Title
The French Train a Grande Vitesse: Focusing on the TGV-Atlantique

Author
Streeter, Walter C.

Publication Date
1992-04-01

CalSpeed
California High Speed Rail Series

The French Train à Grande Vitesse: Focusing on the TGV-Atlantique

Walter C. Streeter

April 1992
Working Paper, No. 100

The University of California Transportation Center

University of California
Berkeley, CA 94720

The University of California Transportation Center

The University of California Transportation Center (UCTC) is one of ten regional units mandated by Congress and established in Fall 1988 to support research, education, and training in surface transportation. The UC Center serves federal Region IX and is supported by matching grants from the U.S. Department of Transportation, the California State Department of Transportation (Caltrans), and the University.

Based on the Berkeley Campus, UCTC draws upon existing capabilities and resources of the Institutes of Transportation Studies at Berkeley, Davis, and Irvine; the Institute of Urban and Regional Development at Berkeley; the Graduate School of Architecture and Urban Planning at Los Angeles; and several academic departments at the Berkeley, Davis, Irvine, and Los Angeles campuses. Faculty and students on other University of California campuses may participate in Center activities. Researchers at other universities within the region also have opportunities to collaborate on selected studies. Currently faculty at California State University, Long Beach, and at Arizona State University, Tempe, are active participants.

UCTC's educational and research programs are focused on strategic planning for improving metropolitan accessibility, with emphasis on the special conditions in Region IX. Particular attention is directed to strategies for using transportation as an instrument of economic development, while also accommodating to the region's persistent expansion and while maintaining and enhancing the quality of life there.

The Center distributes reports on its research in working papers, monographs, and in reprints of published articles. For a list of publications in print, write to the address below.

University of California Transportation Center

108 Naval Architecture Building
Berkeley, California 94720
Tel: 415/643-7378
FAX: 415/643-5456

Authors of papers reporting on UCTC-sponsored research are solely responsible for their content. This research was supported by the U.S. Department of Transportation and the California State Department of Transportation, neither of which assumes liability for its content or use.

The French Train à Grande Vitesse: Focusing on the TGV-Atlantique

Walter C. Streeter

Institute of Urban and Regional Development
University of California at Berkeley

CALIFORNIA HIGH SPEED RAIL SERIES

Working Paper, No. 100

The University of California Transportation Center
University of California at Berkeley

TABLE OF CONTENTS

LIST OF FIGURES **PAGE**

PREFACE

This is one of a series of reports now being produced as the first output of our study of the potential for a high-speed passenger train service in California. Each report deals with a specific high-speed train technology; it attempts an evaluation, standardized as far as available data permit, of its technical and economic viability.

Specifically, each report assesses the particular high-speed technology against a number of criteria:

1. *Technical Performance:* configuration of roadbed in terms of gradients, curvature, and construction cost; power sources; capacity and speed; capacity to integrate with existing transportation facilities.

2. *Economic performance:* traffic levels; revenues; financial appraisal and overall cost-benefit analysis; level of public subsidy required, if any.

3. *Resource consumption and environmental performance:* type and amount of energy required; impact on non-renewable resources; environmental impact, including emissions, noise, visual intrusion and effect on local communities.

The present series includes five studies. Two companion studies, on British Rail's InterCity 125 and 225 services and on Tilting Trains (the Italian *Pendolino* and the Swedish X-2000 service), will follow shortly. Thereafter, a systematic comparative analysis will be published.

The CalSpeed study will continue with preliminary route alignments, also to be produced shortly, followed by market assessments, to be completed in Fall 1992. These will bring to a close the present phase of work, which will be the subject of an overall report also to be completed in Fall 1992.

We gratefully acknowledge the support provided by the U.S. Department of Transportation and the California State Department of Transportation (Caltrans) through the University of California Transportation Center. Of course, any errors of fact or interpretation should be assigned to us and not our sponsors.

PETER HALL
Principal Investigator

REVIEW AND EVALUATE EXISTING SYSTEMS: TGV and TGV-ATLANTIQUE

INTRODUCTION

The purpose of evaluating the French Train à Grande Vitesse (TGV) system is to allow its comparison with other systems and technologies for use in California. The TGV system in France is a specialized system that has undergone several technological transformations since its inception. For purposes of technical evaluation, this report concentrates on the latest incarnation of the growing family of TGV train technologies: the TGV-Atlantique. General information on the operation of the high speed system within the established framework of the conventional network and the railway's philosophies of marketing and operations pertain to the high speed system as a whole.

This task involved collecting and evaluating information on:

1. Current technical development
2. Status of future use proposals both in Europe and worldwide

The following major subject areas are examined in this report:

1. General Background
2. Engineering—Tracks/Route/Structures
3. Engineering—Trains
4. Services/Service Level
5. Economic Results
6. Environmental Impacts
7. Summary

It should be noted that the TGV-Atlantique system is fairly new; service began in late 1990. Where appropriate, particularly in measures of financial and operational performance, data and other information pertaining to the TGV-Paris-Sud Est line will be offered. All data will be referenced accordingly.

The following abbreviations are used in this report:

TGV	Train à Grande Vitesse (High Speed Train)
TGV-A	TGV-Atlantique
TGV-PSE	TGV-Paris-Sud Est
TGV-N	TGV-Nord
SNCF	Société Nationale des Chemins de Fer (French National Railway)

This report was created for use by the California High Speed Rail Group at the Institute of Urban and Regional Development, University of California at Berkeley.

1. GENERAL BACKGROUND

Development of the TGV

High speed rail service has been operating successfully in France for ten years. The TGV, or Train à Grande Vitesse, currently holds the world speed record for wheel-on-rail technology and is operating on an expanding network that will soon connect cities in France with Brussels, London, and Cologne.

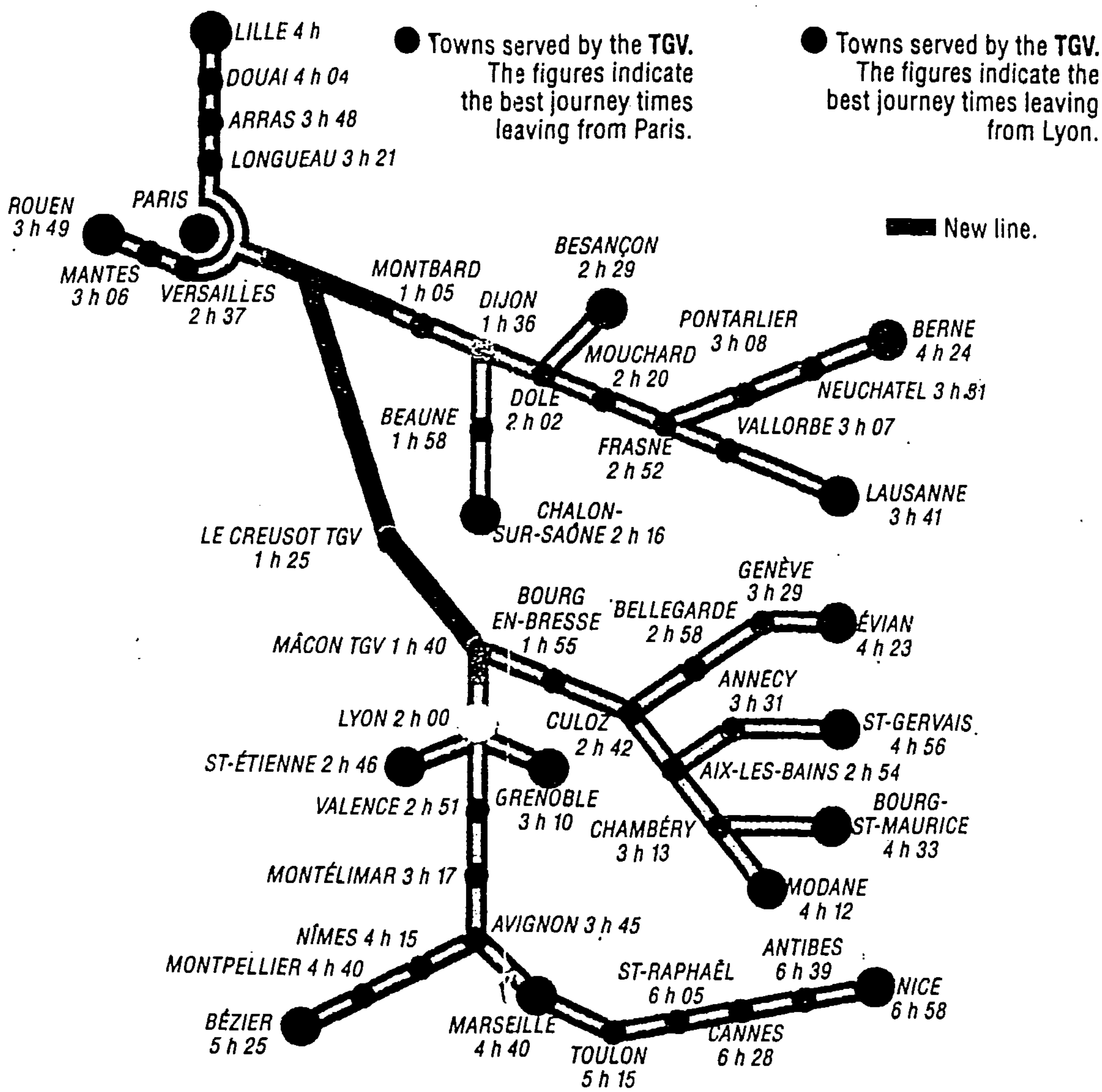
France's first high speed train system was constructed in the late 1970s along the busy Paris-Lyon corridor. The TGV-PSE[1] was conceived and developed in response to a severe congestion problem along that route. The Paris-Lyon corridor historically has been and continues to be the busiest rail corridor in the nation, and in the late 1960s and early 1970s the SNCF was faced with near saturation along that corridor. Various types of passenger rail service and freight service were operating on shared infrastructure, causing scheduling problems as passenger demand increased over the years. General ridership nationwide, however, was facing serious decline due to competition from air and auto modes (Walrave, 1985: 1,063). The SNCF studied several proposals to alleviate the congestion problem, including the quadrupling of the track between Paris and Dijon. This alternative would have been prohibitively expensive considering that there was a long tunnel on the route that would have to be expanded and that this "solution" would do nothing to counter the declining ridership on the rest of the country's rail network. What was needed was a means to compete with the speed of the airplane and the convenience of the automobile.

The high speed concept was consequently developed as an exclusive passenger line, separated from the conventional lines, along which high speed service could be operated on close headways and which could tie back into the conventional rail network to serve existing stations. Not only would this solution alleviate the congestion problem along the Paris-Lyon corridor (since the original main line would still operate), it would also greatly improve travel times between Paris, Lyon, and points south and east of Lyon, making rail service more attractive to passengers in those areas. Figure 1 shows the TGV-PSE line's dedicated segment between Paris and Lyon and the cities served by that line.

Three fundamental principles were adhered to in the development and implementation of the TGV-PSE system (which were carried through to the development of subsequent TGV systems in France). These principles are the backbone of the SNCF's high speed service philosophy. They are (Walrave, 1985: 1,065):

FIGURE 1

TGV-PSE Service Network



- *Compatibility with the existing rail system.* This ensures that passengers can be served by existing terminal facilities and that trains can reach into existing urban areas without the need for new rights of way. By running on conventional track in the provinces, no passengers are excluded from the system; all passengers can benefit from the high speed service. Also, such compatibility allows for the gradual development of a nation-wide high speed network.

- *Dedicated lines for high speed passenger traffic.* Dedicated lines can be tailor-made for the high speed passenger trains that will run on them. Close headways can be scheduled because of the uniformity of the rolling stock on the dedicated segments. Safety and reliability are enhanced because there is only one type of traffic on the dedicated line.

- *Train services scheduled at frequent intervals.* Flexibility and frequency meet the passengers' needs and make the train competitive with the auto and the airplane.

When the PSE service began in 1981, its effect on passenger rail service was quickly recognized. Ridership grew dramatically and, by 1984, revenues more than covered operating and capital expenses. Rail's share of traffic in the corridor rose sharply, while the air and auto modes' share of passengers declined. There were also a significant number of "induced" travellers who would not have made the trip if the TGV did not exist. With this dramatic success, the SNCF had the green light for a second high speed line to serve western and southwestern France: the TGV-Atlantique.

TGV-Atlantique

The TGV-A network is a complex system of dedicated track segments, upgraded conventional track segments, and conventional track segments throughout western and southwestern France. Service is offered from Paris-Montparnasse to Le Mans, Brest, Tours, Bordeaux, Toulouse, Biarritz, Lourdes, and many other destinations in between. Figure 2 shows the TGV-A network. A complete listing of cities served and service frequency can be found in Appendix A.

The network contains three dedicated track segments (see Figure 3). The first is the west-southwest common line which begins just outside Paris at Fontenay-aux-Roses and runs approximately 124 km to Courtalain. Next, the west branch runs from Courtalain approximately 51 km to Connerré, then connects to existing track for service to Le Mans and west. Finally, the southwest branch runs from Courtalain for approximately 100 km around Tours to Monts and connects to

FIGURE 2

TGV-Atlantique Network

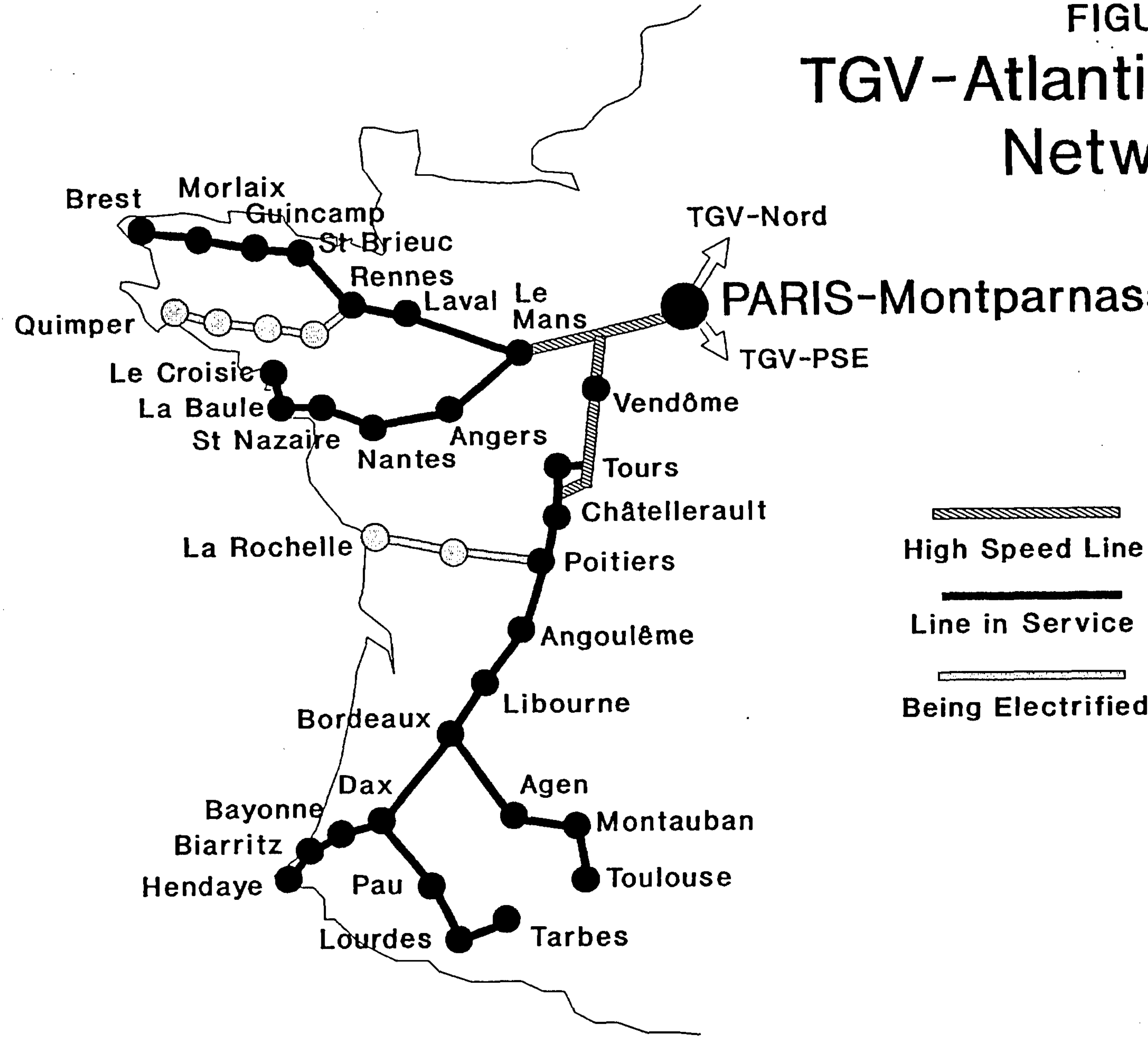
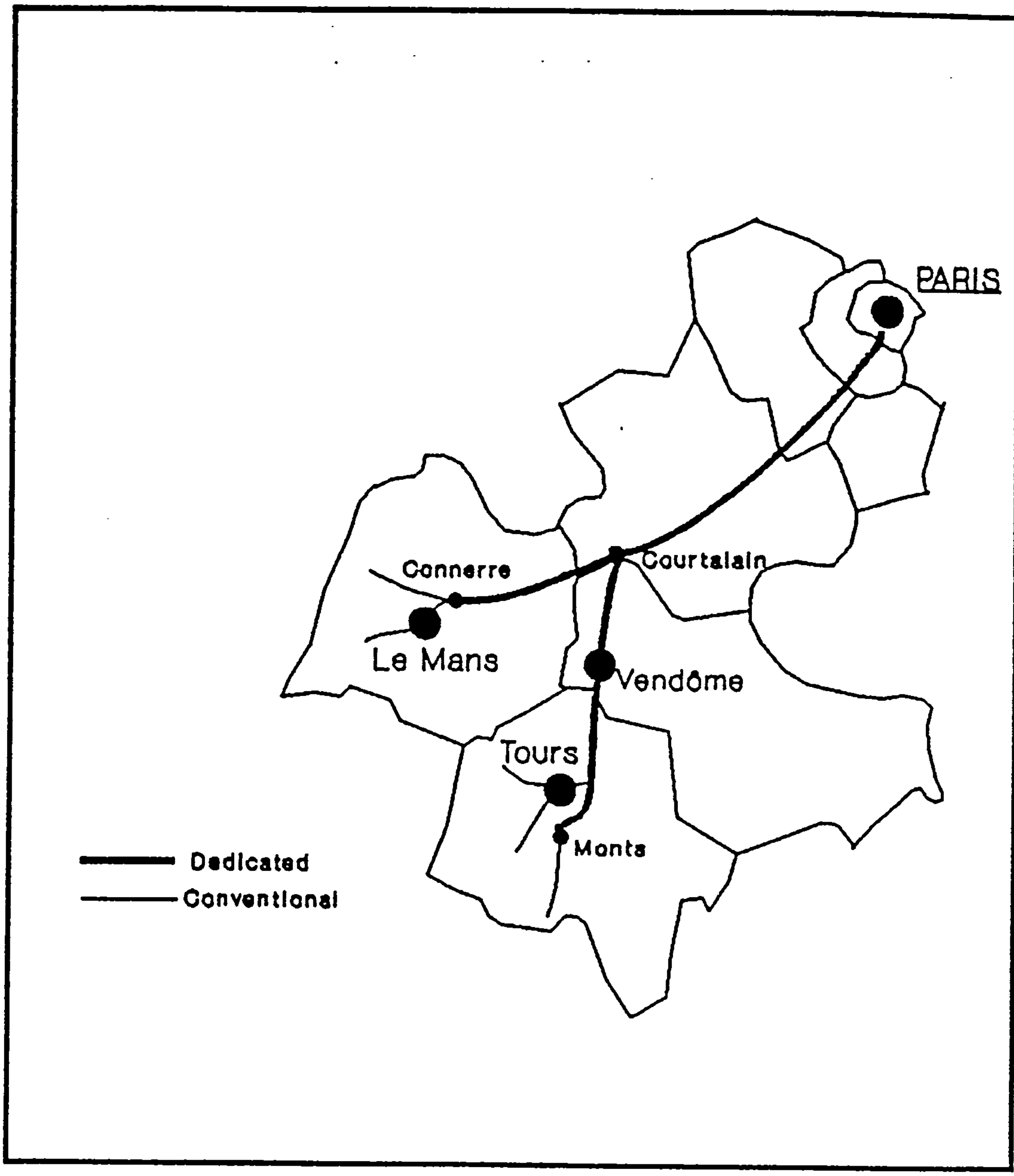


FIGURE 3 -- TGV-A
Dedicated Track Segments



existing track into Tours and on to the conventional Paris-Bordeaux line. There is one station along the dedicated segments, at Vendôme, and another is planned in the Paris suburbs at Massy once the suburban interconnection is completed.

Service began on the west branch in the fall of 1989. The southwest branch opened a year later with service to Bordeaux. Lines to Quimper and La Rochelle are currently being electrified and the SNCF expects to begin TGV-A service on them over the next two years.

Future TGV Service

In early 1991, the French government adjusted its plan for a French TGV network. By the year 2010, France plans to have built a TGV network of 4,700 km (*IRJ*, 1991: 48). As Figure 4 shows, sixteen projects have been planned over and above those currently under construction (TGV-Nord, Lyon Bypass, Paris Interconnexion). The total projected cost of this network is set at over 209 billion French francs or nearly 35 billion dollars. The SNCF has recently placed orders for 45 new double-deck TGV trainset to increase passenger capacity on PSE line (*IRJ*, 1991: 16). These new trains will carry 540 passengers each and will help to reduce the SNCF's operating costs per seat-kilometer.

The TGV-Nord project currently under construction will connect Paris and the other TGV lines with Lille (France), Brussells (Belgium), and the Channel Tunnel and London (England). It will open in 1993.

What could be considered the heart or hub of the entire French TGV network is currently being built around Paris: the TGV-Interconnexion. A completely dedicated orbital route around the capital will, when complete in 1994, connect the Atlantique, Sud-Est, Nord, and future lines, creating a high speed bypass around the city of Paris. Along the interconnexion will be several new TGV stations that will serve Charles de Gaulle International Airport, the Euro-Disney complex now under construction at Marne-la-Vallée, and the future high-tech Research and Development site at Massy-Palaiseau. The ability to bypass Paris at high speed will make travelling between provincial cities on the TGV network much more time-efficient and therefore much more attractive to prospective customers.

The TGV-Est, or east line, is in the final planning stages. This ambitious project will connect Paris with Strasbourg (travel time estimated at 1 hour 50 minutes) and will branch into three regions in eastern France: Champagne-Ardenne, Alsace, and Lorraine, which has a combined population of more than 5 million. Cities to be served include Reims, Metz, Nancy, Strasbourg,

FIGURE 4 -

French TGV Projects Planned to Year 2010

Project	New Line (km)	Cost (FF billion) Infrastructure	Trains	Cost* (US $ billion) Infrastructure	Trains
Est	460	22.00	6.30	3.67	1.05
Transalpin	261	29.50	6.00	4.92	1.00
Rhin-Rhône	425	17.80	4.30	2.97	0.72
Provence	219	14.30	0.40	2.38	0.07
Côte d'Azur	132	8.80	1.70	1.47	0.28
Languedoc-Rousillon	290	14.80	3.70	2.47	0.62
Aquitaine	480	22.20	0.90	3.70	0.15
Normandie	169	10.10	1.50	1.68	0.25
Midi-Pyrénées	184	8.70	-	1.45	-
Limousin	174	5.30	1.40	0.88	0.23
Grand-Sud	70	3.70	0.90	0.62	0.15
Bretagne	156	5.70	0.80	0.95	0.13
Picardie	165	6.30	-	1.05	-
Auvergne	130	4.60	1.30	0.77	0.22
Interconnexion Sud	49	3.10	0.20	0.52	0.03
Pays de la Loire	78	3.20	0.10	0.53	0.02
TOTAL	3,442	180.10	29.50	30.02	4.92

Source: International Railway Journal, July 1991 * US $1 = FF 6

MANY lines will be upgraded in addition to the new lines shown above.

Luxembourg, as well as cities in southern Germany and Northern Switzerland. The cost for this 430-km infrastructure is estimated at 22 billion francs (1989) and is projected to open in 1997. Under study is a connection with the German high speed network, the ICE (InterCity Express).

2. ENGINEERING– TRACKS/ROUTE/STRUCTURES

Track Design[2]

Track design and rail type for the TGV-A dedicated segments have not had to be significantly modified from TGV-PSE standards. Heavy rails (type UCI 60) that are 36 meters in length are welded to 396-meter lengths at the factory and are then shipped to site and laid. The rails are continuous-weld rails (no expansion gaps) that provide a uniform surface for high speed operation.

Ties (or sleepers) are made of concrete (twin block type) and placed every 60 cm (1,666 per km). Such ties are relatively inexpensive, easy to fabricate, particularly durable, and lend exceptional lateral strength to the track system. Steel spikes are double-curved with nylon isolating abutments that lend strength and superior lateral resistance to the track assembly.

