High-Speed Passenger Rail:
Considering Where the US Has Come From and Where the World Is Going

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I. Why has America been slow in adopting fast passenger trains?

In the United States, high-speed passenger rail (HSR) is a transportation option that reveals a long history of limited achievement. The US government first attempted to initiate HSR in 1965 under the High Speed Ground Transportation Act. The legislation's goal was to incubate HSR technology along the heavily traveled Northeast Corridor between Boston, New York, and Washington and then diffuse it to other promising corridors across America. But instead, decades of false starts and failed attempts to create true HSR in the US ensued, spanning nine presidential administrations and 24 sessions of Congress to date.

Inside the Washington, DC, Beltway, Congress and the executive branch have argued for decades about whether or not to shut down Amtrak, whose primary mission has been preserving traditional passenger trains. And outside the Beltway, several attempts to launch HSR were made by states, private corporations, and public-private partnerships. These were each stymied by the challenge of building new railroad infrastructure.

The most important lesson from America's 48 years (to date) of inertia in deploying HSR can be gained by identifying what has been missing from prior attempts to deploy this technology in America. Since HSR was first identified as a promising transportation option, no administrative or fiscal mechanisms have been created (or adapted) to support building the necessary infrastructure.

Every project from 1965 through 2008 has relied upon *ad hoc* measures to acquire the infrastructure over which proposed HSR would operate. No projects made use of the collaborative planning mechanisms that were jointly developed by national and state governments to develop highways, ports, airports, and transit infrastructure. Nor was the trust fund financing instrument, which has been central to underwriting most modern American transportation infrastructure, ever considered as a means for capitalizing HSR infrastructure.

II. How the US railroad infrastructure developed differently from the network of roads, ports, airports, and public transit.

America's private railroads flourished, declined, and then renewed themselves while relying on an infrastructure paradigm that was forged in the mid-19th century. This "do it yourself" mode of planning, financing, and building railroads predates the intergovernmental collaboration that has contributed so much to developing America's network of roads, ports, airports, and public transit.

Government's support for railroads during the 19th century was detached from the subsequent public engagement in building roads, airports, and transit that emerged during the 20th century. Although many of America's railroads would not have been built without public funding and land grants, these were discrete transfers for developing property that remains privately owned, for the most part.

Conflict over the use of that property has, at times, been fueled by a major difference between the railroads' business environment and that of other transport modes. Beyond coastal areas and navigable waterways, railroads were once holders of America's most extensive transportation monopoly. For three to four decades during the late 19th and early 20th centuries, railroads were often able to charge whatever traffic would bear. Public dissatisfaction with monopoly pricing eventually led government to curb the railroads' market power through regulation and by building roads that fostered competition.

For decades, the limitations of America's railroad infrastructure paradigm were easy to ignore because there was no need to expand that mode's capacity. Railroads had built such an extensive network during the 19th century that 20th century competition from other modes created a huge oversupply. From 1950 through the 1990s, railroads' survival strategy depended on downsizing their operations and infrastructure in response to falling demand. Tens of thousands of miles of track were abandoned or sold to shortlines. Over 20,000 miles of railroad have been converted to recreational trails since the 1970s. Only recently has new demand for both freight and passenger movement by rail prompted a serious focus on how to build new rail capacity.

One reason for this focus on adding rail infrastructure is demographic. Since the Tokaido Shinkansen's launch in 1964 in Japan, the US has added almost 100 million to its population. Metropolitan areas have experienced growing populations since the 1990s, and this growth has been greatest at their core. An urban renaissance has seen a return of Generation X and Millennials to city living. Since the 1990s, the US has moved closer to Asia and Europe in the way that people move *within* cities, raising the question of whether this could affect the way that people move *between* cities. American attitudes toward mobility have evolved in ways that suggest openness to using HSR for intercity travel.

