: Economic Productivity

High-speed rail systems depend heavily on business travel to sustain ridership and business travel is highest in places with more productive economies. Studies also show that travel increases with increased income, whether for business, personal, or leisure travel.[8 9] Gross Domestic Product (GDP) per capita is the broadest measure that is associated with both economic productivity and personal income. Six of the ten largest metropolitan regions (with populations over 2.5 million) with the highest per capita GDP are located in two megaregions: the Northeast and the Texas Triangle. The Northeast Megaregion accounts for four of the top ten most productive metro regions in the nation and accounts for one-fifth of the nation's GDP. The productivity of the metro regions in California and Texas (each with two metros in the top ten of per-capita GDP) contributes to their overall productivity as the nation's top two states in terms of total economic output with 13 and 8 percent of the nation's GDP respectively.

This economic productivity in these three regions has lead to a well established intercity travel market between their major cities. Air and rail travel data are not counted in the index, but are discussed here to illustrate how economic productivity and demand for intercity travel frequently co-exists. Everyday there are more than 70 flights each between New York and Boston and New York and Washington. And the city pairs of New York to Washington, New York to Philadelphia, and Philadelphia to Washington represent the top three city pairs in terms of ridership in the Amtrak system with four million annual passengers.

There is also significant intercity travel in California; however, it is currently dominated by air and private auto trips. There are nearly 200 daily flights between Los Angeles metro airports (LAX, ONT, SNA) and the airports in the San Francisco Bay area (SFO, OAK, SJC). This is in addition to the scores of other daily flights between other cities in these megaregions including San Diego and Los Angeles to Las Vegas and Sacramento.

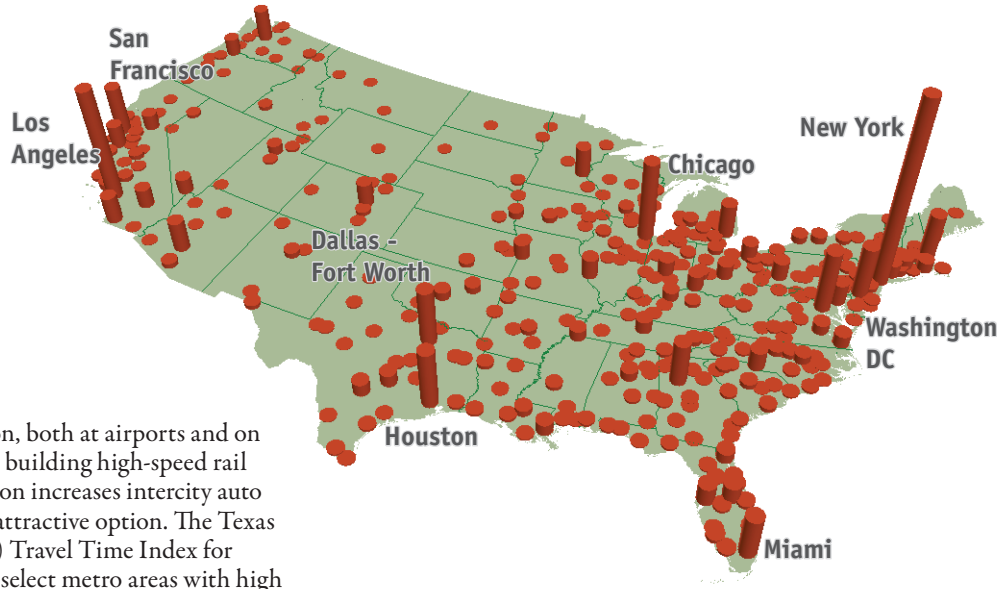
The travel market between the major cities in Texas is less well defined. There is currently no rail option between Dallas and Houston. There are approximately 60 daily flights between these two cities, and although both the Houston and Dallas metropolitan areas are among the top ten most congested, Interstate 45 that connects the two cities is not among the most heavily trafficked non-metro highways in the country.

