Chapter 1 Introduction

With the official operation of the world's first High-speed Rail (HSR) in Japan on October 1, 1964, HSR opened a new era of transportation development. Speed and capacity are eternal pursuit of mankind. The requirements of human beings for any means of transportation (trains, cars, airplanes, ships, etc.) not only depend on speed but also on transport capacity.

Although the aircraft operates at a high speed, its capacity is poor. The train has a large capacity, but it runs at a slow speed. Therefore, the pace of human pursuit of transport never ceased, and HSR is the crystallization of human wisdom in transportation. The French Wheel High-speed Rail TGV is as shown in Figure 1.1.

Figure 1.1 French WHSR: TGV

HSR is an abbreviation for high-speed rail. It is a large system composed of dedicated lines, high-speed trains, and dedicated control systems. Therefore, HSR is a system concept but not an individual concept. The "high-speed" in the high-speed rail refers to the quality, and the "rail" is the property. In addition to Wheel High-speed Rail (WHSR), HSR also includes Magnetic High-speed Rail (MHSR) and Super-speed Rail (SSR). Therefore, the narrow sense of HSR refers to the WHSR transport system. The broad HSR includes

not only the WHSR transport system, but also the MHSR, which is using the magnetic levitation technology, and the SSR transport system in the vacuum track. Figure 1.2 is a diagram of high-speed rail train.

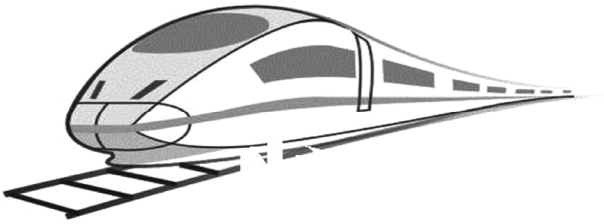

Figure 1.2 HSR train

HSR has become a hot issue in the world. This is because HSR has some technological advantages that are incomparable to other modes of transportation. The first advantage is the high speed. The French WHSR TGV set a world record with the speed of 574.8 km/h. Japan's MHSR set a world record with the speed of 603 km/h. The America SSR set a world record with the speed of 1,000 km/h (faster than the normal speed of the airplane). The second advantage is the large volume. The interval of HSR trains can be as short as 4 min. Twelve trains can be operated per hour in one direction, which is incomparable to highways and aviation. The third advantage is the high safety. The quality and precision of HSR line facilities are high. The train operation control system uses mature electronic technology and intelligent software which ensures the safety distance between the two trains. Therefore, there are few accidents in HSR around the world. Fourthly, HSR can operate throughout the day because it cannot be affected by rain, snow, fog, wind. Fifthly, HSR also has the features of low energy consumption, land conservation, light pollution and high comfort. Therefore, HSR has been welcomed by most countries in the world since its birth.

1.1 Emerging conditions of HSR

(1) The production of vehicle requires certain conditions. In any means of transportation, human beings appraise it from three aspects. Human beings judge the quality of vehicles usually from the following three criteria. First is the functionality such as speed, capacity, and safety. Second is the economics such as cost, energy, and efficiency. The final one is the ecology such as noise, radiation, and environmental protection. As a means of transportation, HSR also takes the load into account while pursuing high speed. Noting that high speed and heavy loads are the eternal pursuit of mankind, HSR exactly meets human needs. Figure 1.3 shows Wheel High-speed Rail train.

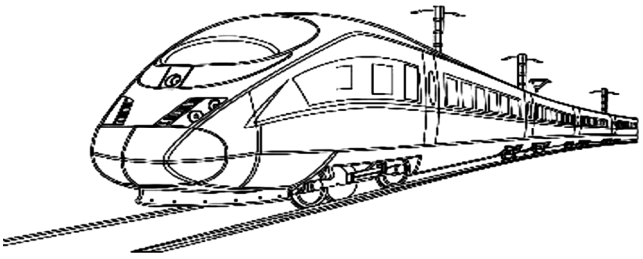

Figure 1.3 WHSR train

(2) The speed of HSR. Speed is the basic requirement for transportation. It is exactly for the rapidity and high efficiency that the HSR has been loved by humans and has been greatly developed. A comparison of speed between HSR and other vehicles is shown in Figure 1.4.

