THE PERFORMANCE AND EFFICIENCY OF HIGH-SPEED RAIL SYSTEMS IN EUROPE AND ASIA

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ABSTRACT

Since the introduction of high speed in railways in Japan in 1964 and in France in 1981 high-speed rail systems have been developed in various countries in Asia and Europe. Governments try to create new dynamics in railway transport to cater for the rising need for high-speed travel demand and railways are revitalized to be able to compete better with other modes of transport. An important focus is on the development of new high-speed networks in order to facilitate growth in mobility and to limit air travel.

The building of high-speed rail systems requires substantial investment in infrastructure, railway stations and rolling stock. Meeting the expected performance and efficient use of capital-intensive infrastructure and rolling stock assets is needed to justify the investments made.

This study presents the best practices in high-speed rail performance by comparing the world's major high-speed rail systems currently in operation regarding travel performance, ridership, train fleet and network. The efficiency of these railway systems in Europe and Asia is benchmarked against selected key performance indicators for network, fleet and station utilization derived from the actual system characteristics and performance. The goal of the study is to identify the best high-speed rail practices in the world. Countries that are planning for a high-speed rail future may benefit from these results.

Significant differences are found between Europe and Asia in the key performance indicators considered. Differences are explained by assessing the actual performance of the railway system and the benchmark methodology applied. The case for China is not assessed in full as longer time series of data on travel volume and fleet performance is currently not available.

Keywords: rail transport, high-speed rail, performance, efficiency, benchmark

1. INTRODUCTION

The building of high-speed rail systems requires substantial investment in infrastructure, railway stations and rolling stock. Efficient use of these capital-intensive assets is needed to justify the investments made. National governments decide on the development of high-speed rail systems based on the expected future demand for high-speed travel and the social benefits for the country. Long-term performance forecasts for high-speed rail are a basic input for the decision-making process. Ex post, in the operational stage, the assumptions can be validated based on the actual system performance. The goal of this study is to find the best practices in high-speed rail performance by comparing the world's major high-speed rail systems currently in operation. The performance and efficiency of these railway systems is benchmarked against selected key performance indicators derived from the actual system characteristics and performance.

The study is split into two stages. Stage 1 gives an overview of the major high-speed rail systems in the world and their performance. An initial comparison is made to find the key variables for a more elaborated benchmark. Stage 2 presents a detailed benchmark study to compare five high-speed rail systems in Europe and Asia against a selection of key performance indicators. The paper is structured as follows. Section 2 describes the performance and characteristics of the eight most important high-speed railway systems in the world, four in Asia and four in Europe. It gives an overview of the development of world's high-speed train fleet, the networks and system performance. Some indicative results for the benchmark study are presented. In Section 3, the methodology and data used in the study are presented to benchmark the high-speed rail systems in detail. Section 4 provides the results for the calculated key performance indicators for five high-speed rail systems. Section 5 discusses the results. Finally, the conclusion from the benchmark is presented in section 6.

2. HIGH-SPEED RAIL PERFORMANCE AND CHARACTERISTICS

This section gives an overview of the traffic performance and associated fleet and infrastructure characteristics of the worlds' leading high-speed rail systems. An initial indicative comparison based on the performance data gives some preliminary results that are studied in a more detailed benchmark in section 3.

When looking at the adoption of high-speed rail transport on the world map, there are two regions that have substantial experience in developing, building and operating high-speed rail networks: Europe and Asia. Although there are some good examples of countries across the world adopting new high-speed rail technology, there are in fact eight countries in the world leading: in Europe: France, Germany, Italy and Spain and in Asia: Japan, Taiwan, Korea and China.

Appropriate infrastructure and rolling stock are needed for supplying high-speed train services. The total length of high-speed lines in the network, the number of railway stations for access and egress of passengers and the number of available high-speed trains and their seating capacity are key parameters for the high-speed rail system performance. The final output performance of high-speed rail systems can be expressed in terms of travel volume and is defined as the product of the yearly number of passengers, i.e. ridership, and the average travel distance per passenger.

High-speed rail performance

The traffic performance delivered by high-speed rail networks in terms of ridership (number of passengers per year) is sketched in figure 1 for the eight selected Asian and European countries that run high-speed rail services.

It shows the early start of Japan in 1964 and the steady growth over the last decades. JR is the front-runner in traffic performance due to the early adoption and continuous development of high-speed rail technology in Japan. The start of the TGV projects in Europe in 1981 can be recognized. Due to the steep growth in China since 2006, in 2010 the high-speed rail ridership has reached the same level as in Japan. Looking at the ridership Japan accommodates the same amount of passengers per year as China and Europe but on a network that is half that of China and one third of the Europe one.

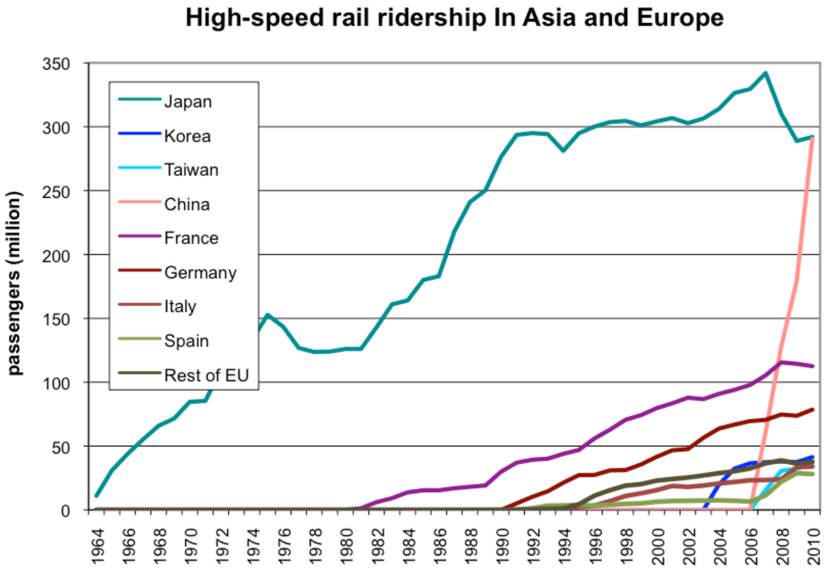

Figure 1: High speed rail ridership in Europe and Asia from 1964 till 2010 (Europe: UIC, 2011, Asia: KTX, 2012)

