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INTERNATIONAL UNION OF RAILWAYS

# UIC STUDY

# ORIGIN AND FINANCING OF FIRST HIGH-SPEED LINES IN THE WORLD

## FINAL REPORT

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**Prepared for:** International Union of Railways

**Prepared by:** Polytechnic University of Catalonia

**Author:** Prof. A. López Pita, andres.lopez-pita@upc.edu

**Technical Direction:** Michel Leboeuf (SNCF),
Chairman Intercity & High Speed Committee

Iñaki Barrón (UIC), Director Passengers & High Speed Department

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# PRESENTATION

On 1 October, 1964, the first commercially operated high-speed line in the world was opened between Tokyo and Osaka, with a length of 515 km.

Since then, other countries in Europe such as France (1981-1983), Italy (1981-1992), Germany (1988-1991), Spain (1992), Belgium (1997), the United Kingdom (2003-2007) and Holland (2009) have joined the group of countries offering high-speed rail services.

Similar cases exist in other countries such as China (2003), South Korea (2004-2010), Taiwan (2007) and Turkey (2009).

Overall, at the present time and in accordance with the UIC (November 2013), there is a 7,378 km network in commercial service in Europe, and 13,732 in Asia. Within a few years, other countries like Morocco and Saudi Arabia will join the group of countries with high speed on some rail links.

In this context, i.e. in celebrating the 50th anniversary of the birth of high-speed rail, the UIC, through its Department of High Speed and Intercity & High Speed Committee, considered it of interest to analyze the origin of the first high-speed lines in each country and, in parallel, the financing system adopted for their practical implementation.

This paper aims to respond, in a necessarily abridged form, to that interest.

# PART ONE

# ORIGIN OF FIRST HIGH-SPEED LINES

# CHAPTER 1.

# THE FIRST HIGH-SPEED TRAIN LINE IN JAPAN

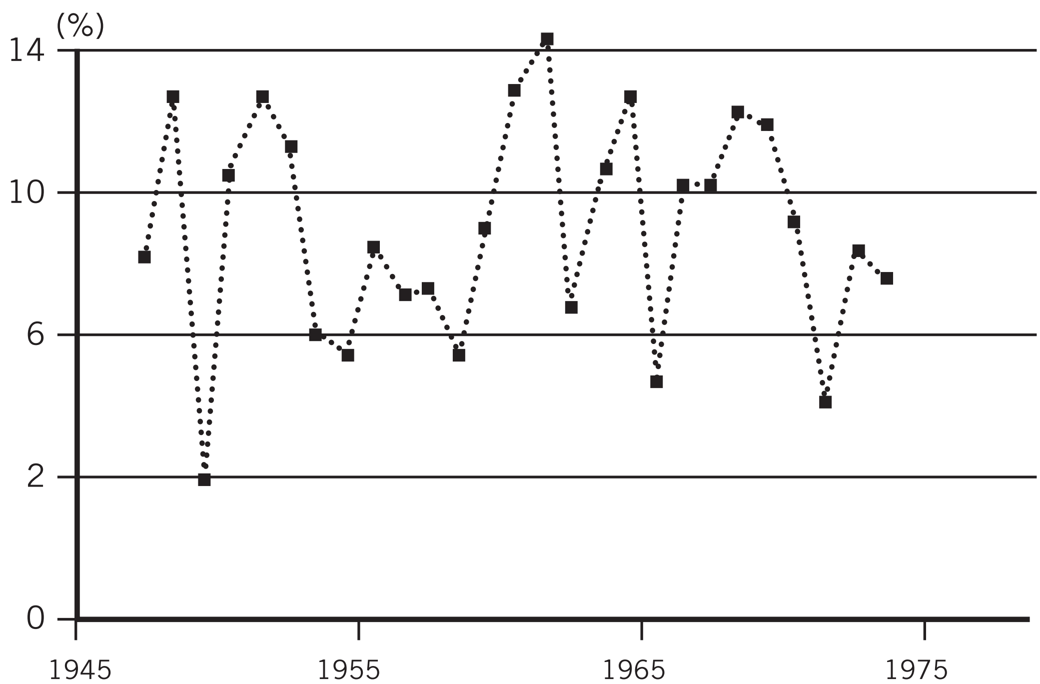
## 1.1 REFERENCE FRAMEWORK

In the 1950s, the Japanase government embarked upon numerous, large social projects to help its populace which had been severely affected by World War II (1939-1945). Its first aim was to rebuild the national economy. Once that was done, it introduced initiatives which would aid in the economy growth, optimal land management and social development of the country. The Shinkansen rail network was one of these iniciatives.

The most visible and symbolic results of these changes were seen in the political and economic domains .In the latter case, the development of the nation was supported by the establishment of a solid industrial infrastructure based mainly on the production of goods with national as well as international markets (e.g. cars). The Japanese State helped bring about favorable conditions for the economic growth of the nation by the means of its institutions: the Economic Planning Agency, the Ministry of International Trade and Industry, public corporations and their legislative and financial arms.

The Korean war (1950-1953) gave the national economy another boost. At about the same time, there arose a big demand, from within as well as from outside, for consumer and manufactured goods. These conspired to inject new life into the Japanese economy which henceforth experienced phenomenal growth rates almost every year till 1974 (Figure 1.1)

**REAL GROSS NATIONAL PRODUCT GROWTH, 1947-1990 (FIG. 1.1)**

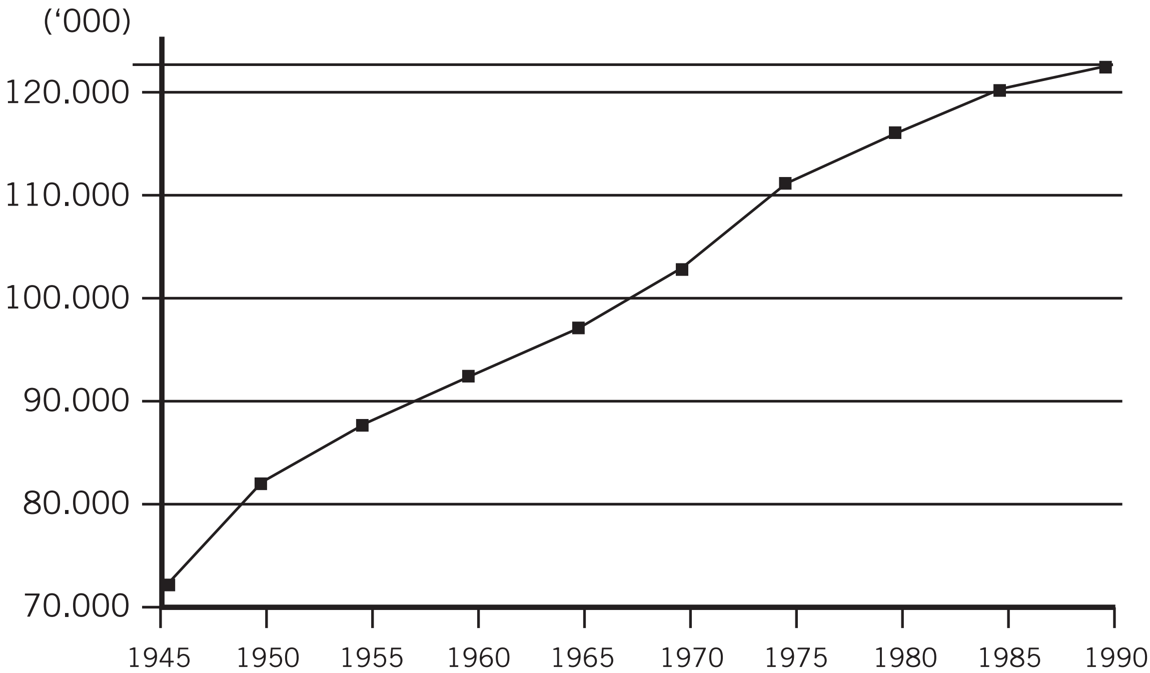



*Souce:* R. Leclerc (2002)

The first plans were directed towards three major objectives: autonomy, economic growth and eradication of unemployment. From the 1960s , a growing emphasis was placed on the establishment of conditions which would lead to a healthy Japanese contribution to the international community and to better living standards for its people. Henceforth, the government would advocate a lasting economic development which leads naturally to an improvement in the living standard of the average Japanese.

These new orientations were as important and necessary as the construction of new infrastructure (e.g. railways) necessitated by the growing population (Figure 1.2), the rapid urbanization of Japan and the concentration of people and mayor business activities in the Tokyo-Osaka megalopolis.

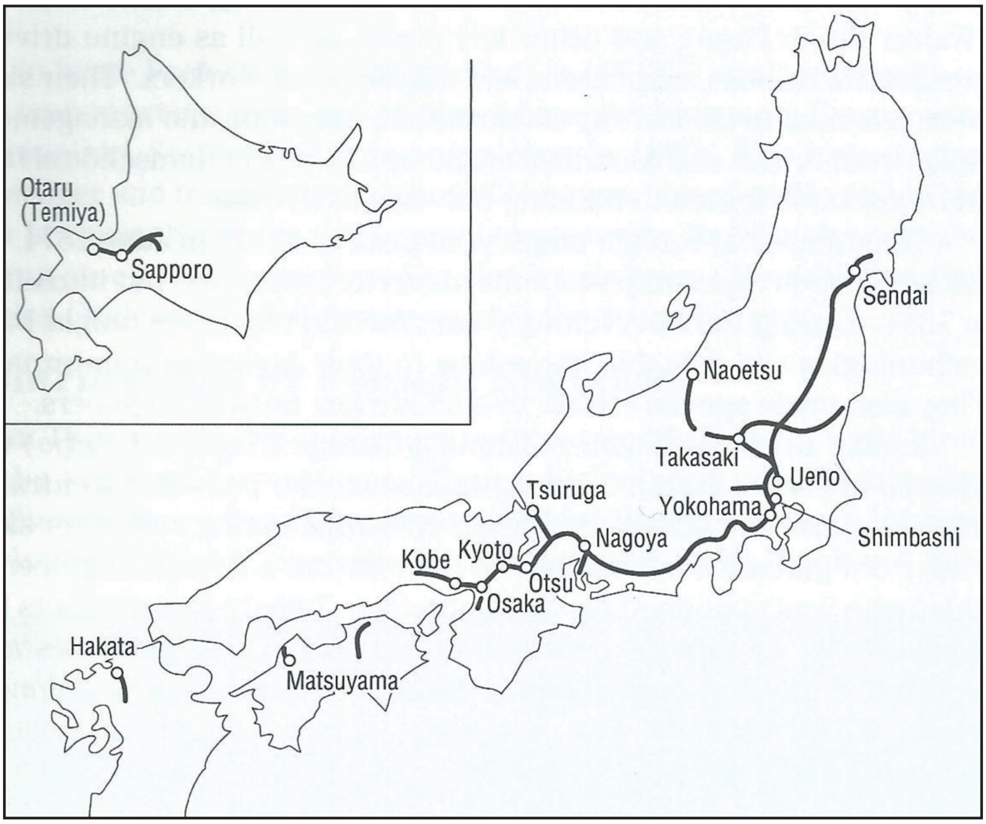
**POPULATION GROWTH (JAPAN), 1945-1990 (FIG. 1.2)**




*Souce:* R. Leclerc (2002)

In Japan, the transport between Tokyo-Osaka has been the axis of politics and economics since the foundation  of Tokugawa shogunate at Edo (former name of Tokyo) in 1603. ( Y.Sato, 1992).The first trunk railway line in Japan was constructed on this axis in 1888 .The first section of line was inaugurated iin 1872, between Shimbashi (Tokyo) and Yokohama (30 km) (Figure 1.3).

**FIRST RAILWAY LINES IN JAPAN (1890) (FIG. 1.3)**



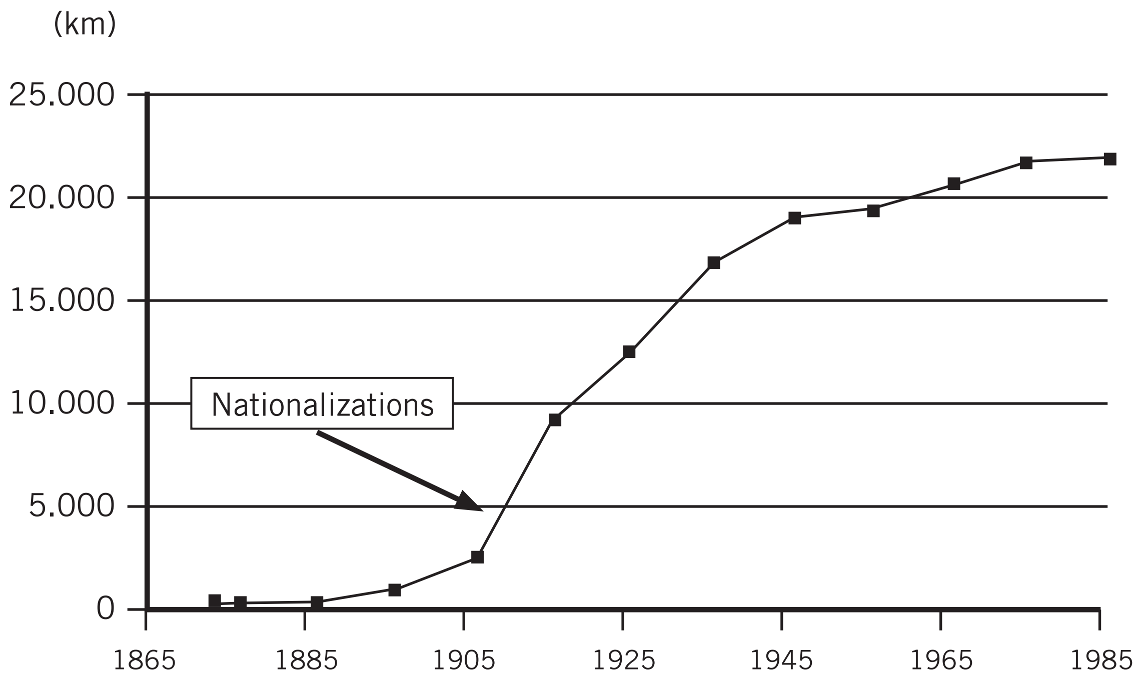

*Source:* E. Aoki et al (2000)

The British engineers recommended using a track gauge of 1067 mm. This recommendation was made because of the difficulty of building a railway through mountainous and densely populated areas as was the case with Japan. The widening of the gauge up to 1435 mm of standard one had been vigorously discussed since 1890' s.

In 1907, a scheme was mapped out by Mr. Zenjiro YASUDA et al. to construct a new line with the gauge of 1435 mm between Tokyo and Osaka and let the train run with the speed of 80  km/h which was a unexpectedly high one in those days. As the scheme premised the operation by a private company, it was not realized, because this was bought on the table just after the nationalization of railroad effective in 1906, but it was the same scheme on Tokaido Shin-kansen itself excluding its speed.

Figure 1.4 shows the evolution of the length of the railway network in Japan from 1872-1965.

**LENGTH OF GOVERNMENTAL RAILWAYS, 1872-1985 (FIG. 1.4)**

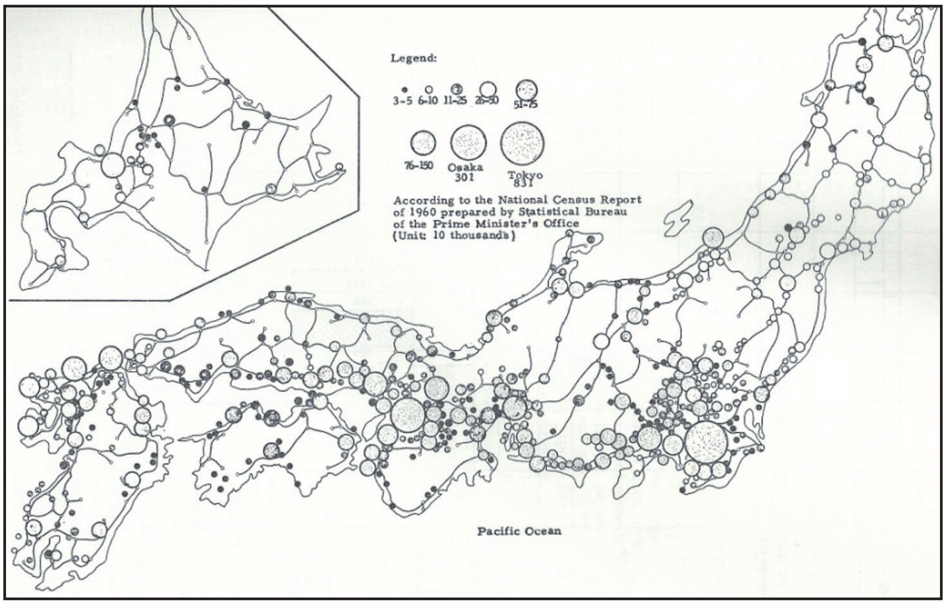



*Souce:* Japan Statistics Association (1987)

## 1.2 THE EXISTING PROBLEM

Historically, the most important railway line was the one that connected Tokyo with Osaka, covering more than 550 km..As an example, in the mid-1950s, its route was used by 22% of the total passenger-kilometre traffic on the Japanese railways. About 34 % of the total population (Fig 1.5) and 60 % of Japan´s industrial products was concentrated in the area along this line.

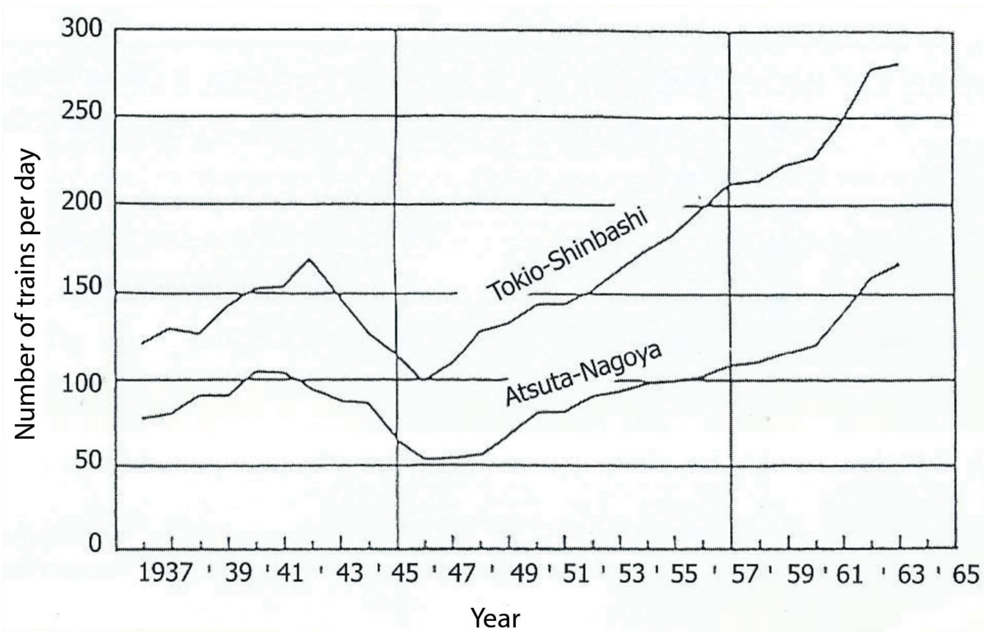
**THE LOCATION OF MAIN CITIES IN JAPAN 1960 (FIG 1.5)**




*Source:* H. Yokohama et al. (1968)

With regard to traffic demand, in order to address it, 130 to 190 trains travelled per day and direction (Figure 1.6). It can be seen, thus, that the line was close to saturation. Consequently, an increase in transport capacity was necessary.

**EVOLUTION OF THE NUMBER OF TRAINS BY DAY ON TOKYO-OSAKA METRE-GAUGE LINE (FIG. 1.6)**

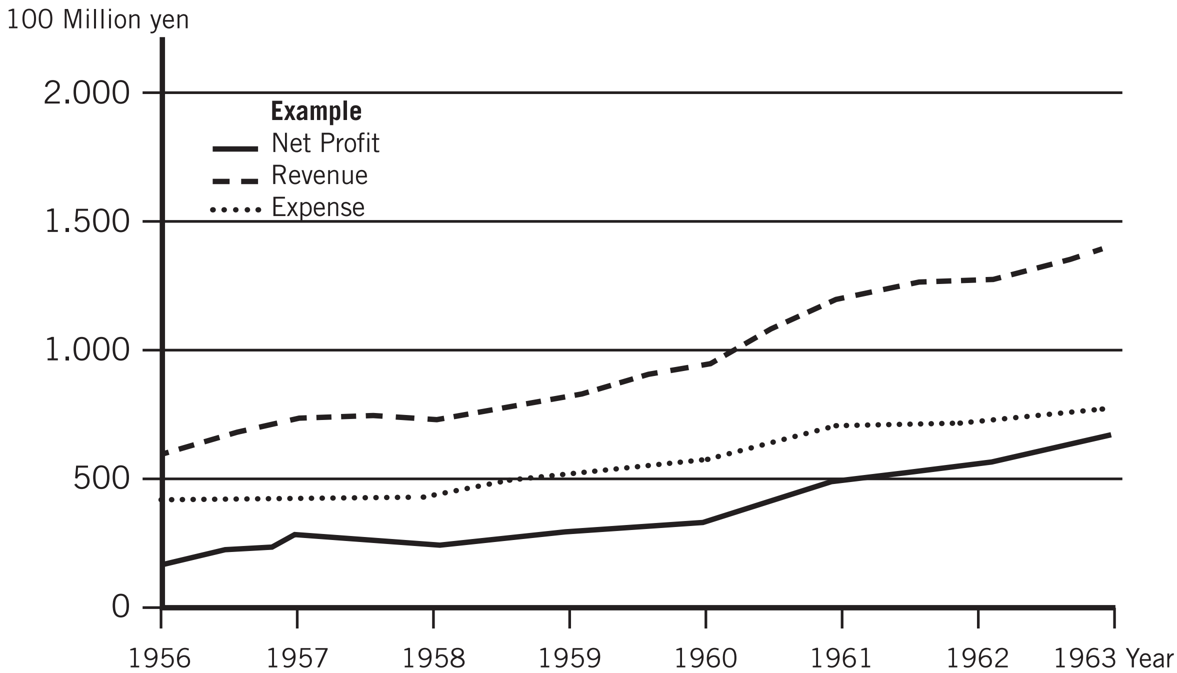



*Source:* M. Sugawara (1989)

Furthermore, Prof. K. Amano, who in 1956 worked at the JNR Construction Department, said in 1994: on the opening day of the sale of train tickets, usually three months before the date of making a trip, there was a long line of travellers at Kyoto Station to buy them. A few minutes after tickets went on sale, the train was full. There was, therefore, alongside the problem of capability, a commercial problem.

It is of interest to display in figure 1.7 the evolution of operating balance, i.e. the difference between income and operating expenses for the Tokyo-Osaka line, metre gauge line, during the 1956-1963 period.

**EVOLUTION OF INCOME AND OPERATING EXPENSES FOR THE TOKYO-OSAKA CONVENTIONAL LINE (1956-1963) (FIG. 1.7).**




*Source:* H. Yokohama et al. (1968)

## 1.3 THE DECISION TAKEN

Consequently, in May 1956, the so-called “Committee for Strengthening the Tokaido Line”, headed by the engineer, Mr. Hideo Shima, was created. The result of its work was focused on the analysis of the following points:

a) Construction of a new metre gauge line, parallel to the existing path.

b) Construction of a metre gauge double track, not parallel to the original path.

c) Construction of a new standard gauge line which was suitable for high-speed train travel.

In summary, it can be said that the first two proposals could be considered as conventional solutions.

Supporters of the first solution considered that in this way, there would be the greatest possible transport capacity and flexibility. The second alternative would increase the running speed of the fastest passenger trains which, at that point in time, in the late 1950s, stood around 85 km/h.

Finally, regarding the third solution, construction of the standard gauge, a number of “potential dangers” were highlighted.

1. The lack of experience in Japan in operating trains in commercial service at more than twice the speed used up until then (200 km/h compared to 85 km/h).

2. The construction of the new line involved a major financial investment, due its larger geometric parameters (minimum flat curve radius of 2,500 metres), meaning, given the topography of the area where the line would pass, that 46% of its length would have to go through viaducts and tunnels, thus making the necessary investment even higher.

3. The financing of the line was not initially guaranteed (a loan from the World Bank was needed). From this perspective, there was a risk that the line would not be fully completed. In this case, because of the different gauge, it would serve no purpose, since it could not be connected to the rest of the Japanese rail network, which was equipped with metre gauge.

Table 1.1 summarises the primary indicators for the three alternatives mentioned.

## PRIMARY INDICATORS FOR THE DIFFERENT ALTERNATIVES CONSIDERED FOR THE MODERNISATION OF THE TOKYO-OSAKA LINE (TABLE 1.1)

| Indicator | New line parallel to the existing metric track | New line of metric gauge separate from the existing | Standard line (1435 mm) |
|---|---|---|---|
| Length (Km).<br>Intermediate stations | 556<br>All existeng stations | ≃ 500<br>Stations in main cities | ≃ 500<br>Stations in main cities |
| Minimum curve radius (m) | 400 | 1500 | 2500 |
| Maximum gradient (‰) | 10 | 10 | 10 |
| Maximum speed (Km/h) | 120 | 120 a 150 | 250 |
| Travel time | 6h 30 | 6h 30 a 4h 30 | 3h |
| Transport capacity | 300/310<br>Trains/day | 300/310<br>Trains/day | 330<br>Trains/day (equivalent to 375 freigth trains for metre gauge lines) |
| Difficulties with land adquisition | Large | Small | Small |
| Construction period | ≃ 7 years | ≃ 5 years | ≃ 5 years |
| Investiment required (in billions of Yen) | 250 | 192 | 1625 |
| Material investiment (in billions of Yen) | - | 10 | 10 |

*Source:* Adapted from Y. Tomi (1968)

It is recognised that in the final decision by the Government of Japan to build the high speed line, a major role was played by the firm conviction of H. Shima and the President of JNR, Shinji Sogo, who considered it the most suitable solution.

It should also be noted that in May 1957, on the occasion of the 50th Anniversary of the Institute of Technological Research of the National Railways of Japan, the study was presented under the title: "The High Speed Railway of the Future". That document demonstrated the technical feasibility of linking Tokyo with Osaka, in a time of 3 hours, at a maximum speed of 250 km/h.

It is not surprising, then, that in December 1958, the Japanese government approved the construction of this line. Work began in 1959 and on the 1st October 1964, it entered into commercial service.

The new line was designed with a minimum flat curve radius of 2500m and a maximum gradient of 20 mm/m. As shown in Figure 1.8, there were a total of 12 stations, including Tokyo and Osaka, spaced apart at the distances indicated in Table 1.2

### STATIONS ON THE TOKYO-OSAKA HIGH-SPEED LINE (1964) (FIG. 1.8)


*Source:* P. Semmens (2000)

### DISTANCE BETWEEN STATIONS IN TOKYO-OSAKA LINE (TABLE 1.2)

| Station | KP | Distance (km) |
|---|---|---|
| Tokio | 0 | 25,5 |
| Shin-Yokohama | 25,5 | 51,2 |
| Odawara | 76,7 | 18,7 |
| Atami | 95,4 | 72,0 |
| Shizuoka | 167,4 | 71,5 |
| Hamamutsu | 238,9 | 35,3 |
| Toyohashi | 274,2 | 67,8 |
| Nagoya | 342,0 | 25,1 |
| Gigu-Hashima | 367,1 | 41,1 |
| Maibara | 408,2 | 68,1 |
| Kyoto | 476,3 | 39,1 |
| Shin-Osaka | 515,4 | |

*Source:* A. Caire (1985)

## 1.4 THE TECHNOLOGY REQUIRED TO RUN AT HIGH SPEED

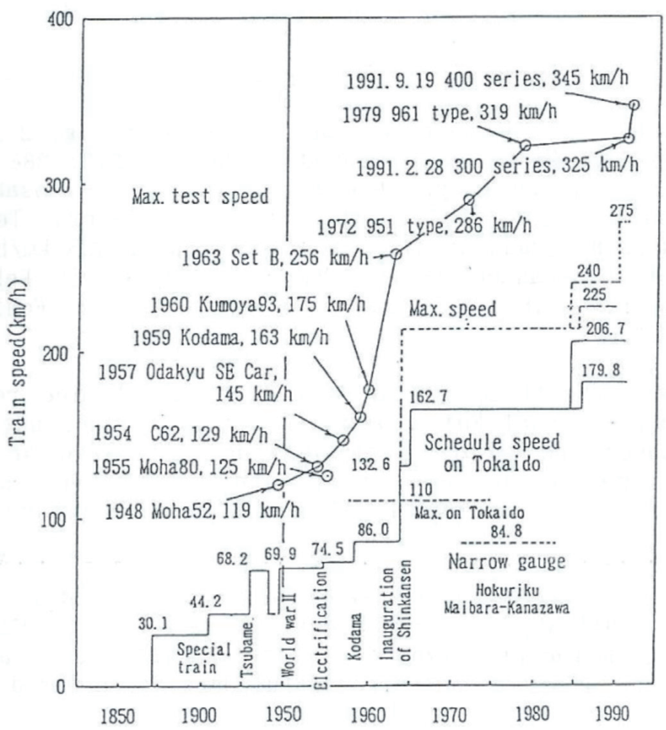
On November 19, 1956, the whole Tokaido line was electrified. At first. locomotive trains connected Tokyo-Osaka in 7 hours and 30 minutes, but In November, 1958, the newly developed business super-express "KODAMA" connected them in 6 hours and 50 minutes. Having the weight decreased, this train could run with the speed of 110 km/h on the track where the locomotive train ran with the speed of 95 km/h. Before this, the "SE car train" of super light weight RTRI designed and Odakyu railway Co., Ltd.made in reality attained 145 km/h in September, 1957. This speed was the maximum speed on narrow gauge lines in those days. Two years later, KODAMA attained 163 km/h on July 31, 1959. Thus Tokyo-Osaka had been connected in 6 hours and 30 minutes since June, 1960. As for the test speed, 175 km/h was attained with a catenary car November,1960.

Prior to the completion of the whole line, a short section of 32 km was completed in order to carry out various tests on rolling stock and ground facilities. Tha test-run section was located near Odawara southwest of Tokio between Kamonomiya and Ayase.

On this line two protoype trains called Set A composed of 2 cars and Set B of 4 cars were operated with the speed of 200 km/h and more, accumulating many experiences.

The first test-run was held on June 23, 1962. The speed of test trains was raised gradually as the roadbed settled and on March 30, 1963, the highest speed record of 256 km/h was acomplished (Fig. 1.9). This together with the results obtained from various test carried out incessantly on the section, served to prove that trains could be safely operated at the maximum commercial speed of 210 km/h upon completion of the line.

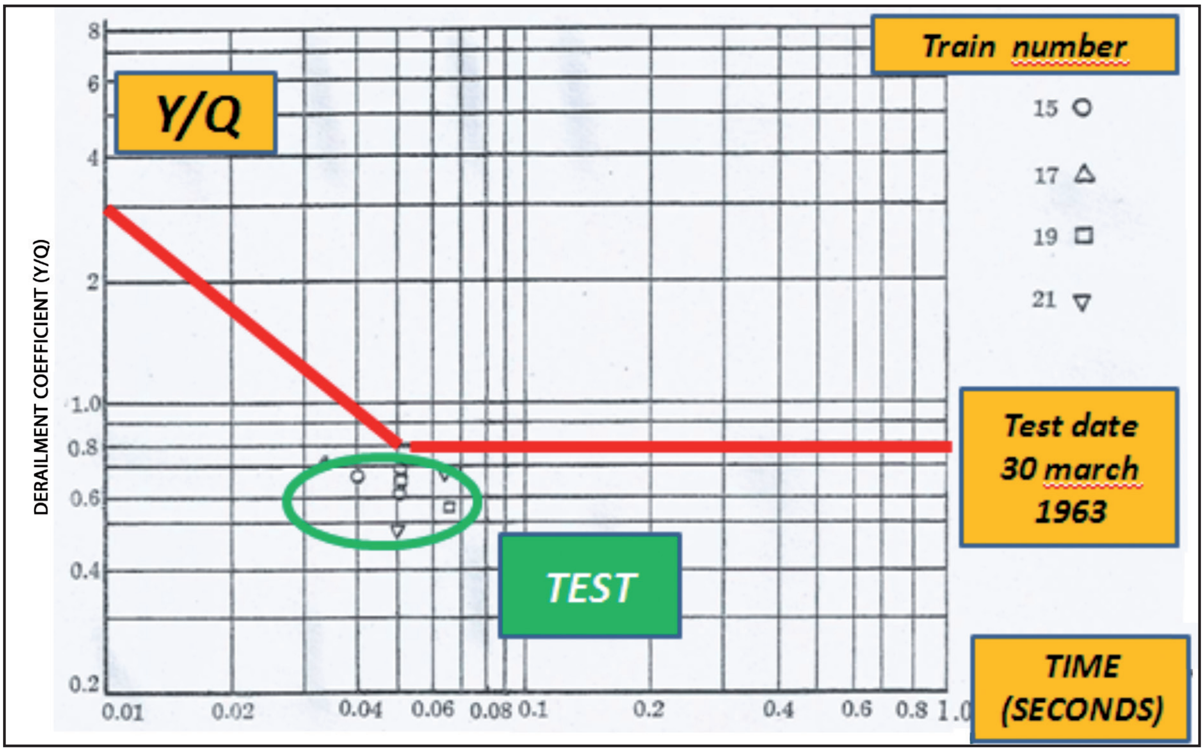
**HISTORY OF SPEED-UP IN JAPAN (FIG 1.9)**




*Source:* Y. Sata (1992)

It is of interest to note that, during travel at the maximum speed of 256 km/h, at no time was the derailment limit reached, as shown in figure 1.10. this reflects the coefficient (Y/Q), on the ordinate, with Y being the axial force applied by a wheel and Q being the vertical force applied. The abscissa shows the time (t) in seconds during which axial force it is applied.

**DERAILMENT PREVENTION AT 256 KM/H IN 1963 (FIG. 1.10)**




*Source:* (JNR, 1965)

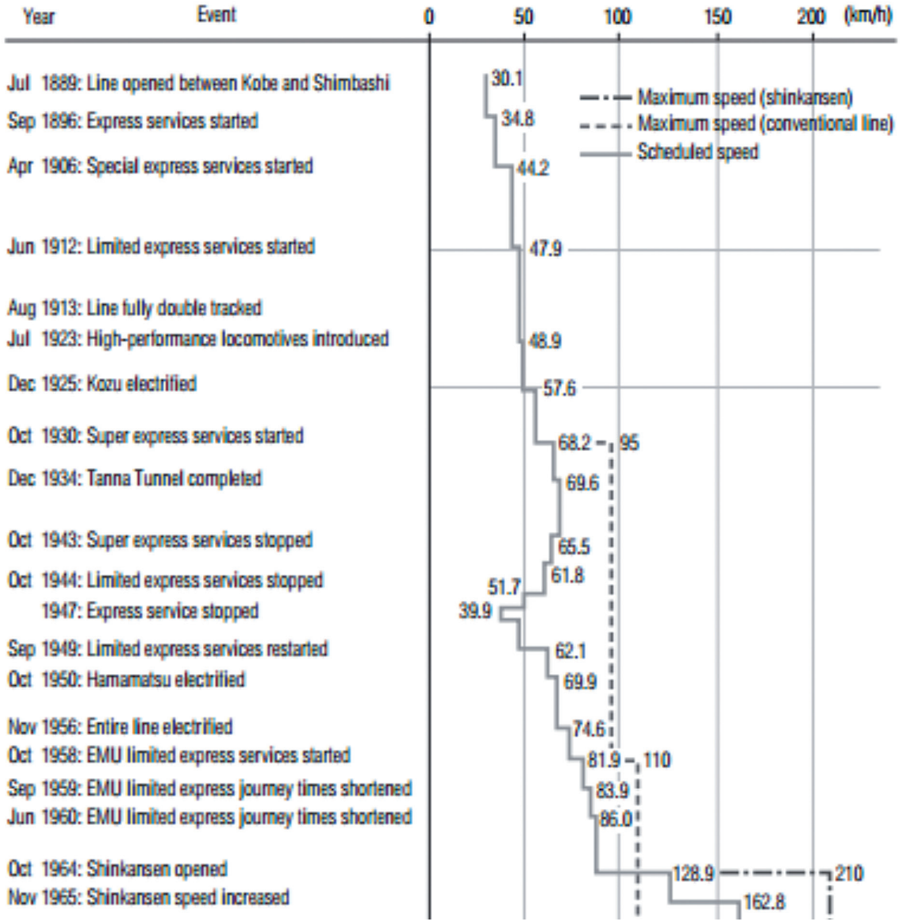
## 1.5 THE RANGE OF SERVICES

The operation of the new line was first begun in October 1964, with two types of trains:

a) HIKARI, which only stopped in Nagoya and Kyoto, taking 4 hours between Tokyo and Osaka, that is, achieving a commercial speed of 129 km/h (Figure 1.11);

b) The KODAMA trains, which stopped at all the stations, making the journey from start to finish in 5 hours, at a commercial speed of 103 km/h.

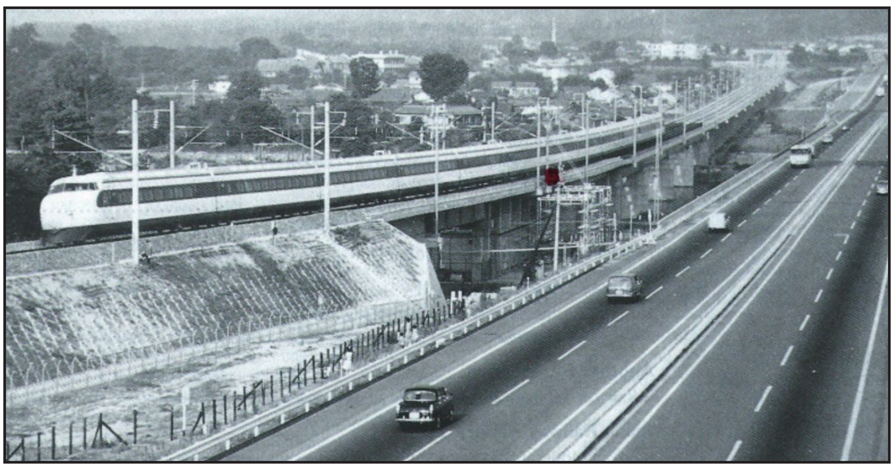
## SPEED INCREASES ON TOKAIDO MAIN LINE (FIG. 1.11)




*Source:* A. Mochizuki (2011)

As regards material, O Series trains were used (Figure 1.12) which had a capacity of 987 passengers, distributed into 12 cars.

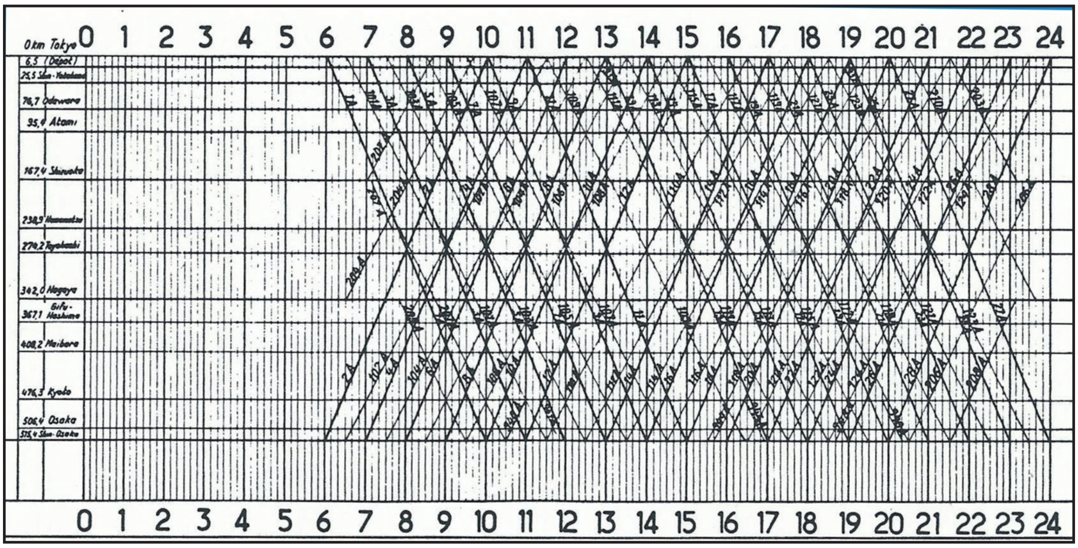
## O SERIES HIGH SPEED TRAIN (FIG. 1.12)



The range of services was set up based on 14 trains per day per direction, for Hikari trains, and 12 trains per day for Kodama trains. That is, a total of 26 trains per day and direction. Fig. 1.13 shows the graph relating to this range of services.

Note that the first train left Tokyo and Osaka at 6am and the last one arrived in either city at 12 midnight.

**GRAPH OF TRAINS LEAVING TOKAIDO (1ST OCTOBER 1964) (FIG. 1.13)**




*Source:* A. Caire (1985)

Regarding fares, recall that prior to the entry into commercial service of the first high-speed line in Japan, between Tokyo and Osaka, there were two types of services on the metre gauge line: Kodama and Naniwa, offering different travel times because of the different number of stops they made. The level of fares for each is shown in Table 1.3.

## FARE LEVELS FOR TOKYO-OSAKA ROUTE WITH AND WITHOUT HIGH SPEED (TABLE 1.3)

| Reference | Travel Time | Base | Fare (yen) Supplement | Total |
|---|---|---|---|---|
| Metre gauge line | | | | |
| -Kodama trains | 6h 30m | 1,180 | 800 | 1,980 |
| -Naniwa trains | 7h 30m | 1,180 | 300 | 1,480 |
| High Speed Line | | | | |
| -Kodama trains | 5h 00m | 1,180 | 1,100 | 2,280 |
| -Hikari trains | 4h 00m | 1,180 | 1,300 | 2,480 |

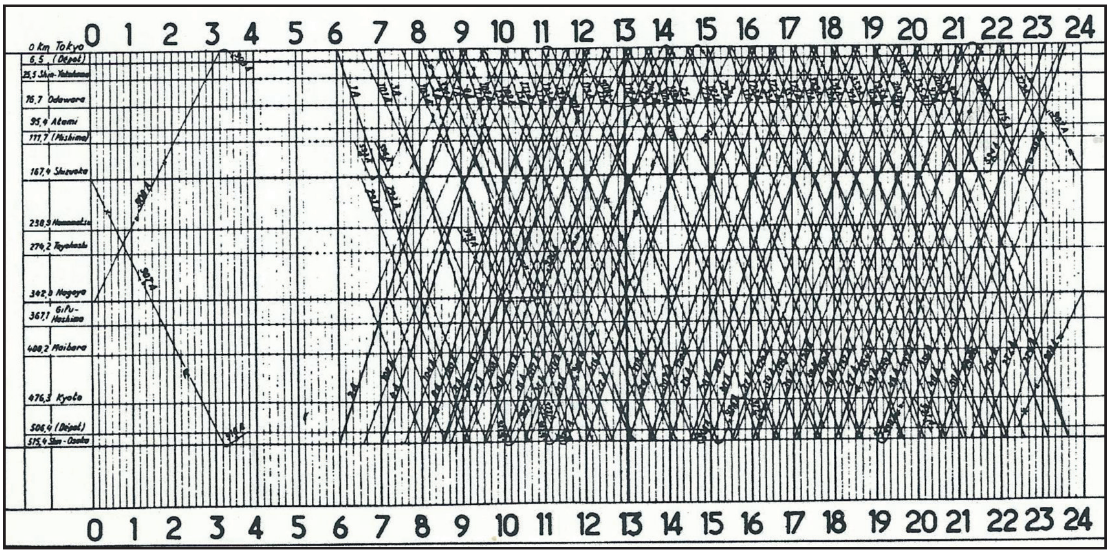
*Source:* Y Matsumoto (1965)

With the launch of the Shinkansen, both types of services were maintained in the new line, with Kodama trains now being the slower of the two (5h00) and the Hikari trains being the faster (4h00). The respective fare levels are explained in Table 1.2. Observation of the table shows how the high-speed services continued to have the lowest basic fare level and what was increased was the supplement, which was variable based on whether Hikari or Kodama trains were being used. Overall, the passengers fare went from Y1,980 to Y2,280 or Y2,480. That is, it increased between 15% and 25%.

It is interesting to compare the fare increase in the high-speed services with the reduction in travel time they offered. Thus, the shift from 6h 30m in the Kodama trains to 5h 00m on the new line meant a cost of 3.3 yen per minute gained. Finally, it highlights the fact that the difference in fares between the Kodama and Hikari high-speed trains was lower than that in conventional trains, even when the difference in travel time of each one was the same.

It should be highlighted that one year after the entry into commercial service of the Tokyo-Osaka line, the increase in speed in some sections allowed the travel times of Hikari trains to be reduced from the initial 4 hours to 3 hours (commercial speed of 171 km/h). Meanwhile the Kodama trains went from 5 hours to 4 hours. In 1965, as a result of increased passenger demand, the frequency of services of Hikari trains went from 14 per day/direction in 1964, to 26 per day/direction. The offering of Kodama trains in 1965 stood at 29 trains per day/direction. Figure 1.14 displays the densification of the mesh of services.

**GRAPH OF TRAINS LEAVING TOKAIDO (1ST OF NOVEMBER 1965) (FIG. 1.14)**




*Source:* A. Caire (1985)

## 1.6 PASSENGER DEMAND

Prior to the entry into commercial service of the new high-speed line between Tokyo and Osaka, railway and air passenger demand was as follows.

With respect to land transport, in 1963 the average number of passengers per day was approximately 6,400, as displayed in table 1.4. This rate equates to an annual demand of nearly two million passengers.

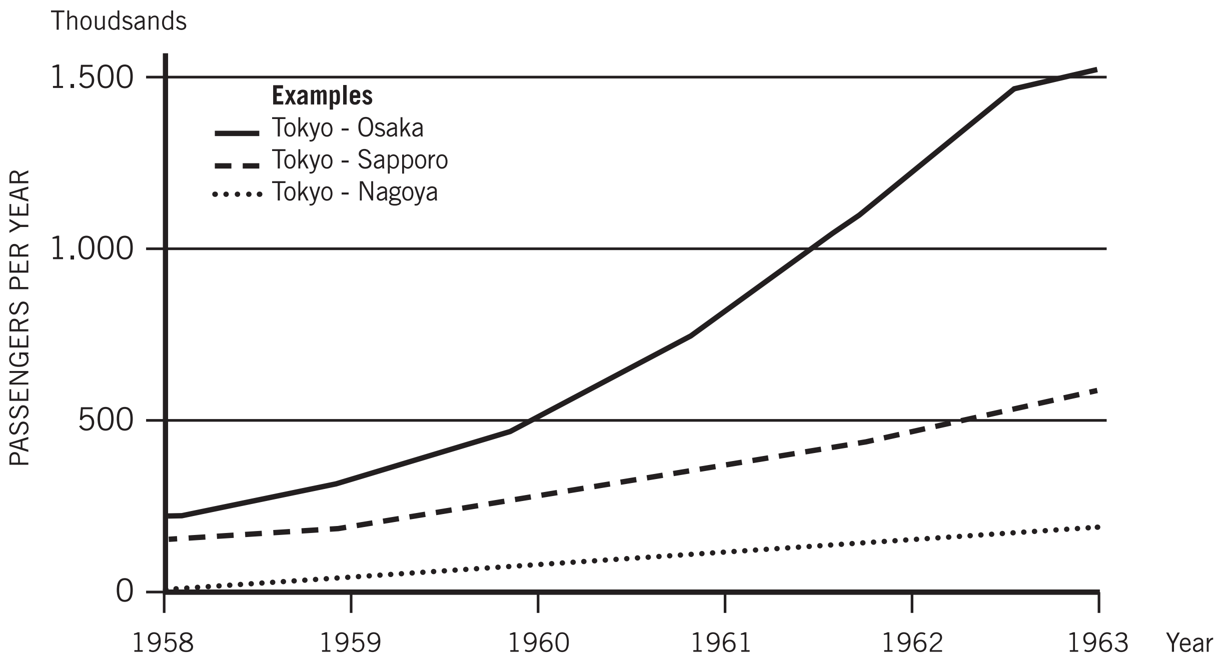
**AVERAGE NUMBER OF RAILWAY PASSENGERS ON TOKYO-OSAKA ROUTE (1963) (TABLE 1.4)**

| Type of Service | Number of Passengers |
|---|---|
| Day Trains | 3.555 |
| Night Trains | 2.845 |
| Total | 6.400 |

*Source:* Adapted from H. Yokohama (1968)

In terms of air traffic between Tokyo and Osaka, figure 1.15 shows a significant increase during the 1958-1963 period. It went from 200,000 passengers to more than 1.4 million passengers

**EVOLUTION OF AIR PASSENGER TRAFFIC FOR CERTAIN JAPANESE ROUTES (1958-1963) (FIG. 1.15)**




*Source:* Y. Sato (1968)

Consequently, it was determined that rail had a market share of 59% against 41% for air travel.

The response to the offering of services referred to in the preceding paragraph was very rapid, as can be seen in Table 1.5

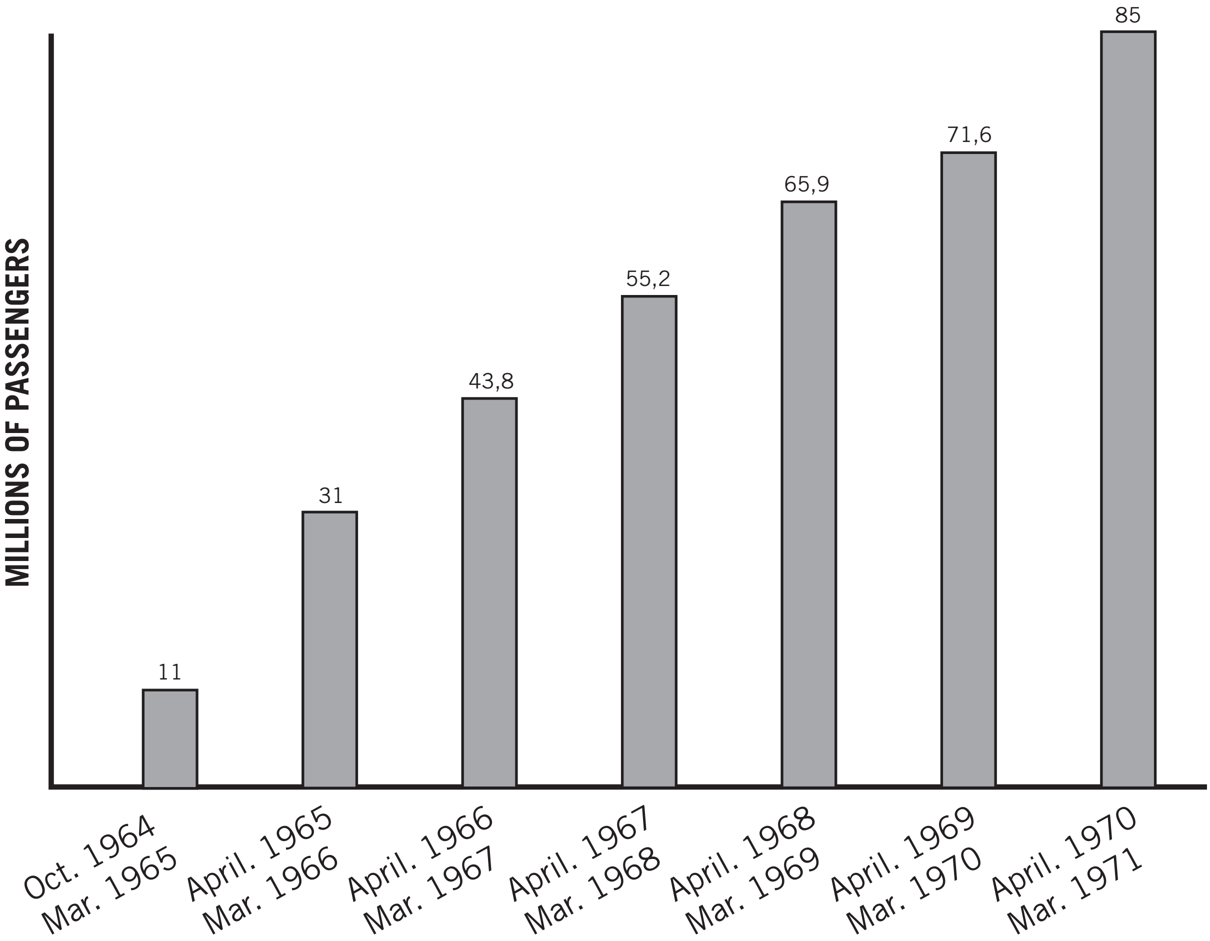
**PASSENGER TRAFFIC ON THE TOKYO-OSAKA HIGH-SPEED LINE (OCTOBER-DECEMBER 1964 (TABLE 1.5)**

| Month | Passengers per day |
|---|---|
| October | 56,000 |
| November | 60,000 |
| December | 70,000 |

*Source:* Author's own work. Data: A. Caire (1985)

The growth in demand in subsequent years remained high. During the first six months of operation (October 1964 – March 1965), the total demand grew to 11 million passengers. In the period April 1965-April 1966, the traffic reached 31 million passengers. This meant that six years after the entry into service of the high-speed line, the demand exceeded 85 million passengers (Figure 1.16)

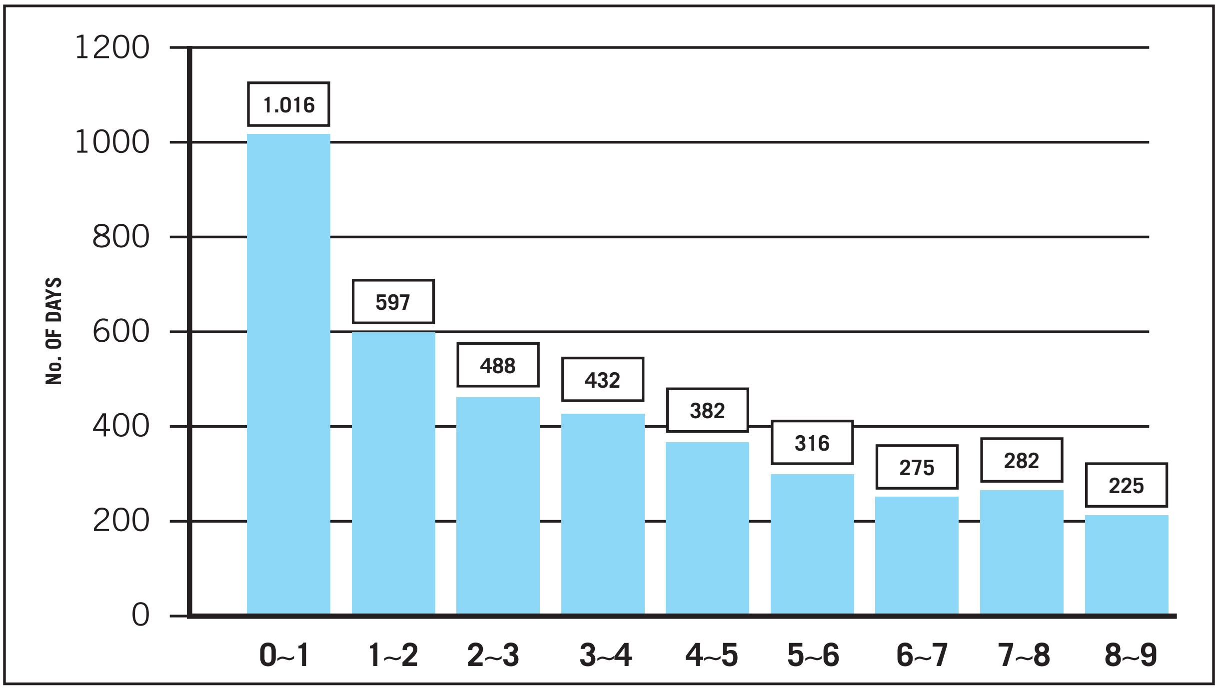
**EVOLUTION OF PASSENGER TRAFFIC ON THE TOKYO-OSAKA LINE (1964-1974) (FIG. 1.16)**




*Source:* Author's own work. Data: Y. Ogura (1977)

Figure 1.17 shows the number of days taken to carry each 100 million passengers.

**NUMBER OF DAYS TAKEN TO CARRY EACH 100 MILLION PASSENGERS (FIG. 1.17)**




*Source:* Shinkansen, JNR (1977)

Regarding the impact of the high speed train on the demand for air travel in1965.Y. Matsumotó made the following analysis:

"The Tokyo-Osaka flights have long been the most important source of revenue for Japanese airway companies, and traffic on this route was on a steady increase until the opening of the New Tokaido Line. The New Tokaido Line has reduced the difference, rail and air, a travel time between Tokyo-Osaka, to the stage where travel by rail has become extremely competitive with travel by air over this route. The total number of air passengers per day since the opening of the New Tokaido Line (October 1964) is 3,647 passengers (Japan Air Lines and All-Nippon Airways combined) or 22% less than the corresponding figure of October 1963.

Assuming that the natural increase of air traffic for 1964 is 30% over 1963, the passenger traffic diverted from the air lines to the New Tokaido Line amounts to 2,400 passengers per day.

During this one year period, the number of daily flights was increased from 35 to 43 one way. And as a result, the utilization ratio of aircraft has decreased from 86% in October 1963 to 50% for JAL and from 89% to about 60% for ANA. (Table 1.6)

**CHANGES IN AIR PASSENGER TRAFFIC BETWEEN TOKYO AND OSAKA (AVERAGE PER DAY ROUND TRIPS) (TABLE 1.6)**

| Month & Year | JAL | | ANA | | Total | |
|---|---|---|---|---|---|---|
| Oct. 1960 | 1,218 | % | 239 | % | 1,457 | % |
| Oct. 1961 | 1,598 | (131) | 552 | (231) | 2,150 | (143) |
| Oct. 1962 | 2,022 | (127) | 1,499 | (272) | 3,521 | (164) |
| Oct. 1963 | 2,866 | (142) | 1,792 | (120) | 4,658 | (132) |
| Oct. 1964 | 2,148 | (75) | 1,499 | (84) | 3,647 | (78) |

*Figures* in parentheses are percentage comparisons with preceding years.

*Source:* Y. Matsumoto

JNR had always obtained a greater share of 1st class Tokyo-Nagoya passenger traffic than airways (64% in 1963), but the proportion has been declining each year. But the opening of the New Tokaido Line has had a great effect on air transportation; the number of air passengers per day has decreased from 592 in 1963 to 487 this year, a decrease of 18% (Table 1.7)

**CHANGES IN AIR PASSENGER TRAFFIC BETWEEN TOKYO AND NAGOYA (AVERAGE PER DAY ROUND TRIPS) (TABLE 1.7)**

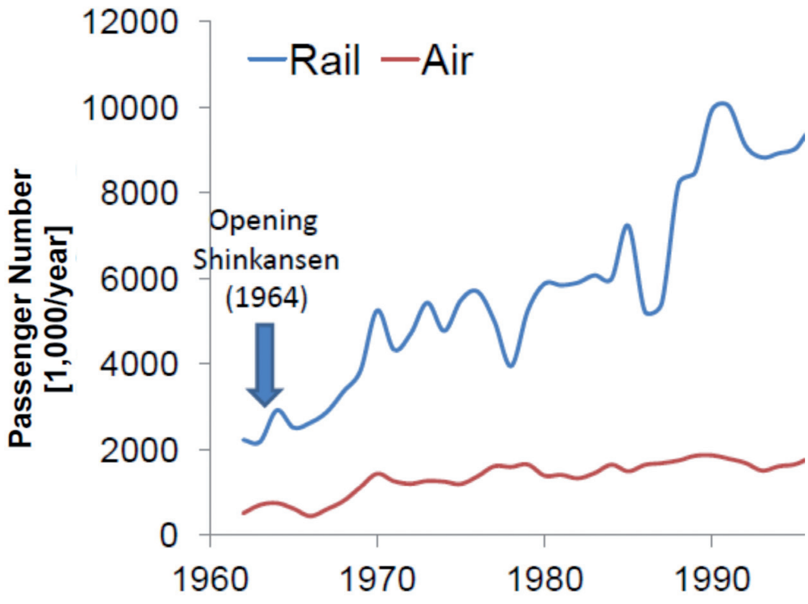
| Month & Year | ANA | % |
|---|---|---|
| Oct. 1960 | 233 | |
| Oct. 1961 | 279 | (120) |
| Oct. 1962 | 468 | (168) |
| Oct. 1963 | 593 | (126) |
| Oct. 1964 | 487 | (82) |

*Figures* in parentheses are percentage comparisons with preceding years.

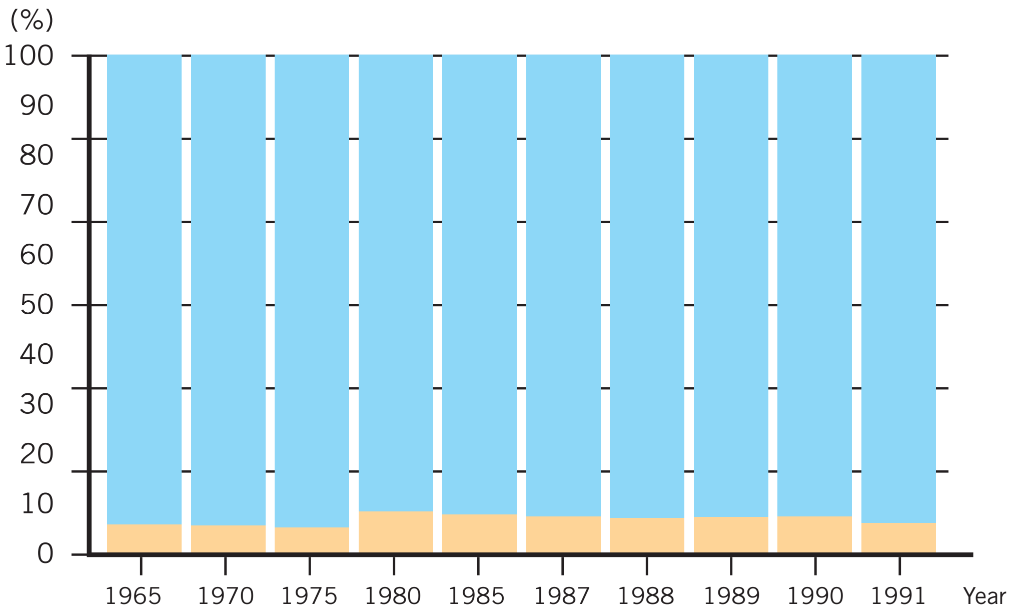
Assuming that the natural increase in air travel for 1964 is 25% over 1963, the number of passengers diverted from air to JNR amounts to about 250 passengers per day."

Figure 1.18, shows the evolution of rail and air traffic on the Tokio-Osaka route(1964-1990), and Figure 1.19 the market share of Shinkansen and airplane (Tokyo-Osaka) from 1965 to 1991.