While America was the birthplace of the car culture and the identity of baby boomers was intimately connected with the automobile, evidence suggests that subsequent generations are much more agnostic about their means of mobility. Car and bike sharing, as well as walking, have gained popularity, especially among those under 40. A 2012 poll conducted for the American Public Transportation Association (APTA) highlighted overwhelming interest in using HSR among Americans aged 18-24. In their numbers, residential location, and attitudes toward travel, Americans have thus become *less* different from the Asians and Europeans who make considerable use of HSR on a regular basis.

The different methods by which government and railroads have developed America's transportation infrastructure will need to be reconciled in order to advance HSR as well as significantly expand rail freight capacity. Until recently, both railroads and the government showed limited interest in creating a new approach to infrastructure constraint, but a window for such change has recently opened.

III. How the 2008 election yielded conditions that stimulate HSR development in the US.

While collaborative planning has made American highways, airports, and transit what they are today, the absence of intergovernmental partnership left HSR an orphan transportation mode without an effective development mechanism. Before 2008, government spending on passenger rail infrastructure had been disjointed and sporadic. Congress would occasionally fund Amtrak's maintenance and upgrading of the Northeast Corridor. And states like California or New York would independently invest in other passenger rail corridors, either by funding improvements on private railroads within their state or by acquiring some of these tracks.

But after 2008, both the federal and some state governments seriously began to pursue multi-billion dollar HSR projects that will require new, or substantially expanded, rail infrastructure. The November 2008 election ratified HSR goals that require creating intergovernmental partnerships that are analogous to those supporting airport, transit, and road infrastructure.

California voters approved Proposition 1A, authorizing $9.95 billion in general obligation bonds to build HSR between the Bay Area and Southern California. And nationwide, voters elected Barack Obama, who was the first successful presidential candidate to recognize HSR publicly as an essential part of America's transportation system.[1] The American Recovery and Reinvestment Act of 2009 (ARRA), which became law soon after President Obama's inauguration, translated this priority into an $8 billion federal investment in HSR.

California is blazing a trail for states that seek to share the cost of HSR development. California recently authorized selling $4.7 billion from the 2008 HSR bond measure; $2.6 billion of these funds will be used to build 130 miles of track between Merced and Bakersfield, America's first, purpose-built, HSR infrastructure. Washington will match this contribution with $3.2 billion from ARRA. This ratio of 55 percent state to 45 percent federal funding is approaching the original 50 – 50 split in federal aid to (pre-Interstate) highways.

The cost-sharing precedent could launch a new method of inter-governmental collaboration that supports building America's national HSR infrastructure network.

IV. Identifying four HSR waves that have emerged over five decades.

HSR deployment has demonstrated an increasing scale and ambition over the five decades since 1964. TABLE 1 presents the current and committed plans for global HSR development as of July 2012. These applications reveal that there is no one standard formula for deploying and operating HSR. Nor is there a single measure of success for the results.

[1] Speaking at a Miami campaign event in June 2008, Obama stated "We'll also invest in our ports, roads and high-speed rails – because I don't want to see the fastest train in the world built halfway around the world in Shanghai, I want to see it built right here in the United States of America." (McSherry, 2008)

TABLE 1

Global High-Speed Passenger Rail Development in Operating Systems as of July 2012[2]

	Miles in operation	Miles under construction	Miles planned	Total miles
China	3,979	2,632	1,803	8,414
Spain	1,332	1,043	1,058	3,433
France	1,265	470	1,496	3,231
Japan	1,655	264	334	2,253
Turkey	278	471	758	1,507
Germany	829	266	347	1,442
Italy	574	0	245	819
USA	225	0	559	784
South Korea	256	116	31	403
Taiwan	214	0	0	214
United Kingdom	70	0	127	197
Belgium	130	0	0	130
Netherlands	75	0	0	75
Switzerland	22	45	0	67

Since 1964, HSR has been applied to increasingly ambitious goals. These can be classified into four categories, based on their scope.

