The Channel Tunnel

John Noulton

A 250-year Dream

Although the Channel Tunnel between England and France only opened for business in 1994, the story of the project is far, far longer. As much as 250 years ago, people in France, at least, were trying to think of a better way than boat of crossing the Channel.

In 1751, the Academy of Amiens launched a competition on how to cross the Channel and history records that the winner was Nicolas Desmarets, who suggested construction of a tunnel. In those days, cross-Channel travel was not dominated by the leisure business as it is today. Other than military action, the main reasons were to do with trade.

For the next 100 years, a succession of mainly French proposals emerged with increasingly sophisticated ideas for the new link. Since this was before the development of railways, these tunnels were inevitably road tunnels.

One proposal by Hector Thoreau involved two artificial islands where stagecoaches using the gas-lit tunnel would come above ground to change the horses.

Although Desmarets is the first documented proponent of a fixed link, the generally acknowledged 'Father of the Tunnel' was the 19th century French engineer Thomé de Gamond whose investigation of the seabed—at great personal risk—was the groundwork for the eventual Eurotunnel project.

Why Not a Bridge?

De Gamond showed that the chalk measures underlying Kent and Nord/Pas de Calais also lay beneath the seabed. Subsequent geological studies revealed that at an average depth of about 40 m below the seabed, the chalk merged with clay to form an almost uniform stratum of chalk marl, probably the best tunnelling medium in the world. This accident of geology was one of the two reasons why the fixed link is a tunnel and not a bridge. The other reason is that the Channel is the busiest seaway in the world, with over 600 shipping movements each day. Any bridge or other structure in the Channel would almost certainly be rammed by a ship in due course. If anything, the risks of such an accident would have been even greater during construction than during subsequent operation.

Previous Tunnel Attempts

Despite the French enthusiasm for a tunnel, actual excavation did not start until the latter 19th century. The British viewed their continental neighbours with considerable suspicion, particularly after the Napoleonic campaigns earlier in the century, and were reluctant to end their 'splendid isolation.' Lord Palmerston, the Tory Prime Minister, greeted one proposal with the words, 'You surely do not expect me to agree to shorten a distance I already consider short enough?'

Many people did not share Palmerston's distaste for things French. Even during Anglo-French hostilities, there was still a ready market in Britain for French wines and brandy and cross-Channel trade continued without interruption, much of it by smuggling. The south coast of England closest to France has many relics of the illegal trade, and the 18th- century smugglers have now been succeeded by a much less romantic breed of villain who take advantage of the sharp differences in excise duty between Britain and its neighbours. It is estimated that 20% of the bottled or canned beer consumed in Britain is bought in France. Much of it is British beer that has been exported to France only to be reimported by British shoppers or 'bootleggers.'

In the 1880s, it did begin to seem as though the dream of a tunnel would be realized. Colonel Beaumont, a British military engineer, led a construction team that bored nearly 2 km of undersea tunnel from Dover. A French team of engineers began work on a similar tunnel from Sangatte. But it was not to be. Senior members of the British defence

One of runnning tunnels (Eurotunnel)

Breakthrough of service tunnel on 1 December 1990 (Eurotunnel) establishment were still obsessed by the fear of invasion and persuaded the government to stop the project.

Oddly enough, it was not until after the two World Wars that the British defence objection to a Channel tunnel was finally dropped. In 1957, it seemed the last obstacle to construction of a tunnel had disappeared and by 1973, work had re-started in a blaze of optimism. The engineers were encouraged when they opened up the Beaumont tunnel of 1880 to find that it was still intact, despite the fact that it had never been lined. But within 2 years, the optimism had vanished and the project was cancelled by the British government again, although for a more complex set of political motives. In particular, the trade-union supporters of the then Labour government were fiercely opposed to the tunnel, because they were concerned that members' jobs in road haulage and stevedoring would be lost with the massive shift of international freight from road and ship to rail.

Private Finance

The fears of the UK government about public expenditure was another reason for the cancellation of the 1973 project. By 1979, when the possibility of a tunnel was being considered again, the government's view had hardened. The government would not stand in the way of a fixed link provided it was funded wholly by the private sector; there would be no public funding and no guarantees of a financial or commercial nature. Although the French government had no qualms about committing public funds to the link, they accepted the British insistence on private funding, and in 1985, an 'Invitation to Promoters' was issued calling for bids for a privately funded project.