Gross Domestic Product by Metropolitan Regions with population of over 2.5 million

Metropolitan Region	Per-Capita GDP
San Francisco, CA	$69,478
Washington, DC	$69,097
Boston, MA	$61,513
Houston, TX	$61,214
Seattle, WA	$59,736
New York, NY	$59,712
Minneapolis, MN	$56,007
Dallas-Fort Worth, TX	$55,084
Philadelphia, PA	$53,447
San Diego, CA	$52,947

Source: Bureau of Economic Analysis 2006

FIGURE 2: Total Gross Domestic Product by Metro Region



source: Bureau of Economic Analysis

Criterion 5: Congestion

The goal of congestion reduction, both at airports and on highways, is one motivation for building high-speed rail systems. Metropolitan congestion increases intercity auto travel time making rail a more attractive option. The Texas Transportation Institute (TTI) Travel Time Index for metropolitan areas was used to select metro areas with high rates of auto congestion. Three of the top four and four of the top ten most congested metro areas in the nation are located in California. Again, California, Texas, and the Northeast have multiple metropolitan regions on the list of the top ten. Although metro regions in each of these megaregions appear on this list, as noted above, I-45 is not one of the more heavily traffic routes, whereas I-5 in California and I-95 in the Eastern Seaboard have consistently high traffic volumes throughout the megaregions. The I-95 Corridor Coalition estimates that over 60 percent of the urban road miles of Interstate 95 are heavily congested.[10]

Relative Auto Congestion Levels

Metropolitan Region	TTI Index
Los Angeles, CA	1.50
Chicago, IL	1.47
San Francisco, CA	1.41
San Diego, CA	1.40
New York, NY	1.39
Miami, FL	1.38
Washington, DC	1.37
Houston, TX	1.36
Dallas-Fort Worth, TX	1.35
Riverside-San Bernardino, CA	1.35

Source: Texas Transportation Institute 2005 [11]

While relieving auto congestion is a major potential benefit, high-speed rail systems tend to compete more with short-haul air travel than intercity auto trips and have the potential to decongest some of the nation's most congested airports. Although not included in rankings, airports with high levels of congestion may indicate high volumes of intercity passenger travel originating or ending in that city—though the effect of airlines hubs on congestion must be discounted. The airspace above New York is the most complex and congested in the nation. All three New York metro airports (Newark, La Guardia, and JFK) are among the five airports in the nation with the worst on-time arrival rate. When delays occur at these three airports, they ripple through the system causing delays across the nation. In testimony before the Senate last year, the U.S. Government Accountability Office (GAO) cited the air congestion in the New York metropolitan region as a particular concern to the efficiency of the entire national aviation system. Since one-third of aircraft in the national airspace system move through the New York airspace at some point during a typical day, this region has a disproportionate impact on delays nationwide.[12] In total, there were five Northeastern airports in the bottom ten performing airports in the nation for on-time performance, including Philadelphia and Boston. The other five airports in the bottom ten for on-time arrival rate are spread out over five separate megaregions.

On Time Arrival Performance for most delayed airports

Airport	Percent on time arrivals Jan-Apr 2009
Newark (EWR)	57.25
New York (LGA)	65.24
San Francisco (SFO)	71.40
Atlanta (ATL)	71.99
New York (JFK)	73.33
Philadelphia (PHL)	75.07
Miami (MIA)	77.04
Boston (BOS)	77.48
Chicago (ORD)	77.72
Seattle (SEA)	78.13

Source: Bureau of Transportation Statistics

Criterion 6: Megaregion

The final criterion included in the index takes into account urban form and population density, by determining whether a city is located in a megaregion. Megaregions are networks of metropolitan regions with shared economies, infrastructure and natural resource systems, stretching

over distances of roughly 300 miles - 600 miles in length. High-speed rail systems work best as part of a network with multiple connections, as has been shown in European and Asian megaregions. Cities that are located in one of the eleven megaregions are more likely to be part of a network of interconnected cities with the appropriate density to support high-speed rail systems, rather than an isolated city pair. Most of these megaregions have population densities similar to European countries with successful high-speed rail systems. The most densely populated megaregion is the Northeast, which approaches densities found in Japan and other Asian countries, followed by Southern Florida.[13]

Results

The six criteria described above were used to create an index that ranked 27,000 city pairs on their suitability, based on potential market demand, to act as origin and destination nodes of one leg of a high-speed rail corridor.[14] The top 50 pairs in the index are shown below. The top 50 city pairs identified were primarily concentrated in the Northeast, California, and the Midwest. The results of the ranking were also used to inform America 2050's suggested prioritization of corridors for the development of high-speed rail networks, which also takes into account the concentration of high-ranking city pairs in one megaregion, the progress of high-seed rail planning in those regions, and local political support.