First Wave: HSR was developed to serve a single corridor of 300-350 miles anchored by two megacities. Japan's pioneering Tokaido Shinkansen line linked Tokyo and Osaka, covering 320 miles at 130 mph for a capital cost of $920 million (approximately $6.8 billion in 2012 dollars).

[2] Data obtained from the International Railway Union's high-speed rail website, accessed on 6 January 2013: http://www.uic.org/IMG/pdf/20120701_a1_high_speed_lines_in_the_world.pdf

Speeds have been incrementally increased to 170 mph with today's journey times reduced to two and one-half hours.

While little economic or technical critique of the original Shinkansen can be found, the subsequent expansion of Japanese HSR to serve less densely populated regions yielded losses that eventually left Japan National Railways insolvent and prompted its reorganization into private companies. Japan's experience demonstrated that HSR worked well in linking megacities with a high population density connected by excellent public transit systems.

Second Wave: **HSR was developed as both a trunk line and interconnected branch lines along conventional tracks, thus multiplying the origins and destinations that could be served.** In Europe, HSR was expected to simultaneously expand rail capacity while enhancing competitive performance, since railroads had been experiencing congestion along their busiest routes and decline on less busy segments.

French HSR operation began in 1981 through TGVs linking Paris with the principal cities of *two* distinct regions, Dijon in Burgundy and Lyon in the Rhone-Alps. And Germany's ICE train was launched in 1991 linking multiple urban centers between Hamburg and Stuttgart and sharing much of its route with conventional passenger trains. Freight trains were operated over the high-speed rail infrastructure at night.

Whereas Japan's Shinkansen was physically separated from an existing narrow-gauge railway network, both the French TGV and German ICE operate on shared tracks. Using existing tracks to access the core of Paris, Frankfurt, and Munich avoided the need for costly tunneling, while enabling HSR to serve existing rail terminals. Europe's HSR captured trips well beyond its new infrastructure by continuing along conventional track.

Reflecting its wider range of goals, Europe's HSR performance has been more diverse. Only the Paris – Lyon HSR corridor has covered its full capital and operating costs. The modal split for travel between Paris and Lyon shifted from 40 percent rail, 31 percent air, and 29 percent road in 1981 to 72 percent rail, 21 percent road, and 7 percent air by 1984. Other routes in France, Germany, Italy, and Spain have been seen as more or less able to recover their operating costs but not the capital costs of infrastructure.

The work of De Rus puts the relationship between HSR's travel time and market share in perspective, as presented in TABLE 2 on page 6. Generally speaking, passenger rail services that can link major cities of 200 – 400 miles in less than three hours have established themselves as the dominant common carrier in that market, equaling or surpassing air travel.

Third Wave: HSR was designated as Europe's preferred continental high-speed transportation option. During the 1990s, the European Union broadened the scale of HSR development to promote inter-regional integration and development on a continental scale. Directive *96/48/EC* provided a common legal and regulatory framework for HSR planning among European Union (EU) member states.

Beyond administrative integration, this directive supported HSR interconnection projects that extended the reach of national networks. Projects connecting EU members' HSR infrastructure could receive supranational funding, the first example of government investment in HSR that crossed national boundaries.

TABLE 2
Selected Global HSR Performance and Market Share in 2008[3]

	Length (mi)	Travel time	Speed (mph)	Market share Rail	Market share Air
Madrid-Barcelona	392	2:45	142.30	50	50
Madrid-Seville	293	2:25	121.1	83	17
Paris-Amsterdam (1)	280	4:00	69.90	45	55
Paris-Brussels	193	1:25	135.96	95	5
Paris-London	276	2:15	122.62	81	19
Paris-Lyon	267	2:00	133.60	90	10
Rome-Bologna (2)	223	2:30	88.98	75	25
Rome-Milan (3)	348	4:30	77.32	35	65
Stockholm-Goteborg (4)	283	3:00	94.24	62	38
Tokyo-Osaka	320	2:25	132.41	85	15

(1) High speed only Paris-Brussels
(2) High speed only Rome-Florence
(3) High speed only Rome-Florence
(4) Upgraded conventional line

This EU directive legally defined HSR as operating at 155 mph or faster on new infrastructure and 125 mph or faster on upgrades to existing infrastructure. This has become the international standard for HSR everywhere except the United States. The EU has funded trans-European HSR network links in Belgium, the Netherlands, eastern France, and northern Spain.