Europe

In 2009, the high-speed rail traffic performance in Europe exceeded 100 billion passenger kilometers (figure 2). More than 50% was generated by SNCF and 20% by DB mainly on their national high-speed lines. Over the last 10 years traffic volumes doubled with an average annual growth rate of 7%. This strongly correlates with the opening of new high-speed lines in the various countries. The TGV Rhine –Rhône high-speed line (Dijon-Mulhouse) is opened for commercial service in December 2011. Most recently, on 8 January 2012, the Spanish high-speed Barcelona-Figueres section was inaugurated. This railway infrastructure completes the total length of the 804 km Madrid-Barcelona-French Border high-speed line.

In France the high-speed rail policy focusses on the building of entirely new high-speed lines for 300 km/h on congested transport axes. DB in Germany runs in an operational model with their ICE trains using both new high-speed lines and upgraded conventional tracks.

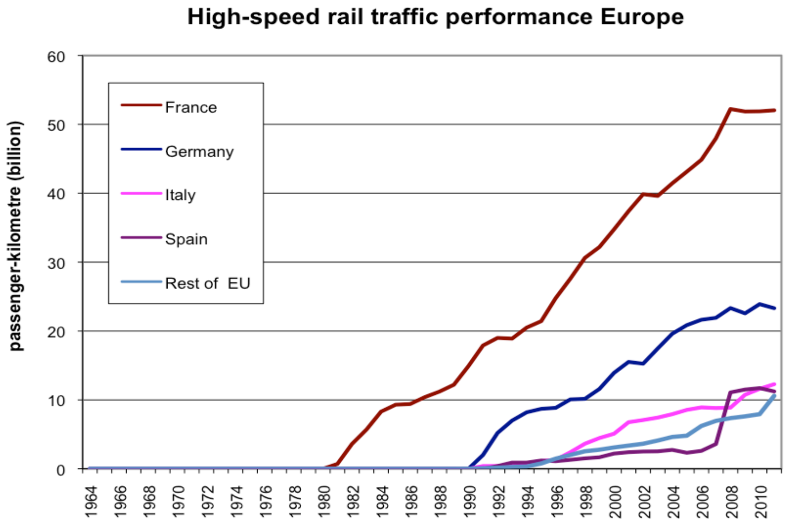

Figure 2: High speed rail traffic growth in Europe till 2011 (UIC, 2011)

Asia

On October 1964 the Toikado Shinhansen was put into service between Tokyo and Osaka, just before the Olympics. In ten years time this line reached a travel performance of more than 50 billion passenger kilometres and has carried over 6 billion passengers since opening (figure 3). In 1975 the Toikado line extension to Hiroshima and Fukuoka (Sanyo line) was completed. After that year the network gradually developed North-East of Tokyo with new lines: Joetsu (1982), Tohoku (1991), Yamagata, Nagano and Akita (UIC 2010). Today, the Japanese Shinkansen network is operated by JR Central (Toikado), JR East (Joetsu, Tohoku, Yamagata, Nagano, Akita), JR West (Sanyo) and JR Kyushu producing more than 80 billion passenger kilometres in 2010.

Having a closer look at China we find that detailed official travel volume figures for the high-speed rail services are generally not available. A recent World Bank report shows that in 2010 290 million passengers (17% of total carried in China) travelled on services operating at 200 km/h both on dedicated high-speed lines and "speeded-up" conventional lines (Bullock et al 2012). Introduction of high-speed rail led to a shift from conventional to high-speed rail services and induced a significant amount of new traffic as can be seen from the three cases presented by the World Bank: Changchun – Jilin, Wuhan – Guangzhou and Beijing – Tiajing (Bullock et al 2012). These generated trips come on one side from competing modes like private cars, busses and airplanes and on the other side new travellers will enter the system as a consequence of growing mobility needs. On 26 December 2012 China's Ministry of Railways inaugurated the world's longest high-speed rail line which connects Beijing to

Guangzhou. The 2,298 km line will be covered at an average line speed of 300 km/h and enable the journey to be completed in approximately 8 hours. As high-speed rail operations in China have only started recently the expectation is that the continuous growth of the network and rising incomes will lead to increasing travel demand and ridership.

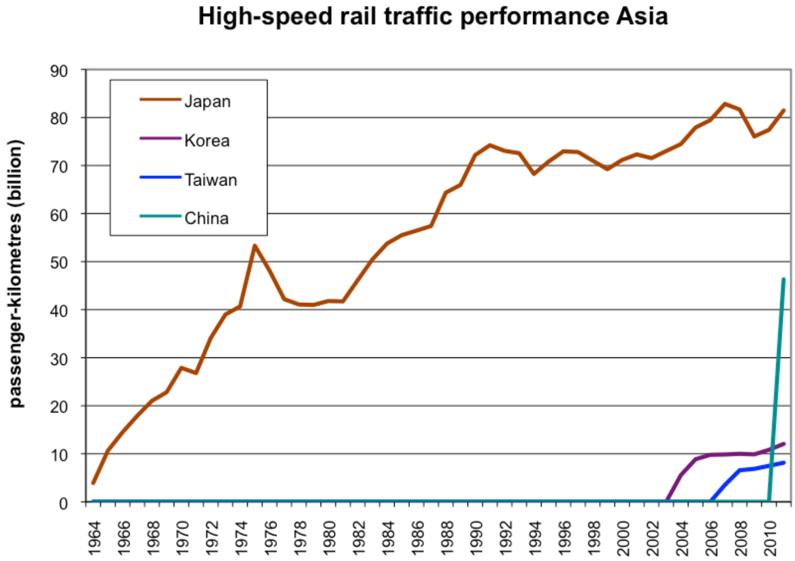

Figure 3: High speed rail traffic growth in Asia till 2011 (KTX, 2011)

The world's high-speed train fleet

A fast growing fleet of high-speed train sets provides high-speed rail services in the world. Figure 4 shows the development since 2008 in Europe and Asia and the projection made for 2025 by UIC (UIC 2008, 2010, 2012). The world's high-speed train fleet will double towards 2025.