It is no surprise that the nation's four largest cities (New York, Los Angeles, Chicago, and Houston) are all represented near the top of the list as part of city pairs with potential demand for high-speed rail. These are the places that not only contain a critical mass of population to support these systems, but also a large percentage of the nation's economic productivity, existing travel markets, and metropolitan congestion.

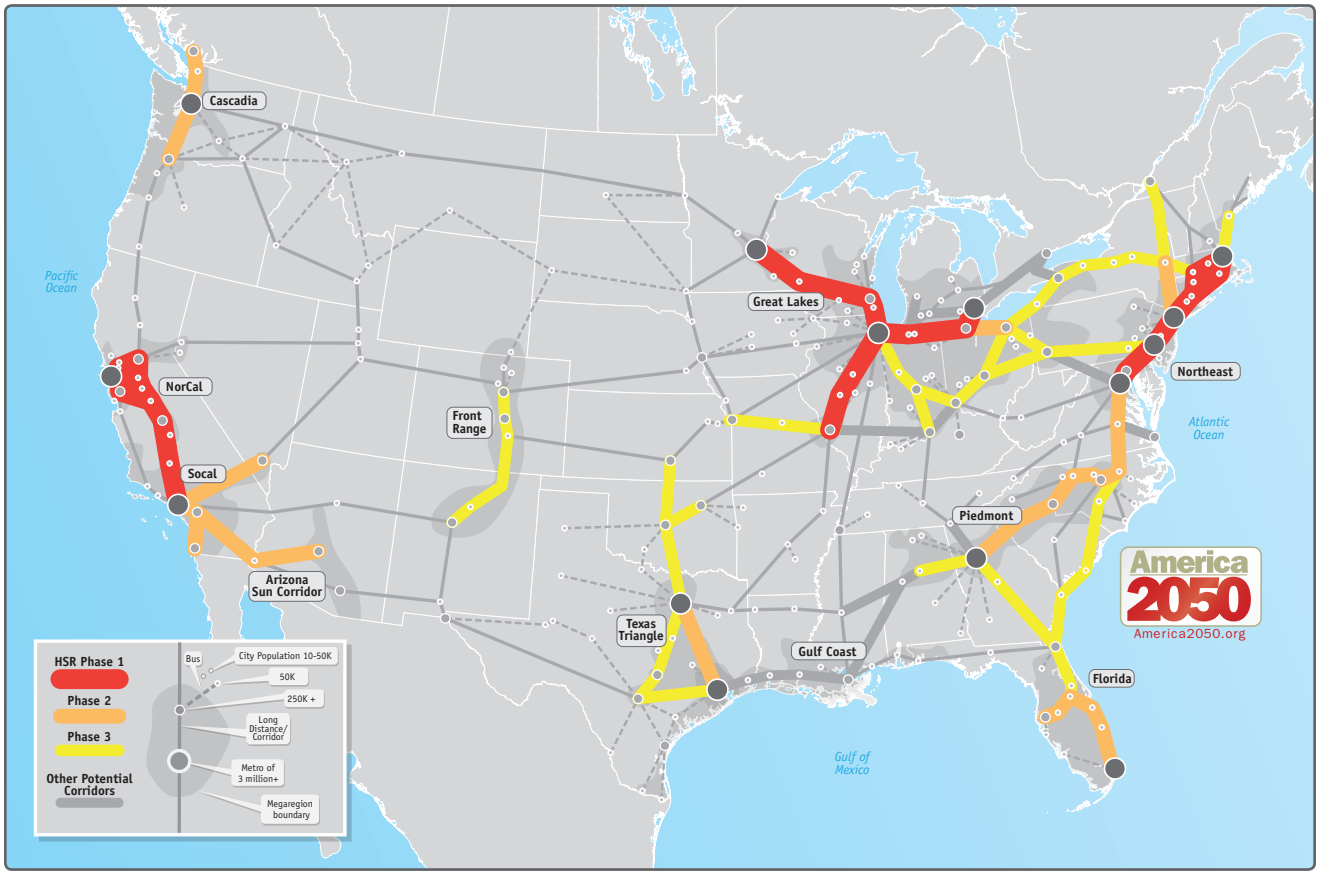
The New York to Washington, D.C. market was the top pair of the 27,000 pairs analyzed.[15] In many ways this city pair typifies the ideal corridor for high-speed rail and shares similar attributes with successful existing corridors around the word. Population density in the Northeast Megaregion is higher than anywhere else in the nation, is higher than almost anywhere in Europe, and is similar to densities in Japan. Both cities have extensive transit and regional rail systems to complement intercity rail traffic. Both cities have productive economies and have an extensive existing travel market. And the two cities are separated by just over 200 miles with two major cities in between, Philadelphia and Baltimore. This corridor shares many of the characteristics with the most successful (in term of ridership) high-speed rail corridor in the world, Tokyo to Osaka, which is similar in distance, density, existence of supportive transit systems, and major intermediate cities, Nagoya and Kyoto.