European HSR currently extends over 575 miles west to east between London, England, and Berlin, Germany, and over 1,500 miles north to south from Stockholm, Sweden, to Marseilles, France. This continental HSR network is developing at a modest but steady pace, much like the United States Interstate Highway System that took decades to build out. Although trans-European HSR will extend over thousands of miles, most trips taken over the network are likely to remain in the 200–500 mile range. This compares closely to US intercity road travel, where the median trip length is 209 miles and the mean trip length is 520 miles.

Fourth Wave: HSR has been adopted as a primary link between many of China's major cities, covering routes up to 1,000 miles long. This most recent, and ambitious, development wave positions rail to meet a large share of 21st century mobility growth within China. As seen in TABLE 1, the scale of China's HSR network is already in a class by itself. HSR operations have grown from 25 million annual train-miles in 2007 to 156 million train-miles in 2011, accounting for 25

[3] Adapted from De Rus (2008: 34) with permission.

percent of total passenger train-miles operated in China. At the 2012 World Congress on High-Speed Rail, it was reported that HSR services are carrying 30 percent of total railroad passenger volume in 2012, a five percent annual increase.

Serving China's vast and growing market of intercity travelers appears to be profitable, based on estimates made by Morgan Stanley and echoed at the World Bank. Morgan Stanley research analysts estimate that the average annual operating costs of Chinese HSR amount to 4.5 billion renminbi (approximately $700 million) per 1,000 kilometers (621 miles), while commercial revenue brings in an average of 6.5 billion renminbi (approximately $1 billion) per 1,000 kilometers. Both Morgan Stanley and the World Bank analysts appear optimistic regarding China's HSR.

V. How will the differences between US and international railroad operations affect HSR development in the US?

Railroad operations developed differently in the US from those in Europe and Asia. Since 1964, parts of the world have embraced an increasingly ambitious agenda for HSR. Through the 1980s, however, America's railroads were in survival mode, struggling with decline, bankruptcy, and restructuring. The US railroads recovered by becoming technically and functionally specialized in ways that could be seen as incompatible with developing HSR.

Following deregulation with the passage of the Staggers Rail Act of 1980, US railroads were able to focus on profitable business segments through a process of rationalization. They shed business units that were not profitable, including selling many branch lines to shortline railroads, commuter rail agencies, or Amtrak. The railroads focused on moving freight bulk commodities, such as coal, lumber, and grain, as well as increasing automobile-related shipments. While containerized intermodal traffic over long distances was just beginning to grow in the 1980s, it would eventually make a major contribution to the railroads' profitable business model in subsequent decades. Almost everything else that railroads had done prior to 1980 was either abandoned or offloaded to other operators.

US rail infrastructure has become optimized for higher volumes and slower speeds than previously. Only the Northeast Corridor's tracks are optimized for intercity passenger operation, making it the most comparable infrastructure to railroads in Europe and Asia. Transit agencies in the Northeast, Illinois, California, Florida, and elsewhere have rebuilt commuter lines for trains moving mostly below 80 mph.

America's railroads remain vertically integrated, with a single private or public entity owning both trains and tracks. Access rights are negotiable but not guaranteed, with the exception of Amtrak, which maintains a statutory access to tracks owned by freight railroads.

Since 1991, the EU has divorced track ownership from railroad operations through regulation. Infrastructure was transferred to public enterprises that are distinct from the public, private, or mixed-ownership rail carriers. Open access has made Europe's railroad organization and operations much different, with multiple freight and passenger carriers now sharing a common infrastructure across that continent on a pay-as-you-go basis.

