Development and Economic Evaluation of High Speed in France

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The introduction of the French TGV in 1981 was a milestone in both the history of transportation and the history of railways, similar to the commissioning of the shinkansen in Japan in 1964.

This article discusses the high-speed railway in France: the past situation of the South-East TGV and Atlantic TGV, the present situation with the commissionings of the North-Europe TGV, Trans-Manche, Interconnection, and the future prospects with the French master plan for high-speed railway links. The economic aspects of the high-speed railway in France are also the subject of an in-depth analysis.

1. THE HIGH-SPEED RAILWAY IN FRANCE

1.1 Commissioning of South-East and Atlantic TGVs

Technical Options of TGV System

Since 1967, the SNCF has been involved in studies and research to define the concept of the high-speed railway in France. The first concepts were aired in 1970 with a proposal to construct a new line between Paris and Lyons, designed around the following three principles: 1. Specialisation of new line for passenger traffic, 2. Compatibility with existing railway network, and 3. High-frequency operating system with reduced load interruptions.

These technical design options for the high-speed railway in France have proven very reliable. They made it possible to achieve high commercial speeds of about 240-270 km/h, to optimise the use of TGVs and the commercial capacity of the new line, to reduce operating and maintenance costs of the new line and rolling stock, and to free large freight transportation capacities on existing conventional lines. All these factors have contributed to the growth of traffic and to the increased profitability of the high-speed railway project.

South-East TGV

The technical choices made at the establishment of the South-East TGV contributed strongly to the undisputed success of the TGV in France. The South-East TGV is a great technical, commercial, economic and financial success.

The newer section of the South-East TGV line is 417-km long. It was commissioned in two stages: 1. In September 1981, south section of Saint Florentin to Sathonay new line (275 km), and 2. In September 1983, north section of Combs-la-Ville to Saint Florentin new line (115 km).

The maximum speed permitted on the new South-East TGV line is 270 km/hour which should soon be raised to 300 km/hour after adaptations of the signalling and the rolling stock.

Atlantic TGV

The success of the South-East TGV has been confirmed by the Atlantic TGV, the second-generation TGV system. The Atlantic TGV was commissioned in two stages: 1. In September 1989, west branch to Rennes, Nantes and Brittany (180 km), and 2. In September 1990, southwest branch to Bordeaux, Toulouse and Spain (101 km). The world rail speed record of 515.3 km/hour was recorded in May 1990 on this line.

The Atlantic TGV rolling stock marks significant technical progress in terms of performance (8800 kW as opposed to 6450 kW for the South-East TGV), capacity (485 seats as opposed to 368 seats) and comfort, as confirmed by runs at 300 km/hour and beyond. Numerous tests (1991 km travelled at more than 400 km/hour and 696 km travelled at more than 450 km/hour), which preceded or followed the world rail speed record, have confirmed that the stability and comfort of the cars are quite exceptional due to their sophisticated pneumatic suspension. The interiors also mark significant progress with high-comfort seats, private compartments for 4 people, group or family compartments, telephones, etc. These amenities are greatly appreciated by passengers.

1.2 Present Development of High-Speed Network in France

The opening of the North-Europe TGV in May 1993, the commissioning of the railway link through the Channel Tunnel, and the interconnection of the north and southeast links in the Paris region, have created a true high-speed network in France and mark the first step in the Pan-European development of high-speed railway transportation.

North-Europe TGV

Following the earlier TGV projects, the North-Europe TGV is the first highly international TGV project.

It constitutes the French part of the North-European network linking London-Paris-Brussels-Amsterdam-Cologne-Frankfurt and involves five countries: France, Great Britain, Belgium, the Netherlands and Germany. The new high-speed line of 333 km was fully opened in September 1993. The trip between Paris and Lille is made in 1 hour. Lille benefits from 16 direct round trips, and one TGV departs every 30 minutes during the rush hour.