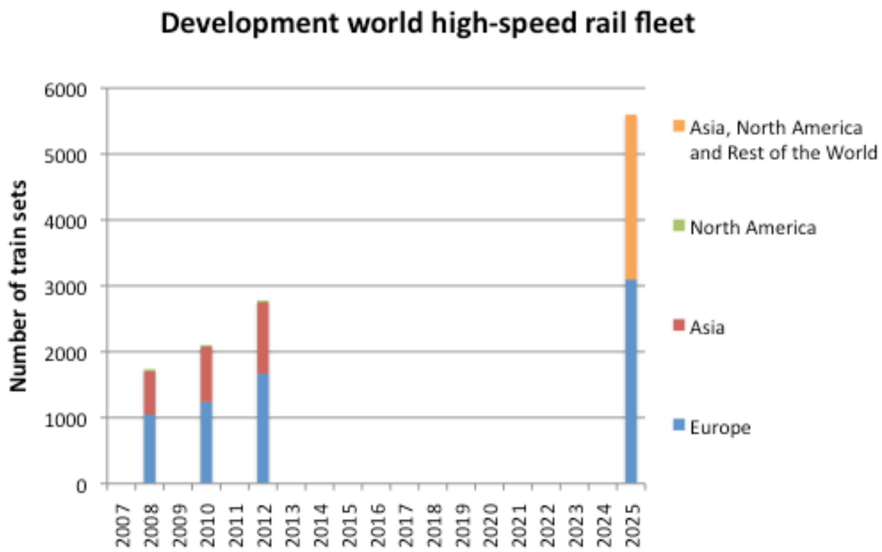

Figure 4: High-speed train fleet development in the world (UIC, 2008, 2010, 2012)

As there is a large variety in train sets, a detailed analysis is made based on the UIC world high-speed rolling stock database (UIC 2011a).

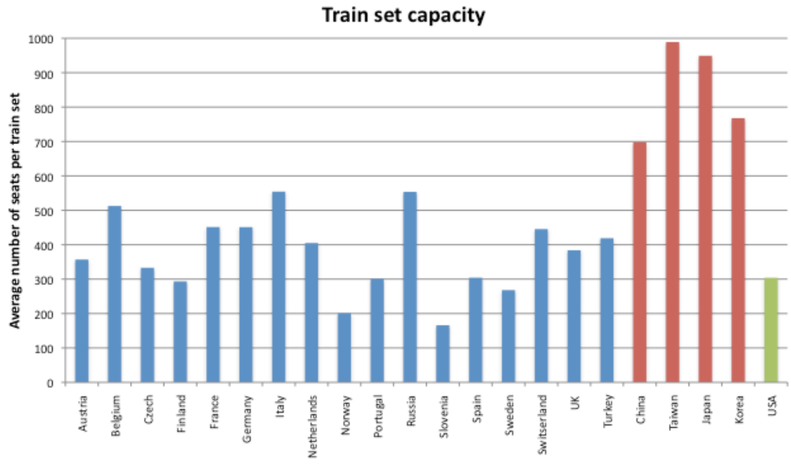

Figure 5: Train set capacity in Europe, Asia and USA (UIC, 2011)

There is a remarkable difference in capacity per train set between Asia and Europe. The average train seating capacity in Asian countries is 851 and in Europe 376 seats. The reason is that in Asia high-speed trains have train set configurations with more coaches (figure 5).

The high-speed rail network

In 30 years time, starting in 1981, more than 6,500 km high-speed line was built in Europe (UIC 2011b). The length of new high-speed lines in Europe doubled from 1998 till 2008 (average growth of about 300 km or 8.6% per year). It is expected that this growth will continue till at least 2025 as can be seen from figure 6. In Asia, Taiwan and Korea introduced high-speed rail technology before the Chinese Ministry of Railways launched their Mid to Long-Range Network Plan (MLRNP) in 2003 targeting 12,000 km's high-speed passenger network by 2020 based on four north-south and four east-west corridors. UIC predicts that the total length of the high-speed network in the world is 42,322 km in 2025 (UIC 2012). They take only projects into account that are in operation, under construction or planned, the latter meaning that the decision for construction is taken and that there are contracts signed and budgets available. Countries like India, the US, Canada, Australia and Norway are studying the opportunities for having high-speed rail. These plans add up to an extra estimated 10,000 km of high-speed rail network.

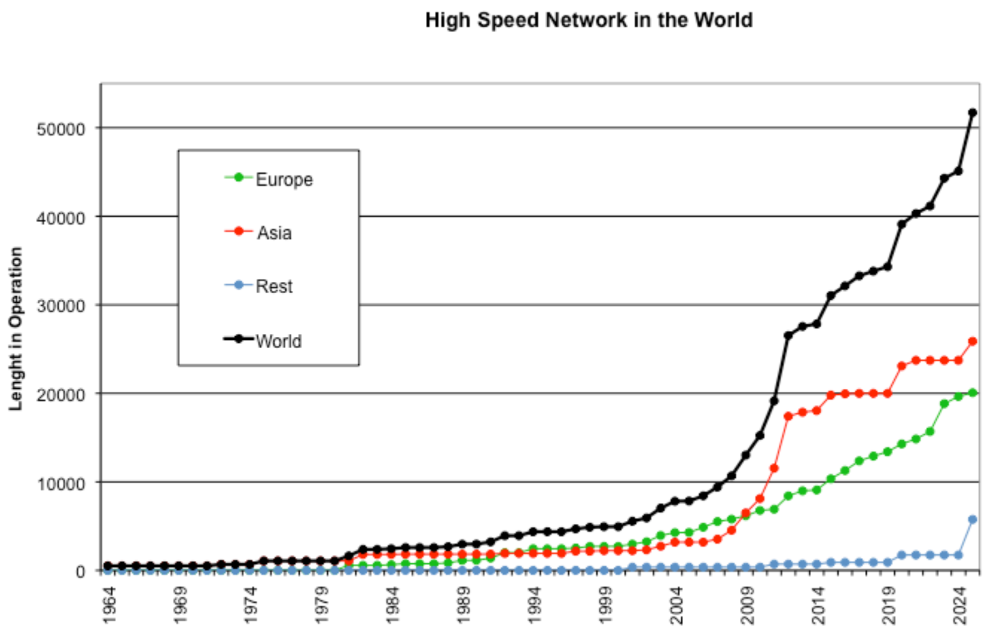

Figure 6: Development of high-speed rail network in the world (UIC 2012)