Railroad infrastructure moves mostly freight in North America while moving passengers is paramount in Asia and Europe, with the exception of China, where both freight and passenger movement is important.

These differences help explain the plural definitions of US HSR that the USDOT Federal Railroad Administration (FRA) promulgated in 2009. With billions of federal dollars to be allocated for HSR development, the need for a definition of qualifying projects became essential. But the resulting trinity of definitions suggests that the gulf between US railroad functions and global HSR practices appeared too wide to span with a single initiative.

> **First**, the FRA defined ***HSR Express*** as a train operating 150 mph or faster over a dedicated and completely grade-separated rail infrastructure between 200 and 600 miles in length. This comes close to the internationally accepted definition of 155 mph or faster.
>
> **Next**, FRA specified ***HSR Regional*** to be operations between 110 and 150 mph using a mix of dedicated and shared tracks over corridors between 100 and 500 miles long. This straddles the EU definition of upgraded conventional rail infrastructure that would extend HSR routes beyond trunk lines at 125 mph or above.
>
> **Finally**, FRA identified ***Emerging HSR*** as routes with a high potential for HSR that would initially operate at 90 to 110 mph over predominantly shared track in corridors between 100 and 500 miles long. This falls below both the EU standards and the international understanding of HSR but suggests that there are many corridors where incremental upgrading of freight railroad infrastructure was judged to be a prerequisite for future HSR.

Whatever the technical merits of FRA's definitions, managing a three-tiered HSR development program will be more administratively and politically challenging than the international approach to HSR. Conflict over prioritizing projects within and between each tier can be expected to rise in proportion to the limits on available funding, which will in turn depend on the cost of delivering projects in each tier. Predicting the cost of US HSR implementation will also be challenging, at least until there is solid evidence from project delivery in each tier.

Global HSR capital costs are becoming well known, but how they would translate into each tier of the US development approach is unclear. A survey of 45 European HSR lines operating in 2008 reported construction costs ranging from approximately $6.9 million per mile for rehabilitation of existing tracks to 125 mph up to $30.7 million per mile for building new infrastructure in urban areas. A World Bank report estimates the cost of HSR construction in China at between $21 million and $32 million per mile, excluding the cost of stations.

The most concrete evidence regarding US HSR development costs can currently be drawn from the capital budgets of the FRA's three development tiers. Beginning with the top tier, California is currently budgeting $44.6 million per mile to build the Merced to Bakersfield segment of the Bay Area to Los Angeles basin route, the only *HSR Express* project to have received ARRA funding. A major *HSR Regional* project was the $1.1 billion granted to Illinois to upgrade parts of the Union Pacific Railroad's 244-mile corridor between Chicago and

St. Louis, at an average cost of $4.6 million per route mile. And in the *Emerging HSR* tier, $782.5 million has been committed to upgrading a 467-mile long corridor between Eugene, Oregon, and Vancouver, British Columbia, where BNSF and Union Pacific freight trains operate at 60 mph and passenger trains will operate at 79 mph. The cost will average $1.675 million per route mile.

This budgetary range for projects in each tier of the US HSR program suggests a rough tripling of cost-per-mile to move from *Emerging* (79 mph) to *Regional* (110 mph) and a tenfold increase in cost-per-mile from *Regional* to *Express* (220 mph) levels of performance. It also suggests that attaining an internationally recognized HSR performance standard will be more costly in the US than it has been globally, while incremental upgrading of US railroads may cost less than international HSR projects. But these cost comparisons must be seen as provisional until the projects yield results.

With the differences between the operations of the US railroads and the global HSR now in clearer focus, it is possible to assess which lessons from the international experience will be more or less valuable to US HSR development.