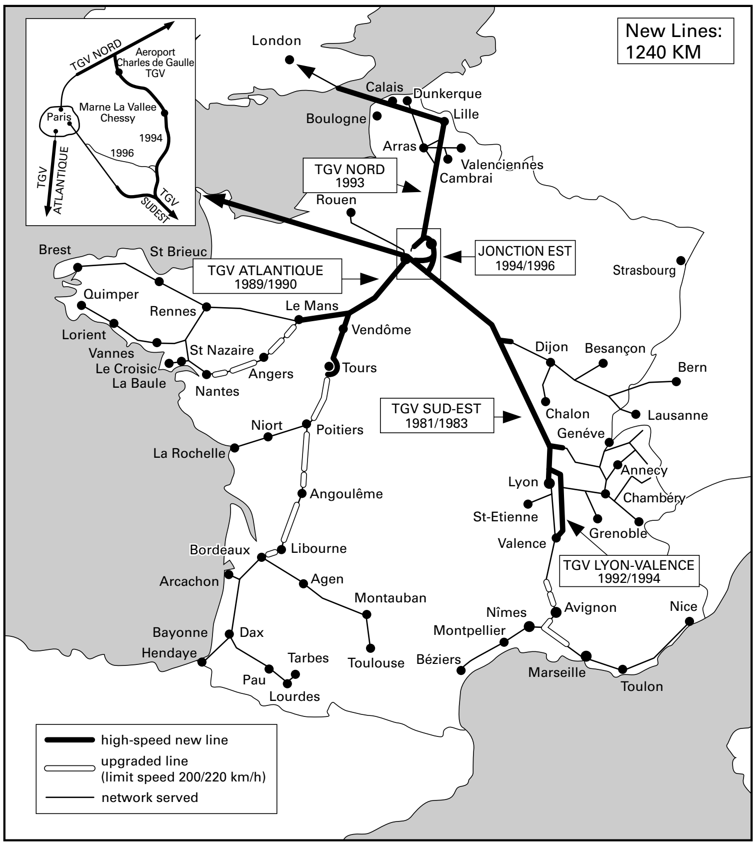
Trans-Channel link

The Channel Tunnel inaugurated on 6 May 1994, will come into service for railway passengers from October 1994. It constitutes the first land link between Great Britain and the European continent. The Eurostar TGV connects Paris with London in 3 hours and Brussels with London in 3 hours and 15 minutes.

Rhône-Alps TGV

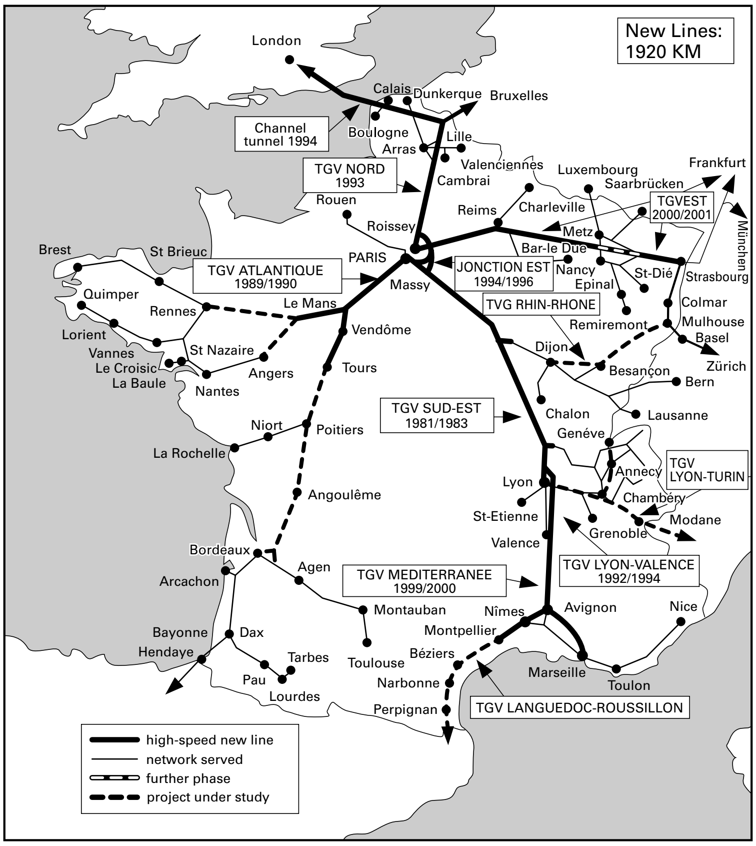
The Rhône-Alps TGV is the extension of the South-East TGV from Lyons to

Map 1 TVG nework in 1994



(SNCF)

Map 2 TVG nework by 2000



(SNCF)

■ Atrantic TGV at Chãtillon Depot near Paris (T.Suga)

Valence. The new line by-passes Lyons to the east and serves the Lyons-Satolas airport route from July 1994. It is the first stage of the South-Europe TGV, an extension of the major north-south axis linking London-Brussels-Paris-Lyons to the Mediterranean coast.