After the opening of the first Shinkansen high-speed line between Tokyo – Osaka in Japan in 1964, it took more than 15 years before Europe adopted the high-speed rail concept starting in France with the opening of the Paris – Lyon TGV line. Also Italy was an early adopter on the Rome – Florence route, followed by Germany in de mid 80's and Spain in the early 90's. In 2009, Asia took over the lead caused by a fast growing high-speed network in China. Based on the situation in 2011, figure 7 shows that in Europe at that time 6,637 km was in operation, 2,427 km under construction, 8,041 km planned and 2,857 under study. In 2025, the total length of category I (> 250 km/h) high-speed lines will be around 20,000 km, about 40% of the world high-speed rail network (UIC 2012, " under study" projects added by aythor).

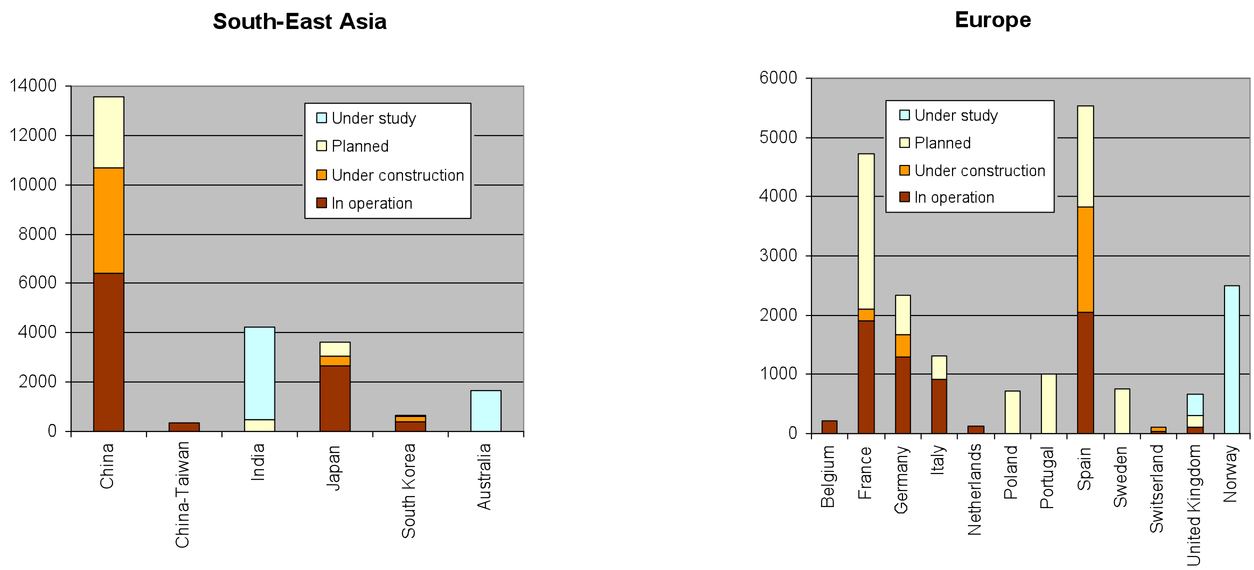

Figure 7: High speed rail network in Europe (UIC 2012) ("Under study" projects added by author)

When we look in more detail per region we see that Japan was worldwide the high-speed rail innovator in the sixties. China was a relatively late adopter, but over the last five years a strong growth in network development and passenger traffic has taken place. Australia and India are planning for a high-speed rail future. Currently studies are investigating the feasibility of new high-speed rail networks in these countries. In Europe a steady network development is observed in 30 years time starting with TGV Paris-Lyon. Projects are still going on and the expectation is that the network will be extended for the next 10 to 15 years. Also Turkey is building new high-speed projects and Norway is studying the feasibility for their country.

Correlation between ridership and fleet capacity

The correlation between performance and the key characteristics of the high-speed rail system can be evaluated by combining the data of the high-speed fleet capacity and network length with the ridership and travel volume data as presented earlier. The correlations of ridership versus fleet capacity and travel volume with network length are investigated and figure 8 and 9 present the resulting graphics. For an asset like a theatre or a football stadium it makes sense to evaluate the ratio between visitors and available seats as an efficiency indicator. As passengers access and egress trains all the time, the situation for railways is more complicated. Trip length and duration are important variables as well that need to be taken into account.

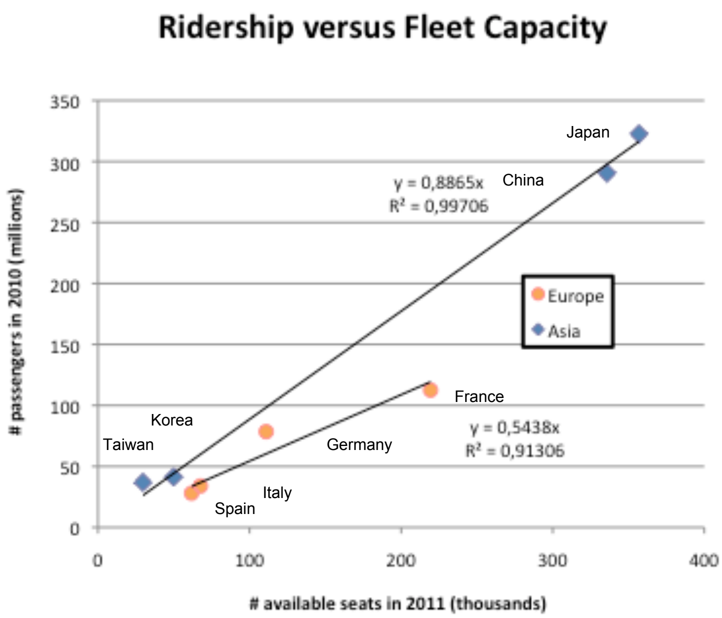

Figure 8: High-speed rail ridership versus fleet capacity in Europe and Asia 2010/11 (based on UIC data)