VI. Drawing lessons from the four waves of the global HSR deployment.

How much of the insight from the four waves of global HSR deployment would be relevant to America's economic, political, social, and spatial circumstances? The global HSR experience can be organized along two dimensions to highlight the relevance of lessons for US HSR development. First, consideration must be given to how *relevant* international knowledge would be in the US context. And second, it is important to be mindful of how *difficult* it might be to transfer that knowledge to the US.

The resulting knowledge configuration is presented in TABLE 3 on page 10. Lessons that are both relevant and easily adaptable are highlighted in **green**, suggesting that they are "ready" to be applied in the US. Lessons that are either difficult to transplant or less relevant are highlighted in **yellow**, suggesting some caution will be needed. And lessons that will be both difficult to import and less relevant are highlighted in **red** to suggest that "Made in America" solutions will have greater value in these circumstances.

An area of global experience that offers particularly relevant lessons for US HSR development is shown in the lower left hand corner of TABLE 3. Experience with purpose-built "bullet trains" that would be transferrable draws from the first wave of HSR deployment and is highlighted in green. By building entirely new infrastructure, the incompatibility between US freight railroad and high-speed passenger rail operations could be avoided.

China's experience in planning and building a large national HSR network offers relevant knowledge that could be difficult to transfer into the US as shown in the upper left quadrant. China's experience would be quite relevant to President Obama's goal of bringing HSR within reach of 80 percent of America's population by 2035, announced in the 2011 State of the Union Address. But, this knowledge could be quite difficult to transfer given China's very different rail infrastructure planning, construction, and ownership arrangements.

Another area where lessons should be drawn cautiously can be seen in the lower right quadrant of TABLE 3 where, although knowledge transfer into the US does not appear difficult, the relevance of the global experience is questionable. An example is blending HSR passenger operations over conventional and high-speed tracks as occurs in France and Germany and is planned by California's HSR project. Such interoperation works well in Europe because freight rail operations are much more modest than in the United States and rail infrastructure is publicly owned with regulated open access.

TABLE 3

Potential Value of Global HSR Experience for US Applications

Difficulty of Knowledge Transfer	Relevance of Knowledge: ***More***	Relevance of Knowledge: ***Less***
More	Designing and implementing a nationwide HSR network (*e.g.,* China)	Upgrading existing rail infrastructure for higher speed service
Less	Deploying "bullet train" technology on separate infrastructure between major metropolitan areas (*e.g.*, Japan)	Blending new high- speed services and shared-use corridors (*e.g.*, France, Germany) Co-financing mechanisms to extend established high(er) speed services into an extended network (*e.g.*, European Union)

Until America's federal transportation development mechanism is fundamentally restructured to embrace rail infrastructure, there is one area of current development activity where the relevance of the global experience is low and the difficulty of transferring any lessons would be high. This upper right quadrant of TABLE 3 suggests limited value in global lessons from incrementally upgrading passenger rail infrastructure. Where this has been done in Asia and Europe, the operating environment and ownership structure differ significantly from the US. As a result, both the technical improvements and the implementation mechanisms are dissimilar. Instead of learning lessons about how to upgrade shared infrastructure from abroad, US proponents of HSR will need to invent new solutions and gain the know-how in implementing them at home.

VII. Building research capacity to close the knowledge gap in US HSR implementation.

Since global knowledge transfer can only yield part of the solutions needed to enable HSR deployment in the United States, there remains an increasingly urgent need for creating new knowledge that can accommodate HSR within America's distinctive railroad context. This gap in know-how needs to be filled through two approaches.

Learning by doing can offer valuable insights into what does and does not work. But this requires capacity to collect data, analyze it, and report objectively on the results. No such capacity has been built into the implementation of current projects.

Rich opportunities to learn by doing will arise from projects in each tier of the FRA's HSR development program. But the decentralized implementation of high(er) speed rail in each tier constrains sharing these lessons with the whole community of HSR experts. If knowledge mobilization procedures are not put in place soon, the default learning environment will be project specific and valuable lessons are unlikely to travel beyond the people working on a particular project.

