Journal of Transport Geography 42 (2015) 134–144

Contents lists available at ScienceDirect

Journal of Transport Geography

journal homepage: www.elsevier.com/locate/jtrangeo

Corridors, hybrids and networks: three global development strategies for high speed rail

Anthony D. Perl [a,1], Andrew R. Goetz [b,*]

[a] Urban Studies and Political Science, Simon Fraser University, 2124-515 West Hastings Street, Vancouver, BC V6B 5K3, Canada
[b] Department of Geography & the Environment, University of Denver, 2050 E. Iliff Ave., Denver, CO 80208, USA

ARTICLE INFO

Keyword:
High-speed rail (HSR)
Intercity transportation networks
Railroad development innovation

ABSTRACT

After 50 years of experience with high-speed rail (HSR) development in Asia and Europe, there are important lessons that can be derived to inform future efforts to introduce HSR. This paper identifies and explores three strategic models of HSR development: (1) exclusive corridors (e.g., Japan), (2) hybrid networks—both national (e.g., France and Germany) and international (e.g., European Union), and (3) comprehensive national networks (e.g., China and Spain). Evaluations of these models yield outcomes that range from generally positive assessments of the corridor and national hybrid models to more concerns and uncertainties about the international hybrid and comprehensive national network models. When applying these lessons to the United States, contextual differences can make direct applications problematic. At the same time, though, certain elements of these three models that have been proven to be successful elsewhere may be adaptable to the U.S. and other newcomers to HSR development.

1. Introduction

Public debates concerning how, where, and even whether high-speed trains should be introduced in places where they have yet to appear, such as Canada and the United States (Loukaitou-Sideris et al., 2012; Vranich and Cox, 2013) raise important questions about how this transportation mode has been designed over the last fifty years. The global diffusion of high-speed trains has been uneven, compared to the uptake of other technology breakthroughs in mobility such as the internal combustion engine powered automobile, or jet powered aircraft. But during the half century since Japan's Shinkansen was launched, high-speed trains have expanded across Asia and Europe, gaining a higher profile in the global transportation system.

High-speed rail (HSR) has matured as a transport mode that can play an important role in moving people between cities more sustainably, especially when powered with electricity generated by renewable energy sources (Gilbert and Perl, 2010). While no mode of motorised mobility can be considered unequivocally sustainable today, Givoni et al. (2009: 85) assert that "rail transport ... cannot be considered 'green,' but it is most likely greener than other modes of transport it competes with." When it is well planned, introducing HSR to the mobility mix can shift travel from non-renewable energy intensive driving and flying. A comprehensive survey of HSR ridership experience revealed that 80% of riders, on average, had shifted from other modes, including conventional passenger trains, planes, and cars, with induced demand accounting for the remaining 20% of riders (Givoni and Dobruszkes, 2013).

Because HSR requires new infrastructure, construction can consume considerable energy and generate corresponding greenhouse gas emissions. The life cycle assessment of HSR projects has highlighted the risk that negative environmental impacts can arise if the new infrastructure is not used efficiently (Chester and Horvath, 2010). Rietveld (2002) found that passenger rail operations designed to accommodate high peak loads can waste energy and generate considerable emissions by running lightly loaded trains during the off-peak period. But well used HSR operations have been assessed as generating net social benefits.

De Rus and Nombella (2007) estimated that a 500 km. HSR corridor used by 8–10 million passengers per year would produce net social benefits. Since their appraisal did not account for any environmental effects of modal shift from autos and aircraft to HSR, the travel volume needed to yield benefits could be even lower if HSR passengers had previously flown or driven. When it comes to life cycle assessment, Westin and Kageson (2012) conclude that when a HSR corridor supports 10 million trips per year or more, and diverts travel from aviation, the greenhouse gas savings will exceed the emissions from building that HSR's infrastructure. Understanding the particular ways in which high-speed trains are providing mobility in different regions of the world, without

* Corresponding author. Tel.: +1 303 871 2866; fax: +1 303 871 2201.
E-mail addresses: aperl@sfu.ca (A.D. Perl), agoetz@du.edu (A.R. Goetz).
[1] Tel.: +1 778 782 7887; fax: +1 778 782 5297.

http://dx.doi.org/10.1016/j.jtrangeo.2014.07.006
0966-6923/

yet offering a uniform transportation option presents a worthwhile research question that has yet to be well explored.

In the analysis that follows, we seek to place the five decades of HSR advances across Asia and Europe in strategic perspective. We will identify and differentiate key principles that have been used to deploy HSR in the pursuit of increasingly ambitious mobility goals. And we will draw lessons for introducing HSR to the U.S. and other potential adopters of these global development strategies by considering possible HSR applications and their spatial configuration in the U.S., as well as related contextual factors, which are key parameters in assessing the likelihood of successful adoption and deployment. We begin by introducing a typology of HSR operation that highlights the ways that infrastructure planning and design for this mode have evolved over time.