The result for the fleet capacity (figure 8) shows that for the same fleet capacity ridership in Asia is about 60% higher than in Europe. It might be the case that Asian travellers take shorter trips or that trains have higher seat occupancies. To clarify the differences a more detailed benchmark is set up as presented in Section 3.

Correlation between travel volume and network capacity

Looking at the travel volume versus network length (figure 9), it shows that the travel volume in Japan is about 75% of Europe, but that this performance is delivered by a network only one third of Europe's. Within Europe large variations can be seen as well. China is missing in figure 9 as longer time series of travel volume data is currently not available. For 2011 travel volume in China was 230 million passenger kilometres (Bullock et al 2012) on a network of 6,405 km (UIC 2012), which is double the EU 27 aggregate value.

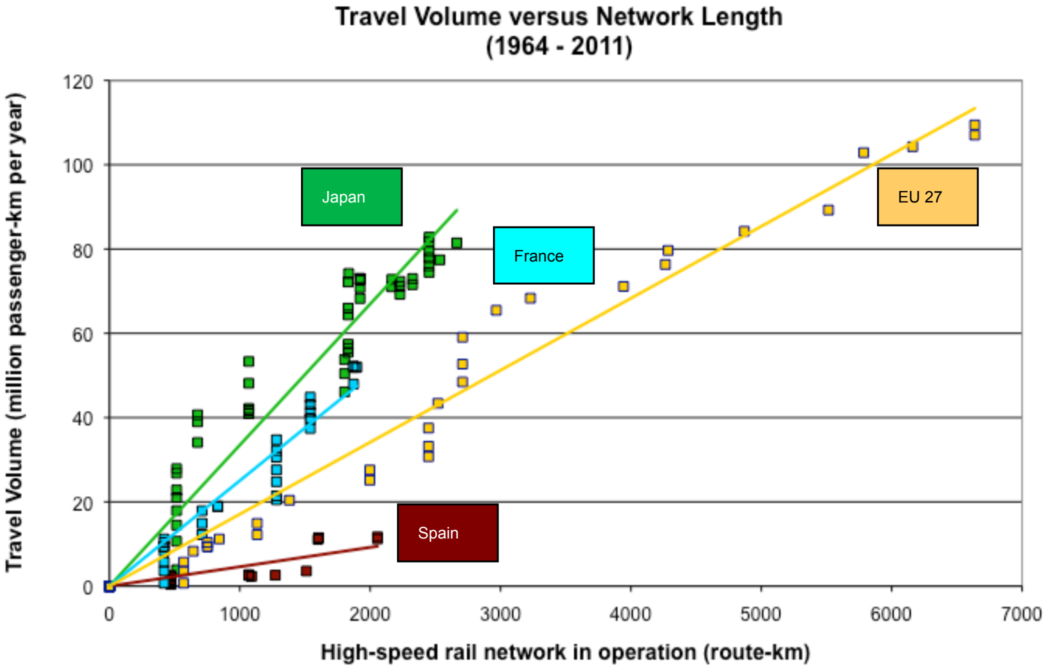

Figure 9: Travel volume versus Network Length (based on UIC and EC data)

From figure 9 one could conclude that there is still a lot of room for growth in Europe, but this strongly depends on the network's layout, the operating model, the type of rolling stock and the systems' maturity. In fact there is an indirect relationship between network length and travel volume. As the performance of the train fleet is the missing variable it would be better to evaluate the correlation between yearly number of train kilometres and the network length. This ratio is further elaborated in a systematic benchmark approach in the next section. A difficulty that appears is that fleet performance is not always publicly available and is seen as confidential information from the train operators' point of view.

3. BENCHMARK METHODOLOGY, VARIABLES AND DATA

This section presents a more adequate benchmark methodology based on a system approach, taking the indicative results from the former section as a starting point.

A railway system can be modelled as a Multiple-Input Multiple Output (MIMO) system for efficiency, productivity and costs analyses (Cantos et al 2010, Mizutani and Uranishi 2012). A system approach with N inputs and M outputs as illustrated in figure 10 is the basis for the benchmark stage of this study. The first step is to define the relevant input and output variables. Choosing appropriate performance indicators for the high-speed rail system is the next step. Finally, key and additional performance indicators can be calculated using the available data.

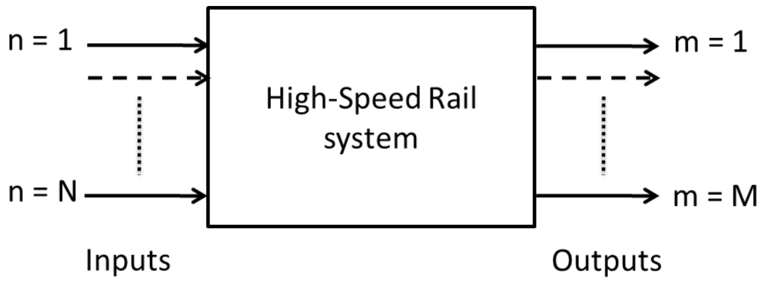

Figure 10: A multiple input multiple output of a high-speed railway system

Variables

To provide high-speed train services in a country three major physical assets are needed:

- A high-speed rail network
- Railway stations for access and egress of passengers
- A fleet of high-speed trains

Besides physical assets, an operational model and timetable to run the trains on the network is required to deliver the rail services. Staff on board and at the railway stations is also a production factor, but we do not take that into account in this study.