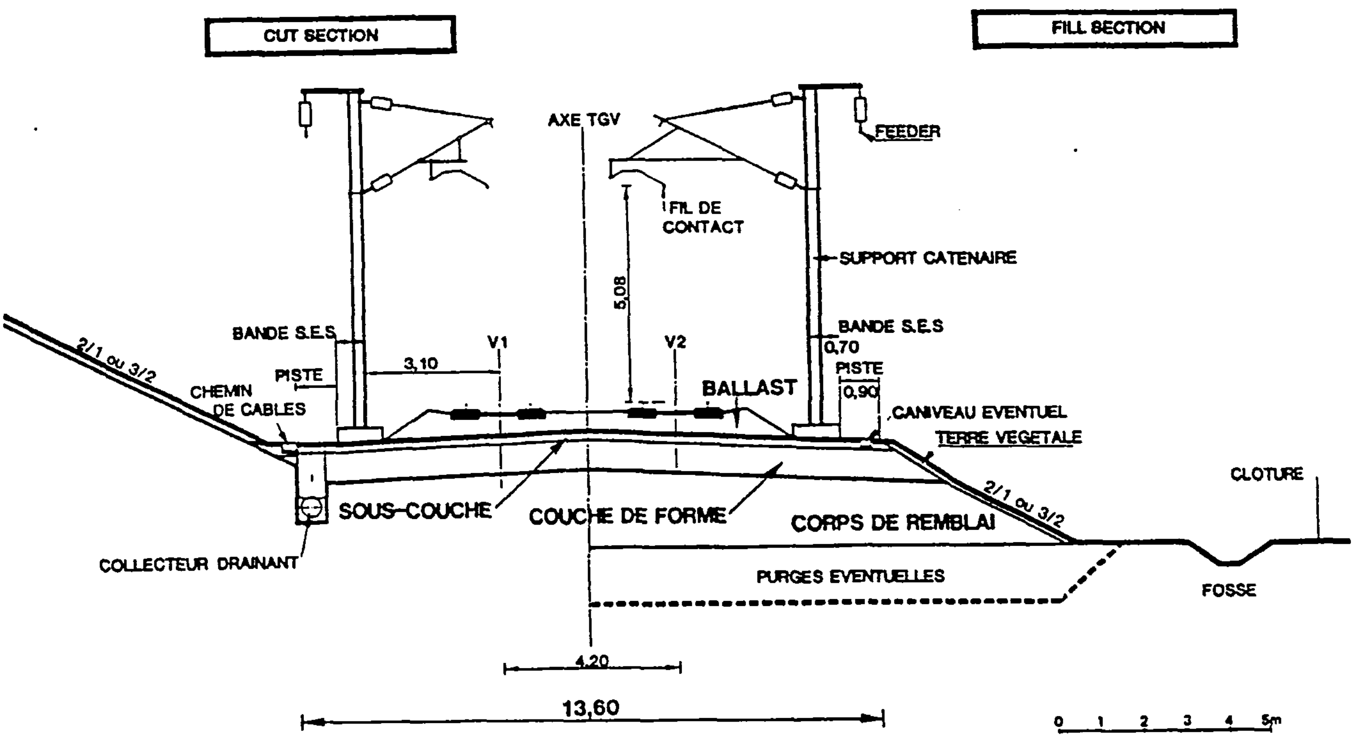
Many of the design specifications for the TGV-A right of way are identical to those conceived for the PSE line; there are, of course, certain exceptions due to local conditions. Figure 5 shows a typical track cross-section. In all, the construction of the new line used 70,000 tons of rail, one million ties, and 2 million tons of ballast (Chambron, 1986: 683).

Ruling grades in the range of 1.5 percent to 2.5 percent are recommended for the TGV-A trainset; however, most grades on the line are at 1.5 percent due to the relatively gentle landscape in the region. This ruling grade was determined by using an optimizing procedure subject to cost constraints relative to the engineering and to the characteristics of the actual trainset (Chambron, 1986: 663). Certain short sections of the line run at 2 percent to 2.5 percent in order to shorten structures (bridges, tunnels, cuts) and thus reduce costs.

TGV-A grade allowances are less than the 3.5 percent grade allowance on the PSE line due to the more gentle nature of the landscape and because longer trainsets are used on the TGV-A line. However, the SNCF says that with TGV-A technology, 5 percent grades are sustainable (at less than maximum speed), and with momentum, short distances at 10 percent are possible. Such performance is, of course, dependent on many variables including size of trainset, load being carried, and distance of run. Currently, no TGV-As are running on grades greater than 2.5 percent. See Appendix F for line profiles of the Atlantique dedicated track segments.

FIGURE 5

Typical TGV-A Dedicated Track Cross Section



The minimum curve radius for trains running at maximum speed is 4,000 meters. Transitions, or separations between successive turns, must be approximately 150 meters (about 500 feet). The standard slope of a cut embankment on the high speed line is 3/2, or 2/1 if the material is unstable. Because of the general forgiving nature of the Atlantique route, great undulations or changes in elevation such as those on the PSE line are not found on the TGV-A route. Therefore, the use of kinetic energy to save power is not significant on the Atlantique route. It is interesting to note, however, that the "roller coaster effect" allows TGV-PSE trains to run nearly one-third of their route unpowered, and an experienced train driver could increase this to nearly 50 percent (Wallis, 1986: 19).

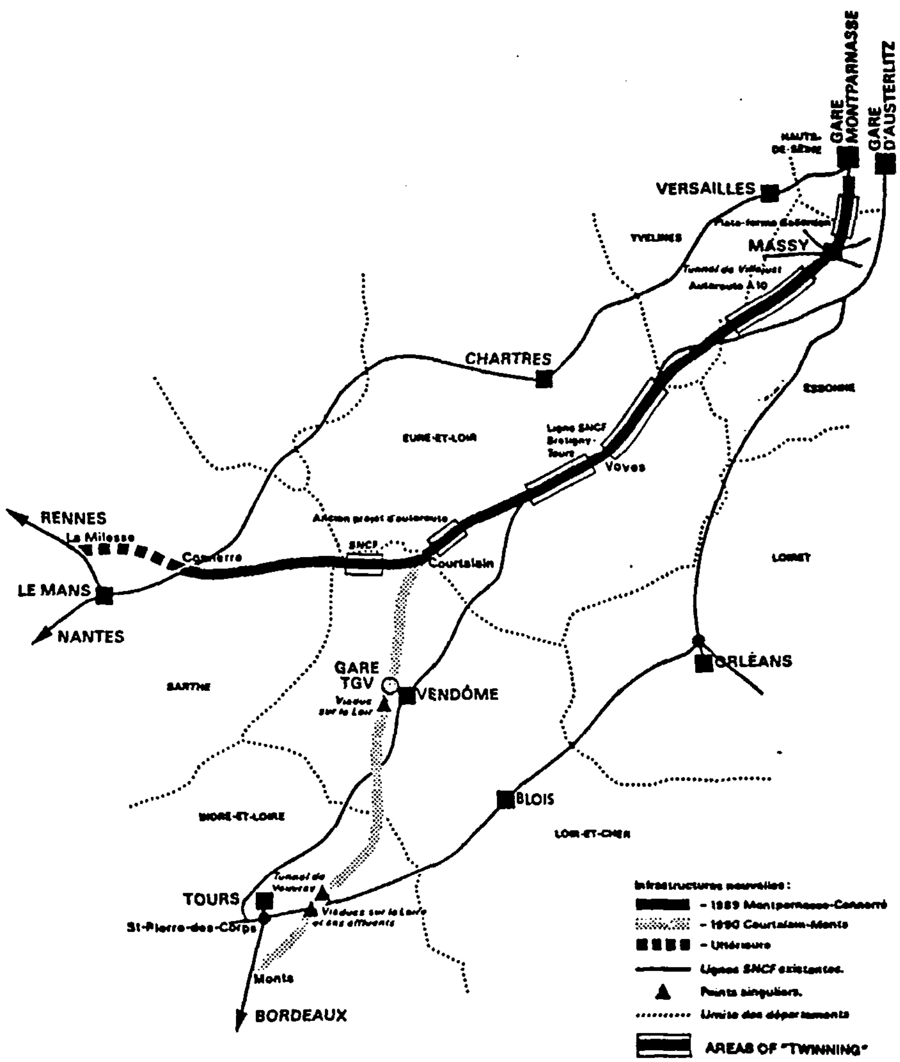
Route Alignment

Strict attention was paid to the route alignment proposals for the Atlantique. Since the completion of the PSE line, the environmental movement in France, as in other countries, has gotten stronger. To avoid too much cutting through the invaluable natural and agricultural landscape, the SNCF planned for the new dedicated line to "twin" with existing state- or SNCF-owned rights of way (see Figure 6). For example, the portion of the line just outside of Paris (from Fontenay-aux-Roses to Massy) was built along an old right of way that was set aside at the beginning of the century for a railroad to connect Paris with Chartres (Chambron, 1986: 665). Here, the TGV line was depressed and covered over with a greenway, called the "coulée verte," that connects other green spaces in the area. This treatment cuts down on noise as the TGV passes through urban areas and also gives something back to those neighborhoods: amenities such as pedestrian and bike paths were constructed over the TGV right of way.

From Marcoussis to Dourdan, the TGV line parallels the A-10 autoroute. Further down the line, the new dedicated tracks follow abandoned rail rights of way, existing rail rights of way, and in the Perche region, the rails follow the right of way set aside for the construction of the A-11 autoroute (which has not been built). In all, from Paris to Courtalain, the new TGV line follows existing rights of way for nearly 60 percent of its length (Chambron, 1986: 665). Savings that might have been expected from the land acquisition perspective, however, were not to be had. Since the new line follows existing infrastructure for a good portion of its length, much money had to be spent on over/underpasses for highway interchanges, stations, and conventional tracks.

FIGURE 6

TGV-A Dedicated Track Segments
Right of Way "Twinning"



Signalling

Because of the high speed nature of the TGV system, traditional trackside color signals cannot be used; safety requires a more sophisticated and reliable system of signalling. This is accomplished through the use of a computerized system of cab signals that digitally alerts the train driver of track and traffic conditions.

Electronic signals are passed continuously through the rails to each trainset on the line (Roth, 1990: 32). Drivers then react to the signals they receive on their console, much as they would to visual signals trackside. Redundancies and system checks are built in to assure reliability and safety. At certain speeds, automatic system overrides are capable of braking a speeding train if a driver does not respond as expected (for example, if he becomes incapacitated). A central control facility monitors all aspects of a trainset's movement along the dedicated track segments, and coordinates the traffic and power requirements of daily operations on the line. Once a TGV trainset leaves the dedicated track segment and begins a run on a conventional line, conventional signalling is used.

Power Collection

TGV-Atlantique trainsets each carry four pantographs. Each power car (at either end of the trainset) has one pantograph for 25kV alternating current and another for 1.5kV direct current (*IRJ*, 1990: 27). Similar to the pantographs on the PSE, the Atlantique's collectors are Faiveley GPU[3] pantographs which are of simpler construction, lighter, and fine-tuned for super high speed operation.[4]

Catenaries are of copper (cross-sectional area 150 mm^2) and are suspended from rigid assemblies that do away with traditional complex stabilizing cables for protection against movement in high winds.

Tunnels/Bridges

All TGV bridges are ballasted to provide a consistent, reliable load-bearing base for the tracks. There are 131 rail-over bridges along the route, 165 road-over bridges, 5 tunnels, 8 viaducts, and other "special constructions" (Chambron, 1986: 673). No at-grade crossings are permitted on dedicated, high speed track segments. A more detailed list of major works is shown in Figure 7.

FIGURE 7

Major Constructions, TGV A Dedicated Line

Does not include rail-over or road-over bridges

TUNNELS	Length (m)
Fontenay	474
Sceaux	827
Villejust (twin bore)	2 x 4,800
Vouvray	1,496
Total	12,397

VIADUCTS	Length (m)
F6	220
le Loir (Bonneval)	108
le Loir (Naveil)	173
Vouvray	387
La Cisse	312
la Loire	431
Rochepinard	315
le Cher	370
Total	2,316

Source: Chambron, 673

CUT AND COVER	Length (m)
Fontenay	306
Fontenay	460
Sceaux	216
Chatenay – Malabry	1,047
Antony	969
Verrières – Massy	1,280
Massy	2,014
Villebon	650
Briis-sous-Forges	1,273
Larçay	203
Total	8,418

The TGV-A dedicated line contains 12,397 meters of tunnelled track. Tunnel length is not a problem for high speed trains. The tunnel's diameter, however, is the key factor to speed and passenger comfort on the TGV-A because coaches are not pressure-sealed. It seems apparent that for high speed operation in tunnel, a twin bore configuration is preferred, or at least some means of separating tubes; the alternative is a double tunnel with a very large diameter which may be cost-prohibitive through certain soil/rock conditions.

Certain pressure waves are created by the train as its front end enters the tunnel and again as its last car enters. These pressure waves move at the speed of sound through the tunnel, and a backwave is produced when they reach the other end of the tunnel. The tail-end-forward wave then interacts with the front-end-back wave and again with the train itself, causing resistance and passenger discomfort. While the air resistance in tunnel is reduced by nose and tail design and by the design of the trainset to minimize drag with flush door mounts, sealed coaches, and so on, passenger discomfort due to abrupt pressure changes is not (Lancien et al., 1985: 117). The next generation of TGV coaches will be pressure-sealed, which should completely alleviate this problem.

On the Atlantique line, tunnels are located (by coincidence) along segments of acceleration or deceleration. Minimum tolerances are as follows (Chambron, 1986: 664):

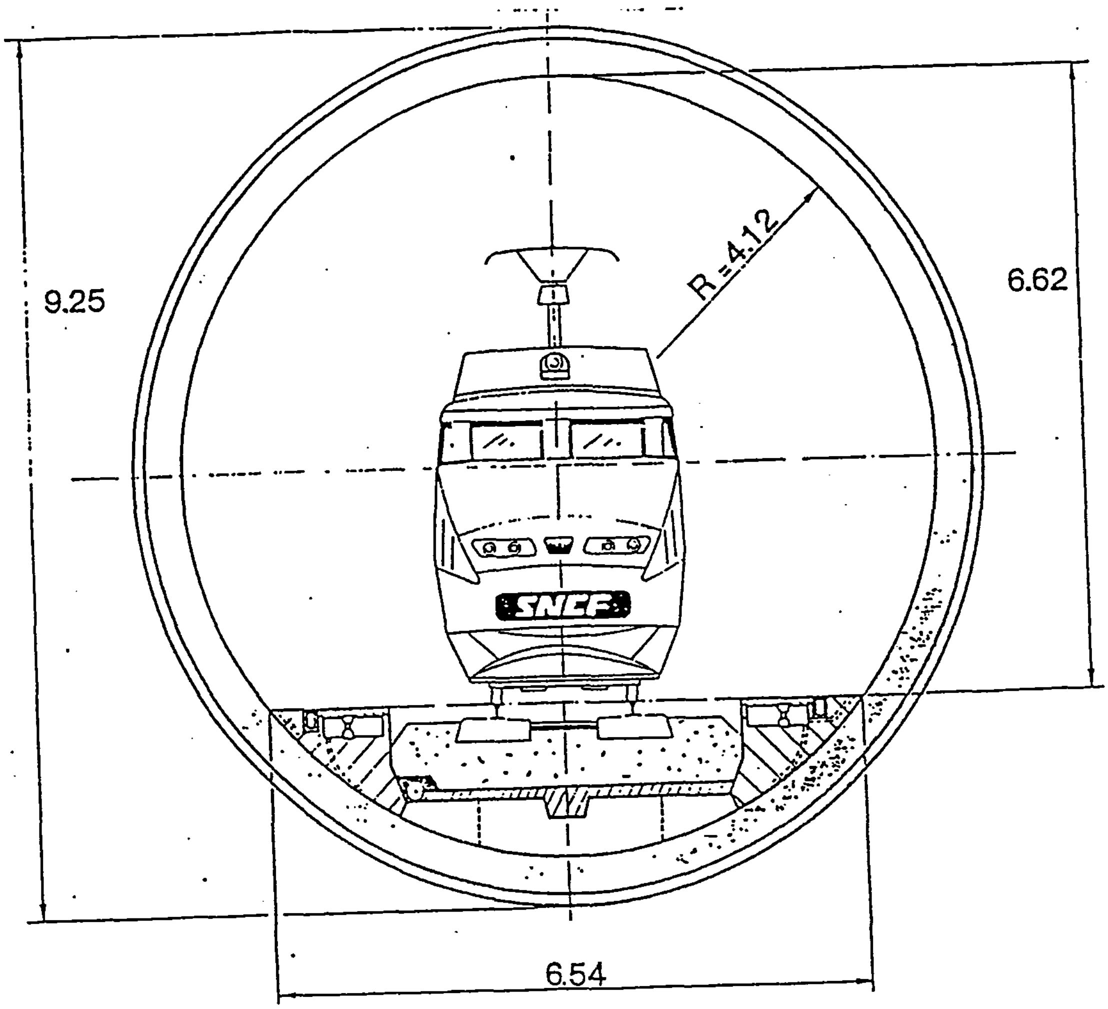
> Tunnels or cut-&-cover sections with double track:
> V = 200 kmh; S = $46m^2$
> V = 270 kmh; S = $71m^2$
>
> Tunnels with single track (Villejust):
> V = 270 kmh; S = $46m^2$
>
> where V is the speed and S is the cross-sectional area of the tunnel minus the cross-sectional area of the train body– that is, the area of free tunnel space around the train body (Chambron, 1986: 664).

The longest of the Atlantique line's tunnels is the twin-bored tunnel at Villejust. Figure 8 shows a sample cross-section of one of the bores. Each bore measures 4,800 meters in length with a cross-sectional radius of 4.12 meters. The distance between bores averages about 30 meters. Each bore took about 18 months to complete, with two tunnelling machines working from each end through sandy soil. Seven hundred thousand (700,000) cubic meters of earth were removed for these two bores; the tunnels were constructed with approximately 150,000 cubic meters of reinforced concrete and 10,000 metric tonnes of steel (Chambron, 1986: 676).

At Villejust, trains reach peak speeds (300 kmh) and each track has its own bore. Each has a diameter of 8.24m (interior diameter). There are two 4m cross-cuts connecting the bores.

FIGURE 8

Typical Cross Section of Villejust Tunnels



Chambron points out that the primary reason for this tunnel being twin-bore is because the soil in this area is particularly soft and crumbly, making large-diameter tunnels difficult to construct. Two smaller tunnels were easier and safer to build.

The Vouvray tunnel (1,496 meters, cross-sectional radius 5.5 meters) was cut using a drill/ jack rig through relatively forgiving material which allowed the tunnelling to progress rapidly (nearly ten meters per day). See Figure 9 for a sample cross-section of the Vouvray tunnel. The tunnel diameter is $100m^2$ and is double-tracked. Trains are decelerated to approximately 200 kmh through this tunnel because the coaches are not air-tight and passenger comfort would be affected at higher speeds. Maximum allowable speed at the Tours by-pass section, however, is 270 kmh.

The tunnels at Sceaux and Fontenay (Figure 10) were cut using standard tunnelling methods borrowed from the RATP.[5] This involves constructing a temporary vault, excavating beneath it, placing the forms, then filling the permanent vault forms with concrete. There were a few water problems at each end of the Sceaux tunnel that caused some delay in its completion. The tunnels at Fontenay and Sceaux are within 10 km of Paris, and trains run at no more than 200 kmh (maximum allowable speed on this line), with double track through the tunnels ($95m^2$, 10m wide). A sample speed through Fontenay: accelerating from 150 to 170 kmh; through Sceaux: decelerating from 173 to 166 kmh (Dupuis, 1986: 741-748).

Over 8,000 meters of the new line are built underground using cut-and-cover methods, the longest section of which is located at Massy (2,014 meters). Much of this section of the line lies below the "coulée verte" or greenway (see section on Route Alignment) just outside of Paris. Figure 11 demonstrates how another cut-and-cover section at Briis-sous-Forges (over 1,200 meters in length) was inserted.

The underground infrastructure was built using a variety of construction methods, including pre-cast and pre-stressed concrete units, and poured-in-place reinforced concrete. An example of the combination of pre-cast and poured-in-place construction can be seen in Figure 12.

3. ENGINEERING– TRAINS

Synchronous Motor

The TGV-A employs a three-phase alternating synchronous traction motor (see Figure 13). This innovation in traction technology has several advantages over previous technologies, such as that of the TGV-PSE. First, its power superiority reduces the number of traction sets needed on

FIGURE 9

Typical Cross Section
Vouvray Tunnel

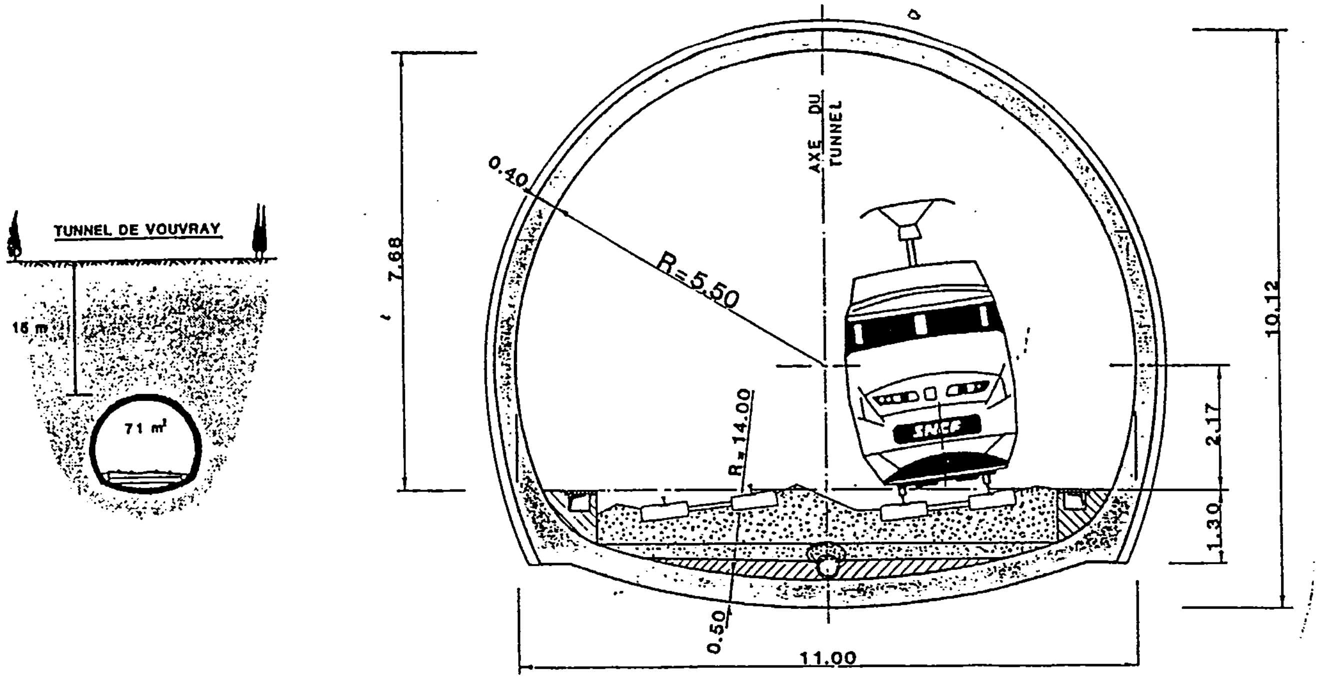


FIGURE 10

Typical Cross Section
Tunnels at Fontenay
and Sceaux

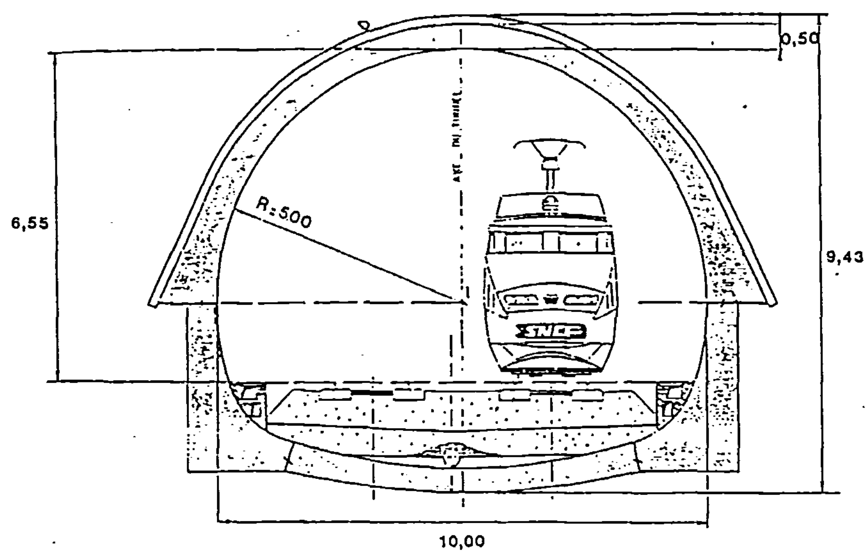
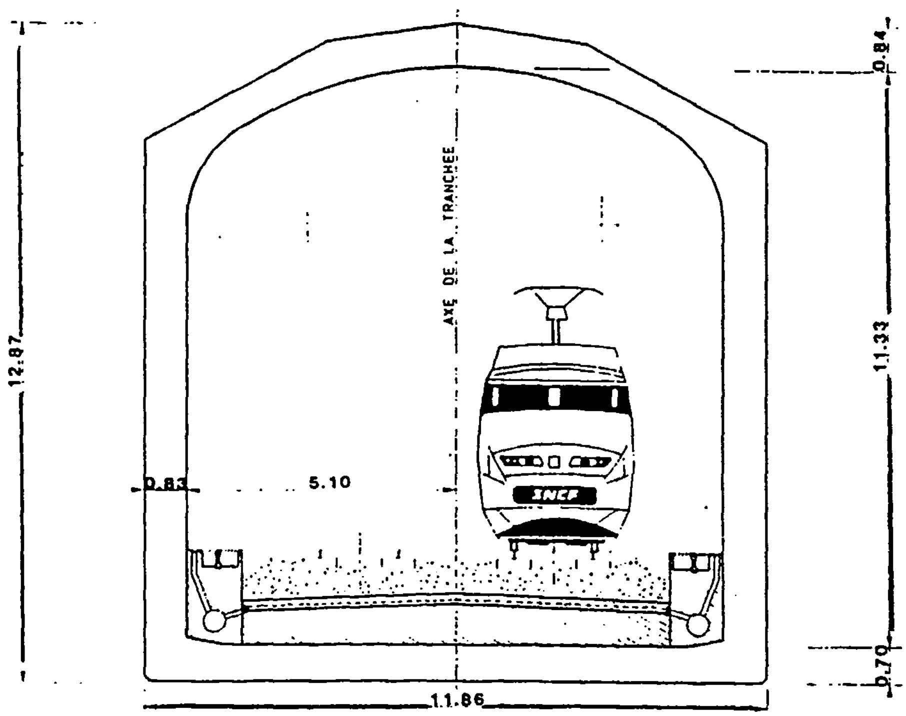


