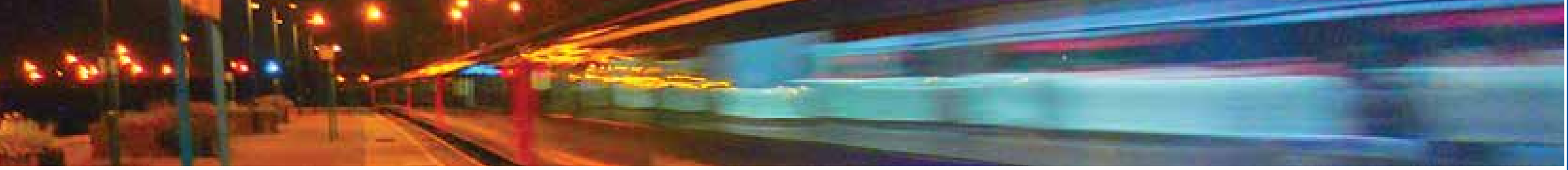

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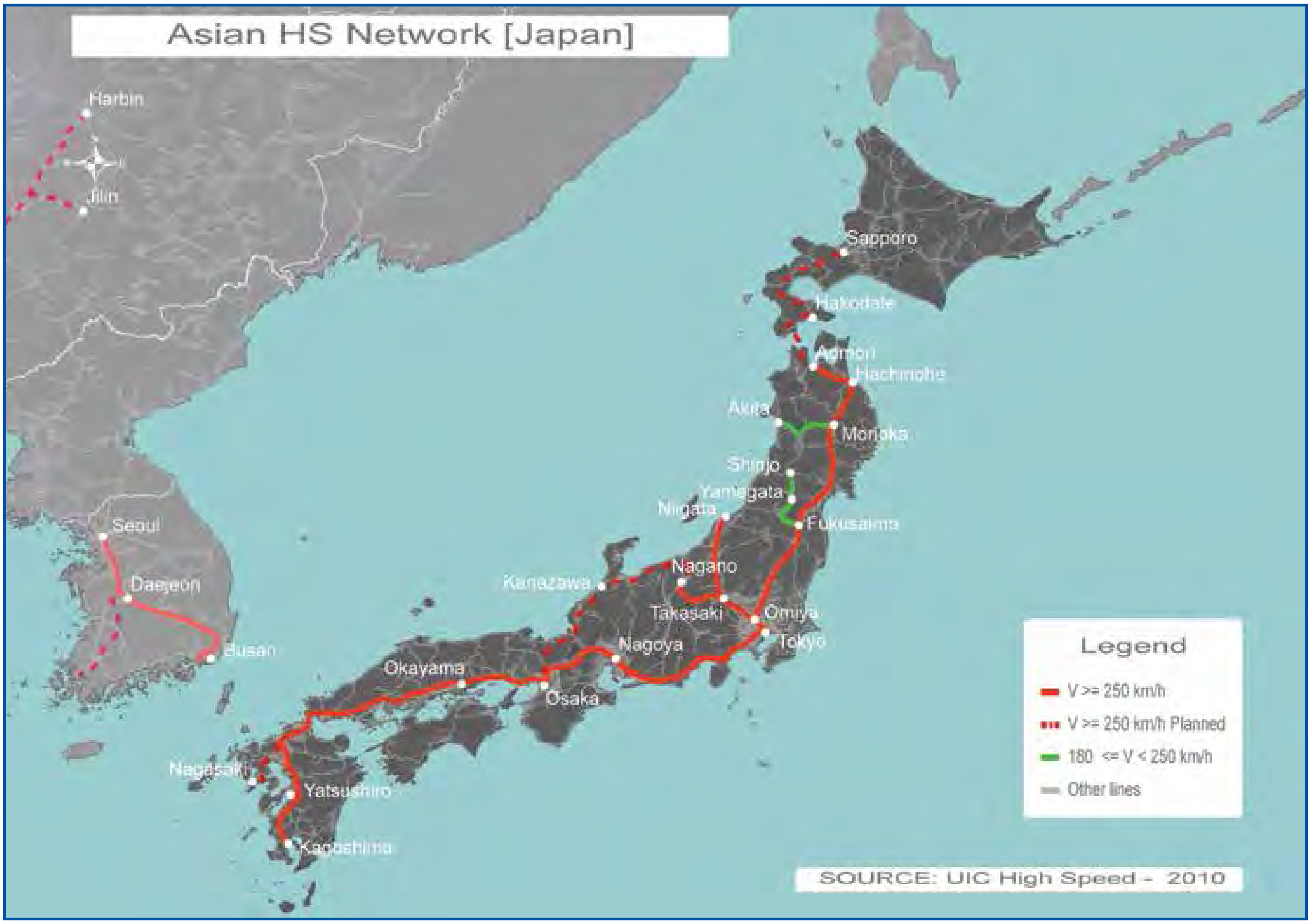
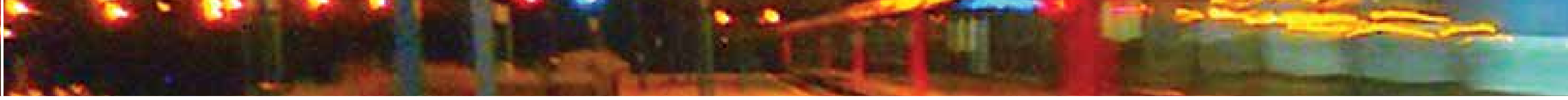


