High-Speed Railway

Subjects: Transportation

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Union Internationale des Chemins (UIC) defines the high-speed railway (HSR) as a high-speed railway system that contains the infrastructure and the rolling stock. The infrastructure can be newly built dedicated lines enabled for trains to travel with speed above 250 km/h or upgraded conventional lines with a speed up to 200 or even 220 km/h. HSR requires specially built trains with increased power to weight ratio and must have an in-cab signalling system as traditional signalling systems are incapable of above 200 km/h.

speed infrastructure rolling stock in-cab signaling system absence of level crossing

HSR systems were divided into four groups depending on their relationship with conventional rail [1]; dedicated line, mixed high-speed line, conventional mixed line, and fully mixed [2]. Each of these types of HSR has some advantages and disadvantages.

Dedicated HSR represents a line that is fully separated from a conventional line, has a high capacity, high safety, and no level crossings. The line has fences all along the line, often built on viaducts or in long tunnels, and has a high construction cost, such as the case in Japan and Taiwan.

Mixed HSR lines have a wider area to serve, increased accessibility as high-speed trains run on dedicated and conventional lines, high capacity of HS lines stretch over larger areas, reduced building costs. HSR trains can use conventional rails in city centres in areas where land is more expensive to build dedicated lines. However, stretches of conventional lines have less capacity and can be a bottleneck for increased traffic, reduces safety, increases maintenance costs, whilst the rolling stock must be equipped with two signalling systems for HSR and conventional rails, such as the case in France and China.

Mixed conventional rail represents lines that are used by HSR trains and by conventional trains. Mixed traffic reduces the capacity of the line because of big differences in the speed of trains, and it also reduces safety. It can be a suitable solution if a country has a different gauge from the standard gauge size to be part of the European railway network and supports interoperability of international services, such as the case in Spain. This type is more difficult and expensive to maintain, needs special rolling stock, which is also more expensive to purchase and maintain.

Fully mixed lines represent lines used by all types of trains, including freight, have maximum flexibility to be used to full capacity, reduces safety, reliability, and punctuality, and increases maintenance costs. An example of such lines as those used in Germany.

There are two ways to develop the HSR system: build new systems or upgrade conventional railways. Building lines, operating, and maintaining them is an expensive business, but it gives an opportunity to develop a system that can operate at a higher speed and with bigger time savings [3].

Each new project includes planning, land purchasing, infrastructure building, and rolling stock costs. Upgrading existing lines will exclude the need for land purchasing, which may bring big savings. Upgrading conventional rail creates lots of disruption for traffic, and it does not allow reaching the required speed on the new lines. However, it is less expensive as it costs approximately US$4.37 million/km in 2007 prices [4]. Table 1 shows the HSR technologies in selected countries. Despite this difference, there is a lot in common in all HSR systems. All are powered by electricity, have a continuous welded rail, which reduces the noise level and the track vibration, in addition to being built on ballast track or on concrete slab tracks.

Table 1. High-speed rail technologies in selected countries Adapted from ref. [5].

Country	Japan	France	Germany	Italy	Spain	Korea	UK
Line	Tokyo-Osaka	Paris-Lyon	Hannover-Wurzburg	Roma-Paris	Madrid-Barcelona	Seoul-Pusan	London-Birmingham
Length of line in km	515	427	327	260	522	412	225
Max. speed (km/h)	260/300	300	250	250	300	250	360
Travel time	2 h 30 min	1 h 50 min	2h	1 h 35 min	2 h 30 min	1 h 55 min	52 min
Radius of curvature R_{min} (m)	2500	4000	7000	3000	4000	7000	7200
Max. longitudinal gradient (%)	20	35	12.5	8	30	35	N/A
Distance of axes of two tracks (m)	4.2	4.2	4.5	4.2	N/A	5.0	5.0
Superelevation (mm)	200	180	150	160	N/A	N/A	N/A

All HSRs must have advanced signalling systems and automated train control systems. The Automated Train Control (ATC) systems were first developed in Japan and introduced for Shinkansen trains. The system was named Digital Communication and Automatic Train Control (DS-ATC) system. In Europe, it is the European Train Control System (ETCS). The next step in the development of the control systems was the introduction of ERTMS. The ERTMS system was first introduced in Italy on a 204 km line between Rome and Naples. The ERTMS combines GSM-R (communication) and ETCS (signalling) systems. With rapid progress from 2G to 5G network

UIC is working on developing the successor of GSM-R, the Future Rail Mobile Communication System (FRMCS) [4]. The system can be introduced to railways as early as 2025. Another common thing for all HSRs is that they are very expensive to build [5] and only two of them recovered construction costs, Shinkansen in Japan, and Paris-Lyon line in France [6].

Rolling Stock is another part of the HSR systems. High-speed trains have a large variety in axle loading ranging from 11.4 t for the Hitachi train to 23 t axle loading for Bombardier and Acela Express [7]. This large difference can be explained by the type of railway that uses this rolling stock. The Shinkansen line that uses Shinkansen-Series 700 is fenced throughout to secure the entire length of the track. In contrast to these, the Acela Express operates on an upgraded line with level crossings. Amtrak trains are equipped with an anti-collision structure to meet USA crash standards. Zefiro, a high-speed train manufactured by Bombardier, is one of the most efficient and advanced trains in the world.

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