Four valid proposals were received by the October deadline—three road schemes and the rail-based tunnel promoted by Eurotunnel. After a detailed assessment of the four bids, the Eurotunnel proposal was selected. The private-sector promoters were awarded a concession of 55 years (later extended to 99 years) in which time they were 'to finance, develop, design, construct and operate the tunnel entirely at their own risk without recourse to government funds.'

By the time of the successful share offer in 1987, the concessionaires had finally answered Lenin's scornful challenge of 1913 in which he said, 'The richest, the most civilized, and the freest countries in the world are now discussing, in fear and trepidation, the *difficult* question of whether a tunnel can be built under the English Channel. On all sides, at every step, one comes across problems that man is quite capable of solving immediately, but capitalism is in the way.'

Not Just a Tunnel

The winning scheme was a system consisting of three 50-km tunnels: two running tunnels of 7.5 m in diameter, and a service tunnel of 4.8 m in diameter. Each running tunnel is unidirectional with a structure gauge for the huge vehicle-carrying shuttles of the Eurotunnel transportation system as well as the more conventional international freight and passenger trains. The service tunnel is a road tunnel used by purpose-built, narrow, diesel vehicles for maintenance and emergency access.

Although the tunnel is not the longest in the world—at 50 km it is nearly 4 km shorter than the Seikan Tunnel linking Honshu and Hokkaido—the 39-km undersea section between Dover and Sangatte is the longest in the world.

Folkestone Terminal (Eurotunnel)

The tunnels themselves are only part of the civil engineering story. The running tunnels are linked to the central service tunnel by cross-passages every 375 m for emergency access and egress. During normal operations, where it meets the running tunnel, each end of each cross-passage is sealed by a heavy door. The running tunnels themselves are linked directly by pressure relief ducts to reduce the air pressure that builds up in front of moving trains. This in turn reduces the power required for traction and cooling.

About 15 km from each tunnel portal, trains pass through large crossover caverns. As the name implies, their purpose is to permit trains to pass from one tunnel to the other. Tunnel sections can be bypassed during regular maintenance or in an emergency using these crossover caverns. Single-line working is required at such times.

The shuttle trains require extensive terminal facilities at each end; the Folkestone terminal covers 130 ha and extends to a length of 2 km. However, this huge facility is dwarfed by the French terminal, covering nearly 700 ha—the size of a major international airport like Heathrow. At the time, the French terminal was the largest construction site in Europe.

Anglo-French differences

Quite apart from the differences in attitude towards the tunnel between Britain and France, there were also technical differences to overcome, not least for the international freight and passenger trains that operate beyond the boundaries of the Eurotunnel system. The British network is built mostly to a much more restricted structure gauge. Rolling stock from mainland Europe cannot operate in Britain, so trains for the tunnel either had to be built specially or limited to the UK gauge. The rail system in the part of southern England served by Channel Tunnel trains is 750 V dc, whereas the French network is 25 kV ac. A further complication is that the British system delivers power through a third rail, while France has a standard overhead catenary.

Tunnel Mechanical Systems

The tunnel contains four main mechanical systems—ventilation, cooling, drainage, and fire-fighting. The design of each of these systems was strongly influenced by the unique characteristics of the tunnel itself, particularly its long length and limited surface access.

The normal ventilation system operates at all times. Large fans at each coast blow fresh air into the service tunnel. The air reaches the running tunnels through non-return air distribution units in selected cross-passage doors. There are air locks at each portal of the service tunnel to ensure that the air pressure in the tunnel is always higher than in the running tunnels—a vital feature in the event of smoke from a fire. A second, supplementary ventilation system blows air directly into the running tunnels in certain emergencies. The supplementary system only operates after trains have been slowed to very low speeds.

The Channel Tunnel is already one of the busiest railways in the world and when it reaches its ultimate capacity it will handle 30 train movements per hour in each direction. The power required to run the 2400-tonne shuttle trains and the aerodynamic resistance of the tunnels (despite the pressure relief ducts) creates waste heat ranging from about 60 MW at present to about 100 MW at full capacity. The amount of heat that can be lost at the portals is limited to about 1.8 MW and the heat dissipated by water seepage is very slight. Therefore, the tunnel needs a cooling system.

