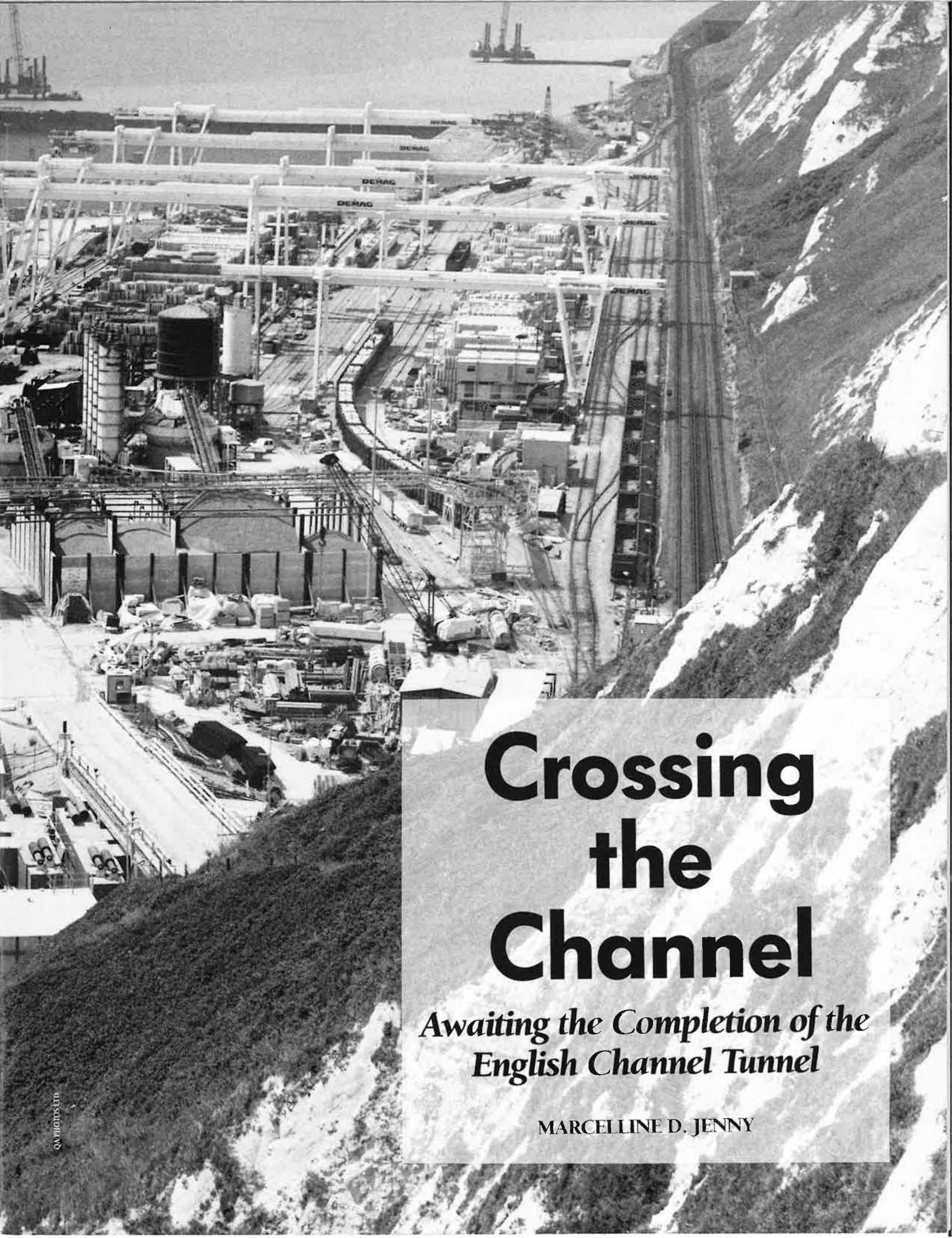


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# Crossing the Channel

## *Awaiting the Completion of the English Channel Tunnel*

MARCELLINE D. JENNY

*The following is a general overview of the progress of the English Channel Tunnel; it is not intended to be an extensive, detailed description of the design and construction of this major engineering project.*

Ever since the land bridge between Britain and France disappeared under a rush of water in a violent storm at the close of the Ice Age, travelers have risked seasickness and sometimes their lives to cross the often turbulent waters of the English Channel. In crafts hardly bigger than bathtubs, in ponderous car-carrying ferries, and in gravity-defying hovercrafts, they have crossed "the great grey highway" separating England from France and the rest of continental Europe.