UIC Map of Japan's High-Speed Rail Lines

Japan is a densely populated country of approximately 128 million people with the fifth largest economy in the world, as measured by gross domestic product (GDP) of $4.497 trillion. The GDP per capita of $34,300 ranks 37th in the world. Considered 67 percent urban, Japan's largest cities include Tokyo (capital) with 36.07 million, Osaka-Kobe (11.325 million), and Nagoya (3.257 million). Japan created the first high-speed rail line in the world with the 515 km (320 mile) line between Tokyo and Osaka in 1964 that operated at a speed of 210 km/h (130 mph). Currently, there are 2,664 km (1,655 miles) of high-speed lines in Japan, with an additional 960 km (600 miles) planned or under construction. The map above illustrates the existing and planned lines in Japan according to the International Union of Railways (UIC).



SYSTEM DESCRIPTION AND HISTORY

The development of the high-speed rail network, known as the Shinkansen, was in response to major capacity constraints on the existing conventional passenger and freight rail network. The table below shows the UIC compilation of the Japanese Shinkansen line segments including an additional 378 km (235 miles) of lines under construction and 583 km (360 miles) of planned Shinkansen lines. The high-speed line names are included in parenthesis for each of the line segments.

Japan's HSR Line (Shinkansen) Segments

Stage	Speed		Year	Length	
	km/h	mph	Opened	km	miles
In Operation:					
Tokyo – Shin Osaka (Tokaido)	270	170	1964	515	320
Shin Osaka – Okayama (San-yo)	270	170	1972	161	100
Okayama – Hakata (San-yo)	300	185	1975	393	245
Omiya – Morioka (Tohoku)	300	185	1982	465	290
Omiya – Niigata (Joetsu)	240	150	1982	270	170
Ueno – Omiya	110	70	1985	27	15
Tokyo – Ueno	110	70	1991	4	2.5
[Fukushima – Yamagata (Yamagata)	130	80	1992 MINI	87	55]
[Morioka – Akita (Akita)	130	80	1997 MINI	130	80]
Takasaki – Nagano (Hokuriku)	260	160	1997	117	75
[Yamagata – Shinjo (Yamagata)	130	80	1999 MINI	62	40]
Morioka – Hachinohe (Tohoku)	260	160	2002	97	60
Yatsuhiro – Kagoshima Chuo (Kyushu)	260	160	2004	127	80
Hachinohe – Shin Aomori (Tohoku)	260	160	2010	82	50
Hakata – Shin Yatsuhiro (Kyushu)	260	160	2011	130	80
TOTAL				**2,664**	**1,655**
Under Construction:					
Nagano – Kanazawa (Hokuriku)	260	160	2015	229	140
Shin Aomori – Shin Hakodate (Hokkaido)	260	160	2016	149	95
TOTAL				**378**	**235**
Planned:					
Shin Hakodate – Sapporo (Hokkaido)	-	-	-	211	130
Kanazawa – Osaka (Hokuriku)	-	-	-	254	160
Shin Tosu – Nagasaki (Kyushu)	-	-	-	118	75
TOTAL				**583**	**360**
GRAND TOTAL				**3,625**	**2,250**

The following table notes 47 Shinkansen rail stations located on the nine high-speed lines (Tohoku and Akita are combined in the table). The distance between stations varies greatly from line to line. For example, the Tokaido Shinkansen that travels between Tokyo and Osaka far exceeds the average with 114 miles average distance between stations, while the Nagano Shinkansen has seven stations over the 138-mile line, which equates to a station every 23 miles. An average distance, based upon the average distances between stations of each line, is calculated as 52.5 miles.