Tunnel engineers will tell you that the French half of the tunnel was designed to be watertight while the British half was always intended to leak. This oversimplification reflects the fact that the ground conditions in the British half of the tunnel are much more favourable than those in French territory, particularly near the French coast where the very fractured ground necessitated a lining method involving segments that were bolted temporarily together pending grouting and watertight neoprene gaskets between each lining segment. No such precautions were considered necessary for the British tunnel drives and the drainage design assumes constant groundwater seepage. Water is collected by gravity drainage lines in the tunnel floor and is directed to holding sumps prior to discharge to the surface treatment plant via one of three pumping stations. The original tunnel design called for five pumping stations and five chambers were excavated, but the actual seepage is so much less than predicted that only three stations were equipped.

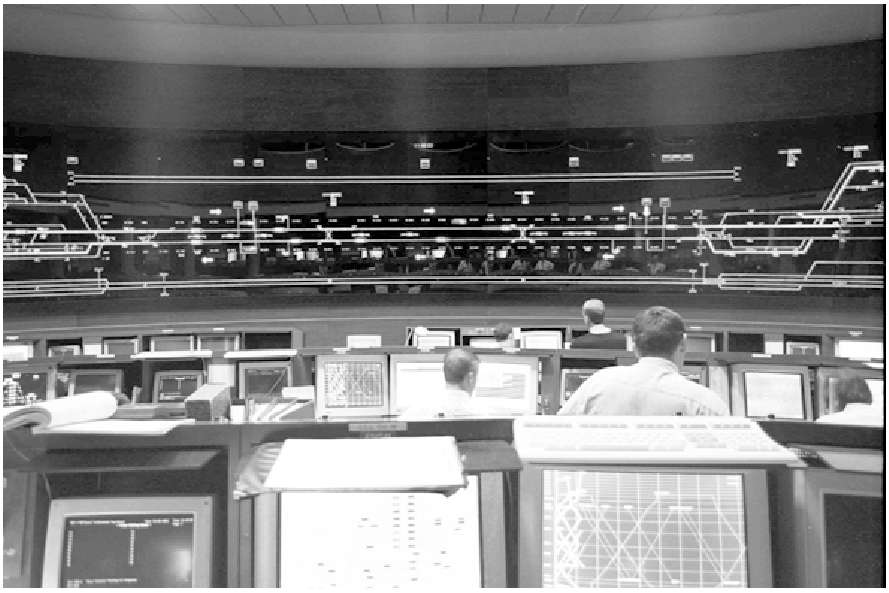
The tunnel system has a wide range of fire detection and protection devices. To fight a major fire, a single 273-mm diameter fire main runs the entire length of the service tunnel. Water tanks and pumping stations are provided at four locations: the two portals and where the tunnels cross the two coasts.

Control and communications

Overall control of both engineering and rail operations is carried out from the main control centre in the Folkestone terminal. A standby control centre at the Coquelles terminal would take over instantly if the Folkestone centre was put out of action for any reason.

The tunnel has a variety of telephone and radio systems for voice and data communication. In addition to the administrative telephone network, there are operational and emergency telephones, linked to the control centre, in a multitude of locations above and below ground. The underground emergency telephone lines are protected against fire.

The signalling system incorporates full automatic train protection (ATP). When there is a stationary train ahead, the permitted speeds are gradually reduced so that a driver following the proper braking procedure slows down smoothly and comes to a halt a full block section before the stopped train. A shuttle train travelling at the normal 140 km/h needs 1500 m—three block sections—to make a normal service stop. If the driver disregarded the instructions to brake, the ATP system would take over and bring the train to a halt.



Railway control centre at Folkestone (Eurotunnel)

Terminal traffic control centre at Folkestone (Eurotunnel)

Power Supply

The tunnel has a high demand for electrical power. Traction accounts for about 80% of total consumption with remainder used for auxiliary facilities such as ventilation, cooling and lighting. Unusually, the power comes simultaneously from the British and French national grids. In the event of a total power failure on one side, it is possible for tunnel services to be kept running with power from one side.

Capacity/Services

The capacity is measured in standard paths, meaning the capacity required for a shuttle train travelling at the normal operating speed of 140 km/h. Trains travelling at speeds greater than 140 km/h use more capacity.