Although one Texas city pair made it into the top ten in the index (Dallas-Houston), the other major connections in the Texas Triangle are further down on the list (Austin-Dallas: 45th; Austin-Houston: 54th; Houston-San Antonio: 56th: Dallas-San Antonio: 70th). These corridors tended to be ranked lower than the city pairs in California (six California city pairs were ranked in the top 25) and

Top 50 City Pairs

Rank	City Pair	Score
1	New York-Washington	100.00
2	Philadelphia-Washington	98.24
3	Boston-New York	97.22
4	Baltimore-New York	96.83
5	Los Angeles-San Francisco	96.43
6	Boston-Philadelphia	96.05
7	Los Angeles-San Diego	94.92
8	Los Angeles-San Jose	94.19
9	Boston-Washington	92.79
10	Dallas-Houston	91.37
11	Chicago-Detroit	91.09
12	Baltimore-Boston	90.39
13	Chicago-Columbus	89.42
14	Chicago-Saint Louis	89.25
15	Los Angeles-Phoenix	89.03
16	Chicago-Cleveland	88.71
17	Charlotte-Washington	88.39
18	San Diego-San Francisco	88.32
19	Columbus-Washington	88.21
20	Cleveland-Washington	88.13
21	New York-Pittsburgh	88.03
22	Phoenix-San Diego	87.97
23	Las Vegas-Los Angeles	87.79
24	Detroit-New York	87.47
25	Chicago-Minneapolis	87.33
26	Detroit-Washington	87.27
27	Cleveland-New York	87.25
28	Philadelphia-Pittsburgh	87.23
29	Portland-Seattle	87.19
30	Pittsburgh-Washington	86.69
31	Los Angeles-Sacramento	86.58
32	New York-Providence	86.58
33	Raleigh-Washington	86.36
34	Detroit-Philadelphia	86.30
35	Chicago-Louisville	86.25
36	Hartford-Philadelphia	86.20
37	San Diego-San Jose	86.14
38	Hartford-Washington	86.13
39	Chicago-Cincinnati	86.02
40	Cleveland-Philadelphia	85.99
41	Charlotte-Philadelphia	85.60
42	Philadelphia-Raleigh	85.58
43	Buffalo-New York	85.58
44	New York-Virginia Beach	85.52
45	Austin-Dallas	85.47
46	Manchester-New York	85.41
47	Philadelphia-Providence	85.36
48	Bridgeport-Philadelphia	85.31
49	Columbus-Philadelphia	85.24
50	New York-Rochester	85.11

FIGURE 3: High-Speed Rail Phasing Plan



America 2050's High-Speed Rail Phasing map illustrates the results from the described research as well as taking into account the current state of rail planning across the country. It prioritizes the connection of major metropolitan centers within 500 miles with high levels of economic activity and integration

source: Regional Plan Association

the Midwest (with city pairs including Chicago, Detroit, Columbus, Cleveland, and Pittsburgh), which all appeared multiple times in the top 50 pairs. Although these Texas corridors scored well in overall population, length of corridor, and economic activity, the lack of (or limited) existing local and regional transit systems in these cities reduced their overall rankings. City pairs with at least one city with local transit and commuter rail systems tended to populate the top 100 city pairs. Corridors which included two such cities including New York, Washington, Philadelphia, Los Angeles, and San Francisco all can be found in the top 10.