**EVOLUTION OF RAIL AND AIR TRAFFIC ON THE TOKIO-OSAKA ROUTE (FIG. 1.18)**




**MARKET SHARE OF SHINKANSEN AND AIRPLANE (TOKYO-OSAKA), 1965-1991 (FIG. 1.19)**

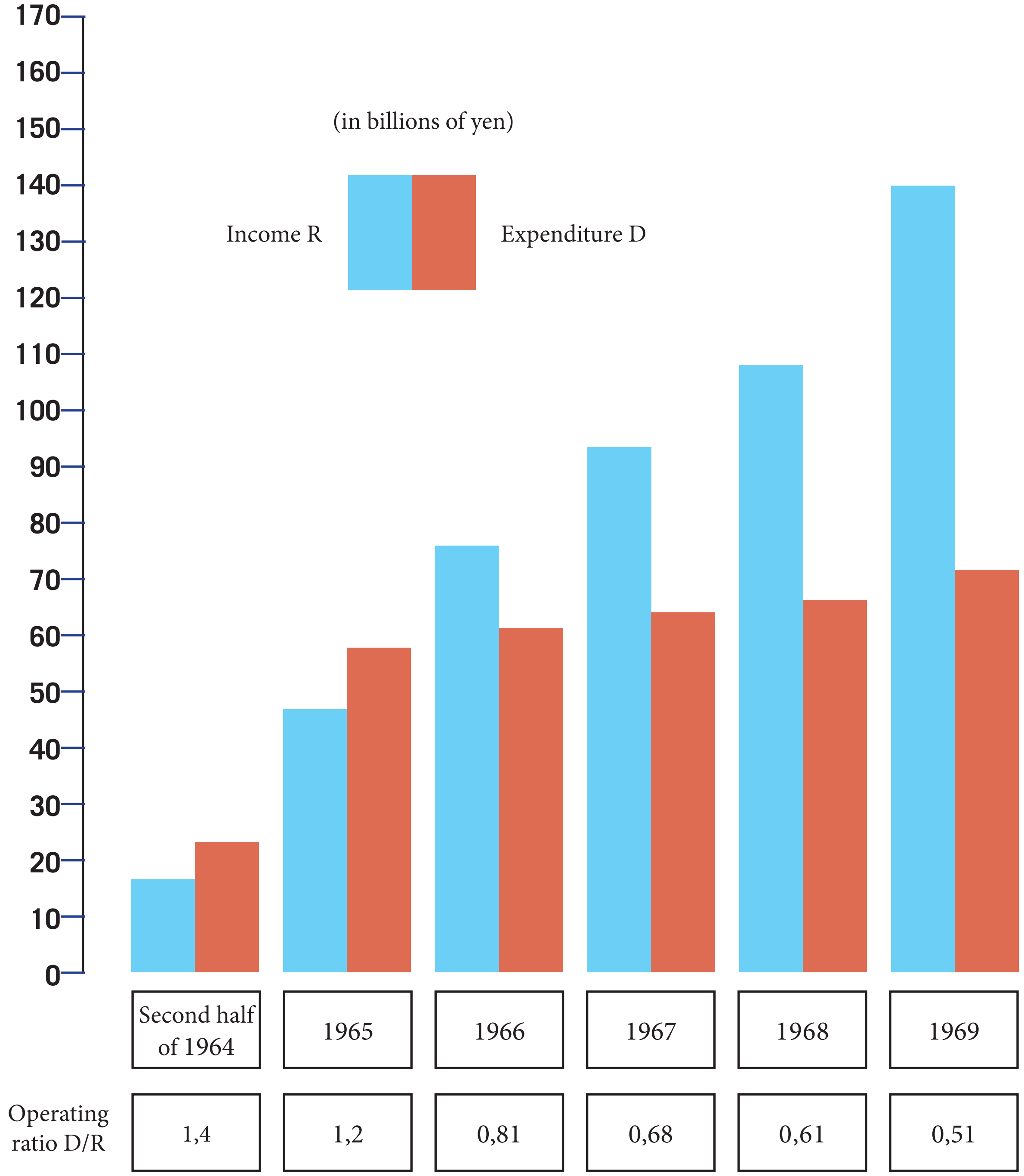



*Source:* JR Central

## 1.7 THE CONSTRUCTION OF NEW LINES

The previous section, figure 1.16 and table 1.7, showed the commercial success of the new high-speed line between Tokyo and Osaka. However, it is equally important to note the financial success of its operation. By the third year of operations, the revenue had exceeded the cost (figure 1.20), including interest and depreciation, of the initial investment.

**OPERATING INCOME AND EXPENSES OF THE NEW TOKAIDO LINE (FIG 1.20)**



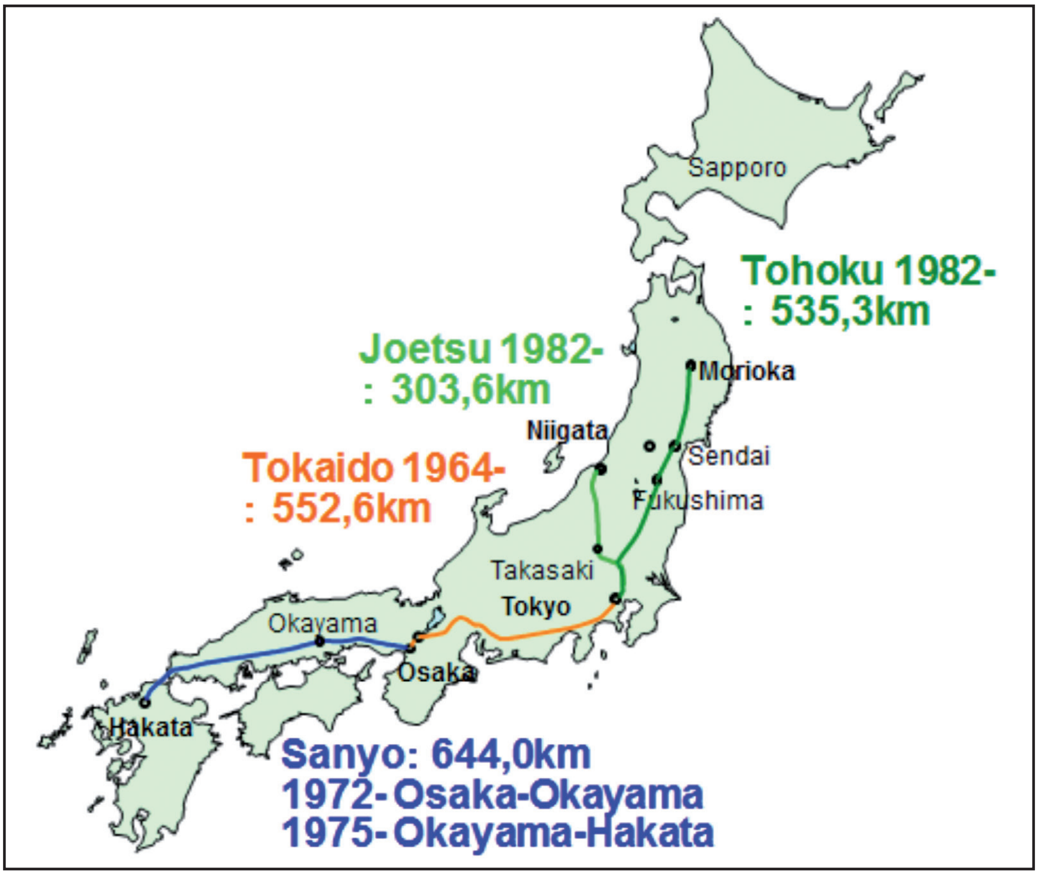

*Source:* Shinkansen, JNR (1986)

It is no surprise, then, that in 1967 construction was begun on the second high speed rail line in Japan, between Osaka and Okayama (161 km). In 1970, a third line was begun between Okayama and Hakata (393 km).

In this context of supreme confidence in high speed rail, which coincided with annual economic growth of 10% in Japan, a commitment was made for the construction of new lines.

Indeed, in 1970, a law was passed on the construction of a national network of high speed railway lines. specifically, this involved the Tohoku and Joetsu lines (figure 1.21)

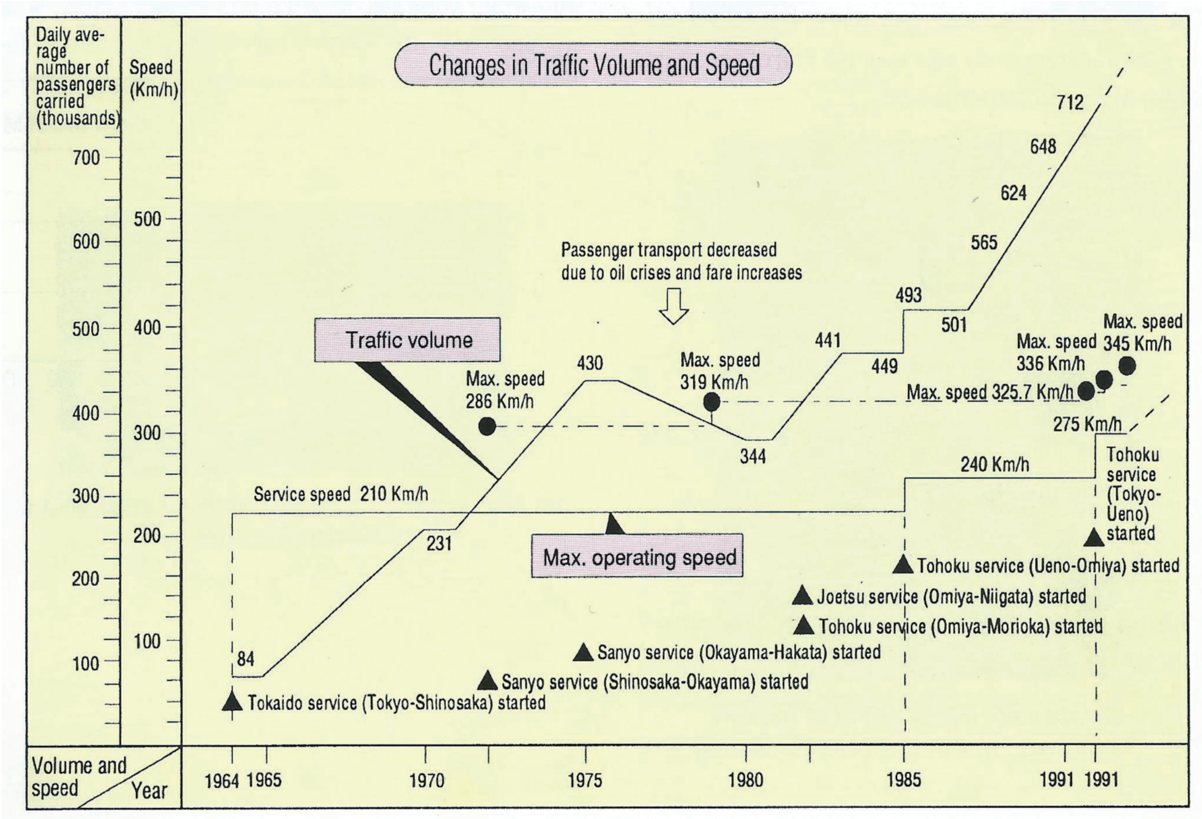
**HIGH SPEED NETWORK IN JAPAN IN 1982 (FIG. 1.21)**




It can be said that in 1982 (Figure 1.21) the country already had an axis in place to link Morioka (in the north) with Hakata (in the south); in total, a length of 1,835 km.

It is useful to show in figure 1.22 the evolution of passenger demand on the network indicated in figure 1.21 it also shows the increase in maximum speeds in commercial service and during test runs.

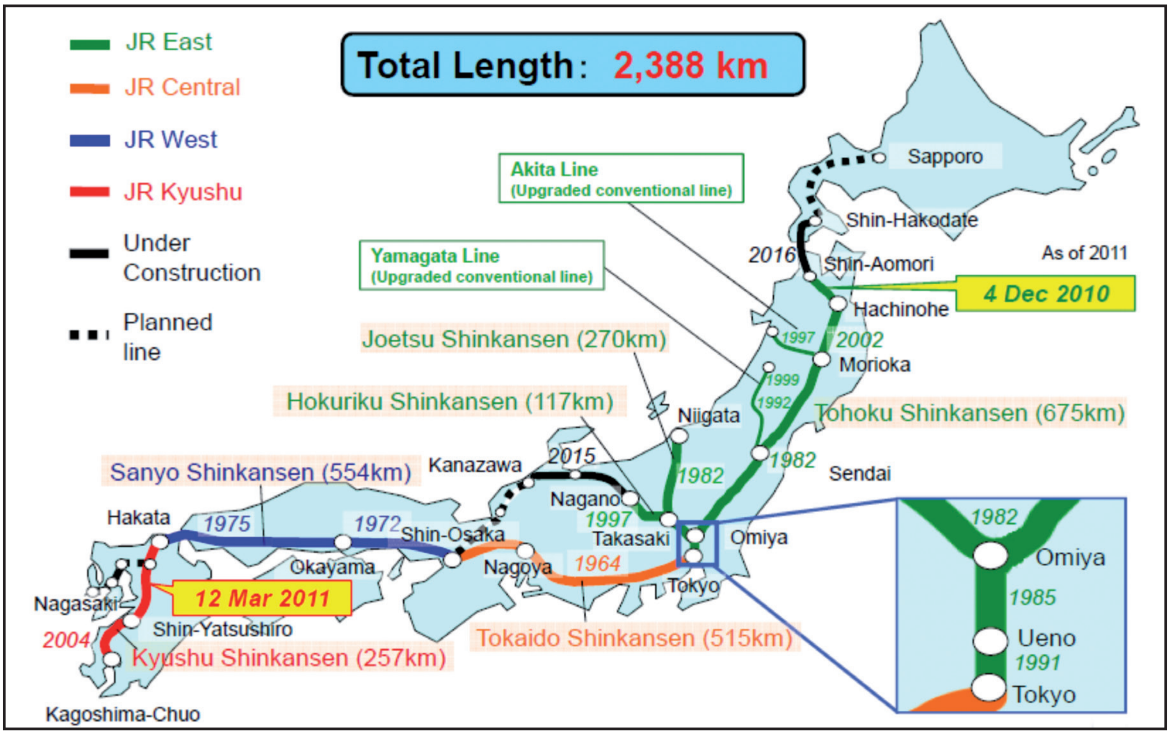
## CHANGES IN TRAFFIC VOLUME AND SPEED (FIG 1.22)




*Fuente:Japan* Railways Group 1992

Since then, the high-speed network has continued to grow in its number of kilometres, through new lines. In 2016 the section between Shin Aomori and Shin Hakodate, 149 km in length, will be completed. At that point in time there will be a continuous high-speed line between Kagoshima Chuo, at the southern tip of Japan and Shin Hakodate, of more than 2,100 km in length (Figure 1.23)

## SHINKANSEN NETWORK IN JAPAN (FIG. 1.23)



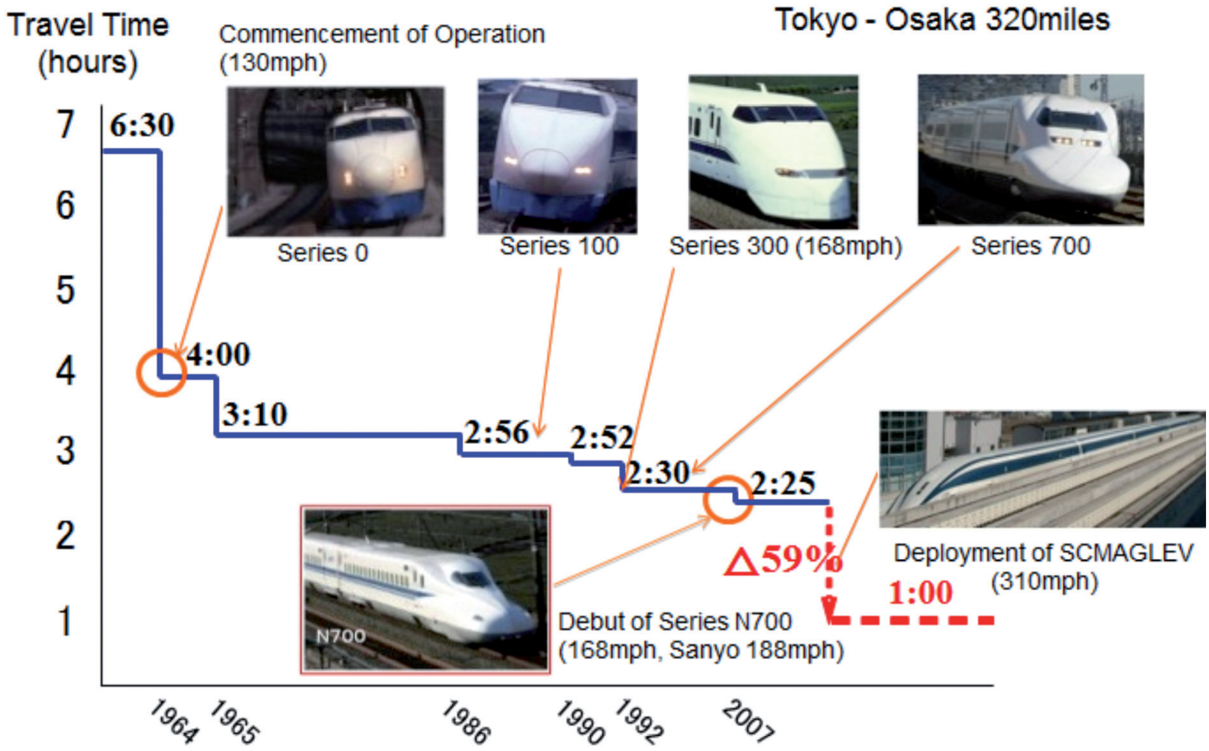

*Source:* A.TAMURA (2012)

Simultaneously they will have developed the spectacular pool of high-speed trains shown in Fig. 1.24.

## HIGH SPEED TRAINS DEVELOPED IN JAPAN (FIG. 1.24)

The progressive introduction into commercial service of high-speed branches with greater services enabled reduction of initial travel times between Tokyo and Osaka from 4h to 2h 25 at the end of the last decade, as shown in figure 1.25.

**EVOLUTION OF TRAVEL TIME BETWEEN TOKYO AND OSAKA FOR HIGH-SPEED LINES (1964-2007) (FIGURE 1.25).**




*Source:* JR Central.

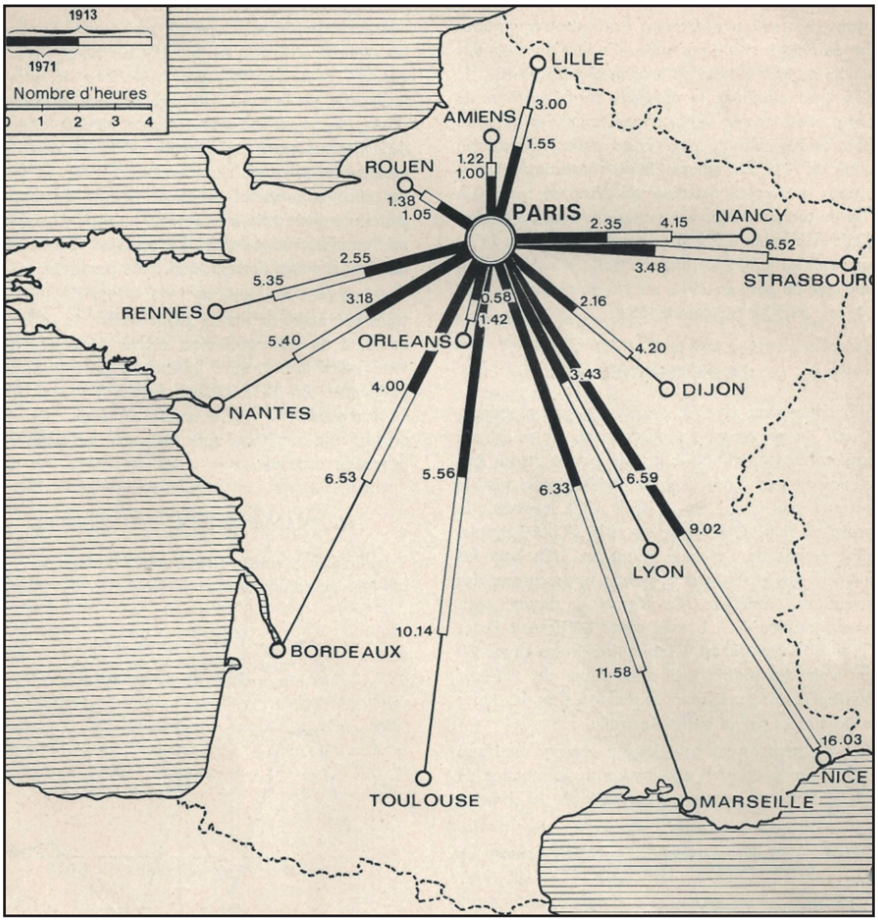
# CHAPTER 2.

# THE FIRST HIGH SPEED TRAIN LINE IN FRANCE

## 2.1 CONVENTIONAL RAIL AND TRAVEL TIMES

One activity that most typically characterises the French railway has undoubtedly been the continuous reduction of travel times in intercity passenger services over medium and long distances. Perhaps one of the most illustrative examples of this fact can be found in Figure 2.1. Here the evolution of travel times of the fastest trains between Paris and the major French cities in the period 1913-1971 is shown.

**RAILWAY TRAVEL TIMES IN FRANCE (1913-1971) (FIG. 2.1)**




*Source:* R. Guibert (1972)

It can be seen that in the early 20th century, the Paris-Bordeaux route achieved a commercial speed of almost 85 km/h. Between Paris and Marseilles (863 km) a 72 km/h average was achieved.

During the 1970s, the French rail network experienced a profound transformation as evidenced by the data in Table 2.1.

### EVOLUTION OF MAXIMUM CIRCULATION SPEEDS IN THE FRENCH NETWORK (1970-1976) (TABLE 2.1)

| **Maximum speed (km/h)** | **Length of track (km) where it is possible to circulate at max. speed** | | | | | |
|---|---|---|---|---|---|---|
| | **1,970** | **1,971** | **1,972** | **1,974** | **1,975** | **1,976** |
| 150 | 6.058 | 6.127 | 6.581 | 7.289 | 7.610 | 8.430 |
| 160 | 3.831 | 4.227 | 4.477 | 5.076 | 5.550 | 6.387 |
| 170 | ------- | | | 886 | 886 | 950 |
| | } | 1.117 | 1.340 | | | |
| 180 | ------- | | | 798 | 816 | 880 |
| 200 | 236 | 533 | 560 | 773 | 779 | 838 |
| Total V ≥150 km/h | 10.125 | 12.004 | 12.958 | 14.822 | 15.641 | 17.485 |
| % of total network | 29% | 34% | 37% | 43% | 45% | 50% |

*Source:* SNCF

Note that in 1970, more than 10,000 km allowed trains to reach maximum speeds of 150 to 200 km/h. In 1976, this figure exceeded 17,000 km, representing almost 50% of the total length of the network. Thus, 143 cities were connected with Paris at over 100 km/h of commercial speed, 67 at over 120 km/h, and 6 over 140 km/h. Table 2.2 shows the developments in the period 1950-1979, for commercial speed and travel time in some routes.

**EVOLUTION OF TRAVEL TIME AND COMMERCIAL SPEED ON SOME FRENCH ROUTES (TABLE 2.2)**

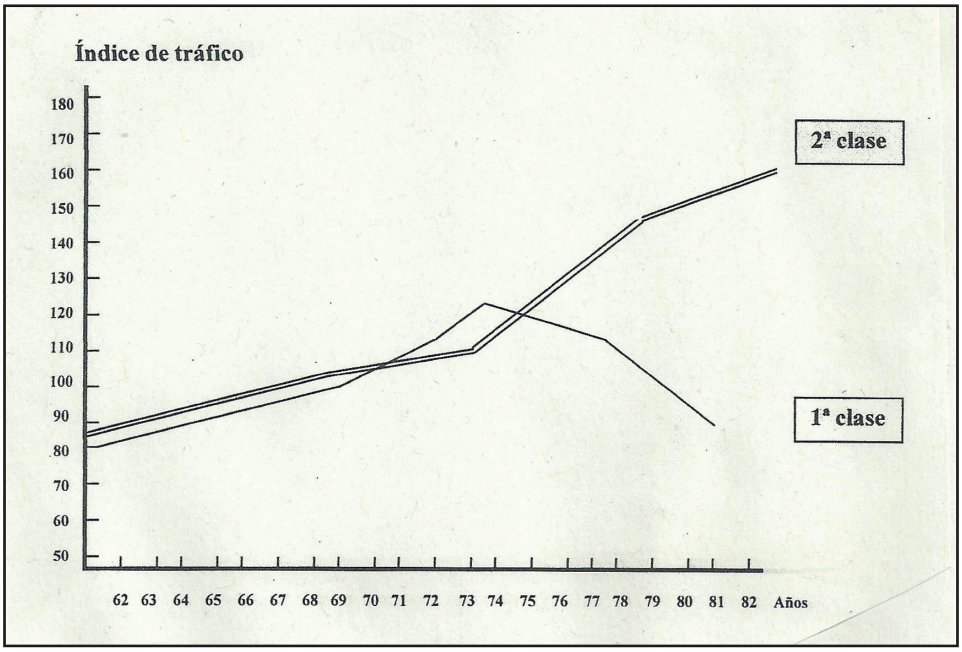
| Route between Paris and | Travel time and commercial speed (km/h) in | | |
|---|---|---|---|
| | 1,950 | 1,960 | 1,979 |
| Bordeaux (581 km) | 5h 55m (98.2) | 4h 48m (121) | 3h 50m (152) |
| Lille (251 km) | 2h 31m (99.7) | 2h 10m (115.8) | 1h 52m (134) |
| Strasbourg (504 km) | 5h 15m (96) | 5h 11m (97) | 3h 52m (130) |
| Marseilles (864 km) | 10h 17m (84) | 7h 33m (114) | 6h 33m (132) |
| Lyon (511 km) | 5h 07m (100) | 4h (128) | 3h 45m (136) |

Source: A. López Pita (1996)

## 2.2 THE NEED FOR HIGH SPEED

The observation of the data in Table 2.2 would seem to invite us to think of it as a significant reaction in demand to improve the quality of the supply achieved by the French railways. However, the reality of the traffic shown in Figure 2.2 does not parallel the theoretical forecast seen previously.

**EVOLUTION OF LONG DISTANCE PASSENGER TRAFFIC IN THE SNCF (1962-1982) (FIG. 2.2)**




*Source:* MIREUX (1985)

Indeed, although, as shown in the figure above, from 1962 to 1974/75 journeys by rail increased by 46% in both 1st and 2nd class, from the mid-1970s the number of first class passengers experienced a rapid decline that ended up as 24% in the period 1975-1982. Without a doubt, the development of the French internal network with air travel, which was faster and more reliable, would have involved, on certain routes, a significant transfer of 1st class rail passengers to the aeroplane. Either way, the reality was a progressive and continuous decline of passenger rail at the higher end.

Considering in particular the situation of the railways in the Paris-Lyon route, it shows that by the middle of the 1960s, the analysis of the modal split in the Paris-Lyon route predicted the results shown in Fig. 2.2. Indeed, in 1963, on the aforementioned route, the railway offered a travel time of 4h, accounting for 515 km of the route at a commercial speed of close to 130 km/h. This feature allowed it to hold a 65% share of the market, compared to 28% for road and 7% for air travel (Table 2.3).

**MODAL DISTRIBUTION OF PASSENGER TRAFFIC IN THE PARIS-LYON ROUTE (1963-1976) (TABLE 2.3)**

| Transport Mode | 1,963 | 1,967 | Forecast 1,976 |
|---|---|---|---|
| Benefit of railway | 4h (128 km/h)* | 4h (128 km/h)* | 3h 45m (137 km/h)* |
| Rail | 65% | 48% | 25% |
| Air travel | 7% | 20% | 39% |
| Road | 28% | 32% | 36% |

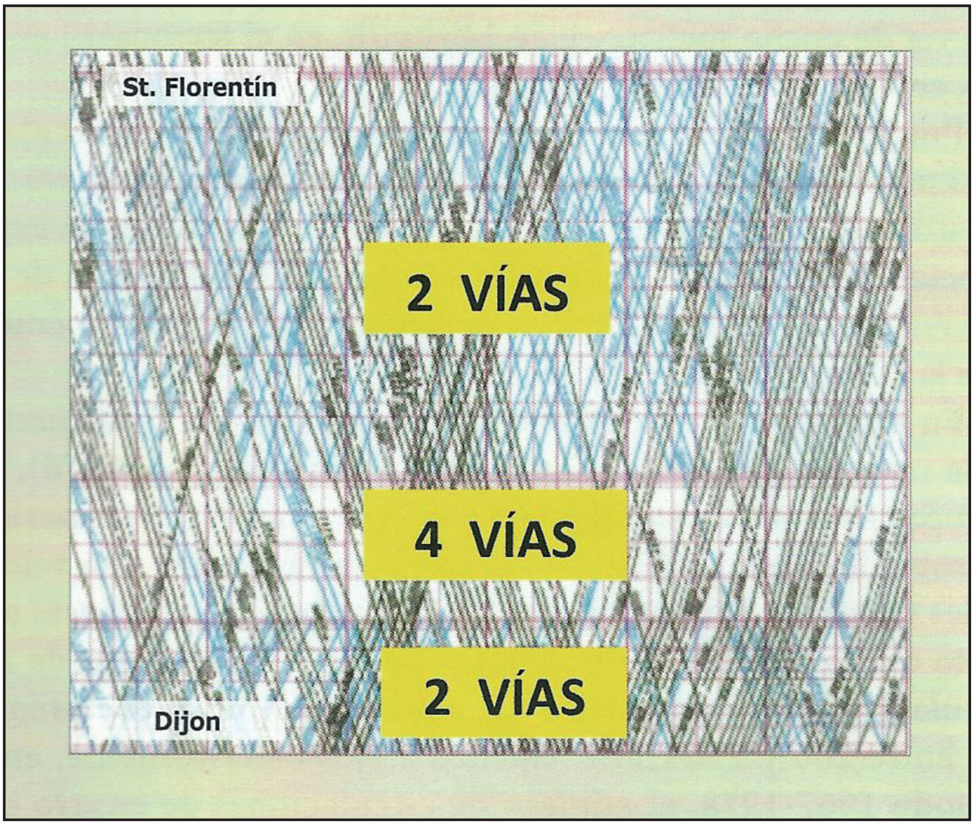
* Commercial speed

*Source:* Adapted from WALRAVE (1970)

However, in Table 2.3, only four years later, in 1967, the railway had lost 17 points of market share, and the forecast for 1976, the year in which the travel time of this mode would be 3h 45 (commercial speed of 137 km/h), indicated that it would lose 23 more points. In summary, it could be said that from 1963 to 1976, the railway would divide its market share by 2.6, while air travel multiplied by more than 5.

Alongside this situation, the transport capacity of the Paris-Lyon line was running out. Indeed, in the section between St. Florentin and Dijon (Figure 2.3), approximately 250 trips per day were reached. This magnitude is in the upper limit of the number of passenger and freight trains that a conventional line equipped with modern signalling systems can support.

**GRAPH OF TRAIN MOVEMENTS FOR THE ST. FLORENTIN-DIJON SECTION (1975) (FIG. 2.3)**




*Source:* SNCF

To address this lack of capacity, there were two options:

a) The first was to add two more routes between St. Florentin and Dijon (109 km).

b) The second was to build a new line between Paris and Lyon.

Undoubtedly, with the first option, the operational capacity of the railway was significantly improved, but travel time between Paris and Lyon would only be reduced slightly, from 3h 45m to 3h 30m. This was clearly an insufficient reduction given the offering from the airlines.

In any case, the economic analysis carried out on the two steps mentioned gave the results in Table 2.4.

## ECONOMIC ANALYSIS OF POSSIBLE ACTION ON PARIS-LYON AXIS IN 1975 (TABLE 2.4)

| Indicator | New TGV line and services | Duplication of St. Florentin-Dijon section |
|---|---|---|
| Total length from Paris to Lyon | 425 | 512 km |
| Length of line to be built | 409 | 109 km |
| Necessary investment in MF75 | 2,600 | 1,200 |
| - Infrastructure | 1,550 | 1,000 |
| - Material | 340 | - |
| Paris-Lyon travel time | 2h | 3h 30m |
| Return to the SNCF | 18% | Reduced |
| Return to the community | 33% | Very low |

Source: Adapted from M. Leboeuf (2013)

The decision was therefore to build a new line, which with the implementation of high-speed rail would recover much of the market share it had in the mid-1960s, as shown in Table 2.5.

## ESTIMATE OF THE IMPACT OF A NEW COMMERCIAL HIGH SPEED LINE BETWEEN PARIS AND LYON (TABLE 2.5)

| Mode | Modal distribution of traffic (%) | |
|---|---|---|
| | No new line | With new line |
| Railway | 25.4 | 58 |
| Air travel | 39 | 12.4 |
| Road | 35.6 | 29.6 |

Source: Adapted from M. Walrawe (1970)

## 2.3 THE TECHNOLOGY REQUIRED TO RUN AT HIGH SPEED

In the mid-1950s, when it was decided to build a new line between Tokyo and Osaka, the maximum speeds in commercial service were 100 km/h in the Japanese railway, equipped with a metre gauge track and 140 km/h in the European railway, on standard gauge tracks.

It can be said, therefore, that the decision to move to 210 km/h from 1964 between two major Japanese urban areas was not supported by extensive experience. In fact, this actually constituted the basis for the doubts of some sectors of Japan, at the time, regarding the construction of this line.

In France, by contrast, when the construction of the first high-speed line in Europe was initiated in 1976, the French railways already possessed considerable expertise on the technical issues to overcome to travel at top speeds above 200 km/h. Consider the developments undergone in this regard between 1950 and 1967. (Table 2.6)

**EVOLUTION OF MAXIMUM SPEEDS IN COMMERCIAL SERVICE IN FRANCE (1950-1967) (TABLE 2.6)**

| Year | Maximum authorised speed (km/h) |
|---|---|
| 1950 | 120 |
| 1953 | 140 |
| 1957 | 150 |
| 1965 | 160 |
| 1967 | 200 |

Source: Author's own work. Data: L. Fieux (2005)

On the other hand it should be emphasised that the SNCF, in the period 1960-1967, made over 240 experimental runs with top speeds between 200 and 250 km/h (Table 2.7). Subsequently, in the period 1967-1978, the number of test runs at speeds of 300 km/h or above would be significant (Table 2.7).

**EVOLUTION OF THE KNOWLEDGE OF THE PROBLEM OF TRAVELLING AT HIGH AND VERY HIGH SPEED IN FRANCE (TABLE 2.7)**

| **1960-1967. Test run at 200/250 km/h** | |
|---|---|
| **Speed (km/h)** | **Number of runs** |
| 200/210 | 166 |
| 220/230 | 57 |
| 240/250 | 30 |
| **1967-1978. Test run at 200/300 km/h** | |
| **Speed (km/h)** | **Number of runs** |
| 200 to 280 | 47 |
| 300 to 318 | 175 |
| 300 to 306 | 100 |

Source: A. López Pita, based on different sources

It is interesting to remember that the high-speed line between Paris and Lyon began its commercial operation at a top speed of 260/270 km/h in September 1981. That means more than three years had elapsed from the time that the French railways had made more than a hundred test runs, during experimental research trials, at over 300 km/h. Therefore, the necessary technology was available to ensure that high-speed services could be implemented with total confidence.

## 2.4 THE DECISION TAKEN

The first ideas on high-speed train travel in France are found in the report prepared in 1965 by the French engineer Robert Geais on the construction of new rail infrastructure, with reduced gauge, parallel to a highway between Paris and Lille. The concept involved reserving an area for the high-speed train in the centre of the highway.

However, it would take until the 5th of November 1969 for the SNCF to send the project «Desserte du Sud-Est de la France à G.V. et à frèquence elevée au moyen d’une ligne nouvelle París-Lyon» (“Serving the South-East of France with GV and High Frequency through a New Paris-Lyon Line”) to the French government. It responded to the problems of existing capacity in some sections of this line, as indicated above.

Until the decision by the French government to build this line, on the 6th of March 1974, the project was the subject of numerous analyses by various committees created especially for the purpose and known by the name of the chairperson who presided over each one.

In this context, the first commission, chaired by R. Coquand, began its work in December 1969, one year after issuing its report. It highlighted the advantages of the TGV solution over other alternative projects with which it was compared, particularly with the Aerotrén and air travel on short-haul flights.

In the final decision approving the high-speed railway, the oil crisis in 1973-74 had a major influence, taking into account the weight of the transport sector in energy consumption nationwide.

As is well-known, the railway significantly outpaces the other modes with respect to its unit energy consumption. In this context, it can be seen that in the late 1970s the power consumption of each mode had the levels indicated in Table 2.8.

**ENERGY CONSUMPTION BY TRANSPORT MODE IN FRANCE (LATE 1970S) (TABLE 2.8)**

| Mode | Consumption by PKO | Use coefficient | Consumption by VK | Contents |
|---|---|---|---|---|
| Caravelle aeroplane | 51.4 | 67 | 77 | 4.42 |
| Mercure aeroplane | 44.7 | 73 | 61 | 3.5 |
| Airbus B2 aeroplane | 39.4 | 69 | 57.4 | 3.3 |
| Car | 14.2 | 1.9 pass. | 35.1 | 2.02 |
| TGV | 11.3 | 65 | 17.4 | 1 |

Source: P.H. Emangard (1981)

Note, in effect, the way energy consumption per passenger-kilometre transported was twice as much in cars as in high speed trains, a magnitude, which rose to 3-4 times depending on the type of aeroplane considered.

Also influencing the decision was the fact that the construction of the new line between Paris and Lyon would not only benefit these cities, but would positively affect a number of cities, which as a whole accounted for more than 30 million inhabitants (Figure 2.4).

**FRENCH POPULATION BENEFITED BY PARIS-LYON HIGH SPEED LINE (FIG. 2.4)**

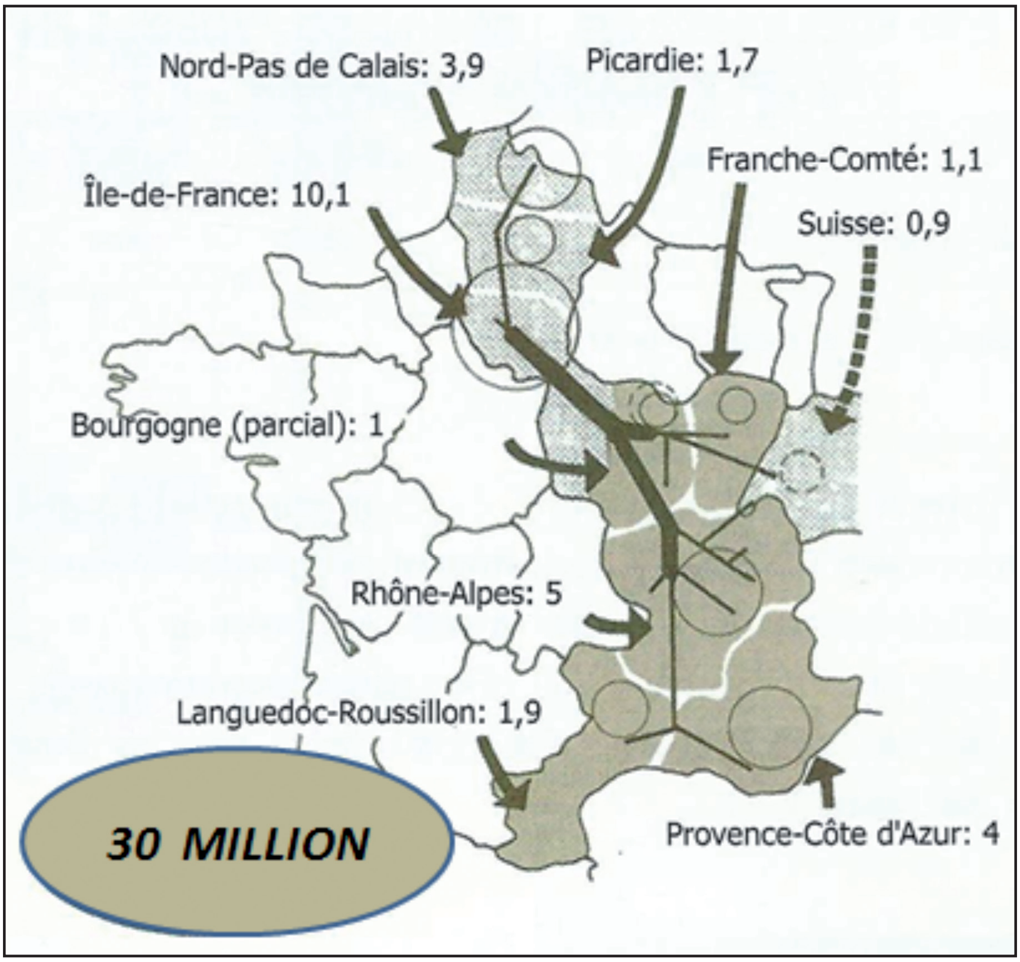
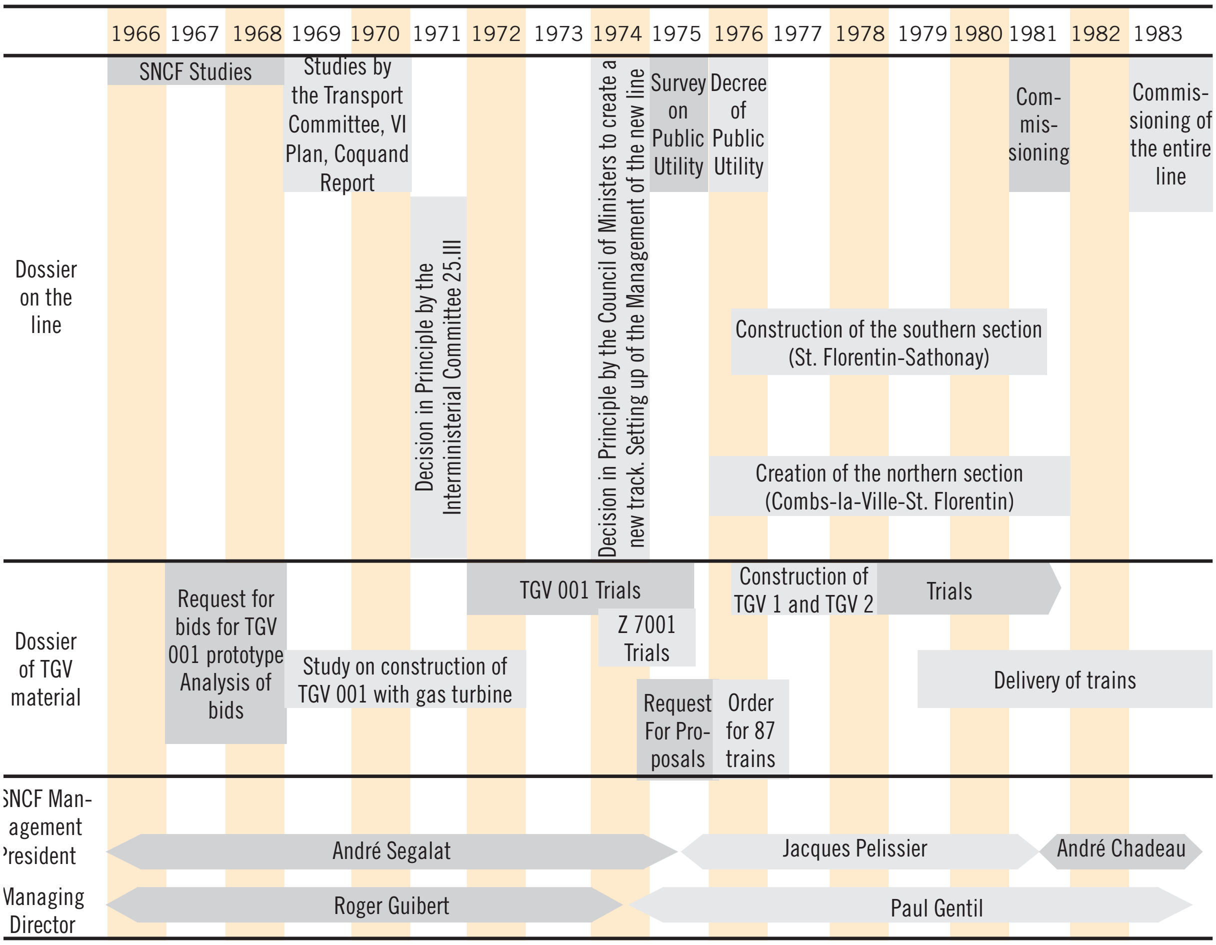



Figure 2.5 shows the main stages leading up to the entry into commercial service of the first high speed line in France. It also includes details relating to the manufacture and servicing of the high speed trains.

## KEY DATES IN THE INTRODUCTION OF HIGH SPEED RAIL IN FRANCE (FIG 2.5)

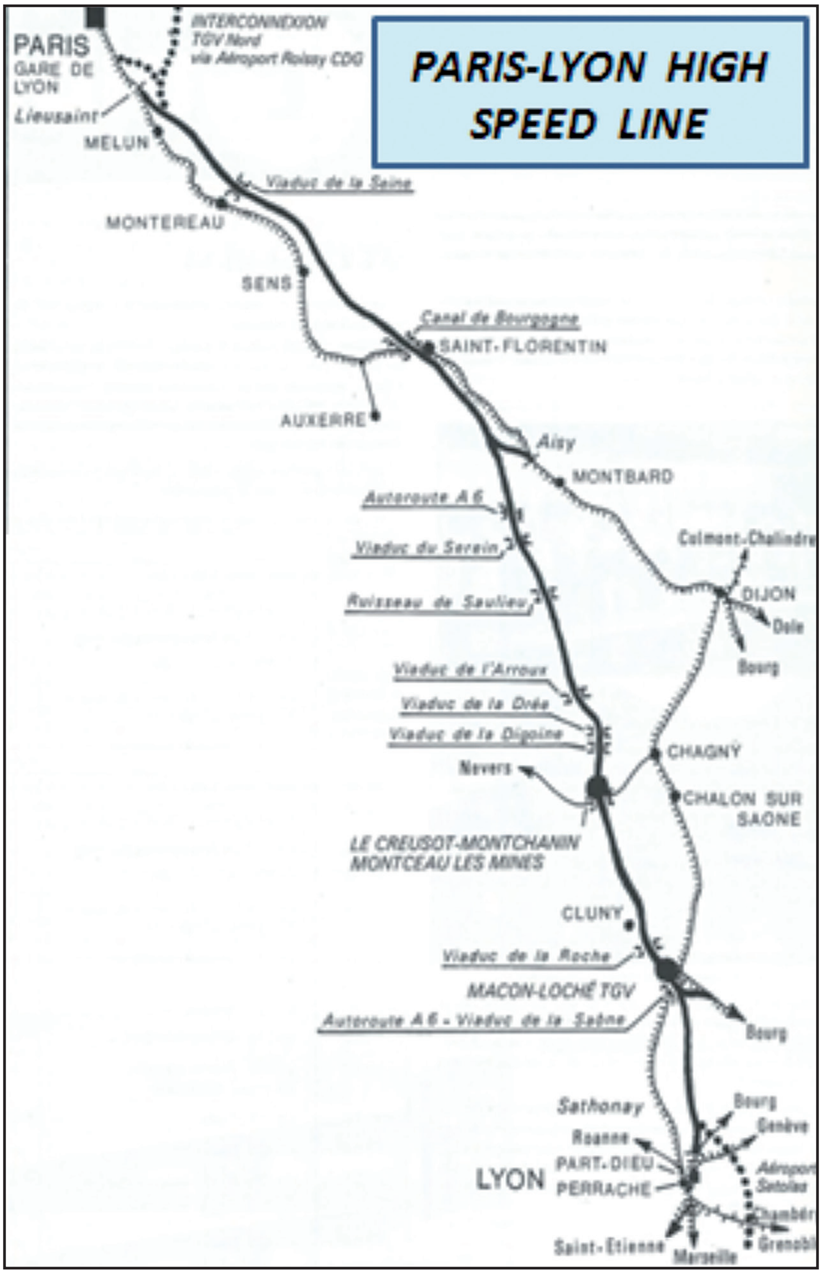



*Source:* P. Gazier (1981)

Note that the first study began in 1966. Fifteen years would pass before the opening of the first stage between St. Florentin an Sathonay (on the outskirts of Lyon). It was such a long time that the french railways had been led in that time by three different presidents and two managing directors.

The line, whose schematic layout is shown in Fig. 2.6, had a length of 419 km and included 2 small intermediate stations: Le Creusot TGV and Macon-TGV. At the latter was begun the conventional line that allowed connections between Paris and Geneva.

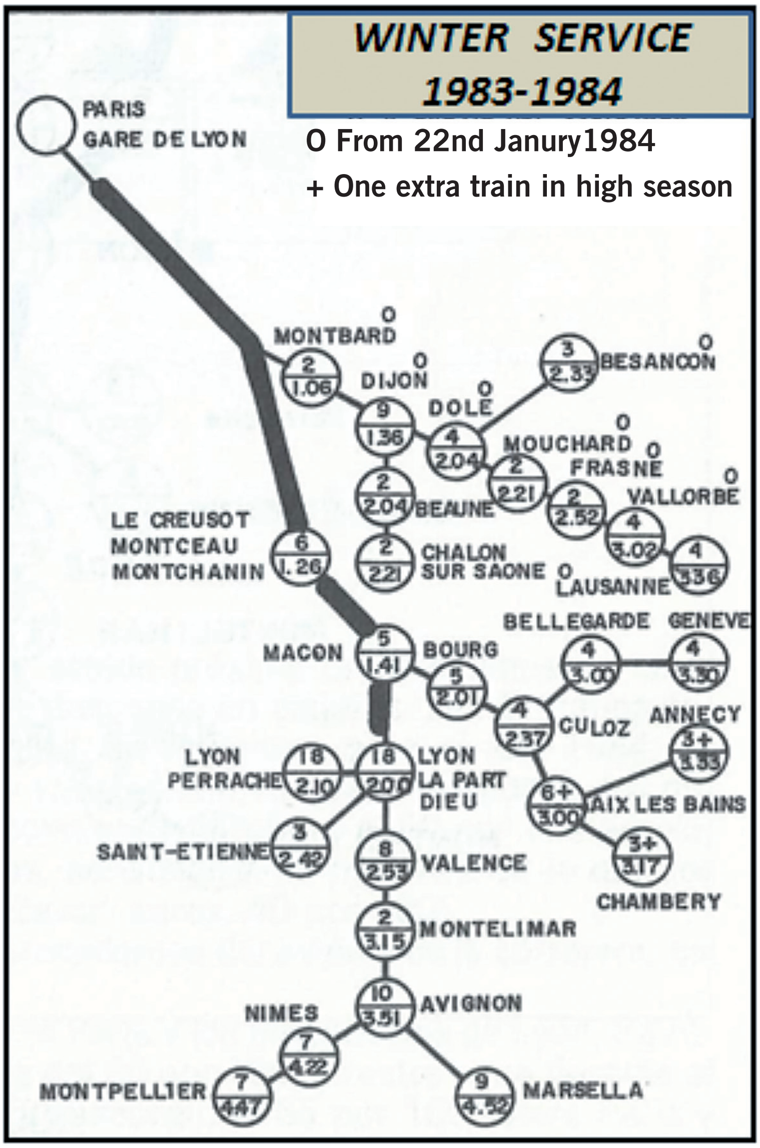
**SCHEMATIC LAYOUT OF THE HIGH SPEED LINE PARIS-LYON (FIG. 2.6)**




## 2.5 THE RANGE OF SERVICES

From September 1983, with the entry into commercial service of the full high-speed line between Paris and Lyon, the travel time between the two cities went from 2h 40m (in 1981) to 2h. The frequency was increased to 18 trains per day in each direction, as shown in Figure 2.7. Note the positive effect on the line on travel times to other towns and cities.

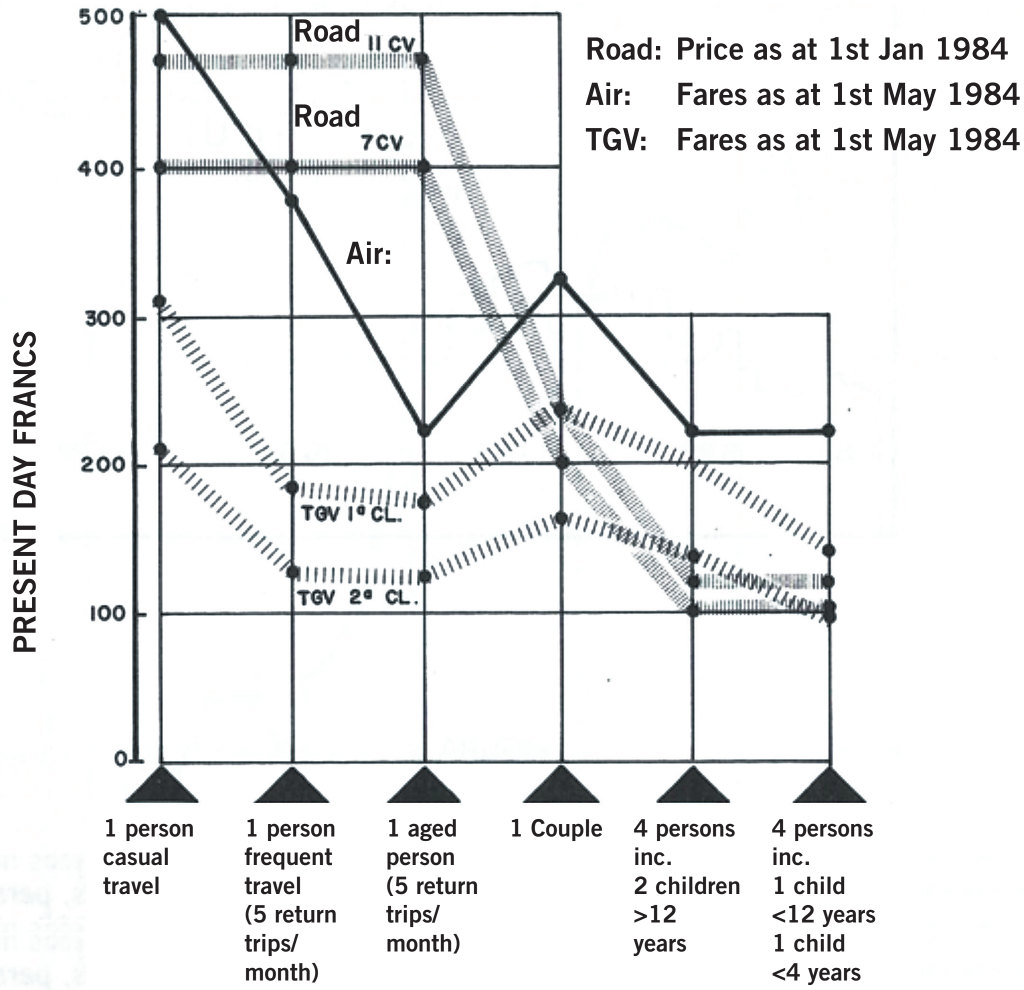
**RANGE OF SERVICES IN THE PARIS-SOUTHEAST AXIS (1983-1984) (FIG. 2.7)**




*Source:* M. Walrave (1987)

Regarding the fare level, Figure 2.8 allows us to appreciate the attractiveness of the rail offering in relation to competing transport modes in the corridor: cars and air travel.

**PARIS-LYON: TRANSPORTATION FARES PER PERSON (FIG. 2.8)**

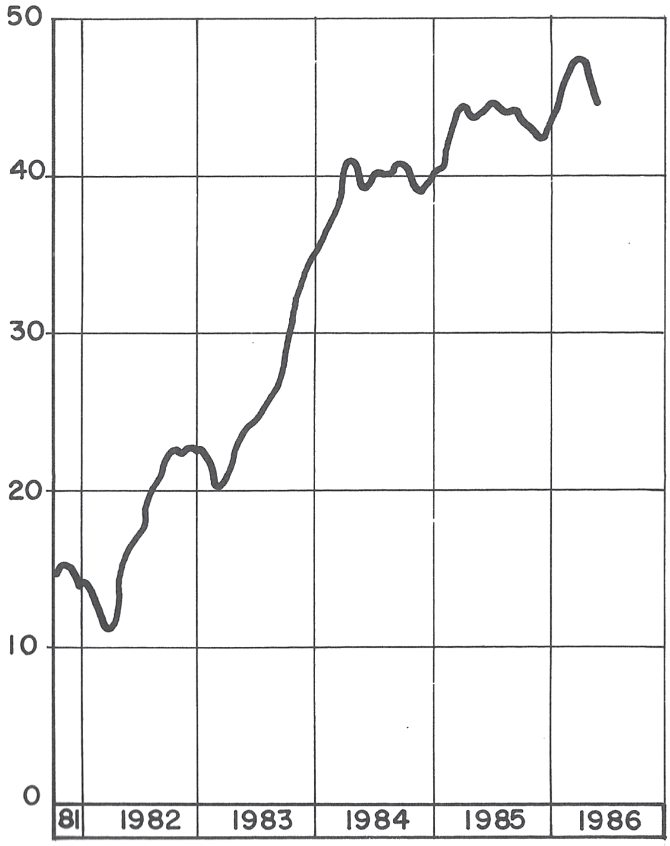



*Source:* C. Berlioz et al (1985)

## 2.6 PASSENGER DEMAND

From the entry into service of the TGV trains, traffic demand kept growing in the early years, as displayed in Figure 2.9. Note how the number of passengers per day, around 15,000 in 1981 and 20,000 in 1983, doubled in just one year, in 1984 rising to more than 40,000 passengers per day.

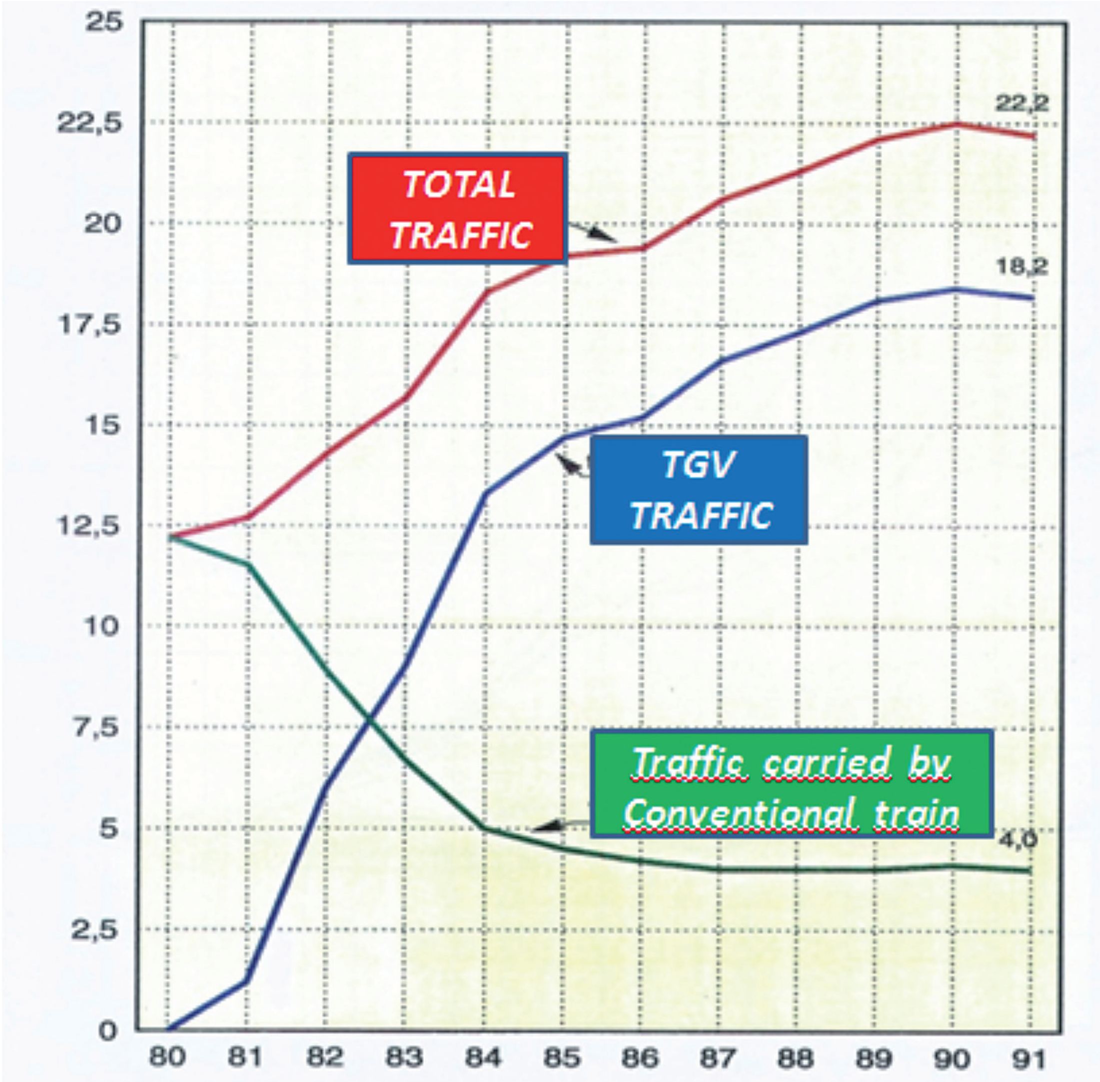
**EVOLUTION OF TGV TRAFFIC (FIG. 2.9)**
**THOUSANDS OF PASSENGERS PER DAY**




*Source:* M. Walrave (1987)

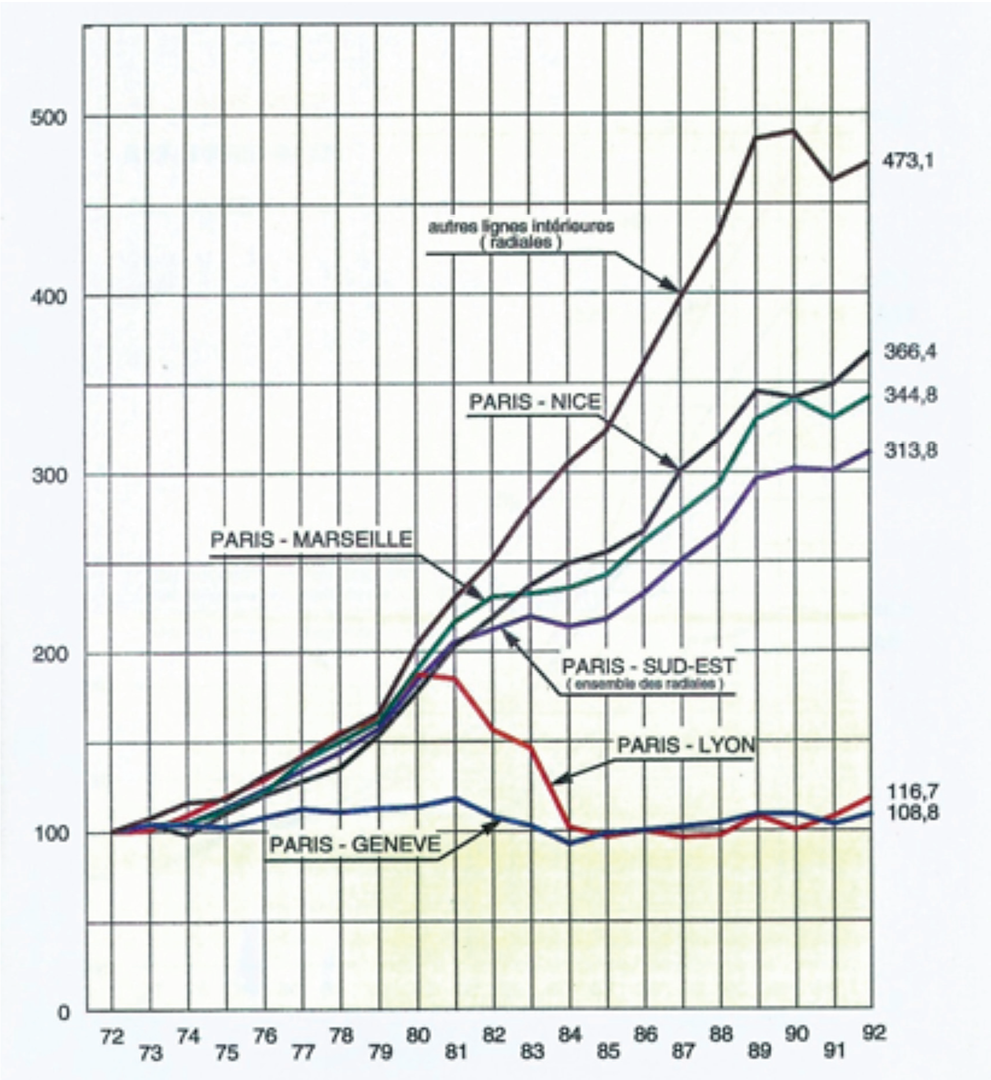
Supplementary information to the foregoing, fig 2.10 Shows annual passenger traffic on the line in the period 1981-1988. The spectacular increase in demand can be seen.