The presently available number of standard paths in each direction is 20 per hour, and about two-thirds of this capacity is already being used. Improved operating techniques will stretch the available capacity to about 24 standard paths per hour. The ultimate capacity, which would require moving block signalling, is 30 standard paths per hour. Under a usage contract signed by Britain and France, up to 50% of tunnel capacity is available for international passenger and freight trains.

National Trains

The opening of the Channel Tunnel connected Britain's 16,000-km railway network to more than 150,000 km of standard-gauge tracks in continental Europe. Before the Tunnel opening, international rail freight between Britain and France was limited to some 2 million tonnes per year, all of which had to cross the Channel on train ferries. Due to the restricted loading gauge in Britain, most continental freight wagons cannot use the Tunnel and most freight traffic consists of intermodal containers that are transferred from rail to road for final delivery. To carry these containers, it was necessary for the operators to purchase a new fleet of wagons with low-level decks.

To haul freight trains through the Tunnel, completely new Class 92 electric locomotives were built. These locomotives can operate on both 750 V dc third-rail and 25 kV ac catenary systems. They have a maximum output of 5 MW (6700 hp) and normally operate in pairs, but are designed to a full train plus a 'dead' locomotive up the 1:90 (11 per mill) grade to the Folkestone portal at 30 km/h. The Class 92s have Tunnel-compatible TVM430 in-cab signalling.

Freight volumes have grown slowly but steadily since freight services began in 1994 and more than 3 million tonnes will be carried through the Tunnel this year.

Like the Class 92s, the Eurostar high-speed passenger trains were built specially. They can operate on three separate systems (Britain, France and Belgium), and, unlike the French TGVs (on which they are based) are able to operate on the British network.

There are about 30 Eurostar services each way each day between London and Paris or Brussels. Each train is operated by a single driver, working from one capital to the other. The Eurostar trains also have TVM430 in-cab signalling system used in the tunnel as well as the conventional in-cab warning systems used on the three national rail networks. In the tunnel, the Eurostar trains run at speeds of 160 km/h, but when they reach the high-speed lines in Belgium and France, they accelerate to 300 km/h. Because the higher-speed Eurostars are relatively wasteful of tunnel capacity, the Brussels and Paris services pass through in 'flighted' pairs with 4-minutes headway.

Journey times are 3 hours from London to Paris and 2 hours and 25 minutes from London to Brussels, making them very competitive with air in terms of city centre to city centre journey times. As a result, the Eurostar services have captured a 60% share of these markets with over 6 million people travelling by Eurostar each year.

High-speed lines have been constructed on the French and Belgian sections of the Eurostar routes and work has started on a new 112-km high-speed line in Britain to connect the tunnel to St. Pancras Station in London. When this section is fully opened in 2007, Eurostar journey times will be cut by a further 30 minutes.

Shuttle Services

Unlike the roll-on/roll-off ferries crossing the Channel, passenger and freight customers of Eurotunnel's shuttle services are conveyed separately by dedicated shuttles and separate terminals.

The passenger shuttles are 776-m long and their vehicles are the largest in the railway world. Each shuttle comprises two rakes—12 double-deck wagons for cars, and twelve single-deck wagons for coaches caravans and other high-sided vehicles. Customers drive their vehicles into special loader wagons at the rear of each rake and continue through the body of the train until told to stop by a member of the crew. During transit through the tunnel, fire-resistant doors between the wagons are closed. Passengers stay in their vehicles during the 35-minute journey to the other terminal. A unique feature of the shuttle system is that British outward and French inward border controls are carried out in Folkestone (the reverse occurs on the return journey). This means that on arrival at the other terminal, customers can drive directly onto the motorway with no further controls. The shuttle locomotives, which are used for both passenger and freight services, are among the most powerful in the world. They produce 5.6 MW (7500 hp) and can

Loading passenger shuttle at Folkestone and Coquelles (right) (Eurotunnel) each pull a 2400-tonne train through the tunnel, although they are invariably used in pairs, one at each end of a train.

Eurotunnel operates two to three passenger shuttles per hour in each direction, rising to four at peak times. As originally conceived, passenger shuttles were to have operated on a 'turn up and go' basis, with no pre-booking. When capacity was restricted following the 1996 fire, a booking system was introduced and this proved so popular with customers and provided such operational benefits, that it was made a permanent feature even after full capacity was restored. It is still possible to simply 'turn up and go' but booking ahead is advisable at times of high demand.