Developing a Phasing Plan for High-Speed Rail

To illustrate how a high-speed rail system might be built out over time, America 2050 used the results of the index above, indicating where there is greatest market demand for these services. This phasing plan also considered the existence of more than one high-ranking city pair located within a megaregion that together can help compose a network. High-speed rail services will be most effective if they connect to other transportation services, including other high-speed rail routes, as well as conventional passenger rail, regional rail and local transit. Metro regions with multiple connections to other large metro regions within 100-500 miles became an additional weight in the creation of the phasing plan. The multiple connections between major metropolitan centers in the Northeast, California, and Great Lakes megaregions create the potential for ideal corridors for high-speed rail networks.

Metropolitan Regions with Greatest Number of Neighboring Metro Regions	Number of Other Major Metros within 100-500 Miles	HSR Megaregion Network
Detroit, MI	5	Midwest
New York, NY	4	Northeast
Philadelphia, PA	4	Northeast
Washington, DC	4	Northeast
Boston, MA	4	Northeast
Los Angeles, CA	3	California
Chicago, IL	3	Midwest
San Francisco, CA	3	California
San Diego, CA	3	California
Baltimore, MD	3	Northeast

Phase One: Phase one of the national high-speed rail network includes the beginning of three megaregion-scale systems. First, improvements to the Northeast Corridor boost speeds between the cities of Boston, New York, Philadelphia, Baltimore, and Washington, D.C. These city pairs dominated the top spots in the ranking. It also includes the first three legs of the Chicago Hub system in the Midwest connecting Detroit, St. Louis and Minneapolis (via Milwaukee), to Chicago. These three city pairs ranked 11, 14, and 25 respectively on the index. The importance of Chicago as a regional travel and economic hub, its size as the nation's third largest metro region, and its supportive transit systems warranted the inclusion of parts of the Midwest system in phase one of the plan. Finally, phase one of the national plan also includes the first phase of the California high-speed rail system from Los Angeles to the San Francisco Bay Area. This system will be the nation's first "HSR Express" service on a dedicated right of way.

Phase Two: Phase two of the plan provides connections to many of the remaining city pairs ranked in the top 100 and includes parts of ten of the eleven megaregions. New routes in this phase include Dallas to Houston (ranked 10th), Los Angeles to Phoenix (ranked 15th), Los Angeles to Las Vegas (ranked 23rd), Portland to Seattle (ranked 29), Miami to Tampa via Orlando (ranked 100), and the "Southeast Corridor" that runs from Atlanta to Washington, D.C. via Charlotte, Raleigh-Durham, and Richmond. Phase two also includes extensions to the three systems begun in phase one extending the California system south to San Diego, the Northeast system to Albany, and the Midwest system east to Cleveland.

Phase Three: The third phase of the national high-speed rail system further extends the megaregion scale systems to include medium-sized cities within 500 miles of the major megaregional centers and begins to make connections between these systems to integrate them into a truly national network. The Midwest system is expanded west to include Kansas City and is connected to the Northeast network via new routes through New York State and Pennsylvania bringing Buffalo, Pittsburgh, Columbus, Cincinnati, and Indianapolis into the system. It extends and connects the Southeast Corridor and the Florida networks, adding connections to Jacksonville and Birmingham. It incorporates the remaining two metro regions in the Texas Triangle, Austin and San Antonio, and extends the system north to Tulsa, Oklahoma City, and Wichita. Finally, the third phase of the plan adds the remaining megaregion system by connecting Denver to Albuquerque along the I-25 corridor.

When complete, this high-speed intercity passenger rail network will be an important part of a larger comprehensive passenger network, which includes air travel, intercity rail and bus services. An emphasis on coordinating these services and enhancing links between intercity, regional, and local networks will leverage the government's investments, maximize ridership, and enhance mobility options for the 440 million Americans that will inhabit the country by mid century.

Although investments in "mega" infrastructure projects are necessary to accommodate future population and economic expansion, they are inevitably fraught with great risks because of the sheer scale of these investments. As the GAO recently observed, each of these high-speed rail systems will cost tens of billions of dollars of upfront costs to build the infrastructure before a single passenger pays a fare.[16] The FRA's focus on project readiness, local matching funds, and organizational capacity will help ensure that the first round of federal funding is awarded to agencies that are capable of delivering the projects on time and on budget. The success of early projects will help pave the way for the continued growth and expansion of the program by building public confidence and support. Yet, another factor in building public confidence and support is investing in corridors where the services will be in high demand. As discussed in this report, investing in corridors with the highest potential ridership—places with the appropriate density, economic activity, supportive transit, and existing travel markets—will maximize fare recovery and minimize project risk.

