The Channel Tunnel

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1 Introduction

The concept of a man-made undersea tunnel connecting England and France has existed since the early 1800s, but it was not until 1986 that the construction effort resulting in the present Channel Tunnel was started.

Since its opening in 1994, the Channel Tunnel, affectionately nicknamed *The Chunnel*, has transported over 300 million passengers and 300 million tonnes of freight between England and France across the English Channel (French: *La Manche*).

As a work of engineering, the Tunnel is rather impressive. The only precedent of its type is the Seikan Tunnel in Japan, which connects the main island of Honshū with the Northern island of Hokkaidō. The Channel Tunnel comprises two main rail tunnels and one service tunnel between them. The boring itself made use of a stratum of chalk marl, which has properties conducive to tunneling. All of its acheivements have contributed to its designation as one of the Seven Wonders of the Modern World by the American Society of Civil Engineers.

The Channel Tunnel offers both freight and passenger access to separate rail operators, in addition to a roll-on roll-off shuttle service for road vehicles named Eurotunnel Le Shuttle.

This document seeks to give the reader (having a background in an engineering discipline) an overview of the history, construction, and operation of the Channel Tunnel, and an insight into its impact on transport infrastructure and the economy in England and France.

2 History of Channel Crossing

2.1 Planning

The earliest proposal for connecting England and France beneath the Channel was made by Albert Mathieu, a French mining engineer, in 1802, and included oil-lamp illumination and an artificial island midway across for changing the horses of one's carriage.[1]

In 1834 eccentric French engineer and entrepreneur Aimé Thomé de Gamond proposed his first projects for a railway line beneath the English Channel. It was met with indifference from both English and French authorities, who at the time preferred to stay separated from their neighbours.

Gamond presented another proposal to the French Emperor Napoleon III in 1856 detailing a rail line from Cap Gris-Nez to Eastwater Point with a port/ airshaft on the Varne sandbank. Gamond's preliminary surveying operations had estimated the cost at 170 million francs, or less than £7 million in the money of the time.[2]

Gamond proposed a total of seven designs over his lifetime. In 1867 his proposal was finally accepted by Napoleon III and Queen Victoria but was brought to an abrupt end by the Franco-Prussian War of 1870. Sadly, Gamond never saw his dream realised; he died ruined and humiliated in 1876[3]

Ironically, this same year an official Anglo-French protocol was established for a cross-Channel railway tunnel[4], and in 1881, the Anglo-French Submarine Railway Company conducted preliminary exploratory work on both the English and French sides. A couple of pilot tunnels no longer than 2km each had been dug when the project was abandoned in May 1882, over fears that the tunnel would compromise English national security.

The idea was next brought up nearly 40 years later, after the First World War, at the Paris Peace Conference in 1919, by British Prime Minister David Lloyd George. The suggestion was made as assurance that Britain was willing to defend France in the event of another German attack. However, the proposal was not taken seriously by the French and nothing ever came of it.

Another undeveloped proposal made in 1929 estimated the cost of construction to be about $150. Military concerns of both nations had been addressed in the proposal, which included floodable sections of the tunnel to block access by either side. However, military leaders were not convinced. In addition, some English objected to the *tourism* the project's completion would bring, which would supposedly ruin England's "splendid isolation" and "make England a holiday resort for hordes of more or less undesirable people, who would introduce foreign customs, deface the countryside, and otherwise interrupt English habits of living".[5]

With air power gaining dominance in the military, the effect of a tunnel on national security became less and less significant. In 1955, British and French governements began to support technical and geological surveys. This culminated in a government-funded project to dig twin tunnels, designed to accommodate car shuttle wagons, on either side of a service tunnel. Construction began in 1974, but was cancelled by the British governement in January 1975 due to growing concerns

over EEC membership and the national economy.

In 1981 British Prime Minister Margaret Thatcher and French President François Mitterand agreed to set up a group, *Eurotunnel* (ET), inviting private companies to put forward propositions. Over the next few years several projects were submitted including a 4.5km suspension bridge, holding a road encased in a tube and a drive-through tunnel.