East Interconnection of TGVs in Paris Region

This new high-speed line (104 km) by-passes Paris to the east and serves the Roissy-Charles-de-Gaulle airport route and EuroDisneyland. It provides high-speed continuity between the North-Europe TGV and the South-East TGV from May 1994. By using the existing line, it also permits connection with the Atlantic TGV. Consequently, high-speed connections can be made between the chief French cities or between these cities and large foreign cities, without changing trains or stations in Paris.

The French railways have 1,240 km of high-speed lines integrated in a network of almost 5,700 km served by TGVs.

1.3 Future Prospects for High Speed in France

France has an ambitious programme with regard to future high-speed railways. In the long-term, the master plan provides almost 4,700 km of new line designed for speeds of 350 km/h or more, and 11,000 km of line served by TGVs.

The gradual implementation of the master plan will improve travel times considerably. All the large regional cities will be less than 3 hours from Paris. European cities like Amsterdam, Cologne, Frankfurt, Zurich, Geneva, Turin, Milan and Barcelona will be less than 4.5 hours from Paris.

Finally, the plan permits transit through France in less than 5 hours on the main European axes, which should make the country a European crossroads.

The main high-speed railway projects constituting the subject of advanced studies are:

1. The Mediterranean TGV from Valence to Marseilles and Montpellier. The selected project consists of 294 km of new line and constitutes a new stage in the establishment of a major north-south railways axis: London-Brussels-Paris to Italy and Spain. The public utility declaration was signed by the French government on 2 June 1994.
2. The East-Europe TGV from Paris to Strasbourg permits establishment of a high-speed link consisting of 460 km of new line towards Germany and central Europe.
3. The Transalpine Link includes a new 54-km tunnel under the Alps, which will also be open to freight traffic, and linking France and Italy via 261 km of new line.

The French high-speed master plan is strongly European.

2. EVALUATION OF RAILWAY PROJECTS

In view of their economic, social, financial and technical importance, major high-speed railway projects require extensive studies taking their specific natures into account.

The first impact of a new railway is the increased traffic. This impact extends over the entire network because the improvement has direct and indirect benefits.

Evaluation of a large railway project is divided into four major sections:

1. Estimation of future traffic
2. Simulation of railway operation
3. Estimation of investment
4. Estimation economic and socio-economic balance.

Estimation of future traffic indicates future earnings, making it possible to calculate the economic advantages of the new line. Future traffic is estimated by econometric models explaining the passengers' choice of transport mode.

Railway operation is estimated by models coherent with the future traffic projections. Simulation of operation provides operating costs, calculates rolling stock, and proposes timetables.

Estimate of investment for construction uses many techniques, and its scope is very wide covering geology, hydrogeology, civil works, etc.

Knowledge of earnings, operation costs, investments and scheduling, makes it possible to calculate the internal rate of return by updating. The internal rate of return depends on the updated difference between the earnings from the traffic (with and without the project) and the operating costs (with and without the project) related to the initial investment.

The socio-economic rate of return takes into account the advantages of the project for the entire national community, such as advantages to SNCF, time savings for passengers, net losses of other transportation operators, net benefit to the State, reduction of road congestion, and impact on economic activity in regions related to the project.

2.1 Estimates of Future Traffic

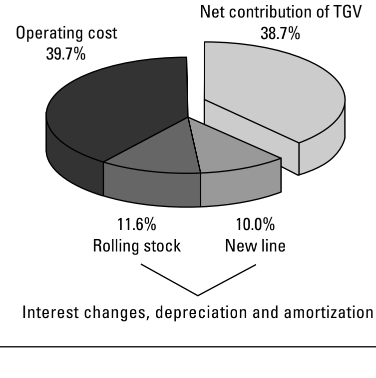
Three situations are defined for studying a major railway project:

1. The basic situation,
2. The reference situation, and
3. The situation with the project.

The basic situation corresponds to the last statistically-known year (the basic year).