Appropriate infrastructure and rolling stock are needed for supplying high-speed train services. The total length of high-speed lines in the network, the number of railway stations for access and egress of passengers, the number of available high-speed trains and their seating capacity are key parameters for the high-speed rail system performance. The final output performance can be expressed in terms of travel volume and is defined as the product of yearly number of passengers and the average travel distance per passenger. Ridership and train or seat kilometres produced by the fleet are additional output variables indicating the railway's performance. Besides the necessary assets an adequate operational model is needed to optimise the rail system performance.

The high-speed rail MIMO system is detailed in figure 11 with four asset-related input parameters (N=4) for the infrastructure and rolling stock and three output parameters (M=3) for the transport and travel performance. From these input and output variables three key and two additional performance indicators are derived for each asset type (network, fleet and stations) to benchmark the high-speed rail systems under study.

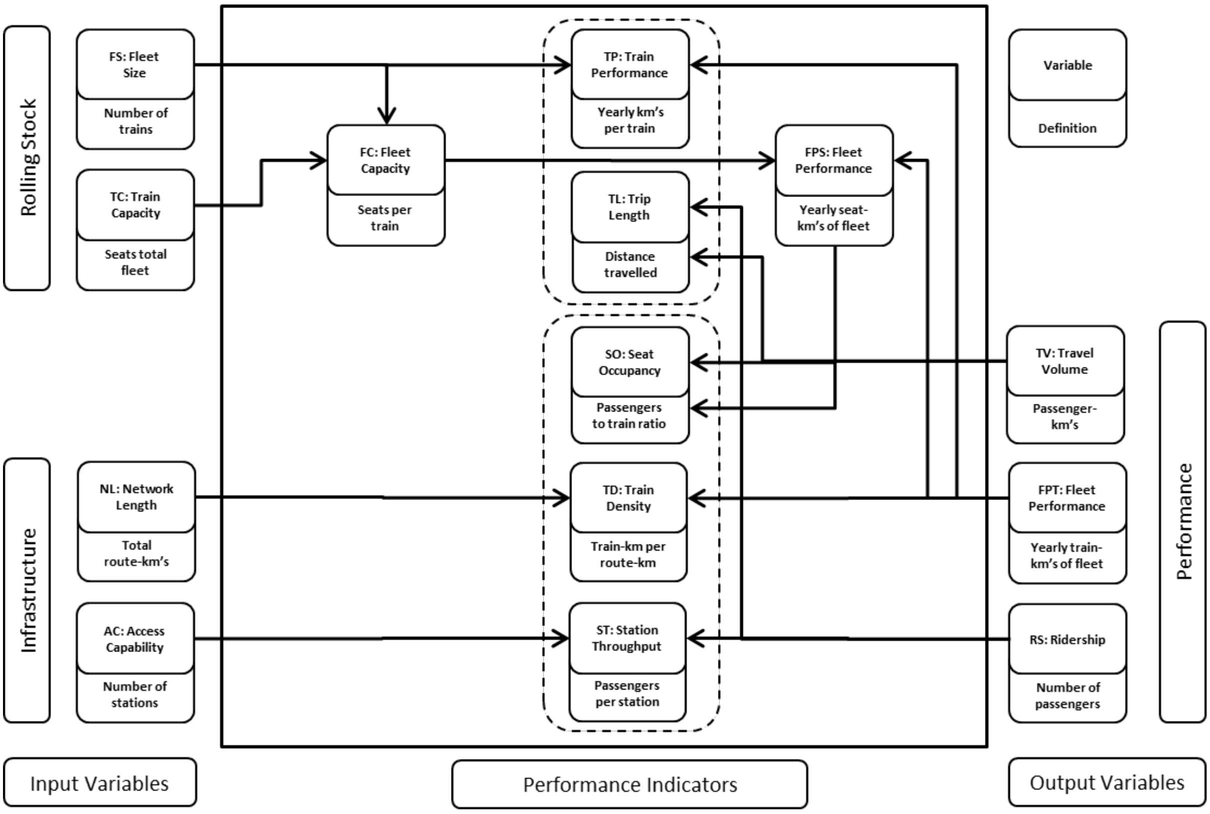

Figure 11: Variables, definitions and output characteristics of a high-speed rail system (figure by Author)

Performance indicators

High-speed rail systems are compared in absolute terms in Section 2. On the basis of the input and output variables as indicated in figure 11 three key performance indicators are proposed for the benchmark to quantify the efficiency: seat occupancy SO as a measure for the efficiency of rolling stock, station throughput ST to express the access and egress performance of the railway stations and train density TD indicating the utilisation of the of the network capacity:

$$SO = \frac{TV}{FPT} \quad (1), \qquad ST = \frac{RS}{AC} \quad (2) \qquad \text{and} \qquad TD = \frac{FPT}{NL} \quad (3),$$

with TV the Travel Volume in passenger kilometres per year, FPT being the Fleet Performance in Train kilometres per year, RS the annual ridership, AC the access capability in terms of number of high-speed rail stations in the network and NL the Network Length in route kilometres of high-speed track. The train seat occupancy depends on the willingness of travellers to use the offered train service. A high density of railway stations gives easy access for passengers, but can reduce the average speed along the route. A better network utilisation can be achieved by running more trains on the network leading to a higher train density.

The three key performance indicators represent the load factors for the three major assets, i.e. train fleet, railway stations and network. Two additional performance indicators are the average trip length of passengers (TL) and the yearly performance of the individual train sets

(TP). These additional performance indicators are the “travel volume over ridership” ratio and “fleet performance over number of train sets” ratio:

$$TL = \frac{TV}{RS} \quad (4), \qquad TP = \frac{FPT}{FS} \quad (5)$$

with RS being the ridership in number of passengers per year, TV being the Travel Volume per year, FPT being the Fleet Performance in Train kilometres per year and FS the Fleet Size in number of train sets.

The three key and two additional performance indicators are the backbone for the benchmark.