The major business of the passenger shuttles is leisure travel and the biggest flows are in the summer holiday period. The short-break business is also flourishing, but the end of duty free sales in Europe in June 1999 saw a dramatic fall in traditional day-trip traffic. Over 3 million cars used the passenger shuttles in 1999 as did 82,000 coaches..

Unlike the passenger shuttles, the freight shuttle wagons are semi-open. Truck drivers do not stay with their vehicles but travel instead in a 'club' car at the front of the train where they are served a meal. Originally 28-wagons long, the freight shuttles have been extended to 32 wagons because of rapidly rising demand. Up to four trains run each hour in each direction and carried 839,000 trucks in 1999.

The cross-Channel road freight market uses both driver-accompanied trucks and unaccompanied trailers. Eurotunnel's shuttles only cater for accompanied vehicles, although the system does accept vehicles weighing up to 44 tonnes—the maximum permitted in Europe on international journeys.

Fire!

The very serious fire in November 1996 was on one of the freight shuttles. Late in the evening, two security guards in the Beussingue Cutting, close to the French tunnel portal noticed smoke coming from a wagon towards the back of a freight shuttle that was about to enter the tunnel. They reported the smoke and the rail control centre in Folkestone advised the driver. By this time, the train was in the tunnel and the control centre had begun to receive indications from the underground smoke and fire alarms.

In accordance with the standard operating practice, the driver was instructed to continue his transit and a route was set for the train to enter the emergency siding at the Folkestone terminal.

Just after passing the French crossover, the driver received a cab warning of a possible trailing jack (jacks are used during loading to steady the train). As he still had to pass the English crossover, the trailing jack could have caused derailment. In discussion with the control centre, the driver brought the train to a controlled halt, with the 'club' car alongside a cross-passage. Anxious minutes passed as the front of the train became enveloped in smoke. Fortunately, the control centre was able to identify and open the cross-passage door. The inflow of ventilation air from the service tunnel cleared the smoke and the train captain was able to evacuate the truck drivers to the safe haven of the service tunnel. Meanwhile, rescue teams had arrived on the scene and the evacuated passengers and crew were loaded onto a shuttle that had been stopped in the other tunnel and taken back to Coquelles.

The fire burned all night before it was finally brought under control and the extensive damage closed the affected tunnel for 7 months while repairs were carried out. During that period, a restricted passenger shuttle service operated together with national trains. The freight shuttle service was suspended until both tunnels were open.

A police investigation showed that the fire was arson but no one has been charged so far.

Ancillary businesses

As well as running trains and managing the Tunnel infrastructure, Eurotunnel has become involved in other business activities. Before the end of duty-free sales in Europe, Eurotunnel was a very successful retailer with income from its duty-free shops rising to £170 million a year. It is also in the telecommunications business and has laid several telecommunications cables through the tunnel for major telephone companies.

Future developments

Because of the very strong growth in the cross-Channel road freight market, following its recovery from the 1996 fire, Eurotunnel decided to double its fleet of 8 freight shuttles. This expansion of its freight business was the key ingredient in Eurotunnel's strategy to replace the lost £170 million in annual revenues from duty-free sales. The current fleet of freight shuttles numbers 11 and further trains are being manufactured. This expansion of capacity enabled Eurotunnel to carry 42% more trucks in the first half of 2000 compared to the same period in 1999.

The freight shuttle is the most successful of Eurotunnel's businesses. It is also a very satisfying business because it is year-round and not seasonal like the passenger business. Freight peaks in the early morning, late evening and mid-week occur conveniently at times of low passenger-shuttle demand. However, this success is not without its problems.

Since the opening of the Tunnel there has been a concentration of road freight traffic on the Channel Tunnel and Dover ferry routes, at the expense of the longer ferry routes in the North Sea and the western Channel. This means that if there is disruption of either the ferries or Tunnel, queues build up rapidly on the approach motorways. The volume of trucks likely to be held up in this way is so huge that the police have introduced 'Operation Stack' in which the motorway is closed to all other traffic and is used as a lorry park.

Apart from technical difficulties, disruption has been caused recently by bad weather in the Channel, strikes by seamen and port operators, and blockades in France by farmers, fishermen and hauliers. The Tunnel was even blocked on one occasion by people protesting the end of duty-free sales.