FIGURE 11

Cross Section of Buried Tunnel at Briis-sous-Forges



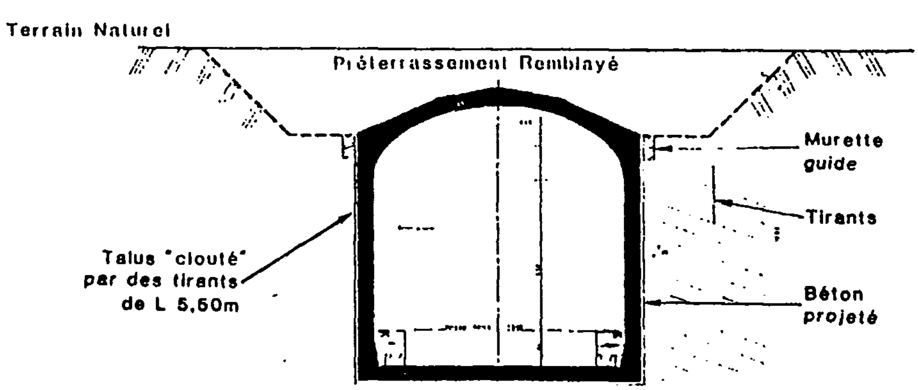


FIGURE 12

Pre-Cast vs. Poured in Place Construction

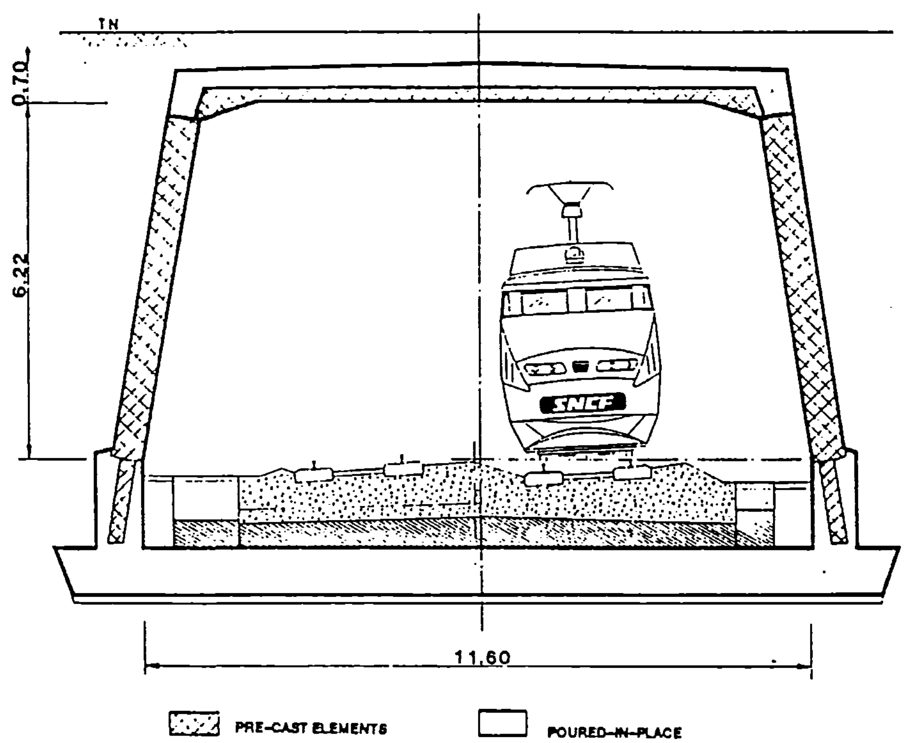
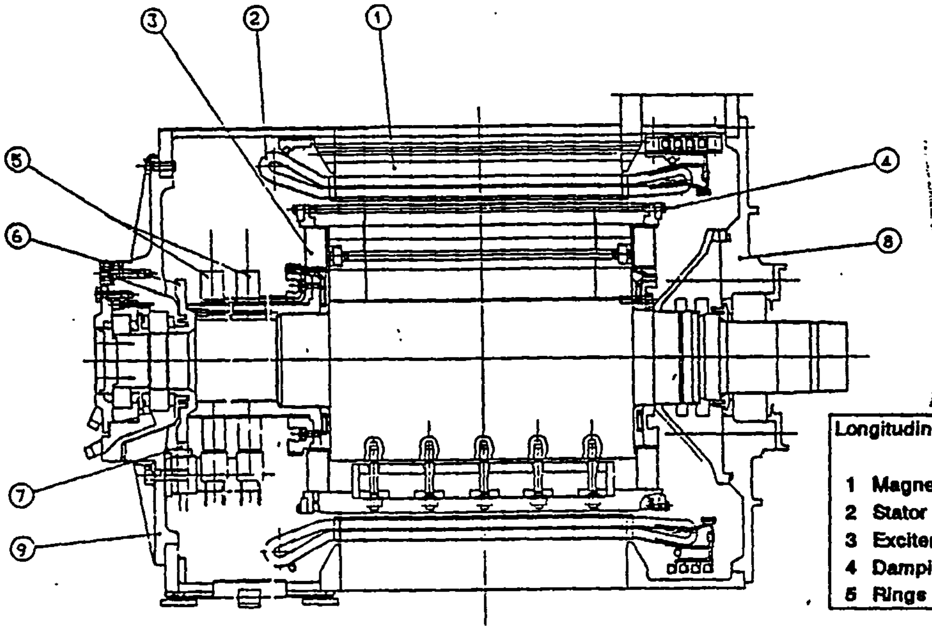


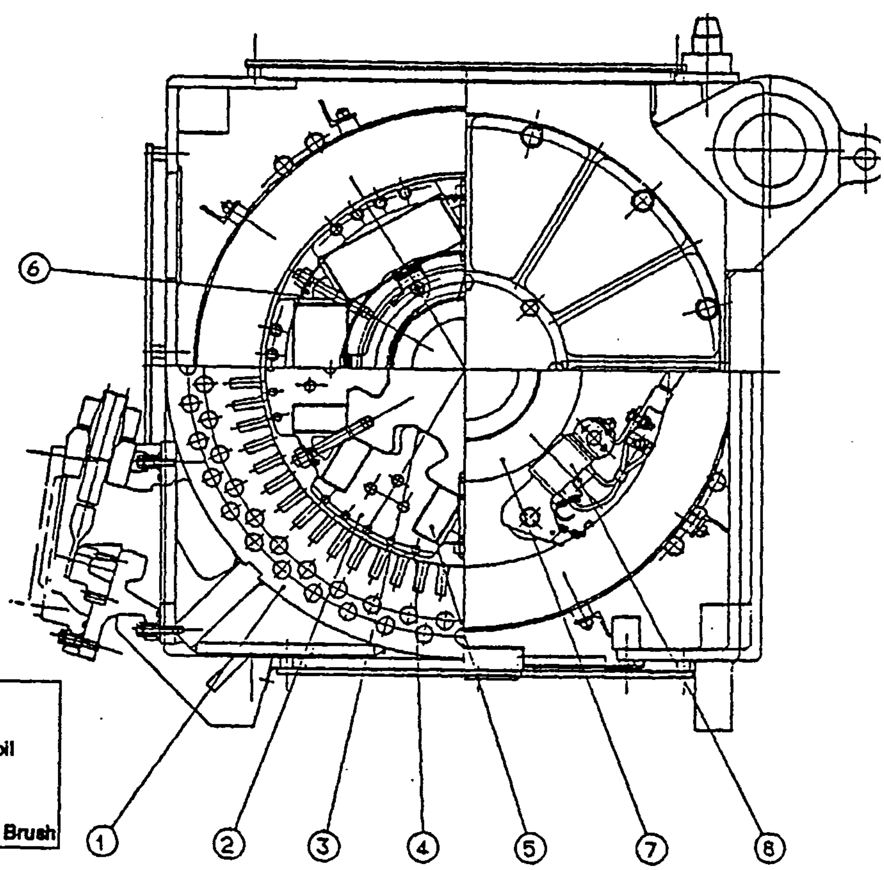
FIGURE 13

TGV-A Synchronous Motor



Longitudinal Section of Synchronous Traction Motor

1 Magnetic Circuit
2 Stator Winding
3 Exciter Coil
4 Damping Cage
5 Rings
6 Notched Disc
7 Position Detector
8 Forward Bearing
9 Rear Bearing



Transversal Section of Synchronous Traction Motor

1 Notched/Ventilated Sheet Metal
2 Rotor Pole
3 Dove-tailed Mounting
4 Damping Rod
5 Magnetic Field Coil
6 Adjustment Bolts
7 Ring
8 Brush Holder and Brush

the TGV-A, allowing for longer, heavier trailers. This results in a passenger capacity gain of more than 30 percent (Lacôte, 1986: 703). Second, more power means higher speed. On dedicated track segments, fully loaded TGV-A trainsets can reach 300 kmh. Third, the operating motor itself becomes a generator for braking power, making the TGV-A (and TGV-PSE) self-reliant for its braking power, independent of catenary power. In addition, the brake discs have been redesigned to higher tolerances, making brake ventilation unnecessary and thereby reducing air drag. Microprocessors are used to aid in braking control (Chambron, 1986: 39). The brake sets thus become simpler and safer.

There are only four motorized bogies per TGV-A trainset compared to 6 per TGV-PSE trainset (the PSE carries two motorized axles in the trailer set), for a total of eight motors per trainset (two axles per bogie). They are installed in two power cars located at each end of the trainset. Each motor obtains a continuous rating of 1100 kW (total 8800 kW per trainset) and a one-hour rating of 1300 kW (Allen, 1988: 73). Two coupled trainsets work in multiple rate at 17,600 kW, making for significant savings in power consumption. TGV-A motor coaches are dual-voltage (25 kV ac, 1.5 kV dc). Some TGV-N power cars have been ordered with specifications allowing for triple-voltage; this third option will allow TGV-N trains to operate in Belgium. When the TGV-A is operating on 25 kV lines, power is drawn from the catenary through only one pantograph (on the rear power car) per trainset. The power is transferred to the second power car via a 25 kV ac bus line located in the roof assembly of the trainset (Allen, 1988: 74).

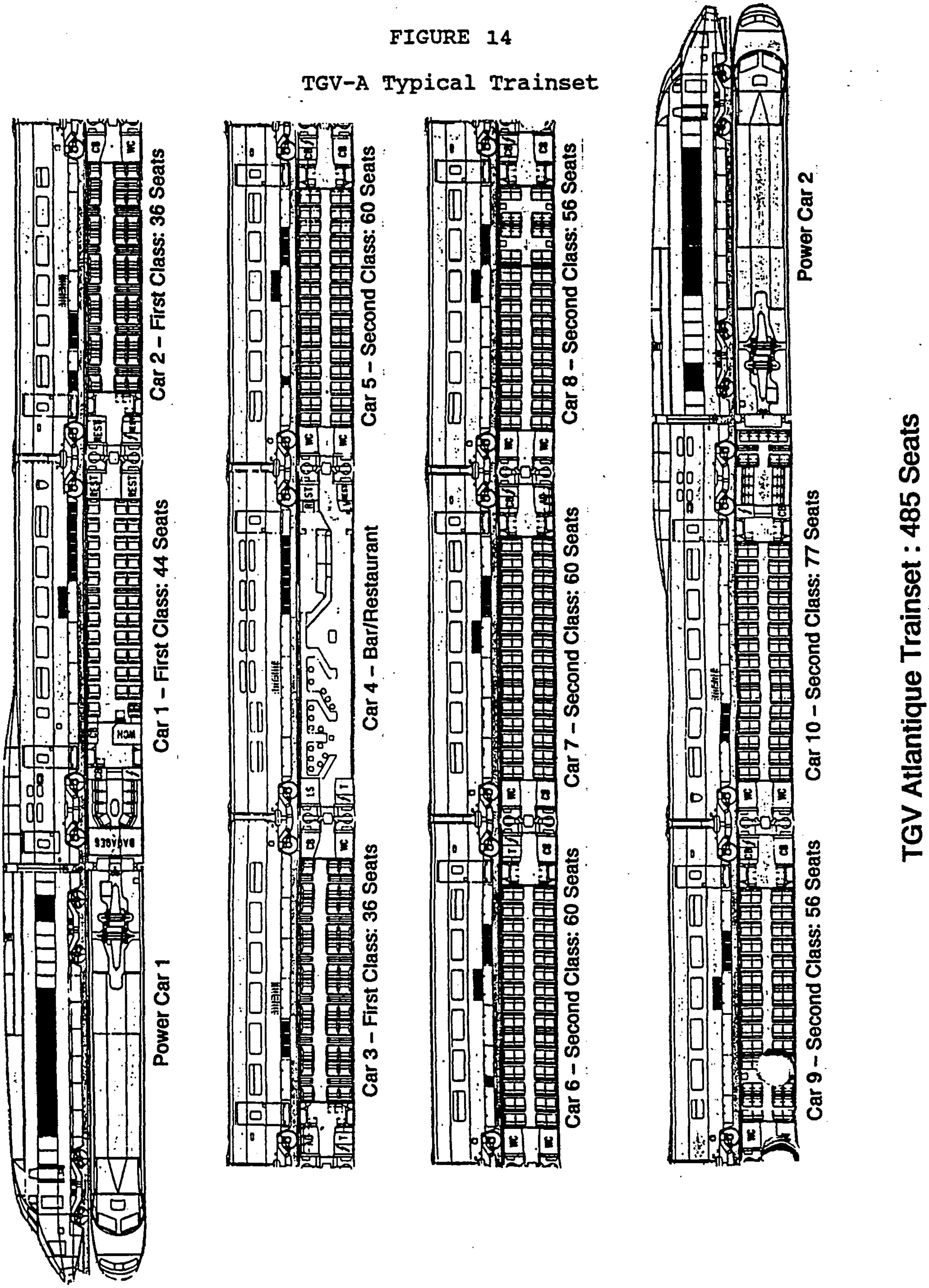
Trailers

Each TGV-A trainset consists of ten passenger trailers: three first-class cars, six second-class cars, and one bar car. The trainsets are articulated, with sealed passageways between trailers to maintain inside air pressure and keep out noise. The trailers are coupled over a single bogie (cars are not separate units); thus, the trainset becomes a single articulated unit. There are no doors between wagons, so air conditioning can be more easily regulated and passenger movement within the trainset is easier. The standard trainset's overall length is just over 237 meters; its overall width is 2.9 meters (Allen, 1988: 75). Figure 14 illustrates the standard TGV-A trainset.

The SNCF has improved on the interior design of the TGV cars with the new Atlantique trainset. TGV-A seating configurations have been diversified to offer passengers more choice. Colors and materials were carefully chosen for comfort and durability.

FIGURE 14

TGV-A Typical Trainset



First-class service offers in-seat meal service, a conference room for eight with a central table, semi-private compartments for four with tables, face-to-face seating for two with a table between, and single and coach-style double seats in one of the cars.

Second-class service offers more face-to-face seating than is customarily found in second class cars, compartments for four with removable seats to accommodate families with children, nurseries in two cars, a room with 17 seats that, when folded away, make room for a play area (located in the last car). A bar car is available for passengers in both classes.

The entire trainset was designed to the highest standards of passenger comfort to provide such features as quiet, self-regulated air conditioning, on-board telephone booths, and sound-absorbing materials throughout.

Vehicle Performance

The maximum running speed of the TGV-A trainset is 300 kmh. In tests, however, a slightly modified trainset broke the industry's imagined speed barrier of 500 kmh, setting the current world speed record for steel-on-steel technology. Of course, the 300 kmh commercial speed can only be achieved on the TGV-A's dedicated track segments. Trains moving through the dense urban areas around Paris are subject to certain speed limits due to shared trackage, relatively sharp curves, and noise reasons. For the first 15 kilometers out of Paris, trains run at 200 kmh, at 270 kmh for the next 10 kilometers, and only then can the maximum speed of 300 kmh can be reached.

Average speeds on a particular run (from departure to arrival) vary from 222 kmh (138 mph) on dedicated segments (Paris to Le Mans, 124 miles, 54 minutes) to 195 kmh (121 mph) on a non-stop Paris-Bordeaux run (360 miles, 2 hours 58 minutes). Once TGV-A trains leave dedicated track segments (or the higher speed conventional line between Tours and Bordeaux), the average speed of a run drops significantly because the TGV is subject to the constraints of a conventional line with mixed traffic, color-aspect signalling, several stops, and sharp curves. It is important to remember, however, that the total time savings for one of these runs is significant because of the use of the high speed, dedicated track segments. Appendix D gives average running speeds and times for several selected runs from Paris.

On upgraded lines such as the conventional Paris-Bordeaux line, the maximum operating speed is 220 kmh. This line is built to standard SNCF main-line specifications; it is designed for conventional service at 200 kmh. TGV-A trains have been running on this line at 220 kmh, however, because their superior braking power gives them a margin of safety at 220 kmh that conventional trains do not have. SNCF has had one problem with running TGV-A trainsets along this line: in the summer months, when demand is high, increased temperatures have stressed the catenary along the line, parts of which date back to 1938 (Douté, 1991). With frequent TGV-A sets running in multiple (more pantographs making contact with the catenary), the increased stress on the catenary has caused it to break on at least one occasion. SNCF's dilemma: whether to upgrade the entire catenary system along the line to TGV standards, or do "patchwork" repairs, reduce TGV-A speeds to 200 kmh along the route, and wait for the new dedicated line to Bordeaux to be built. SNCF will probably do the latter.

Carrying Capacity

The TGV-A trainset can carry up to 522 passengers; trainsets running in multiple can carry up to 1044 passengers. The composition of a standard TGV-A trainset is as follows:

Three First-Class Cars	=	116 seats
Six Second-Class Cars	=	369 seats
Fold-away seating	=	37 seats
Total capacity	=	485 seats + 37 fold-aways = 522

Space for passengers in wheelchairs is available on each trainset and toilet facilities can accommodate handicapped passengers.

Reliability

While the SNCF adjusts to the operations of the TGV-A, and as stations undergo renovations during this adjustment period, the only complaint that passengers have had is that there are not enough trains to meet their demand. Frequently, trains are sold out prior to departure. Some passengers have found on arrival at the station that previously sold-out trains had places available after all. The suspected culprit: passengers who reserve seats on several trains (using their Minitel)[6] for only one trip.

In early 1990, the SNCF reported that the TGV-A's on-time performance was at 92.3 percent. Fewer than 4 percent of scheduled trains were more than 15 minutes late (Durandal: 15). The SNCF is pleased with the TGV-A's performance, attributing minor incidents to its adjustment period, ironing out the minor technological glitches (such as doors that won't unlock), and dealing with major construction in and around stations.

There have been no accidents thus far, and no passenger injuries have been reported on the system. The PSE line holds the same record with one exception: a train operating on a conventional line collided with a loaded truck that was crossing the track at an "unapproved location." The train operator and one passenger were killed (FRA, 1991: 2).

4. TGV-A SERVICE

Commercial Marketing Philosophy of the SNCF

Context

The first step in the commercial market analysis for TGV-Atlantique services was to determine the context for the new service. The TGV-PSE had been running successfully for a number of years; its success was both technical and financial. Certain improvements in the train were necessary, such as the design of the seats for better comfort and a new design for the cramped bar car. TGV service (at the point that the Atlantique became operational) represents only a third of all SNCF traffic[7] (Halaunbrenner, 1986: 751). In this light, care was taken not to promote the new technology at the expense of the national railway's fundamental mission: the provision of excellent, efficient, cost-competitive rail transportation to all of the citizens of France. Marketing the TGV-A was to be done in concert with the general policies of the SNCF with respect to passengers and fares.

Another element considered as part of the context of TGV-A service was the competition for passengers from other modes. The private automobile was seen as the biggest competitor. Approximately 60 percent of the annual passenger market in 1985 was held by private auto (Halaunbrenner, 1986: 752). As in the United States, the private auto is the mode of choice for most suburban and rural travellers. The car symbolizes independence, freedom, individuality, and is becoming an important part of the lives of many French families. The operating cost of a car is independent of the number of passengers it carries, making it relatively inexpensive. For a family of four, a train trip can be very costly compared to the car.

Air traffic was the other serious competitor to consider. Passenger traffic by air was growing at an annual rate of 10 percent (Halaunbrenner, 1986: 752). Business travellers were the largest class of travellers contributing to this increase; in 1985, business travellers made up 40 percent of total air passengers. Like the automobile, air travel carries its own mix of prestige and mystery; travel by air is attractive and is often associated with affluence, modernity, and success.

Potential Market

Identifying and characterizing the future passengers of the high speed service was the next step in the process. Nearly one-third of the French population lives in the regions that would be served by the TGV-A, including a dozen cities with populations of more than 100,000. Benefitting from a well-established conventional train service, the SNCF knew that traffic going to, from, or through Paris from and to the Atlantique's service area was over 17 million passengers in 1985 (split almost equally between west and southwest). This was more traffic than on the PSE corridor. The SNCF estimated that with the new high speed link, traffic in the Atlantique corridors would grow in the early nineties to nearly 26 million passengers per year, 21 million of which would be using the new TGV-A. Sixty-eight percent of the passengers on the TGV-A trains would be diverted from classic train lines, and 32 percent would constitute new train riders diverted from air and auto modes (Halaunbrenner, 1986: 752).

In addition to taking into account the varying types of demand from day to day (for example, the exodus from Paris each Friday) in scheduling service, the SNCF had to cope with the relatively dispersed population in the service region (the populations in the PSE corridor are more concentrated in larger metropolitan areas).

The SNCF employed surveys and special market studies to aid in its analysis of the Atlantique market. One interesting fact they discovered was that the market share of travellers going from the provinces toward Paris was, in general, greater than the market share of travellers going from Paris to the provinces.

Commercial Strategy

Business logic would dictate that TGV service be put in place in those locations where it would be profitable. But the self-described mission of the SNCF is as a provider of a "public service," making it impossible to deny service to localities where profit cannot be made. To bridge the gap between these seemingly contradictory goals, the SNCF modelled the system to give priority service to the large generators of traffic and to provide local and/or connecting service to the TGV at strategic stations along the route.

The SNCF had adopted a particular set of ideals when implementing the TGV-PSE system in the late 1970s. Among the most important of these was the notion that the TGV was a new kind of train with unique features that would take the place of certain traditional trains; it was not to be considered an "airplane on wheels." Also, TGV service was to be available to everyone. This would be manifested in the provision of first- and second-class services on *all* runs of the TGV trains and by the extension of service throughout the target regions either directly or by carefully planned transfer connections.

These ideas made it possible to think of the TGV system as a "democratic" mode of transport, responding directly to the needs of the transportation market. The SNCF considered the TGV the ideal mode of median distance transport and the proof that the national railway was willing to adapt its operations to the changing transport marketplace.

As the TGV-Atlantique came closer to implementation, these ideals were adapted and expanded. First, the TGV-A system incorporated certain technological improvements over the TGV-PSE system. Second, the system would be better configured to accommodate each type of passenger expected. Third, together with the continued success of the TGV-PSE, the TGV-A would mark the beginning of an integrated national high speed network that eventually would look toward the whole of Europe. Finally, the new TGV-A would bolster the image of the SNCF as an efficient, responsive organization, ready and willing to please its customers. The distinctive aerodynamic shape of the TGV nose has become the trademark of the system, a trademark that the SNCF wished to exploit.

Market Targeting Strategy

Before targeting specific markets, the SNCF had to define its product. Taking the point of view of its customers, the railway noted that its product was a trip or a combination of services that made it possible for a traveller to get from her place of origin to her destination. In other words, satisfying the customer is more than just getting her from train station to train station; it includes many services both before and after the actual journey. These services include the physical attributes and design of trains and stations for safety and comfort, wide and frequent schedules, and convenient and efficient means of information distribution and ticketing.

The goals of the SNCF's marketing strategy have for many years been to maintain the traditional rail ridership base it enjoys and to attract new riders (Halaunbrenner, 1986: 752). The TGV-A system has, in the eyes of the SNCF, done much in the way of improving service so as to achieve the first goal. The SNCF sees new riders as families with children and what they refer to as "opinion leaders," or those groups in society who are trend setters, and whose actions will be imitated by other social groups (these "opinion leaders" are currently being wooed by the airlines).

Families with children are an important market for the SNCF; they comprise approximately half of all trip-makers (all modes combined). Currently, families tend to rely on the auto for their trips. The SNCF has so far only been able to capture 10 percent of this market segment (Halaunbrenner, 1986: 754). With the introduction of the TGV-A, the SNCF has made an attempt to make train travel more attractive to families with children by offering a full range of services in second class, including special family fare packages, an expansion of the JVS[8] program for children travelling alone, family-oriented seating configurations including play areas, nursery and infant-changing facilities aboard the trains, and a national advertising campaign.

To cater to the "opinion leaders," the SNCF has billed its new first-class service as top of the line, including a wide variety of seating configurations for individual or group/conference work and an in-seat meal service.

Geographic Marketing Targets

The SNCF established three criteria for identifying geographic market targets in the TGV-A service region. The first of these is the set of *trip origins and destinations*. This first criterion is broken down into three primary components:

- Rail corridor used in trips
- Direction of trips
- Length of trips

The second criterion is the *trip purpose*. This includes home-to-work trips, business trips, or personal (non-business) trips. Also included in this category is the size of the group travelling, be it a single traveller or a group (including families).

Finally, the third criterion is the *mode choice* of the traveller, whether it is rail, air, or auto.

Using these criteria, the SNCF identified nine priority target markets for the TGV-A (see Figure 15).