**EVOLUTION OF PASSENGER TRAFFIC ON PARIS SOUTH-EAST ROUTES (IN MILLION OF PASSENGERS PER YEAR) (FIG 2.10)**




Finally, it underlines how air travel, which had been the predominant mode in most routes from Paris, ceased to be so (FIG 2.11). In particular, with Lyon, the market share of railway rose to 90%. With Chambery it was 84%. With it was Montpelier 53% and with Marseilles 51%.

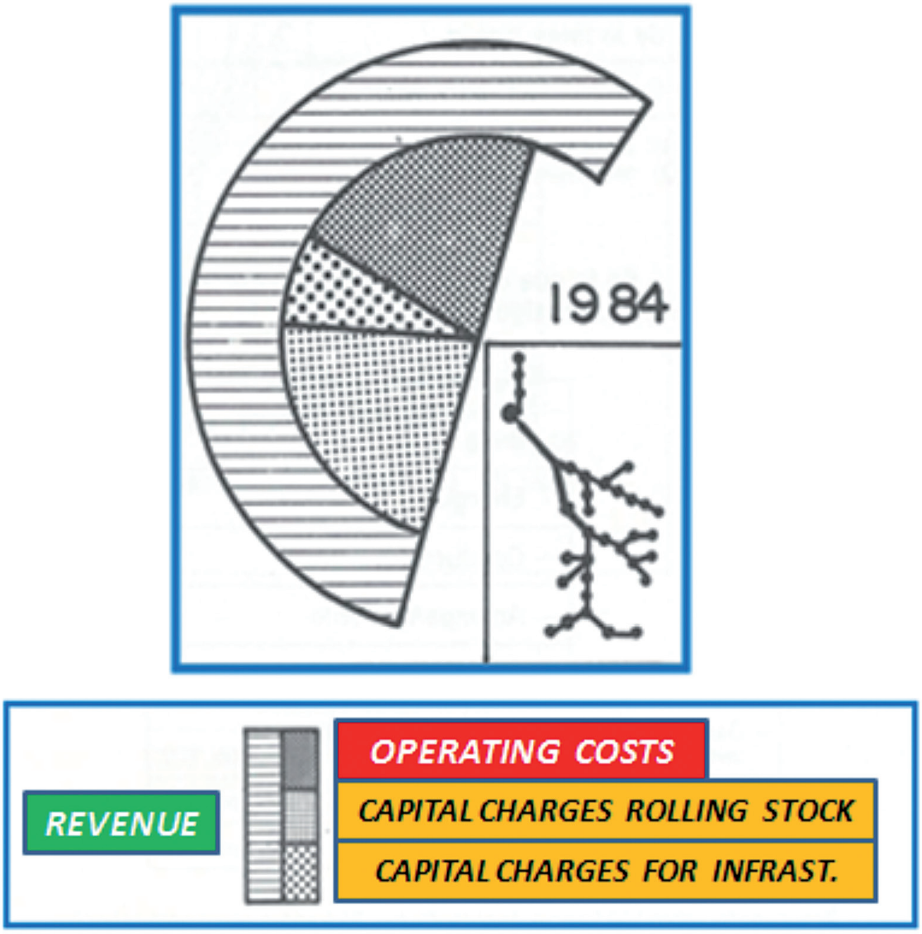
**EVOLUTION OF DOMESTIC AIR TRAFFIC IN THE PARIS-SOUTHEAST AXIS (1972-1992) (FIG 2.11)**




## 2.7 THE CONSTRUCTION OF NEW LINES

The previous section, figure 2.10 And figure 2.11  Showed the commercial success of the new high-speed line between Paris and Lyon however, it is equally important to note the financial success of its operation.(Fig 2.12)

## ECONOMIC RESULTS OF THE OPERATION OF THE TGV-SUDESTE IN 1984 (FIG. 2.12)



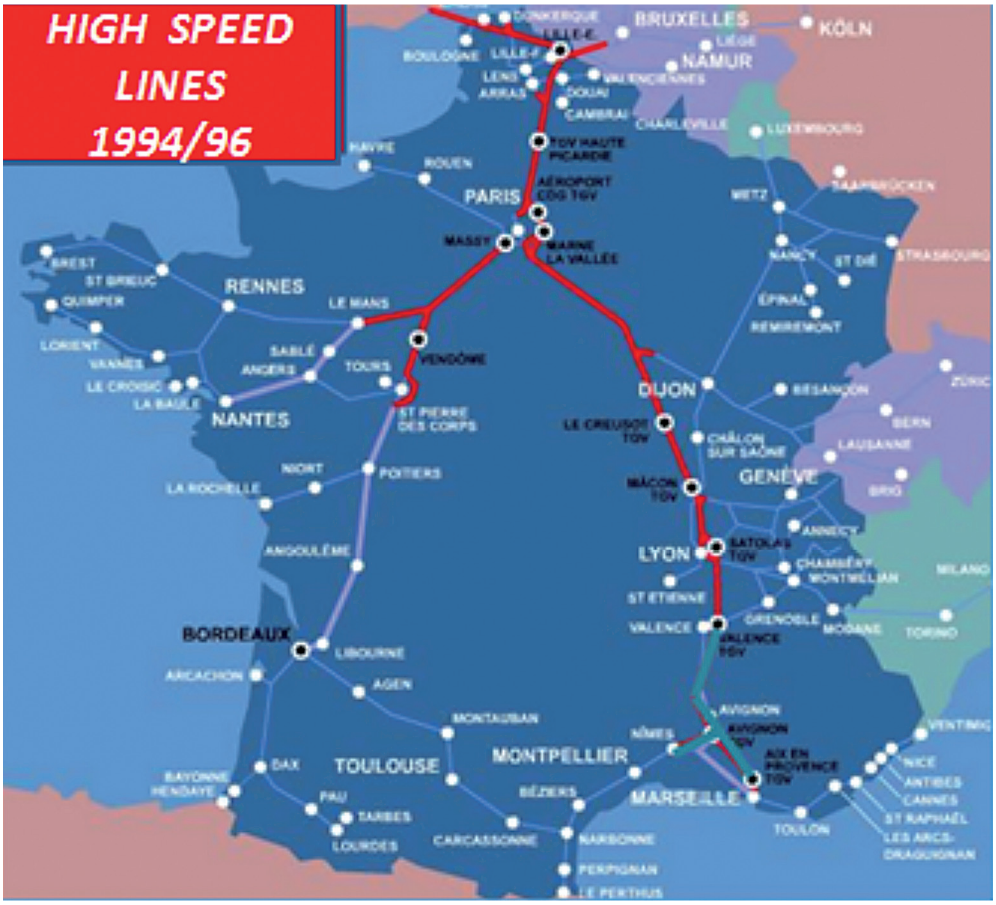

Subsequently, once the Paris-Lyon line entered into service throughout its entire route, M. Leboeuf published in February 1985, in the same journal, the article entitled: «L'evaluation economique et financiere des grands projets d'infrastructure ferroviaire: l'exemple du TGV Sud-Est» ("The Economic and Financial Evaluation of Major Rail Infrastructure Projects: The Example of the TGV Sud-Est").

The article showed how the reality of the commercial operation of the Paris-Lyon line confirmed the predictions that had been made. For this the traffic and economic results from 1984 were taken into account. The rate of return of 15% for the SNCF and 30% for the community was confirmed.

Lastly, it should be noted that the financial simulation performed at that time emphasised that the investments made in the line would be recouped in just 8 or 10 years.

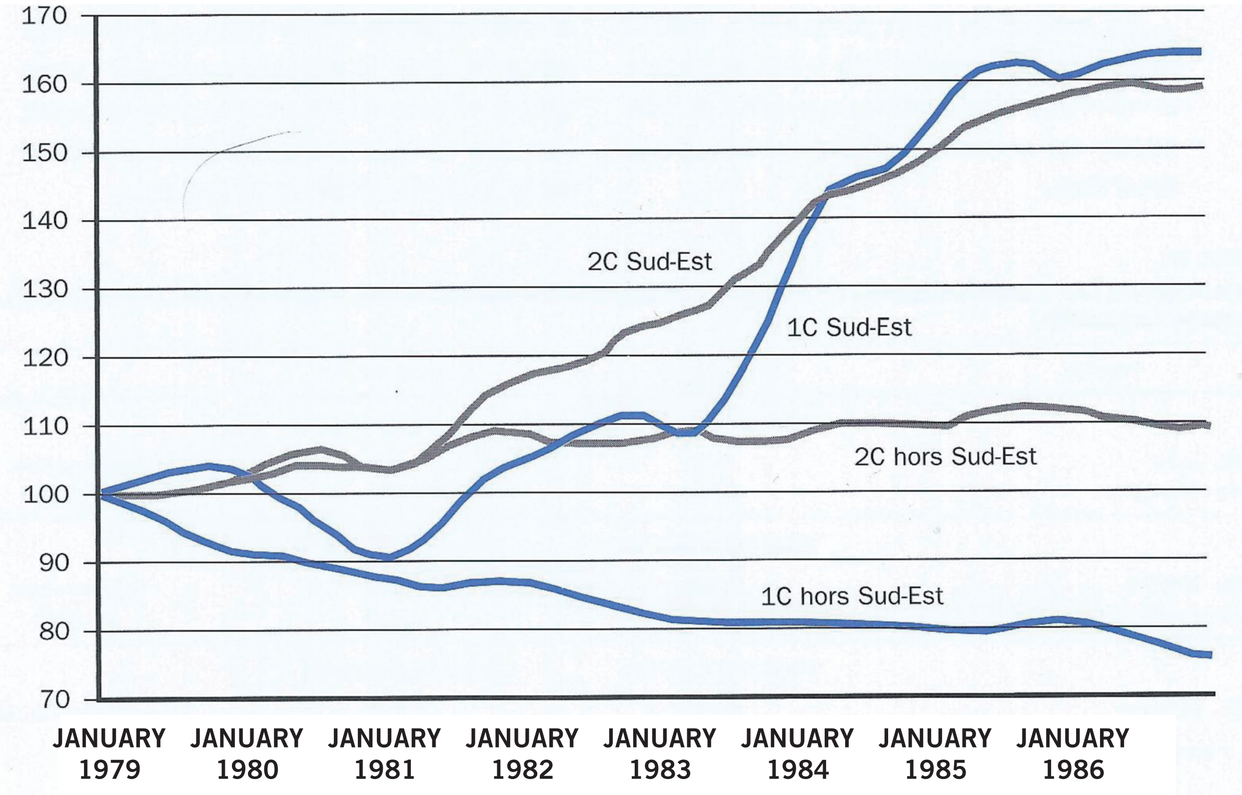
It is not surprising, therefore, that in the following years new high-speed lines were built: TGV Atlantique, TGV-Nord, TGV-Interconnexion Lyon (Figure 2.13) providing, about 10 years after the opening of the Paris-Lyon line, a total of almost 1300 km of high speed lines.

**HIGH SPEED LINES IN 1994/1996 (FIG. 2.13)**




The decision to build new high-speed lines in France is best understood if the graph in Figure 2.14 is observed. There it can be seen, in spite of the high commercial speeds achieved in France in 1980 that the growth in passenger traffic had stalled. The only traffic that had increased was that which used the Paris-Lyon high speed line.

**EVOLUTION OF PASSENGER TRAFFIC BY CONVENTIONAL AND HIGH SPEED LINES (FIG. 2.14)**

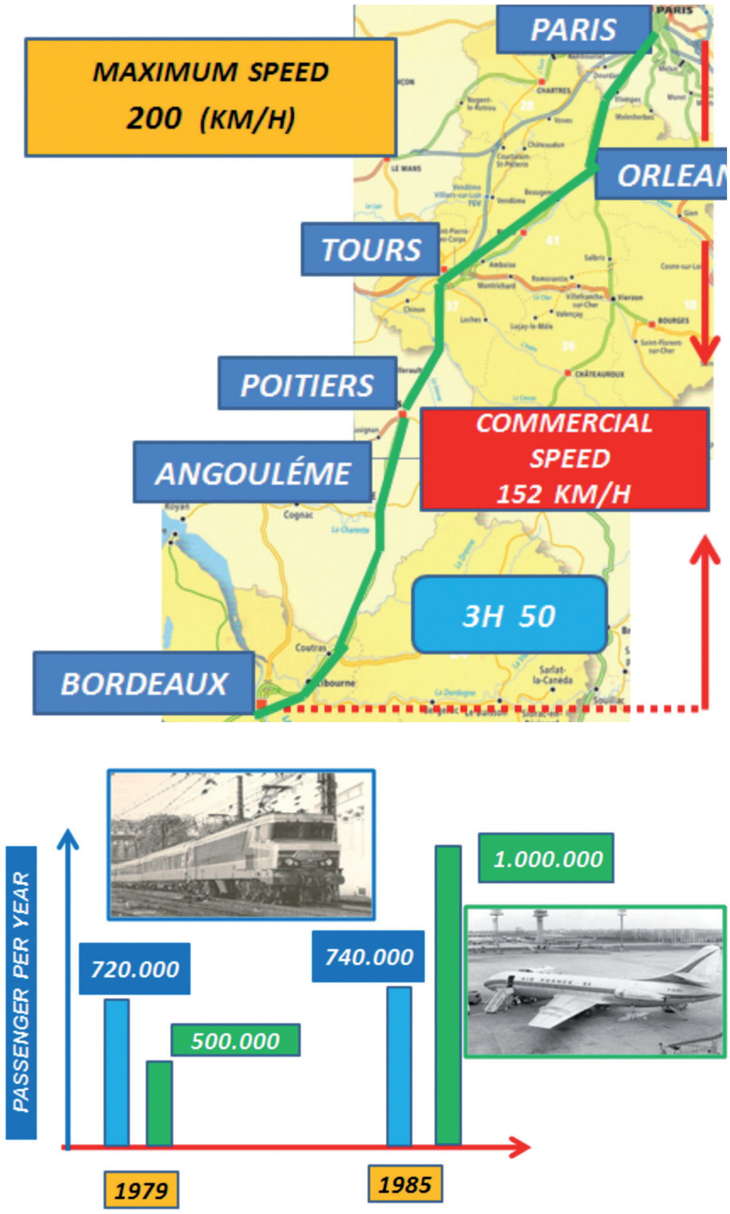



*Source:* SNCF

In this context, stagnation of railway passenger traffic, perhaps the most representative route was the existing one between Paris and Bordeaux.

In effect, note (figure 2.15) that at the end of the 1970s, rail offered a travel time between both cities of 3h 50, equivalent to a commercial speed of 152 km/h. Despite this level of service, during the 1979-1985 period, railway passenger traffic remained practically stagnant, whereas air passenger traffic doubled.

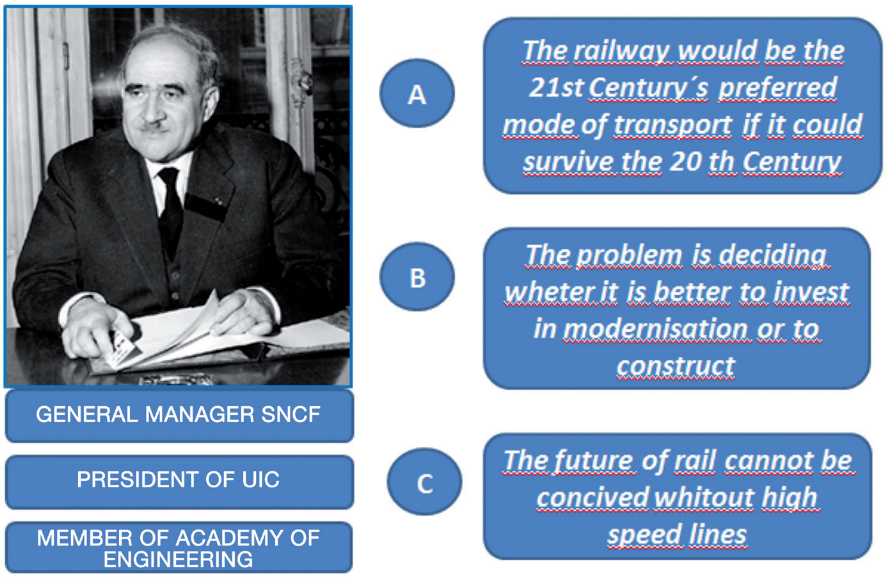
## COMMERCIAL SERVICES AND EVOLUTION OF RAILWAY PASSENGER DEMAND FOR THE PARIS-BORDEAUX ROUTE (1979-1985) (FIG. 2.15)




*Fuente:* Elaboración propia. Datos SNCF

In this context, it is necessary to make reference to the prophetic words of Louis Armand during the mid-1960s (figure 2.16). The most universally *recognised* quote predicted that rail would be the 21st century's preferred mode of transport, if it could survive the 20th century. Nevertheless, for our purposes, the following two phrases take on even greater significance: “the problem is deciding whether it is better to invest in *modernisation* or to construct” and “the future of rail cannot be conceived without high-speed lines”.

## ESSENTIAL REFERENCES BY LOUIS ARMAND 1967 (FIG. 2.16)




*Fuente:* Elaboración propia.

Since 1996, they have continued to build new high-speed lines to the point where now there are 2036 km, with the geographic distribution shown in Figure 2.17. More than 135 million passengers are transported on these lines each year.

## HIGH SPEED NETWORK IN FRANCE 2013 (FIG 2.17)

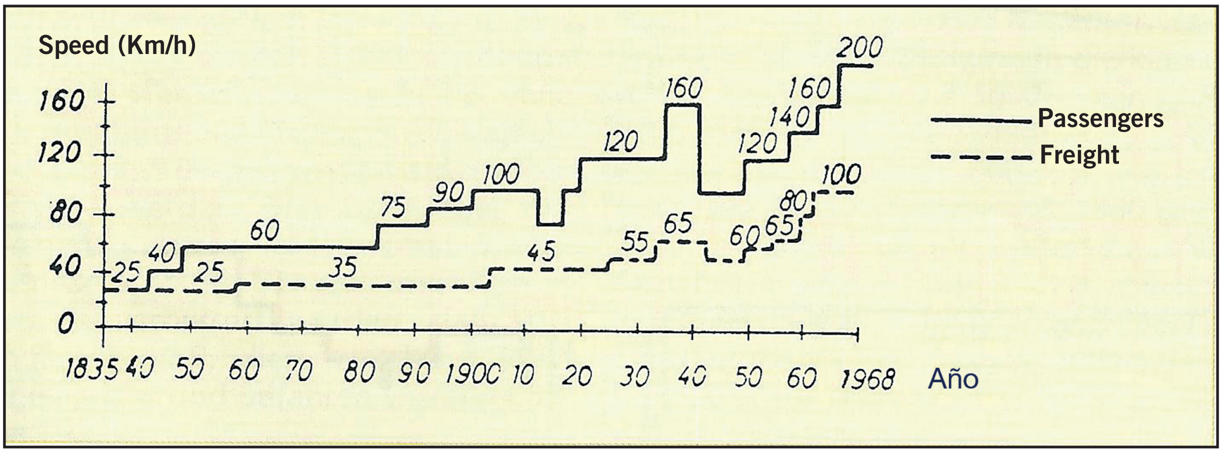
# CHAPTER 3.

# THE FIRST HIGH-SPEED LINES IN GERMANY

## 3.1 CONVENTIONAL RAIL AND TRAVEL TIMES

As in other European countries at the end of the Second World War, the German railways, the DB to be precise, undertook significant work to upgrade the existing network, as displayed in Figure 3.1. Here the evolution of the maximum speeds of passenger and freight trains in the period 1835-1968 is shown.

**EVOLUTION OF MAXIMUM SPEED OF GERMAN TRAINS (1835-1968) (FIG. 3.1)**



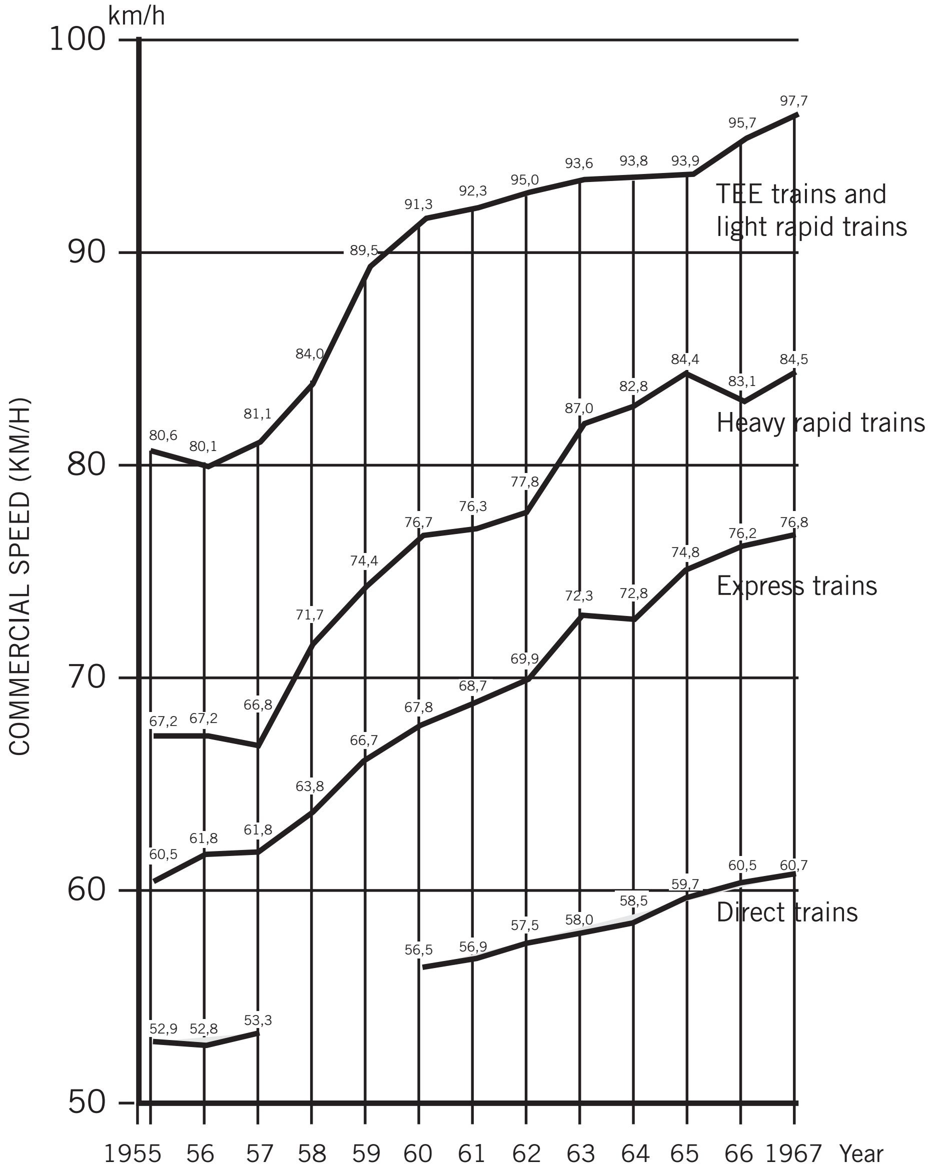

*Source:* Taken from E. H. H. Weigelt (1999)

Note how as a result of those works the speed of freight trains could be raised from 60 to 100 km/h. Moreover, the speed of the fastest passenger trains went from 120 to 160 km/h, and in some places, even up to 200 km/h.

Figure 3.1 displays how, between 1933 and 1939, using steam locomotives, maximum service speed was 160 km/h. This enabled, as a reference, a commercial speed of 132.6 km/h between Hannover and Hamm (Kockelkorn, 1968).

In terms of commercial speeds, figure 3.2 displays the evolution of their magnitude for: TEE trains and light rapid transit; heavy rapid trains; express trains and direct trains. In the first area, TEE trains, commercial speed increased from 80.6 km/h in 1955 to 96.7 km/h in 1967.

**EVOLUTION OF COMMERCIAL SPEEDS FOR GERMAN TRAINS (1955-1967) (FIG. 3.2).**

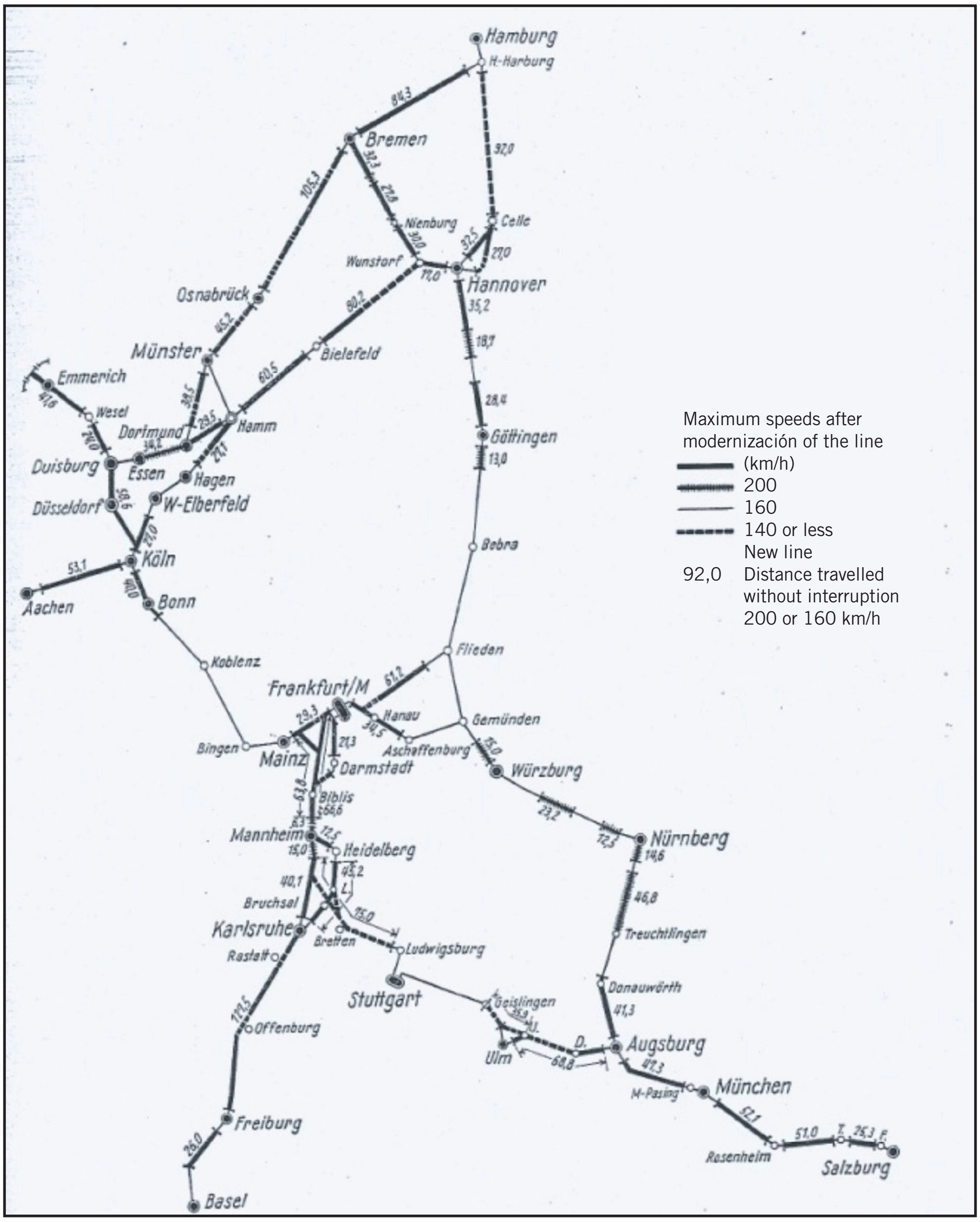



*Source:* E. H. Kockelkorn (1968)

It is notable that while TEE trains had an average distance between stops of 73 km, direct trains stopped every 12 km. The TEE train Blauer Enzian was authorised, from may 1967, to travel at a maximum speed of 180 km/h on the section between Munich and Augsbourg (47 km). It was temporarily authorised to travel at 200 km/h on this section during the International Exhibition of Transport in Munich (1965).

In this context, it should be pointed out that during the period 1962-1964, the DB set up a team of experts, under the direction of engineer A. Baumann, which analysed the feasibility of authorising maximum speeds of 200 km/h for specified routes. The proposed routes are displayed in figure 3.3.

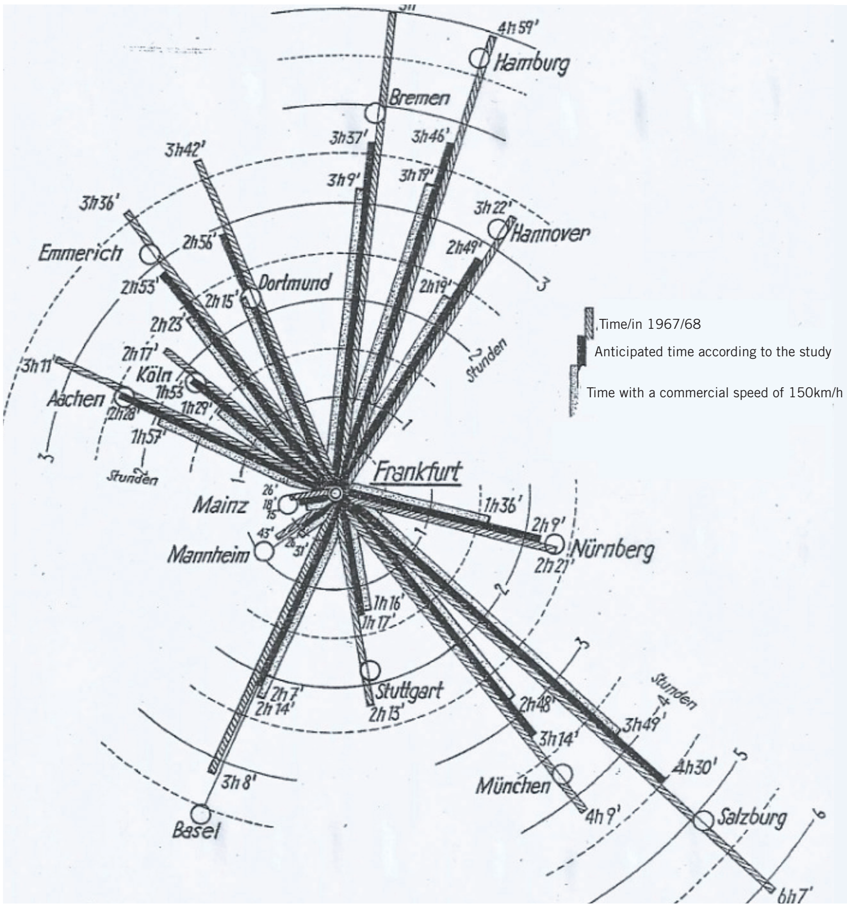
**GERMAN RAILWAY LINES PROPOSED FOR TRAVEL AT HIGHER SPEEDS (1965) (FIG. 3.3).**




*Source:* E. H. Kockelkorn (1968)

Practical implementation of the results of said study (1964) would enable a noticeable reduction of travel times (from Frankfurt as a reference).Figure 3.4 displays a comparison of effective travel times in 1967/68 as well as the speeds that would be achieved under said proposal. In parallel, it describes travel times that would be achieved assuming a commercial speed of 150 km/h, for all routes. Possible maximum speed on conventional routes.

**ANTICIPATED RAILWAY TRAVEL TIMES IN ACCORDANCE WITH THE BAUMANN STUDY (FIG. 3.4)**




*Source:* E. H. Kockelkorn (1968)

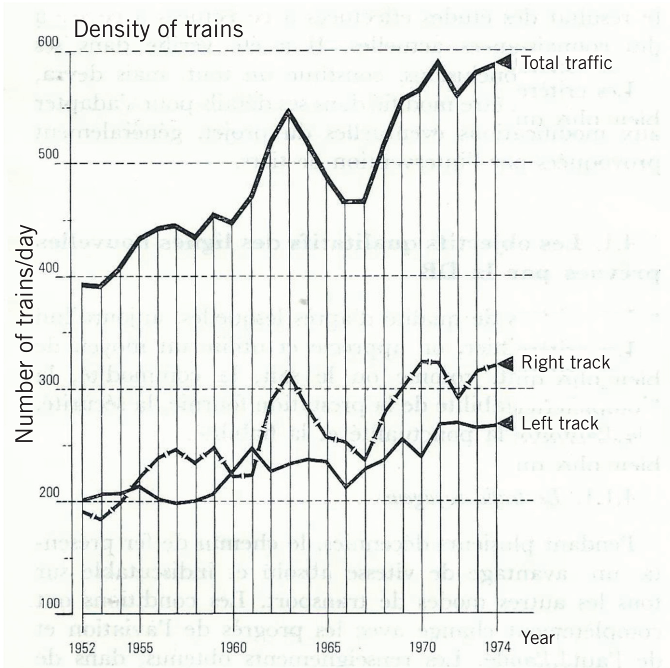
## 3.2 THE EXISTING PROBLEMS

However, the corridors joining Cologne with Frankfurt, Stuttgart and Munich, on the one hand, and Hannover with Würzburg on the other, had problems of lack of capacity.

With regard to the first corridor, Figure 3.5 shows the evolution, for the period 1952 to 1974, of the average number of trains per day on each of the two lines that made up the corridor. Remember that the Cologne-Frankfurt section had two double tracks on either side of the Rhine. (Figure 3.5 b)

## EVOLUTION OF NUMBER OF TRAINS IN COLOGNE-FRANKFURT CORRIDOR (1952-1974) (FIG. 3.5)

a) Density of trains




*Source:* E. Sitzamann (1975)

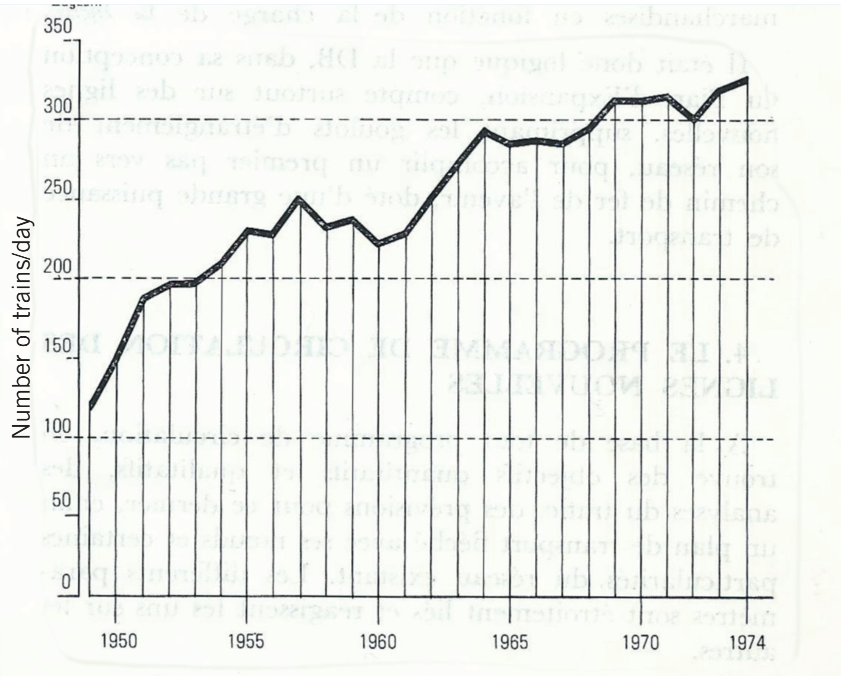
b) Provision of track between Cologne and Frankfurt


*Source:* DB

It can be seen how these lines went from 395 trains per day in 1952 to 589 trains per day in 1974. That is an increase of 49%. The German author noted that despite all the technical improvements introduced, it was impossible to increase their capacity. In commercial terms, the route between Cologne and Frankfurt (219 km) was covered in 2h 15m, which amounted to a commercial speed of only 97 km/h.

As for the north-south axis, in the section between Fulda and Flieden, the number of trains per day went from just under 150 in 1950 to over 300 in 1974 (Figure 3.6).

**EVOLUTION OF NUMBER OF TRAINS IN FULDA-FLIEDEN SECTION (1950-1974) (FIG. 3.6)**

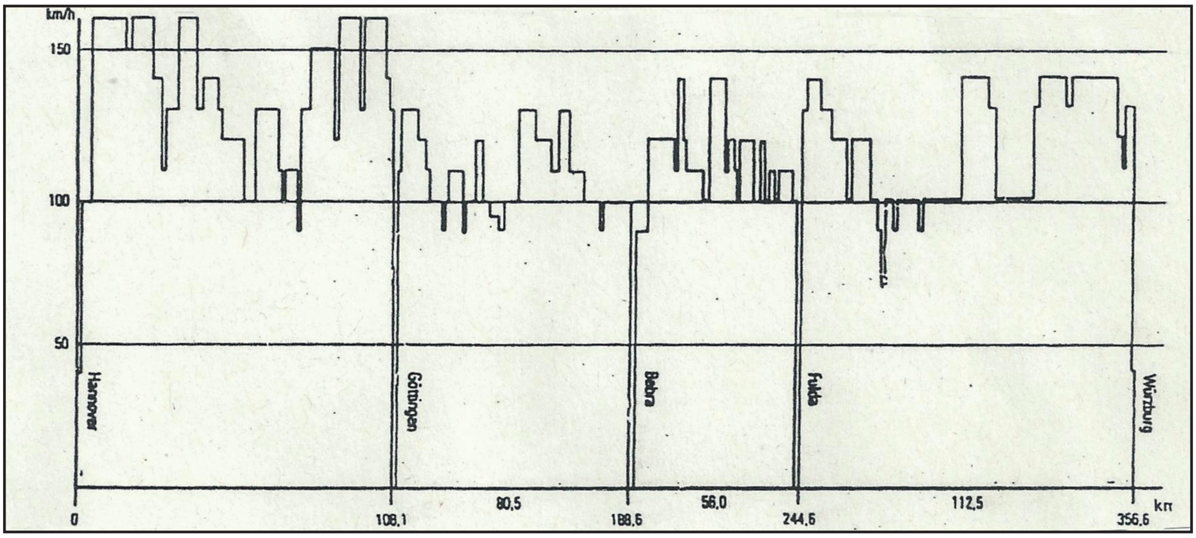


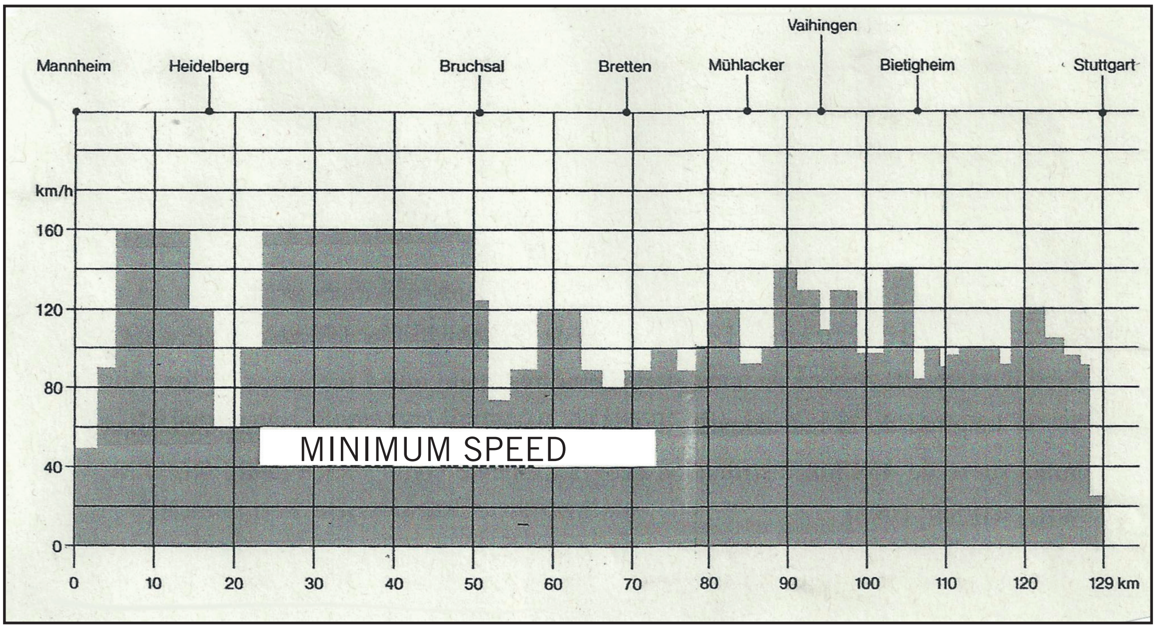

*Source:* E. Sitzanamm (1975)

This increase in traffic caused a significant increase in the delays experienced by passenger and freight trains. This latter type of train was affected by delays in over 40% of its total number of trips.

In a manner analogous to that proposed for the Cologne-Frankfurt line, travel times on the Hannover-Würzburg and Mannheim-Stuttgart routes were affected negatively by the diagrams of maximum speeds allowed on both lines (Figure 3.7).

## MAXIMUM SPEED BY ROUTEIN THE HANNOVER-WÜRZBURG AND MANNHEIM-STUTTGART LINES (FIG. 3.7)




*Source:* J. M. Willigens (1985)

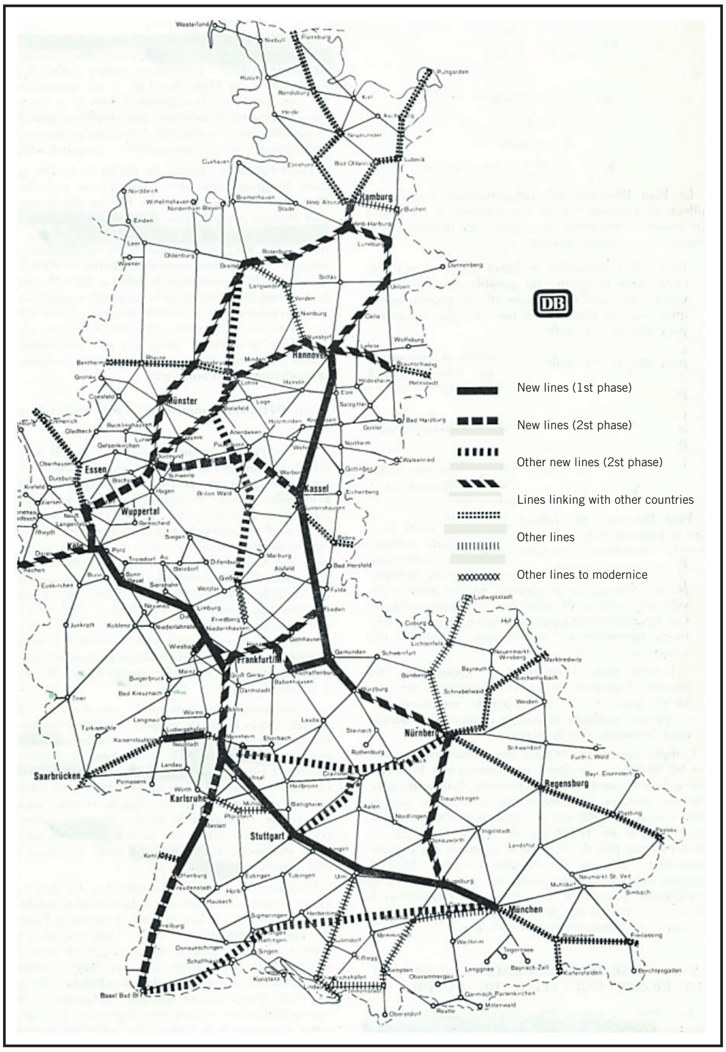
Note, in both diagrams that together with sections authorised for 160 km/h, there are others in which the maximum speed was reduced to 60/70 km/h.

## 3.3 THE DECISION TAKEN

From the issues presented in the previous section, it was clear that the only possible alternative would be the construction of new railway lines on those routes.

It was no surprise, therefore, that in 1970 the German railways submitted to the Minister of Transport the document entitled: “Modernisation Programmes for the DB Network”. This document made reference not only to the refurbishment of the conventional routes, but also the construction of new infrastructure in the sections analysed in the previous section: Hannover-Würzburg; Mannheim-Stuttgart and Cologne-Frankfurt. (Figure 3.8)

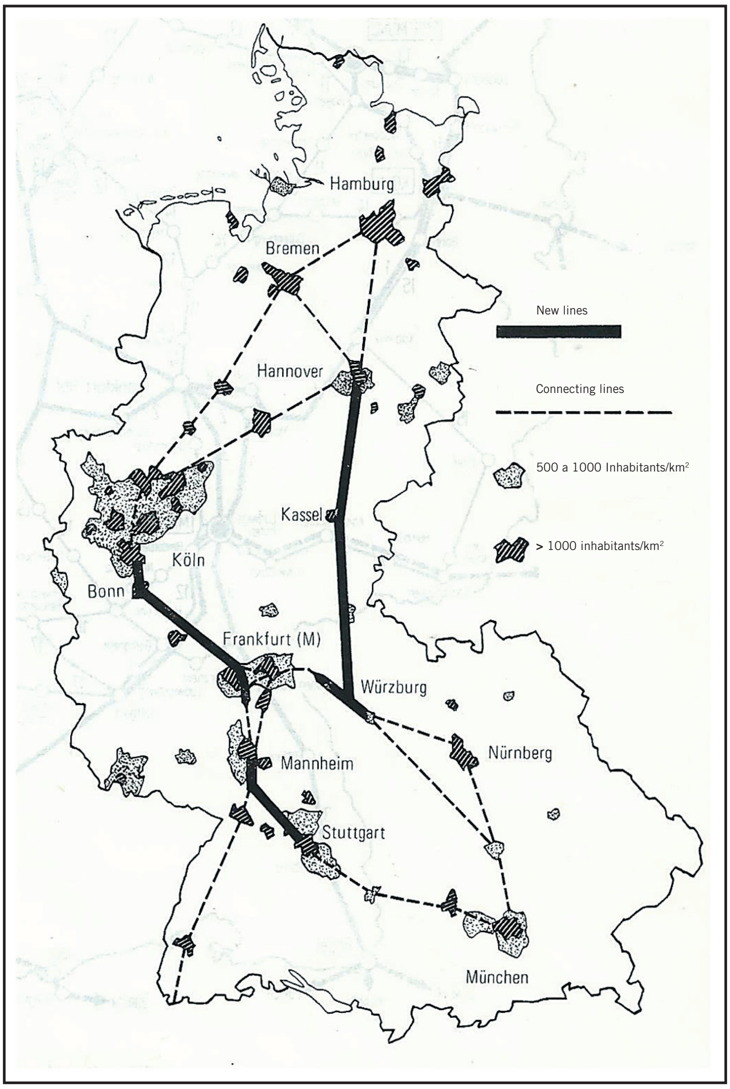
**MODERNISATION PLAN OF DB (1970) (FIG. 3.8)**




*Source:* H. Zeuge (1975)

It is interesting to note in Figure 3.7 the correlation between the new lines that need to be built in the first phase, and the density of the existing population throughout Germany. Areas with densities of 500 to 1,000 inhabitants per km2 and areas with higher values are displayed in Figure 3.9.

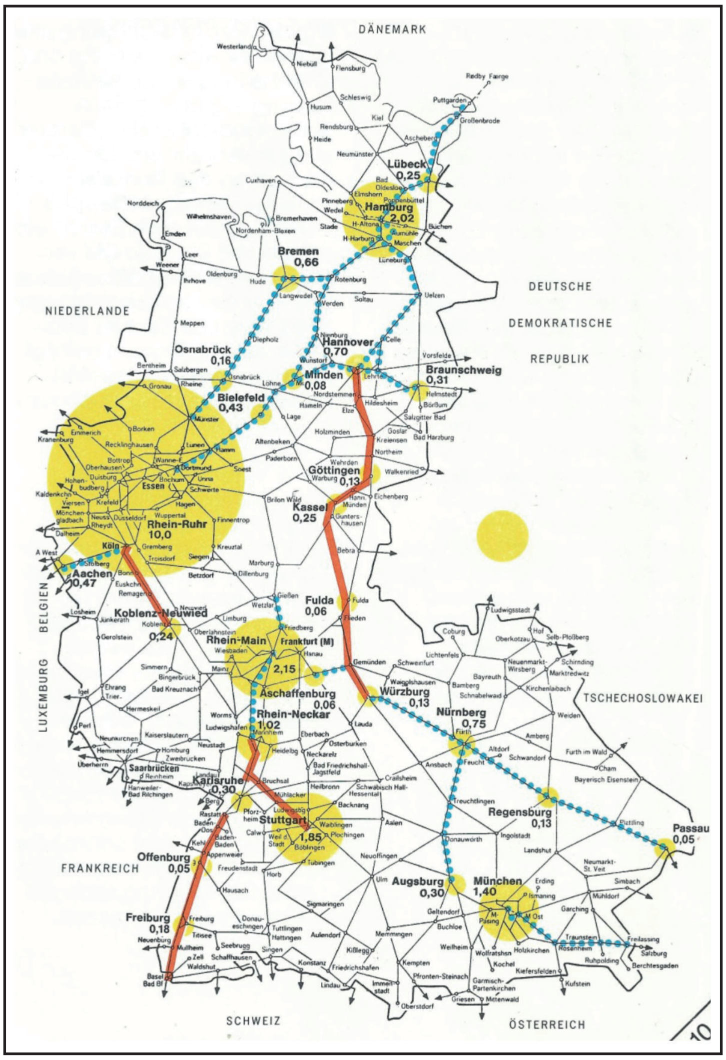
**NEW LINES AND POPULATION DENSITY (FIG. 3.9)**




*Source:* E. Sitzmann (1975)

One of the most innovative aspects of the construction of new lines in Germany was undoubtedly the system adopted for the operation of each line. The rationale of having two operating criteria can be seen in Figure 3.10. This shows the geographical distribution of the population.

## MAIN POPULATION CENTRES IN GERMANY (1980) (FIG. 3.10)

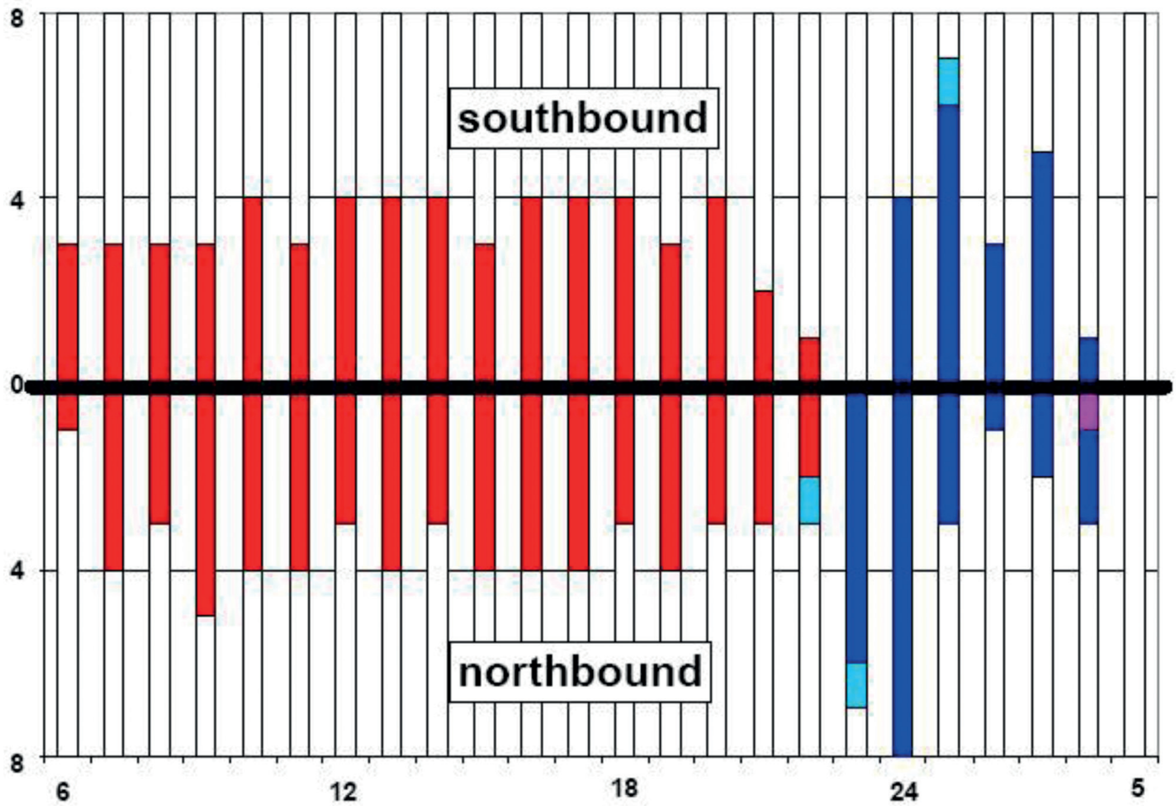



*Source:* DB

Looking at the cities at the ends of the Hannover-Würzburg and Stuttgart-Mannheim lines, it appears that they did not have sufficient population size to justify an operation based on the exclusive use of high speed passenger trains.

Therefore, the German Ministry of Transport, together with the DB, considered it reasonable that in the first stage, maximum speeds of 200/250 km/h for passenger trains and 120 km/h for freight trains should be adopted. To make the operation more viable, the preference was for passenger trains to travel during the day and freight trains by night. (Figure 3.11)

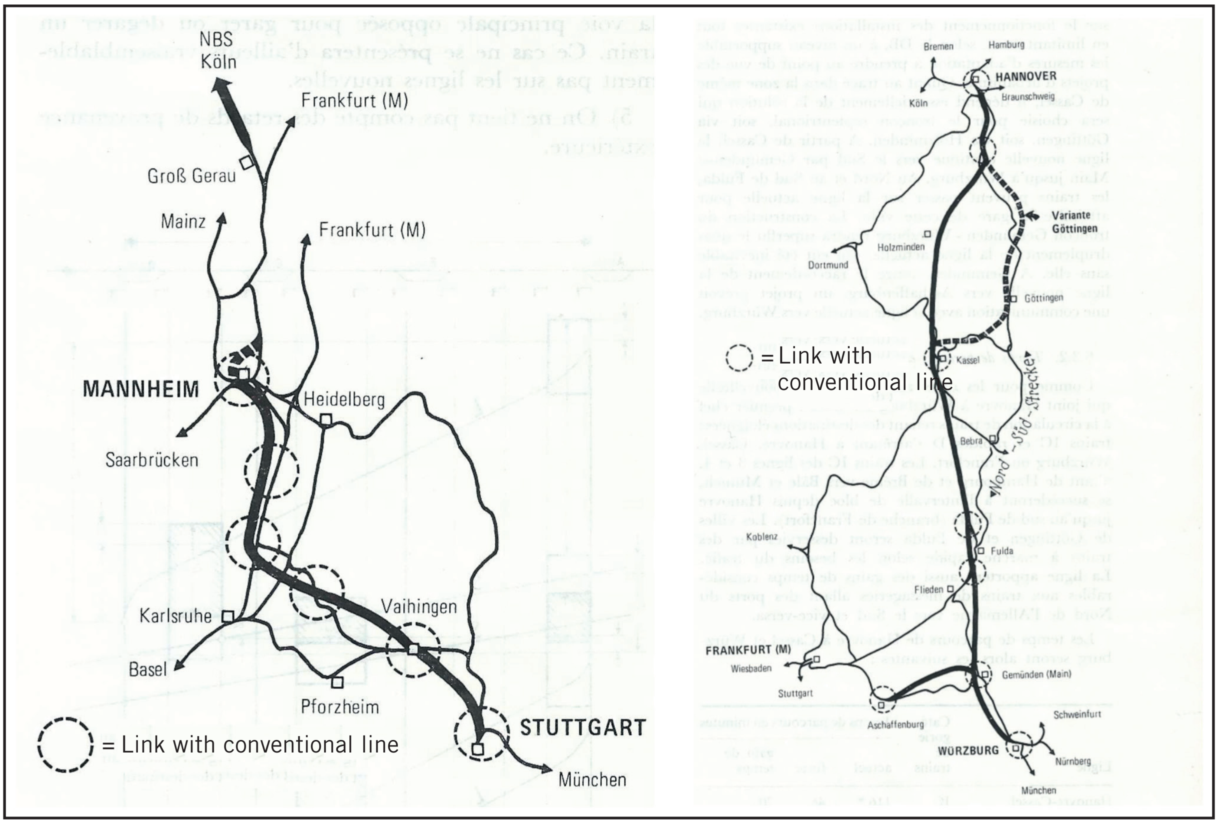
**SEGREGATION OF PASSENGER TRAINS (ICE AND IC) AND FREIGHT TRAINS DURING DAY AND NIGHTTIME (FIG. 3.11)**




*Source:* E. Jansch

Based on this criterion, the new lines were connected to the existing ones in the same corridor at a certain number of points. This made the operating system much more flexible. Figure 3.12a shows these routes in the case of the Mannheim-Stuttgart line, and Figure 3.12b shows those corresponding to the new Hannover-Würzburg line.

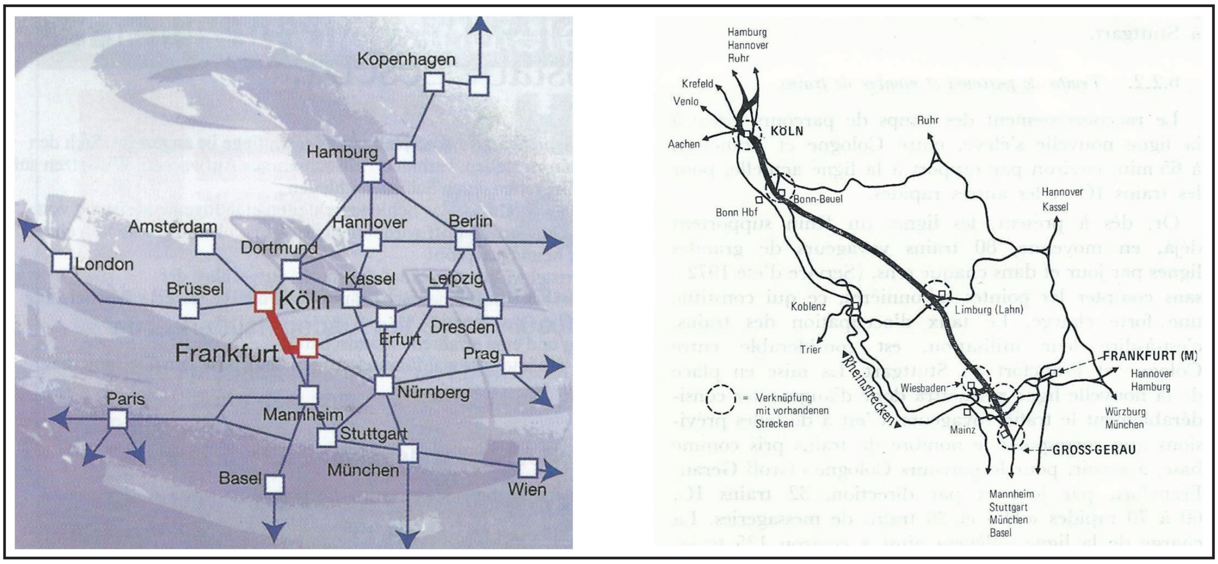
**ROUTE LAYOUTS OF THE MANNHEIM-STUTTGART AND HANNOVER-WÜRZBURG HIGH SPEED LINES (FIG. 3.12)**




*Source:* Taken from E. Sitzmann (1975)

By contrast, the Cologne-Frankfurt line, given its strategic geographical position in central Europe (Figure 3.13) would be affected by a high level of passenger demand, so it would be reserved exclusively for high speed trains travelling at 300 km/h. It is worth noting that the first estimates of traffic placed the passenger demand on this line above 20 million/year

## GEOGRAPHIC LOCATION OF THE COLOGNE-FRANKFURT LINE (FIG. 3.13)




*Source:* G. Brux (2002) and E. Sitzmann (1975)

## 3.4 QUALITY OF SUPPLY AND RESPONSE TO DEMAND

In June 1991 high speed services with the ICE began in Germany through the new Hannover-Würzburg and Mannheim-Stuttgart lines, using the existing lines in the other sections of the main routes. For more significant rail connections, Table 3.1 shows the commercial offering given by the ICE and that existing previously.

### EVOLUTION OF COMMERCIAL OFFERING WITH ICE SERVICES ON SOME COMMERCIAL GERMAN ROUTES (1991) (TABLE 3.1)

| Route | Travel time | | Time saving from 1990 to 1991 | Percentage reduction in time |
|---|---|---|---|---|
| | 1990 IC 200 km/h | 1991 IC 250 km/h | | |
| Hamburg-Stuttgart | 6h 55m | 5h 01m | 1h 54m | 28% |
| Hannover-Stuttgart | 5h 37m | 3h 48m | 1h 49m | 32 % |
| Frankfurt-Stuttgart | 2h 11m | 1h 22m | 49m | 38 % |
| Hamburg-Frankfurt | 4h 37m | 3h 35m | 1h 02m | 22 % |
| Hannover-Frankfurt | 3h 19m | 2h 22m | 57m | 29 % |

Source: Adapted from HEINISCH (1992)

With regard to the modification of the modal distribution, it should be noted that the railway gained (Table 3.2) between 7 and 11 points considering all modes of transport.

**INFLUENCE OF ICE SERVICES IN THE MODAL DISTRIBUTION OF PASSENGER TRAFFIC (TABLE 3.2)**

| Route (km) | Service | Modal distribution | | |
|---|---|---|---|---|
| | | Rail | Air | Road |
| Hamburg-Frankfurt (517) | Without ICE (1990) | 28 | 34 | 38 |
| | With ICE (1991) | 39 | 27 | 34 |
| Hannover-Stuttgart (524) | Without ICE (1990) | 31 | 18 | 51 |
| | With ICE (1991) | 42 | 12 | 46 |
| Frankfurt-Munich (420) | Without ICE (1990) | 30 | 27 | 43 |
| | With ICE (1991) | 37 | 23 | 40 |

Source: E. Jänsch (1993)

If the situation of the railway compared to the aeroplane is analysed, the data in Table 3.3 allow us to state that in the period 1990/1991 to 1993, the former mode experienced an average growth of around 50%, while air travel lost, on average, 20% of the traffic it had at the beginning of the 1990s.

## EVOLUTION OF RAIL-AIR TRAFFIC ON SOME GERMAN ROUTES IN THE PERIOD 1990-1993 (TABLE 3.3)

| Route | Mode | Number of passengers | | | | Variation |
|---|---|---|---|---|---|---|
| | | 1990 | 1991 | 1992 | 1993 | 1993/1990 |
| Hamburg-Frankfurt | Air | 423,031 | 380,259 | 369,382 | 378,918 | 0.89 |
| | Rail | ---- | 211,000 | 264,000 | 299,000 | 1.42 |
| | Total | --- | 591,259 | 633,382 | 677,918 | - |
| Frankfurt-Munich | Air | 389,734 | 389,006 | 338,989 | 301,547 | 0.77 |
| | Rail | --- | 224,000 | 324,000 | 340,000 | 1.52 |
| | Total | | 598,006 | 662,989 | 641,547 | - |
| Hannover-Frankfurt | Air | 87,323 | 72,932 | 65,679 | 66,847 | 0.76 |
| | Rail | --- | 123,000 | 148,000 | 191,000 | 1.55 |
| | Total | | 195,932 | 213,679 | 257,847 | - |

Source: Adapted from HURSTEL (1995)

If 1991 is taken as the base year, the market share of rail and air travel up to 1993 evolved as follows (Table 3.4). It can be seen that in just two years, the railway gained 8, 11 and 15 points of market share from air travel on the routes being considered.