Summary of Japanese Shinkansen Lines

HSR Line	Length of Line (miles)	Number of Stations	Average Distance between Stations (miles)
Tokaido Shinkansen	343	4	114.5
Sanyo Shinkansen	387	7	64.5
Kyushu Shinkansen	180	6	35.9
Tohoku/Akita Shinkansen	412	9	51.5
Joetsu Shinkansen	207	7	34.6
Yamagata Shinkansen	262	7	43.6
Nagano Shinkansen	138	7	23.0

Performance

Several sources highlight the reliability of the Japanese Shinkansen system. One prominent example is the Japan Central Railway (JR Central), which indicates that the Tokaido Shinkansen trains can carry more than 1,300 passengers while traveling at over 160 mph, operating on 5–10 minute headways, and keeping the average annual delay at 0.6 minutes (36 seconds).

One feature that increases reliability to high-speed operations is that the entire Shinkansen network is located in a dedicated right-of-way. This unique feature was required in order to operate faster trains since the existing conventional railway network is narrow gauge and could not support speeds greater than 140 km/h (87 mph). Japan largely consists of mountainous terrain with the major population centers located along the coastlines. These geographic fea-

JR Central N700 series Shinkansen set Z28 on the Sanyo Shinkansen between Okayama and Aioi stations

tures together with the requirement to avoid tight curves and steep grades have resulted in many tunnels and viaducts along the routes.

Sources: Central Japan Railway; Development and Impact of the Modern High-speed Train: A Review; High Speed Rail Passenger Services: World Experience and the U.S. Applications; International Union of Railways (UIC) website; High-Speed Rail: A Study of International Best Practices and Identification of Opportunities in the U.S.; High-Speed Rail: International Lessons for U.S. Policy Maker; High Speed Rail as a Tool for Regional Development.

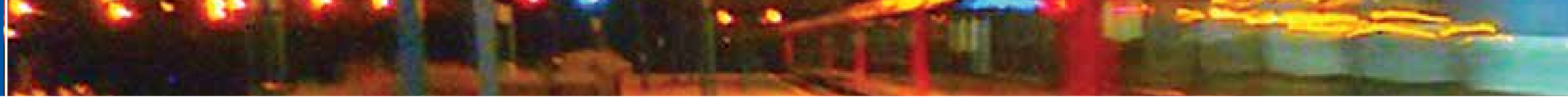
ECONOMICS AND FINANCE

The development of the Japanese high-speed rail system started as a major investment by the public sector but experienced a major shift in system operations that greatly affect how the entities approach business decisions. This section provides an overview of the operational model incorporated in Japan and the business strategies undertaken by the system operators.

Operational Model

The Japan National Railway, a fully integrated state-owned entity, was the sole high speed passenger rail operator in Japan prior to 1987. As a result of annual losses approaching $15 billion and total debt of $250 billion, reform in 1987 divided the national railway into six independent private intercity passenger rail operators. These companies, known as the Japanese Railways Group (JR Group), are based on six distinct geographic regions. The purchase of the existing Shinkansen occurred in 1991 with the JR companies assuming ownership of the infrastructure, real estate, and rolling stock assets while paying an annual fee for 60 years.

Prior to the reform, the national government assumed all debt associated with the construction of the high speed lines. Since 1987, the construction is divided between the national government (2/3) and local governments (1/3), with the national funding coming partially from the JR Group annual payments. Several resources indicate that the JR Group companies contribute a portion of the fi-



nancing for new construction. The Japan Railway Construction Corporation (JRCC) is the government funding conduit, infrastructure provider, and owner of new high-speed lines constructed after 1991. The JR Group companies pay 30-year fixed rate lease payments based on ridership estimates on any new infrastructure but are fully responsible for the operational and maintenance costs of those lines. Two following figures contain both the listing of the six intercity passenger rail companies and the map indicating their geographic location in Japan.