The reference situation is the situation if the project was not executed.

Figure 1 Accounts of South-East TGV Operations Breakdown of 1991 Revenue (Fr 5,024 billion)



The situation with the project is the situation when the project is implemented.

Study Stages

Stage 1 concerns the basic year, the year for which the last statistical results or the most recent surveys are known.

Stage 2 concerns the transition from the basic basic year to the year commissioning of the project, or the reference year.

Stage 3 consists of estimating the additional traffic and the modifications resulting from the project. During this stage, the situation with the project replaces the reference situation and the project starts to be implemented.

Stage 4 permits estimation of traffic for any year after the project has been completed.

Any corporate investment project is studied in a defined socio-economic and competitive context. The study of the passenger traffic and its growth is based on data concerning the transportation sector and the general economy. The economic and competitive environment are factors in each stage of study. The principal data are the socio-economic indicators and the transportation supply of competing modes of transportation.

Implementation of a transportation project causes changes in the overall market and in the market share of each carrier both in terms of volume (resulting from transfer of passengers and creation of new trips), and in the structure and final characteristics of the passengers.

Calculation of Reference Situation

A general model can be made for each of the concerned transportation modes (planes, trains, private vehicles and buses) linking the traffic for each mode to a series of relevant parameters.

The above-mentioned model concerns socio-economic and transportation supply variables.

Calculation of Project Situation

Building a new line may cause a transfer of demand from air transport to the project in question—a passenger may travel by plane in the reference situation, but take the TGV in the project situation; this can be estimated by a price-time model. Similarly, passengers may leave their car or bus and change to the TGV because of reduced travel time.

Traffic may be induced by mobility, either by an increased number of trips of railway users or by the appearance of new trips; this can be forecast by a gravity model.

Consequently, it is appropriate to estimate these various components of the additional traffic. This is the purpose of the two SNCF models: the price-time model, and the gravity model of generalised cost.

Price-Time Model

The price-time model can determine the shares held by the different modes of transportation with respect to the total number of passengers travelling.

The model is based on the hypothesis that the choice a passenger makes between types of transport, is based on the value that the passenger places on time, and on the cost and travel time. Thus, user "k" selects the transport mode for which the generalised cost, taking into account its time value "h_k", is the lowest.

It is assumed that the total number of passengers on a given link is characterised by a distribution of the value of time of the passengers *f(h)* and that the distribution function:

$$F(h) = \int_0^h f(x)dx$$

gives the percentage of passengers whose time value is lower than "h".

By using the distribution of earnings in the population of a large number of countries, it is possible to select a log-normal density function for the time value f(h).

Gravity Model

The gravity model predicts the total volume of additional traffic for each transportation mode.

The induction or generation of traffic is a fundamental phenomenon and can be estimated from the gravity model.

The gravity model is unimodal insofar as it is only applied to the transportation mode for which it is desired to calculate the increased traffic. This increase can be linked to the fluctuation in demand for the particular transportation mode by means of a generalised cost.

The traffic between two geographic zones "i" and "j" can be expressed in the following form:

$$T_{ij} = K\frac{P_iP_j}{Cg_{ij}^{\gamma}}$$

where:

P_i and P_j: Respective populations of two geographic zones "i" and "j",

Cg_{ij}: Generalised cost of transportation mode between zones "i" and "j",

γ : Elasticity of traffic at generalised cost,

K: Adjustment parameter.

In this formula, the numerator contains the attraction factors and the denominator contains the resistance factors.

Economic Coherence of Supply and Demand

After calculating the traffic using these models, the coherence between the supply and the demand is verified in accordance with the following criteria:

1. Relevance of stops on route with respect to passenger flow,
2. Calculation of train occupation rate for purpose of remaining in commercially- and economically-acceptable range,
3. Calculation of required fleet of TGV trains and of corresponding productivity ratios, and
4. Calculation of operating costs.