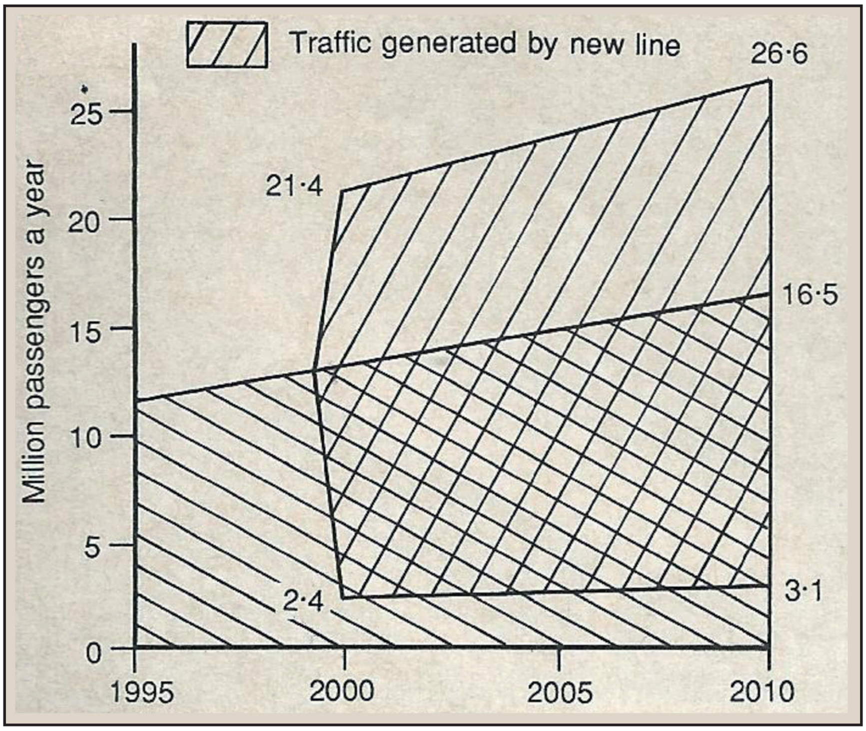
## RAIL-AIR MODAL DISTRIBUTION IN GERMANY IN THE PERIOD 1991-1993 (TABLE 3.4)

| Route | Mode | 1991 | 1992 | 1993 |
|---|---|---|---|---|
| Hamburg-Frankfurt | Air | 64 | 58 | 56 |
| | Rail | 36 | 42 | 44 |
| Frankfurt-Munich | Air | 62 | 51 | 47 |
| | Rail | 38 | 49 | 53 |
| Hannover-Frankfurt | Air | 37 | 30 | 26 |
| | Rail | 63 | 70 | 74 |

*Source:* E. Jänsch (1993)

For various reasons, the new high speed line between Cologne and Frankfurt did not begin construction until December 1995. It entered into commercial service in 2002. At that point in time the forecast for passengers expected for the horizon of 2010 was over 26 million. (Figure 3.14)

## RAIL PASSENGER TRAFFIC IN THE COLOGNE-RHINE MAIN CORRIDOR (FIG. 3.14)



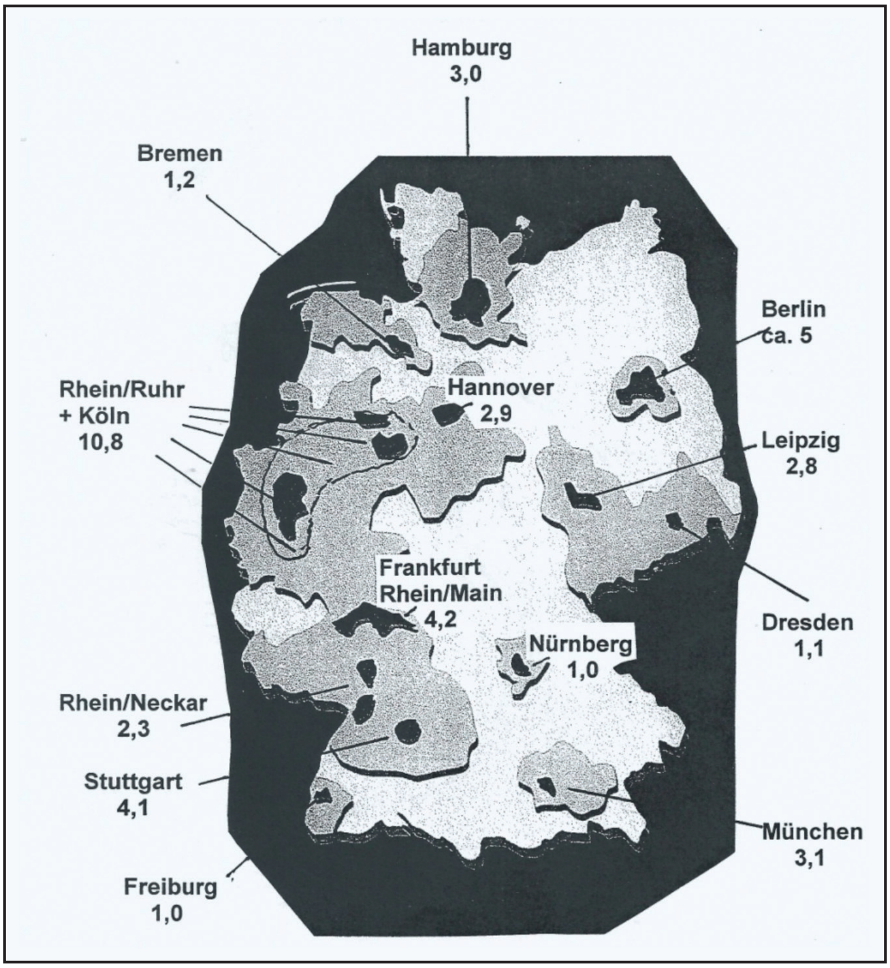

*Source:* E. Jänsch (1993)

The travel time between the two cities was reduced to 1 hour, travelling at a top speed of 300 km/h. In relation to the experience of the German railways with travelling at high speed, it is enough to recall that in 1988, the ICE train running on the Fulda-Würzburg high-speed line reached a speed of 407 km/h.

## 3.5 CONSTRUCTION OF NEW HIGH-SPEED LINES

The reunification of Germany in 1990 meant strong support for the modernisation of the railway previously set up by the GDR. In this context, Berlin became a priority centre of focus and, as a consequence, so too did the rail lines making connections to this city. In particular, this meant the Berlin-Hamburg and Berlin-Hannover connections. Simultaneously, the corridor running from Berlin to Munich via Leipzig and Nuremberg took on a new dimension, because of its density of population (Fig. 3.15)

**POPULATION DISTRIBUTION IN REUNIFIED GERMANY (FIG. 3.15)**




*Source:* E. Jänsch (2002)

With this new geographical structure, it was no surprise that the Federal Transport Plan (1992-2003) should include the actions shown in Figure 3.16.

**HIGH-SPEED LINES IN OPERATION, CONSTRUCTION OR PLANNING IN GERMANY IN 1995 (FIG. 3.16)**


*Source:* M. CHLASTACZ

Note how the Hannover-Berlin and Berlin-Munich routes gained a new dimension. In the former, it was possible to travel at 250 km/h over 170 km, and at 200 km/h in the remaining 94 km. In the latter route, the commercial aim was to link the two cities in 4h, after travelling just under 700 km. This would involve the construction of new lines in some sections (Fig. 3.17).

At present, Germany has 1334 km of high speed lines (Fig. 3.16). Another 428 km are under construction.

## HIGH SPEED NETWORK IN GERMANY IN 2013 (FIG. 3.17)


*Source:* Le Train

# CHAPTER 4.

# THE FIRST HIGH-SPEED TRAIN LINE IN ITALY

## 4.1 THE EXISTING PROBLEM

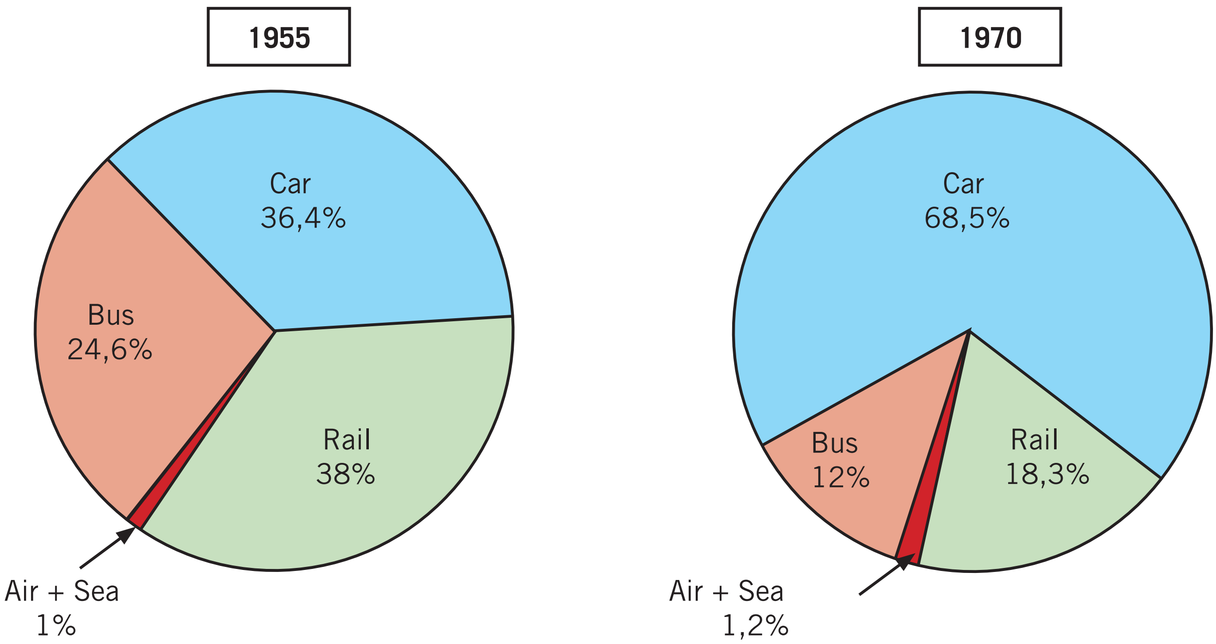
As has also occurred in other countries, the modernisation of the transport system after the Second World War essentially focused on a major improvement in the railway infrastructure network.

In the case of Italy, the need to improve the quality of the railway offering for medium and long distance travel already began to become apparent in the 1950s.

Indeed, in just 5 years, from 1950 to 1955, road traffic went from being almost equal with the railway to carrying almost double the volume.

Moreover, from 1955 to 1970, the comparison would only deteriorate further for the railway since, as can be seen in Figure 4.1, its market share went from 38% in 1955 to 18% in 1970. These figures refer exclusively to the modal split in passenger traffic over medium and long distances. In that period, cars and buses doubled their modal share.

**EVOLUTION OF MODAL SPLIT OF PASSENGER TRAFFIC OVER MEDIUM AND LONG DISTANCES IN ITALY (1955-1970) (FIG. 4.1)**

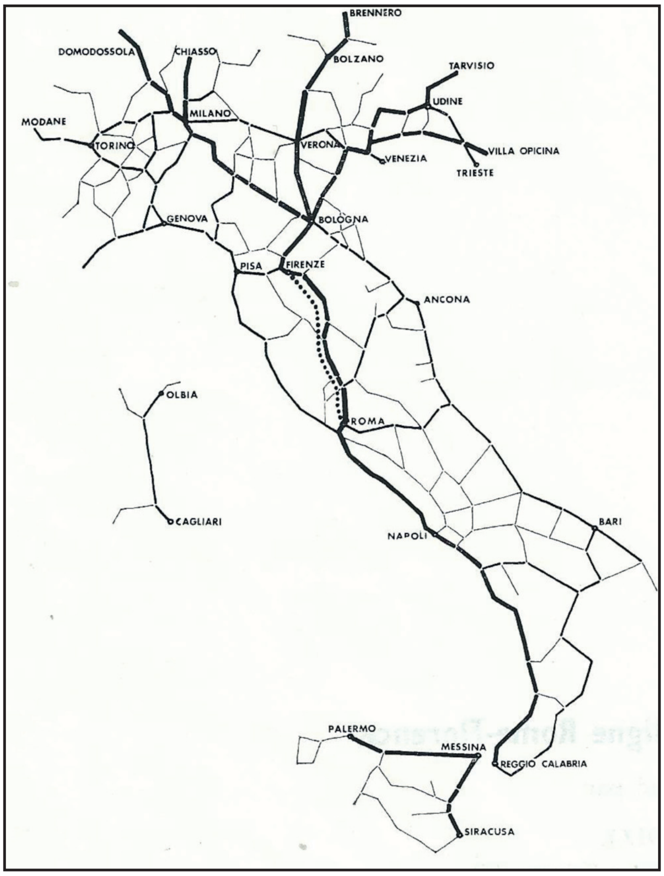



*Source:* C. Podesta (1993)

## 4.2 LIMITATIONS OF THE ITALIAN RAILWAY NETWORK.

What resources did the railway have to cope with the development of road traffic? Of course, the Milan-Naples corridor (Figure 4.2) of 850 km in length, was the main traffic artery of the Italian railways. In support of the above statement it is worth noting that, despite representing 5.3% of the total length of the Italian network, this corridor carried more than 30% of passenger and freight traffic in the 1970s.

**ITALIAN RAILWAY NETWORK (FIG. 4.2)**




*Source:* G. Ruoppolo (1975)

The geometric layout of this railway corridor had the characteristics shown in Table 4.1. In it the following variables are explained

* Straight line distance between the major cities.
* Distance by rail
* Minimum radius of flat curves.
* Maximum gradient

## GEOMETRIC PARAMETERS OF THE MILAN-NAPLES LINE (TABLE 4.1)

| ROUTE | Indicator | | | | |
|---|---|---|---|---|---|
| | l | L | $\frac{L-1}{l}$ 100 | R min. | i |
| | km | km | % | | ‰ |
| Milan-Bologna | 203 | 219 | 8 | 1000 | 6 |
| Bologna-Florence | 82 | 97 | 19 | 600 | 12 |
| Florence-Rome | 232 | 314 | 35 | 350<br>500 | 11.4 |
| Rome-Naples | 189 | 214 | 13 | 800<br>1000 | 10 |

l = straight line distance

*L* = distance by rail

*Source:* Adapted from G. Ruoppolo (1978)

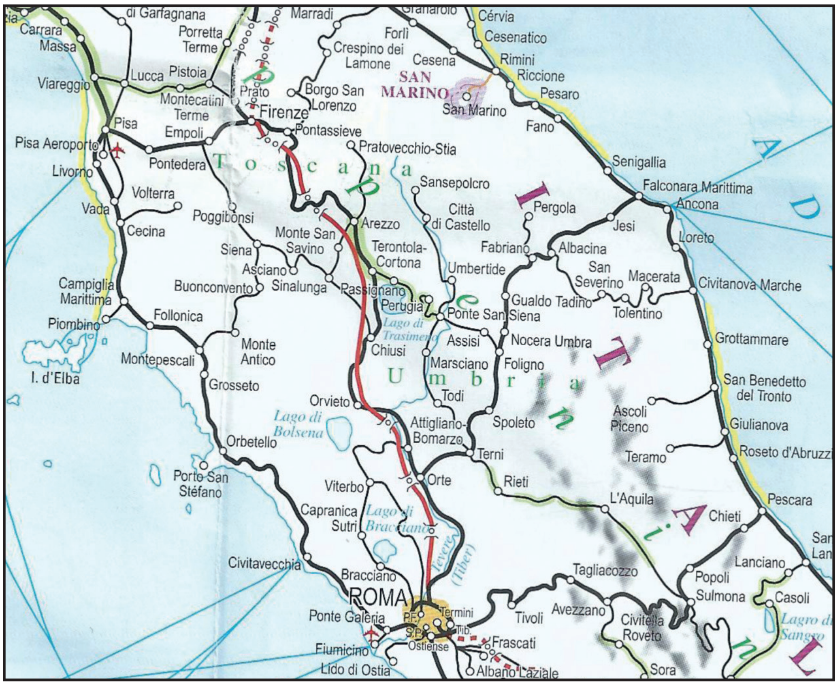
It basically establishes that:

a) The distance by train between Rome and Florence was 35% greater than the corresponding straight line distance.

b) The minimum radius on this same stretch came down to values of 350 to 500 m.

It is worth noting that the main route between Rome and Florence was the one passing through Chiusi (Figure 4.3). Other routes were also possible but with a greater distance.

## RAILWAY PATHS BETWEEN ROME AND FLORENCE (FIG. 4.3)




*Source:* Rail Map of Europe. Thomas Cook (2004)

The first route, via Folingo (372 km) was completed in 1866. The second, wholly to the west and passing through Civitavecchia (414 km) was completed in 1867. It was not until the following decade that the path via Siena (351 km) became operational, in 1875, and finally came the normally used path through Chiusi (314 km).

The effect of the cited geometric features (Table 4.1) on maximum speeds was as shown in Table 4.2

### MAXIMUM SPEEDS BY PATH IN THE MILAN-NAPLES RAIL CORRIDOR (TABLE 4.2)

| ROUTE | Maximum speed (km/h) | | | |
|---|---|---|---|---|
| | ≤ 105 | 110 to 130 | 135 to 155 | 160 to 170 |
| Milan-Bologna | 11 | 2 | 21 | 66 |
| Bologna-Florence | - | 26 | 60 | 14 |
| Florence-Rome | 57 | 15 | 28 | - |
| Rome-Naples | 2 | 17 | 41 | 40 |

*The* figures indicate the % of the length of the route in which each speed range can be achieved

*Source:* G. Ruoppolo (1970)

Note, that in the Milan-Bologna, Bologna-Florence and Rome-Naples sections it was possible to travel at maximum speeds ranging between 135 and 170 km/h over approximately 80% of their length. By contrast, on the Rome-Florence line, for almost 60% of the route it was not possible to exceed 105 km/h.

This significant limitation in the Rome-Florence section was exacerbated by the fact that it had an average daily traffic of more than 96,000 tonnes. This meant that the line was forced to handle over 200 trains/day, between passenger and freight trains.

There was no doubt, therefore, that priority attention needed to be given to this section of line, which was the main bottleneck of the Milan-Naples rail corridor.

## 4.3 THE DECISION TAKEN

The problem highlighted above in relation to the Rome-Florence line essentially manifested itself in the following aspects:

a) The length of the rail distance between Rome and Florence when compared to the distance "as the crow flies"

b) The limited speeds that were allowed by the geometry along its path.

c) The problems caused by lack of existing capacity.

To try to address this problem, an Italian Railways Commission was set up in 1966.

The following alternatives were analysed:

1. Extension of the platform so as to allow the installation of 4 tracks instead of the existing two.

2. Construction of a new line, fully independent of the existing one.

The first approach had the advantage, from the economic point of view, of avoiding numerous works projects, but had the disadvantage of retaining the winding path, with the same geometric characteristics mentioned above. In this case, although the capacity of the line would have increased notably, as far as maximum speeds are concerned, the changes would barely have been noticeable.

The idea of building a separate line had the attraction of being able to adopt the straightest path possible, significantly reducing the distance by rail and travel time. However, from the operations perspective, this was not an ideal solution, since in the event of an accidental interruption of the new line, all its traffic would need to run on the old one, exacerbating the capacity issues mentioned earlier.

At the same time, the market analysis carried out in the North-South corridor showed that while there was "a need to raise the speed above its classic level it was admitted that there was no need to spend enormous amounts of money exclusively on the problems of passenger traffic, rather it was necessary to also benefit freight traffic in one way or another".

The alternative chosen in the end was a project that in the opinion of the FS reconciled the two previous options - quadrupling of tracks and a new line - by combining the advantages of both. The path of the additional tracks would have a new infrastructure which, although it would follow the route of the old line, would present a geometry with very few curves. Furthermore, this new route would connect with the existing route at various points (Figure 4.4) so that it would be possible, where necessary, to operate in sections.

**INTERCONNECTION OF THE CLASSIC LINE AND MORE DIRECT ROME–FLORENCE ROUTE (FIG. 4.4)**


The possibility was not ruled out to achieve in the future the highest speeds that the railway equipment could allow on the new line".

The new line would join Termini station in Rome to Santa Maria Novella station in Florence via a path that was 261 km in length, i.e. 50 km shorter than the classic line. The new path, with minimum curve radii of 3000 m, would allow a speed of 250 km/h; the links between the two lines could be made at 100 km/h.

## 4.4 TIME OF IMPLEMENTATION OF THE ROME-FLORENCE LINE

The new line between Rome and Florence was begun in June 1970. However, due to technical and economic difficulties, its full entry into service did not take place until 26th May 1992. In fact its opening to commercial operation occurred in several stages.

The first was completed on 24th February 1977, with the entry into service of the 122 km stretch located between Settebagni and Citta della Pieve, without including the passage through the Orte tunnel, which would be finished in 1980. With the opening of that section, the maximum speed was increased to 180 km/h.

The second stage, the Citta della Pieve-Arezzo stretch (52 km), entered into service in 1985. Since 72% of the new line was thus available, the maximum speed was raised to 200 km/h, which reduced travel times.

In fact between Rome and Florence, from May 1986, over a total length of 275 km, of which 174 km was new track (between Settebagni and Arezzo), the fastest trains took 2h07 (commercial speed of 130 km/h).

An important milestone was the entry into service on the line in 1988 of the ETR 450 tilting train, which travelled at a top speed of 250 km/h. The travel time between the two cities was thus reduced to 1h35, travelling at a commercial speed of 165 km/h.

With the completion in 1992 of the section between Montevarchi and Figline Valdarno (20 km), the so-called "Direttissima Roma-Firenze" (Rome-Florence Super Direct) was completed.

## 4.5 THE CONSTRUCTION OF NEW LINES

Alongside the construction of the new high speed line between Rome and Florence, the Italian railways were concerned about how to improve the competitiveness of their offering on other routes, particularly those involving intercity passenger services.

In this context, on 12th April 1984 a Working Group, led by the engineer Renzo Frullini of the Rolling Stock and Traction Service and made up of representatives from various FS Services, was set up to discuss the above mentioned problems: the lack of competitiveness of rail travel along the classic paths.

On 9th June 1984, a report was delivered to the FS management, which contained the following conclusion:

"The lines on the FS network cannot be adapted to higher speeds such as those achieved by Range C without problems which are disproportionate to the corresponding reductions in travel times"

Note that Range C referred to trains which travelled at higher speeds.

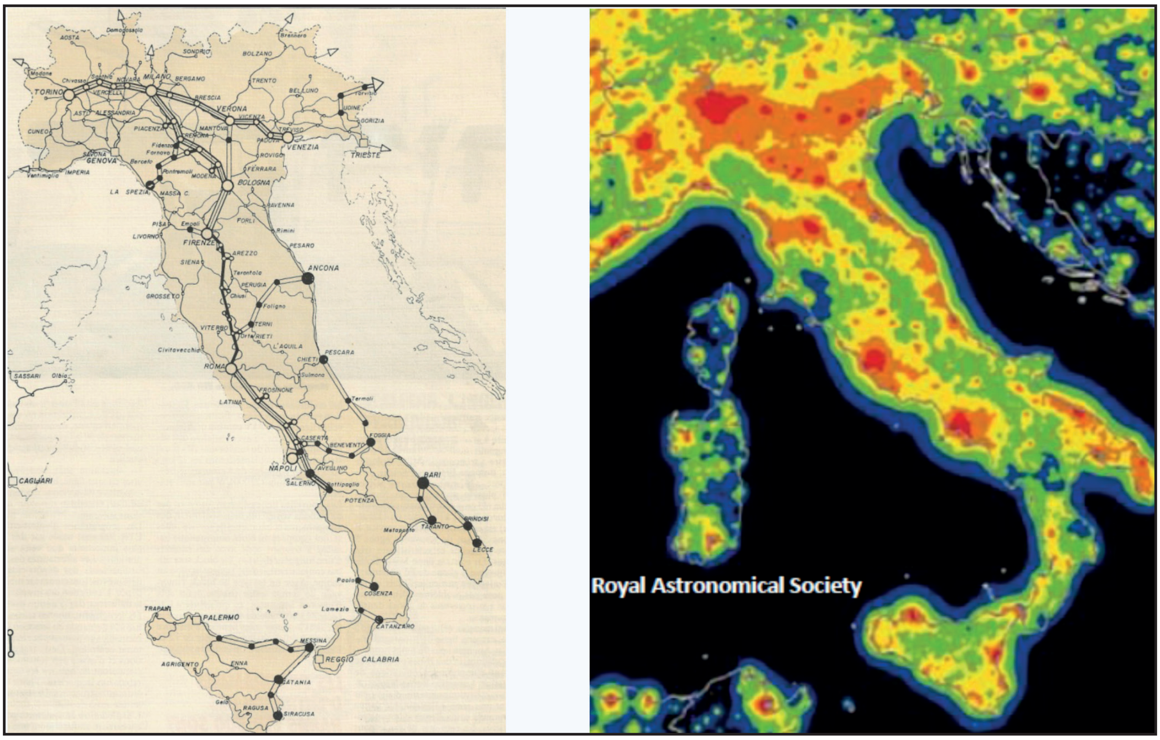
On this basis, the Directorate General of FS decided on 17th February 1986 to establish a multidisciplinary Working Group that was to carry out what was known as the «Studio di fattibilità di un Sistema Ferroviario Italiano ad Alta Velocità» (Feasibility Study for a High-Speed Italian Railway System).

This Working Group, under the leadership of Silvio Rozotti (Deputy Managing Director) and coordinated by the engineer Maurizio Cavagnaro, from the Rolling Stock and Traction Service, was made up of ten members representing various Technical Services from the FS.

The content of that study, conducted in only four months, was approved by the Board of Directors of the FS on 3rd July 1986. The main modification introduced by the Board was to extend the high speed line from Naples to Battipaglia.

The proposal in that study involved building a high speed line from Turin to Naples and a transversal line from Turin to Venice, via Milan and Verona (Figure 4.5). Note that this T-shaped design was aimed at meeting the mobility needs of the principal urban areas in Italy (Fig. 4.5)

**PROPOSAL FOR ITALIAN HIGH SPEED RAIL NETWORK IN 1986 (FIG. 4.5)**




*Source:* M. Cavagmaro et al (1987); F. Croccolo (2013)

It is interesting to note that the presentation document for the proposed high-speed network said the following:

“The history of the major infrastructure projects in our country has often been synonymous with great misunderstandings. It seems that the construction of Italian high-speed rail system, surely one of the most important projects of the late 20th century, does not belie this rule.”

Again the usual accusations were made: A headlong rush into the unknown, megalomania, and in this particular case, the idea that the FS would create two railways: one with modern technology and projected towards Europe, the other obsolete and uncompetitive.

However, the FS responded to the above allegations by noting that:

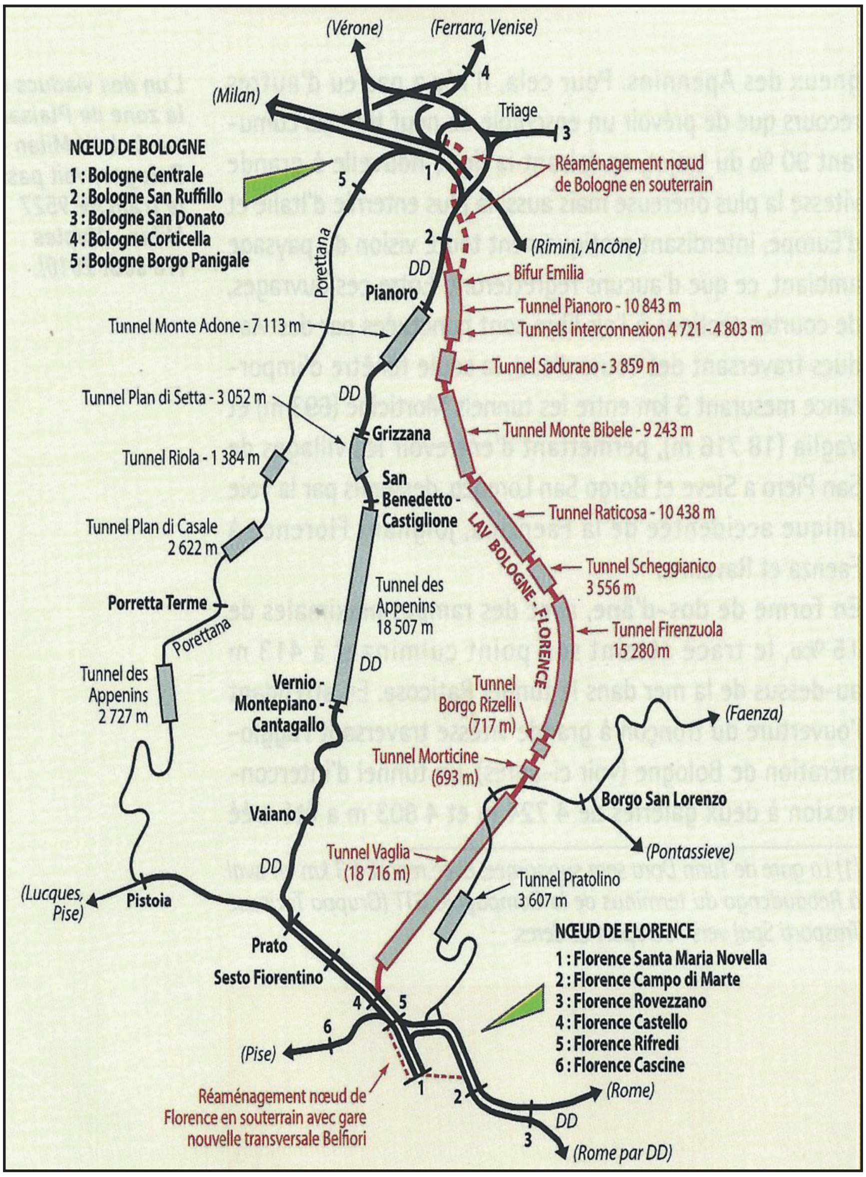
“The choice of a high speed train is not synonymous with a step forward for a privileged part of the railway, but a new strategic positioning of the entire national rail system. This approach justifies the size of the technical and financial resources being allocated to the project, as well as the importance being given at a political and economic level to this project’.

The north-south axis of the Italian high-speed system, that is, the Turin-Milan-Bologna-Florence-Rome-Naples-Salerno, corridor, with a total length of 923 km, opened to full commercial operation in December 2009.

Because of its exceptional character in Europe, it is interesting to reflect, in Fig. 4.6, on the path of the line between Bologna and Florence.

In Figure 4.6 above, we can also see the three existing railway paths linking the mentioned cities. The initial itinerary, which went via Pistoia, was greatly enhanced with the completion (in 1935) of the line called the “Direttissima” (Super Direct), which began in Prato. The Apennine Tunnel, 18.5 km long, was built along this path. The unique feature of the high speed line between Bologna and Florence is the fact that 90% of it runs through tunnels. This means that apart from the 3 km stretch between the tunnels of Morticine and Vaglia, it is not possible on the rest of the path to look out at the landscape.

**BOLOGNA-FLORENCE RAIL CORRIDOR (FIG. 4.6)**



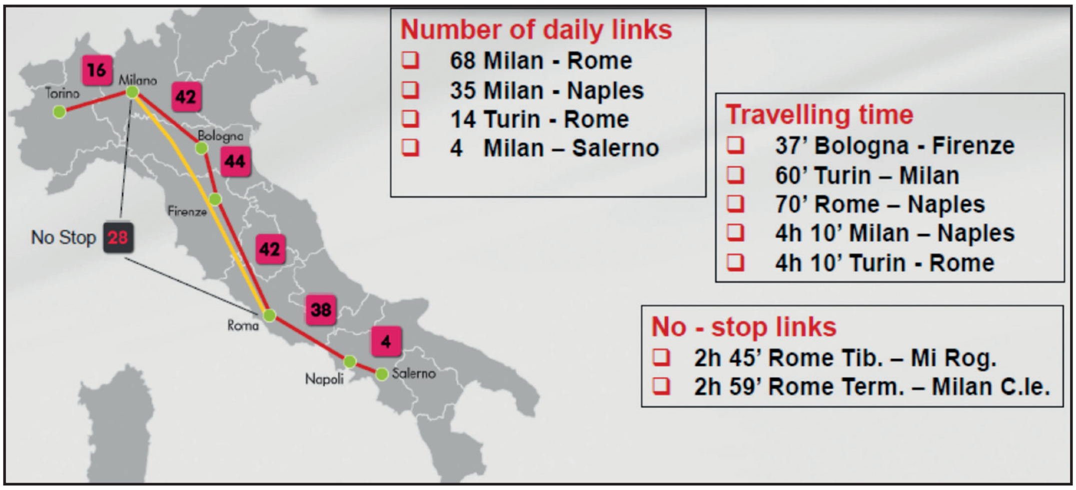

*Source:* B. Collardey (2011)

## 4.6 THE SERVICE OFFERING AND DEMAND RESPONSE

With the beginning of commercial operations on the new line between Rome and Florence in 1992, the travel time between these cities was reduced to 1h22. The demand response to this new offering resulted in a market share for rail of 59% and 34% for the road.

For the Turin-Naples-Salerno high-speed rail corridor, the railway offering, in terms of service frequency and journey times, is shown in Figure 4.7

## HIGH SPEED SERVICES AND TRAVELLING TIME (FIG. 4.7)

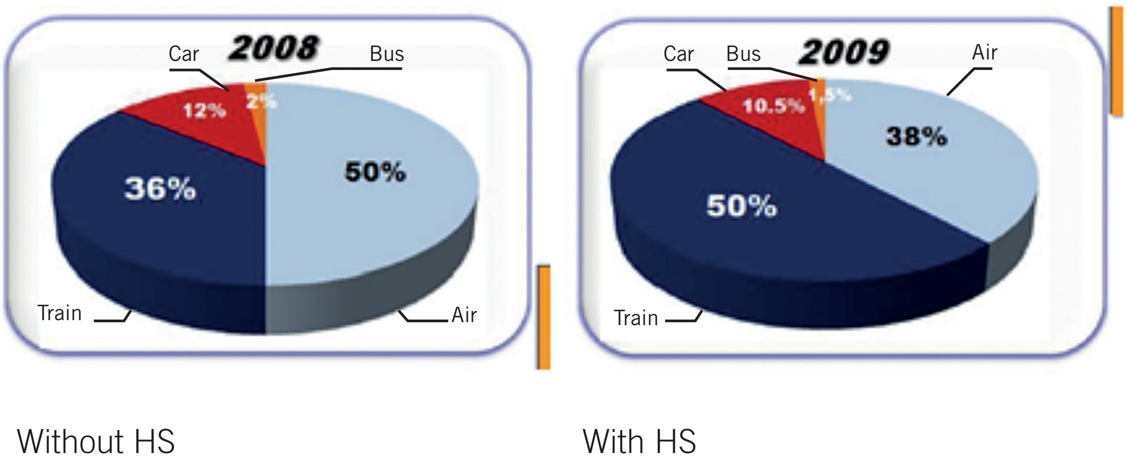



*Source:* F. Croccolo (2013)

It offered 28 daily non-stop services between Rome and Milan. The travel time, depending on the final destination, ranged from 2h45 to 2h59.

The demand response to this new offering changed, in highly significant ways, the modal split of passenger traffic on the routes in the Milan-Rome corridor, in particular on the Milan-Rome route. Indeed, in 2008, before the introduction of high-speed rail, the railway had a market share of 36% compared to other transport modes. From 2009, with high speed rail services, the railway has had a market share of 50%. (Fig 4.8)

## MILAN-ROME MODAL SPLIT (FIG. 4.8)




*Source:* Adapted from F. Croccolo (2013).

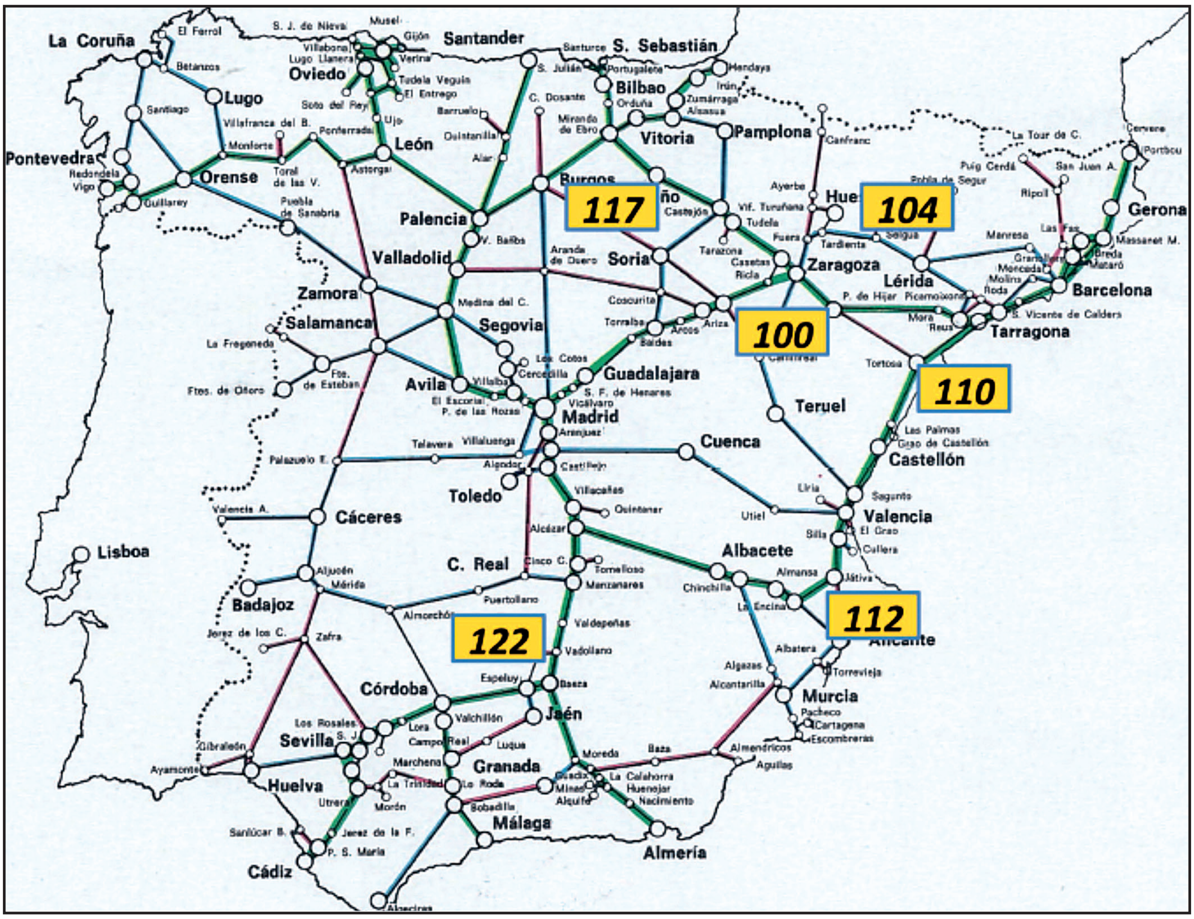
# CHAPTER 5.

# THE FIRST HIGH-SPEED TRAIN LINE IN SPAIN

## 5.1 THE EXISTING PROBLEM

In the Spanish railway network in the mid-1980s, there were essentially two main problems. The first was the low commercial speeds that could be achieved on the classic paths, because of their sinuosity. These were generally located in the range of 80 to 90 km/h. The second was the low percentage of sections fitted with double track, which caused major problems as a result of lack of capacity (Figure 5.1). The main effects were the delays caused to trains.

### LEVEL OF USE OF CERTAIN SECTIONS OF THE SPANISH RAILWAY NETWORK (1985) (FIG. 5.1)

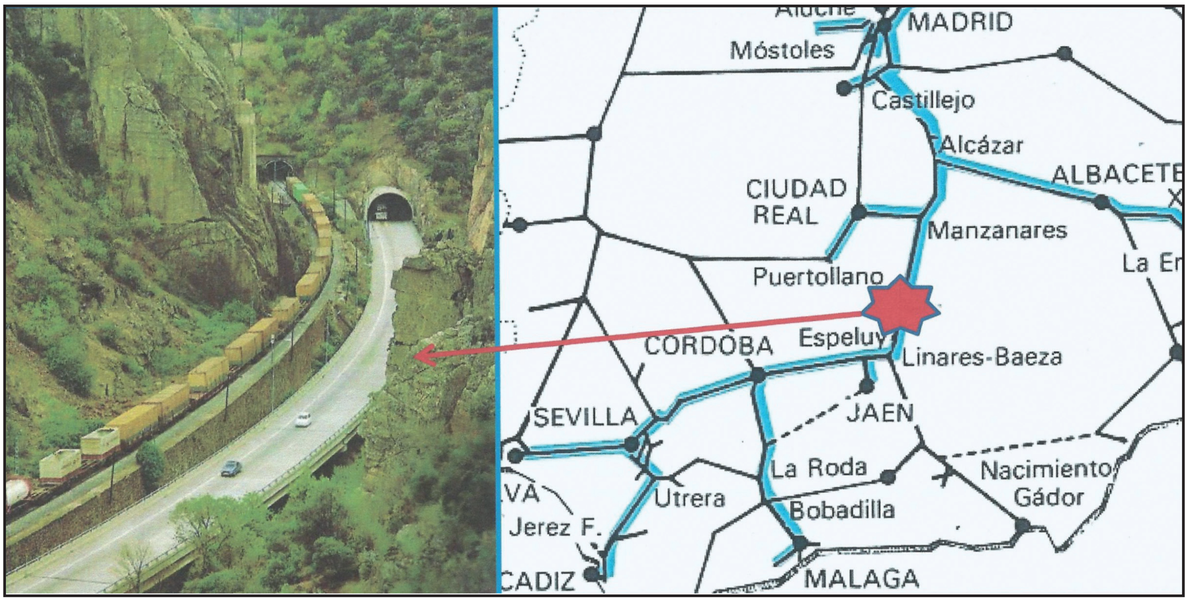



*Source:* Adapted from Renfe

In particular, these sections were: the Ricla-Calatayud section (Madrid-Zaragoza line); Zaragoza-Lleida; Mediterranean Corridor; Xátiva-La Encina (Madrid-Valencia line via Albacete); Castejón-Miranda de Ebro and without a doubt the route through Despeñaperros, Venta de Cárdenas-Vadollano stretch, on the Madrid-Córdoba/Seville line. Therefore special attention was paid to the solution of the problem presented by this last stretch (considering it was the only means of access by rail to Andalusia from the Central Plateau). Priority attention is also devoted to the solution of the problems on the Madrid-Barcelona line, in order to unite the two main cities.

Regarding the Madrid-Seville corridor, Figure 5.2 allows us to physically locate the geographical area with the greatest difficulty, known as Despeñaperros. Note that in this area, the geometry of the railway path was characterised by flat curve radii of 350 m, and maximum gradients of 16‰.

**DESPEÑAPERROS ZONE BY RAIL (FIG. 5.2)**



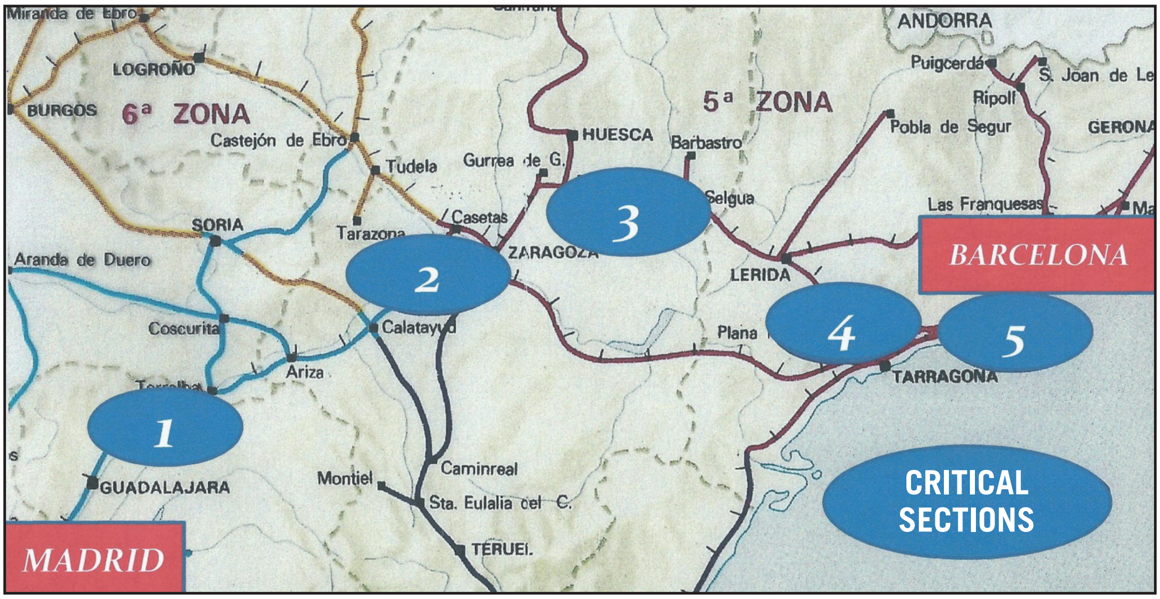

*Source:* Author's own work. Photos from Renfe

It is not surprising, therefore, that the degree of saturation in Despeñaperros was almost total, and that freight trains had to wait, sometimes for a number of hours, until the passenger trains left them some capacity so they could go through.

Additionally, in terms of passenger demand on the Madrid-Seville route, the railway only had a market share of 20% compared to all modes of transport.

As for the Madrid-Barcelona line, it had at least five critical sections. With some of these it was a result of their sinuosity, while others were sections with only a single track. Figure 5.3 shows the locations of the aforementioned critical sections.

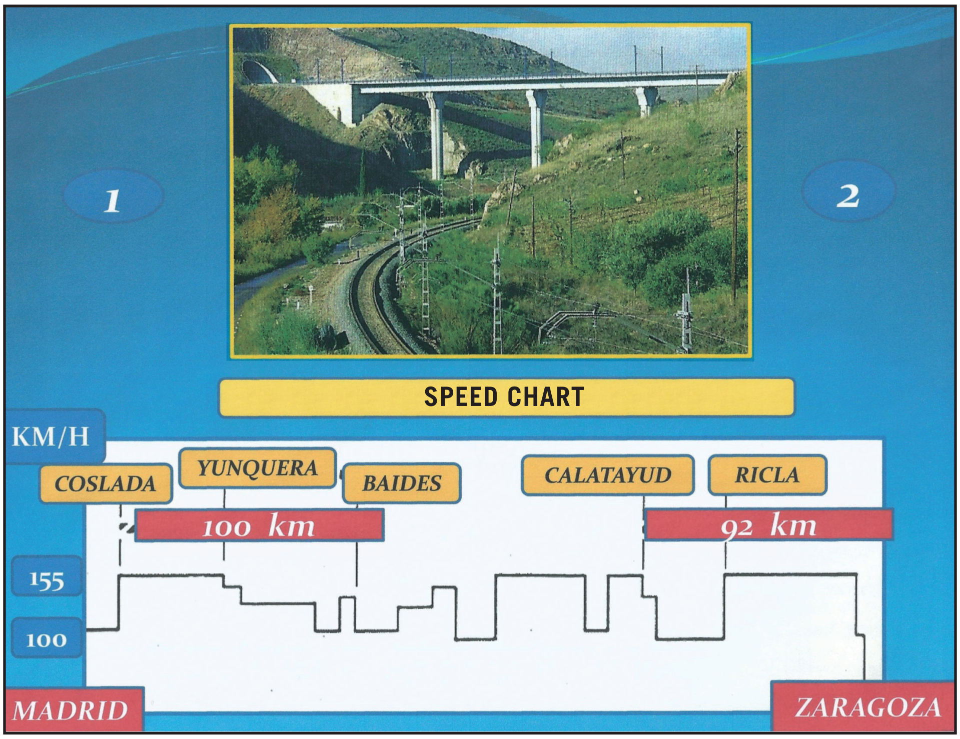
## MOST ADVERSE SECTIONS OF THE CLASSIC MADRID-BARCELONA LINE (FIG. 5.3)




*Source:* Author's own work.

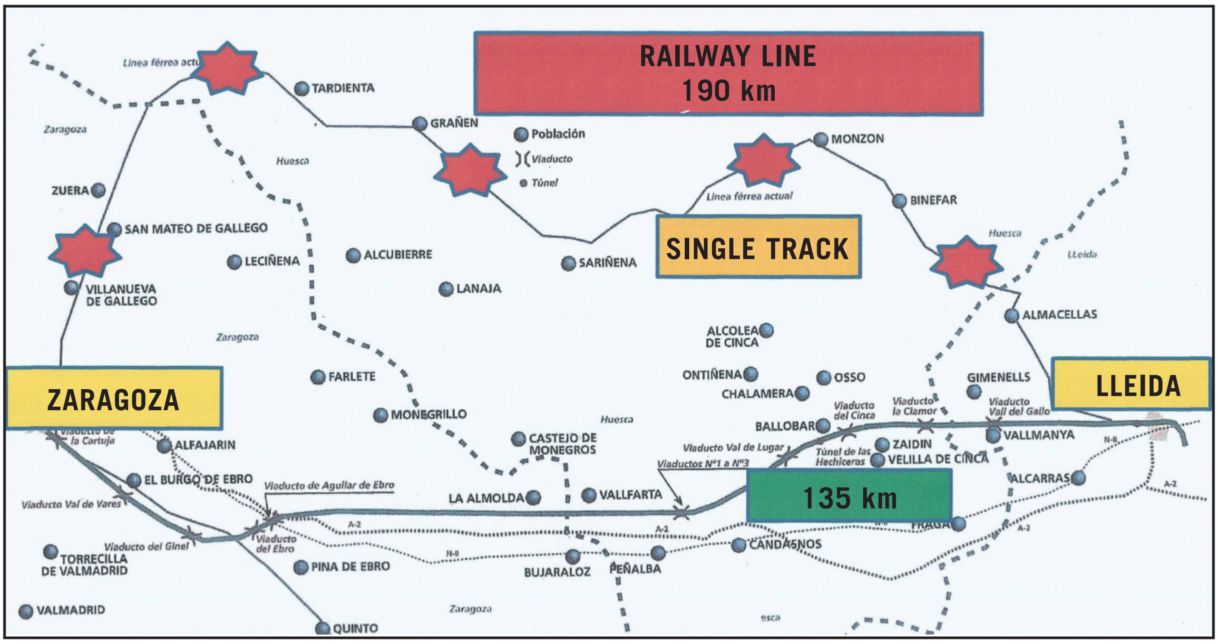
For the critical sections (1) and (2), Figure 5.4 shows the diagram of maximum speeds between Madrid and Zaragoza. It also displays the difficulty that would be entailed in doubling the track along the existing path.

## CHART OF SPEEDS ON THE ZARAGOZA-MADRID LINE (FIG. 5.4)



Additionally, critical section number three, which ran between Zaragoza and Lleida, was on a single track. Note, in Figure 5.5, that the distance between the two cities by rail (190 km) was clearly superior to the distance by road, which was around 135 km.

**RAILWAY PATH BETWEEN ZARAGOZA AND LLEIDA (FIG.5.5)**

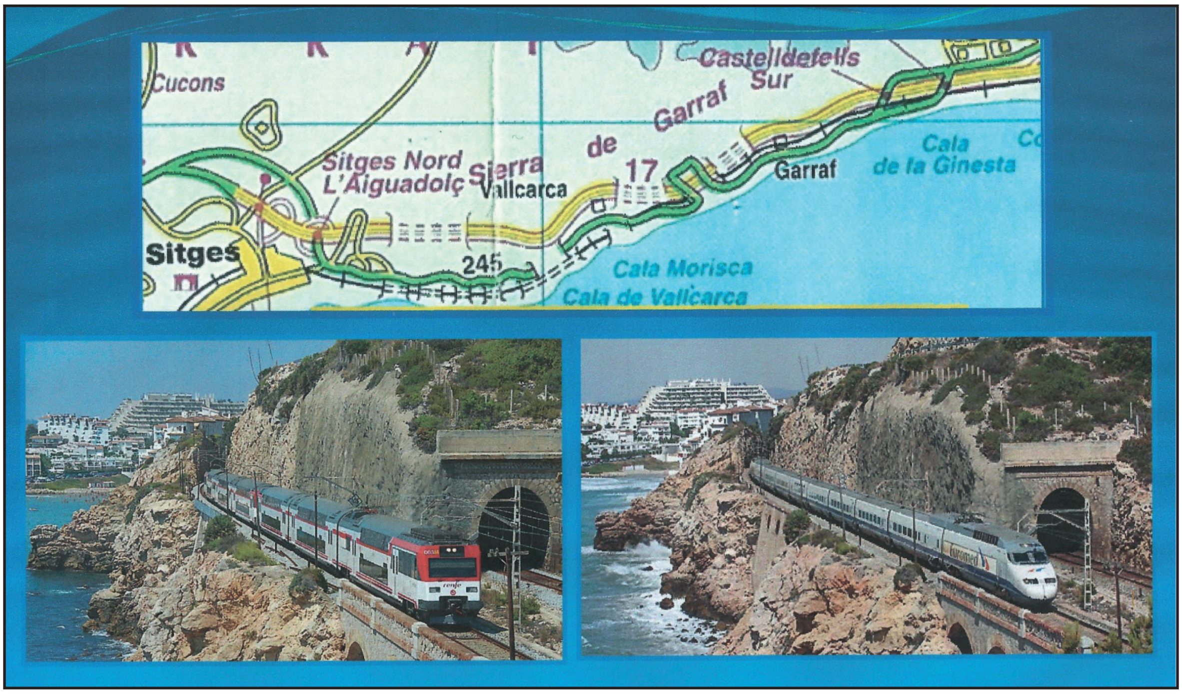



*Source:* Author's own work.

The fourth critical section was between Lleida and Tarragona, where the path, on a single track, sometimes did not allow a top speed of more than 100 km/h.

The last section (Figure 5.6) was in the area of Garraf, near Barcelona. In this section, in addition to the difficult terrain, there were problems arising from operations that meant a high frequency of commuter trains running alongside long distance trains.

**DIFFICULTIES FOR THE MADRID-BARCELONA LINE IN THE GARRAF AREA (FIG. 5.6)**




*Source:* Author's own work, compiled from various references.

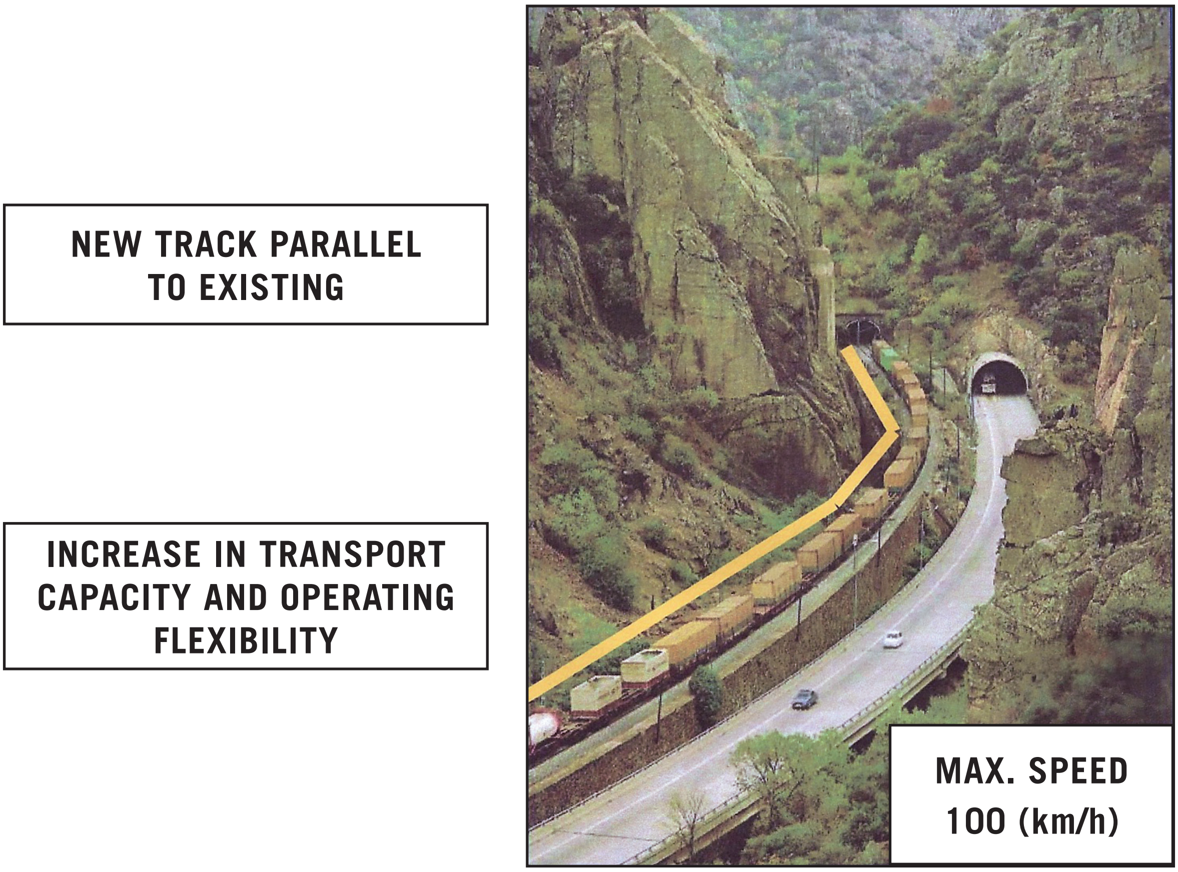
Between Madrid and Barcelona, the railway had a market share of 11% compared to air travel, which offered a cadenced flight service with more than 40 flights per day in each direction.

## 5.2 THE DECISION TAKEN

If we look firstly at the Madrid-Seville line, one might wonder how to solve the problem of lack of capacity mentioned.

At first, one might consider something along the lines of what the Japanese railways did to solve the problem of lack of capacity of the classic line between Tokyo and Osaka. That is, doubling the track along the existing path, as displayed in Figure 5.7.

**CONVENTIONAL ALTERNATIVE SOLUTION OF THE PROBLEM OF THROUGH TRAINS AT DESPEÑAPERROS (FIG. 5.7)**




*Source:* Author's own work.

However, the work would involve a major investment due to the difficult terrain in the area, it would have an effect on the environment that was far from negligible, and lastly, the travel times for long distance routes would not be changed much, since the trains would end up travelling at the same speed that was allowed on the existing track, i.e. in the vicinity of 100 km/h.

Based on the foregoing it did not seem that work on the existing path was the alternative that would best use the economic investment involved. In support of this conclusion, it should be mentioned that there was a long travel time between Madrid and Cordoba/Seville of up to 6 hours (Figure 5.8). It is not surprising, therefore, that the role of the railway in passenger transport on the mentioned routes was deteriorating. In fact, the experience observed in later years (between 1988 and 1991) reflected that trend. The Madrid to Seville route was reduced by 12.5%, and the Madrid to Cordoba route in a similar proportion, as shown in Figure 5.9.

## TRAVEL TIME MADRID-SEVILLE IN THE 1980S (FIG. 5.8)

| Km | Train No | | Exp. 30993 30992 | Exp. 1993 1992 | TALGO 114 | Rap. 512 | Rap. 693 692 | TALGO 110 |
|---|---|---|---|---|---|---|---|---|
| | Services: Seats | | 1-2 | 1-2 | 1-2 | 1-2 | 1-2 | 1-2 |
| | Sleeper | | | | | | | |
| | Type of catering | | | | | | | |
| Km | Special Features | | 2 | 1 | 8 A | E | 2 B | 8 A |
| | MADRID-ATOCHA | S. | | | 8. 50 | 10.45 | | 14. 41 |
| 49 | Aranjuez | | | | | 11.24 | | |
| 149 | Alcázar de San Juan | Ll. | | | 10.18 | 12.19 | | 16.09 |
| | | S. | 4.39 | 5.56 | 10.19 | 12.20 | 14.47 | 16.10 |
| 296 | Vilches | | | | | 14.00 | | 17.39 |
| 307 | Vadollano | | | | | | | |
| 315 | Linares-Baeza | | 6.48 | 8.16 | 12.12 | 14.18 | 16.42 | 17.57 |
| 329 | Jabalquinto (apt.) | | | | | | | |
| 341 | Espeluy | Ll. | 7.06 | 8.34 | | 14.35 | 16.59 | 18.13 |
| | | S. | 7.08 | 8.35 | | 14.36 | 17.00 | 18.14 |
| 350 | Villanueva de la Reina (apt.) | | | | | | | |
| 363 | Andújar | | | | 12.41 | 14.51 | 17.19 | 18.29 |
| 442 | CORDOBA | Ll. | 8.25 | 9.57 | 13.37 | 16.07 | 18.25 | 19.24 |
| | | S. | 8.30 | 10.12 | 13.42 | 16.33 | 18.48 | 19.29 |
| 568 | San Jerónimo | | | | | | | |
| | SEVILLA | Ll. | 10.20 | | 14. 57 | | 20.02 | 20. 42 |
| | | Ll. | | 11.36 | | 17.56 | | |
| | | S. | | 11.46 | | 18.07 | | 20.51 |

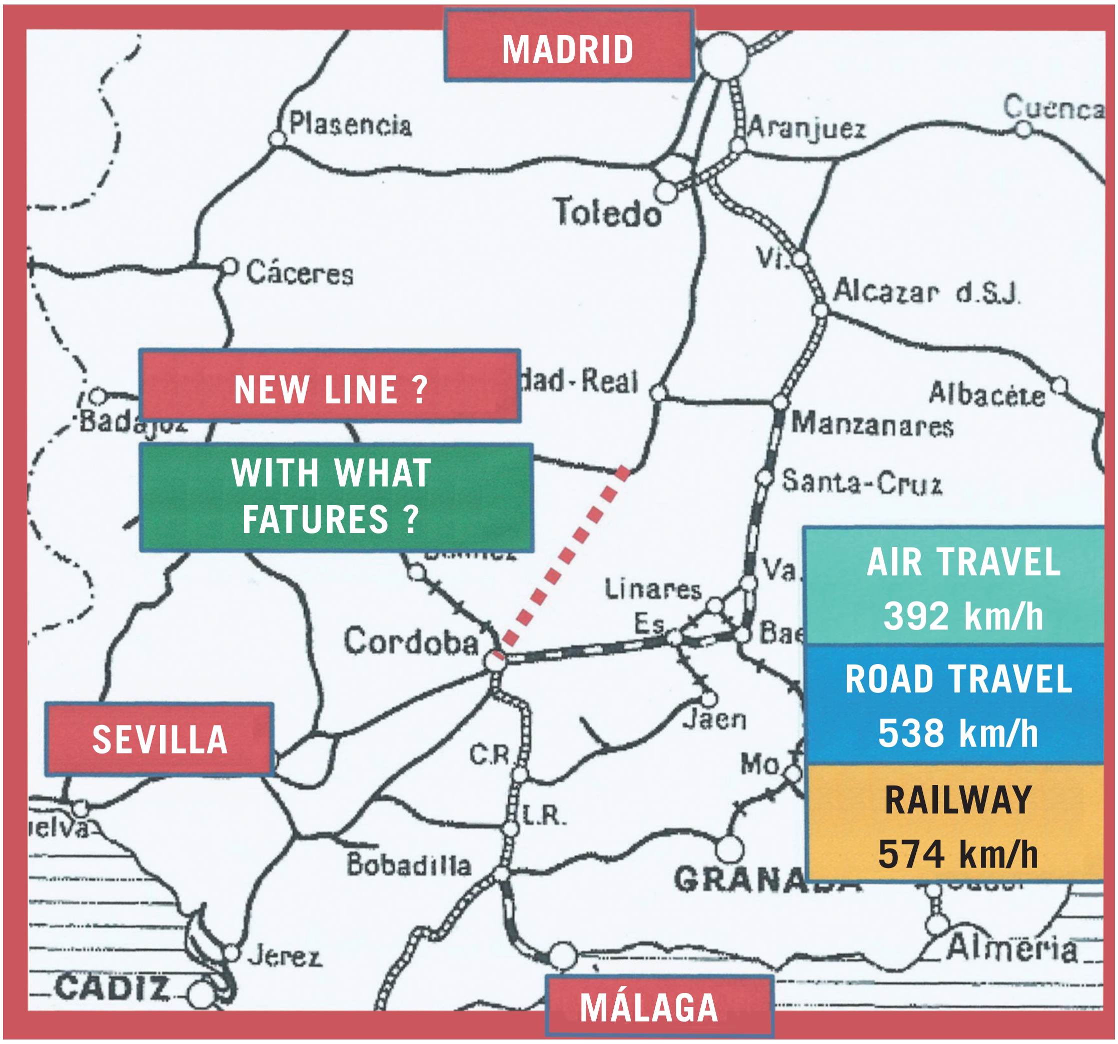
*Source:* Adapted from Renfe timetables

## EVOLUTION OF RAIL TRAFFIC ON THE MADRID-CORDOBA-SEVILLE ROUTES (1988-1991) (FIG. 5.9)


*Source:* Author's own work. Renfe Data

Accordingly, it seemed reasonable to build, as an alternative to the doubling of the Despeñaperros track, a variant path along the axis indicated in Figure 5.10. This would allow the distance between Madrid and Seville to be reduced by about 100 km.