Data

Table 1 shows the definition of all input and output variables used in the study with their associated values from the data collected for five high-speed railway systems for a single year. Spain, Italy and Taiwan were eliminated from the analysis, as no reliable data on train performance was available. For China 2011 data from the World Bank is used. For all other countries the figures are derived from UIC data for 2010.

Table 1: Variables and values for the calculation of output characteristics of five high-speed railways

Input				Output		
Infrastructure		**Rolling Stock**		**Performance**		
NL	**AC**	**FS**	**TC**	**FPT**	**RS**	**TV**
Network Length	Access Capability	Fleet Size	Train Capacity	Fleet Performance	Ridership	Travel Volume
Total route-km	Number of stations	Number of trains	Average number of seats per train	Yearly train-km of fleet *(millions)*	Yearly number of passengers *(millions)*	Yearly passenger-km *(billions)*
km	-	-	-	km	-	km
1.896	24	450	451	172,2	112,6	51,9
1.285	34	254	451	103,0	78,5	23,9
2.664	82	367	949	116,2	292,0	77,4
412	11	46	768	20,8	41,3	10,8
6.405	128	484	698	213,0	420,0	46,3

Note: Data for China 2011, all other countries 2010.

China has the largest high-speed rail network in the world, is operating the largest fleet and is servicing the largest number of passengers yearly. Although France and China have a comparable fleet size, China’s fleet capacity is larger as their train sets can carry more passengers. Japan is the outperformer regarding travel volume, although ridership is lower compared to China. This indicates that on average Japanese travellers take longer trips. Travel volume and seat kilometres in Japan exceed the numbers in France with less train kilometres due to high-capacity train sets.

The data sources used for the analysis are summarised in table 2. The main data comes from the Union International de Chemins de fer (UIC). UIC gives data on travel volume, number of passengers, network length, fleet performance and fleet configuration. The travel performance data for Asia is completed with information from the KTX website and from the World Bank

(Bullock et al 2012) specifically for China. To fill in information gaps additional data is used from several other sources. Missing data on annual train kilometres for the fleet in Korea and Japan are covered by expert judgements based on the operational 2012 timetables.

Table 2: Major data sources for the study

Variable	Source	Version
Network Length	UIC Railway Statistics	September 2012
Access Capability	European Rail Timetable, Thomas Cook	June 2012
	www.hochgeschwindigkeitszuege.com	Viewed December 2012
Fleet Size	World High Speed Rolling Stock Database	October 2011
Train Capacity	World High Speed Rolling Stock Database	October 2011
Fleet Performance	UIC Railway Statistics	September 2012
	World Bank (for China)	2012
	www.chinatrainguide.com	2011
Ridership	UIC Railway Statistics	September 2012
	http://whhh.fc2web.com/ktx/hikaku.html	Update October 2012
Travel Volume	UIC Railway Synopsis	2011
	http://whhh.fc2web.com/ktx/hikaku.html	Update October 2012

4. RESULTS

In table 3 shows the comparison is made between Europe (France, Germany) and Asia (Japan, Korea, China) for the identified performance indicators based on the data from table 1.

Table 3 – Performance indicators for two European and three Asian high-speed rail networks.

	(Key) Performance Indicators			(Additional) Performance Indicators	
	FPT/NL	RS/AC	TV/FPS	FPT/FS	TV/RS
Characteristic	TD Train Density	ST Station Throughput	SO Seat Occupancy	TP Train Performance	TL Trip Length
Definition	Train-km per route-km *(thousands)*	Passengers per station *(milllions)*	Passengers per trainset to capacity	Yearly km per trainset *(thousands)*	Passenger distance travelled
Unit	-	-	-	km	km
France	90.8	4.69	0.67	383	461
Germany	80.2	2.31	0.51	406	304
Japan	43.6	3.56	0.70	317	265
Korea	50.5	3.76	0.68	452	262
China	33.3	3.28	0.31	440	110

Key Performance Indicators

The train densities for Europe are considerably higher than for Asia. The main reason is that high-speed trains in Europe not exclusively run on high-speed track, but on conventional lines as well. Japan and Korea operate their high-speed trains only on high-speed lines leading to lower train densities. A high network utilisation is achieved in Korea as their high-speed network is just one line from Seoul to Busan with a very intensive timetable and small headways. The fast growing high-speed network in a young and still immature high-speed rail market causes the low train density value for China.

The highest value for station throughput is realised by the TGV network in France. When all railway stations on the conventional network that are also serviced by TGV trains are included instead of only the railway stations that are part of the high-speed network, the station throughput drops considerably. The French station throughput is twice the German value, which is remarkable as in Germany the average station distance is 38 km compared to 79 km in France. The three Asian cases show similar values for station throughput, although the networks differ considerably.

Japan realises a seat occupancy above 70% and is outperforming the other networks in this respect. In Korea seat occupancy is low and train density is high. Reducing the number of trains per day would lead to increased rolling stock efficiency. Seat occupancy in France is 14% higher than in Germany and has therefore more efficient utilisation of the train sets. With 31%, the Chinese high-speed train operations show the lowest seat occupancy in the peer group. The benchmark does not confirm that trains have higher seat occupancies in Asia than in Europe as indicated in the preliminary results of Section 2. An important factor leading to higher ridership figures compared to fleet capacity in Asia is the shorter trips that travellers take.

Additional Performance Indicators

In 2010 for Europe the average trip length is 368 km compared to 145 km for Asia. Differences are related to geography and the origin-destination relationships in the high-speed rail network. In China, passengers take shorter trips. An average trip length of 110 km is remarkably low. Comparing travel length with average station distance shows that a trip in China covers only two stops, where for the other high-speed rail systems six to eight stops are typical.

The low yearly mileage of Japanese train-sets is caused by the series 800 train-sets. All train sets in the world perform in a range of 350 to 450 thousand kilometres a year when JR's 800 train-sets are excluded.