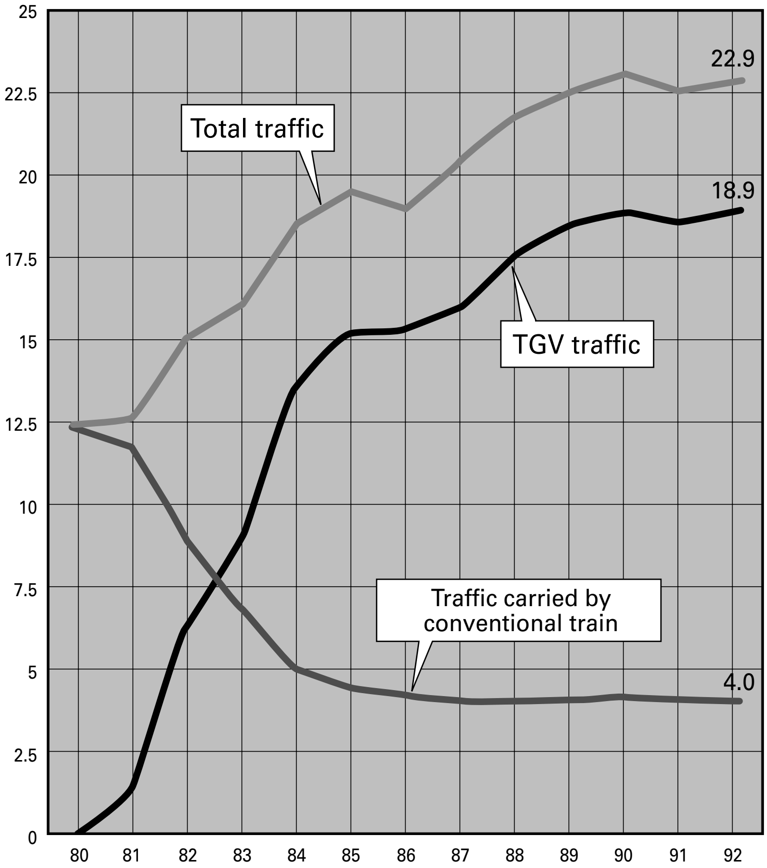
■ World Record Breaking TGV (T.Suga)

The model for simulating operation is therefore associated with the model for estimating future traffic.

2.2 Economic Balance

The knowledge of the earnings provided by the anticipated traffic, the op-

Figure 2 Evolution of Passenger Traffic on Paris South-East Routes (in million of passengers per year)



erating costs, and the investment, and their scheduling over time, makes it possible to calculate the internal rate of return of the project by updating.

The project profitability can be evaluated on the basis of several criteria, the main ones of which are:

1. The internal rate of return (IRR), defined as the rate of updating cancelling out the updated profit, and
2. The updated profit calculated at a given rate.

Differential Balance for SNCF

Measurement of the potential of high-speed trains comes down to comparison of two possible situations: 1. Carrying out the project, or 2. Not carrying out the project.

The economic balance of the project is presented in the form of a differential balance comparing these two situations, and consists of collating all the net impacts of the project.

Differential Balance for Community

The preceding micro-economic analysis gives the intrinsic profitability of the project for the SNCF. But for public investments, it is also essential to take the consequences of the project for the community in general into consideration.

In the eyes of the State and other authorities, the project must be the most advantageous for the entire community; the profits and losses of all the economic agents related to the project (State, consumers, companies, etc.), must be evaluated. These updated profits and losses are then added to form a general balance. Consequently, all the transfers between economic agents are cancelled out and only the net impact on the community remains.

3. TRAFFIC AND RESULTS

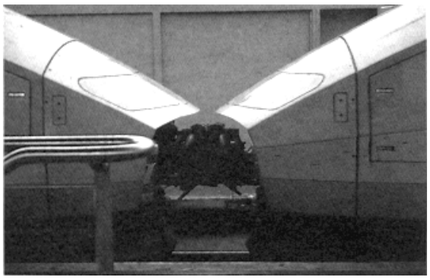
3.1 South-East TGV

Growth of High-Speed Railway Traffic

The traffic on the South-East TGV has increased by more than 90% since commissioning; more than 200 million passengers have been carried at a speed of 270 km/h.