2. Considering three models of HSR development

The evolving design and use of HSR infrastructure have covered a lot of ground over five decades, exhibiting an increasing diversity of scale and scope since this transportation option initially captured the world's attention in 1964. Table 1 presents the current distribution of HSR infrastructure being operated as of July 2013, listed in descending order of system length. As the use of HSR technology has spread, it became apparent that more than one formula exists for deploying and operating HSR infrastructure (Givoni, 2006; Campos and de Rus, 2009). It is also obvious that no single measure of success has been adopted for measuring the results of these diverse applications. Although some HSR applications are widely recognized as successful, there are other HSR operations whose outcomes have not yet fulfilled their promise.

Since 1964, HSR has evolved to undertake increasingly ambitious mobility goals. These can be classified into three categories, based on their design, operational characteristics and network topology (see Table 2 and Fig. 1). This categorization builds upon those developed by Givoni (2006) and Campos and de Rus (2009) by considering not only train and track compatibility (dedicated and/or shared use of infrastructure[2]), speed, and cost, but also factors such as the ambition for HSR's role in providing intercity mobility, the geographic scope of development (corridor, national, continental), and network configuration (trunk lines, bridge lines, radial, decentralized). Each category illustrates a new model in the organization and expectations for moving passengers by train.

2.1. Exclusive corridors

In its original model, HSR was deployed on an exclusive right-of-way to serve a corridor of 480–560 km (300–350 miles) anchored by two megacities.[3] Japan's pioneering New Tokaido line linked Tokyo (1964 population ~10 m) and Osaka (1964 population ~3 m),[4] covering 512 km (320 miles) at 210 kph (130 mph) for a capital cost of $920 million (approximately $6.8 billion in 2012 dollars). Speeds have been incrementally increased to 300 kph (186 mph) on the 700 series Nozomi trains, with today's journey times reduced to two and one-half hours (Albalate and Bel, 2012; de Rus, 2008) .

Table 1
Global high-speed rail infrastructure in operation as of July 2013.[a]

	Kilometers in operation	Kilometers under construction	Kilometers planned	Total kilometers
China	9760	9081	3777	22,618
Spain	2515	1308	1702	5525
France	2036	757	2407	5200
Japan	2664	779	179	3622
Turkey	444	603	1758	2805
Germany	1334	428	495	2257
Italy	923	0	395	1318
USA	362	0	777	1139
South Korea	412	186	49	647
Taiwan	345	0	0	345
United Kingdom	113	0	204	317
Belgium	209	0	0	209
Netherlands	120	0	0	120
Switzerland	35	72	0	107
Austria	93	0	0	93

[a] Data obtained from International Railway Union's High Speed Rail web site: http://www.uic.org/IMG/pdf/20130701_high_speed_lines_in_the_world.pdf Accessed September 8, 2013.

While little economic or technical critique of the original *Shinkansen* can be found, the costs of expanding this exclusive corridor model to serve smaller cities and less densely populated regions yielded losses that eventually left Japan National Railways insolvent and prompted its reorganization into private companies in 1987 (Mizutani, 1999; Yamaguchi and Yamasaki, 2009). Japan's experience demonstrated that HSR worked well in linking megacities with a high population density and served by extensive public transit systems. A cumulative impact assessment that compared Japanese domestic aviation and high-speed rail revealed that the original Tokaido Shinkansen corridor produced lower environmental impacts, even when the greenhouse gas emissions of infrastructure construction were taken into account (Ha et al., 2011).

But Japan also demonstrated that the HSR corridor strategy could not be expanded beyond megacity linkages without incurring a significant financial burden. Fig. 2 illustrates the current high-speed rail operations that expanded well beyond the Tokyo–Osaka line to other urban centers throughout the country. Both the success, and the limitations, of the corridor strategy prompted railway designers and developers to pursue a different strategy for implementing HSR in Europe.

2.2. Hybrid networks

The second model of HSR was designed as a hybrid system that blended high speed travel across new dedicated trunk line infrastructure together with operation at conventional speeds along interconnected branch lines shared with regular trains. By leveraging existing rail infrastructure, especially within built up areas using existing lines and stations, this hybrid strategy multiplied the number of origins and destinations that could be served by HSR. In Europe, the hybrid design of HSR infrastructure was intended to simultaneously expand freight rail capacity by clearing conventional trains off congested track segments and shifting travel to higher performing HSR on the hybrid infrastructure (Banister and Hall, 1993). This design enabled western European railroads to address both congestion along their busiest tracks (Givoni, 2006), while simultaneously boosting passenger train performance to regain market share along routes where ridership had been declining.

France introduced HSR to Europe in 1981 by inaugurating the Train à Grande Vitesse (TGV) connecting Paris with the provincial

[2] Campos and de Rus (2009) detailed four HSR models according to the relationship with conventional services: (1) Exclusive exploitation (only high-speed trains on high-speed tracks and only conventional trains on conventional tracks), (2) Mixed high-speed (high-speed trains on both high-speed and conventional tracks), (3) Mixed conventional (conventional trains on both high-speed and conventional tracks), and (4) Fully mixed (high-speed and conventional trains on both high-speed and conventional tracks).

[3] The contemporary definition of a megacity is considered to be an urban agglomeration with a population greater than 10 million. In the 1960s, the population threshold for a major urban agglomeration was much smaller.

[4] As of 2013, the population of the greater Tokyo agglomeration was ~35 m, and the population of the greater Osaka agglomeration was ~17 m.