5. DISCUSSION

Operational model

In the analysis focus has been on the performance of the three major railway assets: network, stations and train fleet. The operating model, timetable and scheduling of trains over the day is also from major importance for the performance of the railway system. Figure 12 gives four basic operational models that can be recognised in various countries (Rus et al. 2009):

1. Exclusive model: Japan, Korea
2. Mixed high speed: France, China
3. Mixed conventional: Spain
4. Fully mixed: Germany

An exclusive operation or a mixed operation with infrastructure sharing will give different results for the key performance indicators under study. For the interpretation of the benchmark results the operational model needs to be taken into account, i.e. only high-speed rail systems with the same operational model will give meaningful comparisons. The assumption behind the benchmark methodology used is the exclusive model, where only high-speed trains run only on high-speed tracks like in Japan and Korea. The method will produce comparable and meaningful results in this case for all key performance indicators. For the mixed high-speed model, high-speed trains also run on conventional tracks at lower speeds. In this case the high-speed train fleet is servicing a larger network and more railway stations. This influences the key performance indicators in the benchmark: train density and station throughput will be overestimated as a part of the train kilometres and the number of passengers will be realised on conventional track. Seat occupancy, trip length and train performance are independent of the network length and will remain unchanged. Besides high-speed trains, conventional trains run on high-speed lines as well in the mixed conventional model. This will not affect the key performance indicators in the benchmark. In the fully mixed model the effect on the key performance indicators will be the same as in the mixed high-speed model.

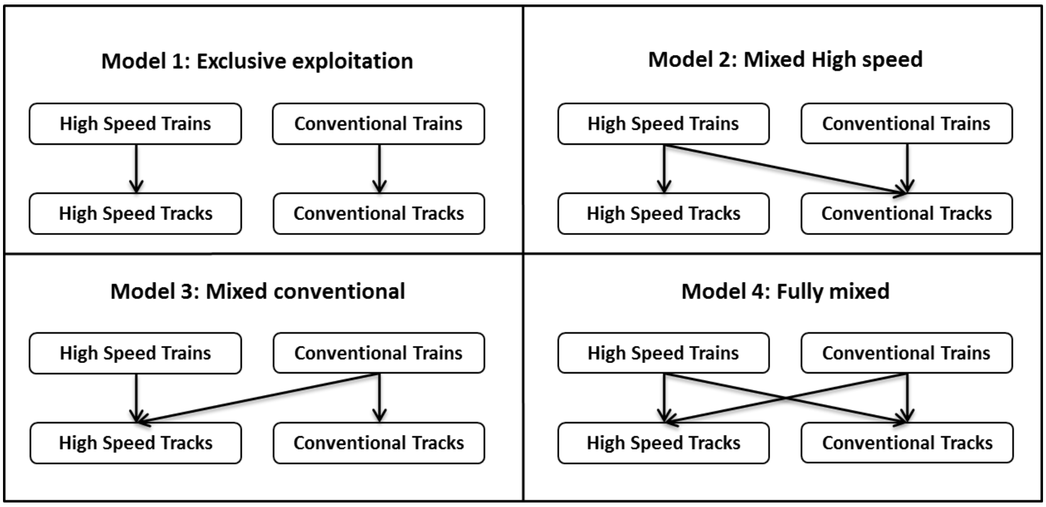

Figure 12: Operational models for high-speed rail traffic (Rus et al. 2009)

The exclusive model where high-speed trains run exclusively on high-speed track and are not hindered by conventional trains can achieve the best network utilisation. When high-speed trains may also run on conventional track, the fleet performance may increase as the high-speed network length stays the same. This leads to a higher network utilisation, but the actual high-speed network loading remains unchanged. The French and German network utilisation may therefore be overestimated.

Network configuration

Three different basic structures can be recognised regarding network configuration:

1. Line structure: this can be a single line (Korea) or a trunk line with branches (Japan)
2. Radial structure: lines departing form a capital city to various directions (France)
3. Meshed structure: a network with interconnected North-South and East-West axes (Germany, China)

Structures depend strongly on the countries' geography and the need for high-speed rail connections. The benchmark is indifferent to the network structure, but in practice the performance can be different due to operational limitations given by the network structure.

Besides network configuration the spread of railway station across the network is influencing the operational performance. Frequent stops reduce the average train speed, but can improve the high-speed railway accessibility. This trade-off is country-specific.

System maturity

Early adopters of high-speed rail like Japan and France already have a well-established high-speed rail system integrated in society. The network will develop in smaller steps with new lines and further extensions. Countries that only recently have adopted high-speed rail, like China, need some time to develop and mature their high-speed services. Their score on train density and seat occupancy can gradually improve over time as travel demand grows.

New high-speed rail systems

Countries that are planning for a high-speed rail future can take lessons from existing networks. They can identify their high-speed rail peers in Asia and Europe and benchmark their plans to existing cases. The results from this study give guidance on the major identified key performance indicators and indications for scores that need to be achieved.

6. CONCLUSION

Outcome

The train densities for Europe are considerably higher than for Asia as high-speed trains in Europe not exclusively run on high-speed track, but on conventional lines as well. Comparing fleet performance between Europe and Asia it is found that Japan is performing best and China worst on seat occupancy. For Europe, France is giving the best results. The case for China is not assessed in full as longer time series of data on travel volume and fleet performance is currently not available. There are significant differences between Asia and Europe regarding the infrastructure and rolling stock fleet and the way the high-speed railway is run. High-speed trains in Asia have in general larger seat capacity and equal or even better performance is achieved with less train kilometres. More passengers and shorter trips are characteristic for Asia, especially for China. Japan realises seat occupancies above 70% and is outperforming all the other networks in this respect, with China being an underperformer.

Methodology

The study shows that high-speed railways can be represented as a MIMO-system with 4 input and 3 output variables for benchmark purposes. Meaningful comparisons can be made on the basis of 3 key performance indicators; seat occupancy, station throughput and train density, to express the train, station and network loading. Two additional performance indicators give information on travel behaviour (trip length) and the performance of train sets (train kilometres per year). Careful interpretation of the results is needed as various operational models can be distinguished. Train density and station throughput may be underestimated as high-speed trains run on conventional track as well (operational model 2 and 4 in figure 12).

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