The $8 billion appropriated for intercity rail projects represents a major commitment to intercity rail by the federal government. It will take many more of these appropriations, however, to realize the ultimate goal. These initial federal investments in intercity rail should be directed toward corridors with the greatest demand for intercity travel. In general, this demand occurs in city pairs located 100 – 500 miles from each another, with large populations, economies, and the presence of regional and local transit networks that can provide connections for intercity passengers. America's 11 emerging megaregions—networks of metropolitan regions connected by linked economies, travel patterns, and shared environmental resources—are among the prime areas suited for intercity rail investment. The success of these investments in attracting sufficient ridership to offset operating expenses and the ensuing public support for the projects selected for the first round of funding, will determine whether this is a one-time expenditure or a sustained commitment by the federal government. Ultimately the FRA will need to develop a comprehensive strategic plan that details the federal role in the future high-speed rail network. The forthcoming National Rail Plan being prepared by the FRA and due to Congress on October 16 could serve this purpose. In the meantime, the FRA must have a mechanism for assessing the corridors with the greatest potential return on this investment—the ranking system detailed in this report offers one such mechanism.

Acknowledgements

The authors would like to thank Jeff Zupan, Senior Transportation Fellow, Regional Plan Association, for his guidance and technical support with this analysis as well the Rockefeller Foundation, Surdna Foundation, Lincoln Institute of Land Policy, the William Penn Foundation, and the J.M. Kaplan Fund, for their generous support of America 2050.

Technical Appendix

This technical appendix defines the terms and equation used in this analysis.

In this study, evaluation criteria were applied to city pairs to analyze potential high-speed rail corridors. However, before doing so, these "city pairs" were created using a geographic information system. First, we selected every incorporated place in the nation with a population of at least 50,000. This process yielded approximately 600 cities and towns. From these 600 places, city pairs were created by connecting each one of the cities to every other city located between 100 and 500 miles from the originating city. This yielded approximately 27,000 city pairs across the nation on which the analysis was based.

Twelve variables were used in the creation of the index across six categories: metropolitan size, distance, transit connections, economic vitality, and congestion. These variables were weighted and then summed into an index that scored the city pairs. An explanation of each variable with its associated value and the equation used to create this index follows.

The scores for the 27,000 city pairs ranked in this index ranged from 3.9 to 44.9. The scores listed beside the city pairs in the table in the text of this document represent that city pair's scores as a percentage of the top score.

TRANSIT VARIABLES:

Commuter Rail

Is there a commuter rail system in the metropolitan area?

Yes	**1**
No	**0**

Syntax in equation:
CR = Commuter Rail Starting City
CR_1 = Commuter Rail Ending City

Light Rail

Is there a light rail system in the city?

Yes	**1**
No	**0**

Syntax in equation:
LR = Light Rail Starting City
LR_1 = Light Rail Ending City

Light Rail System Route Miles

If a light rail system exists, how many route miles are there in the system?

0	**0.0**
>0 -15	**0.5**
15-30	**1.0**
>30	**1.5**

Syntax in equation:
S_LR_Len_I = Starting City Light Rail System Mileage
E_LR_len_I = Ending City Light Rail System Mileage

Heavy Rail Transit

Is there a heavy rail transit system in the city?

Yes	**1**
No	**0**

Syntax in Equation:
HRT = Heavy Rail Transit Starting City
HRT_1 = Heavy Rail Transit Ending City

Heavy Rail Transit System Route Miles

If a heavy rail transit system exists, how many route miles are there in the system?

0	**0**
>0 -25	**0.5**
25-100	**1**
>100	**3**

Syntax in equation:
S_HR_Len_I = Starting City Heavy Rail Transit System Mileage
E_HR_Len_I = Ending City Heavy Rail Transit System Mileage

POPULATION VARIABLES

Metropolitan Area Population

What is the population of the metropolitan area in which the city is located?