**THE BENCHMARK FRAMEWORK FOR THE MADRID-SEVILLE CORRIDOR (FIG. 5.10)**




*Source:* Author's own work. Renfe Data

At the same time, the "vision of the corridor as a whole" emphasised the lack of interest in providing the high performance variant mentioned above, if it could be possible along the rest of the path to Madrid to travel at a top speed of 100 or 160 km/h.

It was thus decided to build a high speed line between Madrid and Seville, which reduced the distance by rail from 574 km to 471 km and the travel time from 6h to 2h30.

If we look at the Madrid-Barcelona route, we can see:

a) The impossibility of modernising, at a reasonable cost, the critical sections along the path. See, in particular, Figures 5.4 and 5.5.

b) The adverse situation of the railway in terms of distance travelled compared to other modes of transport: 70 km more than the road distance and 210 km more than the distance by air.

c) The high quality of the supply of air transport, with more than 40 flights per day in each direction, between the aforementioned cities.

It was therefore unthinkable to consider any other action that was not the building of a new line suitable for high-speed trains. With the new path, the total distance was reduced from 700 km to 621 km and the travel time by the fastest train went from 6h30 to 2h30.

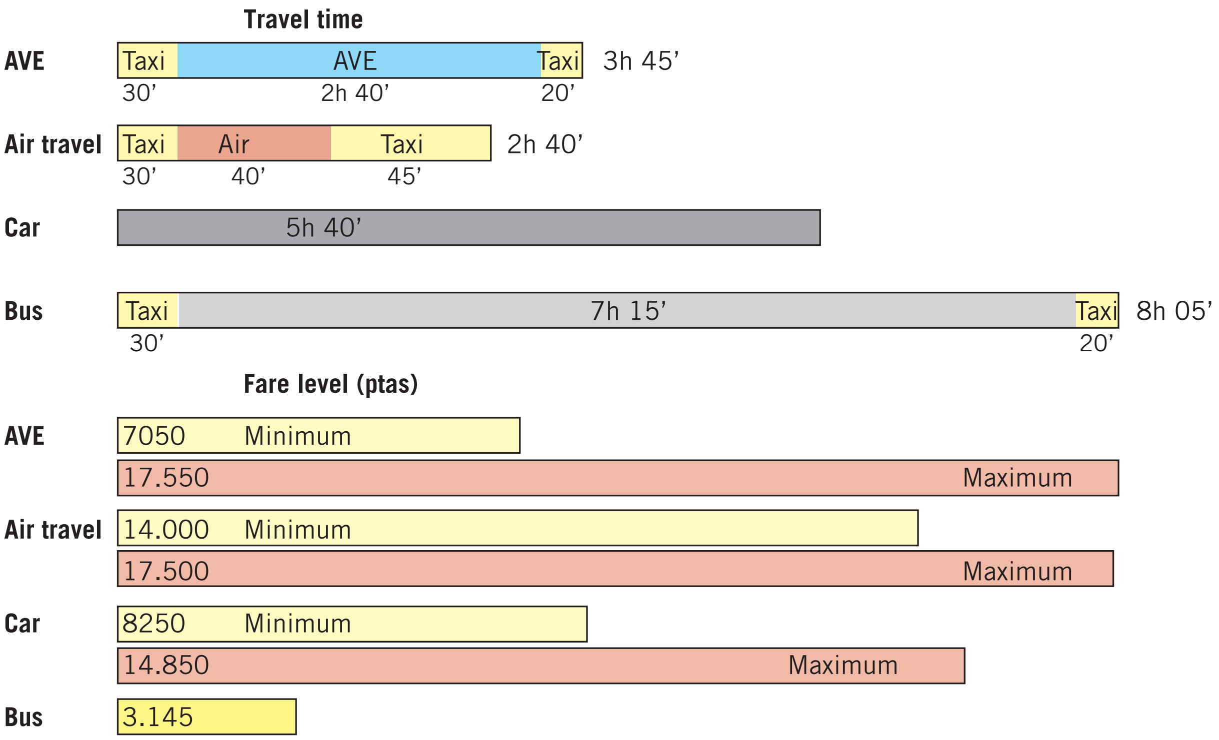
The decision to build a new standard gauge line between Seville, Madrid, Barcelona and the French border, suitable for high-speed travel, was adopted by the Spanish government in December 1998.

## 5.3 THE RANGE OF SERVICES AND RESPONSIVENESS TO DEMAND

With regard to the Madrid-Seville line, its entry into service in April 1992 resulted in an initial travel time of 2h50.

The offering on the AVE at that time, compared with other modes of transport, is summarised in Figure 5.11. The frequency of the AVE at the beginning of operations was 6 trains/day/direction, which were progressively increased (up to the current 22 services).

## SERVICE OFFERINGS COMPARED BY MODES ON THE MADRID-SEVILLE ROUTE IN APRIL 1992 (FIG. 5.11)




*Source:* R. Ramos (1992)

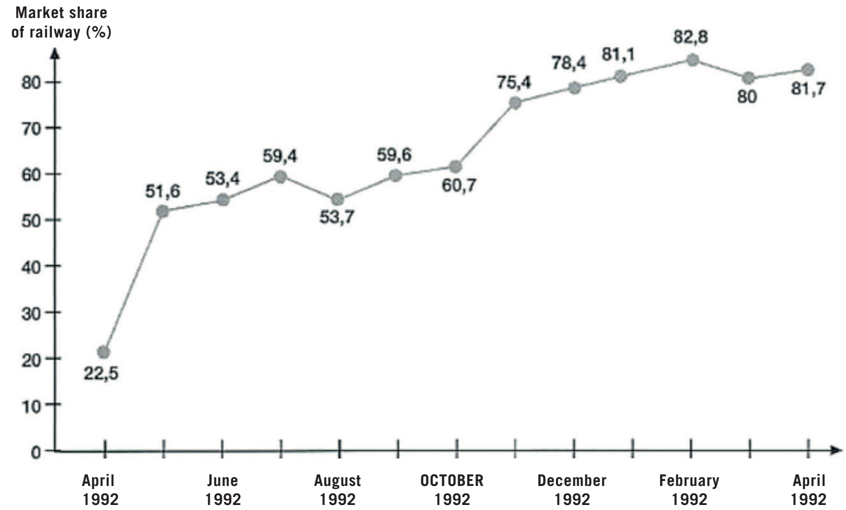
With regard to the rail-air dichotomy, the impact of the AVE was similar to that observed already in the first high-speed lines in Japan and France. Indeed, in the first full month of operation of Spain’s high-speed rail service (AVE), in May 1992, the number of rail passengers already overtook air passengers, rising quickly over the following months, as shown in Table 5.1.

## EVOLUTION OF AVE/AIR TRAFFIC ON THE MADRID-SEVILLE ROUTE (APRIL 1992-APRIL 1993) (TABLE 5.1)

| Mode | 1992 (thousands of passengers) | | | | | | | | | 1993 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | April | May | June | July | August | Sept. | Oct. | Nov. | Dec. | January | Feb. | March | April |
| Iberia | 85 | 92 | 74 | 72 | 47 | 107 | 75 | 30 | 27 | 20 | 19 | 27 | 27 |
| AVE (high speed rail) | 25 | 98 | 108 | 105 | 102 | 158 | 115 | 92 | 98 | 86 | 92 | 108 | 121 |

From the data given in the table it is possible to plot the curve of the evolution in the market share of the railway (Figure 5.12). Looking at it allows us to see how in the first month of operation of the high-speed train, the railway managed to more than double its market share from 22.5% to 51.6% and thus overtake air services. From that time, apart from a slight downturn in the fourth month, the railway continued to increase its presence gradually, stabilising at around 80% after the first anniversary of the opening of the high-speed line.

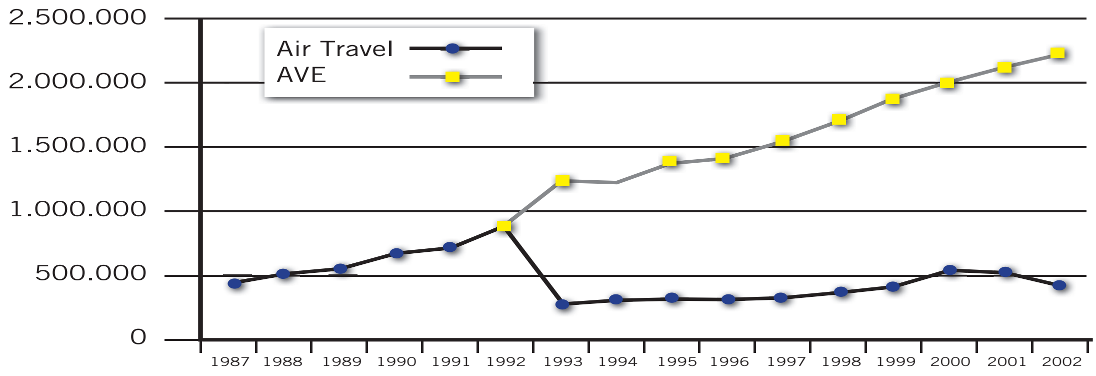
**EVOLUTION OF THE MARKET SHARE OF THE RAILWAY COMPARED TO AIR TRAVEL ON THE MADRID-SEVILLE ROUTE (APRIL 1992 - APRIL 1993) (FIG. 5.12)**




*Source:* Author’s own work. Renfe Data.

Since then, the market share of the railway compared to air travel has remained above 80% as can be seen in Figure 5.13.

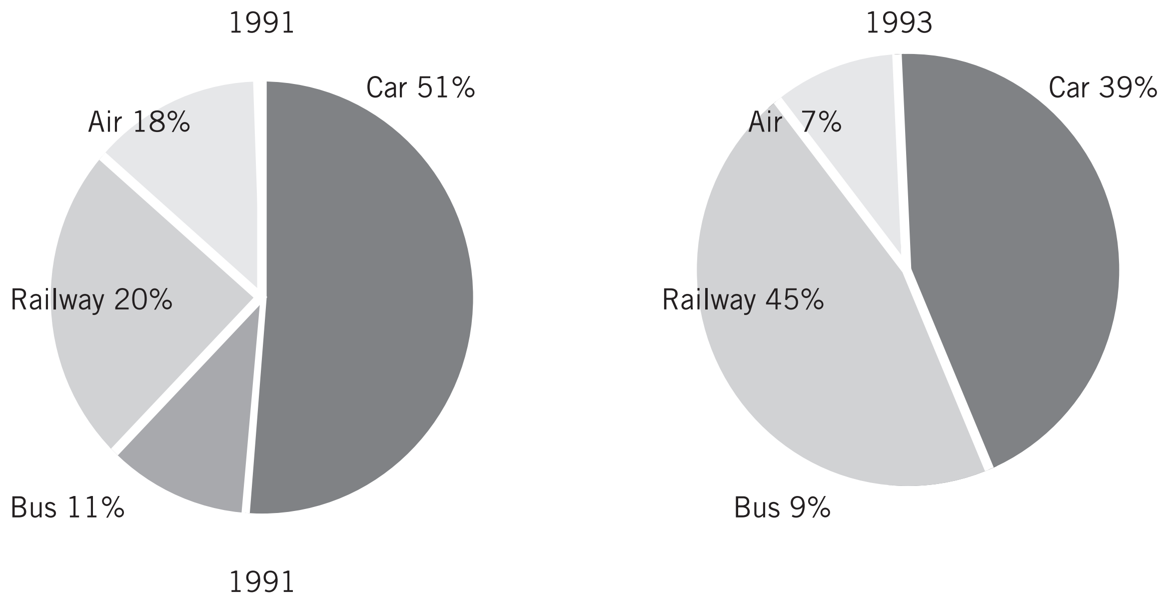
**EVOLUTION OF AIR AND HIGH SPEED TRAIN TRAFFIC BETWEEN MADRID AND SEVILLE (FIG. 5.13)**




*Source:* Taken from P. Alonso (2004)

The effect of the AVE on the other modes is shown in Figure 5.14

**EFFECT OF AVE ON MODAL SPLIT OF PASSENGERS ON THE MADRID-SEVILLE ROUTE (FIG. 5.14)**




*Source:* E. Fernández (1993)

As regards the effect on air traffic, note the way that, before the AVE, both modes (rail and air) had a similar market share (18-20%) in the total. However, the AVE managed to reduce the presence of air travel from 18% to 7%, while the railway rose from 20% to 45%.

As for the effect on car travel, Figure 5.14 shows that while the rail journey time between Madrid and Seville in 1991 was 6 hours, and the same journey took 5h40 by road, the car-rail modal split was 72% and 28% respectively. With AVE services, the rail travel time was initially reduced (i.e. in 1993) to 2h45. At that time the above aforementioned modal split went to 46% and 54% respectively.

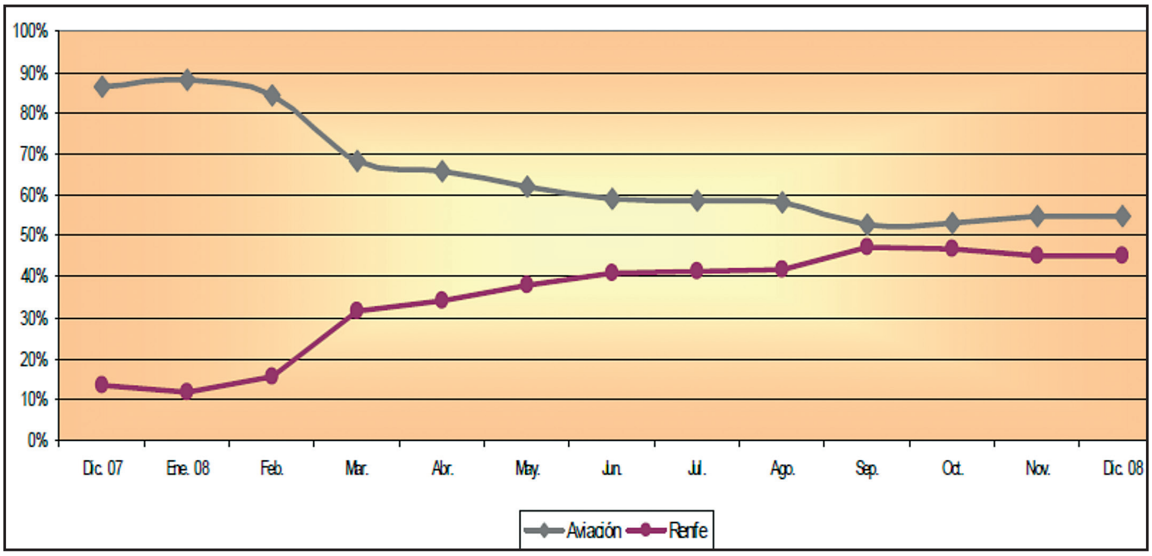
If we look at the newly installed line between Madrid and Barcelona, it should be noted at the outset, given its greater length (621 km) and the problems arising from the introduction of ERTMS Level 2, its entry into commercial service and the authorised levels of maximum speed evolved over time as indicated in Table 5.2.

**DEVELOPMENT BY STAGES ON THE NEW MADRID-BARCELONA LINE (TABLE 5.2)**

| | |
|---|---|
| 10th October 2003 | Beginning of the Madrid-Zaragoza-Lleida connection (train runs at 200 km/h) |
| 19th May 2006 | Increase of speed to 250 km/h |
| 16th October 2006 | Increase of speed to 280 km/h |
| 19th December 2006 | Opening of Lleida-Camp de Tarragona section, Lleida is no longer the terminal on the line |
| 7th May 2007 | Increase of speed to 300 km/h |
| 20 de febrero de 2008 | Inauguración AVE a Barcelona |

The initial impact of the AVE on passenger demand for air travel on the Madrid-Barcelona route, can be seen in Figure 5.15 for the corresponding time period, which is approximately the first year of service of the high speed train. Note how the initial share of air travel, nearly 90%, fell in seven months to around 50%.

**EVOLUTION OF RAIL-AIR MODAL SPLIT ON THE MADRID-BARCELONA ROUTE (DECEMBER 2007-DECEMBER 2008) (FIG. 5.15)**




*Source:* Renfe

At present, the AVE has a market share of 60% compared to air travel.

## 5.4 THE CONSTRUCTION OF NEW LINES

The commercial success of the Madrid-Seville high-speed line was undoubtedly the basis for the construction of the other new high speed railway lines. Currently there is a rail network of 2,515 km in length, geographically distributed as indicated in Figure 5.16.

## HIGH SPEED RAIL NETWORK IN SPAIN IN 2013 (FIG. 5.16)


**Source***:* Adif.

# CHAPTER 6.

# THE PARIS-BRUSSELS-COLOGNE-AMSTERDAM-LONDON PROJECT

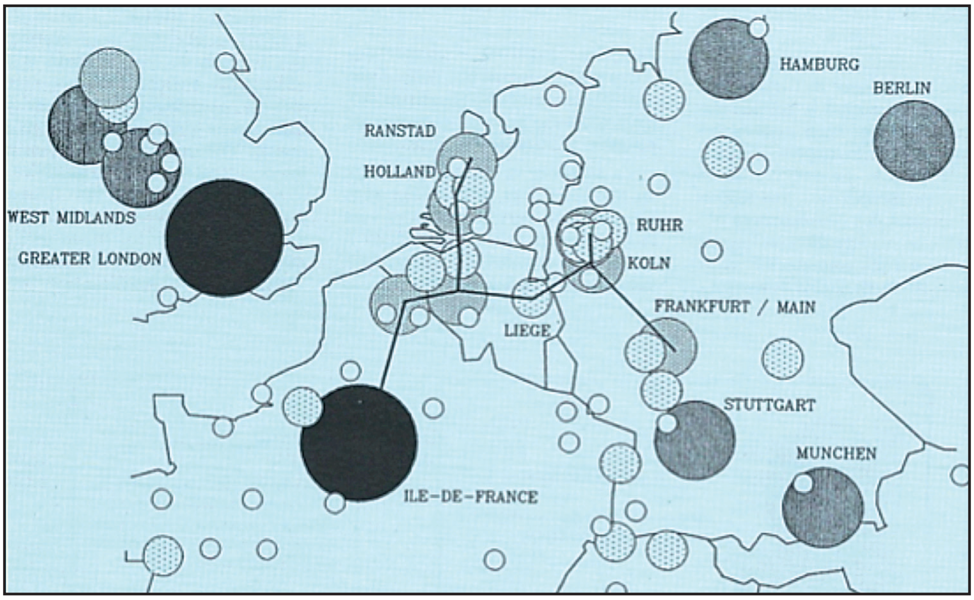
## 6.1 THE GENESIS

It is often noted that the first ideas on setting up high-speed lines in France date back to the early 1960s, with the proposal to build a new line between Paris and Lille which could be covered in 1 hour.

There was no doubt, however, that its implementation would take on greater interest if it were to continue, on the one hand, to Brussels, Cologne and Amsterdam, and on the other, if the tunnel under the English Channel were to be built, to London. However, at that point in time the international form of high speed rail was not yet ready to take its first steps. Thus it was the Paris-Lyon line that was built first.

It was not until the beginning of the 1980s that preliminary studies were made concerning the interest in building a new line in the above geographical area, identifying possible paths and evaluating the expected passenger demand. Figure 6.1 shows the large urban areas affected by this line.

**MAIN URBAN AREAS AFFECTED BY THE PROJECT (FIG 6.1)**




*Source:* G.Chironnier (1992)

Undoubtedly, an important milestone in the progress of these ideas came in July 1983. At that time the transport ministers of France, Germany and Belgium set up a working group to analyse the technical, economic and legal implications of the project.

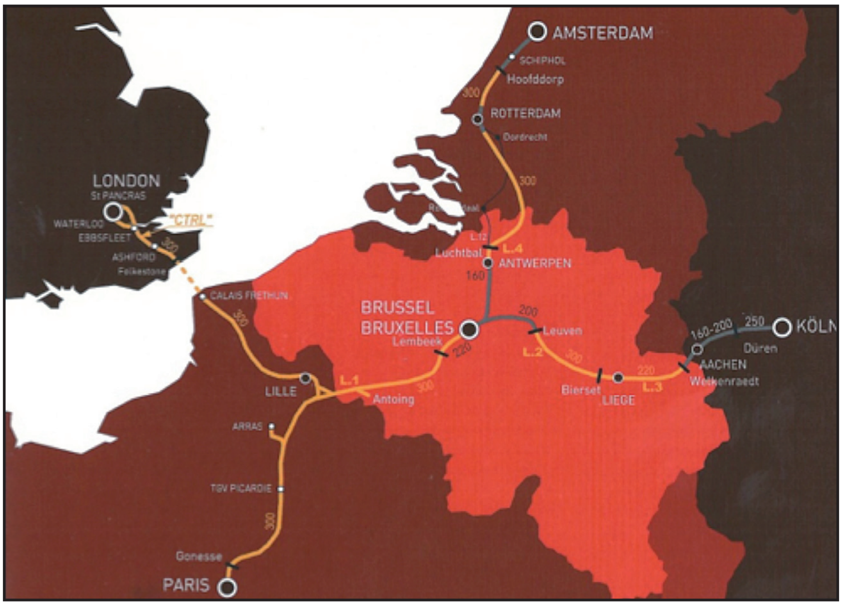
In particular, the completion of the TGV-Nord in France and the construction of some sections of high-speed rail lines in Belgium and Germany, among other countries, would make it possible to:

- Connect Paris with Lille in one hour.
- Link Paris with Brussels in 1h30
- Travel from Paris to Cologne in 2h30

The in-depth work done from 1984 to 1986 on the studies listed above meant that in October 1987 the respective transport ministers of France, Germany and Belgium were able to agree to bring about the project to build a new high-speed line. Each country would be responsible for the section that fell within its own territory.

The Netherlands joined the project and, at the same time, the decision to build the Channel Tunnel in 1984 gave form to the project that was known under the acronym PBKAL. (FIG 6.2)

**PBKAL PROJECT (FIG 6.2)**




*Source:* Tuc Rail (2008)

## 6.2 HIGH-SPEED LINES IN BELGIUM AND THE NETHERLANDS

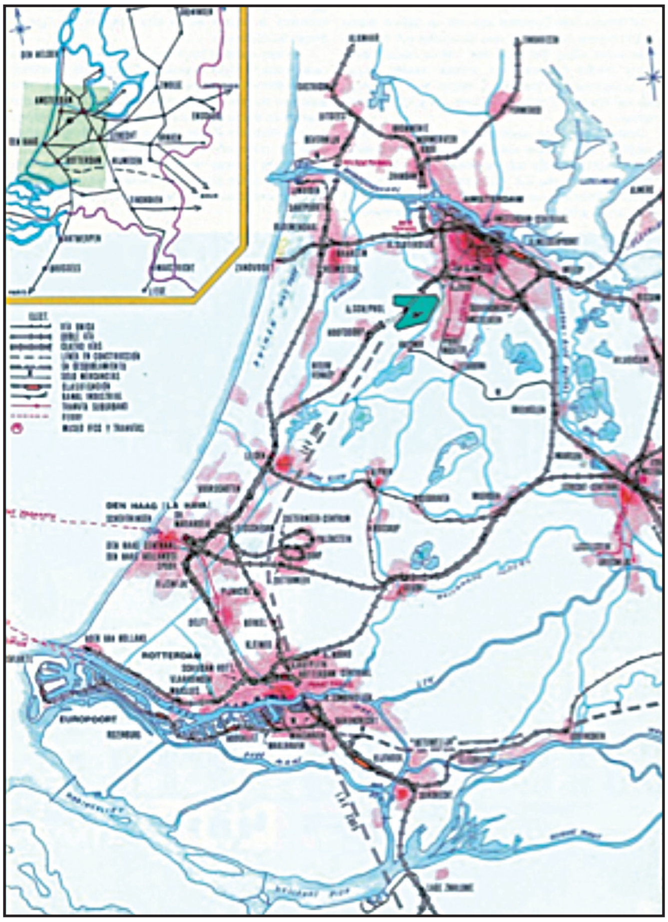
The proposed high-speed line in Belgium began to take shape in 1990, when the Belgian government decided that this would be made up of the lines that are displayed in Fig. 6.2

HSL 1, French border-Brussels (72 km)
HSL 2, Leuven-Liege (65 km)
HSL 3, Liege-German border (36 km)
HSL 4, Antwerp-Dutch border (36 km)

In all it would involve the building of 200 km of high-speed lines, and simultaneously the modernisation of around 150 km in order to allow maximum speeds of up to 220 km/h.

HSL 1 entered service in 1997, HSL 2 in 2002, and HSL 3 and HSL 4 in 2009. The same year saw the commencement of commercial operations on the Belgian border-Schiphol airport section. (FIG 6.3)

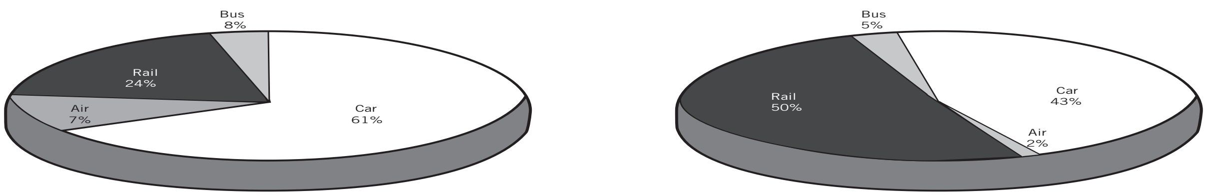
**CONNECTION OF THE HIGH-SPEED LINE WITH SCHIPHOL AIRPORT (FIG 6.3)**



## 6.3 RANGE OF SERVICES AND DEMAND RESPONSE

We refer specifically to the impact on the Paris-Brussels and Paris-London routes. With respect to the former, Fig. 6.4 allows us to appreciate the change made in the passenger modal split, when travel time was reduced from 2h30 in 1994 to 1h25 in 1998.

**CHANGE IN MODAL SPLIT WITH THE TGV IN THE PARIS-BRUSSELS ROUTE (1994-1998) (FIG. 6.4)**




*Source:* UIC

It can be seen that the market share of the railway was doubled compared to its previous share before the high-speed line. Air passenger traffic was virtually non-existent.

# CHAPTER 7.

# THE FIRST HIGH SPEED LINE IN UK

## 7.1 CONVENTIONAL RAIL AND TRAVEL TIMES

It is often recognised that the formula for frequent, fast and regular services introduced by BR in 1966, with the Intercity Services, was one of the first steps to putting together a quality supply in European railways that could efficiently confront the development of road and air travel.

In fact, the word Intercity, was later generalised to mean “fast service” (160 km/h top speed in the first phase, 200 km/h in the second) over medium and long distances with greater frecuency and regular cadence.

In the middle of the 1960´s, on the main routes in the United Kingdom, the commercial speed was more than 90 km/h and on some routes even 120 km/h. (Table 7.1)

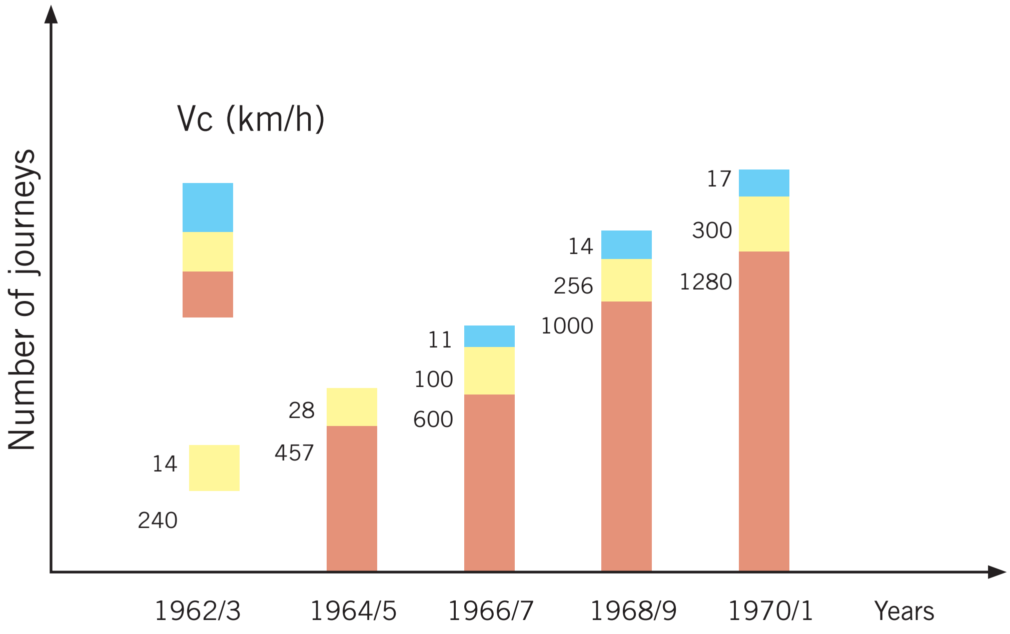
### THE FIRST INTERCITY SERVICES IN THE UNITED KINDOM (THE 1960'S) (TABLE 7.1)

| Connection (km) | Journey Time | Commercial Speed (km/h) | Frequency of Service |
|---|---|---|---|
| London-Manchester/Liverpool (300/320) | 2h 35 | 120 | Hourly |
| London-Newcastle-(430) | 3h 30 | 123 | Hourly |
| London-Bristol-Cardiff (190/232) | 1h 30 / 2h 07 | 127 / 110 | Hourly |
| London-Norwich (185) | 2h | 92 | Hourly |
| London-Birmingan (186) | 2h | 93 | Hourly 30 minutes |
| London-Sheffield (270) | 2h 50 | 95 | Hourly |

*Source:* A. López Pita (1997)

It is interesting to show (fig 7.2) the effort made by BR during the period 1962-1971 in order to increase the commercial speeds on its first itineraries. Within this period the number of daily journeys where $V_c > 112$ km/h went up from 14 to 300

**THE NUMBER OF BR JOURNEY MADE DAILY AT DIFFERENT COMMERCIAL SPEEDS (1962/1971) (FIG. 7.1)**




*Source:* Smith (1973)

As previously shown, the supply of Intercity services initially set up a maximum speed of 160 km/h, was improved in 1976,with the opening to service of the Intercity 125 (125= maximum speed in miles)capable of reaching top speeds of 200 km/h.

In terms of journey time, this new supply brought with it saving of up to 30 minutes on services whose distances were more than 400 km (Table 7.2).

**THE EVOLUTION OF COMMERCIAL RAIL SERVICES IN THE UNITED KINDOM (1966-1978) (TABLE 7.2)**

| The connection from London to (km) | Journey Time and commercial Speed (km/h) | |
|---|---|---|
| | 1966 | 1978 |
| Newcastle (430) | 3h 30 (123) | 3h 04 (140) |
| Edimburgh (630) | 5h (126) | 4h 30 (140) |
| Sheffield (270) | 2h 50 (95) | 2h 15 (120) |
| Norwich (185) | 2h (92) | 1h 40 (111) |
| Manchester (300) | 2h 35 (120) | 2h 25 (124) |
| Bristol (190) | 1h 30 (127) | 1h 30 (132) |

The result was commercial speeds of more than 120 km/h, with maximum values in the region of 140 km/h. All of this on conventional Infrastructures built more than 100 years ago.

From the point of view of the impact on the demand for rail transport of this Improvement in the supply, it is of interest to underline that, at the end of the 1970´s, the railway held significant market shares in maximum distances of around 400 km (Table 7.3).

**THE MODAL DISTRIBUTION OF PASSENGER TRAFFIC IN SOME ENGLISH SERVICES (1980) (TABLE 7.3)**

| The connection from London to (km) | Modal Distribution (%) | | |
|---|---|---|---|
| | Road | Air | Rail |
| Manchester (300) | 42 | 27 | 31 |
| Newcastle (430) | 20 | 35 | 45 |
| Leeds (288) | 48 | 9 | 43 |

## 7. 2 THE STATEGIC ORIENTATION

The experience  from the United Kingdom ten years after the introduction of the Intercity services, in the middle of the 1970´s, made in from part of English policy with respect to the future strategy in relation to the interurban medium and long distance passenger services.

Within the framework of this experience, It is worth highlighting that the commercial results achieved on some service such as London-Birmingham or London-Liverpool, where within barely 4 years the traffic doubled, extrapolating that a journey time by rail of less than 3 hours should constitute an objective in this mode of transport In order to attract a significant part of the demand.

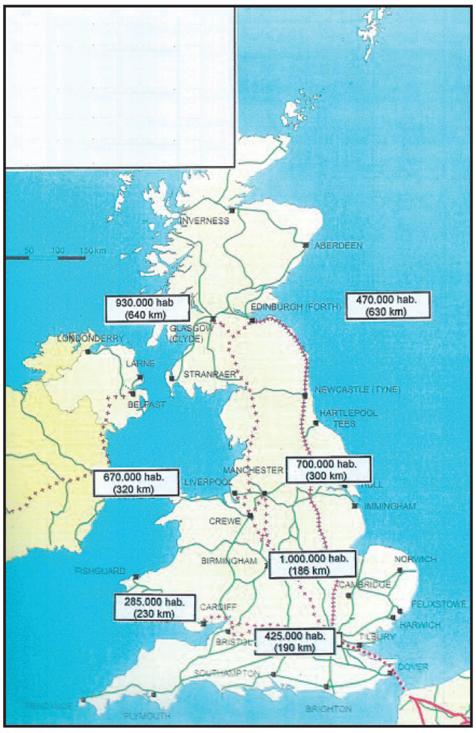
The achievement of the aforementioned "time objective" is of greater technical and economic interest. At it must be obtained on the basis of the modernisation of the existing routes without the need to resort to construction new lines.

The use of APT rolling stock (Advanced Passenger Train) equipped with a system of assisted  tilting, increasing the sensitivity of the travelling speed round a curve, would, therefore, reduce the journey times.

Some of the main arguments on which the previously mentioned orientation strategy is based, can be found in the following facts:

a) The main population centres are found within a maximum radius of some 400 km from London (fig 7.3) with the exception of Glasgow and Edinburgh, situated about 640 km away.

**POPULATION CENTRES WITH A GREATER NUMBER OF INHABITANTS IN THE UNITED KINGDOM IN THE 1970`S (DISTANCE FROM LONDON) (FIG. 7.2)**



b) Within this radius, the journey times in the middle of the 1970´s were less than the criteria previously stated (3h) or were well on the way of being so.

c) Determined corridors permitted already higher speeds, or the feasibility of the modernisation of their geometry was being established.

Thus, on the line between London and Bristol It was possible to travel at 200 km/h after only 5 km from leaving Paddington Station In the English Capital.

On the London-Edinburg service, except for singular points like the Selby gap (which was resolved in 1983 by the construction of a by-pass), a continuous speed of 160/200 km/h was achieved.

d) The introduction of the APT , with top speeds of 250 km/h made It possible to achieve the excellent journey times detailed in Table 7.4, signifying, on some services, a journey time of less than by air.

**THE PREDICTABLE INCIDENCE OF TILTING TRAINS IN THE REDUCTION OF JOURNEY TIMES IN THE UNITED KINGDOM (TABLE 7.4)**

| From London to | Km | Time | | | | |
|---|---|---|---|---|---|---|
| | | Conventional trains | | | APT train | |
| | | 1971 | 1975 | | | |
| | | 144/160* | 160* | 200* | 200* | 250* |
| Newcastle | 430 | 3h 35 | 3h 20 | 3h | 2h 40 | 2h 20 |
| Leeds | 298 | 2h 36 | 2h 25 | 2h 07 | 1h 55 | 1h 45 |
| Glasgow | 642 | 5h 54 | 5h 10 | - | 4h 15 | 4h |
| Manchester | 302 | 2h 31 | 2h 25 | - | 2h 10 | 2h |
| Cardiff | 232 | 2h 07 | - | 1h 44 | 1h 36 | 1h 26 |
| Bristol | 189 | 1h 40 | - | 1h 23 | 1h 17 | 1h 07 |

**Maximum* speed

Source: Cambell (1979)

e) On the hypothesis of the APT travelling at 250 km/h, for the main connections from London, the rail market share with respect to the rail/air binomial was more than 50% (Table 7.5).

**THE PREDICTABLE RAIL/AIR MODAL DISTRIBUTION ON SOME SERVICES FROM LONDON WITH THE ATP (TABLE 7.5)**

| From London to | Railway journey time | Market share % | |
|---|---|---|---|
| | | Rail | Air |
| Manchester | 2h | 85 | 15 |
| Newcastle | 2h 20 | 80 | 20 |
| Edinburg | 4h | 64 | 36 |
| Glasgow | 4h | 51 | 49 |

*Source:* Compiled by Author from data from Marsh (1973)

In summary, the reasons for the orientation adopted by BR for the interurban passenger services seem objectively solid: the modernisation of the existing routes (with intrinsically favourable characteristics for the development of higher services), the use of tilting trains and the refusal to build new lines.

## 7.3 THE FIRST HIGH-SPEED LINE IN THE UK

The opening of the Channel Tunnel in May 1994 from November of that year allowed the Eurostar train to join Paris and London, using the layout shown in Fig. 7.3.

**ROUTE OF PARIS-LONDON EUROSTAR SERVICES IN NOVEMBER 1994 (FIG. 7.3)**

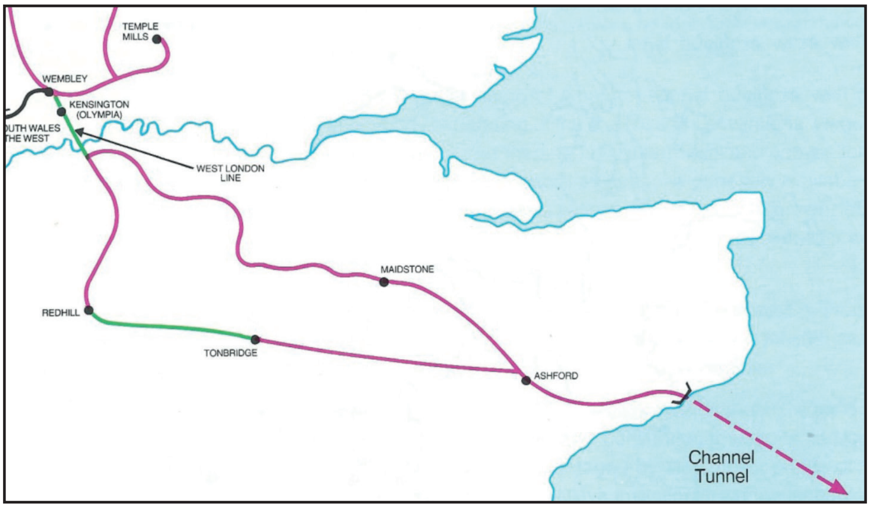

*Source:* M. Lomazzi (1995)

Note that from Paris to Calais there was a high-speed line available, suitable for travelling at a speed of 300 km/h. From Calais to Folkestone, that is, through the Channel Tunnel, it was possible to travel at 160 km/h.

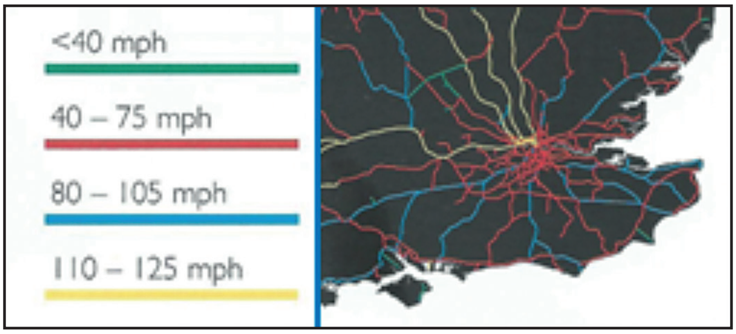
Lastly, from the tunnel exit to London the Eurostar used the classic line, via Ashford and Tonbridge (Fig. 6.3), with third rail electrification, and whose maximum speed was in the range of 80 to 105 mph (130-160 km/h), as shown in Fig. 7.4

## PATH AND FEATURES OF THE LINE USED BY EUROSTAR BETWEEN FOLKESTONE AND LONDON IN 1995 (FIG. 7.4)

a) Path




b) Maximum speeds




c) Third rail electrification

*Source:* Author's own work, compiled from various references.

This meant that the travel time of the Eurostar train between London and Paris was 3 hours for non-stop trains. The total distance was 494 km. For the purpose of this section, it is interesting to show some timetables in Table 7.6.

### DISTANCES AND TRAVEL TIMES ON PARIS-LONDON ROUTE (TABLE 7.6)

| Station | km | Timetable | | |
|---|---|---|---|---|
| Paris (Gare du Nord) | 0 | 17:43 | 13:04 | 14:43 |
| Calais-Fretun | 326 | ↓ | 14:31 | ↓ |
| Ashford | 401 | ↓ | 15:08 | 16:42 |
| London Waterloo | 494 | 20:43 | 16:09 | 17:43 |

Source: Author's own work. Data from European Timetable, Thomas Cook (1999)

Looking at this table, we can see that:

a) On the Paris to Calais-Fretun high-speed section (326 km), the Eurostar took 1h27. That is, a commercial speed of 225 km/h.

b) The trip through the Channel Tunnel and the arrival in Ashford (75 km), took 37 minutes. That is, a commercial speed of 122 km/h.

c) The final section, between Ashford and London (93 km), took 1h01. That is, a commercial speed of 91.4 km/h.

Consequently, the negative effect on travel time posed by the features offered by the classic line between Folkestone and London was apparent.

In fact the construction of a new line between the two cities which was suitable for high-speed travel would reduce the travel time between Paris and London from 3 hours to 2h15 or 2h20.

Consequently the construction of a new line between London and the Channel Tunnel was begun, with the aim of:

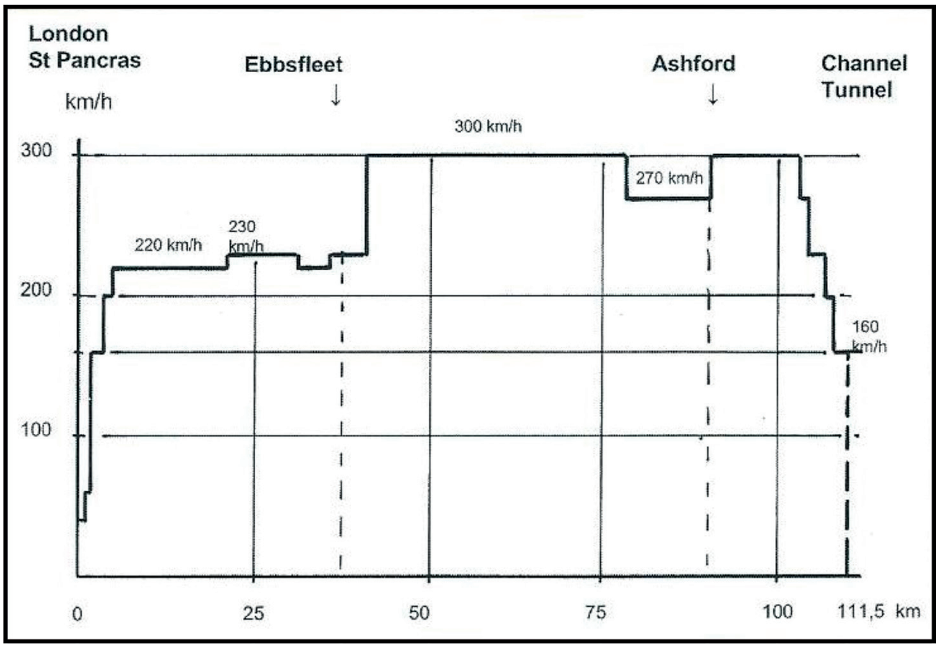
a) Allowing a faster and above all more reliable service (since it would not be affected by local traffic).

b) Increasing the capacity of the existing rail network in South-East London, releasing the timetable slots left by the Eurostar.

c) Creating new regional routes, using the new line between London and Kent.

This new line of 113 km in length was opened in two phases: the first section, between the Channel Tunnel and Fawkham Junction (74 km), in 2003, and the second, from there to London (39 km) in 2007. Fig. 7.5 shows the chart of maximum speeds. Note the difficulties involved in entry to London at high speed.

**DIAGRAM OF MAXIMUM SPEEDS OF THE LONDON-CHANNEL TUNNEL LINE (FIG. 7.5)**




## 7.4 RANGE OF SERVICES AND DEMAND RESPONSE

As regards the Paris-London route, various milestones can be differentiated.

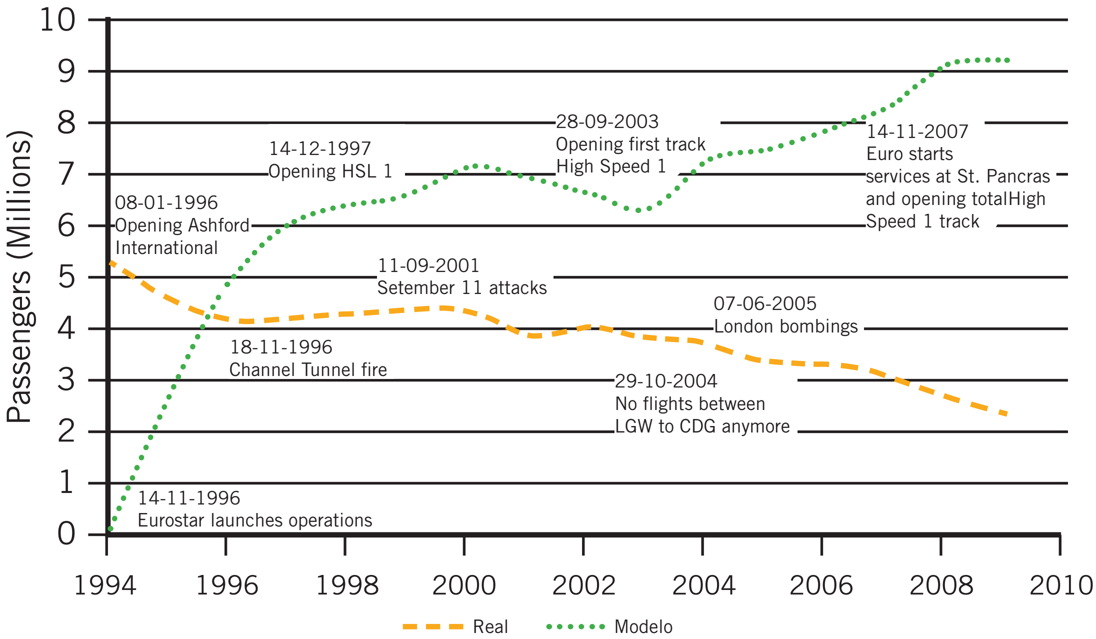
The first comes with the entry into operation of Eurostar services, with a journey time of 3 hours. The market share of these services was around 50%.

After the opening in September 2003 of the first high speed section between the Channel Tunnel and Fawkham, travel time was reduced to 2h35, increasing market share progressively: February 2004 (66%), August 2005 (71%), 2006 (76%).

Finally, when the time dropped to 2h15, with the opening of the second high speed section between Fawkham and London, in November 2007, the market share of the railway exceeded 80%.

Figure 7.6 displays the evolution of railway and air passenger demand since the launch of the Eurostar service in 1994.

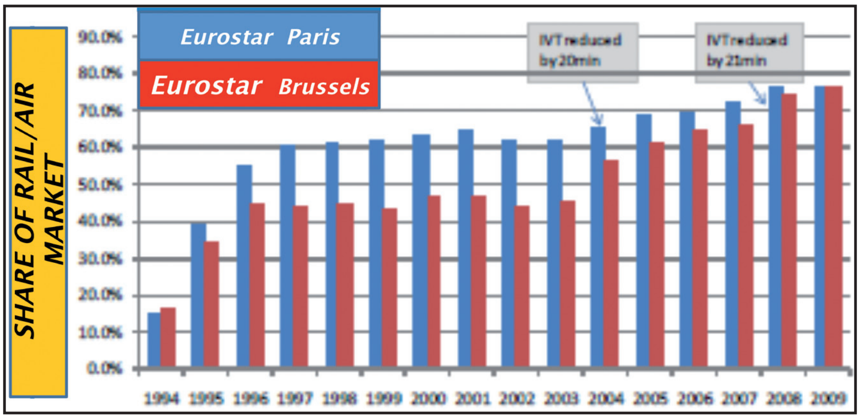
**IMPACT OF THE EUROSTAR SERVICE ON AIR TRANSPORT (FIG. 7.6)**




*Source:* Behrens and Pels (2012)

The preceding information may be completed in accordance with figure 7.7. This figure shows the evolution of the Eurostar market share during the 1994-2009 period, for the London-Brussels and London-Paris routes, in comparison with air transport services.

### EUROSTAR SHARE OF RAIL/AIR MARKET (FIG. 7.7)

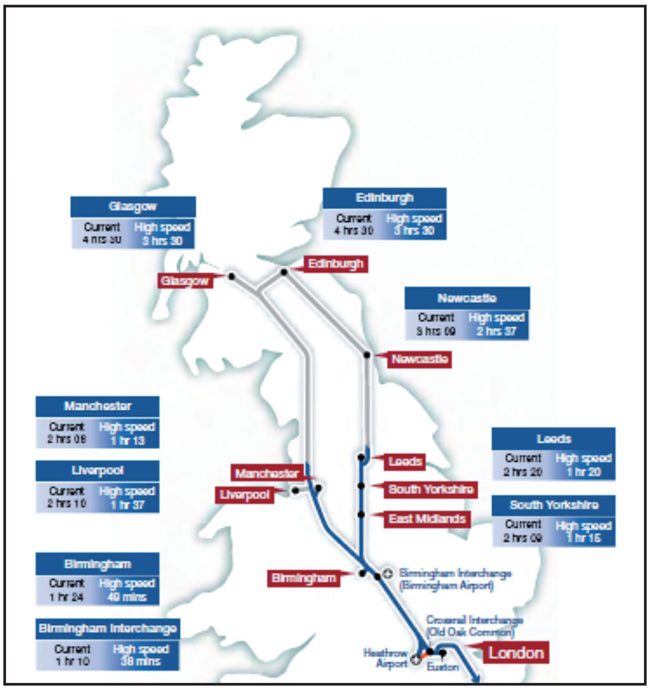



*Source:* SKM (2010)

## 7.5 CONSTRUCTION OF NEW LINES IN U.K

The success of HS1 has led us towards a national HSR network. The building of a second high speed line in the UK is currently in the planning stages. Specifically it would involve the creation of a Y-shaped line. The common section would connect London with Birmingham. From Birmingham, a new path would go to Manchester and the other to Leeds (Fig. 7.8).

### HIGH SPEED LINES PLANNED IN THE FIRST PHASE FROM LONDON (FIG 7.8)



It underlines the fact that one of the primary motives necessitating the construction of the lines indicated in figure 7.9 lies in the problems stemming from lack of capacity, which it is estimated will occur within approximately 15 years, as displayed in figure 7.9.

**TRANSPORT PROJECTIONS FOR RAILWAY ROUTES FROM LONDON UP TO 2030 (FIG. 7.9)**


*Source:* J. Sterr (2012)

# CHAPTER 8.

# THE FIRST HIGH-SPEED TRAIN LINE IN SOUTH KOREA

## 8.1 THE EXISTING PROBLEM

In the 1980s, South Korea, which covered an area of 99,000 km2, had a population of 43 million. Out of this, around 70% was distributed along the diagonal linking the towns of Seoul (10 million inhabitants) and Busan (then known as Pusan, with 3.7 million inhabitants). (Figure 8.1) In economic terms, this corridor accounted for 70% of the country's GDP.

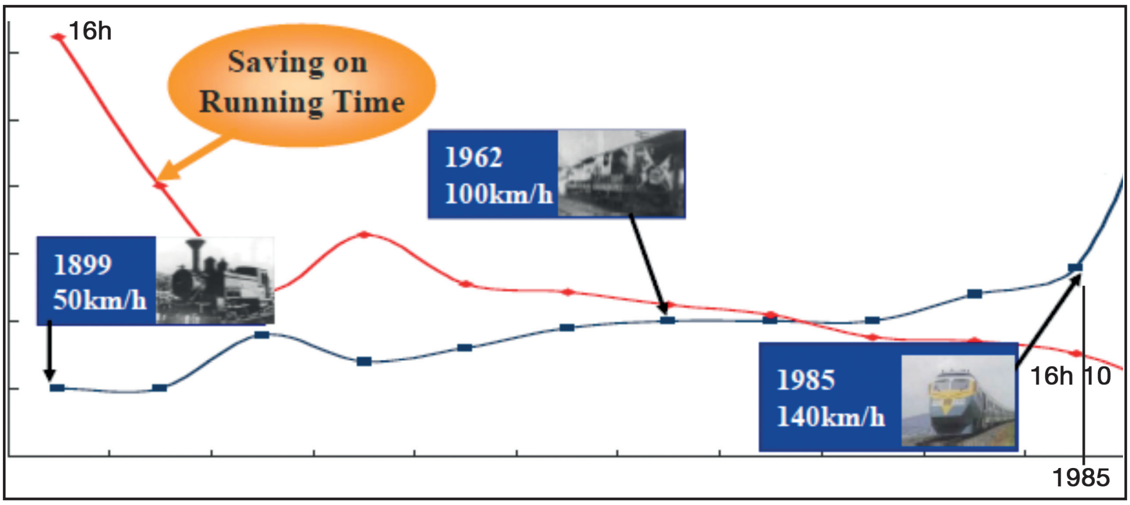
**POPULATION DISTRIBUTION IN SOUTH KOREA (FIG. 8.1)**


The rail network was made up of a collection of lines (Figure 8.2) that stretched along more than 3,500 km. The main one, called the "Gyeongbu Line" connected Seoul to Busan and had its main intermediate stations in the cities of Daejeon and Daegu.

## CONVENTIONAL LINES (FIG. 8.2)


With respect to travel time, it can be seen that during the 20th century the maximum speed went from 50 km/h in 1899 to 140 km/h in the mid 1980s. In 1962, it reached 100 km/h. In 1985, the fastest train covered the Seoul-Busan route in 4h10m. (Figure 8.3)

## EVOLUTION OF MAXIMUM SPEED AND TRAVEL TIME ON THE SEOUL-BUSAN ROUTE (FIG. 8.3)




*Source:* Jin Ho LEE (2012)

The rapid growth of the economy from the early 1950s was not accompanied by a strengthening of the transport system, or at least, only of the road infrastructure. It is no wonder, then, that since the early 1980s that road infrastructure has been saturated.

As an example, a trip by car between the aforementioned cities, just 400 km apart, required a travel time of between 8 and 10 hours because of the lack of capacity on the existing highway. By motorway circulated 70,000 vehicles daily. But its capacity was only 40,000 vehicles per day

In terms of air travel, it should be noted that although the flight on that route only took 50 minutes, the travel time from door to door was considerably longer. Indeed, the road access to Seoul's main airport at the time (Kimpo, now Gimpo) required one hour and boarding procedures took another hour or so. Access from Busan airport to the city centre took 90 minutes. That is, a total of 4h30m.

With regard to rail, and as noted above, the travel time in the mid 1980s was 4h10m. Nevertheless it was necessary to book the ticket at least 10 days in advance. Furthermore, in the time frame we are looking at, the Seoul-Busan line was close to its saturation point. The number of circulations per day and per direction was over 130.

It is not surprising, then, that the South Korean government should have been thinking since 1981 about providing the Seoul-Busan corridor with a new transport infrastructure. Indeed, preliminary feasibility studies sponsored by the International Bank for Reconstruction and Development (IBRD) were undertaken in 1973-74 and continued with follow-up feasibility studies from 1978 to 1981.

Also, in 1983, the Korea Transport Institute (KOTI) commissioned the US consultant Louis Berger to conduct a study on the feasibility of carrying out the construction of a high-speed line.

## 8.2 THE DECISION TAKEN

In any case, when deciding which type of infrastructure was the most convenient between Seoul and Busan, the following alternatives were considered:

a) To build a highway with four lanes in each direction
b) To build a conventional two-way railway line
c) To build a high-speed line

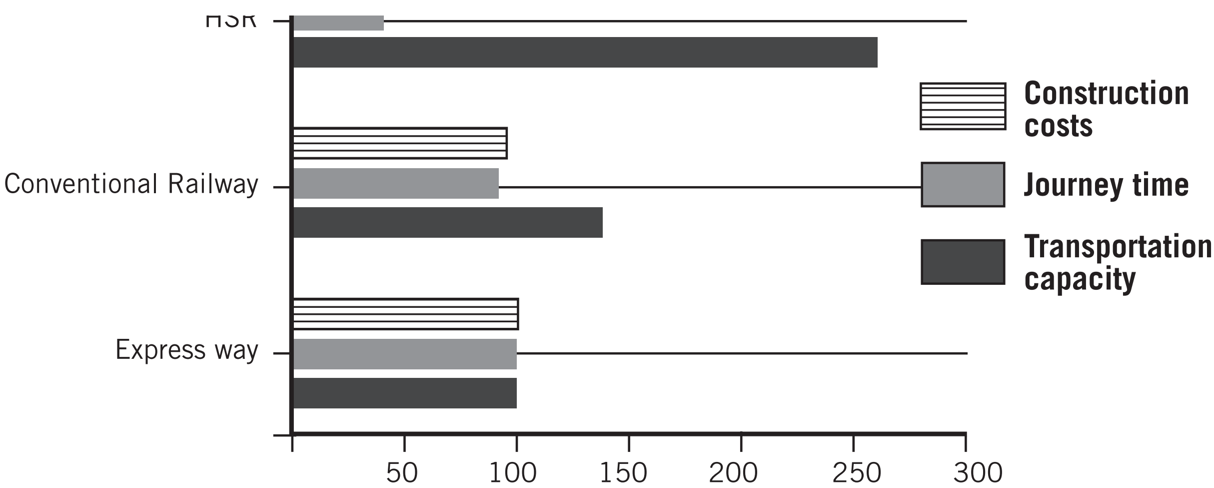
The above analysis led to the Table 8.1. This shows the main indicators for each of the alternatives mentioned above: investment required, travel time and transport capacity.

## COMPARISON OF ALTERNATIVES FOR CAPACITY INCREASE ON THE SEOUL-BUSAN CORRIDOR (MINISTRY OF CONSTRUCTION AND TRANSPORT, SOUTH KOREA) (TABLE 8.1)

| | High-speed rail (A) | Highway (B) | Double track rail (C) | A/B | A/C |
|---|---|---|---|---|---|
| Construction costs | 0.382 bil. Won | 262 | 250 | 1.46 | 1.53 |
| Transport capacity | 520,000 passengers per day | 25 | 27.5 | 2.08 | 1.89 |
| Travel time | 1h 56m | 5h 20m | 3h 50m | Δ 27 | Δ 1.98 |
| * Transport Efficiency | 3.93 | 1 | 1.60 | - | - |

Based on the results obtained (fig 8.4) , the construction of a new high speed line between Seoul and Busan was recognised as the most suitable alternative to resolve the problems of lack of capacity in the corridor. The decision to build this line was taken in May 1989, and the first work began in December 1992.

## COMPARISON OF ALTERNATIVES FOR TRANSPORT EFFICIENCY (FIG 8.4)



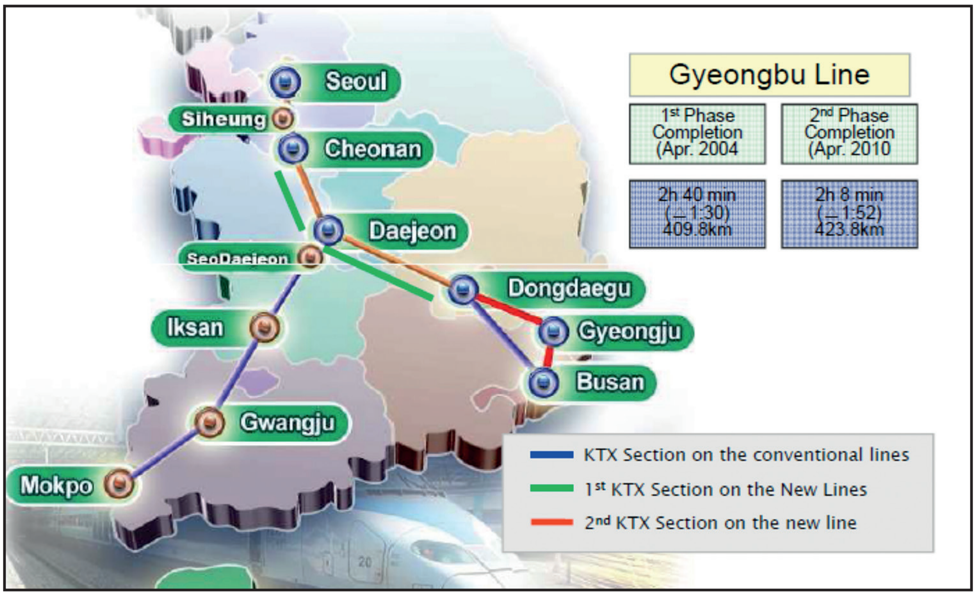

**Transport* Efficiency: Transport Capacity / Travel Time x Construction Costs

*Source:* Dong-Chun Shin and Lee Kwansup (2011)

With a daily transport capacity of 520,000 travellers, the high-speed line is expected to increase transport capacity 2.6 times over. In addition, the transfer of passenger traffic from the conventional line to the high-speed line would increase freight capacity in the Seoul-Busan corridor, which is expected to go from 350,000 containers to more than 3 million.

A modification to the basic business plan was made in 1998, reflecting changing economic and social environments, including escalating construction costs during a financially difficult period and a regional conflict between the southeast and southwest regions. In accordance with the modified plan, a new KTX line from Seoul to Daegu would be completed, and the Daegu-Busan sector would be electrified by 2004 (the first phase). The remaining work on the new Daegu-Busan line would be finished by 2010 (the second phase). (Figure 8.5)

**SEOUL-BUSAN HIGH-SPEED LINE (FIG. 8.5)**




The second section of the new line, between Daegu and Busan, finally entered commercial service in November 2010.

## 8.3 RANGE OF SERVICES AND DEMAND RESPONSE

The first section of the new line between Seoul and Busan, which was completed in Daegu, entered commercial service in April 2004, with the travel times indicated in Figure 8.5.

As for fare level, Table 8.2 shows the attractiveness of the rail offering over that of air travel. Note how high-speed train services had significantly lower fares than those of air travel.

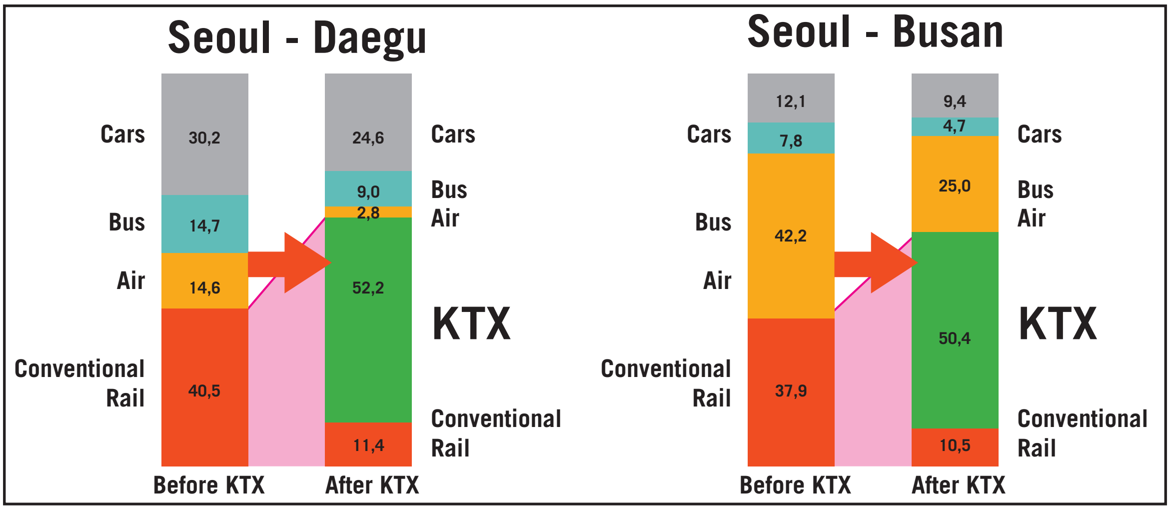
### FARE LEVEL FOR HIGH-SPEED RAIL AND AIR TRAVEL IN SOUTH KOREA (TABLE 8.2)

| Section | High-speed train | | Air travel | Rail/air share |
|---|---|---|---|---|
| | Business | Economy | | |
| Seoul-Daegu | 42.08 | 30.03 | 53.36 | 56% |
| Seoul-Busan | 54.23 | 38.73 | 60.67 | 64% |

*Source:* Chun-Hwan (2005)

It is not surprising, therefore, that the modal split in passenger traffic in all modes of transport was changed significantly. Figure 8.6 shows the effect of high-speed rail on the Seoul-Daegu and Seoul-Busan connections.