If all goes according to plan, a better way will soon be realized when the Channel Tunnel, affectionately known as "The Chunnel," opens to railway traffic between France and England in June 1993.

The engineering world has been following the progress of this tunnel with interest; first, because it is a major engineering project that gives life to a dream that has lasted for almost two centuries. Second, it is a privately funded and operated project that requires extraordinary cooperation among corporate units. Such an enterprise has never before been attempted by an organization other than government because of the scope and extent of the project. Third, potentially disastrous events such as stock market upheavals, discord among leaders of the project, the opposition of the English Channel ferry industry, financing difficulties, cost overruns, and construction delays have continually threatened the feasibility of the project. In spite of these problems, all signs indicate that this time the project will succeed.

## Background

Plans for a fixed link between France and Britain were proposed in 1802 by a French engineer, Albert Mathieu, who envisioned horse-drawn carriages driven through a candle-lit tunnel with air shafts to the sea surface for ventilation. Since then, 26 attempts have been made to construct the tunnel, and a number of tunnels have been started and abandoned.

Some efforts were relinquished because of lack of funding or technological difficulties. But over the years it was usually the British who made the decision to drop the project. Initially they rejected the enterprise because Napoleon had expressed interest in Mathieu's idea. A tunnel as a potential invasion route for continental troops was always a possibility from the British point of view. This fear persisted, and it was not until 1955 that the British finally dropped their military defense-related objections to a tunnel. However, the latest fears expressed by some opponents is that the tunnel could provide an easy target for terrorist attack.

Since the current project started three years ago, opponents of the tunnel have raised other objections. For example, Great Britain is free of rabies and opponents argue that this dry link could be a means by which the disease might enter the country. Others oppose it because tunnel traffic would pass through Kent, the "garden" of England, with possible adverse effects on the environment. Most agree, however, that British opposition to a permanent link to the continent runs deeper. A fixed link destroys the British feeling of "islandhood" and thus the nation's unique identity.

The contrast between British and French reception to the idea of the tunnel is certainly striking: towns in the northwest of France are vying over the construction of highways and railroad tracks leading to the tunnel. The French apparently view the tunnel as a great commercial opportunity. In England, on the other hand, residents of the towns along the proposed routes of access are protesting the construction of highways on both aesthetic and environmental grounds. Even though the service tunnel was "holed through" in December 1990 and the fixed link is virtually an accomplished fact, protests against the tunnel are still reported daily in the British media.

In spite of the numerous past attempts to construct a fixed link between France and Britain, it is doubtful that the tunnel could have been started any sooner than the 1980s even if the difficulties already mentioned had not been present. Two factors occurring in the past decade contributed to the decision to construct the tunnel. First, the concept of a European confederation is now more acceptable to both the people of continental Europe and the British. The establishment of the European Community in 1992 lends credibility to the idea that cooperation on an economic level can lead to cooperation in other areas. Some say that this has led to the beginning of a feeling of unity of purpose on other less tangible levels, and that this is breaking down the "island people's" isolationist tendencies.

Second, the recent globalization of capital markets has made financing possible. Financing the project, initially expected to cost about $9 billion, required close cooperation among a network of banks, a relatively new phenomenon in the banking industry. One example of the high degree of cooperation needed between financial institutions in the funding of the enterprise serves to illustrate this point: the project needs mostly French francs and British pounds, because it cannot afford to take large currency exchange risks. The bankers who are cooperating in this project have therefore developed a system to provide needed currencies without the exchange risks that would normally be involved.

With these two major conditions satisfied, it appears that after almost 200 years of aborted attempts the English Channel tunnel is on its way toward becoming a reality.

## Financing

The tunnel could never be built, of course, without adequate funding. In the past it was most often the governments of France and Britain who tried, albeit unsuccessfully, to fund the project. But in 1985 a group of private banks assured the British and French governments that a private tunnel could be financed; and in early 1986, Eurotunnel, a consortium of private French and British companies, was awarded a 55-year franchise to build and operate the system.

Eurotunnel is not only responsible for the construction of the largest private infrastructure project of this century, it is also trying to establish a hallmark in the

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world of international finance. To raise the initial estimated cost of the project of some $9.5 billion, Eurotunnel began by lining up $8.5 billion in credit, initially through an international syndicate of about 50 banks. By the time the syndicate was complete, there were more than 200 banks in more than a dozen countries involved in the initial financing. These banks, which represent the largest private sector syndication in history, have extraordinary control over Eurotunnel. They can take it over and sell the project assets if certain targets are not met. It is therefore crucial that the project adhere to its construction schedule and financing targets so that it achieves its estimated completion date.