Under 250,000	**0**
250,000 – 1,000,000	**1**
1,000,000 – 2,500,000	**2**
More than 2,500,000	**3**

Syntax in Equation:
Met_Pop = Metro population Starting City
Met_Pop_1 = Metro population Ending City

Largest City in Metro Area

Is the city the largest city in the metro region? Note: This variable is heavily weighted in the equation to select for the primary city in metro region for HSR location.

Yes	**1**
No	**0**

Syntax in Equation:
Metro_Main = Largest city in Metro Area Starting City
Metro_Ma_1 = Largest city in Metro Area Ending City

City Population

What is the population of the city?

Under 100,000	**0**
100,000 – 500,000	**1**
500,000 – 1,500,000	**2**
More than 1,500,000	**3**

Syntax in Equation:
City_pop = City Population Starting City
City_pop_1 = City Population Ending City

LOCATION VARIABLE

In Megaregion

Is the city located in a megaregion?

Yes	**1**
No	**0**

Syntax in Equation:
Mega = In Megaregion Starting City
Mega_1 = In Megaregion Ending City

DISTANCE VARIABLE

Corridor Length

What is the distance between city pairs?

For lengths < 150 miles the value is obtained by ((length/100) +1); for lengths 150 – 300 miles the value plateaus at 2.5; for lengths 300 - 350 values is obtained by (((500-length)/100) +0.5); for lengths > 350 miles (500-length/100).

The value begins at 2 for corridor lengths of 100 miles, increases linearly and peaks at 2.5 for corridor lengths between 150 – 300 miles, decreases linearly to 2 at lengths of 350, then decreases to 1.5 and continues decreasing linearly to a value of 0 for lengths of 500 miles.

100	**2**
150 - 300	**2.5**
350	**2**
400	**1**
500	**0**

Syntax in Equation:
C_Length = Corridor Length

ECONOMIC VARIABLE

Metro GDP

What is the combined geometric mean of the two metro areas GDPs that make up the city pair?

The geometric mean of the two metro regions' per capita GDP was created by taking the square root of the product of the per capita GDP of the starting metro area and the per capita GDP of the ending metro area.

< 20,000	**0**
20,000 - 30	**0.5**
30,000 - 40	**1**
40,000 - 50	**1.5**
50,000 - 60	**2**
> 60,000	**2.5**

Syntax for Equation:
C_GDP_Cap = Geometric mean of GDP of the two metro regions

CONGESTION VARIABLE

TTI Index

What is the combined Texas Transportation Institute's Travel Time Index (TTI) for of the two cities that make up the city pair? TTI ranges from 1 to 1.5. The combined index was created by subtracting 1 from the TTI from each city and multiplying their sum by 2.5. This resulted in a value for this variable that is a continuous scale between 0 and 2.275.

Note: Not all metro areas have TTI indices. Cities not specifically identified with a TTI were given the TTI for their class of metro region, either "small" (150,000-500,000 = 1.09), "medium" (500,000 – 1,000,000 = 1.16), or "large" (1,000,000 = 1.23) metro region.

Syntax for
TTI_IND = Combined TTI index of two cities in city pair

Equation

[CR]+ 0.5*[LR]+ 0.5*[S_LR_Len_I]+ 0.5*[HRT]+ 0.5*[S_HR_Len_I] +[Met_Pop]+10* [Metro_Main] + [City_pop] + [Mega] + [CR_1] + 0.5*[LR_1]+ 0.5* [E_LR_Len_I] + 0.5*[HRT_1]+0.5* [E_HR_Len_I]+ [Met_Pop_1]+10* [Metro_Ma_1]+ [City_pop_1] + [Mega_1]+ [C_Length] + [C_GDP_Scal]+ [TTI_Ind]

Starting City [Does city have of Commuter rail (0,1) + 0.5 times does the city have light rail (0,1) + 0.5 times length of light rail system (0, 0.5, 1, 1.5) + 0.5 times does the city have heavy rail transit (0,1) + 0.5 times length of heavy rail transit system (0, 0.5, 1, 3) + What is metropolitan population in which the city is in (0,1,2,3) + ten times is the city the largest city in its metro region (0,1) + what is the city population (0,1,2,3) Is the city in a megaregion (0,1)] + **Ending City** [Does city have of Commuter rail (0,1) + 0.5 times does the city have light rail (0,1) + 0.5 times length of light rail system (0, 0.5, 1, 1.5) + 0.5 times does the city have heavy rail transit (0,1) + 0.5 times length of heavy rail transit system (0, 0.5, 1, 3) + What is metropolitan population in which the city is in (0,1,2,3) + ten times is the city the largest city in its metro region (0,1) + what is the city population (0,1,2,3) Is the city in a megaregion (0,1)] + **Corridor** [what is the length of the corridor (0-2.5) + what is the geometric mean of the GDPs of the two cities (0, 0.5, 1, 1.5, 2, 2.5) + combined TTI index of the two cities.