Business Strategies

The massive number of passengers attracted to the Japan Shinkansen provides abundant opportunities to stretch business strategies beyond that of just operating a train. The master development of the train stations to include retail and office space is often cited in documents examining the Japanese high-speed rail system. Ernst & Young (2009) states that almost 15 percent of the JR Group's revenues are derived through the leasing of these ancillary spaces. A major example of this type of development is the JR Central Towers built by the Central Japan Railway as part of its affiliated business diversification plan. Located above Tokyo's Nagoya station, the complex comprises of two 50-story high- rises that include a hotel, department store, offices, and Japan's largest indoor garden.

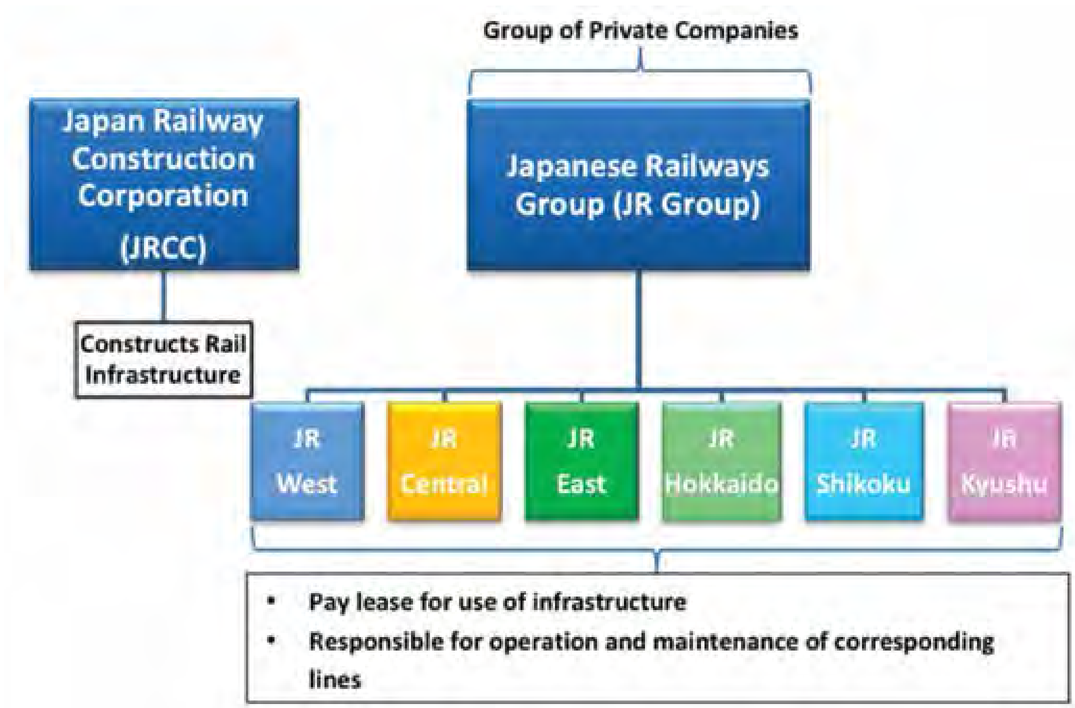
The Central Japan Railway Company's *Data Book 2011* indicates that only 6.3 percent of its revenue comes from non-Shinkansen and conventional rail line operations. However, JR Central emphasizes their diversification plan calls for active pursuit of "business strategies that broaden the operating foundation of the group"; that foundation being the Shinkansen and conventional rail. Major business areas outside the passenger railway services include travel agency services, wholesale and retail sales, parking lot operations, sales and leasing of real estate, food and beverage sales, and casualty insurance agency services.

System Revenue

With the national government providing no operating subsidies for high speed rail passenger operations, station-area development and diversification of the business operations provide for a means to expand revenue beyond the core train operations. For JR Central, the rail operations comprise almost 94 percent (85.3 percent Shinkansen and 8.4 percent conventional lines) of their $14.1 billion in revenue. The tremendous ridership associated with all the Shinkansen lines (stated at approximately 345 million in 2009) drives the revenue for the companies.