Public sale of Eurotunnel stock was planned for November 1987, but the October 19, 1987, stock market slump shook international finances. That the project survived this financial shock is probably due not only to the cooperative efforts of the financial companies involved, but also because the management of Eurotunnel remained calm and in control and downplayed the effect of the drastic market downswing on the enterprise.

Refinancing the tunnel at the end of 1990 was made easier by the "hole through" in December 1990. Public confidence in its progress is reflected by the relative ease with which stock was sold—particularly to those who already owned shares. Refinancing was necessary because the estimated cost of the project is now more than $14.7 billion for the construction of tunnels, terminals, track, specially

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***Top left:* Channel Tunnel progress: French service tunnel, probe breakthrough.**

***Center left:* Site engineer inspecting marine service tunnel.**

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***Right:* French and British workers meet at breakthrough point in Channel Tunnel.**

designed double-deck trains, and other equipment. Approximately one-half of the project cost is a fixed price that covers onshore terminal construction and fixed equipment. The tunnel itself is contracted on a target cost basis and accounts for about 40 percent of the total cost.

During its 55-year lease, Eurotunnel has contracted for government railroad use for only approximately one-half of the time (that is, for approximately 12 hours of the day); it plans to operate its own railway system, and will lease time to other transport companies for the remainder of the period.

## Geology, Design, and Construction

The floor of the English Channel is formed of green sand overlain by gault clay, chalk marl, and grey chalk. The tunnel was designed to be constructed primarily in the chalk marl layer. Chalk marl is a relatively soft variety of limestone. It is formed from calcareous remains of prehistoric algae and sea life. It is largely a soft, white rock, described as "a tunneler's dream." Chalk marl is easy to cut, faults and joints are tight, and water seepage is rare.

When completed, the English Channel Tunnel will be 50 kilometers long, with approximately 21 kilometers of this distance under the channel. Three tunnels are being constructed: two 7.6 meter inside diameter main railway tunnels and one 4.8 meter inside diameter smaller service tunnel. (It is the latter tunnel that has been holed through.) The center lines of the tunnels are approximately 15 meters apart. The tunnels are interconnected with cross passages at intervals of approximately 1,200 meters and pressure relief ducts, at approximately 250-meter intervals, to relieve air pressure caused by moving trains. In addition, two large crossover passages between the railway tunnels are being constructed to provide for shunting trains from one railway tunnel to another in the event of emergency or breakdown.

The design team had to take into consideration the special geometric requirements for a tunnel that would be used by high-speed trains. For example, designers used a minimum horizontal curvature of 4,200 meters, and a maximum gradient of approximately 1 percent. At the same time, the designers had to take advantage of the best geological conditions by staying in the chalk marl layer as much as possible at a maximum depth of about 115 meters below the seabed.

From Shakespeare Cliff on the British coast, the line of the three tunnels follows the seam of a variety of chalk marl known as blue chalk, which, of all the chalk marls, is generally considered the ideal tunneling material. Unfortunately, the seam undulates and eventually plunges down near the French coast. The landward drives from Sangatte—the site of the French access shaft—were largely through grey clay, a highly fractured material that is filled with water under high pressure. The seaward drives from Sangatte had been expected to reach blue chalk within 488 meters, but risk of clipping valleys of upper fractured grey chalk and peaks of gault or clay continued for another 4.8 kilometers.

Eleven tunnel boring machines (TBMs) are being used, six on the British side: two for the service tunnel bore (now completed), two for the landward main tunnel bore, and two for excavating the seaward main tunnel. The French are using five TBMs at Sangatte: three for the seaward drive and two landward. The three seaward TBMs are specially designed to isolate the space in which the chalk is being cut and pump pressurized slurry into it to hold back the water. The depths of water to be held back by this slurry technique were estimated to be approximately three times greater than usually experienced.

Each drive was started from the surface using ordinary optical surveying techniques. Lasers fixed to the tunnel walls line up with reference points backward to the surface and forward to a target at the rear of each TBM. Computers on the TBMs analyze laser readings and instantly correct any drift. As testimony to the accuracy of this method, when the two TBMs stopped just short of meeting in the service tunnel, engineers found the two tunnel segments to be off by only 5 centimeters vertically and 50 centimeters laterally.

Behind each TBM is a rolling assembly line running back almost 229 meters. Chunks of chalk pass through the cutting head onto a conveyor into muck cars that roll on tracks to the surface. Liner components arrive on parallel tracks. Approximately 700,000 concrete and cast iron modular segments must be poured. A factory on the Isle of Grain in Britain can produce approximately 500 precast concrete segments a day. In addition, a factory on the construction site in France can provide about 600 liner plates a day directly to the project.