Endnotes

1 An additional $5 billion over five years was proposed in the Obama administration's budget request; the House of Representatives recently raised this amount $4 billion in the first year alone, however in the Senate version of the bill it was reduced back down to $1.2 billion.

2 U.S. Department of Transportation Federal Railroad Administration, April 2009, "Vision for High-Speed Rail in America." p 2.

3 Data obtained from Amtrak and Port Authority of New York and New Jersey.

4 U.S. Department of Transportation, June 23, 2009, Federal Railroad Administration, *The Federal Register*, p. 29,902.

5 Ibid.

6 Ibid. p.29,903.

7 http://www.apta.com/research/stats/ridership/riderep/documents/08q4hr.pdf

8 Polzin, S. E., 2004, "Relationship Between Land Use, Urban Form And Vehicle Miles Of Travel: The State Of Knowledge And Implications For Transportation Planning," Tampa: University of South Florida, Florida Department of Transportation, Federal Highway Administration. http://www.cutr.usf.edu/pubs/Trans-LU%20White%20Paper%20Final.pdf

9 Ewing, R. and Cervero, R., 2001, "Travel and the Built Environment: A Synthesis." *Transportation Research Record 1780.* Washington, D.C.: Transportation Research Board, National Research Council. http://depts.washington.edu/trac/concurrency/lit_review/trr1780.pdf

10 http://www.i95coalition.org/i95/Home/I95CorridorFacts/tabid/173/Default.aspx

11 In the 2007 TTI index, which was published after the data portion of this study was completed, San Jose, CA and Atlanta, GA replaced Houston and Dallas in the top ten. The two Texas cities dropped to 11 and 12 respectively in the= rankings.

12 Susan Fleming, United States Government Accountability Office, July 15, 2008, "Testimony Before the Subcommittee on Aviation Operations, Safety, and Security, Committee on Commerce, Science, and Transportation." U.S. Senate. http://www.gao.gov/cgi-bin/getrpt?GAO-08-934T

13 The densities of the major European countries range from 200 to 650 people per square mile (sq. mi.). France and Spain, two countries that have successfully deployed high speed rail networks have population densities of 300 and 200 per sq. mi. respectively. In the U.S. seven of the eleven megaregions have population densities in the 200 to 400 range with the Northeast as a notable outlier with a density of 800 per sq. mi. Although a comparison between international countries and domestic megaregions may not be an equal comparison, it does provide some evidence that high-speed rail networks at this density are viable. For a complete listing of densities of all eleven U.S. megaregions, see: Regional Plan Association, 2008, "America 2050: An Infrastructure Vision for 21st Century America." p. 11. http://www.america2050.org/2008/11/an-infrastrucutre-vision-for-2.html

14 A complete description of the criteria and equation used to create this index is included in the technical appendix at the end of this report.

15 This study only analyzed city pairs between 100 and 500 miles apart. However, city pairs either less than 100 miles or more than 500 miles could potentially be good candidates for high speed rail based on congestion levels between the cities and geographic constraints. For example, city pairs such as New York-Philadelphia and Chicago-Milwaukee are not included in this study because they are separated by only 90 miles, but rank second and seventh respectively in current intercity rail volume. Despite their omission, both of these city pairs are part of a larger network included in the first phase of the proposed plan discussed below.

16 U.S. Government Accountability Office, March 2009, "High-speed Passenger Rail: Future Development Will Depend on Addressing Financial and Other Challenges and Establishing a Clear Federal Role."

America 2050

America 2050 is a national initiative to develop a framework for America's future growth and development in face of rapid population growth, demographic change and infrastructure needs in the 21st century. A major focus of America 2050 is the emergence of megaregions – large networks of metropolitan areas, where most of the projected population growth by mid-century will take place – and how to organize governance, infrastructure investments and land use planning at this new urban scale.
www.America2050.org