(3) The load of HSR. The basic demand of human for transportation is huge load capacity. The comparison of the loading capacity between HSR and existing vehicles (cars, airplanes, ships, traditional trains, etc.) is shown in Figure 1.5, from which we can obtain that the HSR is the vehicle with the largest load.

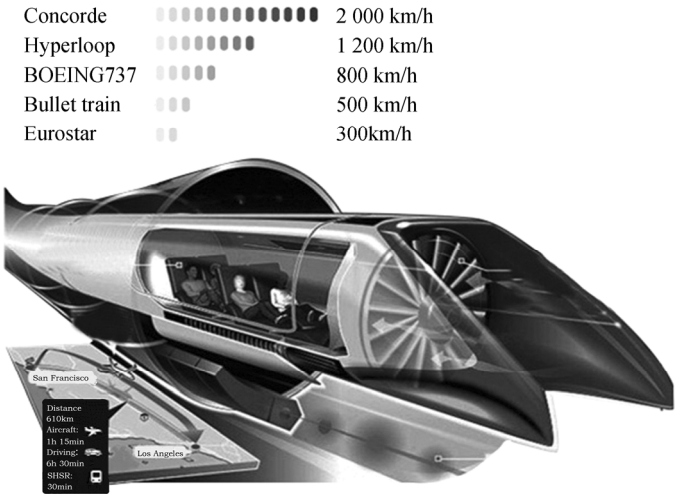

Figure 1.4 the operating speed of different vehicles

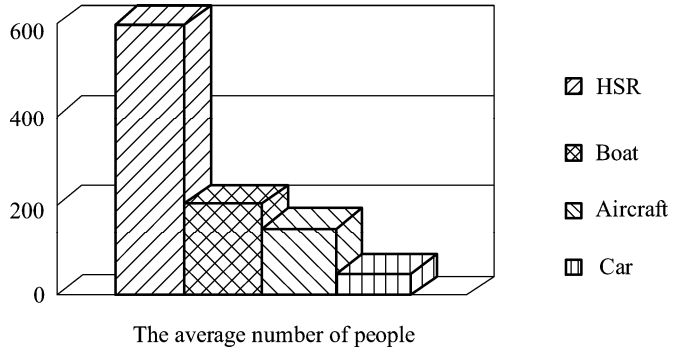

Figure 1.5 Comparison of the loading capacity between HSR and other vehicles

(4) The safety of HSR. Since HSR is operating in a fully enclosed environment and has a series of comprehensive safety protection systems, its safety is unmatched by any other means of transportation. Several major HSR countries have to operate thousands of HSR trains every day. While the accident rate and casualty rate are far lower than other modern modes of transportation. Therefore, HSR is considered as the safest transportation. The comparison of safety between HSR and other various vehicles is shown in Figure 1.6.

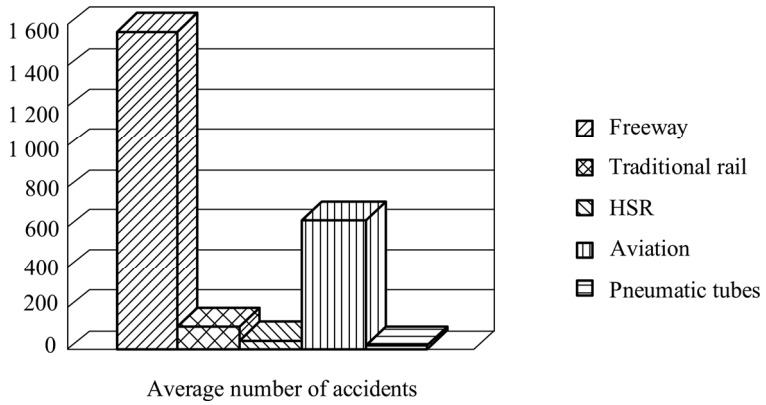

Figure 1.6 Comparison of safety between HSR and other various vehicles

1.2 Three leaps of HSR

In order to satisfy the demands for both speed and capacity, the HSR experienced three qualitative changes, namely three leaps. From WHSR to MHSR to SSR, from the operating speed of 200 km/h to 500 km/h to 1,200 km/h, this is also the three leaps in human demand for transportation.