An estimated 7.8 million cubic meters of soil—enough to build three great pyramids of Egypt—will eventually be removed from below the Channel floor. Some of the excavated material will be used to fill in and level the construction sites. In Britain the rest will be dumped behind an existing seawall at the base of the cliffs near Dover. In France a coastal hollow still pitted with World War II bomb craters is being diked to receive the muck.

## Transportation Considerations

The idea of building a vehicular tunnel was discarded early because such a long tunnel would be extremely difficult and costly to ventilate. Thus the running tunnels were designed for train traffic only. Passenger automobiles and trucks, however, will be loaded onto double-decker shuttle trains built for this purpose and passengers will remain in their vehicles for the approximately half-hour tunnel ride. Regular French and British trains will carry passengers without vehicles through the tunnel.

The French are busy building new tracks and rerouting trains, especially the TGV high-speed trains, to take advantage of the tunnel. On the other hand, the British government appears reluctant to spend money on upgrading their existing train system. As it now stands, trains will travel at speeds of 290, 161, and 97 kilometers per hour, and allowing for customs delays, the trip between London and Paris is expected to take as little as three hours.

Passenger use of the tunnel during its first year of operation is projected to be approximately 28 million people; annual escalation of that number is expected to be between two-and-a-half to three percent.

## Scheduling Problems and Penalties

Financial arrangements between the construction contractor, Transmanche-Link (TML), and the owner, Eurotunnel, are currently under renegotiation. At this date, and in accordance with the target cost arrangements made with TML, the latter will be paid actual costs plus a fixed fee of 12.36 percent of the target value. If the tunnel is completed below the target price, TML will receive half of all savings. Should the costs exceed the target, however, TML will have to pay back 30 percent of the excess cost to a maximum of six percent of the target cost. Furthermore, should the completion date of June 15, 1993, not be met, and should TML not be granted an extension, TML can lose $620,000 per day, rising to $940,000 per day after six months to a maximum of $290 million.

Financial penalties start accruing as soon as TML fails to meet program milestones. For example, TML forfeits a specified amount for every extra day that it takes to reach a milestone, up to a maximum figure that is roughly equivalent to three months' delay.

The project has been plagued by postponements from the beginning. By early November 1988, TML had submitted approximately 80 claims for extension of time for delays beyond its control. Eurotunnel, under pressure from the banking syndicate, is taking a tough line. For the most part, the delays have been caused by breakdowns in the TBMs or for longer-than-estimated drive times. Steps have been taken to mitigate these problems.

## Conclusion

The English Channel Tunnel has presented an engineering challenge for more than two centuries, but only in the past three years has it been possible to face that challenge and change concept to reality. The cost of this project has been high, shown by the nine lives lost and the money and energy expended. Yet despite the problems encountered by private enterprise in taking on such a massive project, the tunnel will likely continue to stir excitement, admiration, and controversy—and finally gain acceptance.

*Because of the size of this project, many articles have appeared in professional and trade periodicals. For further information, please refer to the selected, recently published titles that follow.*


Channel Tunnel Special Report. *Engineering News-Record*, Dec. 10, 1990.

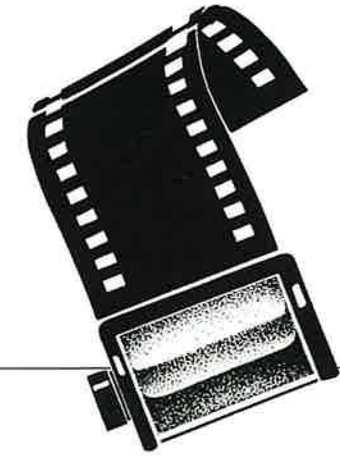
A. Benard and A. Morton. Bon Voyage Under the Sea. *Railway Gazette International*, Vol. 146, No. 4, April 1990.

P. Vandebrouck. Channel Tunnel: Current Status of the French Tunnel Work. In *Proc., Rapid Excavation and Tunneling Conference*, Los Angeles, Calif., 1989. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, N.Y., 1989.

*The Channel Tunnel.* Conference held in Paris, 20–22 Sept., 1989. Institution of Civil Engineers and the Société des Ingenieurs et Scientifiques de France. Telford Ltd., London, England.

The Right Tracks to Europe: The Regional and Environmental Impact of the Channel Tunnel. *Transport 2000*, London, England, Feb. 1989.

D. Ivor-Smith and S. Nandagiri. Channel Tunnel, Texas Style. *Civil Engineering*, Vol. 59, No. 12, Dec. 1989.

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