The new trains are not identical to those in the original fleet. Experience of operating the existing vehicles has led Eurotunnel to develop a simpler design more suited to the intensive shuttle-based system.

Expansion of the freight shuttle business is not simply a matter of buying more trains. Substantial modification of the terminals will also be necessary, such as doubling the number of platforms from 8 to 16. Fortunately, space for such an expansion was provided in the original designs.

One direct result of the fire was the decision to develop an on-train fire suppression system for freight shuttles. The existing safety systems proved that they could save the lives of passengers and crew, but the Tunnel itself was not protected. A prototype system is now undergoing in-service trials.

Next—A Road Tunnel?

When the governments awarded Eurotunnel its concession in 1986, there was some disappointment in both countries that the chosen scheme was a rail tunnel. Competing 'drive through' projects had been judged impractical but the promoters of those schemes attracted considerable public and political support. The governments therefore imposed an obligation on Eurotunnel to develop proposals for a 'drive through' link by last year. The company does not have to build such a link unless it is technically and financially feasible and, even then, there is no binding obligation to go ahead with the project. However, the governments would be free to invite other promoters to build such a link that would enter service no earlier than 2020.

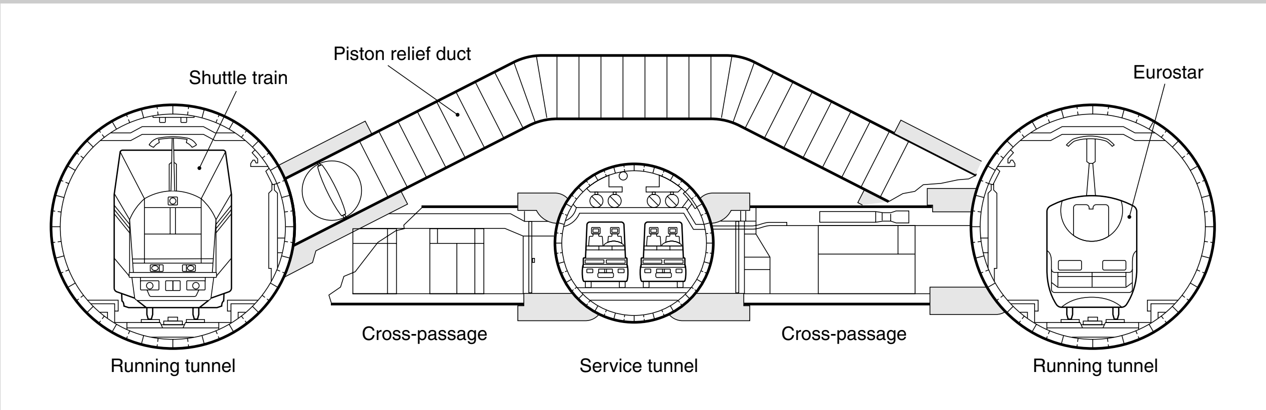
To comply with this requirement, Eurotunnel submitted a feasibility study for a second tunnel to the British and French governments in December 1999. Because of changes in public attitudes towards pollution and the motor car, the study looked at both 'drive through' schemes and at the possibility of a second rail tunnel. It identified two possible options, one rail and one road. Both were large single tunnels of about 15 m in external diameter, within which, it is believed, all the safety features of the present three tunnels could be combined.

The road tunnel was based on two one-way two-lane carriageways on separate levels for cars and light vehicles only. Heavy vehicles would continue to use the freight shuttle as now.

The rail option would have two unidirectional tracks side-by-side, but separated by a fire wall. It would cater to Eurostar passenger trains and international freight trains, leaving the whole capacity of the present tunnel for the Eurotunnel shuttles.