Basic TGV-A Service

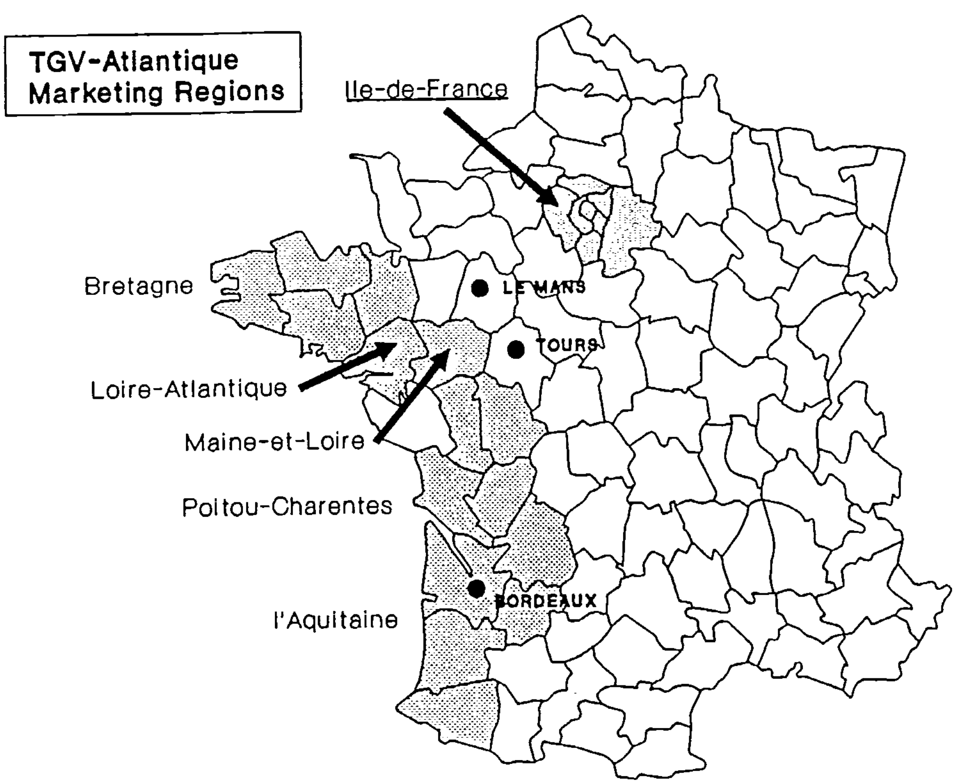
The TGV-A service offered to travellers by the SNCF is based on four large geographic centers. These are Paris, Bordeaux, Nantes, and Rennes[9] (Halaunbrenner, 1986: 754). Basic service to and from these centers consists of a high frequency of trains, a certain number of non-stop trains, a moderate number of stops on other runs, and reduced travel times (resulting in at least a one-hour savings over traditional trains).

FIGURE 15

TGV-A's Marketing Program

Priority Targets by Type of Trip

1. **BUSINESS TRIPS**
   - Between Ile-de-France and Loire-Atlantique
   - From l'Aquitaine toward Ile-de-France
2. **PERSONAL TRIPS**
   - Between Ile-de-France and Bretagne
3. **BUSINESS AND PERSONAL TRIPS**
   - From Ile-de-France toward l'Aquitaine
   - From Poitou-Charentes toward l'Aquitaine
4. **HOME-TO-WORK TRIPS**
   - From Poitou-Charentes toward l'Aquitaine
5. **OTHER TRIPS**
   - Personal trips between Maine-et-Loire and Ile-de-France
   - Medium distance trips by Ile-de-France residents
   - Regional trips within Bretagne



Fares

The philosophy of the TGV-A fare structure was based upon the SNCF's experience on the TGV-PSE line. Studies showed that travellers were willing to pay a premium price for the faster, higher-quality service that the TGV offered. On the PSE line, for example, base fares were more or less consistent with the traditional line fares. Premiums were charged for travel at peak periods, and a seat reservation system was introduced.

This approach to fare structuring was applied to the TGV-A system, but was fine-tuned to four different supplement levels based on the intensity of travel at any given time. Travel at the highest peak times carries the highest supplement charge and caters to business travellers. Vacation and family fares are structured for travel at off-peak periods. These supplement fares are now included with the ticket purchase to eliminate an often confusing step for passengers. Fares are different, therefore, depending on the day and time of travel, passenger class, and destination. Sample ticket prices are shown in Figure 16 for various destinations. For a more complete fare schedule, in French francs and US dollars, see Appendix B.

The SNCF would have liked to keep the TGV-A ticketing process as similar to the traditional trains' ticketing process as possible for the convenience of passengers. Certain differences, however, were inevitable. Among these is the seat reservation requirement. The SNCF found that passengers appreciated the reservation system; it helped them avoid the last-minute anxiety of rushing to a full train only to find no seats available, or having to get to the station early to find a seat (Halaunbrenner, 1986: 756). The reservation system has made it possible for passengers to get to the station minutes before departure and be assured of their choice of seat. This has the very beneficial effect of reducing, in many cases, the actual total trip time of a passenger by cutting down the amount of time one must spend in station prior to departure.

The SNCF is currently in the process of upgrading its ticketing system. In 1989, the SNCF contracted with American Airlines to purchase computer software similar to that which runs the SABRE airline ticketing system. This software, extensively modified and adapted to rail operations, will run on seven mainframe computers being installed at a new central ticketing facility in Lille and will use SNCF's modern X25 data network to revolutionize the nation's rail booking process. Called *Socrate*, the new system will handle tickets, reservations, informational inquiries, and hotel bookings not only in France, but throughout the world ("Resarail Revolutionizes...": 201). The system will be phased in from 1991 until early 1992. This new software will help the SNCF to monitor more accurately and more quickly the demand for various services as well as information about regular passengers' travel preferences. The Socrate system also includes an interface with

Figure 16
Fares From Paris to Selected Cities
1990 (US $1 = FF6)

	First Class Base + Supplement				Second Class Base + Supplement			
PARIS TO:	1	2	3	4	1	2	3	4
VENDOME	$31	$42	$42	$45	$22	$27	$30	$27
LE MANS	$36	$47	$47	$49	$25	$30	$33	$30
TOURS	$38	$49	$49	$52	$26	$32	$34	$32
ST PIERRE D CPS	$38	$49	$49	$52	$26	$32	$34	$32
POITIERS	$50	$60	$60	$63	$34	$39	$42	$39
RENNES	$53	$64	$64	$66	$36	$42	$44	$42
BORDEAUX	$71	$82	$82	$85	$48	$54	$56	$54
BREST	$75	$86	$86	$88	$51	$56	$59	$56
TOULOUSE	$94	$104	$104	$107	$60	$65	$68	$65
BIARRITZ	$90	$101	$101	$103	$61	$66	$69	$66
LOURDES	$96	$106	$106	$109	$65	$70	$73	$70

Source: SNCF

the French Minitel system (see previous section on reliability, Chapter 3), allowing passengers the option of self-booking. Tickets will continue to be available through automated ticketing machines throughout the country.

Other Services

Other services that were to come on line with the TGV-A include various telephone and computerized (MINITEL)[10] information and reservation services, ticket sales in suburban commuter stations, the opening of several "SNCF Boutiques" in large commercial centers, and automated ticket and reservation vending machines that take coin and credit cards in the stations in an attempt to shorten queues at the ticket counter. A station renovation and upgrading program has begun to increase passenger convenience and safety. This was done in part to replace the old image of the station as a dark, dirty place with a new image of modernity, safety, and convenience.

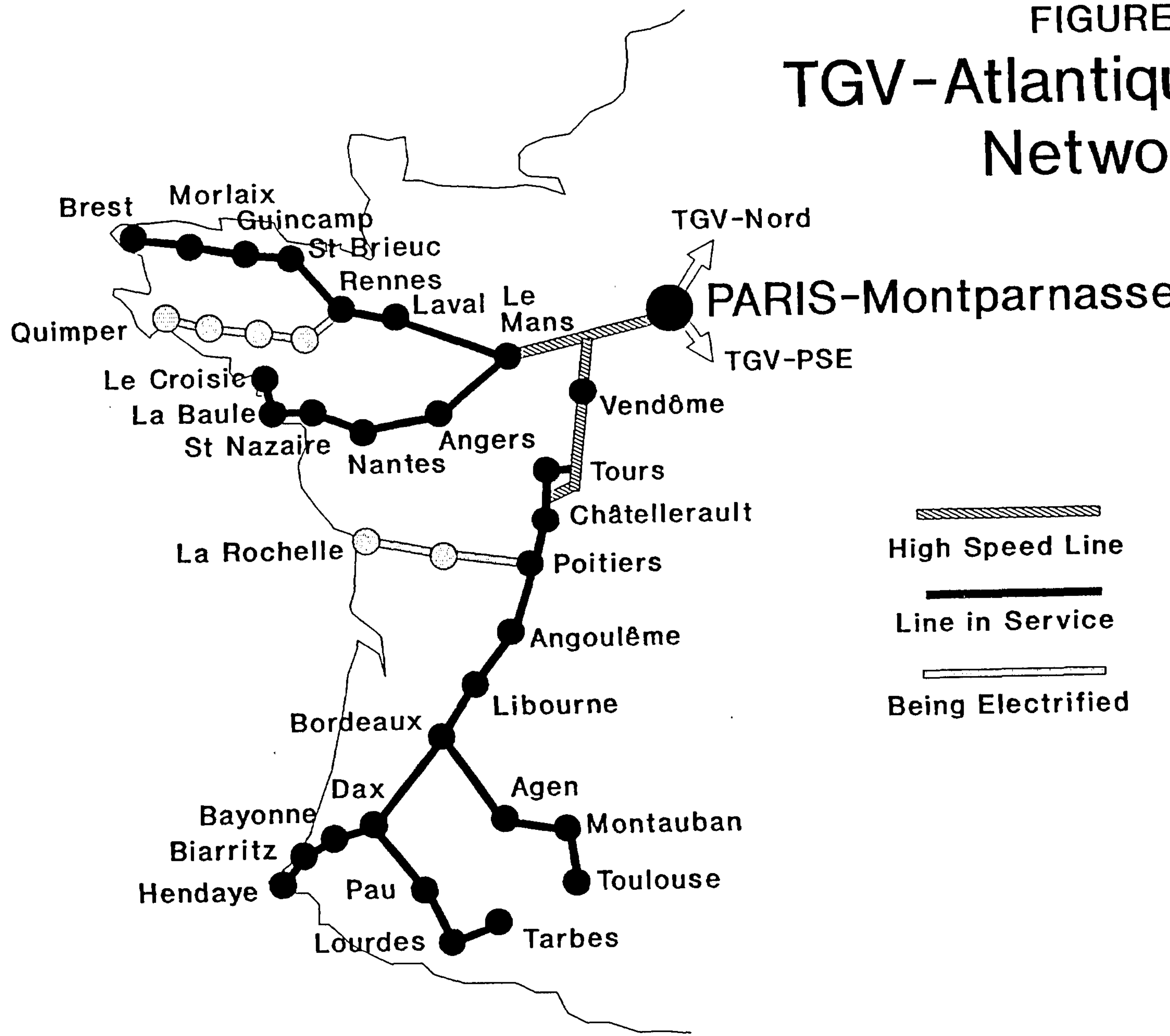
Actual Service Level

As of early 1991, the SNCF offers 316 TGV-A runs each week from Paris-Montparnasse to cities in Bretagne, Loire-Atlantique, Charentes-Poitou, and l'Aquitaine. The TGV-A network can be seen in Figure 17. Bordeaux enjoys at least 15 daily trains (some non-stop), a total of 112 trains per week. Forty-seven trains are scheduled from Paris-Montparnasse each Monday, 46 on Tuesday, Wednesday, and Thursday, 54 on Friday, and 38 and 39 on Saturday and Sunday, respectively.[11] This schedule is modified slightly on holidays. By mid-1991, the TGV-A fleet was composed of 95 trainsets (compared with 108 trainsets on the TGV-PSE, and 2 TGV-Poste trainsets).

In the first three months of operation, the TGV-A (west branch) was a smashing success. More than 1.6 million passengers used the line between September 24 and December 31, 1989. That's more than 100,000 passengers each week. The TGV-A southwest branch opened in late 1990, and SNCF preliminary reports say that 3.8 billion passenger-kilometers were travelled on the TGV-A network over the entire year. In contrast, the TGV-PSE line accounted for 11.1 billion passenger-kilometers for the same year. TGV travel as a percentage of total travel (in France) rose from 20.8 percent in 1989 to 27 percent in 1990.

FIGURE 17

TGV-Atlantique Network



5. ECONOMIC RESULTS

Costs

The following is a 1986 assessment of the costs of the TGV-A dedicated track segments and acquisition of rolling stock (Leboeuf, Palade, 1986: 770):

	Costs (in 1985 francs)
Stations and Maintenance Buildings	490,000,000
Land Assembly	508,000,000
Preliminary Construction	1,269,000,000
Large Projects	2,622,000,000
Safety Measures	92,000,000
Track and Ballasting	1,080,000,000
Track Upgrades	586,000,000
Environmental Protection	254,000,000
Unforeseen Costs	153,000,000
Safety and Telecom	653,000,000
Electric Traction System	543,000,000
SUB-TOTAL (line)	8,160,000,000
Locomotives and Trailers	6,891,000,000
1986 Reassessment Adds:	1,204,000,000
TOTAL	16,345,000,000

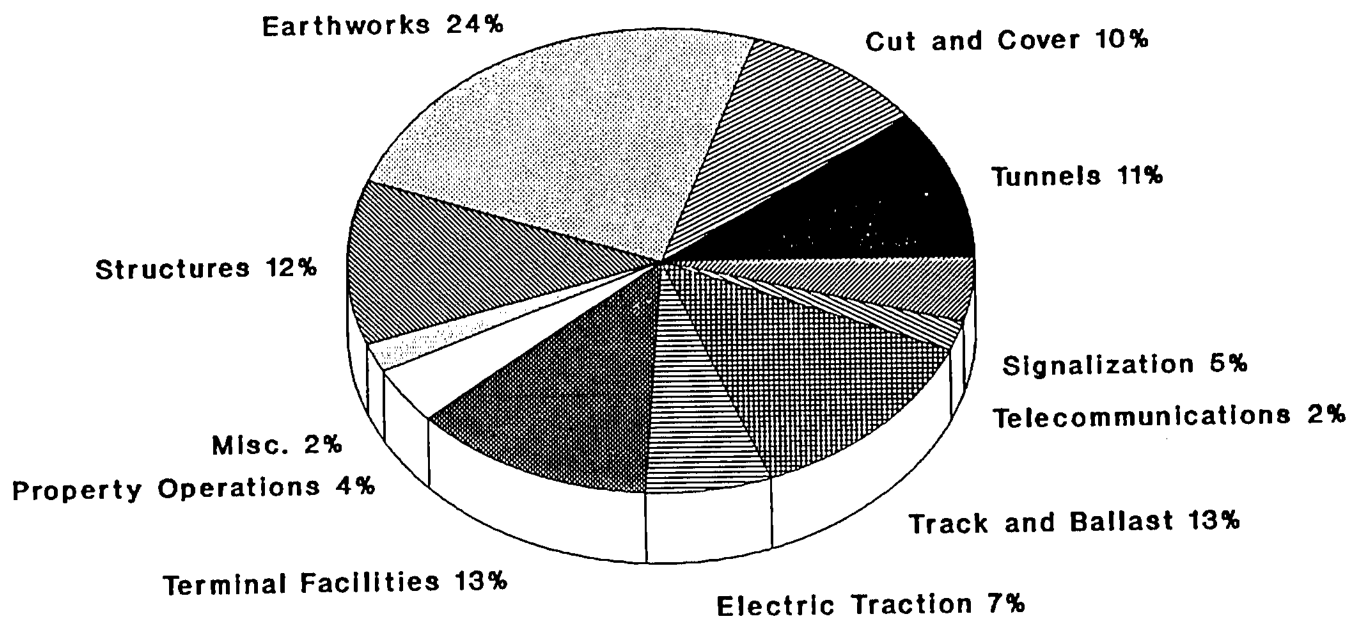
Figure 18 breaks down the total construction costs of the Atlantique system into its constituent components. This 1989 summary of costs brings the total expenditure on the line (excluding rolling stock) to nearly 11 billion francs ($1.8 billion). Total reported TGV expenditures for infrastructure and rolling stock during the period 1985-1989 were FF 18 billion (1989 francs) or US $3.6 billion.[12] This was the primary spending period for the implementation of the TGV-A network. The current SNCF budget plan calls for additional TGV expenditures during the 1990-1994 period of FF 45.5 billion (1989 francs) or US $9.1 billion. This includes a small amount for TGV-A, but is primarily to cover the costs of three new TGV projects: TGV-Nord, TGV-Interconnexion around Paris, and the extension of the TGV-PSE around Lyon to Valence. Figure 19 shows the trends in major SNCF expenditures during the TGV era and projected to 1994. TGV expenditures are sure to increase once the plans for TGV-Méditerranée and TGV-Est are finalized.

In 1986, the Canadian Institute of Guided Ground Transport oversaw a study of magnetic levitation technology for the Los Angeles-Las Vegas corridor in the United States. In their alternative analysis, the CIGGT undertook a costing study for French TGV technology for the same corridor. The costs for various components of the system were analyzed in detail and revised

FIGURE 18

Construction Costs: TGV-A

Dedicated Track Segments

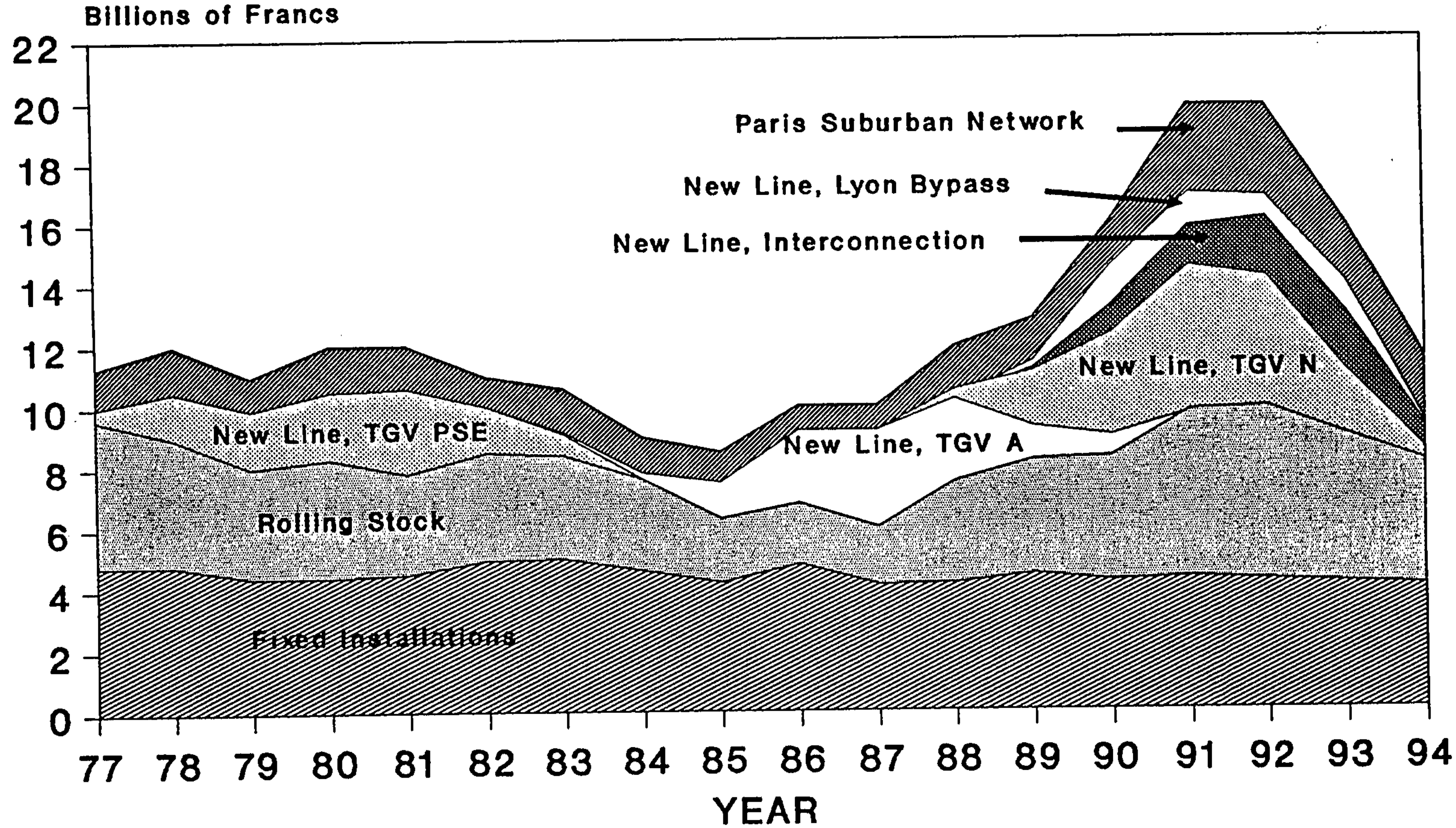


Total Construction Cost: 10,900 MF 1989

Source: Daniel L. Roth

FIGURE 19

SNCF Major Expenditures 1977 to 1994



Source: *La Vie du Rail*, No. 2229, 1990
1990 Francs (6 FF = 1 US $)

several times to reflect actual conditions in California with respect to land types, labor and material costs, and projected maintenance schedules based on a specific train consist and fleet size. These costs (Figure 20), while only estimates, are helpful in understanding what the basic capital and operating costs of an American, particularly a Californian, TGV system might be.[13]

Projections based on the experience of the TGV-PSE line indicate that the capital costs of the TGV-A system could be amortised near the year 2000. The PSE line earned FF 4.4 million in fiscal year 1988 (Roth, 1990: 84). Forty percent of that revenue went for operations and maintenance, and 26.2 percent went for the financing of infrastructure and rolling stock.

It is interesting to note the financial success of the Atlantique's immediate predecessor, the TGV-PSE. Constructed without government subsidy (the SNCF self-financed and borrowed money on the international market), the PSE new line was completed for approximately 7,770 million francs (1983) or about 1.3 billion dollars (Walrave, 1985: 642). By 1984, when the network was completed, the line was making money. An illustration of the dramatic financial experience of the PSE line and its continued increasing returns through 1988 can be seen in Appendix G. It should be remembered, however, that on the PSE line, the SNCF was responding to an increasing demand for service in that corridor. By building the PSE line, the SNCF was able to increase capacity and therefore meet that demand. As revenue passenger-kilometers grew, so did SNCF-TGV revenues. Growth projections along the Atlantique line have not been as robust due to current economic conditions, and the capacity situation is not similar to the oversaturation that the southeast line was experiencing. The Atlantique project did receive 30 percent infrastructure subsidy from the French government (Roth, 1990: 85) because of the SNCF's concerns over economic conditions.

Traffic

As previously noted in Chapter 4 of this report, the TGV-Atlantique line is currently offering service between Paris and destinations throughout the western and southwestern regions of France. Electrification of two lines (Rennes to Quimper, Poitiers to La Rochelle) is under way which, when completed, will extend the TGV-A's reach into the region. The SNCF's figures for 1990 indicate that over 3.8 billion passenger-kilometers were travelled on the Atlantique network. Because the southwest branch to Bordeaux did not open until in September 1990, the traffic on the line for 1991 should be significantly higher.

FIGURE 20

CIGGT Cost Estimates for California TGV system

As reported in 1984; 1988 costs calculated with CPI (Transportation)

Item	Unit	Cost/unit (1984)	Cost/unit (1988)
Category: Land Acquisition			
Range land	acre	$640.00	$695.68
Pasture/Cultivated	acre	$2,795.00	$3,038.17
Orchards	acre	$12,500.00	$13,587.50
Vineyards	acre	$7,095.00	$7,712.27
Built-up, scattered	acre	$13,000.00	$14,131.00
Built-up, dense	acre	$98,824.00	$107,421.69
Railroad/Highway land	acre	$100,000.00	$108,700.00
Industrial land	acre	$175,000.00	$190,225.00
Legal costs	acre	$3,050.00	$3,315.35
Category: Earthworks			
Site preparation	cubic meter	$3.43	$3.73
Cut, ripper	cubic meter	$4.12	$4.48
Cut, explosives	cubic meter	$22.46	$24.41
Borrow	cubic meter	$6.43	$6.99
Embankment	cubic meter	$5.10	$5.54
Spoil	cubic meter	$7.33	$7.97
Purge	cubic meter	$14.71	$15.99
Subgrade	cubic meter	$27.45	$29.84
Landscaping	square meter	$2.94	$3.20
Category: Structures			
Hydraulic:			
3 m width	each	$34,313.00	$37,298.23
10 m width	each	$73,529.00	$79,926.02
20 m width	each	$147,059.00	$159,853.13
50 m width	each	$343,137.00	$372,989.92
Road-over bridges:			
pedestrian	each	$171,569.00	$186,495.50
2-lane	each	$343,137.00	$372,989.92
4-lane	each	$637,255.00	$692,696.19
Rail-over bridges:			
over trail	each	$196,078.00	$213,136.79
over 2 lanes	each	$294,188.00	$319,782.36
over 4 lanes	each	$490,000.00	$532,630.00
over 6 lanes	each	$735,294.00	$799,264.58
2 TGV over 1 railroad	each	$1,203,922.00	$1,308,663.21
Retaining walls (5 m height)	meter	$2,530.00	$2,750.11
Tunnels (74 sq. meters)	meter	$19,472.00	$21,166.06
Category: Superstructure			
Track	trk-mi	$519,104.00	$564,266.05
Turnouts	each	$380,000.00	$413,060.00
Crossovers	each	$1,200,000.00	$1,304,400.00
Signalling	trk-mi	$317,460.00	$345,079.02
Catenary	trk-mi	$275,443.00	$299,406.54
Power supply	trk-mi	$87,302.00	$94,897.27
Telecommunications	rte-mi	$14,000.00	$15,218.00
Buildings	rte-mi	$56,000.00	$60,872.00
Terminals	lump sum	$71,757,000.00	$77,999,859.00
Maintenance facilities	lump sum	$69,440,000.00	$75,481,280.00
Trainset preparation center	lump sum	$1,522,000.00	$1,654,414.00
Category: Fleet			
Trainsets	each	$11,500,000.00	$12,500,500.00

Source: Canadian Institute of Guided Ground Transport Report No. 86-16

Land Use Impacts

The TGV, in general, has accompanied some interesting changes in land use and development at several locations in the system. That is not to say that the TGV itself is the direct cause of any particular land use changes, but that it has been part of a larger scheme of development. In some cases, the development that was planned did not occur. In others, development patterns have met expectations.