### EFFECT OF HIGH-SPEED RAIL IN SOUTH KOREA (2004/2005) (FIG. 8.6)




In terms of the number of railway passengers, the new line produced the following results:

a) During the first month of operation of the new line (1st to 30th April 2004), the demand exceeded 2 million travellers.

b) During the first eight months (April-December 2004), traffic amounted to 19.88 million passengers.

c) Finally, during the first full year of operation (2005), 32.37 million passengers were transported.

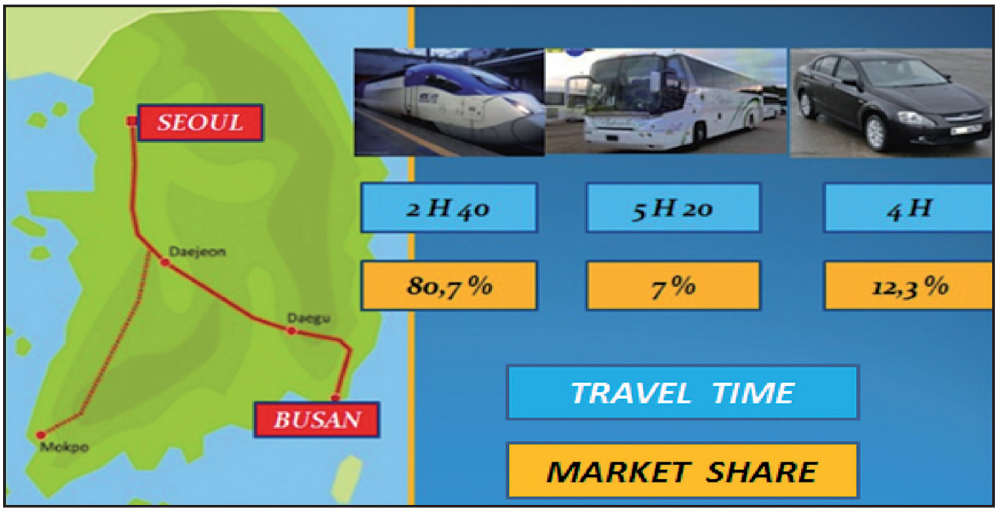
The preceding values showed the size of the impact that high-speed rail had on the transport system in South Korea.

For the first route, Seoul-Daegu (around 300 km), the railway became the dominant mode of transport, with 52.2% of market share for high-speed trains. Air services came to play a minor role with only 2.8 % of travellers.

On the second route, Seoul-Busan (around 410 km) and with a travel time of 2h40m, the railway was also the preferred mode of travel (50.4% market share). However, air travel maintained a share of 25% (although it lost 17 points with the advent of the high-speed train).

If we compare the modal split for the land modes on the Seoul-Busan route, we obtain the results shown in Figure 8.7

**EFFECT OF HIGH-SPEED SERVICES ON ROAD TRAVEL (SOUTH KOREA), 2008 (FIG. 8.7)**




*Source:* Author's own work.

We can see the absolute predominance of the railway with a market share of 80%, compared with 20% for road travel.

## 8.4 THE CONSTRUCTION OF NEW LINES

Although major mobility problems existed in the Seoul-Busan corridor, from the outset, the idea that governed the advent of high-speed rail in South Korea was the construction of a section with these characteristics between Osong and Mokpo, of around 250 km in length (Figure 8.8). Its completion is scheduled for 2017. Other lines are currently under analysis.

**NEW LINE OSONG-MOKPO (FIG. 8.8)**

# CHAPTER 9.

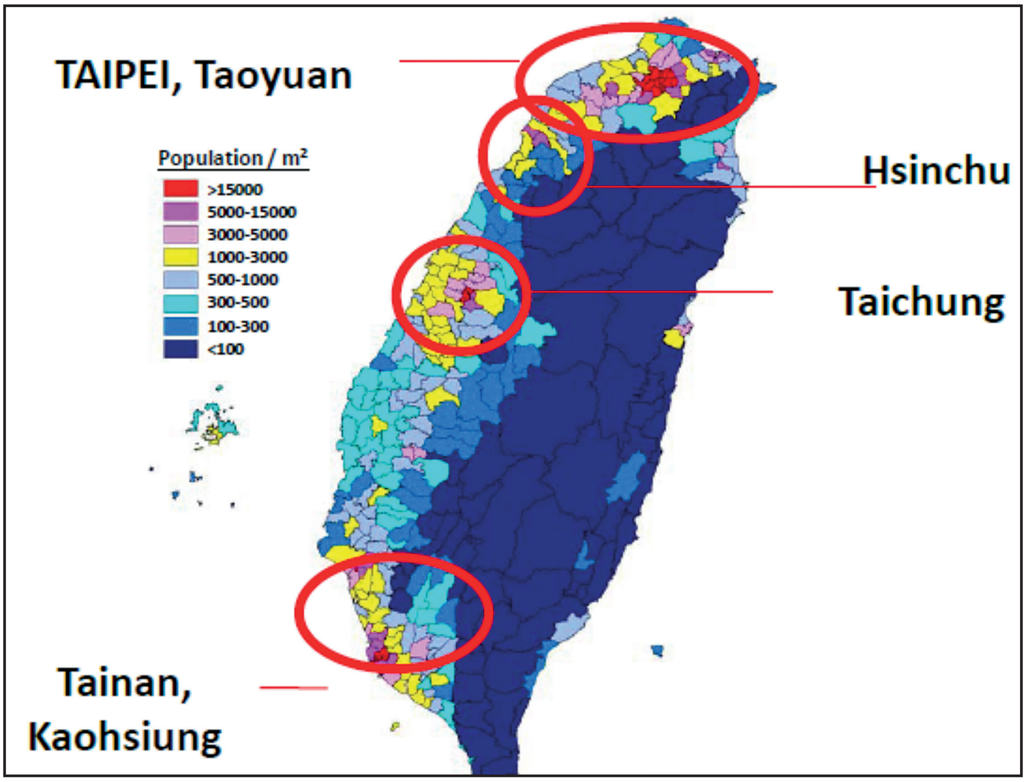
# THE FIRST HIGH-SPEED TRAIN LINE IN TAIWAN

## 9.1 THE EXISTING PROBLEM

The island of Taiwan has an area of 36,000 km2. At its longest it is 394 km in length, with a maximum width of 144 km. Taiwan has one of the highest population densities in the world, with an average value of 716 inhabitants/km2. However, in some areas this value rises to a staggering 2148 inhabitants/km2.

In the early 1980s, the total population was 18 million people, 90% of whom were located on the west coast of the island, in a narrow zone of 50 km that lay between the sea and the mountains (Figure 9.1)

**POPULATION DISTRIBUTION (FIG. 9.1)**




*Source:* T. Kao

The major cities in terms of population were Taipei, in the north, with 4 million inhabitants in 1990, and Kaohsiung in the south, with 2 million.

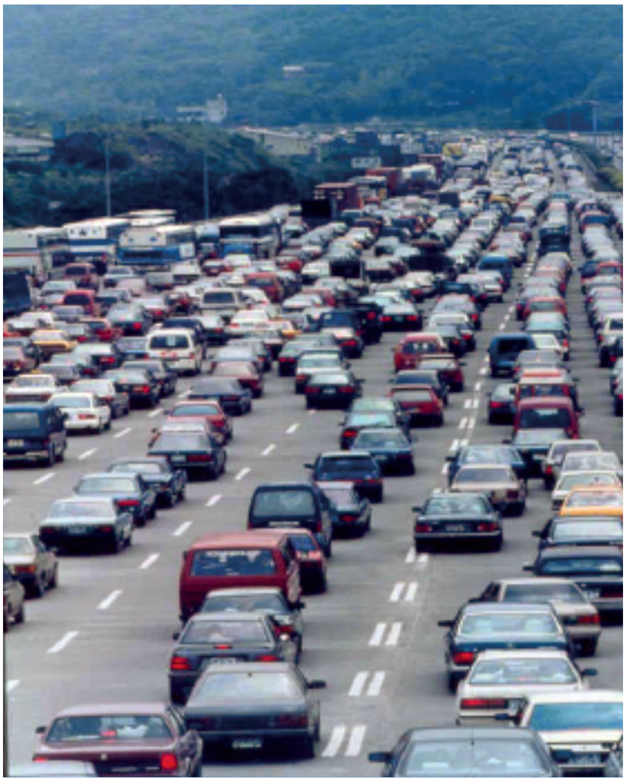
In economic terms, this western corridor accounted for approximately 98% of total GNP.

Addressing the mobility needs of this corridor were the following:

1) Air services offering over 200 flights a day on the main routes from Taipei, which was principally with the cities of Taichung, Chiayi, Tainana and Kaohsiung.

2) A high-performance road infrastructure, built in the early 1970s, between Taiwan and Kaohsiung. This had a minimum of two lanes per direction in some sections, while in others there were up to five lanes (Figure 9.2)

**SATURATION OF THE TAIPEI-KAOHSIUNG HIGHWAY (FIG. 9.2)**



Despite this, the problems with lack of capacity were constant. As a result, the distance between Taipei and Kaohsiung (350 km) could not be covered in less than 6 hours.

3) The railway, with a metre-gauge line, on which it was not possible to travel faster than 120 km/h. The fastest train, the Tzu-Chang, obtained an average speed of 87 km/h, equivalent to a travel time of around 4 hours between the aforementioned cities. Nevertheless, the railway, after the opening of the highway in 1978, continued to lose market share at a steady rate.

Technical studies conducted at that time to analyse the possibility of changing that line to standard gauge, in order to increase its carrying capacity, showed the following:

a) It would need major investment.

b) It would take several years to carry out.

c) There were minimal benefits to be gained from this action.

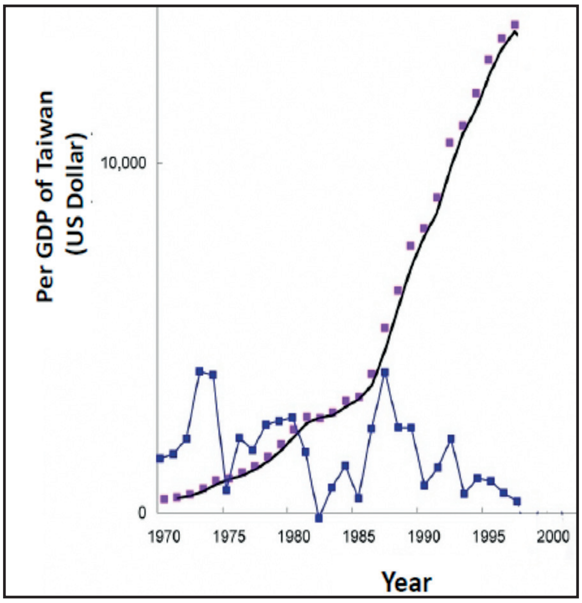
## 9.2 THE DECISION TAKEN

The problems discussed in the previous section and the fact that:

1) Forecasts regarding the evolution of the number of cars in that corridor indicated that it would go from 424,000 in 1980 to over 2 million in 1990.

2) Gross Domestic Product continued to grow significantly (Figure 9.3),

**EVOLUTION OF GDP OF TAIWAN (FIG 9.3)**




led the Taiwanese Prime Minister to commission an investigation, in 1987, regarding the feasibility of providing the corridor with a high-speed train line.

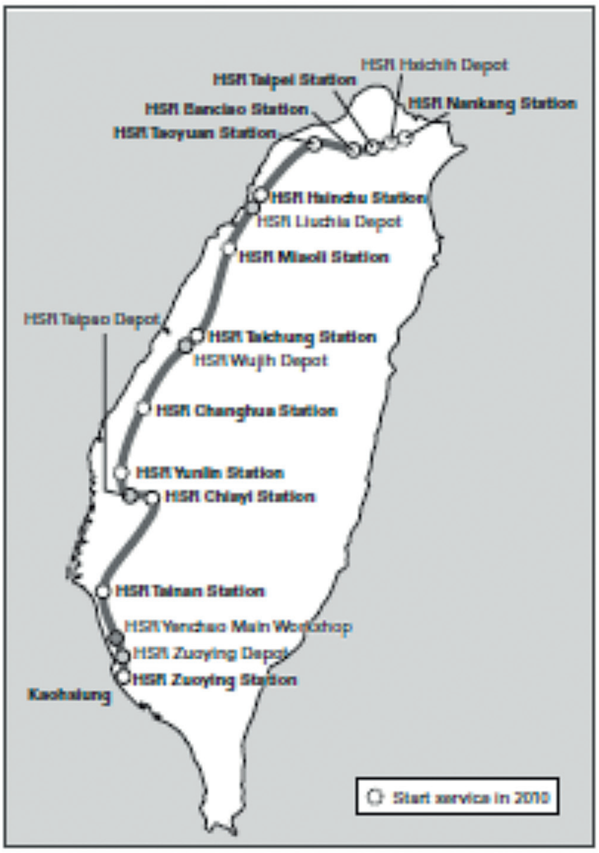
The Institute of Transport at the Ministry of Transport and Communications (MOTC) was commissioned to carry out the investigation, working alongside local and European engineers. The conclusion they reached, in 1990, was that the high-speed line was viable. The central government approved the preliminary plan that year.

The Government gave its agreement, in principle, that year, and an agency was set up called BOTHSR (Bureau of Taiwan High-Speed Rail), which was responsible for carrying out the planning and construction of the new line.

It should be noted that the preliminary plan, approved in 1991, was revised in 1992 in order to encompass development projects involving new cities and industrial locations.

In this new approach it was considered necessary for the line initially to have 7 to 10 intermediate stations. (Fig. 9.4)

**ROUTE OF TAIWAN HIGH SPEED RAIL (FIG 9.4)**




*Source:* T.Shima (2007)

The new line, 345 km in length, entered commercial service in January 2007.

## 9.3 RANGE OF SERVICES AND DEMAND RESPONSE

The offering of commercial services evolved gradually, going from 19 services per day in January 2007, to 44 in September 2007, as shown in Table 9.1

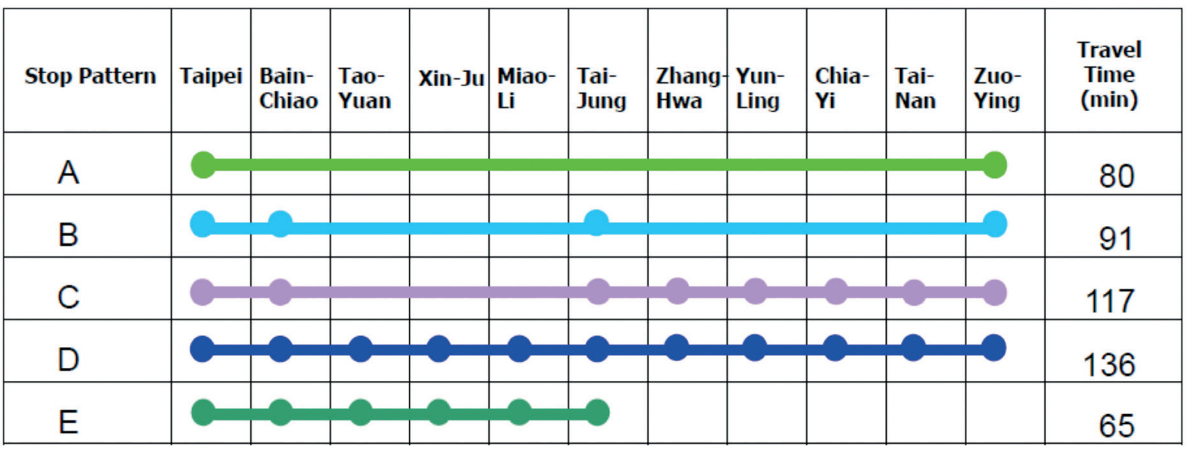
### EVOLUTION OF THE FREQUENCY OF SERVICES ON THE TAIPEI-KAOHSIUNG ROUTE (TABLE 9.1)

| MONTH | TRAINS/DAY/DIRECTION |
|---|---|
| JANUARY 2007 | 19 |
| MARCH 2007 | 25 |
| JUNE 2007 | 31 |
| JULY 2007 | 37 |
| SEPTEMBER 2007 | 44 |

Source: Author's own work. Data from S. Lin

It can be seen in Figure 9.5 that the services on the line were grouped into five categories. The first included direct non-stop trains between Taipei and Zuoying. Their travel time was 1h20m. The second category featured trains which stopped at two intermediate stations: Banciao and Taichung. In this case, the travel time from the beginning to the end of the line rose to 1h31m. The rest of the train categories are shown in Figure 9.5 above.

### STOPPING PATTERNS (FIG 9.5)




*Source:T.Shima* (2007)

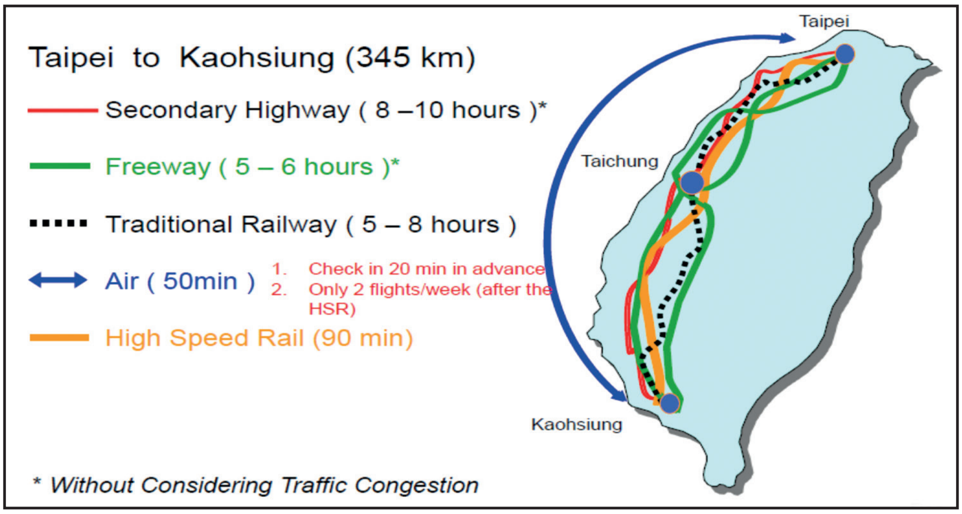
Table 9.2 shows an excerpt from the timetables which were current in June 2007. There was a total offering of 31 trains per day and direction.

### EXCERT FROM THE THSR TIMETABLE (JUNE 2007) (TABLE 9.2)

| Train No | Taipei | Banciao | Taoyuan | Hsinchu | Taichung | Chiayi | Tainan | Zouying |
|---|---|---|---|---|---|---|---|---|
| 103 | 07:00 | 07:09 | - | - | 07:52 | - | - | 08:36 |
| 403 | 07:30 | 07:39 | 07:52 | 08:04 | 08:30 | 08:56 | 09:15 | 09:30 |
| 107 | 08:00 | 08:09 | - | - | 08:52 | - | - | 09:36 |
| 405 | 08:30 | 08:39 | 08:52 | 09:04 | 09:30 | 09:56 | 10:15 | 10:30 |
| 111 | 09:00 | 09:09 | - | - | 09:52 | - | - | 10:36 |
| 407 | 09:30 | 09:39 | 09:52 | 10:04 | 10:30 | 10:56 | 11:15 | 11:30 |
| 505 | 10:06 | 10:15 | 10:28 | 10:40 | 11:03 | | | |
| 207 | 10:18 | 10:27 | - | - | 11:10 | 11:34 | 11:53 | 12:06 |
| 409 | 10:30 | 10:39 | 10:52 | 11:04 | 11:30 | 11:56 | 12:15 | 12:30 |

Lastly, Figure 9.6 shows a summary of the travel time offered by each mode of transport on the Taipei-Kaohsiung route

### TRAVEL TIME OFFERED BY EACH MODE OF TRANSPORT ON THE TAIPEI-KAOHSIUNG ROUTE (FIG 9.6)




Regarding the fare level, Table 9.3 shows a comparison of the fares for conventional rail service with those of high-speed rail. Alongside them are shown the fares for competing modes: air and bus.

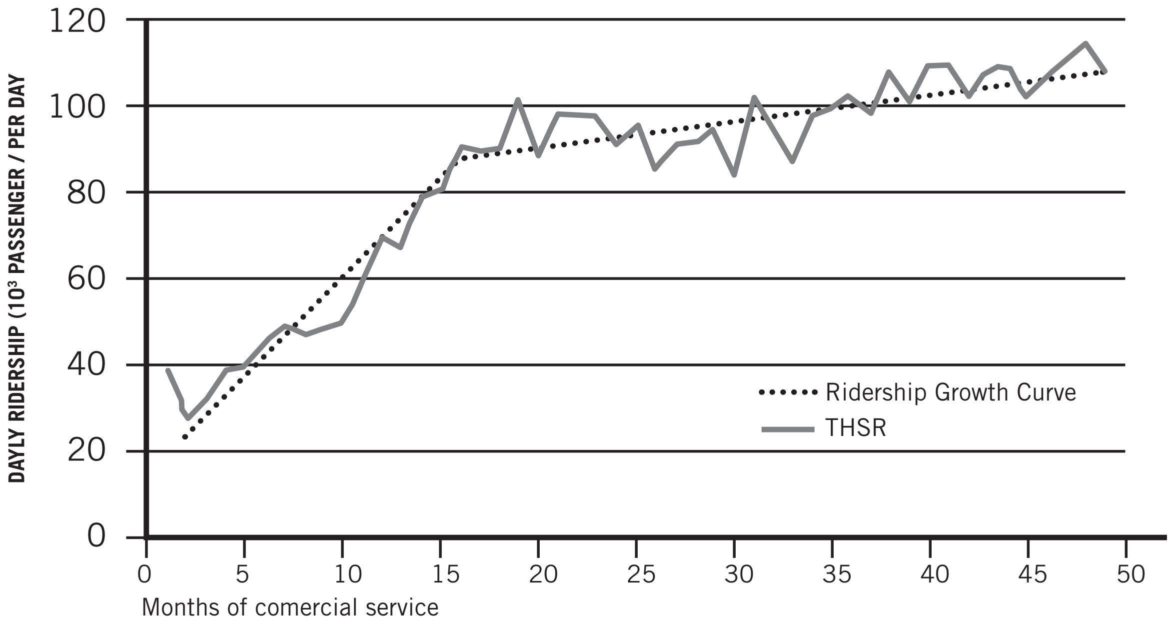
## SERVICES PROVIDED FROM TAIPEI BY DIFFERENT TRANSPORT MODES (TABLE 9.3)

| trip | Conventional Rail | | HSR | | | Bus | | Air | |
|---|---|---|---|---|---|---|---|---|---|
| | Travel time | Fare Price (SUSD) | Travel | Fare Price (SUSD) | | Travel time | Fare Price (SUSD) | Travel time | Fare Price (SUSD) |
| | | | | Business | Standard | | | | |
| Taipei-Taichung | 2hr 15 min | 11 | 53 min (direct) | 30 | 21 | 2hr | 12 | - | - |
| Taipei-Chiayi | 3hr 30 min | 18 | 1hr 34 min | 44 | 33 | 3hr | 10 | - | - |
| Taipei-Tainan | 4hr 14 min | 22 | 1hr 55 min | 54 | 41 | 4hr | 18 | 55 min | 41 |
| Taipei-Zouying | 4hr 40 min | 25 | 1hr 34 min (direct) | 59 | 45 | - | - | - | - |
| Taipei-Kaohsiung | 4hr 50 min | 26 | - | - | - | 5hr | 22 | 50 min | 52 |

*Source:* Lin (2008)

As for demand response, Figure 9.7 shows the evolution undergone by passenger traffic on the new line in the months following its opening for commercial operations.

## EVOLUTION OF PASSENGER DEMAND (FIG. 9.7)

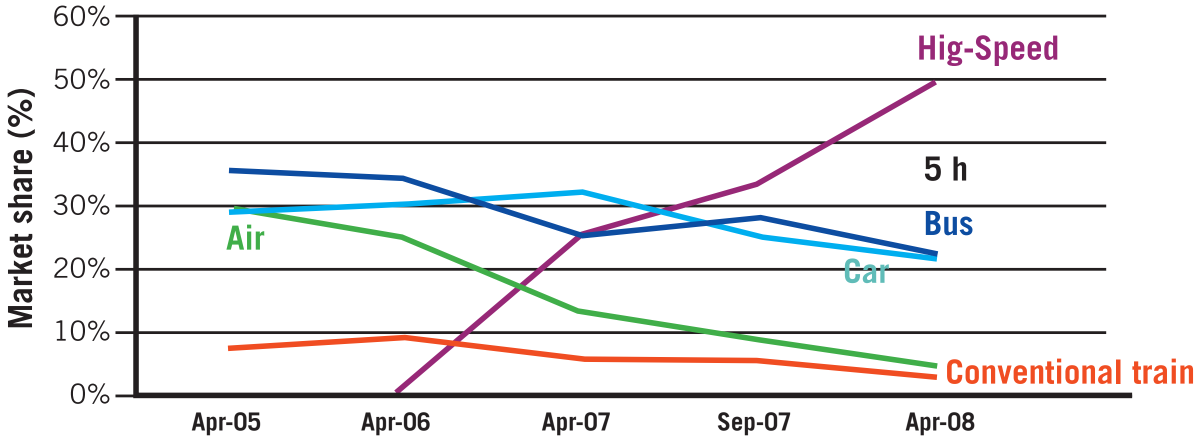



*Source:* T.C.kao (2011)

It can be seen that from the initial 40,000 passengers per day during the first month, the number rose to over 60,000 after the first year. In absolute annual terms, during 2007 traffic demand rose to 15.55 million passengers. In 2008, the figure doubled to 30.58 million.

Finally, with regard to the impact on the modal distribution of high-speed services, Figure 9.8 shows the situation before and after the arrival of the high-speed train.

**MODAL PASSENGER DISTRIBUTION ON THE TAIPEI-KAOHSIUNG ROUTE (345 KM) (FIG. 9.8)**




*Source:* Y. H. Cheng (2010)

It can be seen that high-speed rail services achieved a market share of 50% compared to all modes. Cars and buses each maintained a 20% share. Air services basically disappeared.

# CHAPTER 10.

# THE FIRST HIGH-SPEED TRAIN LINE IN CHINA

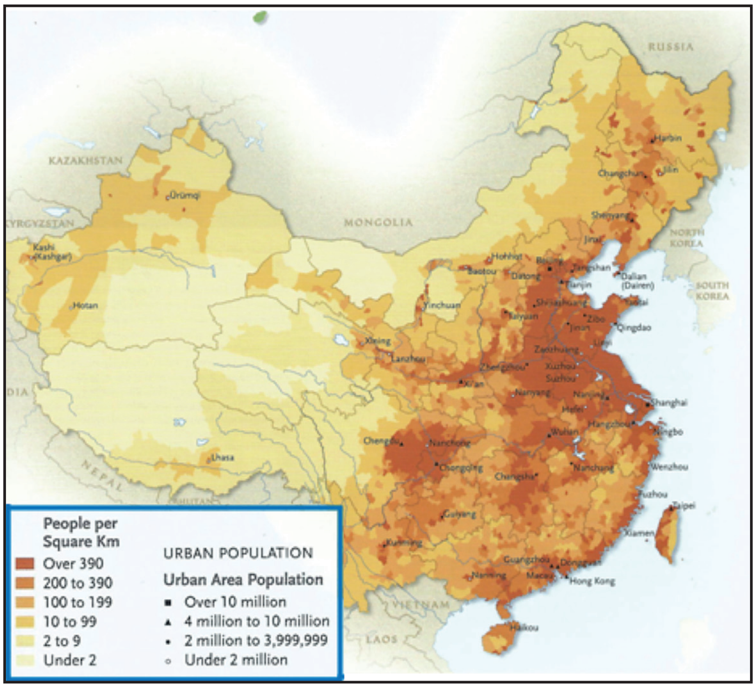
## 10.1 THE EXISTING PROBLEM

To better understand the existing railway problem in China, we need to consider some basic facts.

- Area (9.5 million km2)
- Population (1,300 million)

Figure 10.1 allows us to see how the population is distributed over that area. Note the significant number of cities with more than two million inhabitants.

**POPULATION DISTRIBUTION IN CHINA (FIG. 10.1)**




*Source:* Atlas of China. National Geographic (2008)

These data, which in themselves show the size of China, take on even greater significance when compared with those of countries like Germany and France (Table 10.1).

## EXTENSION AND COMPARATIVE POPULATION OF CHINA, GERMANY AND FRANCE (TABLE 10.1)

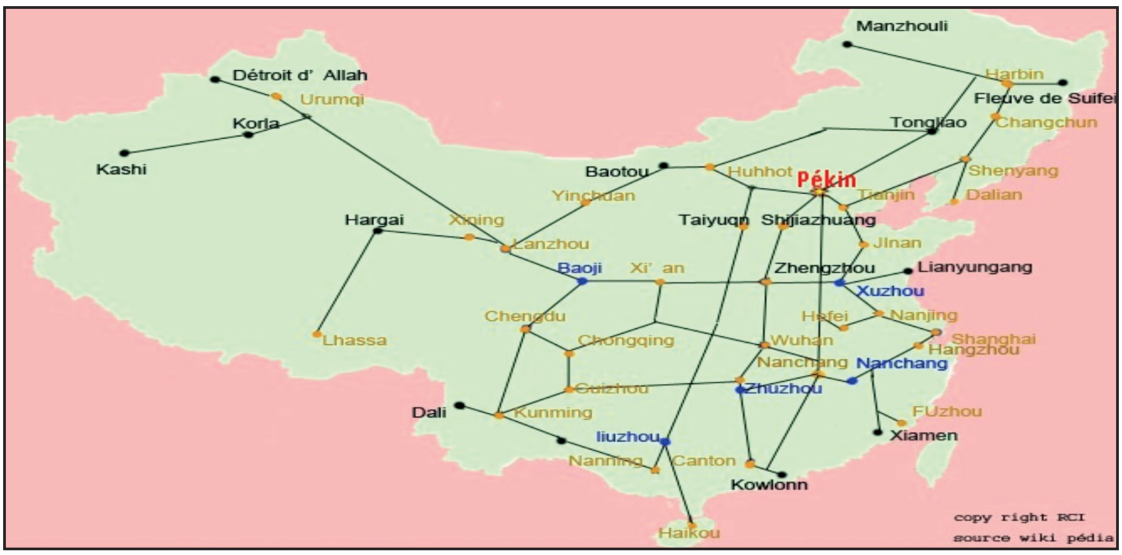
| Country | Total area (millions km²) | Population (millions) |
|---|---|---|
| China | 9.50 | 1300 |
| Germany | 0.36 | 82 |
| France | 0.67 | 66 |

Source: Author's own work.

The above table shows that China is 26 times larger than Germany and 14 times larger than France. In terms of population, China has 16 times more inhabitants than Germany and 20 times more than France.

Despite this fact, the railway network in China in the second half of the 20th century only had 66,000 km. This figure is comparable with the networks of 34,000 km in Germany and 30,000 km in France. It followed, therefore, that there was a major problem: the limited extension of China's railway network.
A second problem was the maximum speeds allowed for the faster trains, which were around 80 to 100 km/h. This limit had a great effect if we take into account the long distances between the main urban centres in China. (Figure 10.2)

## MAIN RAIL NETWORK (FIG. 10.2)



**Reference Distances (km)**

| | |
|---|---|
| Beijing-Shanghai | (1300) |
| Beijing-Guangzhou | (2100) |
| Beijing-Wuhan | (1000) |
| Wuhan-Guangzhou | (1100) |
| Shanghai-Wuhan | (850) |
| Shanghai-Chengdu | (2100) |

The third and final problem was the lack of capacity in the main corridor in the country: Beijing-Shanghai. The importance of the corridor was clear when we see that more than 26% of the population was located along it. In addition, it accounted for 34% of China's GDP.

To cope with the mobility of people and transport of goods, the Chinese railways ran more than 120 trains per day per direction in that corridor. Consequently the saturation on the line was evident.

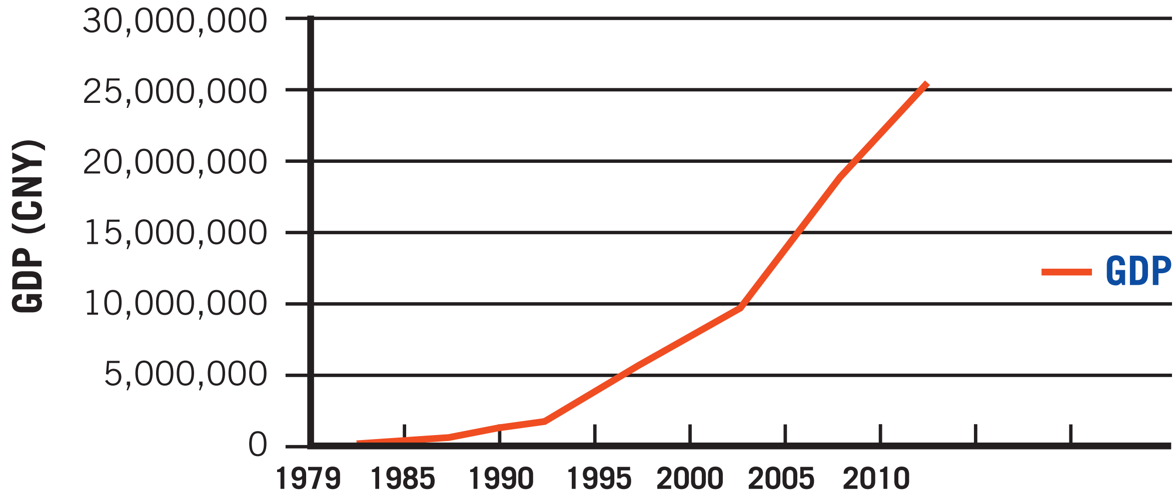
## 10.2 THE DECISIONS TAKEN

The previous section outlined the three main problems that needed to be faced by the Chinese railway system.

a) The network length was insufficient
b) Low authorised speed limits
c) Saturation on the Beijing-Shanghai line

The insufficient extension of the rail network became even more evident when one considers (in Figure 10.3) the evolution of China's Gross Domestic Product in the period 1979-2010.

**CHINA GDP FROM 1979-2010 (FIG. 10.3)**

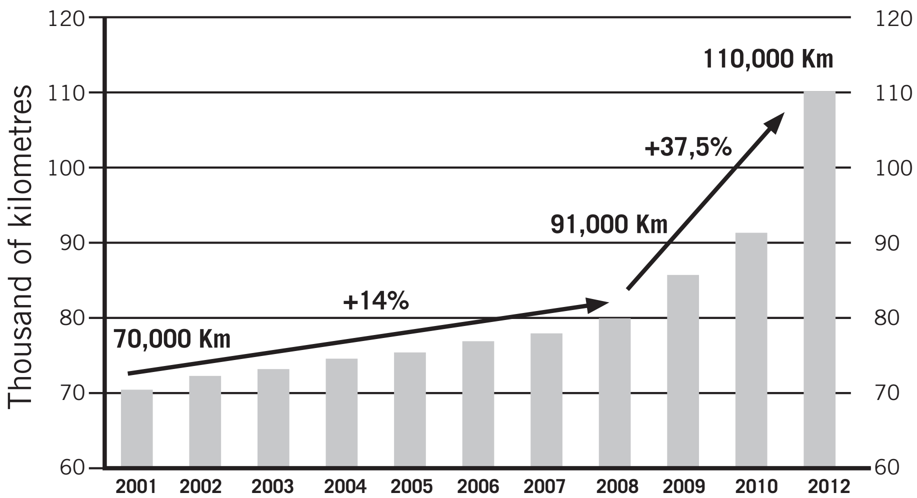



*Source:* Dennis Li (2011)

To address the problem (a), in January 2004, the government announced a development plan which provided, by the year 2020, for the construction of a network of 100,000 km (as against the existing 66,000 km mentioned above). The new lines, around 16,000 km in all, would be used exclusively for passenger traffic with speeds of at least 250 km/h.

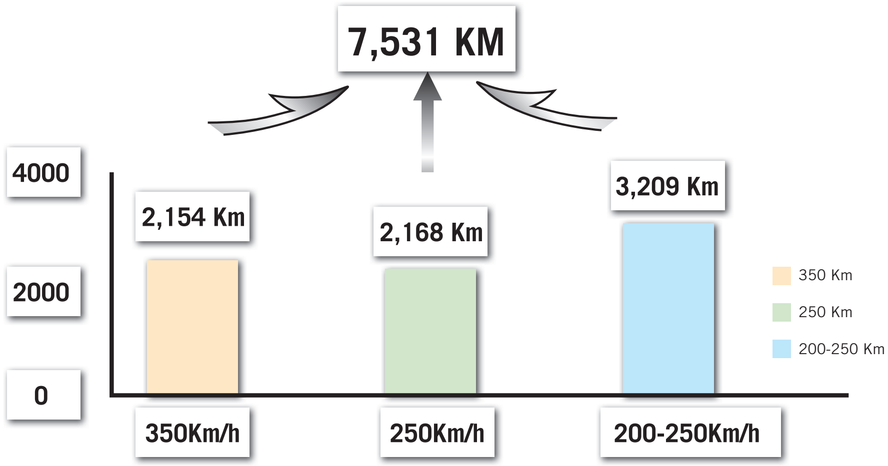
Regarding the progress of the railway network in China, Figure 10.4 highlights the developments in the period 2000-2012.

**EVOLUTION OF THE GLOBAL RAIL NETWORK IN CHINA (2000-2012) (FIG. 10.4)**



Notice that at the beginning of the last decade, the extent of the network approached 70,000 km. In the period 2000-2008 it increased by 14%, reaching 91,000 km by 2010 and 110,000 km by 2012. With regard to high-speed lines, Figure 10.5 shows the distribution of length based on the maximum speed which was planned for each line.

## DEVELOPMENT OF THE HIGH-SPEED RAIL NETWORK IN CHINA IN 2010 (FIG. 10.5)




*Source:* An Guodong (2010)

With regard to problem (b), it was decided to raise the maximum speed gradually to 120, 140 and 160 km/h. The progress made in the period 1997-2007 is shown in Table 10.2.

## EVOLUTION OF MAXIMUM TRAVEL SPEEDS ON THE CLASSIC LINE (1997-2007) (TABLE 10.2)

| Year | Length (km) at speed of | | |
|---|---|---|---|
| | ≥120 km/h | ≥140 km/h | ≥160 km/h |
| 1997 | 1398 | 1340 | 752 |
| 1998 | 6449 | 3522 | 1104 |
| 2000 | 9581 | 6458 | 1104 |
| 2001 | 13166 | 9779 | 1104 |
| 2004 | 16500 | - | 7700 |
| 2007 | 22000 | - | 14000 |

Source: Taken from “High Speed Rail in China”

Finally, regarding the Beijing-Shanghai line, the various analyses conducted served to show that only the construction of a new high-speed line, would respond to the needs of demand. From 1990, therefore, work was done on the idea of creating the new line. After a number of years, in 2011 the layout shown in Figure 10.6 was ready.

**NEW BEIJING-SHANGHAI LINE (FIG. 10.6)**

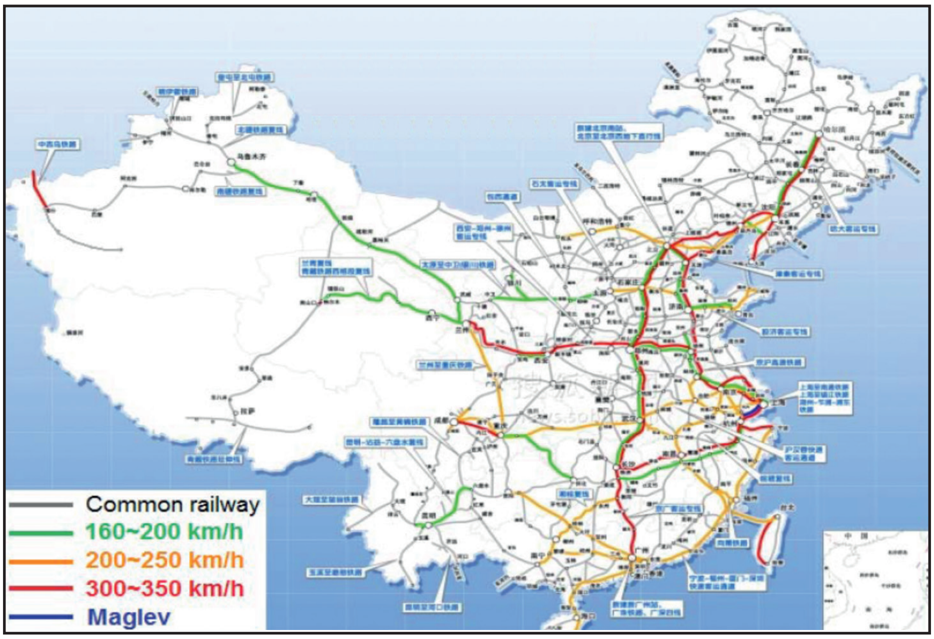

*Source:* C. Scasso (2011)

The new line would have a total length of 1318 km, it would be designed for a maximum speed of 350 km/h, and would reduce the travel time between Beijing and Shanghai from the 15 hours needed on the classic line, to 5 hours. The size of the investment to be made, between EUR 14 billion and EUR 15 billion, prolonged the deliberations on its construction for more than 10 years.

The new route would have a total of 21 stations, including the following, mentioned due to the size of their populations: Beijing (7.4 million), Tianjin (5.2 million), Jinan (3 million), Yanzhou (1.1 million); Xuzhou (1.2 million); Bengbu (1 million), Nanjing (2 million) and Shanghai (9.5 million). Figures refer to 2000.

It should be pointed out that in 2008, in order to meet the development of integrated traffic system in China, the "In Long-Term Railroad Net Plans" was modified to reach 120.000 km railway lines and 16.000 km passenger dedicated lines by 2020 (fig. 10.7)

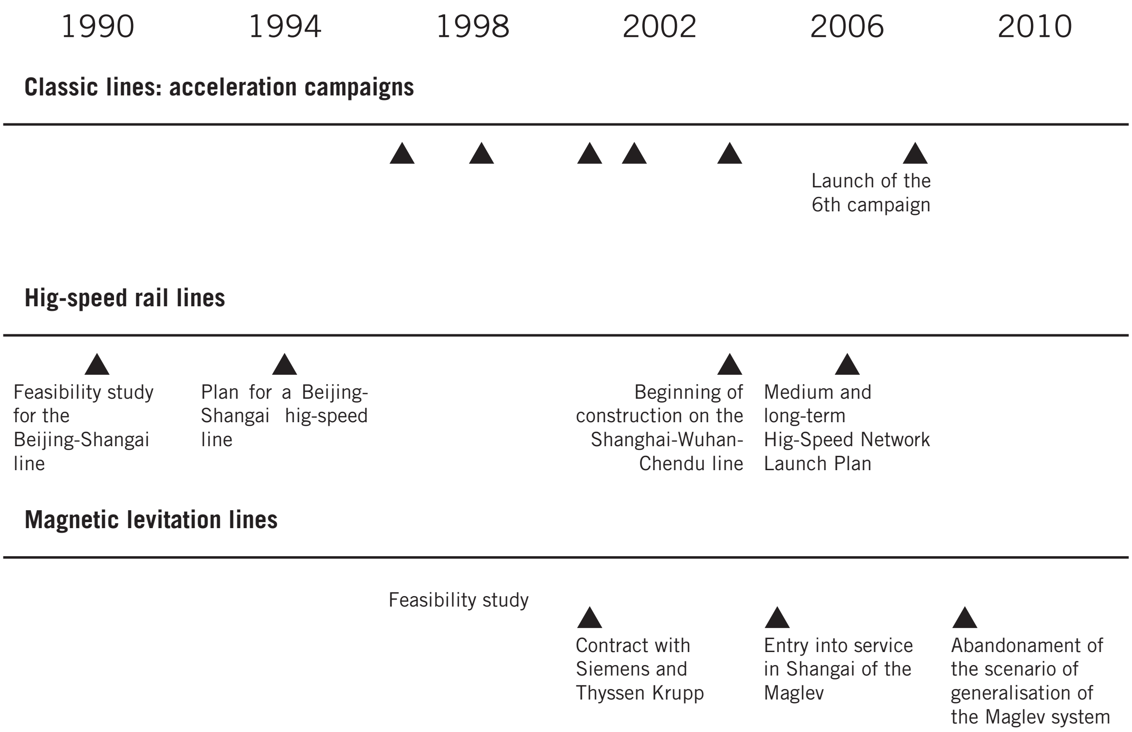
## 2020 HSR IN CHINA (FIG. 10.7)




*Source:* Xia He (2011)

Figure 10.8 provides a global view of the progress experienced in the Chinese railways over the past two decades.

## DEVELOPMENT OF HIGH-SPEED RAIL IN CHINA (FIG. 10.8)



The first high-speed train line opened for commercial use in China was the stretch between Beijing and Tianjin (118 km) in August 2008 (on the occasion of the celebration of the Olympic Games in the Chinese capital). This section was part of the Beijing-Shanghai high-speed line.

The following sections of the line were opened on the dates shown below in Table 10.3.

### THE FIRST HIGH-SPEED TRAIN LINES IN CHINA (TABLE 10.3)

| Date | Line | Length (km) |
|---|---|---|
| Aug. 1, 2008 | Beijing-Tianjin intercity railway line open | 118 |
| Apr. 1, 2009 | Shijiazhuang-Taiyuan high-speed line open | 224 |
| Sep. 28, 2009 | Wenzhou-Fuzhou and Ningbo-Taizhou-Wenzhou high-speed line open (1) | 837 (1)+(2) |
| Dec. 26, 2009 | Wuhan-Guangzhou high-speed line open | 1079 |
| Jan. 28, 2010 | Zhengzhou-Xi'an high-speed line open | 523 |
| Apr. 26, 2010 | Fuzhou-Xiamen high-speed line open (2) | - |
| Jul. 1, 2010 | Shanghai-Nanjing high-speed line open | 323 |
| Sep. 20, 2010 | Nanchang-Jiujiang intercity line open | 119 |
| Oct. 26, 2010 | Shanghai-Hangzhou intercity line open | 147 |
| Dec. 30, 2010 | Haikou-Sanya high-speed line open | - |
| Dec. 30, 2010 | Changchun-Jilin intercity line open | 111 |

Source: Adapted from W. Shai (2011)

On one of the most important corridors, the line linking Beijing to Shanghai, the whole line was opened to commercial operation on 30th June 2011. Figure 10.9 shows the geographic location of the lines indicated in Table 10.3.

## HIGH-SPEED RAIL NETWORK IN CHINA IN 2011 (FIG. 10.9)


*Source:* C. Scasso (2011)

## 10.3 THE RANGE OF SERVICES

The lines generally operate reasonably intensively, typically an hourly or half- hourly service, between 7 am and midnight (table 10.4) normally with 8-car sets.

**SELECTED SERVICE PATTERNS (AS OF JULY 2011) (TABLE 10.4)**

| Section | First Dep. | Last Arr. | Services/Day/Direction |
|---|---|---|---|
| Beijing-Shanghai | 0700 | 2327 | 49 |
| Wuhan-Guangzhou | 0700 | 2349 | 50 |
| Wenzhou-Fuzhou | 0734 | 2245 | 27 |

Source: Adapted from R. Bullock et al. (2012)

These are national fare scales for the two speeds but in practice HSR fares vary slightly from line to line (table 10.5)

**ECONOMY HRS FARES (AS OF NOVEMBER 2011) (TABLE 10.5)**

| Section | Economy Fare | |
|---|---|---|
| | RMB | RMB/Km |
| **350 Km/hr design speed** | | |
| Beijing-Shanghai | 555 | 0,42 |
| Wuhan-Guangzhou | 465 | 0,48 |
| **250 Km/hr design speed** | | |
| Wenzhou-Fuzhou | 91 | 0,31 |

Source: Adapted from R. Bullock et al. (2012)

For comparison, air fares are typically around RMB 0.70/km with shorter trips a bit more expensive and bus trips are about RMB 0.35/km, with sleeper buses slightly more expensive.

## 10.4 DEMAND RESPONSE

If we refer to the most important line, that is, the one joining Beijing and Shanghai, Table 10.6 shows the impact produced by the high-speed services in the railway-air travel modal split.

## CHANGE OF RAIL/AIR MARKET SHARE CAUSED BY BEIJING-SHANGHAI HSR (TABLE 10.6)

| Airport | Rail distance to Beijing | Rail journey time to Beijing | Market Share % | | | |
|---|---|---|---|---|---|---|
| | | | Before (2010) | | After (2012) | |
| | | | Rail | Air | Rail | Air |
| Jinan | 406 km | 1.63h | 91% | 9% | 98% | 2% |
| Xuzhou | 692 km | 2.85h | 93% | 7% | 98% | 2% |
| Nanjing | 1023 km | 4.10h | 55% | 45% | 79% | 21% |
| Wuxi | 1210 km | 4.90h | 57% | 43% | 70% | 30% |
| Shanghai | 1318 km | 5.53h | 34% | 66% | 43% | 57% |

Source: Adapted from J. Wu (2013)

It is interesting to note:

Prior to the introduction of high-speed train services, the role of air travel was less in terms of travel up to 700 km.

For distances of 1000-1200 km, the railway had a market share of around 55% compared to air travel.

With the advent of high-speed train services and the very significant reduction in travel times, the majority of trips were made by rail (Table 10.6). In this regard, J. Wu (2013) noted:

1) In China HSR tends to have a market share of about 80% when rail journey times are within 4 hours or travel distance around 1,000 km, which is significant higher or longer than those of the EU and Japan.

2) This can be explained by the HSR's rather cheaper Price and higher frequency when compared with the air and also the heavy airport delay that happened so frequently in recent years.

Finally, with regard to the railway passenger demand, in absolute terms, the table below shows the average traffic per day and at peak period for the Beijing-Shanghai and Wuhan-Guangzhou lines in 2012.

| High-Speed Train line | Passengers per day | Peak day |
|---|---|---|
| Beijing-Shanghai | 180000 | 300000 |
| Wuhan-Guangzhou | 100000 | 180000 |

Source: Adapted from Yanping, CUI (2012)

# CHAPTER 11.

# THE FIRST HIGH-SPEED TRAIN LINE IN TURKEY

## 11.1 THE EXISTING PROBLEM

Turkey is a country with over 74 million inhabitants which covers an area of 783,000 km2. Looking at Figure 11.1, we can see that the highest population densities occur in the western area of the country.

**POPULATION DISTRIBUTION IN TURKEY (FIG. 11.1)**


*Source:* National Geographic Atlas (2010)

The main cities of the country in economic and population terms are Istanbul, which has more than 10 million inhabitants, Ankara and Smyrna, which both have around 4.1 million inhabitants.

To handle mobility between Istanbul and Ankara, Turkey has a highway and frequent air services (more than 30 flights per day and direction). The railway line connecting those cities has a length of 576 km.

In the early 1990s only 110 km were equipped with two-way tracks. The geometry of the layout featured numerous sections with tight curves. So much so that the travel time for those 576 km was 6h30m. That is, the equivalent of a commercial speed of 88 km/h.

It is no wonder, then, that the railway market share was only 10%. Even more so when we take into account that the same trip by road could be covered in 5h30m, and by air it took just 50 minutes.

## 11.2 THE DECISION TAKEN

There was a clear need to increase the competitiveness of the conventional railway, which had a network of almost 11,000 km (of which only just over 2,200 km was electrified). (Fig. 11.2)

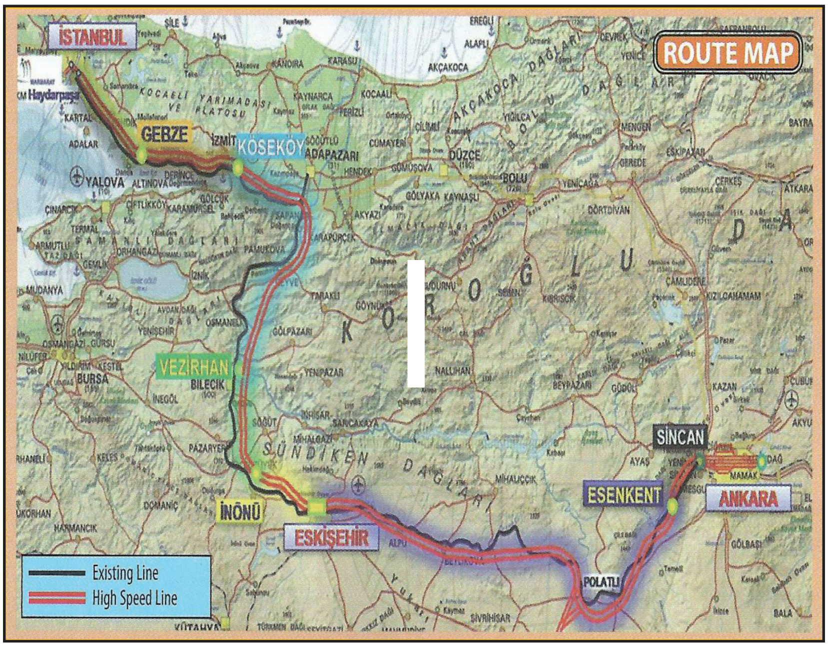
**RAIL NETWORK IN TURKEY (FIG. 11.2)**


*Source:* C. Nangeroni (2009)

In this context, the Turkish government in 1994 developed what was known as the "Rehabilitation Project for the Ankara-Istanbul railway line". The philosophy applied in it was to modify some of the curves in order to achieve a top speed of at least 100 km/h. At the same time it planned for doubling the track in some sections.

However, they soon came to the conclusion that these actions would not allow the railway to achieve a higher market share. So it was decided to build a new line, independent of the classic path (Fig. 11.3). Designed to travel at speeds of 250 km/h, it would allow travel time between Ankara and Istanbul to go from 6h30m to just 3 hours.

**NEW ANKARA-ISTANBUL LINE (FIG. 11.3)**




The construction of the new line was planned in two stages (FIG 11.4). The first, between Ankara and Eskisehir, with over 200 km, entered commercial service in 2009. The second, between Eskisehir and Istanbul, will be opening its commercial operations in 2014.

**CONSTRUCTION OF THE ISTANBUL-ANKARA LINE BY PHASE (FIG. 11.4)**


Simultaneously with the decision to build the aforementioned high-speed rail line, a Plan was set up to provide Turkey with a high-speed rail network as shown in Figure 11.5.

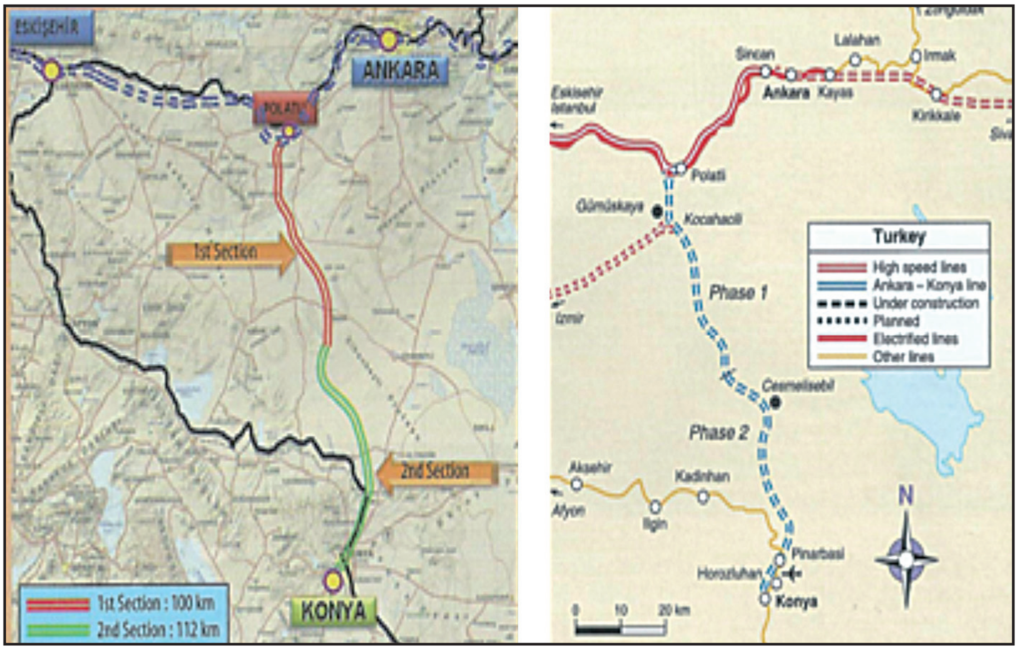
## HIGH-SPEED TRAIN LINE PROJECT IN TURKEY (FIG. 11.5)


*Source:* I.H. Cevik (2012)

Finally, it shows that in August 2011 the new high speed line between Ankara and Konya entered commercial service (Fig. 11.5), with a length of 212 km. The fact that, previously, the classic rail network had no line that would join the aforementioned cities (Figure 11.2) should be noted. To join the two cities it was necessary to go through Eskisehir and Afyon, taking a line with a length of 987 km. This meant a travel time of 10h30m by rail, compared to the 2h30m it took by road to travel the distance of 258 km separating the two cities.

The route diverges from the Ankara-Eskisehir high-speed line by a triangular junction just west of Polath, 94 km southwest from the capital (fig. 11.6).It meets the line from Afyon at Pinabarsi, and parallels the former route for around 12 km to connect at Horoluhan in the northern suburbs of Konya.

**NEW LINE ANKARA-KONYA (FIG. 11.6)**




In the longer term a further triangular junction at Kocahacili, 25 km south of Polath, will form the starting point proposed for the high-speed line to Izmir.

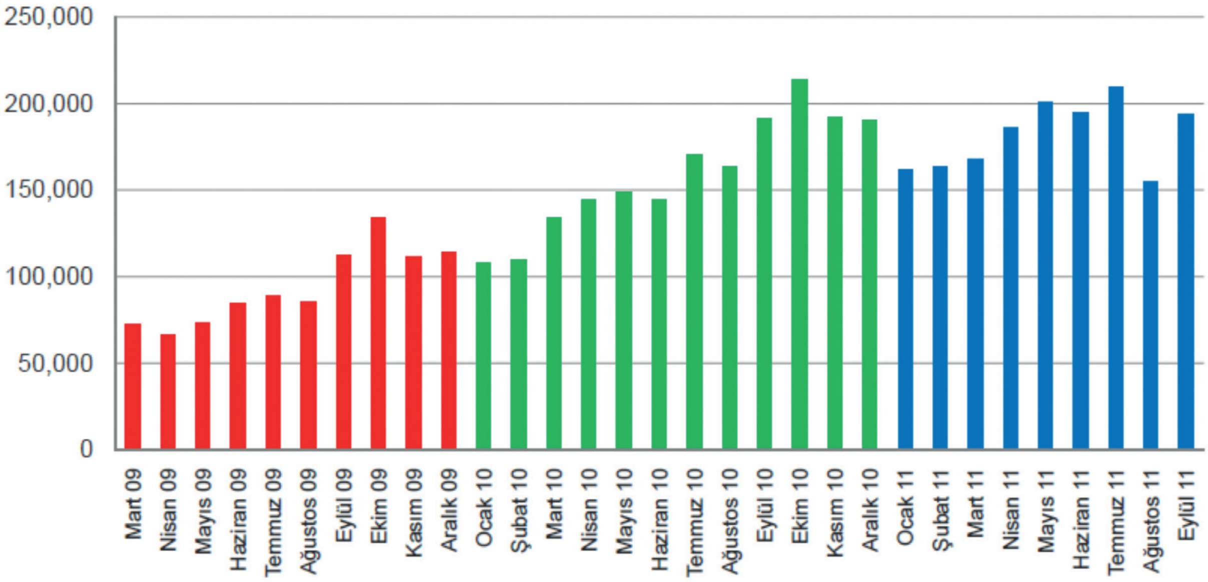
## 11.3 SERVICES AND DEMAND RESPONSE

With regard to the new line between Ankara and Istanbul, the opening of commercial operations on the Ankara-Eskisehir section in March 2009 yielded the following travel times:

- Ankara-Eskisehir (1h30m)
- Ankara-Istanbul (5h30m)

10 trains per day travelled in each direction.The demand response is shown in Figure 11.7, for the period of March 2009 to October 2011.

**NUMBER OF PAX TRANSPORTED ON ANKARA-ESKISEHIR HSL (MARCH 2009-OCTOBER 2011) (FIG 11.7)**




*Source:* I. H. Cevik (2012)

It can be seen that:

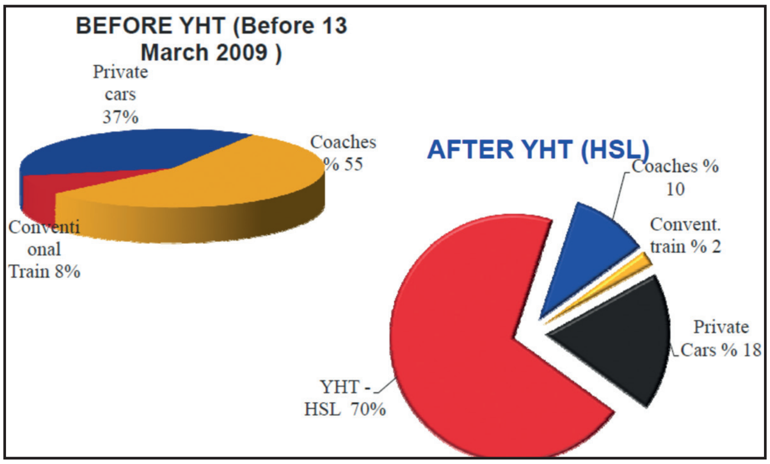
a) During the first year of operation, from March 2009 to March 2010, passenger traffic went from 75,000 to 175,000.

b) The month in 2009 with the most traffic demand was October with 170,000 passengers. By contrast, in October 2010, there were more than 220,000 passengers.

c) Lastly, during the second year of operation of the line, the monthly passenger traffic was not less than 150,000.

Regarding the impact on the modal split of road traffic, it is interesting to analyse the results on the Ankara-Eskisehir section (245 km). Figure 11.8 shows the market share of rail, bus and car travel, with and without the high-speed train line.

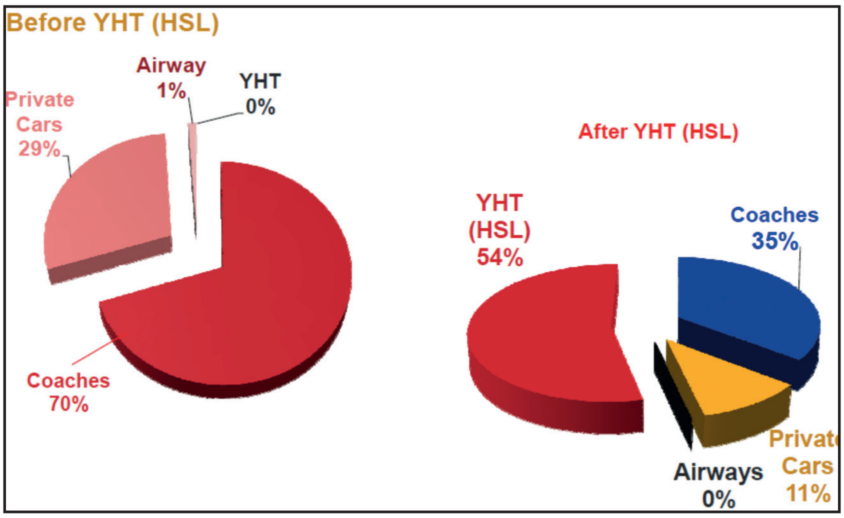
### SHARE OF MEANS OF TRANSPORT BEFORE AND AFTER ANKARA-ESKISEHIR HSL (FIG 11.8)




*Source:* I. H. Cevik (2012)

Note how the railway, which had a market share of about 8% compared to road travel, now has 70% in the wake of the introduction of high-speed services. Similarly, Fig. 11.9 shows the results of the competition between rail and road travel on the Ankara-Konya route, where the travel time for the new line came down to only 1h15m. That is, a commercial speed of 170 km/h.