Capacity in program assessment, evaluation, and knowledge sharing that could prove invaluable for US HSR development could be imported from America's public transportation sector. There, the USDOT Federal Transit Administration (FTA) presides over a robust research and development capability that could be transplanted to HSR. FTA's management of public transit (re)development embraced developing research and development capacity from the outset. Reporting requirements were attached to federal transit grants that yielded an extensive and transparent set of data on public transportation performance across the United States. These data have facilitated a rich output of research from consulting firms, scholars, think tanks, advocates, and critics of American public transit. In 1982, a cooperative research program was initiated by the FTA, APTA, and the Transportation Research Board (TRB) to support applied research into common challenges and opportunities facing American public transportation.

While the FRA has developed a robust research program, the focus on passenger rail research has been uneven. FRA has not required performance measures from those receiving intercity passenger rail grants as FTA does for transit grant recipients. The first wave of HSR projects creates an opportunity for FRA to design and deploy data gathering and analysis that would parallel FTA's oversight of transit operations. To accelerate such innovation, an interagency task force on HSR evaluation and research could work on translating as much of FTA's capacity into the emerging high-speed and intercity passenger rail development program as practicable, as quickly as possible. This knowledge transfer could be further facilitated by the recently launched National Cooperative

Rail Research Program, which was established by Congress in 2008 and funded by the Obama Administration in 2009.

Basic research will also be needed, initially, to fill knowledge gaps and then to develop solutions to as yet undiscovered challenges that will arise during HSR implementation. Asian and European HSR successes were built on decades long R & D programs. New knowledge will be needed to adapt global HSR technology for successful operation in the US.

The FRA's Transportation Technology Center (TTC) in Pueblo, Colorado, would be well suited to supporting this basic research. TTC was launched as the USDOT's High Speed Ground Test Center and funded by the High Speed Ground Transportation Act of 1965 that was intended to bring HSR to the US. When these early efforts ran out of steam, the facility pursued research and development for the freight railroads. In 1998, the Transportation Technology Center, Inc. (TTCI), a wholly-owned subsidiary of the Association of American Railroads (AAR), took over the management of the FRA's TTC.

TTCI operates on a fee-for-service basis and could carry out research funded by governments, private railroads, and equipment suppliers seeking to adapt global HSR technology. Such R & D needs should be built into the procurement specifications for HSR trains and related capital spending. Foreign suppliers' investment in R&D, within the US, could be given credit toward the "Buy America" requirements of federally funded HSR. This R & D effort from industry should be matched by federal and state government funding to encourage a rapid ramp up.

Another source of basic research capacity can be drawn from American colleges and universities that offer training in railroad engineering, planning, operations, and management. The USDOT funds twenty-two University Transportation Centers (UTCs) across the country, recently rationalized from 63 centers and institutes that had been supported since 1987. For the first time, one UTC is explicitly focused on railroad research, the National University Rail Center (NURail), based at the University of Illinois. NURail should partner with other UTCs to pursue basic research in HSR.

While both university-based research and the TTCI can begin to fill knowledge gaps that are now apparent, their capacity will become even more important to resolve the "bugs" that inevitably arise during HSR implementation. Past initiatives, from the *Metroliner* through the *Acela Express*, were plagued by unexpected problems that arose when new, or imported, technology was deployed on US railroads. The inability to overcome such bugs undermined the success of previous HSR attempts and raised skepticism about whether this technology was suited to meeting US mobility needs.

Effective learning, both from global experience where relevant and domestic innovation when needed, can address the unique and unanticipated challenges that should be expected in implementing HSR in the US. If the capacity to solve technical and operational challenges can be developed, and if one or more tiers of the FRA's HSR development program can deliver effective results, if not perfection, then the prospects for an intergovernmental planning and financing framework to carry HSR forward will improve.

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