The first changes that were seen were in the patterns of tourist hotel usage at certain locations in Bourgogne (along the PSE route). Surveys showed that the number of overnight stays in cities such as Dijon, Valence, and sections of Lyon (near the Perrache station), dropped dramatically, while other smaller towns saw great increases in overnight stays (Bonnafous, 1987: 135). The decreases seem to be a direct result of the speed of the TGV, which makes it possible to return to a traveller's point of origin in the same day, while the increases are due to tour operators who include TGV travel as part of many package deals.

Other observations include the fact that many service industries in the southeast have chosen not to locate an office in Paris yet can still benefit from the market there. The high speed link makes it easy to access Parisian markets from the provinces (Bonnafous, 1987: 136).

Several surveys have shown that when businesses were in the process of selecting a location, the TGV was frequently a factor considered. But it was by no means a considerable factor; others-- such as availability of land and/or buildings, local support and incentives, quality of life, and the total transportation picture (roads and airports as well as rail facilities)-- played important roles.

There have been successes and failures in the attempt to spur economic development along the TGV-PSE line. First, in Lyon's Part-Dieu district, the conditions were already right for economic development to take place when the TGV station opened there. In fact, the TGV station was part of local policy to redevelop the area. After the station opened, the development pace continued as expected and Part-Dieu became a leading center for business locations. Since 1983, the demand for office space around the Part-Dieu station has increased from 175,000 m^2 to over 250,000 m^2 in 1990, and, currently, 60 percent of the planned office developments in the Lyon area are slated for the Part-Dieu location (PIEDA, 1991: 21). Such developments, however, tend to be in the direct vicinity of the station; "spillover" effects are not prevelant. There is also evidence to suggest that much of the development at Part-Dieu has been from firms relocating within Lyon, rather than by attracting new firms to the area.

Frequently cited as a development failure is the Le Creusot-Montchanin station between Paris and Lyon. Already suffering from economic decline when the TGV was constructed, hopes were high that the new high speed link to Paris and Lyon would turn things around, and that the old industrial economy would shift into services and begin to prosper. This has not been the case, however. The severity of the economic slump in the area may have contributed to its negative image, and firms have not been attracted there despite ambitious local promotional campaigns. Also, the station is located far from the urban center of Le Creusot and has not been sufficiently linked with new roads or other rail lines. As a result, Le Creusot remains undeveloped.

On the Atlantique line, plans are moving ahead for development in Le Mans and Vendôme. At the Le Mans TGV station, a new business center is planned that will contain 10,000 m^2 of office space, most of which is currently leased up (Pieda, 1991: 22). A second phase of the development is planned to include an additional 22,000 m^2 of industrial and office space. A new Technology Center is also planned for the TGV station area. A recently released report by a British firm (Pieda, plc) states that, over the past three years (the period of construction of the TGV-A line), Le Mans has seen a doubling of land transactions, a doubling of land prices, and a near doubling of apartment rental prices (1991: 23). In Vendôme, a much smaller town with a TGV station, similar trends in land and housing prices have been attributed, in part, to the TGV line. A new technology park is also planned for this location (Pieda, 1991: 23).

Already in Lille to the north, a new business center called Euralille will contain over 600,000 m^2 of office space above and around the new TGV-N station, located within walking distance of the center-city train station. Lille's service sector industries have been expanding as the planned high speed connections to Paris, Brussels, and London take shape. In 1990, over 120,000 m^2 of office space came on line. The new line is anxiously awaited by the inhabitants of the Lille region, who have seen unemployment figures top 13 percent in recent years (Masse, 1991: 12-17).

Around Paris, the new Interconnexion will bring three new stations to that area. The first, at Roissy-Charles de Gaulle Airport, is part of an major airport development plan that is slated to include offices and industrial expansion. The second station, at Marne-la-Vallée, will serve the Euro-Disney complex currently under construction. Finally, the third new station, at Massy-Palaiseau, will come on line to serve a massive new research and development technology park in Paris' southern suburbs. Each of these new stations will become an integral part of their respective developments as well as major points of intermodal transfer (to and from both Paris airports, urban transit lines, as well as autoroutes) and will be directly accessible from major cities in France and across Europe.

It is clear that the TGV is not a panacea; the simple fact of a station opening in a given locale does not mean that economic prosperity is on the horizon. But the TGV can be an integral part of a carefully planned economic development scheme that can give a city or town the edge in competition for new development. High speed rail, on its own, has not been a determining factor in the locational decisions of firms. The TGV has had a "bonus effect" that can push developing areas toward their full potential (Pieda, 1991: 24). Beyond this bonus effect, more time is needed to observe and measure the impact of the TGV in its new service areas, including the Paris suburbs.

Comparison of TGV Service to Air Service

It may still be too early in the life of the TGV-A to measure any real, lasting impact on air service; we may only know how much of the air market the TGV-A has captured after a few years of service once passengers have had a chance to experiment with both modes and an equilibrium is reached. The SNCF has, however, measured the TGV's impact on air travel along the southeast corridor and it has been significant. The railway is hopeful that the experience of the PSE line will be repeated on the Atlantique line.

When the PSE line was opened, dramatic shifts in mode share were observed. Figure 21 illustrates the levelling off and subsequent drop of air traffic between Paris and Lyon after 1981 (the year PSE service was initiated). While the air share to other southeast destinations continued to grow, the rate of growth after 1981 slowed. Figure 22 shows air/rail market shares in 1984 by average daily trips (both directions) between Paris and selected cities on the PSE route.

In late 1990, P.-H. Emangard evaluated the air-rail situation in the Paris-Bordeaux service corridor. This is probably the primary competitive route for air versus train travel. It must be noted that TGV-A service runs on conventional track from Monts (south of Tours) to Bordeaux at a maximum speed of 220 kmh, compared with 300 kmh on its dedicated track section north of Monts. Here are some of Emangard's observations:

Distance, Paris-Bordeaux 580 km

	AIR	TGV-A
Travel Times:		
In Vehicle Travel Time	1 hr	3 hr
Center City to Center City	3 hr	3 hr
Frequency of Service	15 RT/day	15 RT/day

In computing the center-city to center-city travel time, Emangard included the time it takes to get to the station/airport, the waiting times between arrival at the airport, checking in, passing

FIGURE 21

Trends in Air Traffic to Southeast Destinations
Before and After Opening of TGV-PSE

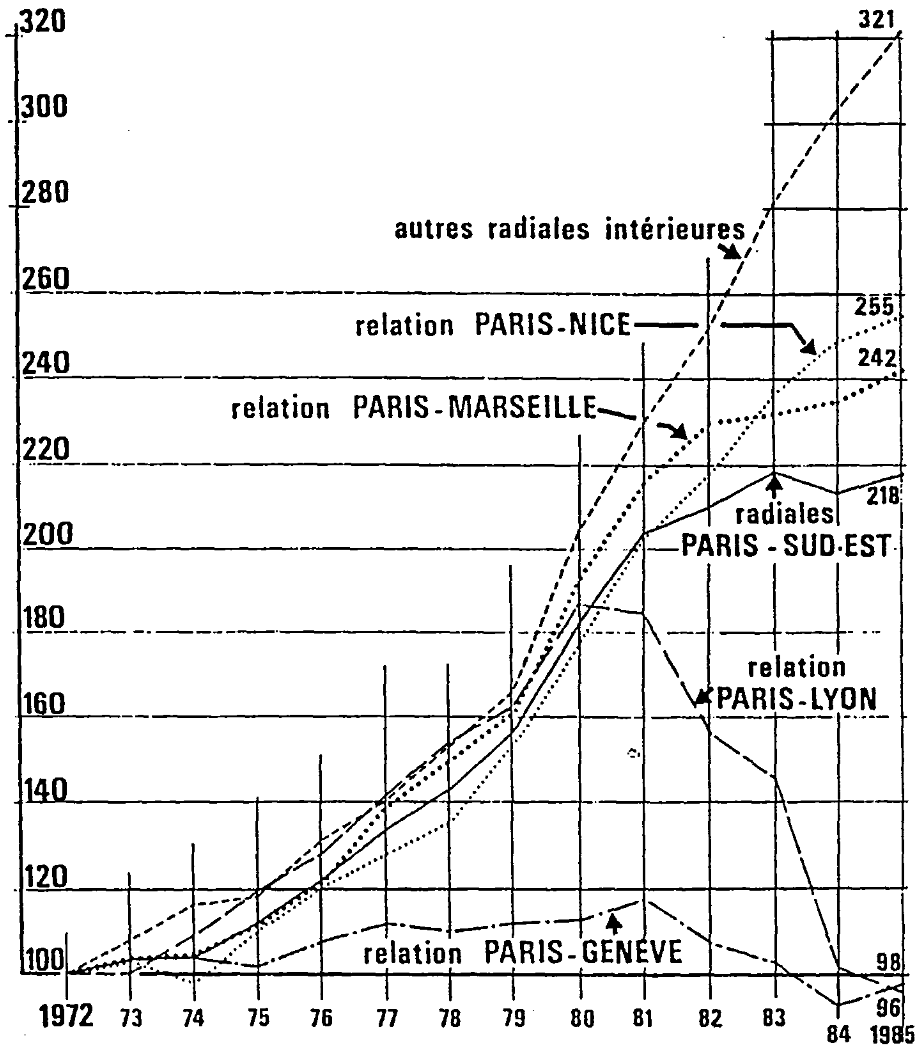
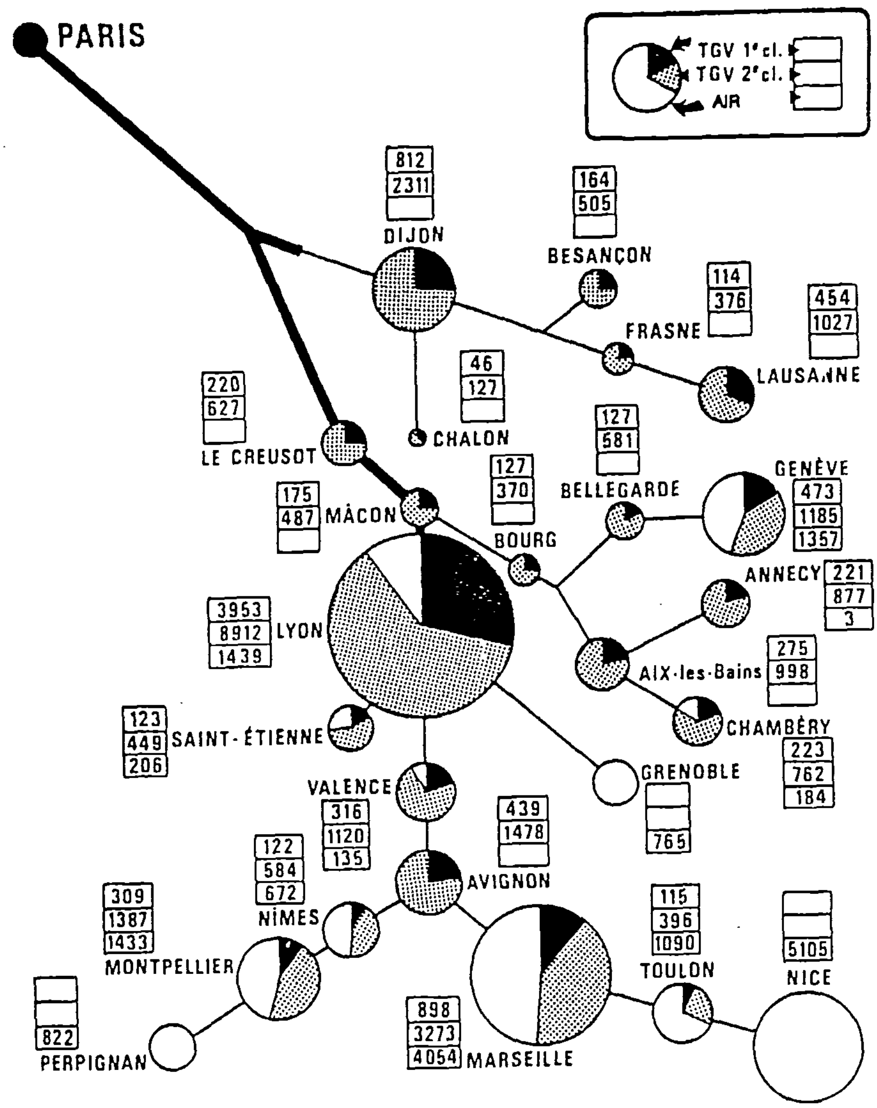


FIGURE 22

Market Share by Mode (TGV PSE 1st and 2nd Class/Air)
Average Daily Round Trips from Paris



through security, boarding, and take off. For TGV travel, a passenger can arrive at the station minutes before departure and still board with ease. Of course, most passengers will probably not be jumping onto their trains during the few seconds before departure, but certainly many passengers arrive at the train station later than they would at the airport. There is, at this time, no elaborate security system at train stations that would require passengers to arrive early. That is not to say there is no security; indeed, French train stations are carefully watched and are among the safest terminal facilities in the world.

Currently, Air Inter (the national domestic airline) is operating airbuses with a capacity of 340 passengers each on the Paris-Bordeaux route. This is slightly less than the passenger capacity of the TGV-A trainset. SNCF hopes to capture a significant (75 percent) part of the market between Paris and Bordeaux, as they did in Lyon. Air Inter contends, however, that the situation on the TGV-A route is very different from that on the TGV-PSE route. Bordeaux's regional airport is only 11 km from the center city. Lyon's airport is 30 km away and is joined to the city center by a toll road. Also, the geographic characteristics of metropolitan Bordeaux place the business locations of most of the primary air transport users (according to Air Inter) closer to the airport than to the city center.

With the current dedicated track configurations, the TGV-A cuts the normal train journey by only 25 percent (compared with 50 percent to Lyon). Air Inter conceded, however, that if the TGV-A does take a significant share of the market, the airline will substitute airbuses with smaller aircraft (170 seats) and maintain service frequency. This will, in theory, preserve the air mode's advantage of fast, frequent service, especially for same-day, down-and-back trips. In addition, the air carrier is planning weekend fare packages to cities on the coast, hoping to underprice the train and offer faster transit times.[14] Figure 23 shows sample fares to selected cities from Paris (one way) for both TGV-A (first and second class) and Air Inter.

TGV Freight Service

Until recently, TGV service has been reserved exclusively for passengers. But what about freight movement? It is conceivable that certain types of freight could be moved by TGV trains. The French postal service, La Poste, currently runs two special TGV trains between Paris and Lyon carrying mail and newspapers (the trains are painted yellow and display the La Poste logo). France's leading freight company, Sernam, uses some of the baggage hold space in the TGV-A for its Direct Express service to 33 cities between Paris and Bordeaux. These are the only two instances of "freight" service using TGV technology to date.

FIGURE 23

Sample Fares (one way) from Paris, January 1990

In French Francs (FF 6 = US $1)

Destination	TGV A First* Low	TGV A First* High	TGV A Second* Low	TGV A Second* High	Air Inter** Low	Air Inter** High
Brest	441	521	299	331	320	725
Lorient	404	484	274	306	345	755
Nantes	319	399	217	249	260	610
Quimper	441	521	299	331	365	785
Rennes	309	389	210	242	340	635
St Brieuc	362	442	246	278	637	995

* TGV A fare range based on day and time of travel

** Air Inter fares based on day and time of travel

Source: La Vie du Rail, No. 2228, p.18, January 1990

General high speed freight transport is much too expensive compared to conventional modes (truck, train, and air). However, the SNCF is looking into TGV-Freight service toward the year 2000. Georges Gac of the Observatoire Économique et Statistique des Transports (OEST) states that for high speed freight service to be economical, four conditions must exist. First, there must be significant investment into making TGV freight loading and unloading fast and easy. Freight facilities should be incorporated into stations or built entirely new. Second, the TGV network must be of sufficient size so that high speed freight traffic can compete with truck routes. This "critical mass" network could be in place by the year 2005. Third, SNCF and Sernam should not hold a monopoly in high speed freight transport. Private companies should be allowed to exploit the network. Fourth, the flow of freight should be at a level high enough to justify the diversion of some traffic to TGV. Gac goes on to say that, with these conditions, there could very well be a niche for TGV-Freight. Air transport is quick but expensive, and truck transport is less expensive but slower; TGV-Freight could offer a viable intermediary choice.

6. ENVIRONMENTAL IMPACTS

In preparation for the construction of the new TGV-A dedicated track segments, the SNCF carried out extensive environmental studies in order to minimize the impact of the high speed service on the landscape. Studies were made in each of five general areas: agriculture, animal and plant life, water systems, national heritage, and noise and vibrations.

Agriculture

The primary problem faced by the agricultural community was the restructuring of land holdings after the SNCF land takes. An effort was made to coordinate this restructuring with a program to increase farm productivity by clustering holdings around "operating centers." Drainage systems and road connections were carefully examined and restored when necessary. Overall, 83 rail bridges and 184 road bridges were constructed to accommodate agricultural needs (Chambron, Escaron, 1987: 32). Excavated earth was used to restore old quarry areas or to improve flood-prone lands for agriculture.

Animal and Plant Life

Aerial and ground studies were made to determine the effects of the new line on plants and animals. The SNCF carried out transplant programs to protect certain species of plants (two new medicinal species were discovered in the course of these studies) and to replace vegetation that served as nesting sites for birds. Of special concern was the mobility of larger animals; the TGV line would act as a barrier to deer and other large animals. To reduce this barrier effect, ten special crossover structures were designed and installed near the identified habitats of such mobile animals. When sensitive wetlands were disturbed or destroyed by the construction of the TGV-A right of way, amphibious wildlife was relocated to ensure its survival (see Figure 24). In all cases, ongoing monitoring programs have been put in place to measure the effectiveness of relocations and to maintain animal protection measures during the operation of the line.

Water Systems

While the water pollution potential of the train line is minimal, the potential for flow disruption and natural drainage pattern changes was considered significant. Hydraulic surveys were made to aid in the minimization of such disruptions. These water studies resulted in the installation of 488 ducts/ canals, 40 rail bridges over sensitive water courses, and 7 viaducts ranging in length from 108 meters to 431 meters and up to a maximum elevation of 465 meters (Chambron, Escaron, 1987: 32).

National Heritage

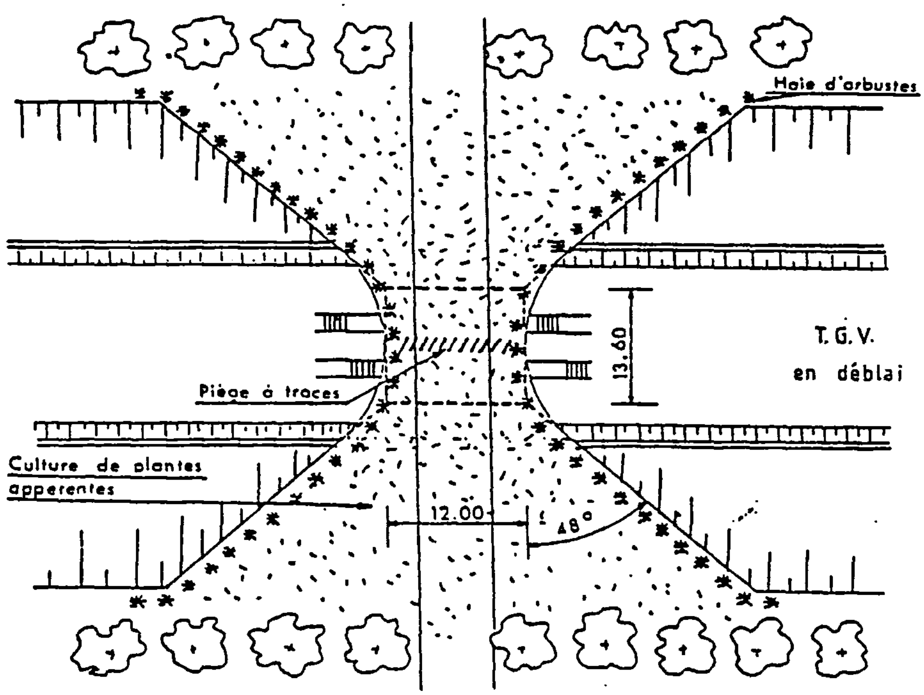
The SNCF employed architects and landscape architects to help in the effort to fit the new line into the landscape, in order to preserve the integrity of the countryside through which it runs. Through the Paris suburbs, the TGV-A line was designed as an urban green-way (coulée verte) with walkways and paths for cyclists. Archaeologically sensitive sites were cleared early on in the construction process and excavated with great care so that evaluations and retrievals could be performed by scientists.

Noise and Vibrations

The major source of noise in the operation of TGV trains is the contact of wheel and rail. Continuous welding of tracks and design innovations in the wheelset have contributed to a small reduction in noise generation. Engine and aerodynamic noise are not considered significant. Particularly in residential areas, but also in wildlife areas, noise is a problem. To mitigate the noise effects of passing high speed trains, the SNCF has installed a series of barriers and noise-absorbing constructions along portions of the line. Over 28,000 earthworks and screens have been installed along the length of the line (see Figure 25). Tunnels and trenching also help to alleviate noise, but these are costly solutions, so barriers and absorbers have been the primary

FIGURE 24

Wildlife Crossover Structure



Example of Pond Relocation

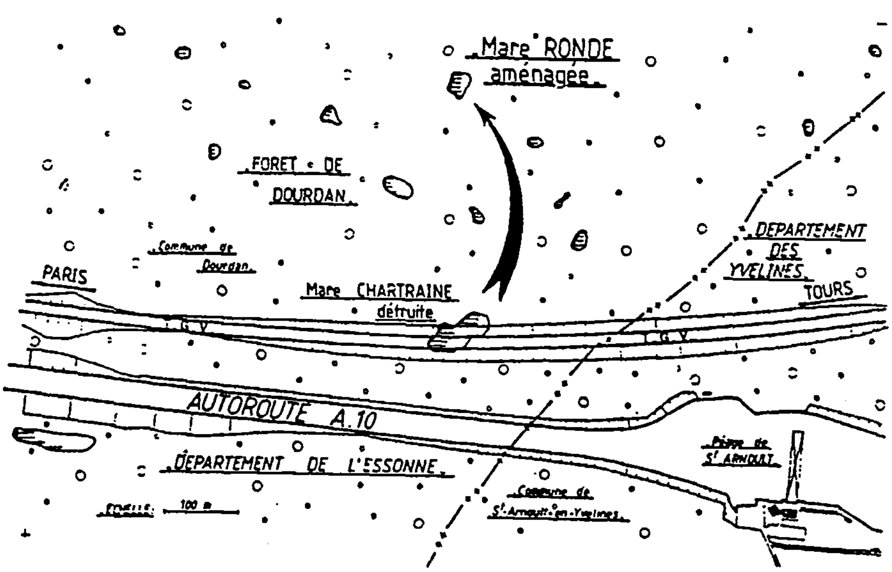
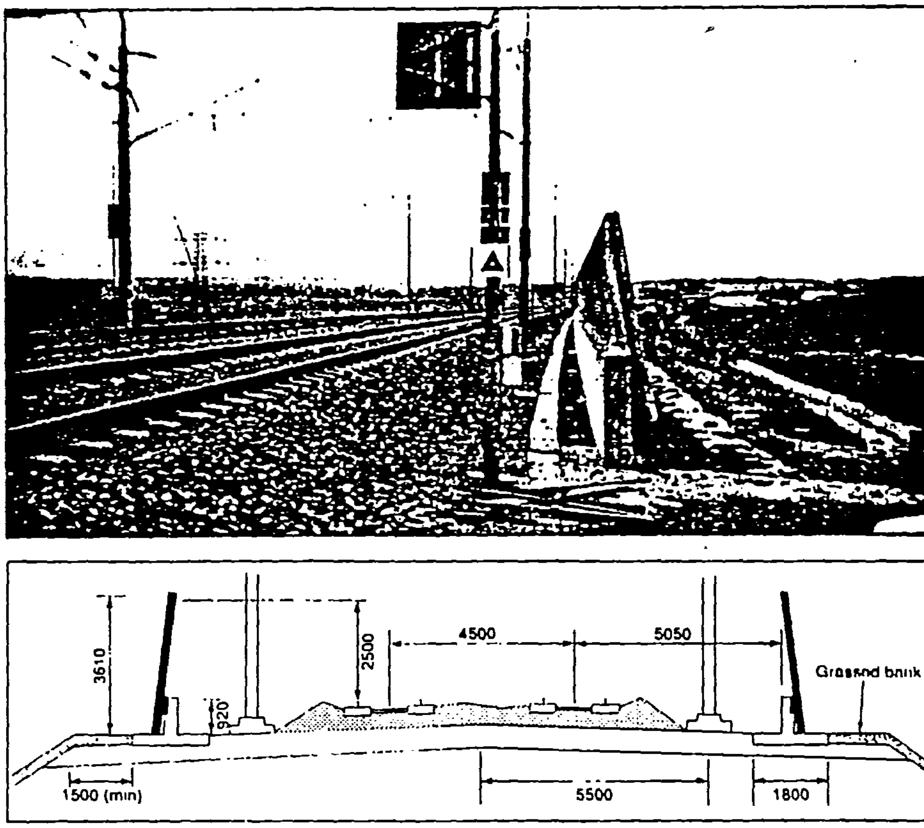


FIGURE 25

Typical Concrete Noise Barrier Along TGV-A Route



The angled design of noise-protection screen adopted for SNCF's TGV-Atlantique line (top) has also been specified for the TGV-Interconnexion route through the more environmentally-sensitive Paris suburbs methods employed to counter the effects of noise. Figure 26 compares the noise generation patterns of the TGV-A trainset to British Rail trains, the TGV-PSE, and a computer-simulated profile of the proposed Three Capitals TGV between London and Paris running at 225 kmh. Figure 27 is a graphical representation of the noise levels of selected train types both in tunnel and in the open as a function of distance from track. At a distance of approximately 15 meters from the track, the vibration levels of TGV-PSE trains is well below the "annoyance threshold" for the most sensitive type of land use (hospital).