### SHARE OF MEANS OF TRANSPORT BEFORE AND AFTER ANKARA-KONYA HSL (FIG 11.9)




It can be seen that the railway went from having no market share (in the absence of a direct line as indicated) to having 54% of all the travellers on the route.

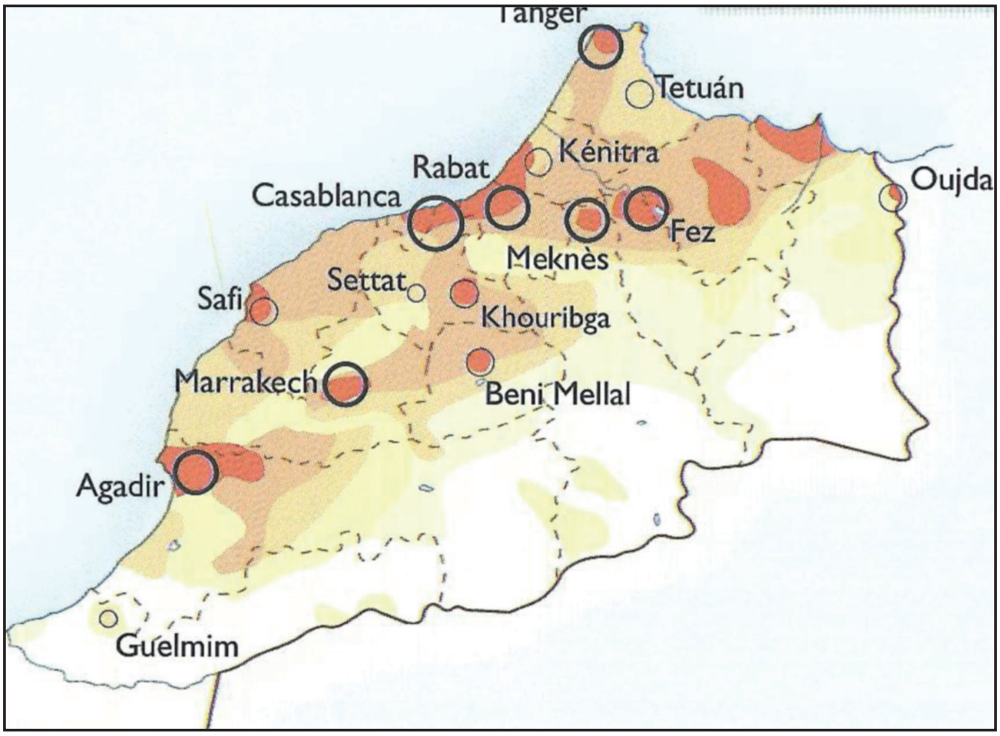
# CHAPTER 12.

# THE FIRST HIGH-SPEED TRAIN LINE IN MOROCCO

## 12.1 THE EXISTING PROBLEM

Morocco has a population of around 30 million, with the geographical distribution shown in Fig. 11.1. The main urban agglomerations are located in: Casablanca (3.5 million inhabitants), Rabat (2.4 million) Marrakesh (1.9 million), Tangier (1.6 mi-llion), Fez (1.4 million); Kenitra (1 million) and Agadir (0.9 million).

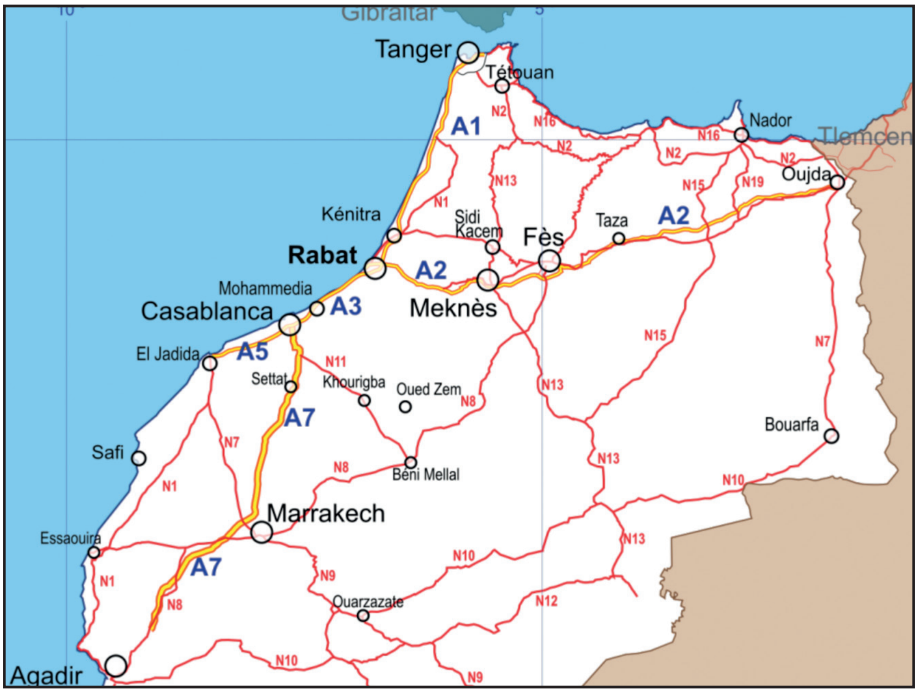
**MAIN POPULATION CENTRES IN MOROCCO (FIG. 12.1)**




*Source:* National Geographic Atlas (2010)

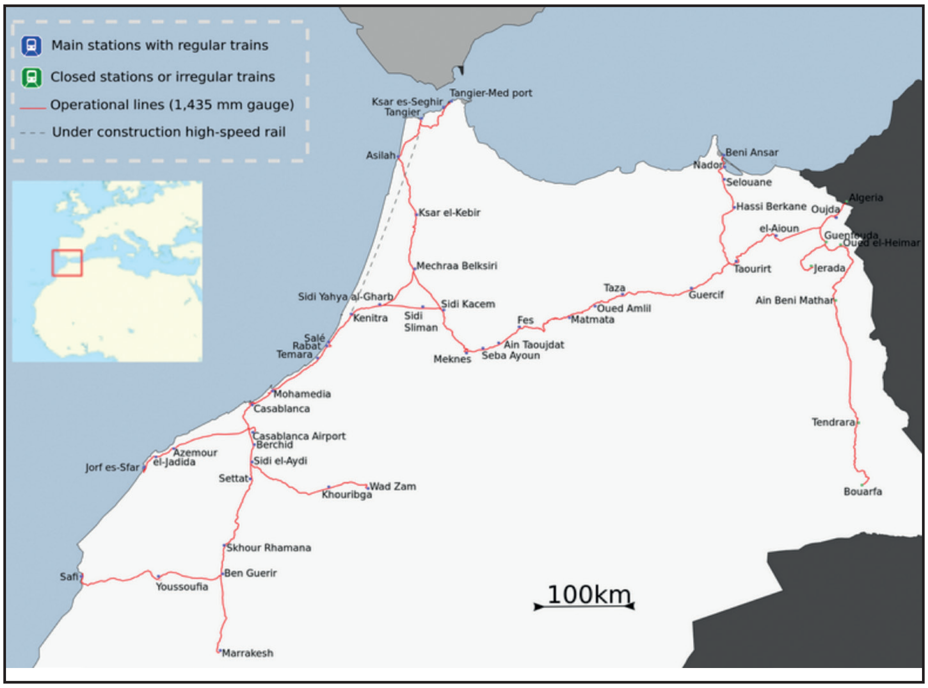
To address the country's mobility needs, there is a network of highways of more than 1,400 km in length. The routes that feature this type of road infrastructure are shown in Fig. 12.2. Domestic air services are very limited.

## HIGHWAY NETWORK IN MOROCCO (2011) (FIG. 12.2)




The railway network is 2,100 km in length (Fig. 12.3), half of which is electrified. A total of 426 km are fitted with double track. The railway alignments are generally quite good, so on some sections it is possible to travel at speeds of up to160 km/h.

## RAILWAY NETWORK IN MOROCCO (FIG. 12.3)



In spite of that maximum speed, commercial speeds were around 80 to 90 km/h, as displayed in Table 12.1.

**AVERAGE REFERENCE SPEEDS FROM CASABLANCA (TABLE 12.1)**

| | Travel time | Av. Speed (km/h) |
|---|---|---|
| Marrakesh (257 km) | 3h 24m | 76 |
| Rabat (89 km) | 1h 02m | 86 |
| Tangier (420 km) | 5h 44m | 73 |

Source: In-house. ONCF travel time data (2008)

It is notable that the Casablanca-Tangier route takes 5 hours by bus and 4 hours by car. By contrast, as indicated above, a train needs 5h 44m to cover the route. It should also be pointed out that the distance by road between the cities in question is shorter than the railway, given the straighter alignment of the highway (Fig. 12.4).

**SCHEMATIC ALIGNMENT OF THE HIGHWAY AND THE RAILWAY LINE ON THECASABLANCA-TANGIER ROUTE (FIG. 12.4)**

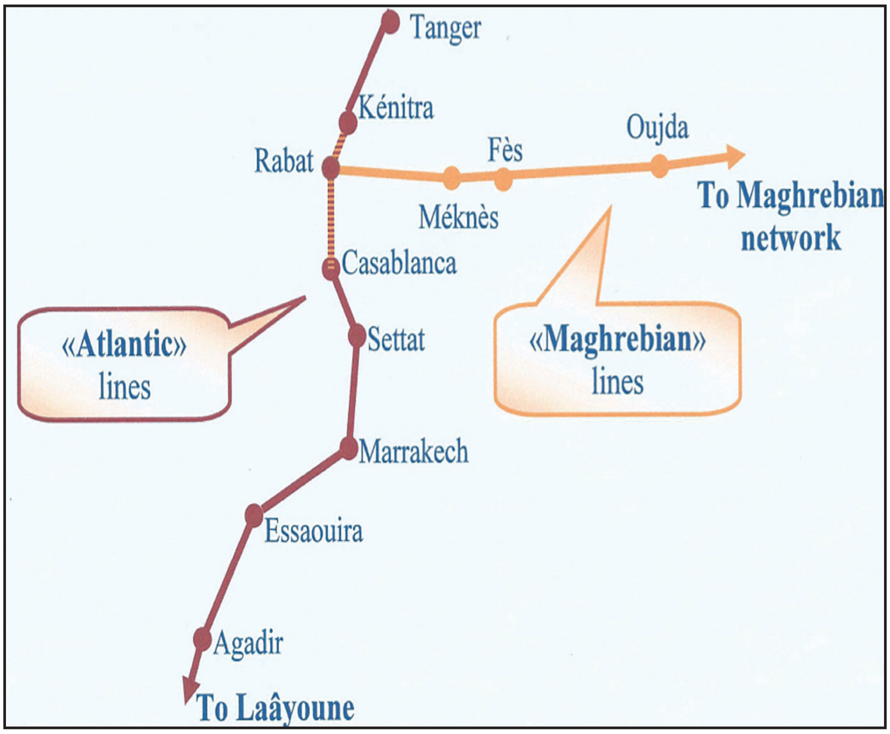

*Source:* In-house. Michelin Cartography.

## 12.2 THE DECISION TAKEN

The efforts made by the Moroccan railways in recent years have resulted in the number of travellers using this mode rising from 14.7 million in 2002 to around 34 million in 2011. To increase the competitiveness of the passenger rail transport offering for medium and long distance travel in the 2003/2004 period, a Preliminary Study was conducted on the advantages of building high-speed railway lines in Morocco.

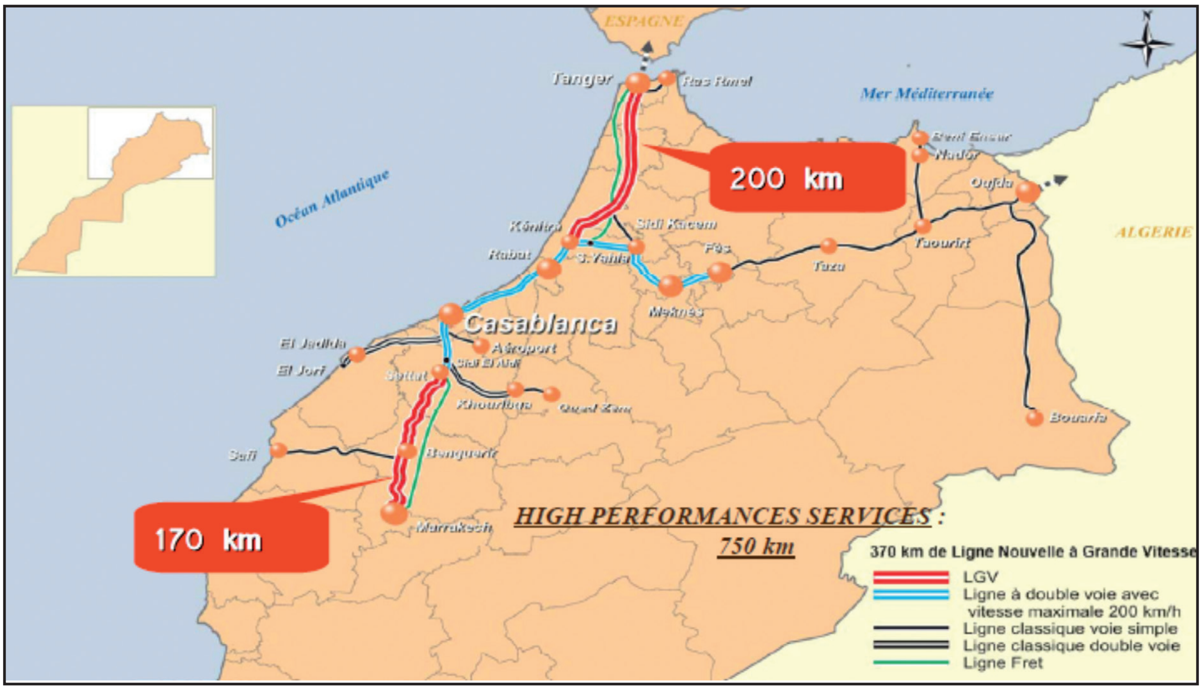
In this context, in the 2005/2006 period, what was called the "Master Plan for High Speed" was established. It was regarded as necessary to have 1500 km of new lines by the 2035 planning horizon year, configured along two axes: the Atlantic Axis (Tangier-Casablanca-Marrakesh-Agadir) and the Maghrebi Axis (Rabat-Fez-Oujda) (Fig. 12.5).

**MASTER PLAN FOR HIGH-SPEED TRAIN LINES IN MOROCCO (2006) (FIG. 12.5)**




Once this Master Plan was approved a deep analysis was conducted of the technical, functional, economic and social circumstances present in each corridor. The results obtained highlighted the priority interest of acting on the Marrakesh-Tangier section as shown in Fig. 12.6.

## PRIORITY ACTION LINES FOR HIGH-SPEED RAIL (FIG. 12.6)

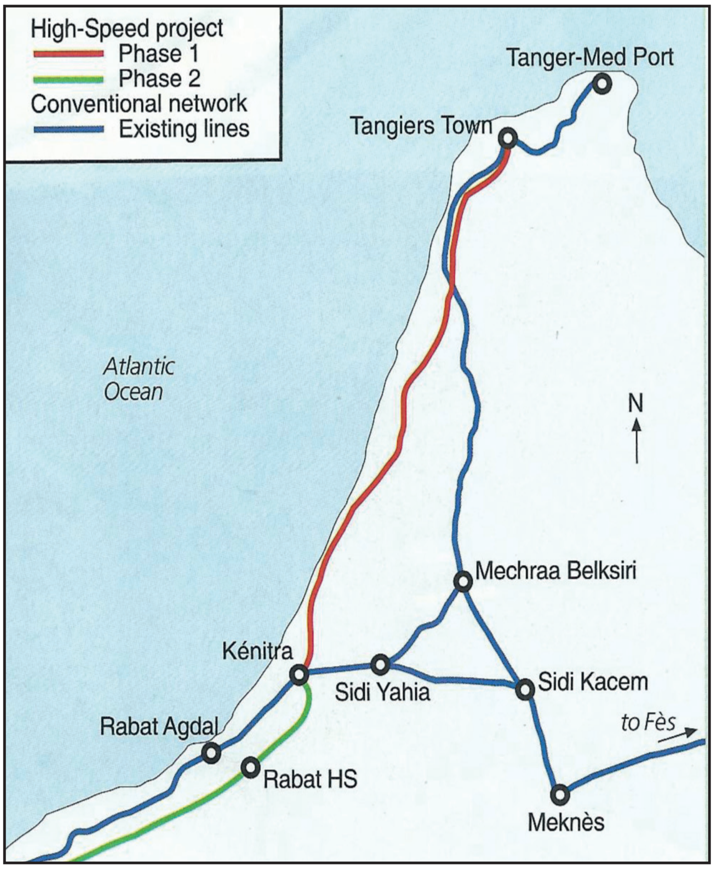



*Source:* A. El Amraoui (2008)

In the first phase, two lines would be built: one, between Tangier and Kenitra, would be about 200 km in length, and the other, from Settat to Marrakesh, would have a length of 170 km. The Fez-Rabat-Casablanca conventional line would be doubled and modernised to handle top speeds of 200 km/h, for use between the two new lines.

Note in Fig. 12.7 that the new line between Tangier and Kenitra would shorten the distance by rail between the two cities by about 100 km. It is expected that the high-speed line will enter into commercial service in the 2005/2006 planning horizon.

## SCHEMATIC ALIGNMENT OF THE KENITRA-TANGIER HIGH-SPEED LINE (FIG. 12.7)




*Source:* K. Barrow (2011)

The main arguments leading to the choice of high-speed rail were, in general, the following:

a) Provide an adequate and sustainable solution to a continuously growing and regular demand of passenger traffic (+80% of volume between 2002 and 2010).

b) Be in phase with the development of European and Maghreb corridors.

c) Support the development of the new economic hub of Tangier.

d) Free up capacity on the existing line for the expected freight traffic.

Considering the strong growth in container volumes to and from the port of Tanger-Med.

## 12.3 EXPECTED SUPPLY AND DEMAND

At present (2011), Tangier-Rabat-Casablanca services operate at intervals of two hours with a typical travel time of 4h 45m. With the launch of commercial services on the new line in December 2015 (expected), the frequency will be doubled to hourly, and journey times will fall by more than half to 2h 10m.

When the Marrakesh-Casablanca-Rabat-Tangier axis is fully equipped with a high-speed line, the following travel times will be provided by rail.

Marrakesh-Casablanca (1h)
Casablanca-Rabat (31m)
Casablanca-Tangier (1h 30m)

Moroccan National Railways (ONCF) anticipate the new line will double passenger numbers on the corridors from around 3 million per year to 6 million in the first year of operation.

# CHAPTER 13.

# THE FIRST HIGH-SPEED TRAIN LINE IN SAUDI ARABIA

## 13.1 THE EXISTING PROBLEM

Saudi Arabia is a country with a large surface area (2,100,000 km2). Its population, however, is only around 26 million, which means there is a low density (12 inhabitants/km2). The main cities in terms of population are:

| | |
|---|---|
| Riyadh | (4.2 million) |
| Jeddah | (2.8 million) |
| Makkah | (1.6 million) |
| Madinah | (1.3 million) |
| Dammam | (0.7 million) |

Their geographical location is shown in Fig. 13.1.

**MAIN CITIES IN SAUDI ARABIA (FIG. 13.1)**


To address the mobility needs of the country, there is a network of highways that link the cities with the most inhabitants.

As a reference and for the purposes of this document, we mention the highway between Makkah and Madinah and the one linking Jeddah and Makkah. (Fig. 13.2)

## MAKKAH-JEDDAH-MADINAH HIGHWAY (FIG. 13.2)


*Source:* Extract from Map of Saudi Arabia. Explorer

With respect to the air services between Jeddah and Madinah, there are around 10 flights per day each way (2013).

Finally, with regard to the railway, it is not very comprehensive. It is basically limited to linking Dammam with Riyadh, as shown in Fig. 13.3.

**RAIL NETWORK IN SAUDI ARABIA (FIG. 13.3)**


From the point of view of passenger demand, the main transportation problem was present in the Jeddah-Makkah-Madinah corridor.

Essentially, there is a huge demand for travel between Jeddah and Makkah (80 km southwest) and Jeddah and Madinah (420 km northwest). Makkah, with a population of 1.6 million, is within commuting distance of Jeddah.

Of the 16 million people who travel between the two cities each year, 7 million are commuters. Another 5 million are visitors, 2 million are Hajj pilgrims, and 2.5 million are Ramadan visitors. Madinah has nearly 1 million inhabitants and has 3 million visitors a year.

To meet this demand for transport, the government of Saudi Arabia in 2003 decided to build a high-speed train line along that corridor. This project was called "Haramain High-Speed Rail".

## 13.2 EXPECTED SUPPLY AND DEMAND

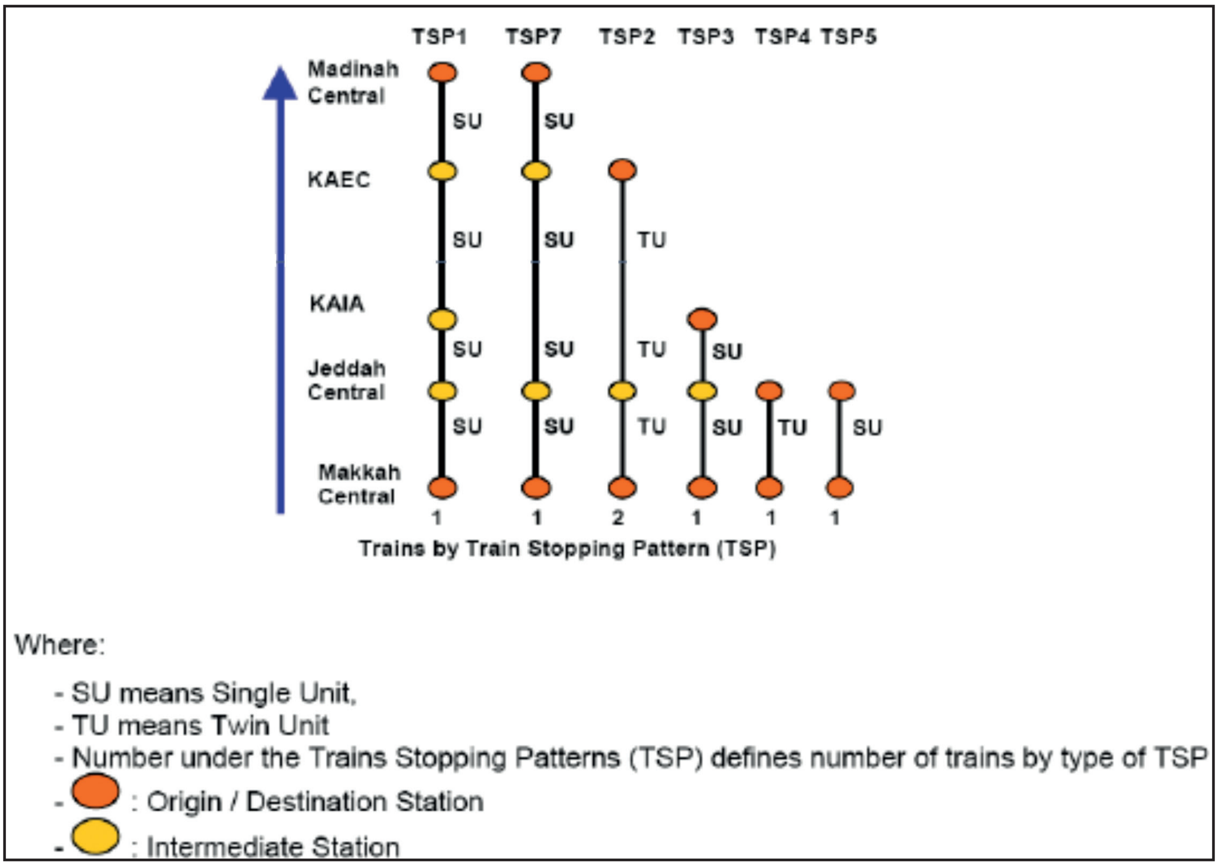
The new line will be approximately 500 km in length: 420 km from Madinah to Jeddah and 80 km from Jeddah to Makkah. The route will have, in addition to the stations in those cities, two supplementary stations. The first is in King Abdullah Economic City (KAEC) (Fig. 13.4). The second is in the main terminal at King Abdul-Aziz International Airport (KAIA). This is the airport in Jeddah. The line is scheduled to enter service in 2016. The travel time will be: 30 minutes between Makkah and Jeddah; 2h 30m between Jeddah and Madinah.

**STATIONS ON THE MAKKAH-MADINAH HIGH-SPEED TRAIN LINE (FIG. 13.4)**


*Source:* Ineco

In the current state of planning the services that the line will have, M. Cheik (2012) published the forecast (Fig. 13.5) for a Friday at peak hour.

## HARAMAIN HIGH-SPEED RAIL EXPECTED RAIL SERVICES (FIG. 13.5)




*Source:* M. Cheikh

With regard to demand, it is expected that in the year the line is opened daily traffic will be around 120,000 passengers daily.

# PART TWO

# FINANCING OF FIRST HIGH-SPEED LINES

# CHAPTER 14.

# FINANCING OF HIGH SPEED LINES IN JAPAN

## 14.1 THE CREATION OF JAPANESE NATIONAL RAILWAYS (JNR)

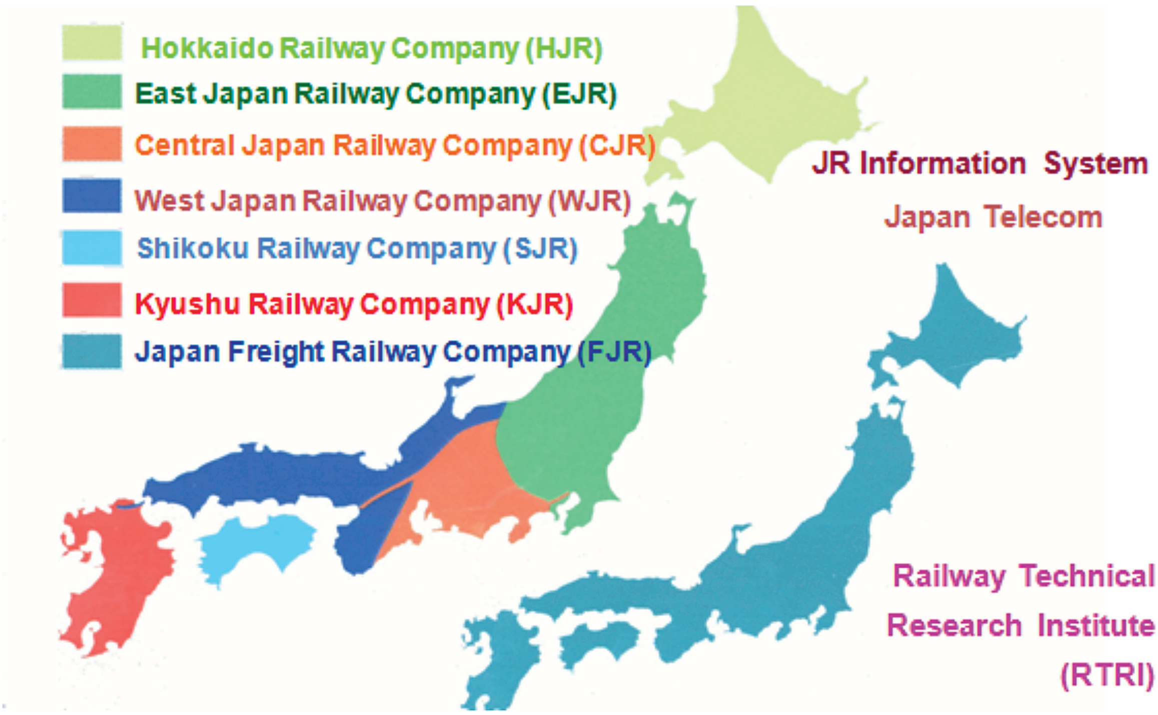
As indicated in section 1, the first railway line in Japan opened between Shimbasi and Yokohama in 1872, using a narrow gauge of 1,067 mm. All main lines built subsequently between major population centres in Japan were to the narrow gauge standard.

Originally the railway was a government enterprise. However, private individual´s ambitions for railway construction were also strong, and 20 years later in 1892, private (company-owned) railway lines totaled 2, 124 km, more than twice the 984 km of national railway lines.

Railways in Japan were nationalized in 1906 except for urban railways. In 1905, right before the nationalization, private railway lines totaled 5, 231 km, substantially more than the 2,562 km of national railway lines, After the nationalization, there were 7,153 km of national railways, leaving 717 km urban railway lines as of private railways.

The national railways grew to 9,991 km, by 1919. In 1931, they exceeded 15,000 km, and in 1945 when Japan was defeated, they extended to 20, 056 km. At this point private railway lines totaled 5, 543 km.

**JAPANASE RAILWAYS- JR GROUP (FIG 14.1)**




*Source:* T. Miyauchi (2008)

In 1949, national railways were placed under the management of the Japanese National Railways (JNR), a public corporation with all of its capital invested by the government. The maximum route length was 21,419 km (S.Sumita).

In 1987, JNR was privatized and divided into six passenger railway companies, one freight railway company and other companies (Railway Technical Research Institute (RTRI), JR Information System and Japan Telecom (now, Soft  Bank Telecom) (Fig 14.1)

## 14.2 FINANCING SYSTEM FOR HIGH-SPEED TRAIN LINES BUILT UP UNTIL 1987

Lines opened for commercial operations since the inauguration of the first high-speed train line in 1964, between Tokyo and Osaka, and up until 1987, are indicated in Fig 14.2. That is, a total of 1, 831 km.

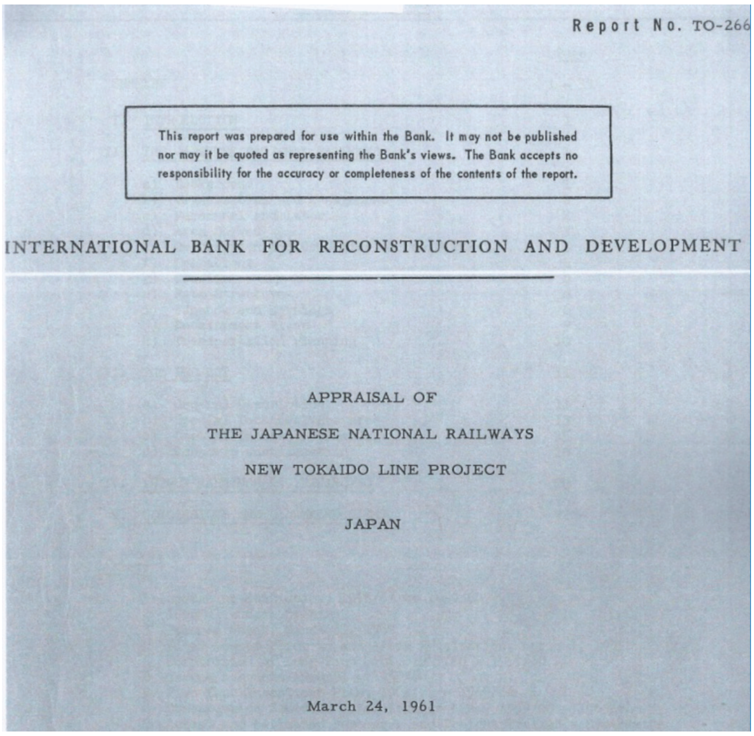
**HIGH SPEED TRAIN LINES BUILT IN JAPAN IN THE 1964- 1987 PERIOD (FIG 14.2)**


*Source:* F.Kurosaki (2013)

Although the construction of Tokaido Shinkansen was a national project, the fund for the construction was appropriated from the revenue of JNR, the borrow from governmental investments and railway bonds, because this line was considered profitable in future. Thus, there was no direct investment from the government. A part of fund was the loan from the World Bank of low interest. This was considered the indirect guarantee for the construction of Tokaido Shinkansen by the government. It was paid back in 1981 (Y.Sato, 1992).

Fig. 14.3 reproduces the cover page of the document from the «International Bank for Reconstruction and Development» which granted this loan.

**PROPOSED LOAN-JAPAN (FIG 14.3)**


Report No. TO-266

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INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT

APPRAISAL OF

THE JAPANESE NATIONAL RAILWAYS

NEW TOKAIDO LINE PROJECT

JAPAN

March 24, 1961

*Source:* Fundación de los Ferrocarriles Españoles

The following paragraphs of the aforementioned document are considered of interest and have been reproduced

TABLE OF CONTENTS



## I. INTRODUCTION

1. The Government of Japan has requested the Bank to assist in financing the construction and equipping of a new railway line between Tokyo and Osaka, referred to generally as the New Tokaido Line. The loan would be made to the Railways, a statutory public corporation wholly owned by the Government, to be used for construction and equipment costs. To be constructed over a period of five years, 1959/60 to 1963/64, the New Tokaido Line is estimated to cost US$548 million equivalent, including interest during construction. The Railways wish to borrow ¥ 28,800 million--US$80 million equivalent.

2. The Project is in addition to a much larger continuing railway development program. The program for the five-year period from 1961/62 to 1965/66 is estimated to cost ¥ 801,500 million, or US$2,226 million equivalent.

3. This report is based on the findings of a Bank Mission, which visited Japan during May and June 1960 to study the Railways generally and the New Tokaido Line specifically, on information provided by Railways' officials who visited Washington in January and February 1961, and on additional data furnished in March 1961.

V. CONCLUSIONS AND RECOMMENDATIONS

119. The Project is technically very advanced. It is practicable and sound.

120. The decision to construct the Project has been reached after extensive and expert economic investigation.

121. The Project is economically justified; it is the only reasonable solution to the current transportation problem in the Tokaido area.

122. The Railways' management is sound and the Railways are operated efficiently and with an excellent record of labor productivity.

123. Fixed assets and depreciation reserves were revalued in 1955 on the basis of reproduction costs. This is a much more realistic financial practice than that employed in many other railway systems. Straight line depreciation based on such costs is charged in the operating accounts.

124. The rate of return on the over-all Railways' system is low, 2 percent in 1959/60. The return should show some improvement in the next six years, gradually increasing to 5.2 percent in 1965/66. The rate of return on the present Tokaido Line is very high, 25 percent in 1959/60. The rate of return on the New Tokaido Line in 1964/65 is expected to be about 25 percent, and the rate for the combined lines about 22 percent. Rate increases have been approved by the Government, are being considered by the Diet and, as favorable action is expected, are reflected in the estimates of future finances. Were no rate increases made effective, the Railways would nevertheless remain financially sound and the Project would remain economically and financially justified.

125. Although it is not the present practice to invite tenders from non-Japanese contractors or suppliers, the Railways have agreed to use international competitive bidding procedures. A letter has been obtained from the Railways stating the method which will be employed in inviting tenders. These arrangements are satisfactory.

126. A Bank loan of US$80 million equivalent has been requested. The Project is suitable for a loan of that amount. The Railways would be the borrower. An appropriate term, considering the nature of the Project, would be 20 years, including a grace period of three and one-half years.

Finally, Figure 14.4 shows the photo of the signing of the loan in the presence of the people mentioned.

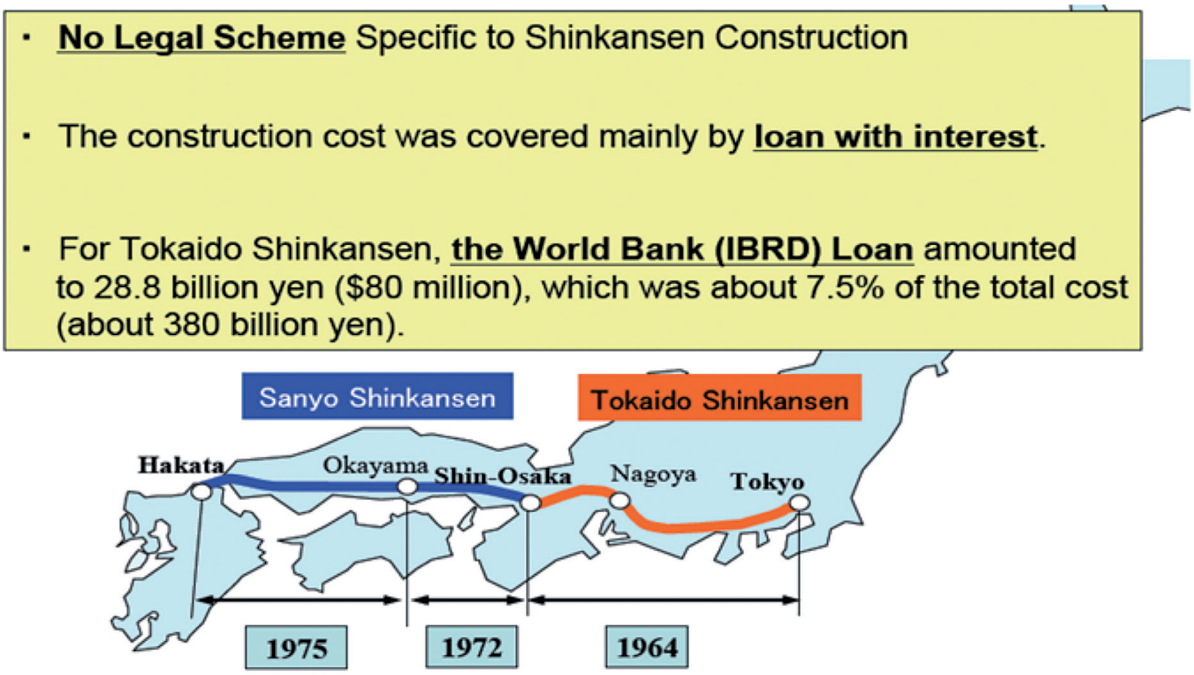
## SIGNING OF THE LOAN TO THE JAPANESE NATIONAL RAILWAYS (FIG 14.4)

Signing of the loan to the Japanese National Railways. From left to right, His Excellency Koichiro Asakai, Ambassador of Japan in the United States; Sir William Iliff, Vice President of the World Bank; and Mr. Shinji Sogo, President of the Japanese National Railways. Standing, left to right: Mr. Gengo Suzuki, Executive Director of the World Bank for Japan; and Mr. Manabu Kanematsu, Managing Director of the Japanese National Railways.

*Source:* World Bank

Figure 14.5 is a summary of the main issues that conditioned the construction and financing of the Tokaido and Sanyo Shinkansen lines.

**TOKAIDO & SANYO SHINKANSEN SCHEME (FIG 14.5)**




*Source:* T. Nishiyama (2011)

Following the successful introduction of HSR in 1964, the Japan Railway Construction Public Corporation (JRCC) was established to procure future HSR on behalf of the State. Subsequently lines were constructed by JRCC, with JNR responsible for service operation and infrastructure maintenance.

Although the original aim was to overcome the capacity constraints of the trunk lines, as mentioned above, the success of the Tokaido and Sanyo Shinkansen Lines aroused the local interest to extend Shinkansen lines to other cities, focusing on its high speed rather than transport capacity. As a result, the government promulgated the Nationwide Shinkansen Development Law in May 1970, and planned a nationwide Shinkansen network.

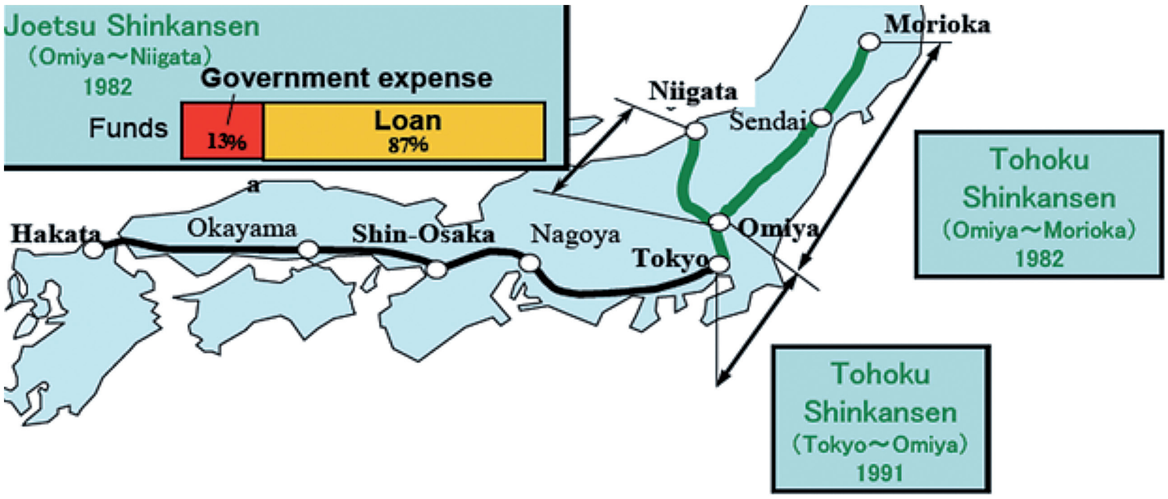
The Law specifies as its objective that: « This law is intended to expand the nationwide railway network by means of the Shinkansen railway system and thus serve to develop the national economy and enlarge the field of activity in life in consideration of the importance of the role played by the formation of a high-speed transportation system for the purpose of a comprehensive and universal development of the national land» (M.Minemoto, 1987).

Prior to JNR reform, both conventional and Shinkansen lines had been constructed with interest-bearing loans. This means that it was a precondition that the construction cost be paid back form sales revenue after the opening of operations. Owing to the financial constraints, JNR could not allow a large investment to construct new Shinkansen lines. Nevertheless, construction work steadily continued, and the Tohoku and Joetsu Shinkansen Lines were opened before JNR reform.(F.Kurosaki,2013)

Tohoku Shinkansen (Tokyo-Morioka) & Joetsu Shinkansen (Omiya-Niigata) were constructed by JNR & Japan Railway Construction Public Corporation (JRCC) under the Nationwide Shinkansen Railway Development Law, enforced in 1970 .

The government paid part of construction costs, but most was covered by loan with interest. Figure 14.6 shows the financing scheme adopted for the Joetsu Shinkansen line.

**JOETSU SHINKANSEN SCHEME (FIG 14.6)**



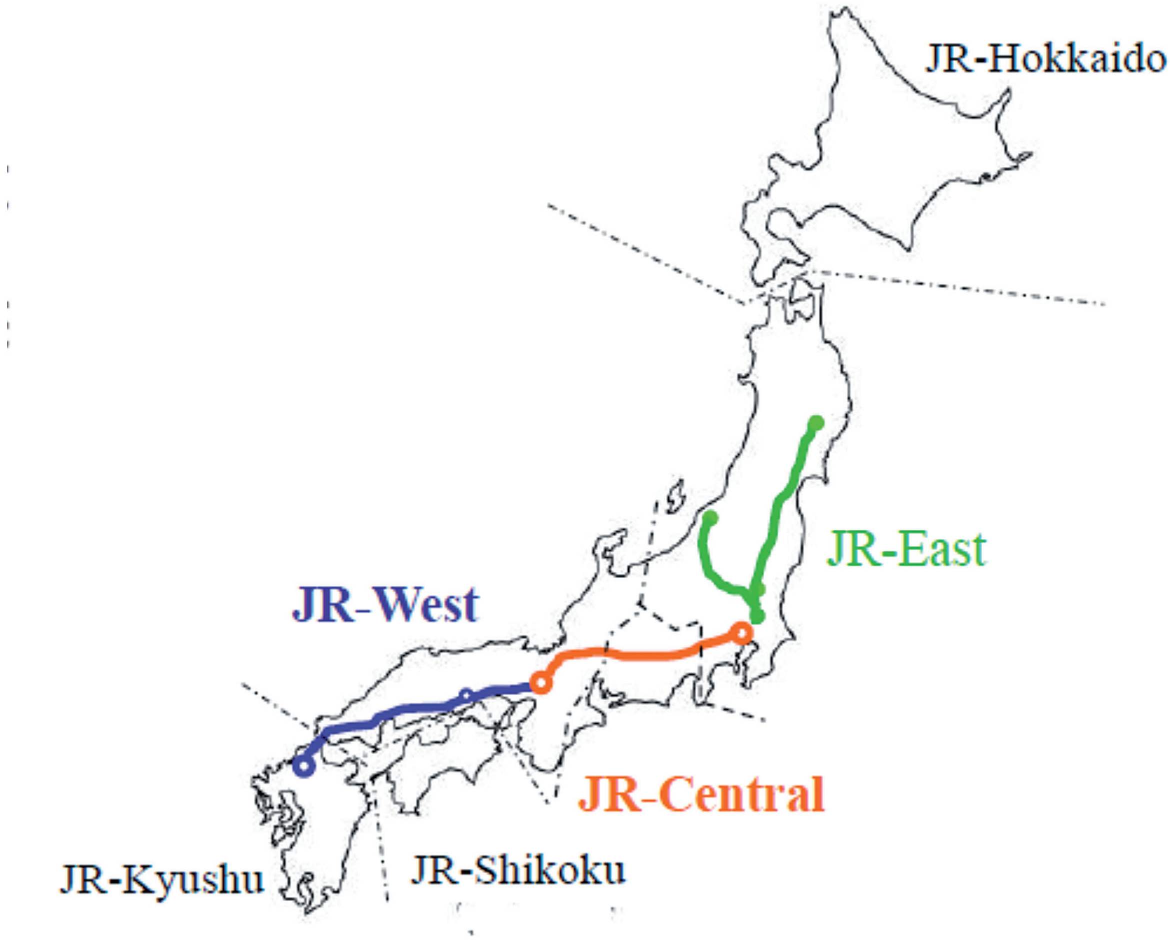

*Source:* T. Nishiyama (2011)

The construction cost placed a heavy burden on the Japanese National Railways.

14.3 Shinkansen projects since JNR reform

On 1 April 1987, the JNR that had been a public enterprise was privatized. In JNR reform, Shinkansen operation was divided among three companies: JR East, JR Central, and JR West (Fig 14.7)

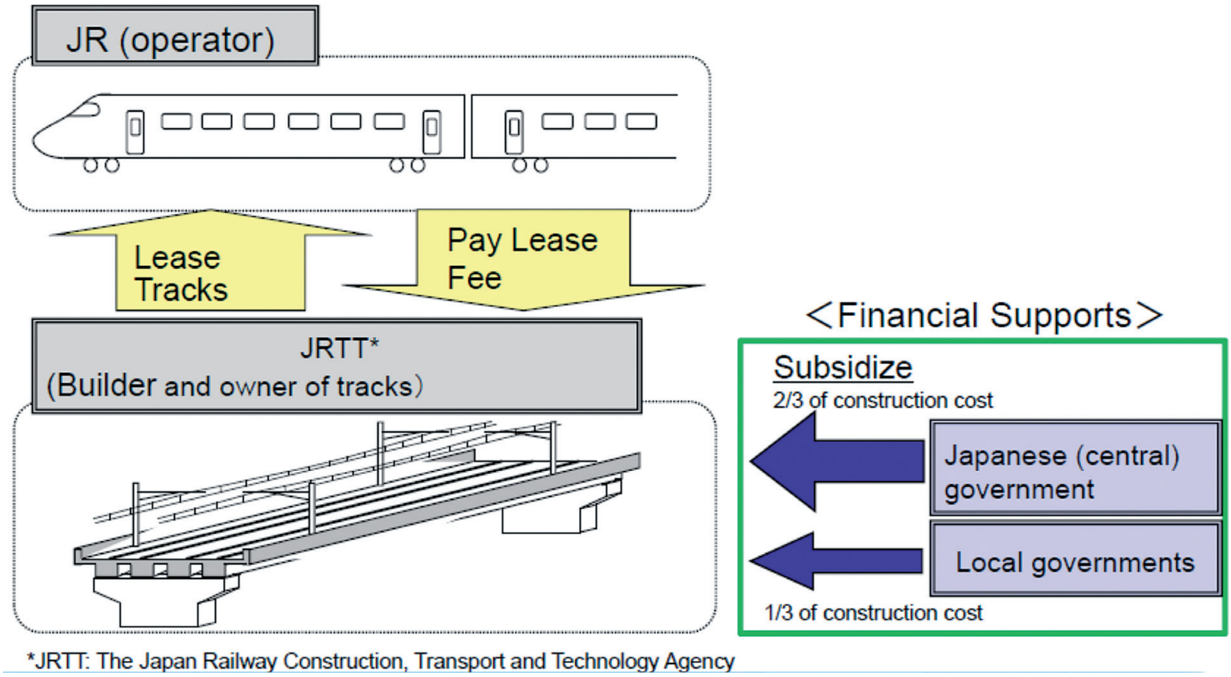
**SHINKANSEN OPERATION (FIG 14.7)**




Since JNR reform, the new lines and extensions of Shinkansen lines have been constructed and operated based on the new scheme, and Japan Railway Construction ,Transport and Technology Agency (JRTT),a wholly government-financed entity, carries out Shinkansen construction works as public projects.

JRTT not only implements construction work but also retains ownership of the infrastructure assets after completion of the projects. It leases the assets to the JR passenger companies, which provide high speed railway services. Thus, different from the initial Shinkansen lines which had been constructed during the JNR era, the newly constructed sections form a vertically separated structure (Fig 14.8)

**NEW FINANCING MODEL FOR THE HIGH SPEED TRAIN LINES IN JAPAN (FIG 14.8)**




*Source:* A. Tamura (2012)

The amount of usage fees paid by an operator of new Shinkansen lines is an essential factor in the relationship between the JR passenger and the public sector.

Payment of usage fees is regulated by the Japan Railway Construction, Transport and Technology Agency Law. The Law stipulates that JRTT basically calculated the amount based on the benefits received as an operator of the new Shinkansen lines after opening. The above-mentioned benefits are calculated by comparing the following two amounts:

1. The estimated revenues and expenses generated by the new Shinkansen lines and related line segments after opening; with

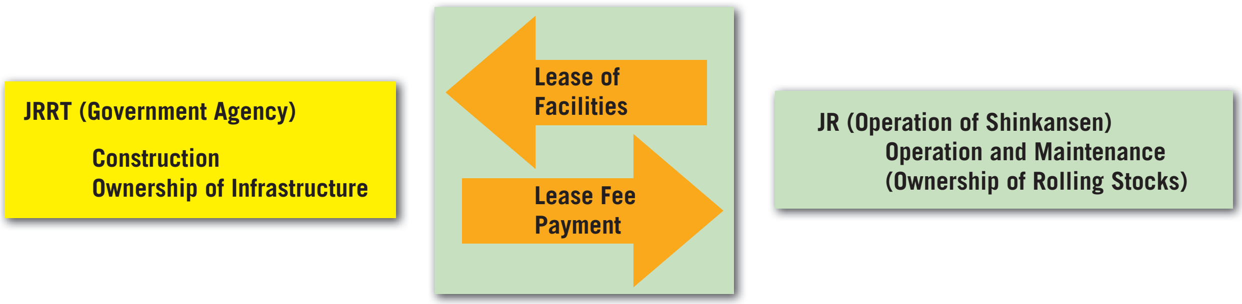
2. The estimated revenues and expenses that would likely be generated by parallel conventional lines and related line segments if the new Shinkansen lines were not opened.

In brief, the amount equals to the operator´s net increase of benefits through the commencement of operation. Then, the above-mentioned amounts are calculated based on expected revenue and expenses over a 30-year period after opening.

Regarding payment of maintenance costs of infrastructure, each JR passenger company pays within its own budget. Although both new Shinkansen lines and European railways form vertically separated structures, the payment of the maintenance costs shows a stark contrast.

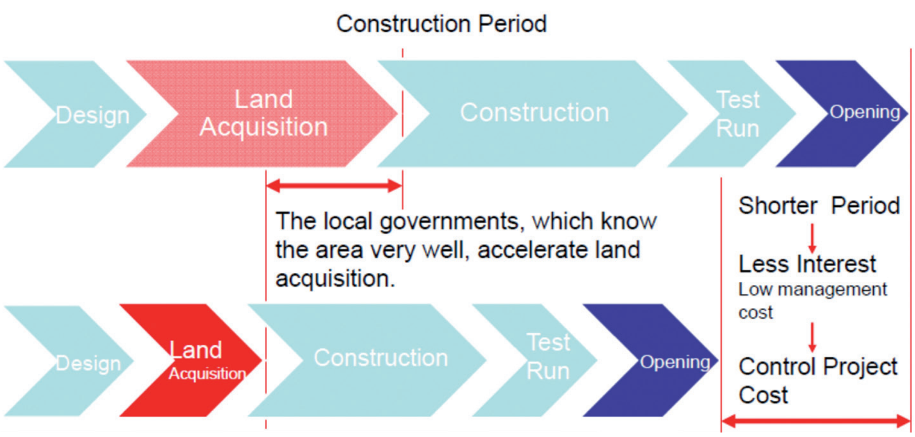
For railways in Europe, an infrastructure manger pays the maintenance costs, although the amount of usage fees can cover the maintenance costs in some costs. However, in the case of Japan, the infrastructure owner (JRTT) does not pay any cost for operation and maintenance works of the infrastructure, and received usages fees are utilized for a part of construction costs of other projects (Fig 14.9)

## SEPARATION OF CONSTRUCTION AND OPERATION (FIG 14.9)




In case of Shinkansen construction extending across local authorities, under entrustment from JRTT, local governments themselves purchase land for quick and smooth acquisition (Fig 14.10). The cost of land adquisition belongs to JRTT.

## REDUCTION OF CONSTRUCTION LEAD TIME DUE TO COLLABORATION BY LOCAL GOVERNMENTS (FIG 14.10)

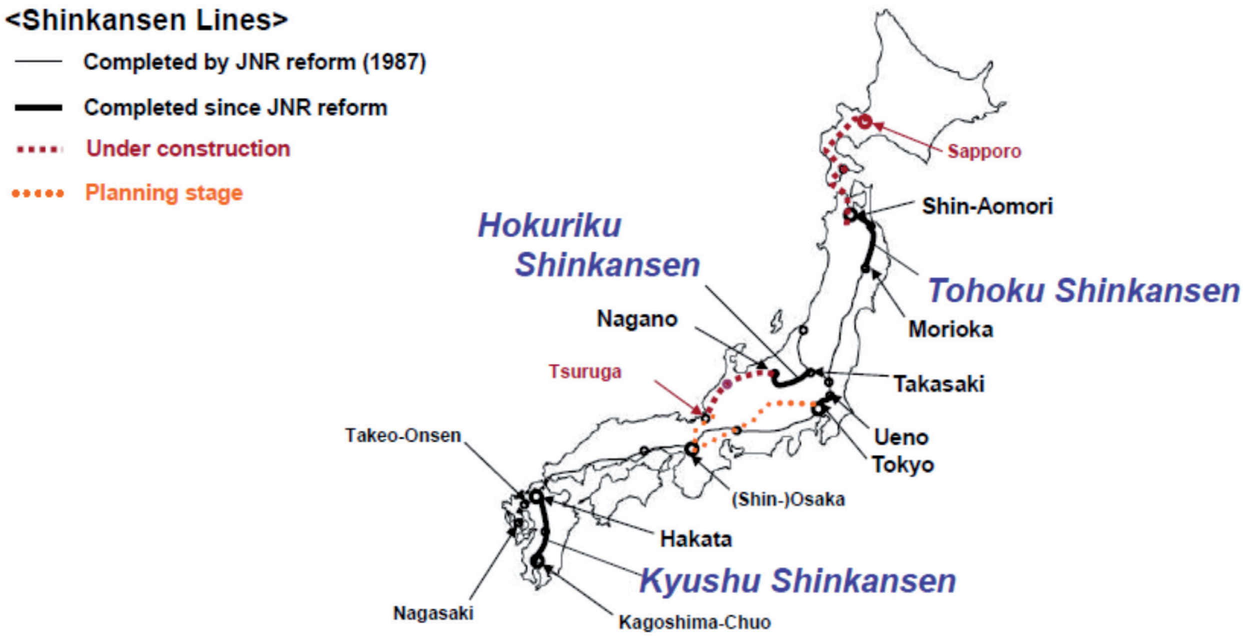



*Source:* N. Fujii (2013)

## 14.3 FINANCING OF THE LATEST HIGH-SPEED TRAIN LINES IN JAPAN.

The high-speed train lines that have been built since the Japanese railway reform are indicated in Fig. 14.11. These lines have been financed using the system described in the preceding section and in Fig. 14.6.

### HIGH-SPEED LINES BUILT AFTER THE 1987 REFORM (FIG.14.11)




*Source:* F.Kurosaki (2013)

Lastly, we will mention the conventional lines on which the Mini-Shinkansen trains run.

Mini-Shinkansen lines are not covered by the government´s new Shinkansen line plan. And ,as the definition of Shinkansen in Japan stipulates that it does not have a level crossing with roads, Mini-Shinkansen lines are not categorized as Shinkansen lines.

In order to provide faster service to cities not on the Shinkansen, JR East promoted two projects(Fig 14.12) with its own finances:

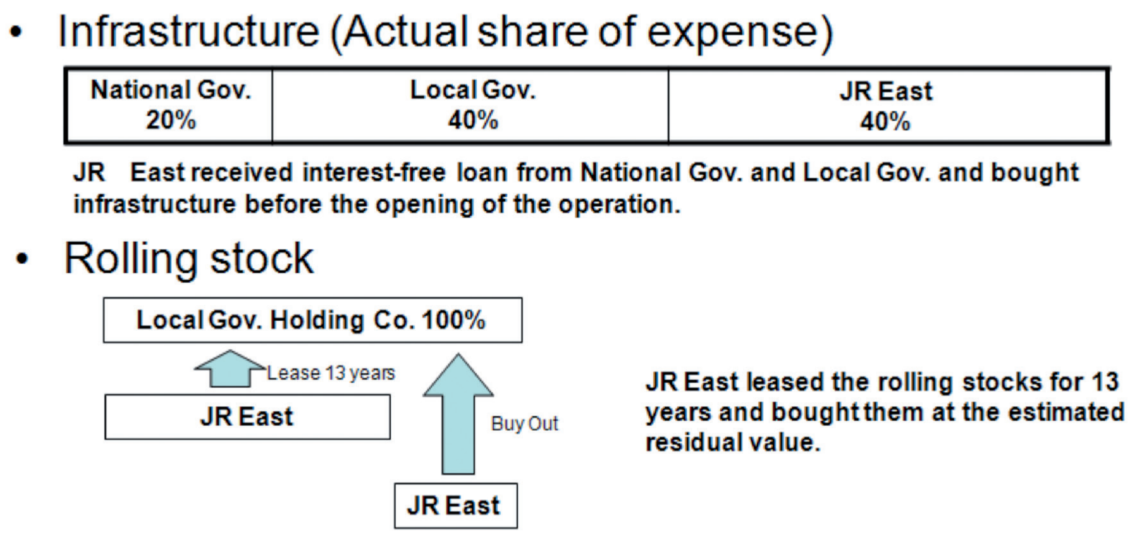
1. Yamagata Shinkansen (section between Fukushima and Shinjo)
2. Akita Shinkansen (section between Morioka and Akita)

## MINI-SHINKANSEN LINES (FIG 14.12)


In these sections, the track gauge was changed from conventional-line 1067 mm gauge to standard gauge, so that trains with standard gauge bogies could run on those lines. JR East then started through-train services between dedicated high speed lines( which are standard gauge) and these modified sections by utilizing rolling stock of the same car-body size as conventional trains.

Fig. 14.13 details the financing system used both for these lines and the rolling stock.

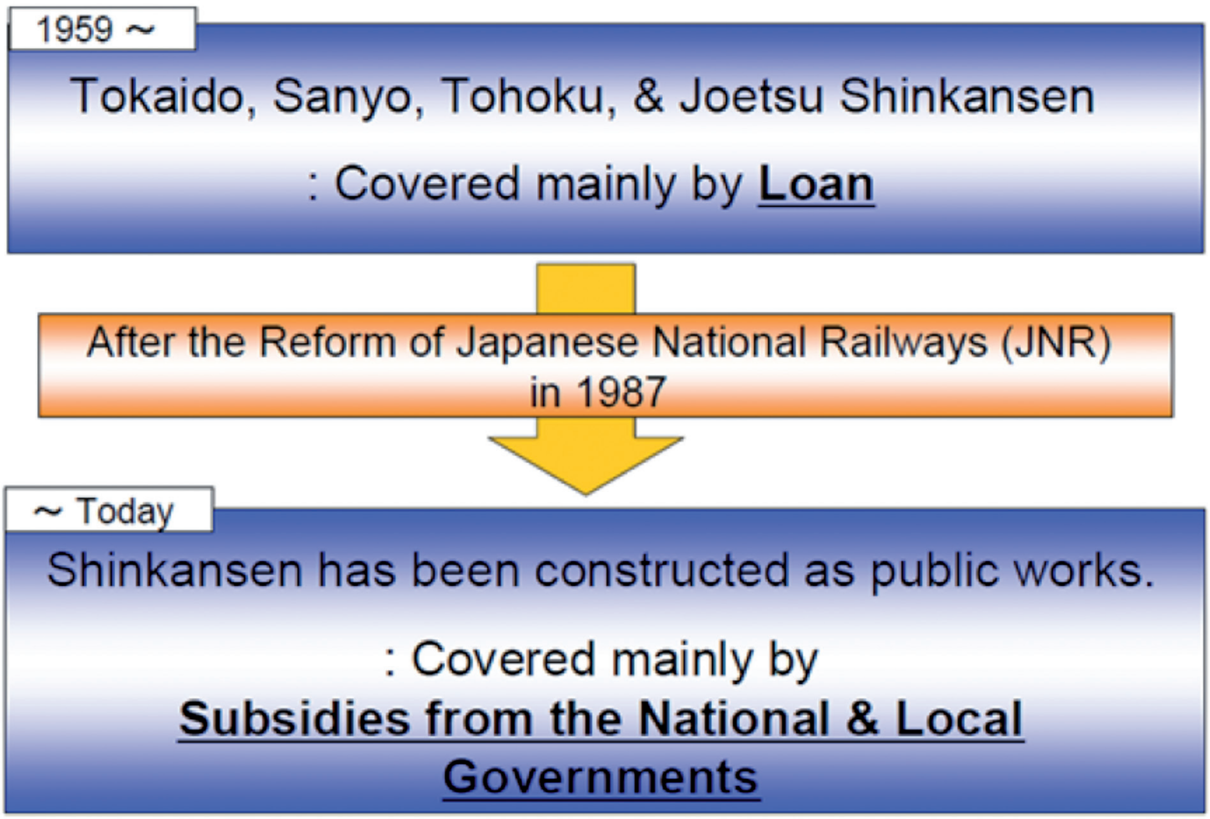
**YAMAGATA AND AKITA SHINKANSEN SCHEME (FIG 14.13)**




*Source:* T. Nishiyama (2011)

In summary, and following T. Nishiyama, we present Fig. 14.14.