The World Bank generally states that railway fare structure "mimics the patterns of fares available on the airlines, and

Japanese High-Speed Passenger Rail Companies Listing



as a result, prices vary greatly depending on the flexibility of the ticket and how far in advance it is purchased." This makes it difficult in both instances to estimate the fare associated with different trips. One approach is to estimate the average yield, which the World Bank reports as $0.25 per passenger-km in Japan. They estimate that elsewhere in Asia the yield is typically $0.10 per passenger-km. One source does capture estimated fares reported by the Japan Railway Group for the different Shinkansen lines and is shown in the table to the right.

The large number of passengers utilizing the Shinkansen enables the Japan Railway Companies to capture higher passenger revenues per route length compared to other systems around the world, as indicated in the figure below. This graphic, captured from the JR Central report, indicates that the JR Central Shinkansen captures approximately $5.85 million per route length.

Estimated Fares Japanese Shinkansen Lines

HSR Line	Operator	Length of Line (miles)	Fare (US$)
Tokaido Shinkansen	JR Central	343	114.5
Sanyo Shinkansen	JR West	387	64.5
Kyushu Shinkansen	JR Kyushu	180	35.9
Tohoku/Akita Shinkansen	JR East	412	51.5
Joetsu Shinkansen	JR East	207	34.6
Yamagata Shinkansen	JR East	262	43.6
Nagano Shinkansen	JR East	138	23.0

Japanese High-Speed Passenger Rail Companies Map

Kagoshima City and Sakurajima, Japan

Sources: High Speed Rail Passenger Services: World Experience and U.S. Application; A Track Record of Success: High-Speed Rail Around the World and Its Promise for America; Central Japan Railway Company Data Book 2011; High-Speed Rail: Fast Track to Economic Development?; High-Speed Rail: A Study of International Best Practices and Identification of Opportunities in the U.S.

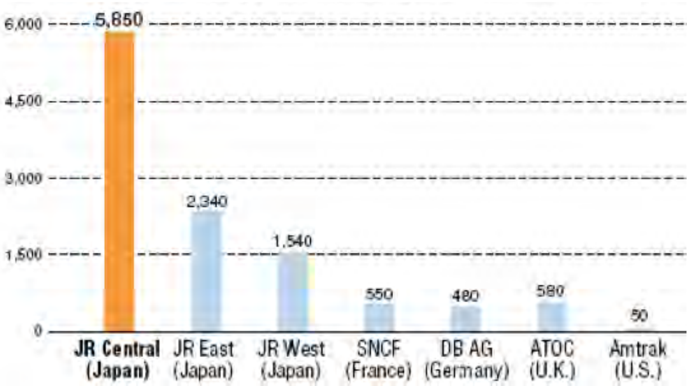
RIDERSHIP AND TRANSPORTATION SYSTEM IMPACTS

The Japanese high-speed rail network is part of a robust multimodal system designed to move persons in and between the major urban areas.

Ridership

The UIC documents a total of over 288.8 million passengers for the year 2009. The first year of operations (1964) experienced a ridership level of slightly more than 11 million.

Comparison of Passenger Revenues per Route Length (thousands of US$/route length



Other milestones include over 100 million (109.8 million) in 1972; over 200 million (206.8 million) in 1987; and over 300 million (301.3 million). Documented ridership peaked in 2007 with over 315.7 million passengers.

Mode Share

The primary competition for the Shinkansen comes from the airline industry with the intercity bus and private auto constrained by road congestion and high tolls (documented in one report as $68 per 100 miles). The figure on page 7 contains the market share comparison among four corridors, ranging from 550 km (340 miles) to 1,175 km (730 miles) in length. Traveling the Tokyo to Osaka corridor takes approximately the same amount of time, with a slight advantage to the Shinkansen (2 hours 25 minutes by train compared to an estimated 2 hours 40 minutes by airplane). The Shinkansen captures 83 percent of the market of the Tokyo to Osaka corridor. The slight increase in both distance (733 km [455 miles]) and total travel time over the Tokyo to Okayama corridor reduces the market share to 68 percent Shinkansen and 32 percent airplane. The Tokyo to Fukuoka corridor measures 1,175 km (730 miles), which translates into a significant gain in travel time by airplane compared to the Shinkansen, 2 hours 40 minutes and 4 hours 50 minutes, respectively. With the great discrepancy in travel time the Shinkansen only maintains a 10 percent market share.