Atlantique trains perform much better than PSE trains; the noise emitted by a passing Atlantique trainset is 30 percent less than that emitted by a PSE trainset (*La vie du rail* 2311, 1991: 19). In 1986, the French National Transportation Safety Institute (l'Inrets) concluded from a survey that while one out of every five French citizens (20 percent) was affected by roadway noise, only 2 percent of the population was affected by train noise. In addition, a TGV trainset running in multiple (two sets connected together) passes a given point in about eight seconds, carrying approximately 800 passengers. Once it has passed, the noise is gone. During peak periods the TGV-A can run once every four minutes or so. On a French national highway the same eight seconds will see about four cars pass, carrying only 20 or so persons. During peak periods the noise level can remain constant.

The noise generated by passing high speed trains, while not negligible, is certainly not an insurmountable problem. Noise barriers, deflectors, and absorbers can effectively mitigate the problem in sensitive areas and not contribute significantly to total cost. Through urbanized areas, high speed trains must travel at lower speeds (generally because of station stops, sharper curves, and mixed passenger traffic), and at such reduced speeds noise is not a problem.

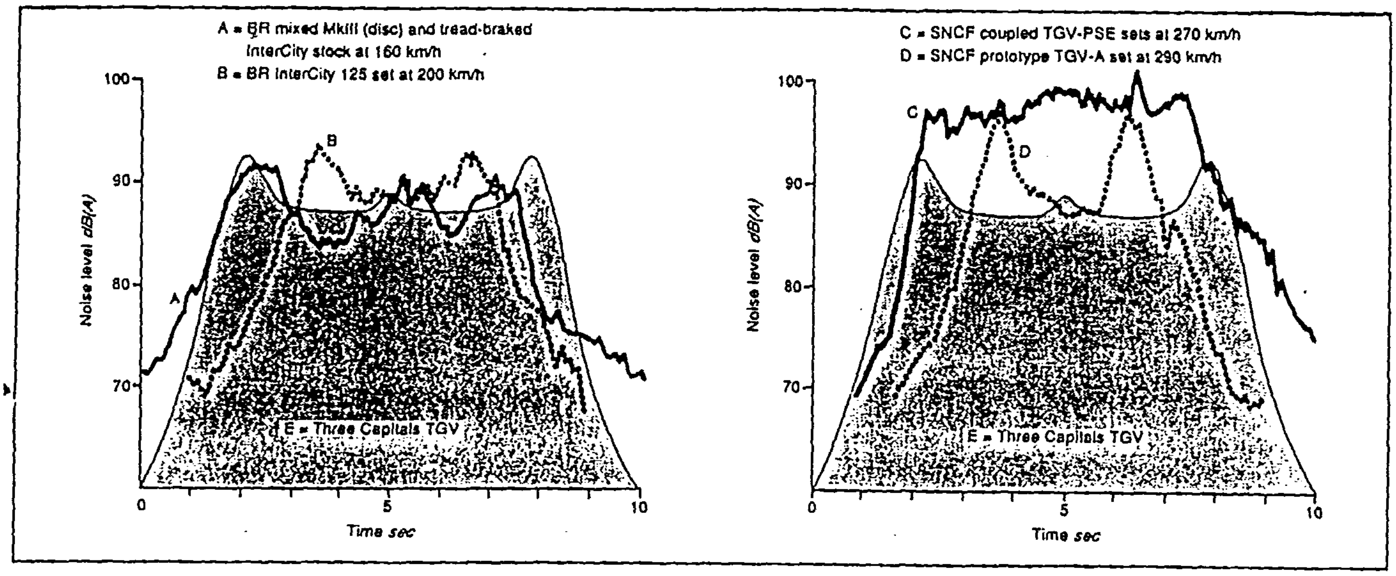
The SNCF anticipated and budgeted for the study and mitigation of the environmental impacts of the TGV-A line. This "foresight" was a product of the experience of the construction and operation of the TGV-PSE line and of the general increase in public awareness of environmental sensitivity to development over the past decade.

7. SUMMARY

The design and development of the SNCF's TGV-Atlantique network comes on the heels of its great success, the TGV-PSE. High speed ground transportation has been and continues to be successful in France because the SNCF has been explicit and consistent in outlining its goals and objectives and its means of achieving them.

FIGURE 26

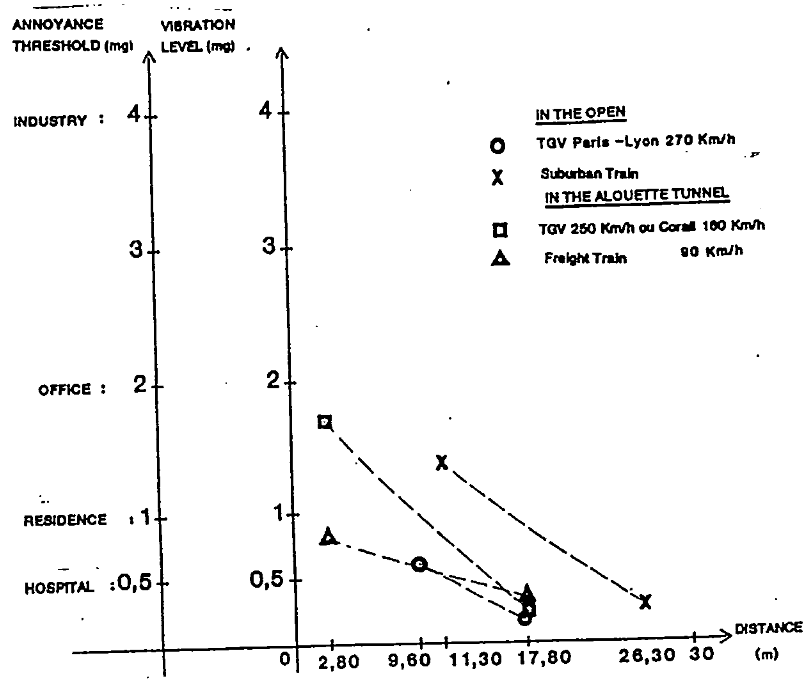
Computer Simulated Sound Patterns



Computer simulation of Three Capitals TGV at 225 km/h compared with recordings made 25 m from the track while BR (left) and SNCF (right) trains pass at various speeds

FIGURE 27

Noise Levels by Train Type, Distance from Track.



The TGV-A was developed following three fundamental principles that are the foundation of the SNCF's high speed program:

- *Compatibility with the existing rail system*
- *Dedicated lines for high speed passenger traffic*
- *Train services scheduled at frequent intervals*

The built-in flexibility of the high speed system, its compatibility with other rail services, and its ability to interact with other modes of transport combine to make it a viable and profitable means of transport for France and, indeed, for Europe.

Technological innovation has played its part in the development of the TGV-A system. A new type of traction motor, and improvements in power collection, braking, and signalization, have all had significant impacts on the proficiency of the system.

In addition, the SNCF has carefully researched the needs and comfort requirements of rail passengers and designed a set of TGV services to accommodate them. The TGV-A service embodies a widely diversified selection of travel options that cater to the business traveller, to the tourist, and to travelling families. With this increased attention to passenger comfort and convenience, the SNCF hopes to divert passenger traffic from air and auto modes to the TGV.

The TGV-A is not the final stage in France's high speed rail journey. The northern link (eventually to the Channel Tunnel) and the Paris and Lyon bypasses will be in operation in late 1993, and plans are currently underway for 16 new sections of dedicated high speed lines throughout the country. In addition, France is beginning to export its technology; TGV technology has recently been chosen for North America's first high speed rail system in Texas. Other countries, such as Taiwan, Canada, and Australia, are considering TGV technology as well. Germany, Japan, and Britain have been developing their own high speed wheel-on-rail systems, but only Japan has seen the kind of success that France has experienced in high speed operations.

The impacts of high speed ground transportation go far beyond the simple movement of people from one station to another. Significant land use patterns are emerging; new TGV stations around Paris, in Lyon, Lille, and other cities have been built in concert with new commercial and industrial developments. TGV links with large airports may relieve congestion at airport gates by replacing feeder air links. The construction of new lines and trains have contributed significantly to the French economy; investments in rail infrastructure in France have caught up with investments in roads and other automobile infrastructure[15] (*IRJ*, 1991, p. 22). Rail expenditures will account for 0.3 percent of the French GNP in 1991, one of the highest shares in Europe.

Still, it is important to point out that the TGV-A (or the entire TGV concept, for that matter) did not directly or indirectly *cause* these changes. The TGV is simply one of many components of a deliberate and carefully executed plan that has been evolving over the past 30 years in France. It is not a stand-alone system; it is a key element of an integrated transportation system that reaches into nearly every corner of the nation and out to nearly all points around the globe. The TGV network has become and will continue to be a vital thread in France's social and economic fabric.

NOTES

[1]Paris-Sud Est or Paris-Southeast line.

[2]Information for this chapter was obtained from the article entitled, "le TGV Atlantique, Voie, Signalisation, Caténaires, Télécommunications," from the December 1986 issue of "Revue Générale des Chemins de Fer." The entire issue was devoted to the technical, financial, and operational aspects of the TGV-A.

[3]GPU = Grand Plongeur Unique (Large single-pole pantograph).

[4]Elements of the pantograph are designed for specific uplift forces and aerodynamics to ensure consistent power collection at high speed in the open and through tunnels.

[5]RATP = Régie autonôme des transports parisiens, the Paris public transit agency.

[6]Minitel is an in-home interactive computer system available by subscription to French homes and businesses that accesses telephone directories, various government information databases, theater, airline, hotel, and train reservations systems, etc.

[7]Measured in trip-kilometers.

[8]JVS = Jeune Voyageur Service (Young Traveller Service). Young travellers between the ages of 4 and 14 are looked out for by an SNCF hostess while travelling on TGV trains without their parents.

[9]Paris is, of course, the largest with over 11 million inhabitants; Rennes is the smallest of these with just under 400,000 inhabitants.

[10]See Chapter 3.5 for explanation of MINITEL system.

[11]This information was obtained from published TGV-Atlantique schedules for September 30, 1990, to June 1, 1991 (SNCF).

[12]Using an exchange rate of FF5 = US $1.00.

[13]The CIGGT reported these costs in 1984 dollars. That figure is included in these tables as well as an updated figure representing that amount brought forward to 1988 dollars.

[14]*La Vie du Rail*, No. 2228, p. 18.

[15]In 1989, the French government spent FF 8 billion more for roads than for rail; in 1990, spending on roads was FF 20 billion in 1990 compared to 16.6 billion for rail; the 1991 budget allocates FF 21 billion to each.

APPENDIX A
TGV ATLANTIQUE TRAIN COUNTS FROM PARIS

Number of Daily Scheduled TGV-A Trains from Paris-Montparnasse:
(excludes special and holiday services)

Monday	47
Tuesday	46
Wednesday	46
Thursday	46
Friday	54
Saturday	38
Sunday	39

Number of Scheduled TGV-A Trains per Week to the Following Cities:

AGEN	6
ANGERS	53
ANGOULEME	73
BAYONNE	28
BIARRITZ	21
BORDEAUX	112
BREST	35
CHATELLERAULT	28
DAX	36
GUINGAMP	20
HENDAYE	28
IRUN	14
LA BAULE	21
LAMBALLE	7
LANDERNAU	7
LAVAL	14
LE CROISIC	21
LE MANS	49
LE POULIGUEN	1
LIBOURNE	28
LOURDES	14
MONTAUBAN	6
MORLAIX	20
NANTES	70
PAU	14
OUARET-TREGOR	7
POITIERS	87
PORNICHET	1
RENNES	68
SABLE	7
ST JEAN DE LUZ	21
ST PIERRE D CPS	82
ST. BRIEUC	35
ST. NAZAIRE	32
TARBES	14
TOULOUSE	6
TOURS	26
VENDOME	20
VITRE	7
TOTAL>>>>>>>>>	316

APPENDIX B: One-Way Fares from Paris-Montparnasse (TGV-A)

US Dollars 1990 (US $1 = FF 6)	First Class					Second Class				
		With Supplement					With Supplement			
PARIS TO:	(Base)	1	2	3	4	(Base)	1	2	3	4
LE MANS	($30)	$36	$47	$47	$49	($25)	$25	$30	$33	$30
SABLE	($36)	$42	$53	$53	$56	($29)	$29	$34	$37	$34
ANGERS	($41)	$47	$58	$58	$60	($32)	$32	$38	$40	$38
NANTES	($48)	$55	$65	$65	$68	($37)	$37	$43	$45	$43
ST. NAZAIRE	($55)	$61	$72	$72	$74	($41)	$41	$47	$49	$47
PORNICHET	($55)	$62	$72	$72	$75	($42)	$42	$47	$50	$47
LA BAULE	($55)	$62	$72	$72	$75	($42)	$42	$47	$50	$47
LE POULIGUEN	($56)	$63	$73	$73	$76	($43)	$43	$48	$51	$48
LE CROISIC	($56)	$63	$73	$73	$76	($43)	$43	$48	$51	$48
LAVAL	($41)	$47	$58	$58	$60	($32)	$32	$38	$40	$38
VITRE	($43)	$50	$60	$60	$63	($34)	$34	$39	$42	$39
RENNES	($47)	$53	$64	$64	$66	($36)	$36	$42	$44	$42
LAMBALLE	($54)	$60	$71	$71	$73	($41)	$41	$46	$49	$46
ST. BRIEUC	($55)	$62	$72	$72	$75	($42)	$42	$47	$50	$47
GUINGAMP	($58)	$64	$75	$75	$78	($44)	$44	$49	$52	$49
PLOUARET-TREGOR	($61)	$67	$78	$78	$80	($45)	$45	$51	$53	$51
MORLAIX	($63)	$70	$80	$80	$83	($47)	$47	$53	$55	$53
LANDERNAU	($67)	$73	$84	$84	$86	($50)	$50	$55	$58	$55
BREST	($69)	$75	$86	$86	$88	($51)	$51	$56	$59	$56
VENDOME	($25)	$31	$42	$42	$45	($22)	$22	$27	$30	$27
ST PIERRE D CPS	($32)	$38	$49	$49	$52	($26)	$26	$32	$34	$32
TOURS	($32)	$38	$49	$49	$52	($26)	$26	$32	$34	$32
CHATELLERAULT	($41)	$47	$58	$58	$60	($32)	$32	$38	$40	$38
POITIERS	($43)	$50	$60	$60	$63	($34)	$34	$39	$42	$39
ANGOULEME	($53)	$59	$70	$70	$72	($40)	$40	$46	$48	$46
LIBOURNE	($62)	$68	$79	$79	$81	($46)	$46	$51	$54	$51
BORDEAUX	($65)	$71	$82	$82	$85	($48)	$48	$54	$56	$54
AGEN	($77)	$83	$94	$94	$96	($56)	$56	$61	$64	$61
MONTAUBAN	($83)	$89	$100	$100	$103	($60)	$60	$66	$68	$66
TOULOUSE	($87)	$94	$104	$104	$107	($60)	$60	$65	$68	$65
DAX	($78)	$84	$95	$95	$97	($57)	$57	$62	$65	$62
BAYONNE	($83)	$89	$100	$100	$103	($60)	$60	$66	$68	$66
BIARRITZ	($84)	$90	$101	$101	$103	($61)	$61	$66	$69	$66
ST JEAN DE LUZ	($85)	$91	$102	$102	$104	($62)	$62	$67	$70	$67
HENDAYE	($86)	$92	$103	$103	$105	($62)	$62	$67	$70	$67
IRUN	($86)	$92	$103	$103	$105	($62)	$62	$67	$70	$67
PAU	($86)	$92	$103	$103	$105	($62)	$62	$67	$70	$67
LOURDES	($89)	$96	$106	$106	$109	($65)	$65	$70	$73	$70
TARBES	($91)	$97	$108	$108	$111	($66)	$66	$71	$74	$71

APPENDIX B: One-Way Fares from Paris-Montparnasse (TGV-A)

French Francs 1990:

	First Class					Second Class				
		With Supplement					With Supplement			
PARIS TO:	(Base)	1	2	3	4	(Base)	1	2	3	4
LE MANS	(177)	215	279	279	295	(148)	148	180	196	180
SABLE	(215)	253	317	317	333	(173)	173	205	221	205
ANGERS	(244)	282	346	346	362	(193)	193	225	241	225
NANTES	(290)	328	392	392	408	(224)	224	256	272	256
ST. NAZAIRE	(327)	365	429	429	445	(248)	248	280	296	280
PORNICHET	(332)	370	434	434	450	(252)	252	284	300	284
LA BAULE	(332)	370	434	434	450	(252)	252	284	300	284
LE POULIGUEN	(337)	375	439	439	455	(255)	255	287	303	287
LE CROISIC	(337)	375	439	439	455	(255)	255	287	303	287
LAVAL	(244)	282	346	346	362	(193)	193	225	241	225
VITRE	(259)	297	361	361	377	(203)	203	235	251	235
RENNES	(280)	318	382	382	398	(217)	217	249	265	249
LAMBALLE	(322)	360	424	424	440	(245)	245	277	293	277
ST. BRIEUC	(332)	370	434	434	450	(252)	252	284	300	284
GUINGAMP	(348)	386	450	450	466	(262)	262	294	310	294
PLOUARET-TREGOR	(363)	401	465	465	481	(272)	272	304	320	304
MORLAIX	(379)	417	481	481	497	(283)	283	315	331	315
LANDERNAU	(400)	438	502	502	518	(297)	297	329	345	329
BREST	(411)	449	513	513	529	(304)	304	336	352	336
VENDOME	(149)	187	251	251	267	(129)	129	161	177	161
ST PIERRE D CPS	(192)	230	294	294	310	(158)	158	190	206	190
TOURS	(192)	230	294	294	310	(158)	158	190	206	190
CHATELLERAULT	(244)	282	346	346	362	(193)	193	225	241	225
POITIERS	(259)	297	361	361	377	(203)	203	235	251	235
ANGOULEME	(316)	354	418	418	434	(241)	241	273	289	273
LIBOURNE	(369)	407	471	471	487	(276)	276	308	324	308
BORDEAUX	(389)	427	491	491	507	(290)	290	322	338	322
AGEN	(459)	497	561	561	577	(336)	336	368	384	368
MONTAUBAN	(497)	535	599	599	615	(361)	361	393	409	393
TOULOUSE	(524)	562	626	626	642	(359)	359	391	407	391
DAX	(465)	503	567	567	583	(340)	340	372	388	372
BAYONNE	(497)	535	599	599	615	(361)	361	393	409	393
BIARRITZ	(502)	540	604	604	620	(365)	365	397	413	397
ST JEAN DE LUZ	(508)	546	610	610	626	(369)	369	401	417	401
HENDAYE	(513)	551	615	615	631	(372)	372	404	420	404
IRUN	(513)	551	615	615	631	(372)	372	404	420	404
PAU	(513)	551	615	615	631	(372)	372	404	420	404
LOURDES	(535)	573	637	637	653	(387)	387	419	435	419
TARBES	(545)	583	647	647	663	(394)	394	426	442	426

Source: SNCF

APPENDIX C

Summary of TGV-Atlantique Characterisitics

Length of Dedicated Track Section	279.4 km (173.6 mi)
Maximum Speed	300 km/h (186 mph)
Maximum Grade	2.5%
Minimum Curve Radius	4,000 m (13,124 ft)
Minimum Crest Radius	16,000 m (52,490 ft)
Minimum Trough Radius	14,000 m (45,930 ft)
Track Center Separation	4.2 m (13.8 ft)
Trainset Consist	1-10-1
Seating Capacity	116 First Class 369 Second Class
Trainset Length	237.6 m (779.5 ft)
Trainset Width	2.9 m (9.5 ft)
Trainset Height	4 m (13.17 ft)
Total Motorized Axles	8
Stopping Distance from Maximum Speed	3.54 km (2.2 mi)

AVERAGE SPEED FOR SELECTED TGV-ATLANTIQUE RUNS

These speeds were calculated using published TGV-A schedules to obtain sample running times to selected cities. The time in minutes between cities is recorded for a selected run, and the average speed between those cities is caculated based on the estimated distance in kilometers between those cities. These average speeds are, therefore, only estimates and not measured or recorded speeds. The total run from Paris to final destination is also analyzed.

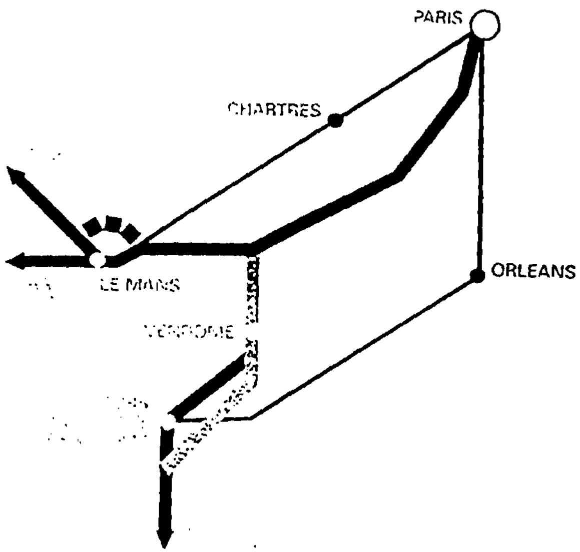
Paris to:	train #8205 time (min)	speed (km/hr)	speed (mi/hr)	train #8267 time (min)	speed (km/hr)	speed (mi/hr)	train #8377 time (min)	speed (km/hr)	speed (mi/hr)	train #8291 time (min)	speed (km/hr)	speed (mi/hr)	distance (km)	distance (mi)	cumul. distance (km)	cumul. distance (mi)
Vendome	42	228.6	142.0	42	228.6	142.0							160	99	160	99
St P des C	19	189.5	117.7	19	189.5	117.7	56	235.7	146.5	56	235.7	146.5	60	37	220	137
Tours	7	17.1	10.7	7	17.1	10.7				7	17.1	10.7	2	1	222	138
total run >>>	68	195.9	121.7	68	195.9	121.7	56	235.7	146.5	63	211.4	131.4	222	138		

Paris to:	train #8405 time (min)	speed (km/hr)	speed (mi/hr)	train #8407 time (min)	speed (km/hr)	speed (mi/hr)	train #8549 time (min)	speed (km/hr)	speed (mi/hr)	train #8499 time (min)	speed (km/hr)	speed (mi/hr)	distance (km)	distance (mi)	cumul. distance (km)	cumul. distance (mi)
St P des C				56	235.7	146.5				56	235.7	146.5	220	137	220	137
Chatellerault				30	150.0	93.2							75	47	295	183
Poitiers	90	220.0	136.7	17	123.5	76.8				40	165.0	102.5	35	22	330	205
Angouleme	47	140.4	87.3	48	137.5	85.4				46	143.5	89.2	110	68	440	273
Libourne				44	136.4	84.7							100	62	540	336
Bordeaux	57	147.4	91.6	19	126.3	78.5	178	195.5	121.5	58	144.8	90.0	40	25	580	360
Agen							65	128.3	79.7				139	86	719	447
Montauban							38	115.3	71.6				73	45	792	492
Toulouse							29	105.5	65.6				51	32	843	524
total run >>>	194	179.4	111.5	214	162.6	101.1	310	163.2	101.4	200	174.0	108.1	843	524		

Paris to:	train #8801 time (min)	speed (km/hr)	speed (mi/hr)	train #8901 time (min)	speed (km/hr)	speed (mi/hr)	train #8909 time (min)	speed (km/hr)	speed (mi/hr)				distance (km)	distance (mi)	cumul. distance (km)	cumul. distance (mi)
Le Mans	54	222.2	138.1										200	124	200	124
Angers							89	198.2	123.2				94	58	294	183
Nantes				119	193.1	120.0	37	144.3	89.7				89	55	383	238
total run >>>	54	222.2	138.1	119	193.1	120.0	126	182.4	113.3				383	238		

Paris to:							train #8737 time (min)	speed (km/hr)	speed (mi/hr)	train # 8721 time (min)	speed (km/hr)	speed (mi/hr)	distance (km)	distance (mi)	cumul. distance (km)	cumul. distance (mi)
Le Mans							54	222.2	138.1				200	124	200	124
Rennes							76	118.4	73.6	124	169.4	105.2	150	93	350	217
St Brieuc										46	127.8	79.4	98	61	448	278
Brest										82	109.8	68.2	150	93	598	372
total run >>>							130	161.5	100.4	252	142.4	88.5	598	372		

ligne
à grande vitesse
TGV atlantique
Paris-le Mans



	aménagée PARIS-BAGNEUX	ligne nouvelle jusqu'à COURTALAIN	au delà de COURTALAIN	traditionnelles parcourues par le TGV	totale avec ligne nouvelle	Longueur ancienne
PARIS - LE MANS	8,4	124,0	51,2	20	201,6	211
PARIS - RENNES (sans le contournement du MANS)	8,4	124,0	51,2	183	364,6	374
(avec le contournement du MANS)	8,4	124,0	77,3	150,3	358	
PARIS - TOURS	8,4	124,0	86,9	6	223,3	235
PARIS - BORDEAUX	8,4	124,0	101,1	334,2	585,7	581

Longueur de ligne nouvelle, à double voie : 279,5 km ; à voie unique : 3,80 km (sans le contournement du MANS de longueur 28,10 km).