**FINANCING OF THE SHINKANSEN NETWORK (FIG. 14.14)**



# CHAPTER 15.

# FINANCING OF HIGH-SPEED LINES IN FRANCE

## 15.1 PRIOR TO THE CREATION OF R.F.F. (1997)

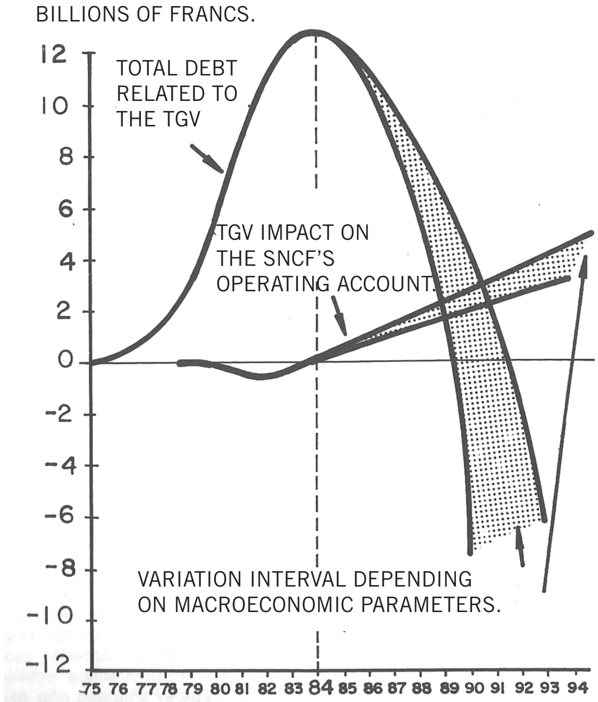
Types of financing for high-speed lines in France have been accurately described by M. Leboeuf in his extraordinary publication «Grande vitesse ferroviaire» (2013). We will therefore rely on Chapter 4 of this publication, which addresses the aforementioned issue. Information that we will complement with other references.

Financing for the first high-speed line in France was conditioned by two facts: first, the reasonable doubts of the French State about the future of the medium and long distance passenger railway; secondly, SNCF's conviction about the need for the new line and its profitability.

Consequently, the SNCF received no subsidy to build the TGV Sud-Est. All the necessary capital originated from self-financing and loans issued in the financial market. SNCF paid all the interest costs and amortization payments for both the new line and the TGV branches.

Financial simulations to assess the project's impact on the SNCF's operating account and debt are summarized in Fig. 15.1. It can be seen that all of the loans would be repaid in 10 years. (Actually, only 7 years were required for the investment to be recovered).

### FINANCIAL SIMULATION OF THE TGV SUD-EST (FIG 15.1)




*Source:* M.Walrave (1986)

Until the creation of Reseau Ferré de France in 1997, successive high-speed lines built in France were also financed by the SNCF. In some cases, they had some subsidy. Namely:

**a)** 30% of the cost of building the infrastructure on the TGV Atlantique line. Subsidy from the French State.

**b)** On the TGV Nord line, a significant contribution to the line construction, when passing through the town of Lille. Subsidy from the French State and the Urban Community of Lille. In particular for the construction of the Lille-Europe station.

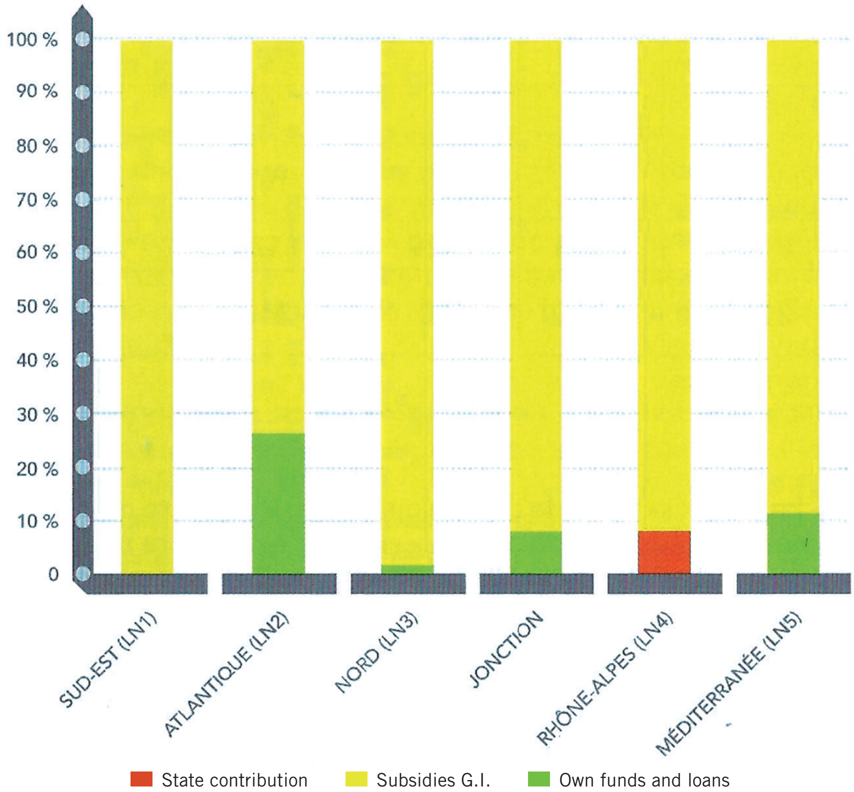
**c)** To build the TGV Interconnexion line, SNCF had subsidies provided by Aéroports de Paris (for the construction of the Roissy station) and the Eurodisneyland Corporation (for the construction of the Marne-la-Vallée station).

**d)** As regards the Rhône-Alpes high-speed line, the SNCF only had the subsidy provided by the Region of the same name, for the construction of the station at the Lyon Saint-Exupéry airport.

**e)** Finally, as regards the TGV Méditerranée, financing, basically by the SNCF, featured various financial contributions for the construction of new stations: Valence, Avignon-TGV and Aix-en-Provence. The subsidies were made by the Regional Councils of Rhône-Alpes and Paca. Also by the General Councils of Drôme and Bouches-du-Rhône.

Figure 15.2 allows us to see the relative importance of the financial contributions by various bodies other than SNCF for the lines mentioned above.

## PERCENTAGE DISTRIBUTION OF FINANCING IN THE FIRST HIGH-SPEED LINES IN FRANCE (1981-2001) (FIG. 15.2)




*Source:* M.Leboeuf (2013

## 15.2 SINCE THE CREATION OF R.F.F

Since the creation of Réseau Ferré de France in 1997, two new high-speed lines have been built in France that are currently open for commercial operation. We refer to the first phase of the TGV Est (Paris-Strasbourg) and the TGV Rhin-Rhône (eastern branch, 1st phase)

With respect to the first line above, Table 15.1 shows the contribution of various stakeholders to its financing.

## TGV EST FINANCING SOURCES (1ST PHASE). TABLE 15.1

| | | |
|---|---|---|
| SNCF | 1% | |
| FRENCH STATE | 39% | 62% |
| RFF | 22% | |
| REGIONAL AUTHORITIES | 24% | 24% |
| EUROPEAN UNION | 10% | 10% |
| GRAND DUCHY OF LUXEMBOURG. | 4% | 4% |

It can be seen how the regional authorities were the second source of financing for the line, after the French State. Note that in the «regional authorities» area, the Regions affected and the Departments are included.

Regarding the financing of the TGV Rhin-Rhône line, eastern branch, first phase, it can be said that its establishment was very similar to the TGV Est. Table 15.2 outlines the contribution made in percentage terms by each institution.

## SOURCES OF FINANCING FOR THE TGV RHIN-RHÔNE, EASTERN BRANCH, FIRST PHASE (TABLE 15.2)

| | | |
|---|---|---|
| FRENCH STATE | 32,48% | 60,25% |
| RFF | 27,77% | |
| FRANCHE-COMTÉ REGIONAL AUTHORITIES | 13,67% | |
| ALSACE REGIONAL AUTHORITIES | 8,91% | 28,25% |
| BURGUNDY REGIONAL AUTHORITIES | 5,67% | |
| SWITZERLAND | 2,85% | 2,85% |
| EUROPEAN UNION | 8,65% | 8,65% |

*Source:* Taken from M. Leboeuf 2013

At present, the 2nd part of the Paris-Strasbourg high-speed line is under construction. The financing system is similar to that adopted for Phase 1. The differences are found in the percentages of each of the contributions made by each body. Table

15.3 (M. Leboeuf 2013) shows, in a comparative way, the contributions corresponding to each phase.

### SOURCES OF FINANCING FOR THE TGV EST (2ND PHASE). TABLE 15.3

| BODY | TGV EST (1st PHASE) | TGV EST (2nd PHASE) |
|---|---|---|
| FRENCH STATE | 39% | 34% |
| REGIONAL AUTHORITIES | 24% | 32% |
| RFF | 22% | 26% |
| EUROPEAN UNION | 10% | 6% |
| GRAND DUCHY OF LUXEMBOURG | 4% | 2% |
| SNCF | 1% | - |
| TOTAL | 100% | 100% |

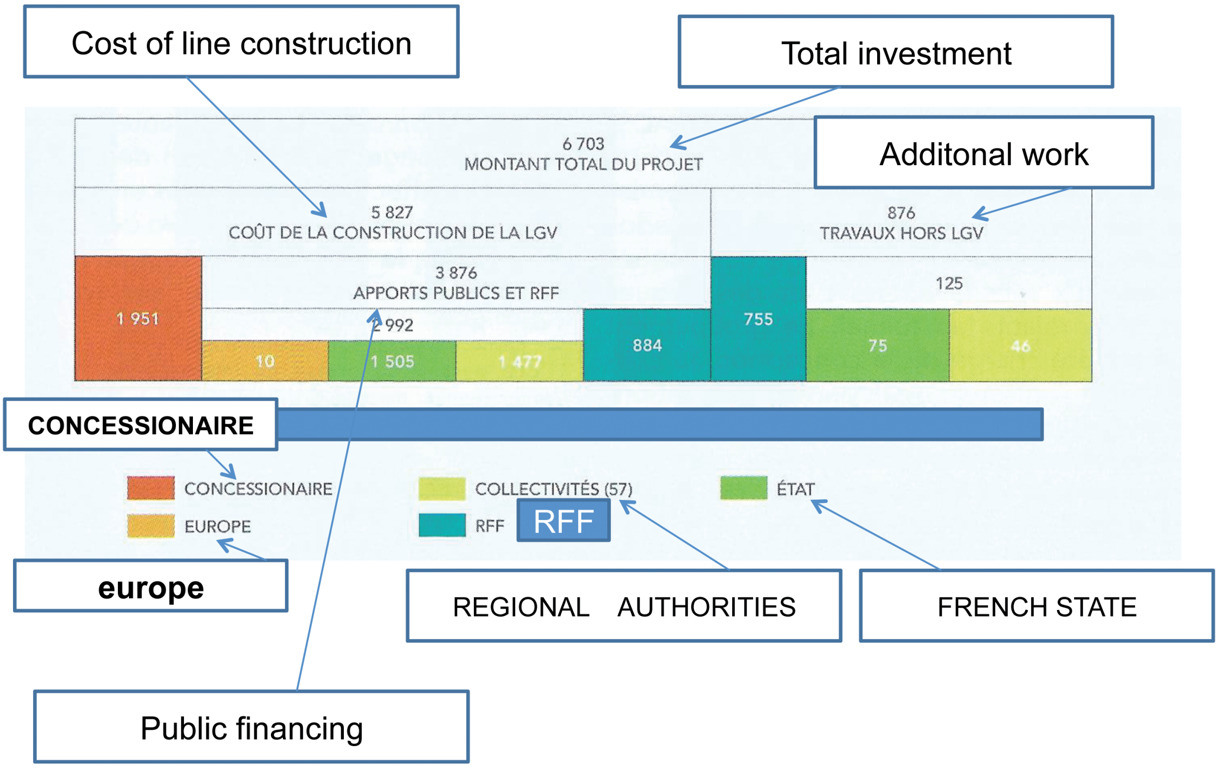
*Source:* M. Leboeuf (2013)

With respect to the first phase, a greater contribution by regional authorities and RFF is observed.

The latest high-speed lines which are currently under construction have a mixed public-private financing.

Indeed, in June 2011, the concession agreement was signed related to the financing, design, construction, maintenance and operation of the high-speed line between Tours and Bordeaux (300 km) with the LISEA group, promoted by Vinci. Fig. 15.3 shows the distribution of total financing (6,703 million euros in 2009) among the various institutions involved.

## FINANCING OF THE TOURS-BORDEAUX HIGH-SPEED LINE (FIG. 15.3)




*Source:* Adapted from M. Leboeuf (2013)

As for the construction of the so-called TGV Bretagne-Pays de la Loire, the financing system adopted is similar to that shown above. It involved financing a new 182 km line, to which it is necessary to add 32 km of sections for links to existing lines. Table 15.4 explains the percentage contribution made by each Body.

## TGV BRETAGNE-PAYS DE LA LOIRE FINANCING SOURCES (TABLE 15.4)

| | | |
|---|---|---|
| FRENCH STATE | 28,40% | 42,35% |
| RFF | 13,95% | |
| BRETAGNE REGIONAL AUTHORITIES | 25,70% | 28,40% |
| PAYS DE LA LOIRE REGIONAL AUTHORITIES | 2,70% | |
| EUROPEAN UNION | 0,39% | 0,39% |
| PRIVATE PARTICIPATION | 28,86% | 28,86% |

*Source:* Adapted from M. Leboeuf (20139)

Note how the financial contribution of regional authorities coincides with that of the private sector (Eiffage group). The latter will receive a return for their share of the investment, and other revenue for the maintenance and renewal of the line in the operating period considered (25 years).

Similarly, the Nîmes and Montpellier high-speed bypass will be constructed through public-private financing. In this last area, it involves the OC'Via group. In Table 15.5 the contribution of each institution is explained.

**NÎMES AND MONTPELLIER HIGH-SPEED BYPASS FINANCING SOURCES (TABLE 15.5)**

| | | |
|---|---|---|
| RFF | 6,8% | 24,6% |
| EUROPEAN UNION AND FRENCH STATE | 17,8% | |
| LANGUEDOC-ROUSSILLON REGION | 6,8% | 9,6% |
| MONTPELLIER AGGLOMERATION | 1,4% | |
| GENERAL COUNCIL OF GARD | 0,7% | |
| NÎMES AGGLOMERATION | 0,7% | |
| PRIVATE ENTERPRISE. OC'VIA GROUP | 65,8% | 65,8% |

*Source:* Adapted from M. Leboeuf (20139)

We refer, finally, to the financing of the Figueres-Perpignan international section, which entered commercial service in late 2010.

The establishment of a new rail link between Spain and France on the Mediterranean border, equipped with the same track gauge, is undoubtedly a historical event. It is a 44 km long line that included construction of an 8.2 km tunnel under the Pyrenees.

To do this, the governments of both countries decided to use a system of public-private financing. Among the various economic groups presented, the concession was awarded to TP Ferro, a company that is jointly owned by the Spanish group ACS and the French group Eiffage.

The necessary investment amounted to 1,096.7 million euros. To cope with this investment, the financing structure adopted had three sources of funds:

| | |
|---|---|
| OWNS RESOURCES | 103.3 million euros |
| PUBLIC SUBSIDIES, INCLUDING AID FROM THE EUROPEAN UNION | 588.4 million euros |
| BANK FINANCING | 400 million euros |

It can be seen, therefore, that it involved public-private financing with a 54% / 46% resource distribution.

# CHAPTER 16.

# FINANCING OF HIGH-SPEED LINES IN GERMANY

Generally, German infrastructures projects are primarily funded by the federal government with contributions from DB via user charges, regional government, municipal and European Union subsidies.

So, in advance, each project is subjected to a macro-economic evaluation. This gives a cost-utility indicator that determines the usefulness of the project.

Once this stage is passed, the project is registered in the master plan for railway infrastructure.

As a reference, the Nuremberg-Ingolstadt high-speed section that was built in 2006, was funded with the following structure:

- Federal Government (58%)
- Deutsche Bahn (32%)
- Regional Government (5%)
- European Union (5%)

# CHAPTER 17.

# FINANCING OF HIGH-SPEED LINES IN ITALY

Following the decision to build the first high-speed line in Italy, between Rome and Florence, in the 1960s, the system of financing new infrastructure has evolved significantly.

The above line was financed with public funds, given that at that point in time, the Italian railways were state-managed. In general, this proceeded in two stages: first, legislative authorization granted by the Assembly was obtained; second, the corresponding loans that made it possible to pass to the work phase were released.

As an illustrative reference, through Law No. 1089 of 25/10/1968, the Italian Parliament granted a first loan of 200 million liras. This was followed by others to allow completion of the new route between Rome and Florence in 1992.

To construct the high-speed network referred to in section 4, a subsidiary of Italian railways was created in 1991, called TAV.

This company would be responsible for the construction and operation of the Naples-Rome-Milan-Turin high-speed lines until 2041. The main features of TAV are listed below (G. Guidoni, 2004):

- The share capital of TAV is private for more than 50% (Italian banks and insurance companies, foreign lending institutions) with public shares held by FS

- Financing is provided by the State 40%-through FS-and by the market 60%.

- The State pays the interest accrued on the market debt up until the start of operating of the line.

- TAV markets the railway services and operate the line and the cash flow are used to distribute dividends to shareholders and to reimburse the debt.

Subsequently, in order to offer he marked a certainty capable of offsetting the long timeframe of the funding, in 1994 and ad hoc law introduced the guarantee of last resort by the State-to be used only in the case in which commercial guarantees would be insufficient to repay the debt-related to the concession, the construction and management of the HS System.

In 1998 the corporate and funding structure of TAV was changed (Savini Nicci, 2006):

- FS/RFI buys back the shares held by private shareholders and becomes full owner of TAV (with 100% of the shares).

- The financial scheme remains unchanged (40/60%), as does the guarantee of last resort by the State and payment of interest by the State.

- TAV concentrates its mission exclusively on the design, construction and the relative financing of the work, whereas the marketing is assigned to an ad hoc transport company owned by FS.

- The debt is rescheduled with the proceeds from the fees paid to gain access to the HS lines that TAV makes available to RFI. In turn, RFI will run the infrastructure and will sell times slots to the ad hoc transport company owned by FS.

At the beginning of the last decade, and in implementing European Directive 91/440 concerning the separation of railway infrastructure and operation, the so-called «Infrastructure Manager» (RFI) was created. This company, RFI, is established (2001) as a subsidiary of the «Ferrovia dello Stato», a public company in the form of a Limited Company, 100% owned by the Italian State.

RFI's mission is the development, operation and maintenance of railway infrastructure. Within the RFI, the TAV subsidiary is established as a company specifically created to design, plan and implement the Italian high-speed network.

From an operational point of view, the construction of the Naples-Rome-Milan-Turin high-speed line was divided into 5 sections. To build each one, TAV joined a private consortium. Each consortium was formed by Italian construction and engineering companies.

These were responsible for pre-financing 60% of the work, constructing the line and delivering it to TAV. The rest of the financing was by the Italian State through FS (including possible cost overruns).

So, in January 2003 a new financial scheme was set up for HSL provided for in the 2003 Budget Law (art 75) with the establishment of «Infrastructure SPA» (ISPA).

The sole shareholder of ISPA is the Cassa Depositi e Prestiti, financial institution of Ministero Economia e Finanze.

ISPA was set up to finance large public works and "..by way of priority, also through the establishment of one or more separate funds, to finance the investments for constructing the railway infrastructure for the High-Speed/High Capacity system also with the aim of reducing the share to be shouldered by the State.

ISPA was authorised to finance the Torino-Napoli-Milano lines up to a total amount of up to 25 billion Euro.

To allow for more effective operation of ISPA, the public resources issued for TAV are transformed into share capital. TAV becomes a special purpose company of RFI and the public concession for HS passes from TAV to RFI. The concession to RFI for the HSL is extended from 2041 to 2061.

ISPA obtains financial resources, either by stipulating funding loans, or by issuing covered bonds. The covered bonds issued by ISPA are based on the separate fund created by high-speed rail proceeds and state funding.

By way of summary, outlined below (Table 17.1), and following Savini Nicci (2007) is the evolutionary process described above on the system of financing for Italian high-speed lines.

## EVOLUTION OF THE ITALIAN HS FINANCIAL PLAN (TABLE 17.1)

| | |
|---|---|
| -Establishment of TAV SpA<br>-Design | 1991<br>**Mixed share capital**: 43% public (Ferrovie dello Stato) - 57% private (banks)<br>**Financing scheme**: private 60% - public 40% |
| ↓ | |
| -Beginning of construction work | 1994<br>**Mixed share capital**: 43% public (Ferrovie dello Stato) - 57% private (banks)<br>**Financing scheme**: private 60% - public 40%<br>→ a State law (78/94) provides a guarantee of last resort by State on private financing |
| ↓ | |
| -State of progress of the work: 8% | 1998<br>→ **Public share capital** 100% (Ferrovie dello Stato)<br>**Financing scheme**: private 60% - public 40% |
| ↓ | |
| State of progress of the work: 43% | **2003**<br>**Public share capital**: 100% (Ferrovie dello Stato) → Rete Ferroviaria Italiana)<br>**Financing scheme**: 20% public - 80% ISPA (Infrastructure SpA),<br>**ISPA** is a company owned by Cassa Depositi e Prestiti (public financial institution controlled by the Ministry for the Economy) devoted to public projects included financing the HSL through bonds and loans from the financial market with a guarantee of led resort by the State |
| ↓ | |
| -Entry into operation of the Rome-Naples and Turin-Novara lines<br>-State of progress of the work: 68% | 2006<br>Incorporation of ISPA in Cassa Depositi e Prestiti.<br>The private financing borrowed by CdP become a financing to the State |
| ↓ | |
| -Progress in construction works: 73% | 2007<br>**Public share capital** 100% Rete Ferroviaria Italiana<br>**Financing: market** (Bank and Financial Institution as BEI) 25%.<br>**Public**: State funds 34% - CdP lending 40% - EU funds 1%<br>According to this last scheme the **market sector** (**banks**) will finance 25% to be paid a part by revenue of the HS business |

*Source:* Savini Nicci (2007)

It should be recalled, finally, that the Naples-Turin high-speed corridor entered full commercial service in 2009.

# CHAPTER 18.

# FINANCING OF HIGH-SPEED LINES IN SPAIN

Similarly to the above-mentioned case of France, railway organization in Spain has evolved over time. This has had an impact on the financing system adopted for the construction of the first high-speed lines.

In the time period in which the new Madrid-Seville line was constructed, the railway system was structured around a single company: Renfe.

In the mid-1990s, the so-called «Railway Infrastructure Manager» (GIF) was created, with the aim of building the following high-speed lines in Spain. It was in this context that work on the new Madrid-Barcelona line started.

Finally, in 2005, and in implementing Directive 91/440, the railway was organized on the basis of two companies: ADIF, owner of the infrastructure and responsible for management (including both conventional and newly constructed lines), and RENFE OPERADORA, which owns the trains and is responsible for their operation.

Since then, all new high-speed lines in Spain have been built by ADIF. Table 18.1 summarises the evolution indicated in the railway organization.

### RAILWAY ORGANIZATION AND CONSTRUCTION OF NEW LINES IN SPAIN (TABLE 18.1)

<table>
<tr><th>High-speed line</th><th>Railway organization</th></tr>
<tr><td>Madrid-seville (1987-1992)</td><td>Renfe is responsible for the railway infrastructure</td></tr>
<tr><td colspan="2">In december 1986, the Gif (railway infrastructure manager) was created. Its mission was to build and, where appropriate, manage new infrastructure that the government attributed to it.</td></tr>
<tr><td colspan="2">On 23 may 1997, the Gif was commissioned to build the new Madrid-Barcelona-French border line.</td></tr>
<tr><td>Madrid-Zaragoza-Lleida (1996-2003)</td><td>From 1996 to 2004 , the Gif was the company responsible for the construction of high speed lines</td></tr>
<tr><td colspan="2">On 1 january 2005, following the insertion of the Gif in Renfe, the latter company was divided into two:<br>Adif: owner of the infrastructure and responsible for its management.<br>Renfe operadora: owner of the trains and responsible for their operation.</td></tr>
<tr><td colspan="2">From that date, Adif was the company responsible for the construction of new high-speed lines in Spain, and the conclusion of those under construction.</td></tr>
</table>

Based on the above, the first high-speed line between Madrid and Seville was financed with public funds (from the State and Renfe). The line included a contribution from the European Regional Development Fund (ERDF) of 267.3 million euros. Total investment in the aforementioned high-speed line was equivalent to 2,200 million euros.

For lines built afterwards, the financing system was based on the elements summarised in Table 18.2

**FINANCING SYSTEM FOR HIGH-SPEED LINES IN SPAIN (TABLE 18.2)**

| | |
|---|---|
| STATE CONTRIBUTIONS | > Budgetary contributions (ADIF)<br>> Subsidies and allowances<br>> Debt:<br>*Financial Institutions<br>*European Bank for Reconstruction and Development |
| EUROPEAN UNION FUNDS | > Cohesions Funds<br>>FEDER<br>>Trans-European Transport Networks |

Source: Adapted from J. Campos (2009)

The distribution of the total investment in each of the lines currently in commercial operation, depending on the source of funds, is shown in Table 18.3. The data are rounded off figures and expressed in millions of euros

## CONTRIBUTIONS FROM THE SPANISH STATE AND EU FUNDS TO FINANCE THE FIRST HIGH-SPEED LINES (TABLE 18.3)

| | | | CONTRIBUTIONS FROM | | | |
|---|---|---|---|---|---|---|
| LINE (YEAR OPENED) | TOTAL INVESTMENT | ADIF | COHESION FUNDS | ERDF | TEN-T | Total European funds |
| Córdoba-Málaga (2006-2007) | 2.539 | 1686 | - | 954 | - | 954 |
| Madrid-Barcelona-French border (2008-2013) | 12.376 | 8.916 | 3.349 | - | 82 | 3.481 |
| Madrid-Valladolid (2007) | 4.205 | 2.418 | 1.731 | 260 | 21 | 2.012 |
| Madrid-Toledo (2005) | 208 | 106 | - | 102 | - | 102 |
| Madrid-Levante (From 2010) | - | 10.216 | 1.299 | 605 | 53 | 1.957 |

Source: compiled independently from ADIF data

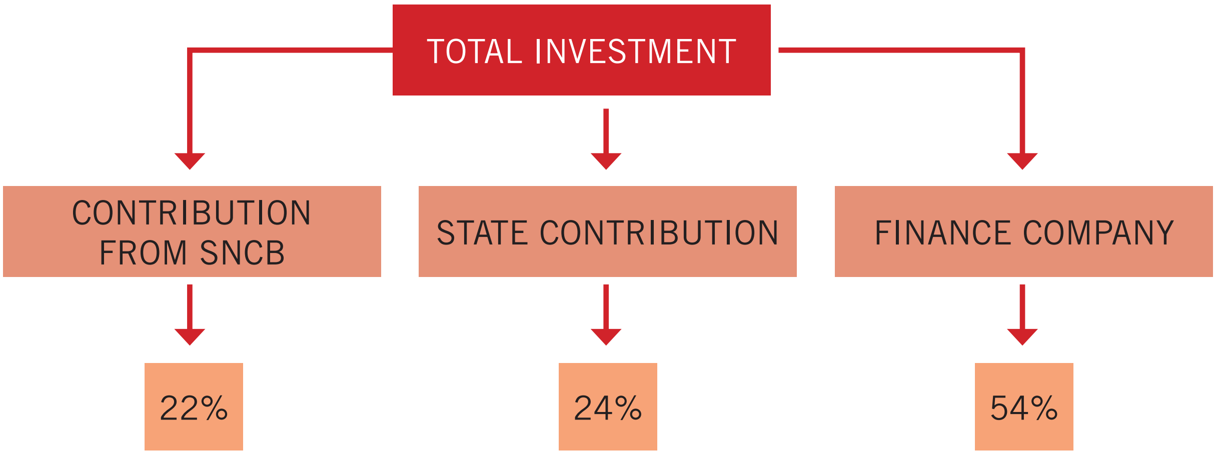
You can see the relevant importance of European funds on some lines, as was the case of the Madrid-Toledo and Madrid-Valladolid routes. Overall, the above funds represented around 27% of the contributions made by ADIF. It should be noted, finally, that ADIF had the collaboration of the European Investment Bank, through the granting of different loans.

# CHAPTER 19.

# FINANCING OF HIGH-SPEED LINES IN BELGIUM

The Belgian high-speed network has a total length of 209 km. The investment required for implementation was estimated at 4.18 million euros (2002).
The financing scheme is shown in Fig. 19.1

**HIGH-SPEED NETWORK FINANCING MODEL IN BELGIUM (FIG. 19.1)**




*SOURCE:* Compiled independently from different references.

With regard to the resources provided by the Belgian railways, it should be noted that they came from loans requested basically from the European Investment Bank.

The contribution by the Belgian State, provided in the form of an annual contribution, was justified by the positive impact that the work of the new line would have on the modernization of approaches to Brussels, Liege and Antwerp.

Finally, the finance company would be formed by the Belgian State and private investors. Meanwhile, the EU provided 215 million euros, given the European interest of the Belgian high-speed network.

# CHAPTER 20.

# FINANCING OF HIGH-SPEED LINES IN HOLLAND

The high-speed line currently existing in Holland runs between the French border with Belgium (near Breda) and Hoofddorp (entrance to the tunnel under the runway at Amsterdam's Schiphol airport (Fig. 20.1), with a total length of 120 km. It is called the HSL-Zuid.

**HIGH-SPEED LINE IN HOLLAND ((FIG. 20.1)**


*Source* : H.V. Amstel (2007)

The completion of this line was the subject of a singular organization by the Dutch government. Three specific areas were distinguished: infrastructure, superstructure and operation.

With respect to the independent consideration of the infrastructure and superstructure, Aecom (2013) noted: « The key reasons for this separation were the expected inability of the construction industry to assume multi-billion euros contracts, competition requirements, existing detailed substructure designs and an agreement with Belgium which put time pressure on the expected completion date»

With regard to infrastructure, six engineering and construction consortiums were hired with payments by the government during and upon completion of the engineering and construction phases.

With regard to the superstructure, its implementation was entrusted to Infraspeed Consortium. Infraspeed is responsible for the design, build, financing, availability and maintenance of the HSL-Zuid superstructure for a concession period of 25-years, in addition to a five-year construction period.

The project includes (P.V der Wilden, 2004), responsibility for managing all system elements, which include signalling systems, traction power supply, command and control systems ,ancillary equipement and telecommunications, rail track and noise barriers, as well as right-of-way fencing where required for safety purposes.

As part of the contract, Infraspeed guarantees 99,46 per cent availability of the line over the 25-year concession period from 2006 to 2031.As of 2006 , the Dutch Government will pay Infraspeed an annual fee for making the HSL infrastructure available, which allows Infraspeed to cover its expenses, and recover its capital investment. If the consortium fails to realise 99,46 per cent availability, the fee is reduced.

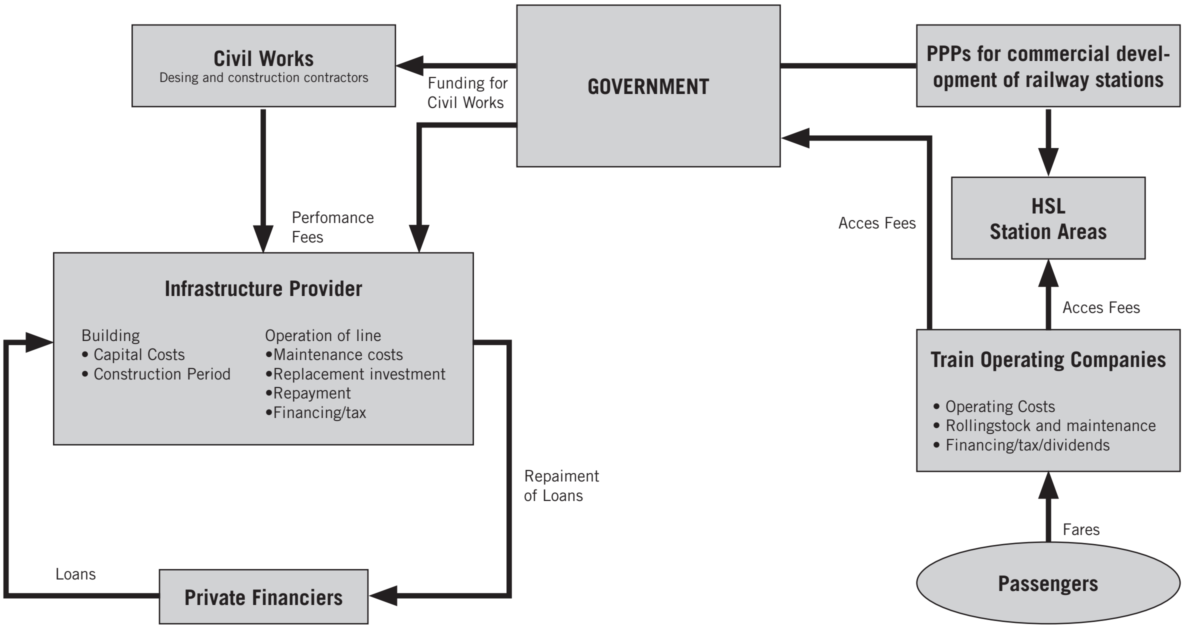
The Infraspeed consortium was formed in February 1999.The members are: Fluor Infrastructure, Siemens Nederland, Royal BAM Group, Innisfree and HSBC Infrastructure.

Fluor Infrastructure is an industry leader with expertise in executive complex capital projects around the world. Siemens Nederland has extensive experience in the ERTMS signalling system and the GSM-R communication systems. BAM Rail had experience in trackside and acoustic protection.

Finally, it should be noted that for operating the high-speed line, the consortium High-Speed Alliance (HAS) was founded, which comprises of Dutch Railways NS (90%) and Royal Dutch Airlines (KLM) (10%).This consortium has the right to operate high-speed transport on the entire route for 15 years. Trains of the HAS will cover the services between Amsterdam and Brussels, while the existing operator Thalys will continue to operate between Amsterdam and Paris.

The HSL-Zuid project team was set up at the start of the project as a separate group under the supervision of the Ministry of Transport. Fig 20.2 illustrates the institutional arrangements for the HSL-Zuild Line. The above figure was published by Daniel Loschacoff in September 2000 during the 14th Session of the OECD Advisory Group on Privatisation (AGP) held in Budapest.

## INSTITUTIONAL ARRANGEMENTS FOR THE HSL-ZUILD LINE (FIG. 20.2)



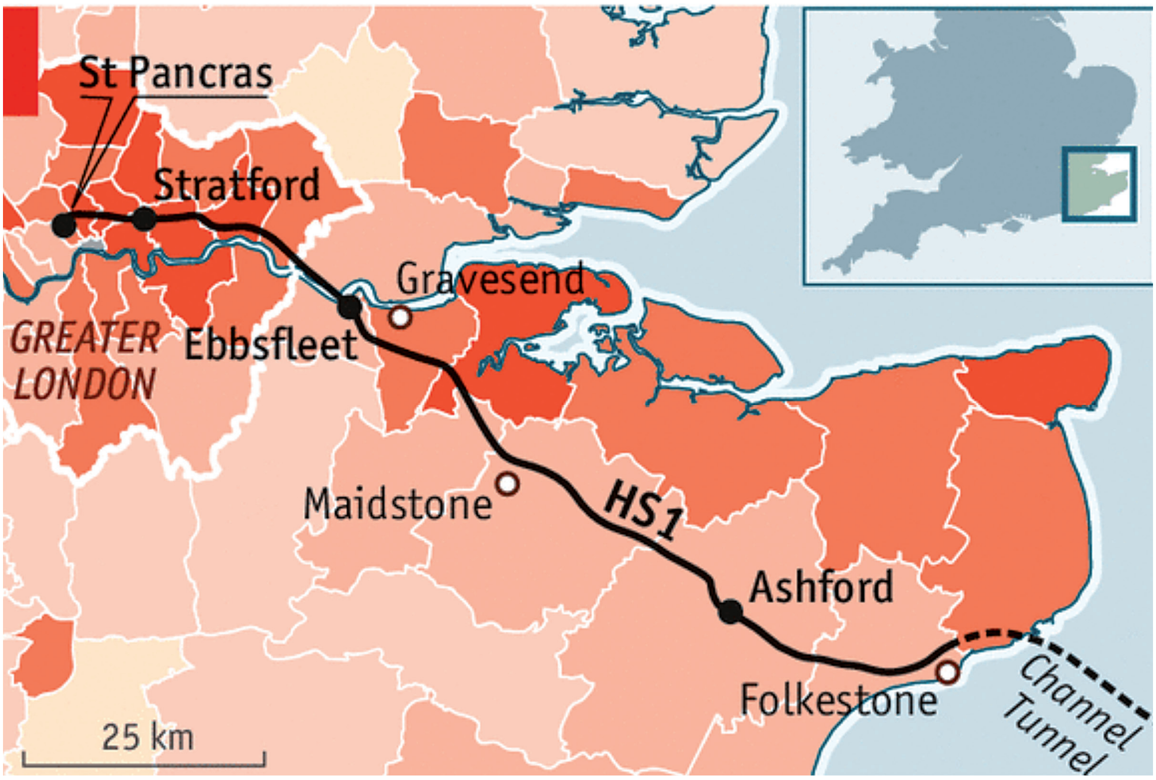

*Source:* D. Loschacoff (2000)

# CHAPTER 21.

# FINANCING OF HIGH-SPEED LINES IN THE UK

It can be said that the first steps that led to the construction of the first high-speed line in the UK began in 1994.
At that point in time, the British government announced a tender to build a line of just over 100 km between London and Folkestone, i.e. between the English capital and the exit from the tunnel under the English Channel (Figure 21.1). It was known as HS1.

**HIGH SPEED LINE LONDON-FOLKESTONE (FIG. 21.1)**




It involved finding a private consortium to implement this line. Two groups responded with bids: firstly, London and Continental Railways (LRC); secondly, Eurail. In 1996, LRC was granted a concession to design, finance, construct, operate and maintain the HSR link.

As indicated above,it was originally planned that the project would be privately financed. However, those plans were abandoned in 1997.were (Aecom (2013) noted that after actual Eurostar Revenues were found to be overly optimistic compared to prior projections. The project was funded by a mixture of government grants and private funding by LCR.

It is interesting to show (Table 21.1) the members of the LRC Group.

**COMPOSITION OF THE LONDON AND CONTINENTAL RAILWAY CONSORTIUM (TABLE 21.1)**

| COMPANY | SHARE (%) | COMMENTS |
|---|---|---|
| ARUP | 2 | Design and civil Engineering |
| BECHTEL | 18 | Important company in enginering work |
| HALCROW | 2 | Leading company in tunnel design |
| LONDON ELECTRIC | 12 | Electricity distribution in London |
| NATIONAL EXPRESS | 17 | The most important long distance Bus company in the UK. |
| SYSTRA | 14 | SNCF and RATP engineering subsi-diary |
| VIRGIN | 17 | Group of companies specialized in tourism and air transport |
| SG WARBURG | 18 | Main european investment bank |

*Source* : Brian Perren/j.P.Masse (1996)

The line between Folkestone and London was originally planned to be constructed in a single phase. In 1998, however, overly optimistic ridership projections caused LCR to have financial difficulties. Thus the project was divided into two sections:

- Section 1, which cost 1,9 ( billion pounds ) to built was completed in 2003.
- Section 2, which cost 3,9 ( billion pounds ) to built,was completed in 2007.

The funding structure of HS1 is summarised in Table 21.2

## HS1 FUNDING STRUCTURE (TABLE 21.2)

| | Section 1 | | Section 2 | |
|---|---|---|---|---|
| **Mode** | **Libras*** | **%** | **Libras*** | **%** |
| Central government debt | 2,65(1) | 69 | 1,25 | 42 |
| Central government grants | 0,70 | 18 | 1,20 | 58 |
| Third party finance | 0,49 | 13 | - | - |

* Billion; (1) includes initial operating eurostar losses

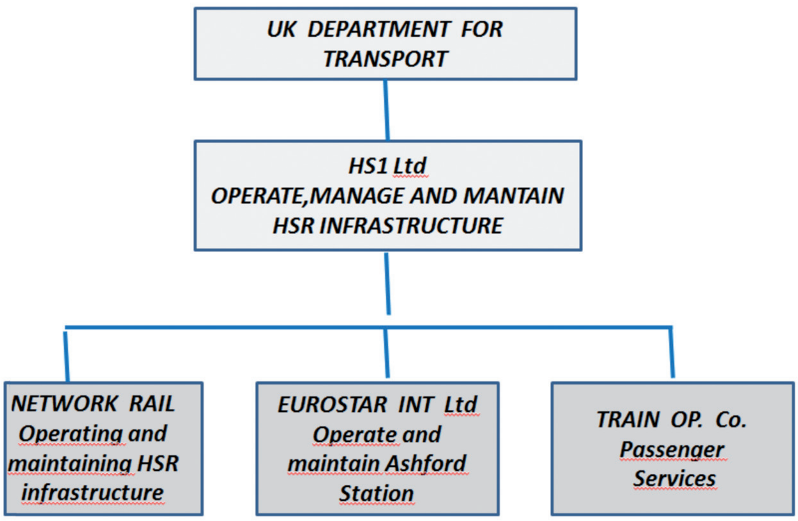
*Source :* California High Speed Rail Project.International Case Studies (2011)

Regarding the term «Third party finance» it should be noted that this figure is a combination of debt and equity used to finance enabling work for first two years of development.

LCR faced further financial difficulties in 2009 and the United Kindgom Department for Transport took direct ownership for a nominal price. This was possible due to the company´s dependence on significant levels of government-guaranted debt.

In 2010, HS1 Ltd purchased the right to operate ,manage and maintain the HSR infrastructure until December 2040 for 2,1 ( billion pounds ). HS1 Ltd is jointly owned by Borealis Infrastructure and Ontario Teacher´s Pension Plan, two Canadian pension funds.Fig 21.2 illustrates the institutional arrangements for HS1.

## HS1 INSTITUTIONAL STRUCTURE (FIG. 21.2)




*Source:* Aecom (2013)

# CHAPTER 22.

# FINANCING OF HIGH-SPEED LINES IN SOUTH KOREA

As indicated in section 7, the first high-speed line in this country was planned between Seoul and Busan, over 424 km. A line that was built under the responsibility of the «Korean High Speed Railway Construction Authority» (KHRC).

Cost were estimated to be 20 trillion won (18,2 (billions of U.S. dollars). The financing plan for the project was devised to minimise financial cost and to secure finance in a timely manner at attractive rates (kee-Dong Kang, 2002). Figure 22.1 shows a summary of the above Plan.

**FINANCING OF THE SEOUL-BUSAN HIGH-SPEED LINE (TABLE 22.1)**

| Government | KHRC |
|---|---|
| (45%) | (55%) |
| (35%) in the form of subsidies. | (24%) from foreign bonds and loans |
| (10%) in government loans | (29%) from domestic loans |
| | (2%) in the form of private capital |

*Source :* A.L.Pita (2014)/D.Briginshaw (2002)

The loans would be repaid by KTX operating revenues in the comming years.

# CHAPTER 23.

# FINANCING OF THE HIGH-SPEED LINE IN TAIWAN

The first ideas to build a high-speed line between Taipei and Kaohsiung date back to the early 1970s. It was necessary to wait until 1990 for the government to give its agreement in principle to the construction of that line.

For its practical implementation, an agency called BOTHSR (Bureau of Taiwan High Speed Rail) was created, in order to take responsibility for the planning and construction of this high-speed line. At the time it was intended that the State would build the new rail infrastructure.

However, in 1993, the Parliament rejected the project budget. According to Y.H. Cheng (2005), there were two main reasons:

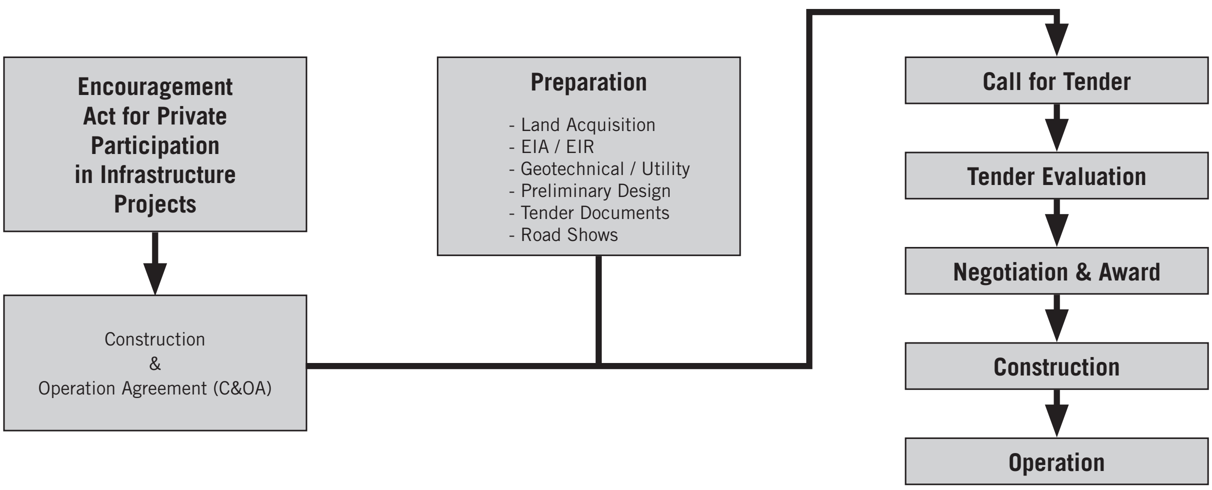
1. The financial burden of the State, which was becoming greater.

2. Doubts about the effectiveness of the public companies which would be entrusted with the construction of the line.

Consequently, it was decided to use a BOT (Build-Operate-Transfer) system. PPP Approach is request by the Congress with a minimum 40% of investment from private sector.

In August 1996, the BOTHSR started the work of preparing the specifications and documents to be given to the candidates for the BOT. It also included the process of selecting and evaluating applications (Fig. 23.1) (T.C. Kao, 2011)

**STEPS OF THE PRIVATIZATION (FIG. 23.1)**



The process was established in two phases: first, the experience of the candidates would be analysed, in addition to their financing schemes, in order to ensure their ability to complete the project; secondly, in-depth meetings would be organized between the Government and the candidate selected.

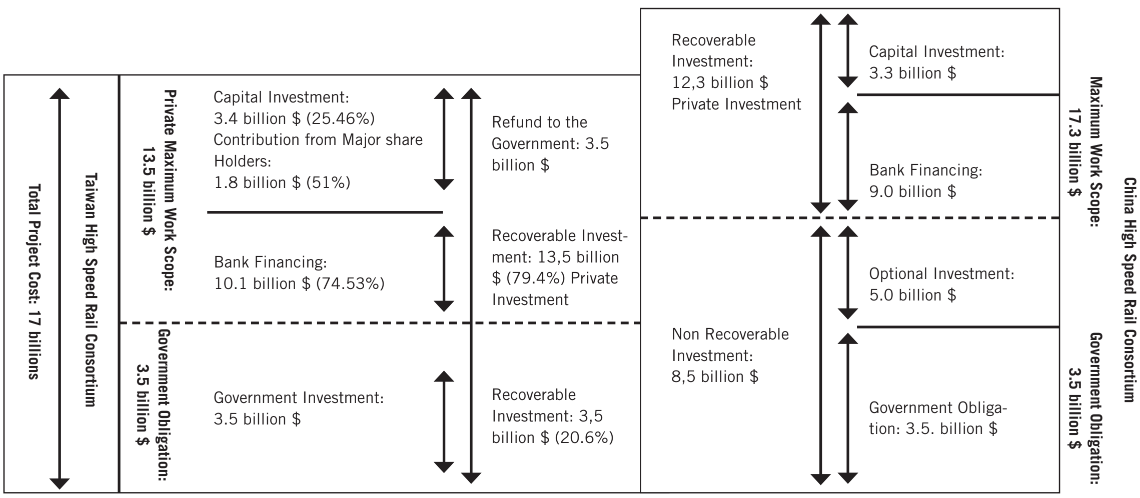
Two candidates were qualified to submit bids:

1. China High Speed Rail Consortium (CHSRC).
   It consisted of twenty companies, including China Development Corporation and China Steel.

2. Taiwan High Speed Rail Consortium (THSRC).
   It was formed by Continental Engineering Corporation (CEC); Pacific Electric Wire and Cable Company (PEWC); TECO Group); Evergreen International Corporation, and Taipei Fubon Commercial Bank Company.

The resolution on the tender, in August 1997, saw it awarded to THSRC. THSRC was chosen as the preferred bidder as a result of its cheaper bid and a promise to build the line with zero net cost to the government (Fig 23.2).

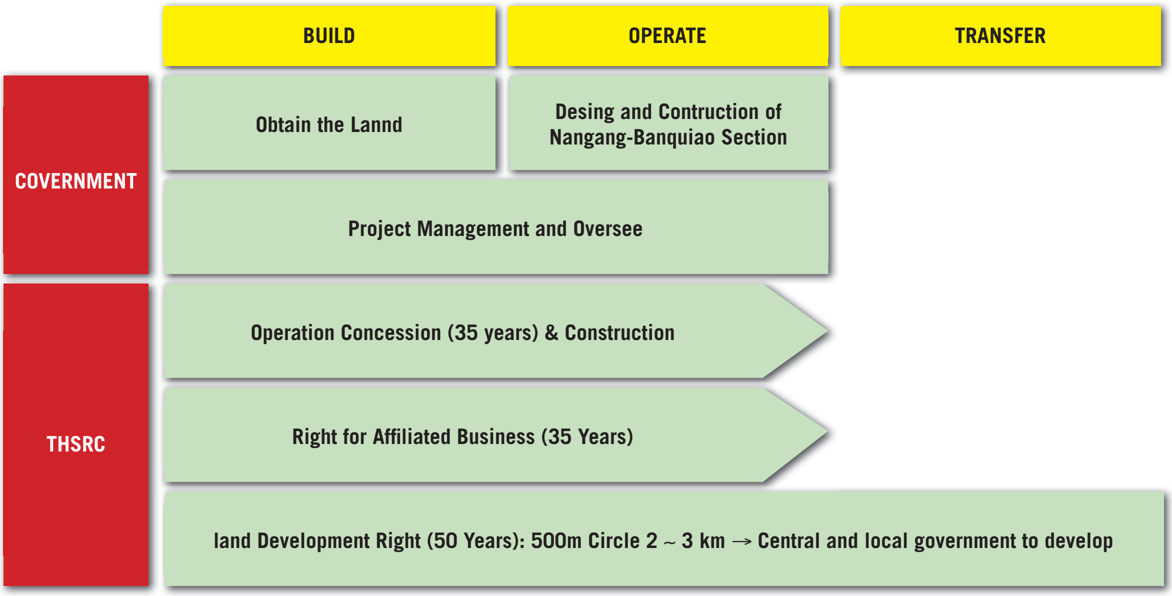
**PRICING COMPARISON (FIG. 23.2)**




*Source:* T.C. Kao (2011)

In July 1998 agreements were signed between the Ministry of Transport and Communications and THSRC, which granted THSRC the concession to finance construct and operate the HSR system for a period of 35 years, and a concession of 50 years for HSR station areas development (Fig 23.3)

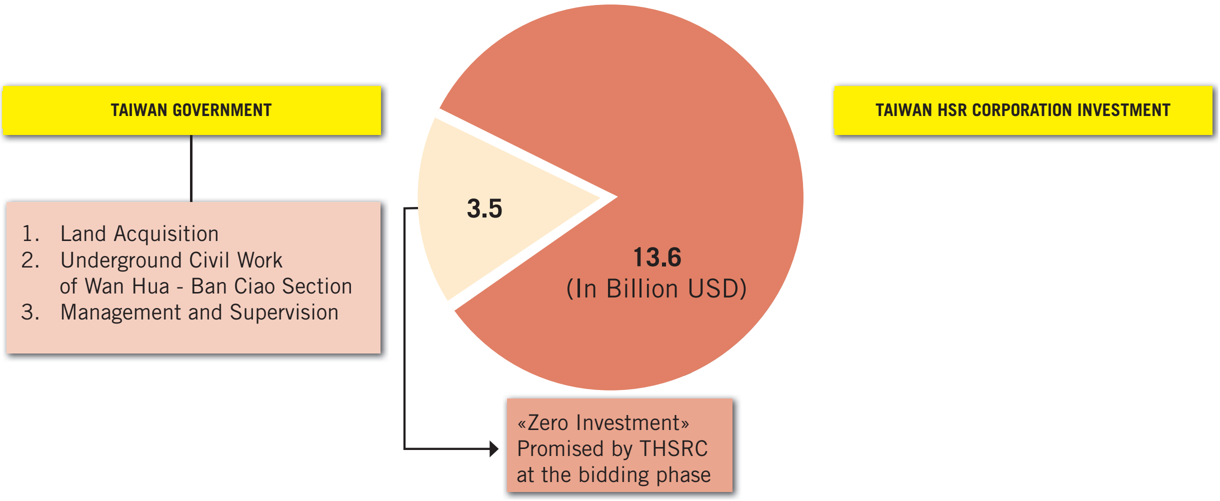
**PPP MODEL - THE BOT (FIG. 23.3)**




*Source:* S.K.J. Chang (2013)

Overall it would involve a total investment of 17 billion dollars, with the percentage distribution shown in Figure 23.4.

## GOVERNMENT VS. PRIVATE INVESTMENT (FIG. 23.4)




*Source:* S.K.J. Chang; T.C. Kao

THSRC finance part of the development costs by borrowing from Taiwanese financial institution. A significant proportion of the funds were guaranted by the government. THSRC faced different problems that caused an increase in the project cost. As a reference, the rolling stock problems are indicated.

Indeed, the HSR line was at first specified to use European train-sets but after much controversy the Japanase Shinkansen bullet train system were chosen instead. This change in specifications caused delays in the starting of service due to problems with adjustment of the Japanase system to infrastructure that had already been built to European specifications.

In addition, the opening of commercial operations on the line highlighted new challenges. The ridership forecasts predicted that over 200,000 daily passengers would use the HSR in its initial stage of operation.This has not materialized. After 20 months of operation, only 84,000 passenger on average have used the HSR service per day.

Not surprisingly, therefore, only three years after the entry into service of the high-speed line, the government was forced to take control of 40% of THSRC, and to reschedule debt.

# CHAPTER 24.

# FINANCING OF THE HIGH-SPEED LINES IN CHINA

The typical financing arrangement for construction bullet trains lines is: about 40-50% of financing is provided by the national government through lending by state owned banks and financial institutions; another 40% by the bonds issued by the Ministry of Railway(MOR), and the remaining 10-20% by provincial and local governments.

# CHAPTER 25.

# FINANCING OF THE HIGH-SPEED LINES IN TURKEY

Financing of the first high-speed lines in Turkey has been achieved from a variety of sources, which can be summarized as follows:

- Own funds.
- European Investment Bank (EIB)
- Funds for Development Assistance (FAD)
- Council of Europe Development Bank (CEB)
- Government of the People's Republic of China, China Eximbank.

Regarding the first source of finance, it should be noted that the Government of the Republic of Turkey spent 2,900 million euros on the railway in the 2006-2011 period.

Moreover, since Turkey is a candidate country to become a full member of the European Union (EU), State Railways of the Turkish Republic (TCDD) have received several loans from the European Investment Bank.

In particular, a loan of 850 million euros in the 2006-2009 period for the first phase of the high-speed line between Ankara and Istanbul.

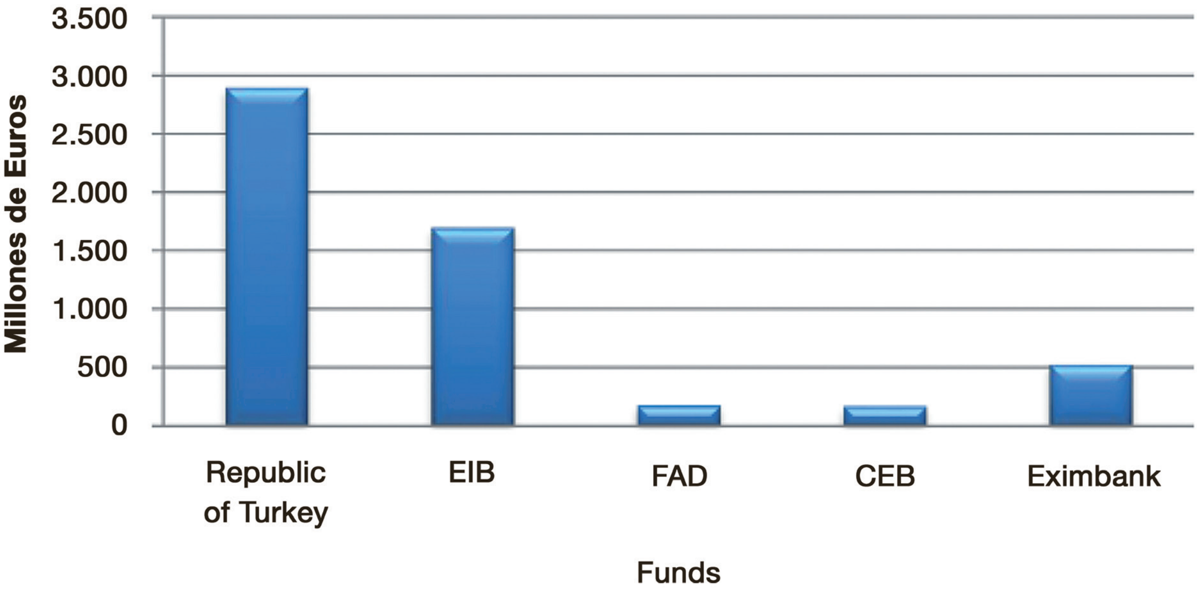
In addition to a second loan of 600 million euros for the second phase of this line.

It should be noted that the Spanish Government, through the Funds for Development Assistance (FAD), granted a loan of 180 million euros for the acquisition of high-speed lines.

We refer, finally, to the 530 million euros loan provided by China Eximbank for the second phase of the Ankara-Istanbul high-speed line.

Figure 25.1 shows the source of investments for the development of high-speed lines.

## SOURCE OF FUNDS TO FINANCE THE FIRST HIGH-SPEED LINES IN TURKEY (FIG. 25.1)



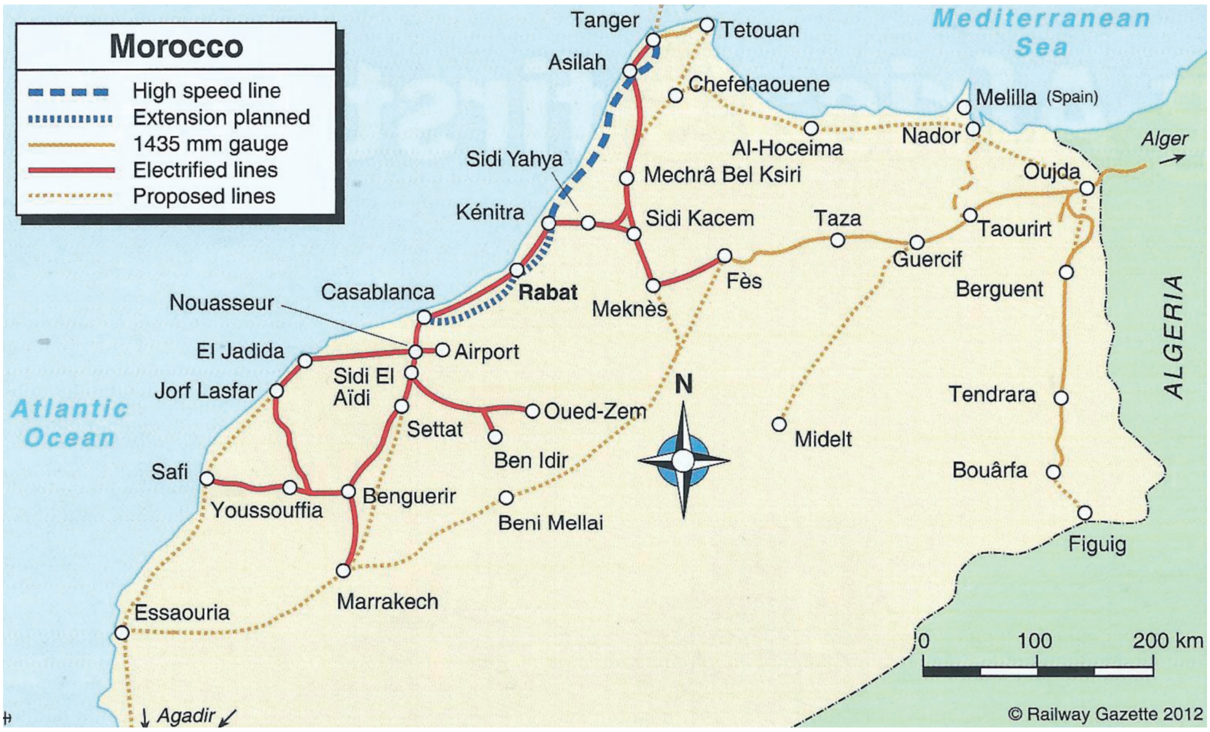

*Source:* M. Can Kaytan (2012)

# CHAPTER 26.

# FINANCING OF THE FIRST HIGH-SPEED LINE IN MOROCCO

As indicated in section 12, the first high-speed line is currently being built, between Tangier and Kenitra (Fig. 24.1). It will have a total length of 200 km. Work began in September 2011, and its opening is scheduled for commercial operation in 2016.

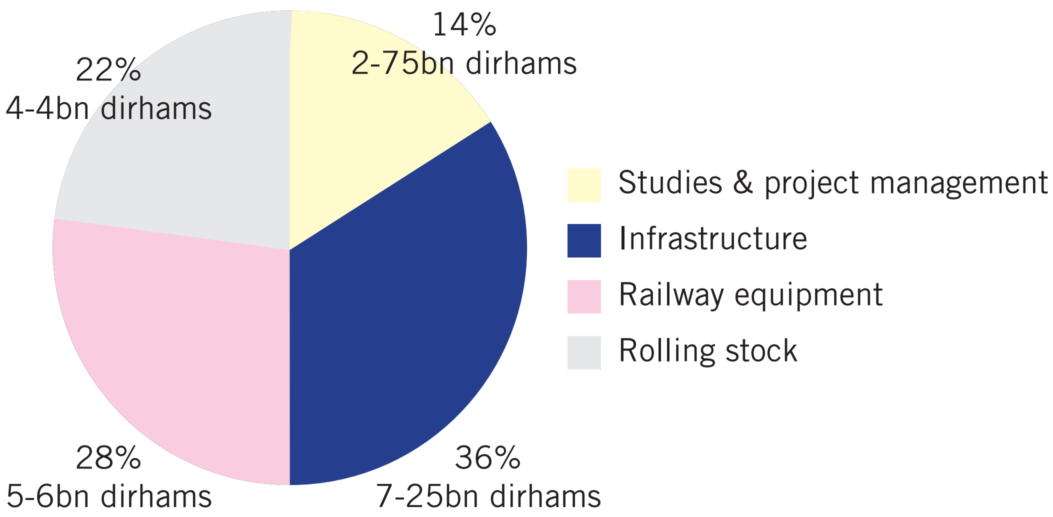
**TANGIER-KENITRA HIGH-SPEED LINE (FIG 26.1)**




*Source:* A.Hocke (2012)

The investment required for the construction of the line and for the acquisition of rolling stock is estimated at 20 billion dirhams (1.8 billion euros). Construction of the infrastructure proper and the fixed railway installations represent 64% of total investment, as shown in Fig. 24.2.

**INVESTMENT REQUIRED FOR TANGIER-KENITRA LINE (FIG. 26.2)**




*Source:* A.Hocke (2012)

In absolute terms, economic resources corresponding to that 64%, plus 14% relating to studies and project management, amount to 15 billion dirhams (1.35 billion euros). Consequently, the average cost per kilometre is 6.75 million euros.

To finance the total investment, a financial arrangement was prepared in which the contribution from the general budget of the State of Morocco was as limited as possible. To be precise, 24% of the total cost of the project (i.e. 4.8 billion dirhams, equivalent to 0.4 billion euros). A contribution to be made over six years, with an annual average of 800 million dirhams (72 million euros).

The French treasury would provide 920 million euros. Of these, 75 million would be in grants; 625 million in loans and, finally, the French Development Agency (AFD) would give a loan of 220 million euros, which would be guaranteed by the Kingdom of Morocco.

The rest of the required funds come from the following sources:

a. Saudi Fund for Development (144 million euros)
b. Abu Dhabi Fund for Development (70 million euros)
c. Arab Fund for Economic and Social Development (30 million euros)
d. Hassan II Fund for Economic and Social Development (86 million euros)

The loans granted will have very favourable conditions for the project.
It follows, therefore, that half of the project will be financed by France.

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