Sources: High-Speed Rail: A Study of International Best Practices and Identification of Opportunities in the U.S.; Central Japan Railway Company Data Book 2011.

SUSTAINABILITY

High-speed rail is often touted as a mechanism for sustainable mobility and transport because of its energy efficiencies and environmental benefits compared to other modes. Electrically powered systems are viewed as more environmentally friendly than those modes of transportation dependent on petroleum, especially if the electricity is generated by means other than fossil fuels. To that point, the Lincoln Institute of Land Policy points out that Japan's high-speed rail system uses geothermal and hydro power to meet up to 56 percent of its energy needs.

Energy Efficiency

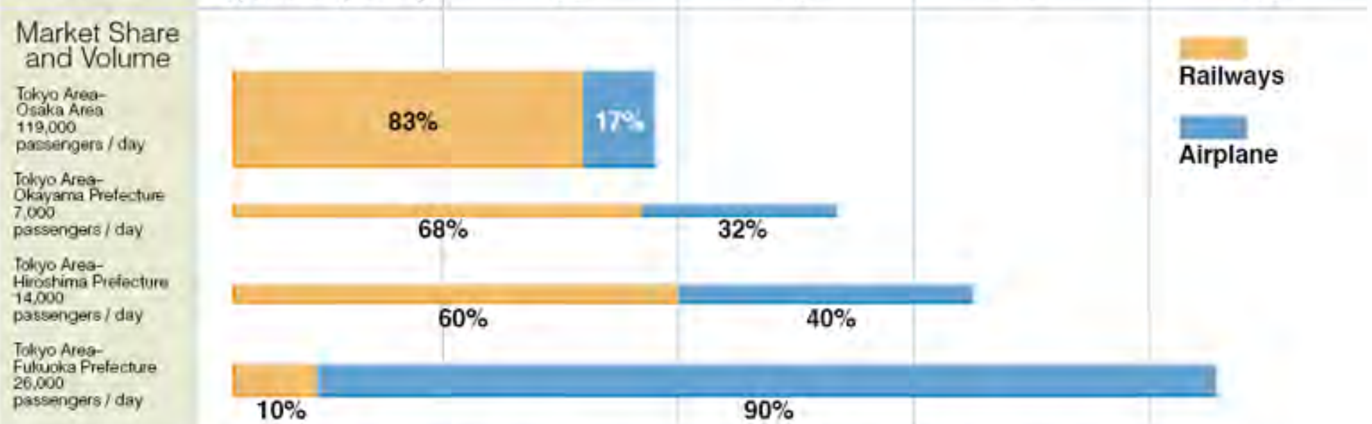
The long history of operation by the Japanese high-speed trains provides an opportunity to review the energy improvements realized through the technological advances in Shinkansen train performance. The first Shinkansen train models used a single locomotive that pulled the train. New models switched to a distributed traction system where the trains are powered by axles on every passenger car, which reduces the axle loads. The Central Japan Railway notes that the introduction of the most current Series N700 rolling stock reduces energy consumption by 32 percent compared to the original Series 0 Shinkansen trainsets based on simulated test runs as shown in the diagram on page 8. As of the third quarter of 2011, the JR Central Railway reports that all the Shinkansen rolling stock is the energy-saving type (Series 300, Series 700 or Series N700), with almost half being the new Series N700.

Noise Reduction

With the first high-speed system in the world, Japan has found itself in the lead in terms of tackling the noise pollution issues that arise from a high-speed train set operating with overhead catenaries. A UIC report titled, *High Speed Rail and Sustainability*, documents the noise abatement history undertaken by Japan over the years. In 1975, the Japanese Environmental Agency established noise level standards for high-speed rail services. Measurements determined the major noise producing areas were the concrete structure, carriage underbody, aerodynamic noise from the carriage body, pantograph, and spark noise. The UIC report indicates that addressing the noise issue from a variety of measures reduced the noise levels from 79.5 dB