1.2.1 The first leap: improve the speed of operation and the birth of WHSR

The first category:Wheel High-speed Rail (WHSR). To improve the speed of the train brings the first leap. So the first type of HSR, the WHSR was born. The traditional train and WHSR train are shown in Figure 1.7.

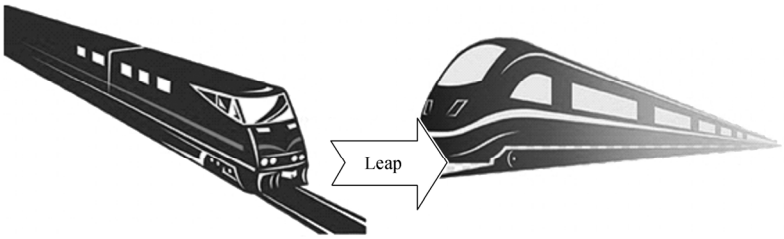

Figure 1.7 Traditional train and WHSR train

In term of capacity, the traditional train is the king of all modes of transportation. However, traditional trains usually run at a speed below 200 km/h. It cannot satisfy human needs for fast travel. By strengthening the study of track and vehicle type, especially the improvement of vehicle type, the friction resistance and air resistance of high-speed train running are reduced, and the running speed is increased. In Japan, the speed of HSR(Shinkansen) train reached 200 km/h in 1964. The train is called HSR when the operating speed is over 200 km/h. However, the WHSR can only operate between 200 km/h and 400 km/h due to air resistance and frictional resistance. The operating speed of 400 km/h is the warning threshold of WHSR. Exceeding this speed is extremely easy to derail and cause traffic accidents. WHSR train is as shown in Figure 1.8.

Figure 1.8 WHSR train

Wheel High-speed Rail is mainly a transportation system running on the track, which people refer to as WHSR, also called conventional HSR. The main features are as follows:

① The operating speed of the WHSR is about 200–400 km/h.

② The warning threshold of WHSR is 400 km/h.

③ The resistances of WHSR are frictional resistance and air resistance.

WHSR belongs to the wheel-rail type HSR. According to the definition of the International Railway Union, HSR refers to the railway system that has an

operating speed of more than 200 km/h by transforming the traditional line (straight line, gauge standardization), or has an operating speed of more than 250 km/h by building a new line. This book divides WHSR into three types. See Table 1.1 for details.

Table 1.1 Types of WHSR

Number	Types	Speed /(km/h)	Name	Main countries	Remarks
1	First	200–300	Low-speed WHSR	Japan, Germany	The warning threshold of WHSR is 400 km/h
2	Second	300–350	Normal-speed WHSR	France, China	
3	Third	350–400	High-speed WHSR	China	

1.2.2 The second leap: the removal of frictional resistance brings the birth of MHSR

The second category: Magnetic High-speed Rail (MHSR). In order to reduce the friction between the wheels and the rails, the second leap has been made. MHSR, the second type of HSR, was born. The WHSR and MHSR trains are as shown in Figure 1.9.

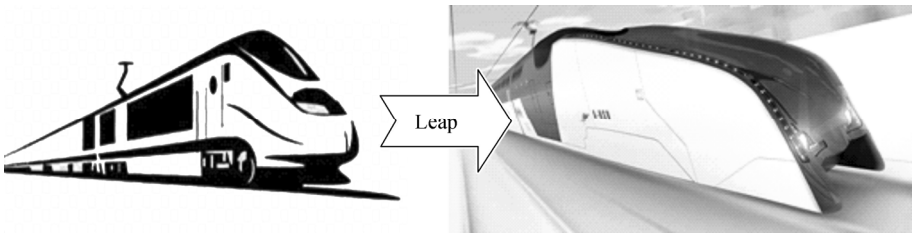

Figure1.9 WHSR and MHSR trains

In order to reduce the frictional resistance and improve the running speed and meet the fast travel requirements of human beings, MHSR was born with the running speed of more than 400 km/h based on the principle of "same-magnet repelling and opposite-magnet attraction". During the operation

of the MHSR, the magnet train does not directly contact the track, but floats on the track so that there is no frictional resistance and then the running speed is improved. In 2015, the MHSR in Japan has reached 600 km/h and more. Although MHSR is not affected by the frictional resistance, it can only operate between 400 km/h and 1,000 km/h due to the limitation of air resistance. The operating speed of 1,000 km/h is the warning threshold of the MHSR. When this speed is exceeded, the operating cost will be too high. MHSR train is as shown in Figure 1.10.