DESCRIPTIF GÉNÉRAL

- Ligne double voie banalisée prévue pour une vitesse de 300 km/h.
- Rail UIC 60 kg - traverses béton - 1667 au km posées sur ballast.
- Electrification en 25 kV alternatif sauf le contournement de TOURS électrifié en 1500 V continu (sur 15 km environ).
- Installations de sécurité - Signalisation type "cab signal" ; informations en cabine sans signaux le long de la voie.
- Gares intermédiaires : MASSY (91) à l'étude,
  VENDOME (41)

CARACTÉRISTIQUES GÉOMÉTRIQUES

Tracé en plan : rayon minimal normal 4200 m.
Profil en long : rampe maximale 25 mm/m,
rayons de raccordement 14 000 m en creux,
18 000 m en sommet

TERRASSEMENTS

Volume des
- Déblais 23 300 000 m³
- Remblais (ferroviaires + routiers) 15 500 000 m³
- Dépôts 12 900 000 m³

OUVRAGES D'ART

LONGUEURS DE :	Tronc commun	Branche Ouest	Branche Sud Ouest	TOTAL
Tunnel double voie	1300 m		1500 m	2800 m
voie unique	9600 m			9600 m
Tranchées couvertes	8170 m		200 m	8370 m*

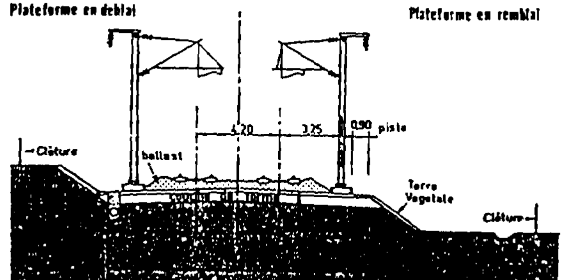
* (y compris couverture coulée verte)

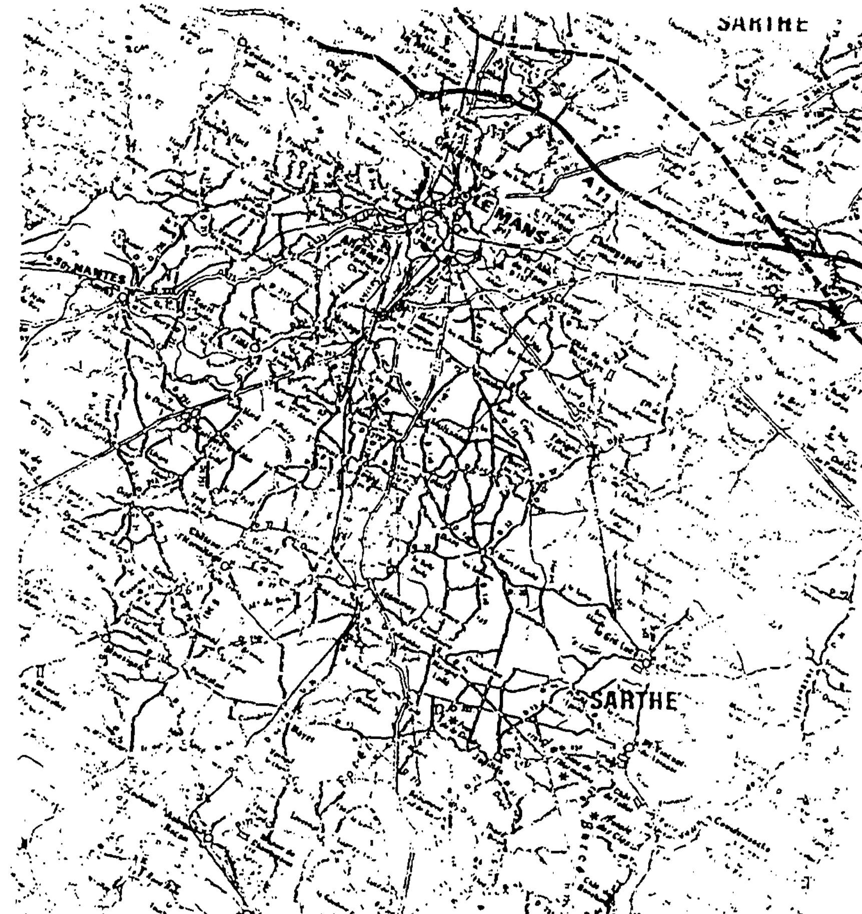
NOMBRE D'OUVRAGES

		Tronc commun	Branche Ouest	Branche Sud Ouest	TOTAL
Grands ouvrages	Autoroutes ou RN	2		2	4
	Viaducs	2		2	4
	Grands cours d'eau	1		4	5
	Voies ferrées	3	2	2	7
Ouvrages courants					
Ponts routiers	RN et CD	48	9	27	82 } 164
	Voiries communales	32	13	37	82
Ponts rails	Hydrauliques	5	14	20	39
	Autres ponts	33	21	28	82
	Voies ferrées	1		4	5
Buses		119	52	78	249

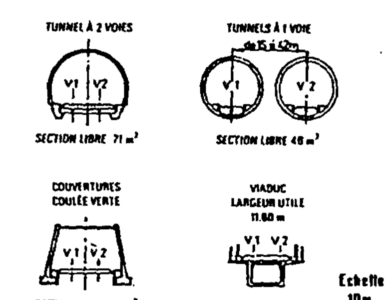
COUPE TRANSVERSALE COURANTE

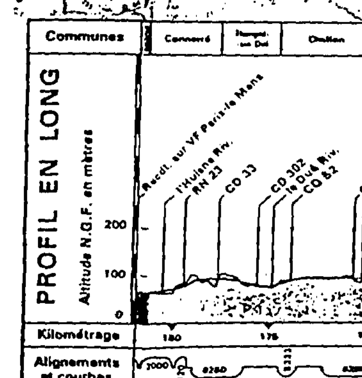
Plateforme en déblai — Plateforme en remblai

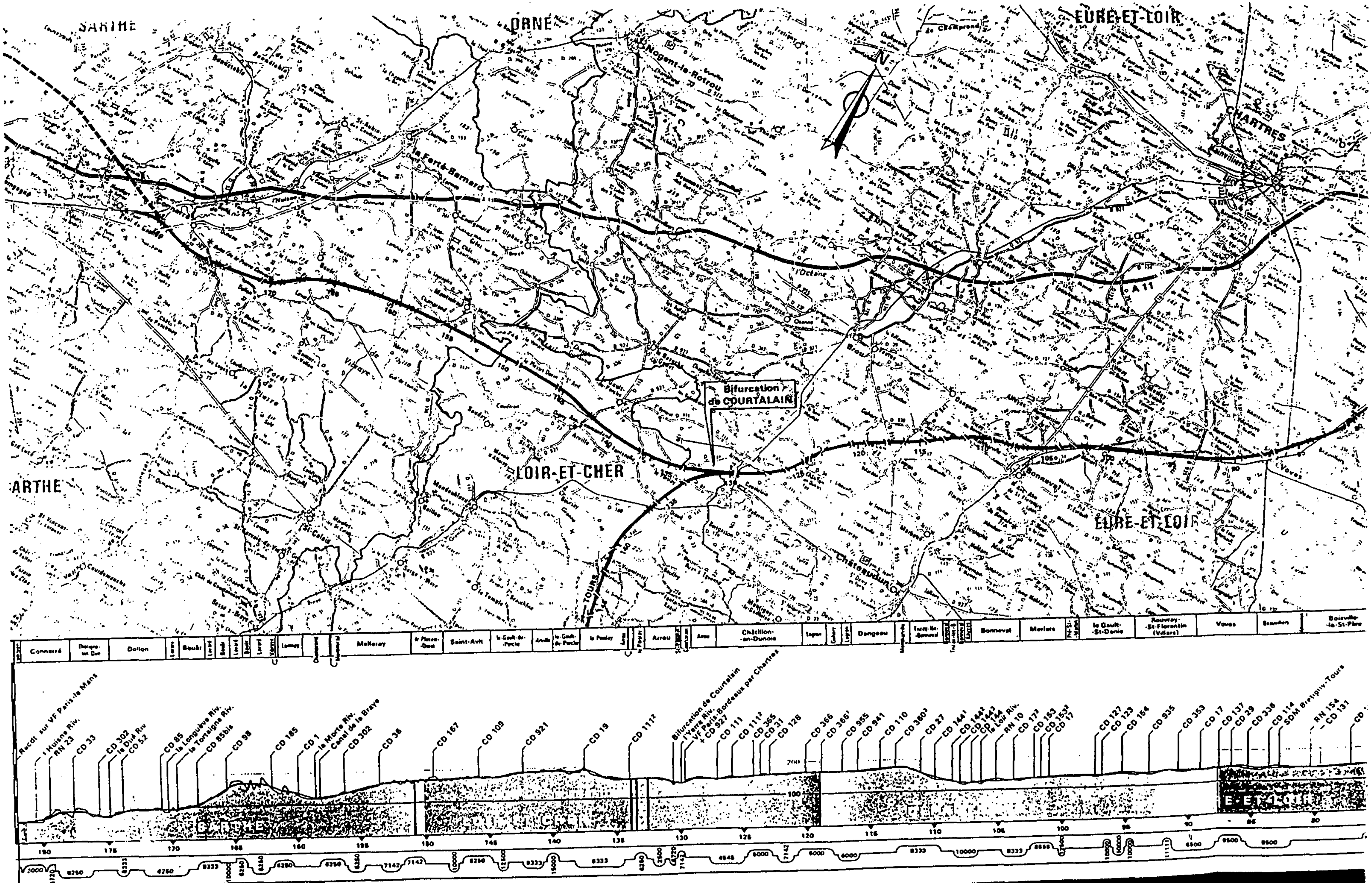




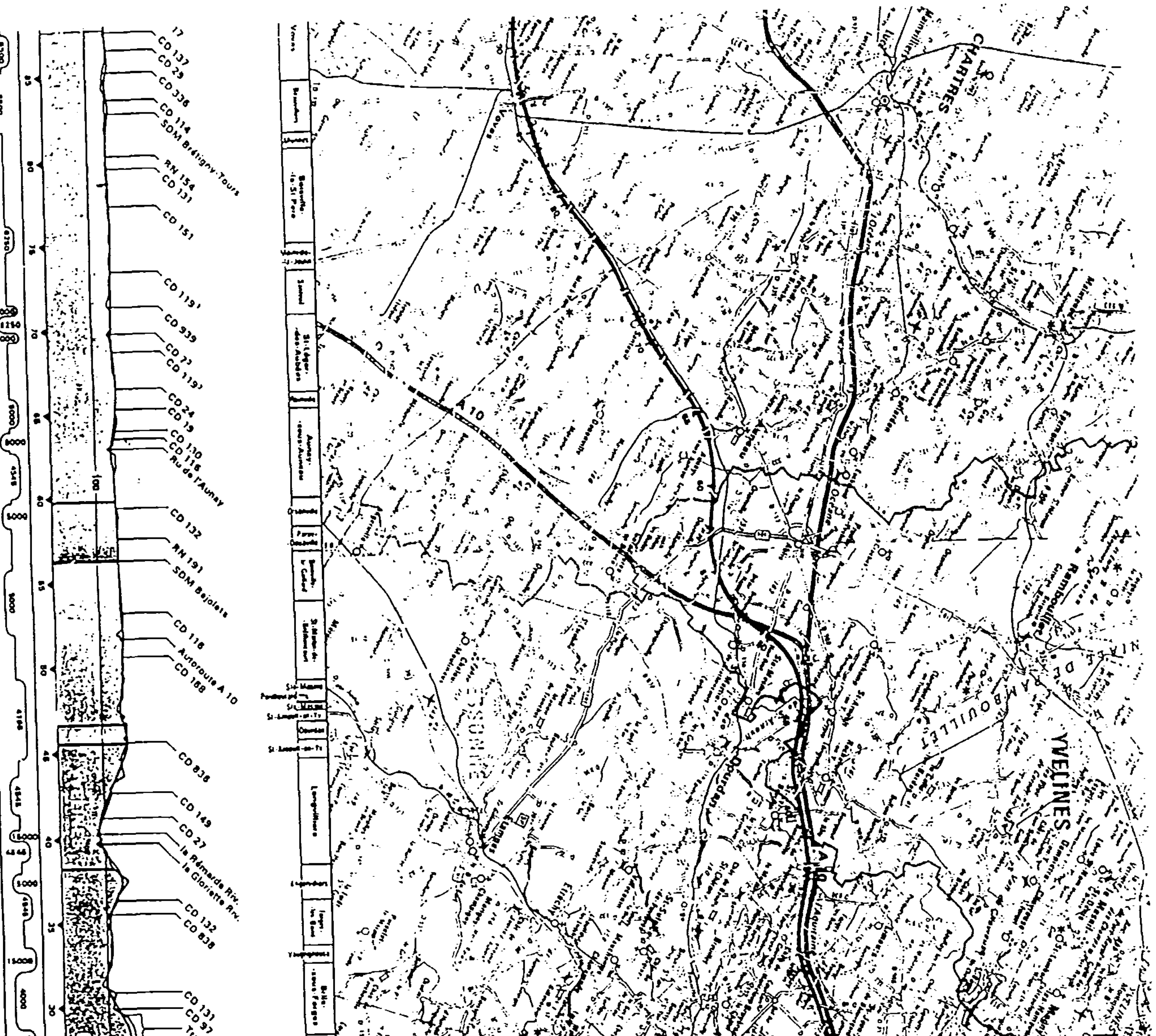
COUPES TYPES







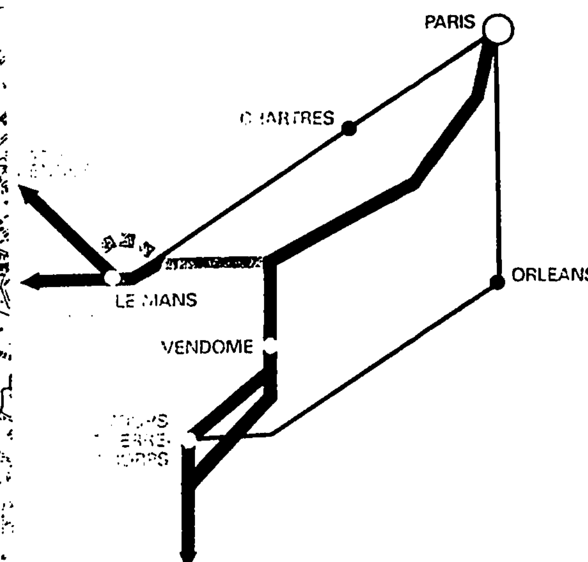
SARTHE
ORNE
EURE-ET-LOIR
Nogent-le-Rotrou
CHARTRES
La Ferté-Bernard
A 11
l'Ozanne
Bifurcation de COURTALAIR
LOIR-ET-CHER
ARTHE
TOURS
Bonneval
Châteaudun
EURE-ET-LOIR
Voves
Connerré
Dollon
Melleray
Saint-Avit
le Poislay
Arrou
Châtillon-en-Dunois
Logron
Dangeau
Bonneval
Moriers
le Gault-St-Denis
Rouvray-St-Florentin (Villars)
Voves
Boisville-la-St-Père
Racct sur VF Paris-le Mans
l Huisne Riv.
RN 23
CD 33
CD 302
la Dué Riv
CD 52
CD 85
la Longuève Riv.
la Tortaigne Riv.
CD 85bis
CD 98
CD 185
CD 1
la Morte Riv.
Canal de la Braye
CD 302
CD 38
CD 167
CD 109
CD 921
CD 19
CD 111
Bifurcation de Courtalain
l'Yerre Riv.
VF Paris-Bordeaux par Chartres
CD 927
CD 111
CD 365
CD 31
CD 128
CD 366
CD 955
CD 941
CD 110
CD 27
RN 10
le Loir Riv.
CD 17
CD 153
CD 127
CD 123
CD 154
CD 935
CD 353
CD 17
CD 137
CD 29
CD 336
CD 114
SDM Brétigny-Tours
RN 154
CD 131

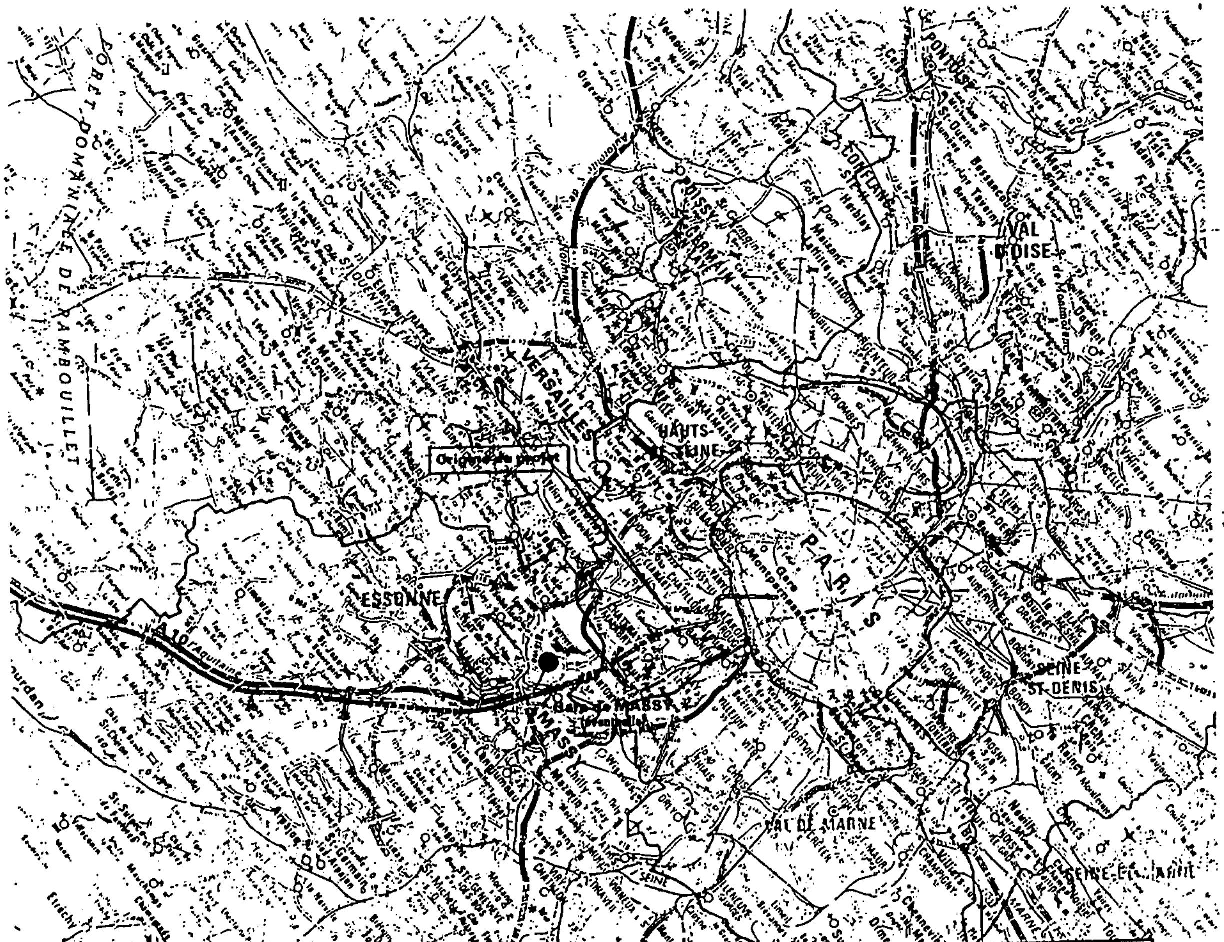

PROFIL EN LONG
Altitude N.G.F. en mètres
Allignements et courbes
Kilométrage
Communes
PARIS-MONTPARNASSE
Tunnel de Fontenay
RER
Tunnel de Sceaux
RN 186
Autoroute A 86
Gare de Massy
A 87
Tr. couv. de Villebon
Tunnel de Villejust
Autoroute F 6
CD 24
Tranchée couverte de Bris-s-Forges
CD 97
CD 131
CD 838
CD 132
la Gloriette Riv.
la Rémarde Riv.
CD 27
CD 149
CD 836
CD 188
Autoroute A 10
CD 116
SDM Bajolets
RN 191
CD 132
Ru de l'Aunay
CD 116
CD 130
CD 19
CD 24
CD 119
CD 73
CD 939
CD 119
CD 151
CD 131
RN 154
SDM Brétigny-Tours
CD 114
CD 336
CD 29
CD 137
17
CHARTRES
A 10
ESSONNE
YVELINES
Rambouillet
CORBEIL-ESSONNES
MELUN
VAL-DE-MARNE

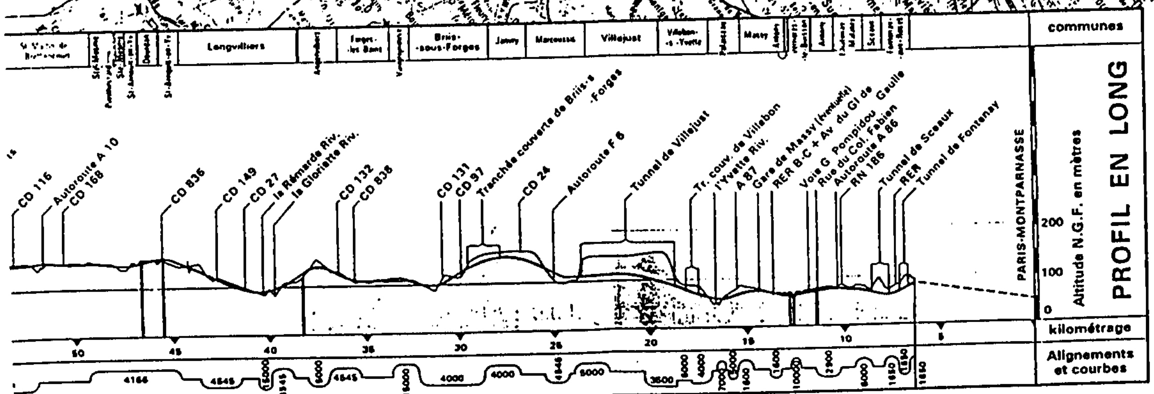
ligne
à grande vitesse

TGV atlantique

Paris-Tours

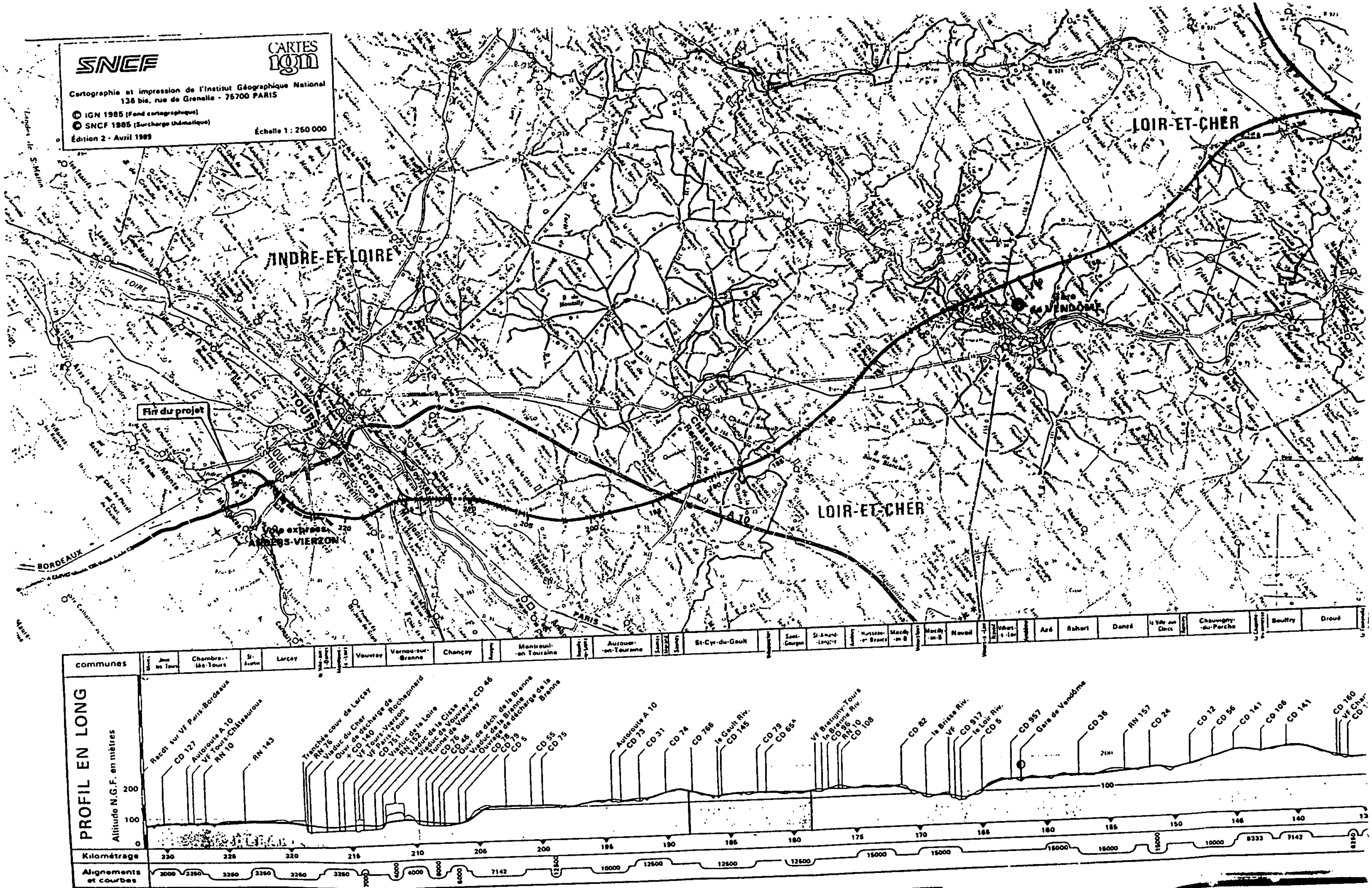






Echelle 1:250 000

Bifurcation de COURTALAIN
CHER
CHARTRES
YVELINES
EURE-ET-LOIR
ESSONNE
Châteaudun
Dourdan
A 10
A 11
Bonneval
Moriers
Voves
Dangeau
Châtillon-en-Dunois
Aunay-sous-Auneau
St-Léger-des-Aubées
Boisville-la-St-Père
Le Gault-St-Denis
Beauvilliers
Droué
Boursay
La Fontenelle
Arrou
Logron
Theuville
Auneau
Ste-Mesme
Longvilliers
Brétigny-Tours
CD 836
CD 168
Autoroute A 10
CD 116
SDM Bajolais
RN 191
CD 132
Ru de l'Aunay
CD 130
CD 116
CD 19
CD 24
CD 119
CD 73
CD 939
CD 119
CD 151
CD 131
RN 154
SDM Brétigny-Tours
CD 114
CD 336
CD 29
CD 137
CD 17
CD 353
CD 935
CD 154
CD 123
CD 127
CD 17
CD 153
CD 153
CD 172
RN 10
le Loir Riv.
CD 144
CD 144
CD 144
CD 27
CD 360
CD 110
CD 941
CD 955
CD 366
CD 366
CD 128
CD 31
CD 365
CD 111
CD 111
+ CD 927
VF Paris-Bordeaux par Chartres
l'Yerre Riv.
Bifurcation de Courtalain
CD 87
CD 13
VF Chartres-Bordeaux
CD 160
CD 141
CD 106
CD 141
CD 56
100


SNCF
CARTES IGN
Cartographie et impression de l'Institut Géographique National
136 bis, rue de Grenelle - 75700 PARIS
© IGN 1985 (Fond cartographique)
© SNCF 1985 (Surcharge thématique)
Édition 2 - Avril 1989
Échelle 1 : 250 000
INDRE-ET-LOIRE
LOIR-ET-CHER
LOIR-ET-CHER
Fin du projet
TOURS
LOIRE
Gare de VENDÔME
Vendôme
Château-Renault
A 10
BORDEAUX
PARIS
Voie express ANGERS-VIERZON
communes
Chambray-lès-Tours
Larçay
Vouvray
Vernou-sur-Brenne
Chançay
Monthreuil-en-Touraine
Auzouer-en-Touraine
St-Cyr-du-Gault
Naveil
Azé
Rahart
Danzé
Chauvigny-du-Perche
Boufflry
Droué
PROFIL EN LONG
Altitude N.G.F. en mètres
Kilométrage
Alignements et courbes

PARIS ▶ BORDEAUX ▶ TOULOUSE

RESA 300

Pour connaître le prix correspondant à la couleur de votre RESA 300, consultez le tableau "Prix des Relations" p. 70 et 71.