Paradoxically, the road option would not

Cross Section of Channel Tunnel Structure



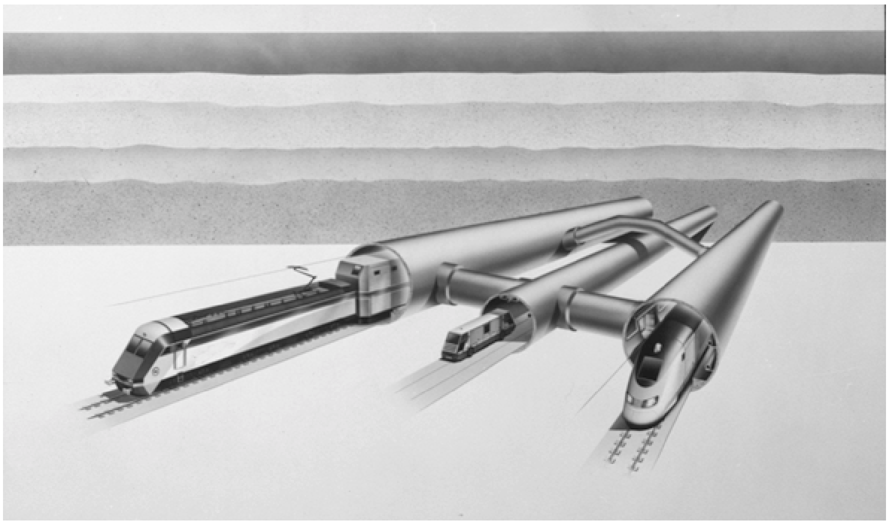
(Eurotunnel)

inhibit transfer of road freight to rail, because a road tunnel would free capacity in the existing tunnel for the passage of 51 million tonnes of rail freight each year, or 13 times the volume expected to be carried this year. The rail option would permit carriage of up to 73 million tonnes per annum, 20 times the current level. Both schemes appeared to be technically feasible, but the viability of the rail option depends very much on the evolution of the cross-Channel freight business.

Changing Public Attitude

One reasons why the feasibility study encompassed both road and rail options was the perceived change in public attitudes to roads since the Eurotunnel concession was awarded. European governments have repeatedly said that they want to encourage a massive shift of traffic, particularly freight traffic, from road to rail. The 10-year transport plan recently published by the UK government has suggested a target of 80% growth in rail freight within the next 10 years. This would translate to an increase in rail's market share from the present 6% to 10% over the same period. International rail freight, which can operate over the distances at which rail competes effectively with road, clearly has an important part to play if these targets are to be met.

There is growing resistance in the so-called 'transit' countries of Europe (Switzerland, Austria, Hungary) to the flood of heavy vehicles using their roads. Switzerland has imposed a maximum weight limit of 28 tonnes on trucks passing through its territory and is developing new rail-based tunnels through the Alps for the carriage of goods vehicles. Germany has its rolling motorways, with heavy freight vehicles carried 'piggyback' on rail wagons. Consequently, the omens for rail freight look good.



View of tunnel system showing shuttle train, Eurostar and service tunnel vehicle (Eurotunnel)

Unfortunately, as things stand, rail freight is anything but competitive with road since the European road haulage market has been fully liberalized. Less than 20 years ago, road hauliers needed a permit for every international journey, but today there is complete freedom of access to most roads in Europe. Hauliers also have the right to practice cabotage and, if necessary, can set up in business in another member state with little difficulty. Liberalization, in turn, has caused strong competition and consolidation in the market, leading to a marked fall in freight rates. The completion of the European single market has seen double-digit annual growth in international road freight.

By contrast, rail freight has been in the doldrums and it is not just market share that has been lost. Freight volumes carried on EU railway networks fell 14% from a peak of 283 billion tonne-km in 1970 to 241 billion tonne-km by 1998. In the same period, the volume of road freight grew by 50% to 1255 billion tonne-km and the growth is quickening. It is no coincidence that the length of motorways in the EU tripled from 16,000 to 49,000 km between 1970 and 1998, while the length of railway lines fell from 170,000 to 153,000 km in the same period.

Eurotunnel has until 2010 to decide whether it wants to pursue a second tunnel. After that date, the British and French governments can invite others to prepare proposals if they wish. The financial restructuring prospectus published in 1997 shows that the present system will not reach saturation until at least 2023, suggesting that the long story of the Channel Tunnel still has several unwritten chapters. ■

John Noulton

Mr Noulton is Eurotunnel Director of Public Affairs. Prior to this, he was Director of Administration at Transmanche-Link, the Channel Tunnel contractors. He has also held a number of other public posts including Director of International Transport at the British Department of Transport and in the British Civil Service. He is a member of the Chartered Institute of Transport and a Companion of the Institution of Civil Engineers.