JR Central Comparison of Intercity Transportation Service Air/Rail Market Shares

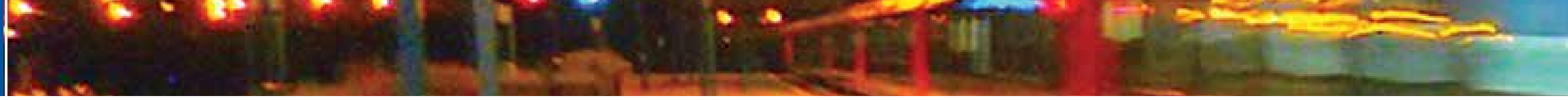
Between Tokyo and . . .		Osaka (552.6 km)	Okayama (732.9 km)	Hiroshima (894.2 km)	Fukuoka (1,174.9 km)
Shinkansen	Travel time	2 hr. 25 min.	3 hr. 12 min.	3 hr. 48 min.	4 hr. 50 min.
	Departures per day	250	128	97	70
Airplane	Travel time	1 hr. 5 min. (About. 2 hr. 40 min.)	1 hr. 15 min. (About. 3 hr)	1 hr. 20 min. (About. 3 hr. 10 min.)	1 hr. 30 min. (About. 2 hr. 40 min.)
	Departures per day	102	18	34	92



Notes: 1. Travel times in parentheses include transfer and access times from airports to city centers, based on the most advantageous service.
2. Market share is the percentage of all railway and airline services based on the inter-prefectural data of the *Inter-Regional Passenger Mobility Survey* (FY 2009.3), published by the Ministry of Land, Infrastructure and Transport.
3. Railway stations and airports for each destination—

Tokyo:	Tokyo Station	Haneda Airport
Osaka:	Shin-Osaka Station	Itami Airport/Kansai International Airport
Okayama:	Okayama Station	Okayama Airport
Hiroshima:	Hiroshima Station	Hiroshima Airport
Fukuoka:	Hakata Station	Fukuoka Airport

4. Tokyo Area: Tokyo, Kanagawa, Chiba, Saitama, Ibaraki
Osaka Area: Osaka, Kyoto, Hyogo, Nara



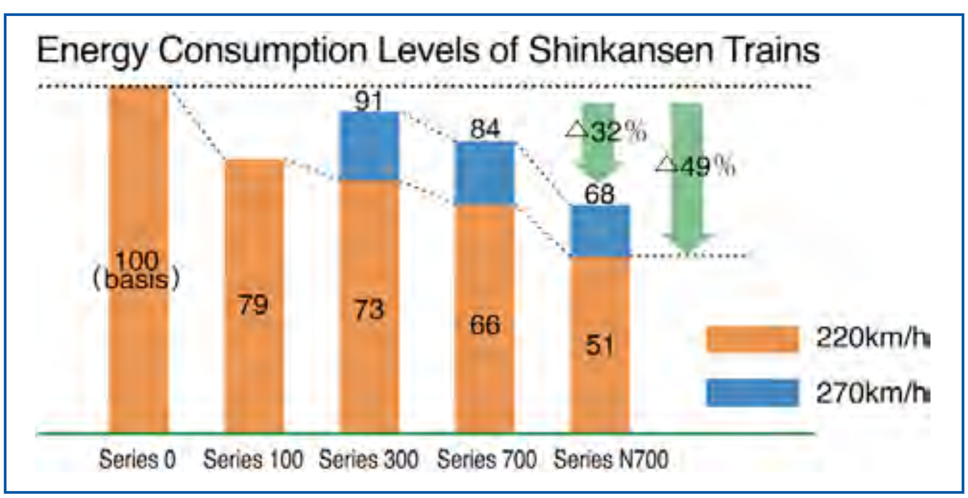
Shinkansen high speed train, Japan

(A) in 1982 to 76 dB (A) in 1997. This is despite three major increases in train speeds over that period, ultimately traveling from 210 km/h to 300 km/h. The report highlights that measures over that time period virtually eliminated concrete structure noise and spark noise, which is an electrical noise caused by contact loss.

An additional significant noise discovery included the sonic booms generated by high-speed trains passing through long tunnels. Several innovative solutions minimized this phenomenon and have provided valuable experience for other high-speed rail developments.

Sources: Central Japan Railway Company website; High-Speed Rail: International Lessons for U.S. Policy Makers; High Speed Rail & Sustainability.

Central Japan Railway Company Shinkansen Train Energy Consumption Levels



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