TGV ne circulant pas ce jour-là.

Possibilités de correspondances: à Angoulême pour Saintes et Royan, à Libourne pour Bergerac, à Bordeaux pour Arcachon et Mont-de-Marsan. Renseignez-vous avant votre départ.

			8401	8405	8507	8407	8409	8515	8419	8423	8527	8433	8535	8441	8543	8549	8453	8557	8559	8565	8469	8471	8477	8481	8489	8499
	N° du TGV		8401	8405	8507	8407	8409	8515	8419	8423	8527	8433	8535	8441	8543	8549	8453	8557	8559	8565	8469	8471	8477	8481	8489	8499
	Restauration		▢	▢	▢			▢	▢	▢	▢					▢		▢	▢	▢	▢	▢	▢	▢		
	Particularité				(1) ✱	✱	✱	✱	✱	✱	✱	✱	✱	✱	✱	✱		✱	✱	✱	✱		✱	✱		
HORAIRES	Paris-Montparnasse 1	D	6.50	7.10	7.55	8.15	8.30	10.00	10.45	11.55	12.45	13.55	14.00	15.25	15.55	17.00	17.15	17.40	17.45	18.30	18.50	18.50	19.30	20.00	21.30	23.55
	Saint-Pierre-des-Corps	A			8.51	9.11			11.41			14.51		16.21			18.11				19.46					0.51
	Châtellerault	A				9.41						15.21					18.41				20.16					
	Poitiers	A		8.40		9.58	9.58		12.22	13.23	14.13	15.38		17.02			18.58				20.33	20.18		21.28	22.58	1.31
	Angoulême	A		9.27		10.46	10.46		13.08	14.10	15.00	16.25		17.48			19.49	19.52			21.19	21.04		22.15	23.45	2.17
	Libourne	A				11.27	11.27		13.48					18.28							22.01	21.45				
	Bordeaux	A	9.48	10.24	11.08	11.46	11.46	12.58	14.08	15.07	15.57	17.22	16.58	18.48	18.53	19.58		20.48	20.45	21.28	22.22	22.06	22.28	23.12	0.42	3.13
	Agen	A		c		c	c		c				c			21.03		c	c		c	c	c			
	Montauban	A				c	c		c				c			21.41					c	c	c			
	Toulouse	A		c		c	c		c				c			22.10					c	c	c			
SEMAINE TYPE	**Lundi**		1		1		1	1	1	1		1	1	1	1		1			1				1		
	Mardi au Jeudi		1		1		1	1	1	1		1	1	1	1		1							1		
	Vendredi		1		1		1	1	1	1	1		1										1	1	1	
	Samedi			1	1	1		1	1		1	1	1	1	1		1	1			1			1		
	Dimanche					1		1	1	1		1	1	1	1										1	1
JOURS PARTICULIERS	**OCTOBRE**	Mercredi 31	1		1		1	1	1	1	1		1										1	1	1	
	NOVEMBRE	Jeudi 1er		1	1	1		1	1		1	1	1	1	1									1		
		Vendredi 2			1	1		1	1		1	1	1											1	1	
	DÉCEMBRE	Dimanche 23			1	1		1	1	1	1	1	1	1	1									1		
		Lundi 24				1		1	1	1		1	1	1	1									1		
		Mardi 25				1		1	1	1		1	1	1	1										1	1
		Mercredi 26	1		1		1	1	1	1		1	1	1	1		1			1				1		
		Dimanche 30				1		1	1	1		1	1	1	1									1		
		Lundi 31				1		1	1	1		1	1	1	1									1		
	JANVIER	Mardi 1er				1		1	1	1		1	1	1	1										1	1
		Mercredi 2	1		1		1	1	1	1		1	1	1	1		1			1				1		
	MARS	Dimanche 31				1		1	1	1		1	1	1	1									1		
	AVRIL	Lundi 1er				1		1	1	1		1	1	1	1										1	1
		Mardi 2	1		1		1	1	1	1		1	1	1	1		1			1				1		
	MAI	Mercredi 1er				1		1	1	1		1	1	1	1									1		
		Mardi 7	1		1		1	1	1	1	1		1											1	1	
		Mercredi 8		1	1	1		1	1		1	1	1	1	1		1	1			1			1		
		Jeudi 9				1		1	1	1		1	1	1	1									1		
		Vendredi 10	1		1		1	1	1	1		1	1	1	1									1		
		Dimanche 19				1		1	1	1		1	1	1	1		1	1			1			1		
		Lundi 20				1		1	1	1		1	1	1	1										1	1
		Mardi 21	1		1		1	1	1	1		1	1	1	1		1			1				1		

A Arrivée D Départ

c ... à F ard aux certains jours

(1) Le TGV 8507 circule aussi les dimanches: **30 septembre, 21 et 28 avril,** RESA 300 ...

▢ Service restauration à la place en 1re classe, en réservation: tous les jours de circulation.

✱ Espaces "Carré" réservables, en priorité, par les voyageurs "Kiwi" et les voyageurs accompagnés d'enfants.

PARIS ▶ RENNES ▶ BREST ⊳ QUIMPER

RESA 300

- (white) Pour connaître le prix correspondant à la
- (black) couleur de votre RESA 300, consultez
- (black) le tableau "Prix des Relations" p. 70 et 71.
- (grey)
- (white) **TGV** ne circulant pas ce jour-là.

Possibilités de correspondances au Mans pour Alençon et à Rennes pour Saint-Malo. Renseignez-vous avant votre départ.

	N° de TGV	8701	8603	8705	8609	8613	8813	8619	8721	8623	8625	8737	8639
	Restauration		[R]	[R]					[R]	[R]			
	Particularité					[K]	[K]	[K]	[K]	[K]	[K]	[K]	[K]
HORAIRES	Paris-Montparnasse 1 D	0.01	7.05	7.20	8.20	9.20	9.50	10.10	11.20	12.20	13.00	14.20	15.20
	Le Mans A		7.59		9.14		10.44	11.04		13.14	13.54	15.14	
	Laval A	1.34	8.43		9.57			11.45		13.57			
	Vitré A												
	Rennes A	2.12	9.20	9.24	10.35	11.24		12.22	13.24	14.35	15.10	16.30	17.24
	Lamballe A				a				a		a	a	a
	Saint-Brieuc A	2.58		10.11	a				14.10	a	a	17.17	a
	Guingamp A			10.29	a				d		a	17.35	a
	Plouaret-Trégor A				a				d		a		a
	Morlaix A			10.59	a				d		a	18.05	a
	Landerneau A				a						a		
	Brest A	4.10		11.33	a				15.22		a	18.39	a
	Redon			a	a		v		a	a			a
	Vannes			a	a		v		a	a			a
	Auray			e	a		v		a	a			a
	Lorient			a	a		v		a	a			a
	Quimper			a	a		v		a	a			a
SEM. TYPE	Lundi	1				1	1		1	1		1	1
	Mardi au Jeudi				1	1	1		1	1		1	1
	Vendredi				1	1	1		1	1	1	1	
	Samedi			1	1	1	1	1	1	1		1	1
	Dimanche				1			1	1	1		1	1
JOURS PARTICULIERS	OCTOBRE Mercredi 31				1	1	1		1	1	1	1	
	NOVEMBRE Jeudi 1er			1	1	1		1	1	1		1	1
	Vendredi 2			1	1	1	1	1	1	1		1	
	DÉCEMBRE Dimanche 23				1			1	1	1		1	1
	Lundi 24				1		1	1	1	1		1	1
	Mardi 25				1			1	1	1		1	1
	Mercredi 26	1				1	1		1	1		1	1
	Dimanche 30				1			1	1	1		1	1
	Lundi 31				1		1	1	1	1		1	1
	JANVIER Mardi 1er				1			1	1	1		1	1
	Mercredi 2	1				1	1		1	1		1	1
	MARS Dimanche 31				1			1	1	1		1	1
	AVRIL Lundi 1er				1			1	1	1		1	1
	Mardi 2	1				1	1		1	1		1	1
	MAI Mercredi 1er				1			1	1	1		1	1
	Mardi 7				1	1	1		1	1	1	1	
	Mercredi 8			1	1	1		1	1	1		1	1
	Jeudi 9				1			1	1	1		1	1
	Vendredi 10				1	1	1		1	1		1	1
	Dimanche 19				1			1	1	1		1	1
	Lundi 20				1			1	1	1		1	1
	Mardi 21	1				1	1		1	1		1	1

	N° de TGV	8647	8649	8753	8655	8757	8761	8663	8671	8771	8775	8777	8681	8679	8683	8689
	Restauration					[R]	[R]		[R]	[R]	[R]					
	Particularité	[K]		[K]			[K]	[K]		[K]	[K]	[K]	[K]	[K]		
HORAIRES	Paris-Montparnasse 1 D	16.20	16.55	17.05	17.20	17.40	18.10	18.20	18.55	19.10	19.20	19.25	19.55	19.55	20.20	21.40
	Le Mans A	17.14									20.14		20.49	20.49		22.34
	Laval A	17.58						19.54					21.32	21.32	21.54	
	Vitré A							20.13					21.51			
	Rennes A	18.35	18.59		19.24	19.44	20.12	20.34	20.59		21.30	21.29	22.13	22.09	22.31	23.50
	Lamballe A		a		a	20.21					22.07	22.07	a	a		
	Saint-Brieuc A		a	19.51	a	20.35	20.57			21.58	22.21	22.21	a	a		
	Guingamp A		a	d	a	20.53				d	22.39	22.39	a	a		
	Plouaret-Trégor A		a	d	a	21.08				d	22.54	22.54	a	a		
	Morlaix A		a	d	a	21.27				d	23.13	23.13	a	a		
	Landerneau A		a	d	a	21.51				d	23.37	23.37	a	a		
	Brest A		a	21.03	a	22.05	22.09			23.09	23.51	23.51	a	a		
	Redon						a		a		a		a	a		
	Vannes				a	a			a		a		a	a		
	Auray				a	a			a		a		a	a		
	Lorient					a			a		a		a	a		
	Quimper				a	a			a		a		a	a		
SEM. TYPE	Lundi						1	1			1				1	
	Mardi au Jeudi														1	
	Vendredi															1
	Samedi				1			1			1					
	Dimanche	1										1		1		1
JOURS PARTICULIERS	OCTOBRE Mercredi 31															1
	NOVEMBRE Jeudi 1er	1												1		
	Vendredi 2															1
	DÉCEMBRE Dimanche 23	1												1		
	Lundi 24										1					
	Mardi 25	1										1		1		1
	Mercredi 26						1	1			1				1	
	Dimanche 30	1												1		
	Lundi 31										1					
	JANVIER Mardi 1er	1										1		1		1
	Mercredi 2						1	1			1				1	
	MARS Dimanche 31										1					
	AVRIL Lundi 1er	1										1		1		1
	Mardi 2						1	1			1				1	
	MAI Mercredi 1er	1												1		
	Mardi 7															1
	Mercredi 8				1			1			1					
	Jeudi 9	1												1		
	Vendredi 10										1				1	
	Dimanche 19				1			1			1					
	Lundi 20											1		1		1
	Mardi 21						1	1			1	1			1	

A Arrivée D Départ

- a Correspondance à Rennes.
- b Correspondance à Laval.
- c Correspondance à Laval, certains jours.
- d Correspondance à Saint-Brieuc.
- e Correspondance à Vannes.
- v Relation assurée via Nantes. Correspondance à Nantes.

⊳ — — — Changement à Rennes pour Quimper.

[R] Service restauration à la place en 1re classe, en réservation : tous les jours de circulation, sauf pour les TGV 8705, 8623, 8771 et 8675 où ce service est assuré **certains jours**.

[K] Espaces "Carré" réservables, en priorité, par les voyageurs "Kiwi" et les voyageurs accompagnés d'enfants.

Appendix G

TGV-PSE FINANCIAL HISTORY

millions of French Francs (1989)

	1981	1982	1983	1984	1985	1986	1987	1988
Passenger Revenue	215	1168	1955	2980	3608	3699	4130	4396
Total Operating Costs	120	513	879	1039	1285	1363	1630	1757
Rolling Stock Interest & Depreciation	119	177	288	395	446	478	497	516
New Line Interest and Depreciation	120	720	842	1145	950	856	632	636
Net Surplus	−144	−242	−54	401	927	1002	1371	1487

millions of US Dollars (FF 6 = US$ 1)

	1981	1982	1983	1984	1985	1986	1987	1988
Passenger Revenue	35.8	194.7	325.8	496.7	601.3	616.5	688.3	732.7
Total Operating Costs	20.0	85.5	146.5	173.2	214.2	227.2	271.7	292.8
Rolling Stock Interest & Depreciation	19.8	29.5	48.0	65.8	74.3	79.7	82.8	86.0
New Line Interest and Depreciation	20.0	120.0	140.3	190.8	158.3	142.7	105.3	106.0
Net Surplus	−24.0	−40.3	−9.0	66.8	154.5	167.0	228.5	247.8

SOURCE: Daniel L. Roth, 1990

BIBLIOGRAPHY

Allen, G. Freeman. 1988. "TGV-Atlantique: France's second high-speed service." *Railway Technology International.*

Barberon, Michel. 1986. "TGV-Atlantique: la plate-forme se destine." *La vie du rail* 2025 (2 January).

____. 1988. "La face nord du TGV." *La vie du rail* 2171 (1 December).

____. 1990. "Massy, naissance d'une gare TGV." *La vie du rail* 2263 (4 October).

Berlioz, Claude. 1985. "An example of response to demand for an improved service offer: the Paris–South-East TGV (high-speed train)." *Transport Policy and Decision Making* 3:3.

Bilan commercial et economique du T.G.V. Sud-Est. 1985. *DTT* 71 (August).

Boiteux, Michel. 1987. "Les equipements de freinage des futures rames TGV-Atlantique." *Revue générale des chemins de fer* 65 F (September).

Bonnafous, A. 1987. "The regional impact of the TGV." *Transportation* 14:2.

Brand, Nicholas M. 1989. "Operating and maintenance costs of the TGV high-speed rail system." *Journal of Transportation Engineering* 115:1, January.

Bromberger, Laurent. 1990. "Sur les traces d'une ligne controversee." *La vie du rail* 2257 (23 August).

____. 1990. "Schema directeur des TGV: le territoire a grande vitesse." *La vie du rail* 2242 (26 April).

Canadian Institute of Guided Ground Transport. 1986. "Super-Speed Ground Transportation System, Las Vegas/Southern California Corridor, Phase II– Maglev Technology Assessment." Task 9.2: Review, Validation and Revision of the Capital and Operating Costs for a TRANSRAPID TR-06 Maglev System and for a TGV System in the Las Vegas-Southern California Corridor. July 28.

____. 1986. "Super-Speed Ground Transportation System, Las Vegas/Southern California Corridor, Phase II– Maglev Technology Assessment." Task 9.3: Analysis of the Current and Potential Performance of the TGV Technology. February 26.

Chambron, Etienne. 1986. "La conduite du projet TGV-Atlantique et les travaux de genie civil." *Revue générale des chemins de fer* 61 F (December).

____. 1986. "TGV Atlantique Takes Shape." *International Railway Journal* (April), 36-39.

Chambron, E. 1987. "New lines: TGV Atlantic and the environment." *Rail International* 18:10 (October).

Charlier, Jacques. 1985. "L'evolution recente des relations ferroviaires Paris-Nantes dans la perspective du TGV Atlantique." *Transports: economie, realisations, equipement* 306 (July/August).

Delacroix, Paul. 1986. "TGV, la deuxieme generation." *La vie du rail* 2062 (2 October).

Douté, Denis. 1991. Railway Systems International. Personal interviews.

"French investment in TGV pays dividends." 1984. *International Railway Journal and Rapid Transit Review*: *IRJ* 24:6 (June).

Fayard, Alain. 1985. "Grande vitesse sous la Manche." *Transports* 310 (December).

Federal Railroad Administration (FRA). 1991. "Safety Relevant Observations on the TGV High Speed Train." US Department of Transportation, Washington, D.C. July.

Fontgalland, Bernard de. 1985. "Reflections on the future of the T.G.V. system: transport between towns." *Rail International* 16:11 (November).

Fourniau, J. M. 1988. "La genese des grandes vitesses a la SCNF: de l'innovation a la decision du TGV Sud-Est." J.M. Fourniau. Arcueil: Institut national de recherche sur les transports et leur securite.

Fradin, Jean-Raymond. 1986. "Quelle clientele pour les gares TGV de banlieue?," une methode de'evaluation." *Transport, environnement, circulation* 77 (July/August).

Frybourg, Alain. 1985. "The public authorities and high-speed trains in France." *Transport Policy and Decision Making* 3:3.

Geais, Robert. 1990. "Contribution a l'histoire du TGV francais." *Revue générale des chemins de fer* 3 (March).

Gerardin, Bernard. 1985. "Les TGV de l'avenir." *Transports* 310 (December).

Halaunbrenner, Gerard. 1986. "Demarche marketing et TGV-Atlantique." *Revue générale des chemins de fer* 61 F (December).

Herisse, Philippe. 1987. "TGV Nord, le feu vert." *La vie du rail* 2115 (22 October).

____. 1986. "TGV, le synchrone aux essais." *La vie du rail* 2035 (13 March).

____. 1986. "Le TGV de la seconde generation: plus rapide, plus comfortable, plus econome." *La vie du rail* 2842 (8 March).

____. 1986. "Bischheim: des TGV comme neufs." *La vie du rail* 2067 (6 November).

____. 1988. "Atlantique, le TGV de deuxieme generation." *La vie du rail* 2143 (5 May).

____. 1985. "Pour le courrier de Lyon, le TGV fait diligence." *La vie du rail* 1976 (10 January).

Iarovay, Daniel. 1990. "Interconnexion des TGV en Ile-de-France: le reseau a grande vitesse prend corps." *Revue générale des chemins de fer* 5 (May).

Huber, André. 1991. Design Manager, Transport Systems, GEC Alsthom. Personal interview.

Iguchi, Masakazu. 1984. "Comparison between Japanese Shinkansen and French TGV: in hope for brace-up of Japanese railway engineers." *IATSS Research* 8.

International Railway Journal. 1991. July.

Jones, Joseph. 1981. "High-speed trains in France: Paris-Sud Est." Prepared by Joseph Jones (History Department, Queen's University). Kingston, Ont.: Canadian Institute of Guided Ground Transport.

Journet, Marcel. 1989. "Link round Paris forges TGV network: construction of a 270 kmh bypass through the eastern suburbs of Paris is due to start next year." *Railway Gazette International* 145:7.

"Le Reseau T.G.V. Note d'information de la direction des transports terrestres." 1988. No 99 (January/February).

Lacôte, Francois. 1990. "La nouvelle generation de material a grande vitesse de la SNCF: le material TGV Atlantique." *Revue générale des chemins de fer* 61 F (December).

Lacôte, F. 1985. "Optimisation des caracteristiques techniques du systeme TGV." Les Aspects socio économiques des trains a grande vitesse. Paris: Documentation française.

Lacôte, Francois, and Louis-Marie Cleon. 1990. "La deuxieme generation de TGV: la maitrise du confort a grande vitesse." *Revue générale des chemins de fer* 7/8 F (July/August).

Lancien, Jutard, and Caille Parent de Curzon. 1985. "Trains Running at High Speeds in Railway Tunnels, Field Measurement and Simulation." 5th International Symposium on Aerodynamics and Ventilation of Vehicle Tunnels. Lille, France (May).

Leboeuf, M. 1985. "L'evaluation économique et financière des projets de TGV." Les Aspects socio economiques des trains a grande vitesse. Paris: Documentation francaise.

Leboeuf, Michel. 1986. "Economic and financial appraisal of large-scale railway infrastructure projects: the example of the TGV Southeast project." *Rail International* 17:4 (Apr.).

Leboeuf, Michel, and Alain Palade. 1986. "Le TGV Atlantique Trafic et économie." *Revue générale des chemins de fer* 61 F, (December).

Leleux, F. P. 1985. "TGV high-speed train telephone system: signal and traffic control box." F. P. Leleux. Conference on Railway Engineering (1985: Brisbane, Qld.) Conference on Railway Engineering, 1985. Barton, A.C.T.: Institution of Engineers, Australia.

"Les Gares de L'Atlantique." 1989. *La vie du rail* 2210 (14 September).

Malone, Frank. 1985. "TGV wows U.S. visitors." *Railway Age* 186:11 (November).

Martin, M. 1985. "Les effets sur l'environnement de la ligue nouvelle TGV Paris-Sud-Est." M. Martin (Centre d'Etudes Techniques de l'Equipement de Lyon). Les Aspects socio economiques des trains a grande vitesse. Paris: Documentation francaise.

Masse, Jean-Paul, and Michel Barberon. 1990. "La grande querelle du TGV Belge." *La vie du rail* 2236 (15 March).

Masse, Jean-Paul. 1990. "Le pays ou le TGV s'appelle le VFT." *La vie du rail* 2261 (20 September).

____. 1988. "Quels TGV por le tunnel?." *La vie du rail* 2140 (14 April).

Mauroy, P. 1989. "TGV heads for Nord-Pas-de-Calais Region." *Rail International* 20:7.

Muller, Matthaus, M. Papinutti, and C. Reynaud. 1987. "Six ans de diffusion des effets du TGV Sud-Est." *Les Cahiers scientifiques du transport* 15-16.

Muller, Mireille. 1984. "TGV operations." (Ministry of Transport). Planning and Transport Research and Computation (International) Company. Meeting. Proceedings of Seminar K held at the PTRC summer annual meeting. 12th.

Perren, Brian. 1988. *TGV.* London: Ian Allan.

Peida, plc, Planning, Economic and Development Consultants. 1991. *Rail Link Project: A Comparative Appraisal of Socio-Economic and Development Impacts of Alternative Routes.* British Railways Board: Reading (England), May.

Pollier, Rene. 1990. "De nouvelles lignes TGV de complement apparaissent." *Transports* 343 (September/November).

Pronost, Jean-Pierre. 1986. "Track and structure maintenance for 170 M.P.H on the new Paris-Lyon TGV line." American Railway Engineering Association. Proceedings of the American Railway Engineering Association. Vol. 87.

"Record-smashing run completes TGV speed trials." 1990. *Railway Gazette International* 146:7 (July).

Retiveau, Roger. 1986. "TGV signaling adapts to mixed operation." *Railway Gazette International* 142:12 (December).

Roth, Daniel L. "The TGV System." University of Pennsylvania. Philadelphia: 1990.

Roumeguere, P. 1985. "The Fixed Installation of the TGV Two Years After Placing in Service." *Rail International* 16:8/9 (August/September).

Societe nationale des chemins de fer francais. 1982. "The TGV Paris-Sud-Est." SNCF. [Paris]: Societe nationale des chemins de fer francais.

____. 1981. "Desserte par trains a grande vitesse de l'Ouest et du Sud-Ouest de la France: TGV Atlantique." SNCF. Paris: Societe nationale des chemins de fer francais.

Steffee, Donald M. 1985. "French and Japanese Unchallenged in World Speed Stakes." *Railway Gazette International* 141:9 (September).

"TGV Atlantique Takes Shape." 1986. *International Railway Journal and Rapid Transit Review: IRJ* 26:4 (April).

"TGV Atlantique: une deuxieme generation de materiel a grande vitesse." 1989. *Transport, environnement, circulation* 92 (January-February).

Vignes, Pierre, and Louis Debosque. 1989. "La maintenance du TGV SE: experience de huit annees d'exploitation." *Revue générale des chemins de fer* 7/8 (July/August).

Wallis, Shani. 1986. "TGV Bores its Way Through France to the Atlantic Coast." *Tunnels & Tunnelling* 18:6 (June).

Walrave, Michel. 1985. "Le TGV Paris-Sud-Est: mise en oeuvre du projet et premiers resultats." *Transports* 310 (December).

Walrave, M. 1986. "The French TGV System: Achievements To-Date and Future Developments." World Conference on Transport Research (1986: Vancouver, B.C.) Research for tomorrow's transport requirements. Vancouver, Canada: Centre for Transportation Studies, University of British Columbia.

"We Are a Long, Long Way From the Limits of Wheel-Rail Technology: According to TGV Design Engineer Francois Lacote There is Still a Margin Available for Even Higher Speeds Than in the 482-4 kmh World Record Attained." 1990. *Railway Gazette International* 146:2 (February).

Weber, H. P. 1985. "Determination of the Increase in Long-Distance Passenger Traffic as a Result of the Construction of Long-Distance Rail Connections Within the Framework of the Federal Traffic Infrastructure Planning." *Transport Policy and Decision Making* 3:3.

Wesselmann, Carl. 1987. "'C'est la voie!': The French National Railways, Flushed by the Success of the TGV, is Gaining a Foothold in the Exportation of a 'Philosophy' of Total Rail Technology." *Modern Railroads* 42:9 (September).