After commissioning, the public reaction was immediate. The traffic reached the levels predicted by the models in 1984. These results are all the more remarkable because they occurred in a competitive context and in an economic environment clearly less favorable than previously expected. These figures show the competitiveness of the TGV system, particularly with

■ South-East TGV with Train Stewardess welcoming Passengers (SNCF)



■ Coupled TGVs at Peak Hours (T.SUGA)

regard to air travel. The traffic has grown vigorously since 1984.

The explanation lies both in the additional facilities offered by the TGV and in the presence of passengers diverted from travel by air. These passengers now travel by train, but their mobility and the increase in the number of trips are the same as that of air travel (approximately 10% per year).

Impact on Other Transportation Modes

Air

The impact of the high-speed railway on air travel is unquestionable. The routes in competition with the new TGVs all have the same characteristics, i.e., a sudden decrease (Lyons), a decrease and then a slow recovery (Marseilles), or a slowdown in growth (Nice). These reactions were predicted by the models of the estimate of future traffic. For example, for Lyons, without the TGV, the traffic for 1984 should have been at an index of 300. However, it was only at 100, or a diversion of traffic away from the airlines of approximately 70%, and a return for air travel to the traffic level of 12 years ago.

Road

The impact of the high-speed railway on road transport is also obvious. The indices for motorway traffic shows that motorways in competition with TGVs experienced a sudden decrease in growth in 1982; this phenomenon is not seen on motorways in the north and west.

Financial Results and Operating Balance

The operating balance has been positive since 1984, the first year of complete operation and can be roughly represented as follows: Out of Fr100 earned, Fr 40 covered actual operating costs (commercial costs and technical costs), and Fr22 were for capital charges for infrastructure and rolling stock. The remaining Fr38 constituted the net profit margin.

Economic and Socio-economic Balance

The financial results of the operating account of the South-East TGV are excellent, as shown by the operating balance. In these conditions, the profitability of the South-East TGV amounts to more than 15%. The socio-economic profitability, combining the money and time saved by passengers and also the losses caused to competing transportation modes, is 30%.

The new line is now completely amortised. It should be pointed out that the South-East TGV was financed completely by the SNCF, with no subsidy, by loans placed on the financial markets.

3.2 Atlantic TGV

Increase of Traffic Volume

From the commissioning of the west branch in September 1989, the traffic growth has been constant and sustained. In 1991, the traffic carried reached 16.6 million passengers. The increase continued in 1992 reaching 18.1 million passengers, a 9% increase in relation to 1991.

Impact on Other Transportation Modes

Air

The impact of the Atlantic TGV on the market share of air travel is quite significant and conforms with the results of the price-time model. The air routes in direct competition with the TGV all have a significant reduction of traffic.

Road

The indices for motorway travel shows that the A10 Paris-Bordeaux, and A11 Paris-Le Mans motorways, which are in direct competition with the Atlantic TGV, have experienced a slow-down in growth since the TGV commissioning, while the motorways of the north and west continue to grow.

Financial Results

The operating balance of the Atlantic TGV was already positive in 1991, the first year of complete operation. Out of Fr100 earned, Fr44 Francs covered actual operating costs (commercial and technical costs), and Fr34 Francs were for capital charges for infrastructure and rolling stock. The remaining Fr22 constituted the net profit margin.

The economic profitability of the Atlantic TGV project is evaluated at 12%, with the socio-economic profitability at 23%.

It is 30 years since Japan inaugurated the first high-speed railway link and pioneered high-speed rail transportation. The Japanese experience has been an undeniable success.

The high-speed railway in France has also been successful since the early 1980s, confirming its role as a very suitable and highly-used mode of transport. Other European countries like Germany and Spain are already enjoying the benefits of high-speed rail transportation; they will soon be joined by Belgium, the Netherlands, Great Britain and Italy. We hope that other continents will also benefit soon from high-speed rail transportation. ■

Jean-Pierre Arduin

Jean-Pierre Arduin was born in 1950. He graduated with a Mining and Civil Engineering degree in 1973. Two years later, he graduated from the Ecole Nationale de la Statistique et de l'Administration Economique as a Statistician-Economist and immediately joined the French National Railways. After working mainly in corporate planning and business administration, he was assigned to the New Infrastructures and High-Speed Department. He participated in studies of high-speed corridors in France, Europe, North and South America, Australia and Asia. His family has been involved with railways for more than 150 years, since 1837.