Figure 1.10 MHSR train (picture from the network)

MHSR is the magnetic suspension type HSR, which is mainly suspended on rails to run. It is also called superconducting high-speed rail. The main features are as follows:

① The operating speed of MHSR is from 400 km/h to 1,000 km/h.

② The warning threshold of MHSR is 1,000 km/h.

③ MHSR has air resistance and no frictional resistance.

MHSR belongs to the magnetic suspension HSR. As a new type of ground transportation, magnetic train has moved from the experimental stage to commercial operation and overcame the problems of traditional train such as the adhesion limit, mechanical noise and wear, etc. Besides that, MHSR has the features of high speed, strong climbing ability and low energy consumption,

high noise, low comfort, no fuel, and less electromagnetic pollution. It has become the ideal vehicle for people.

The MHSR train can be divided into two types: Electromagnetic Suspension (EMS) and Electrodynamic Suspension (EDS). The speed of MHSR train reach 500km/h, which is impossible for traditional train. If the superconducting magnet is installed in the train and an aluminum ring is laid on the ground track，when a relative motion occurs between them, an induced current will be generated in the aluminum ring. Then the magnetic repulsion will occur, lifting the train about 10 cm from the ground, allowing the train to float on the rail and operate at a high speed. This book divides the MHSR into three types as Table 1.2:

Table 1.2 Types of MHSR

Number	Types	Speed /(km/h)	Name	Main countries	Remarks (0 K=－273.15 °C)
1	First	400–600	Low-temperature MHSR	Japan, Germany	4.2K—Liquid helium (rare, expensive)
2	Second	600–800	Normal-temperature MHSR	Japan	15K—Liquid helium (minor, reasonable)
3	Third	800–1,000	High-temperature MHSR	NA	77K—Liquid helium (much, cheap)

MHSR train uses a superconducting magnet to float the vehicle and obtain propulsion power by periodically changing the direction of the magnetic pole. In addition to its high speed, the MHSR train has the characteristics of no noise, no vibration and energy saving. It is expected to become the main means of transportation in the 21st century.

1.2.3 The third leap: reducing air resistance brings the birth of SSR

The third type of HSR: Super-speed Rail (SSR). Flying in vacuum, there is no limit to the operating speed. In order to reduce the air resistance, the third

leap has been made. SSR, the third type of HSR, is the suspension of HSR in the vacuum pipeline. MHSR trains and SSR trains are as shown in Figure 1.11.

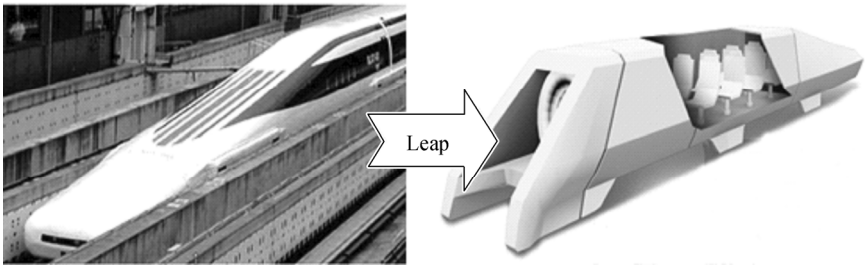

Figure 1.11 MHSR and SSR trains

The SSR was produced to satisfy human beings requirements for fast travel, based on the concept of vacuum pipeline by reducing air resistance. The SSR runs in the vacuum pipeline without air and frictional resistance, and the running speed can reach more than 1,200 km/h. In fact, in vacuum pipeline without air resistance and frictional resistance, the SSR train can operate "willfuly" and speed up to 10,000 km/h. SSR train is as shown in Figure 1.12.

Figure 1.12 SSR train

SSR is a vacuum pipeline suspended HSR. It is mainly a HSR transportation system suspended in a vacuum pipeline. So SSR also can be called vacuum high-speed rail. The main features are as follows:

① The operation speed of SSR is 1,200 km/h (acoustic velocity is 340