Public opinion favoured the drive-through tunnel, but ventilation issues, concerns about accident management, and fear of driver mesmerisation resulted in the decision of the French and UK governements to facilitate the construction of another proposal: the high-speed rail link proposed by the *Channel Tunnel Group/ France–Manche* (CTG-FM) consortium.

Eurotunnel absorbed CTG/F–M and signed a construction cntract with *Transmanche Link*, made up of five English construction companies forming *Translink Joint Venture* boring from Shakespeare Cliff, and the French-formed five-company *GIE Transmanche*, beginning from Sangatte.

The funding was of an unprecedented scale for this ambitious project. Eurotunnel's original estimate of £4.7bn doubled to £9.5bn by the end of construction as can be seen in Figure 1.[8] This was in part shareholder investment and partly £8bn of debt which nearly crippled the company in its early years of operation.

2.2 Construction

Boring began on February 28 1988. Eleven Tunnel Boring Machines (TBMs), six French and five English, worked from both ends, cutting through a stratum of chalk marl. This material provides high impermeability to water, but easy excavation, and its strength allows for minimal added structural support. The tunnel's path

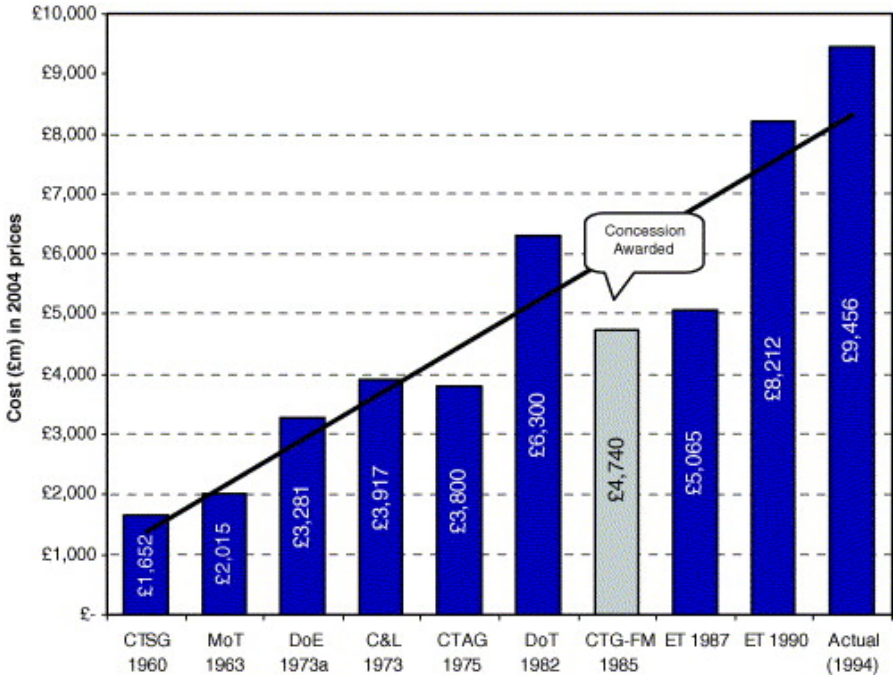

Figure 1: Channel Tunnel cost projections.

through the geology under the Channel is depicted in Figure 2.

The tunneling plan was essentially the same as the cancelled 1975 attempt. The risks taken into account included flooding from the sea above due to weak construction and ground integrity.

The TBMs used combinations of high pressure water jets and rotating disc cutters to burrow at a speed of 75m/day. The central 4.8m-diameter service tunnel was dug first to scout conditions ahead of the two 7.6m-diameter main tunnels. Piston relief ducts connected the rail tunnels to allow for regulation of pressure changes due to the moving trains. A complete cross-section is depicted in Figure 3

The reinforcement strategies differed between the English and French sides. The French used bolted linings of cast iron or high-strength reinforced concrete whereas the English side prioritised speed and thus only applied cast-iron lining

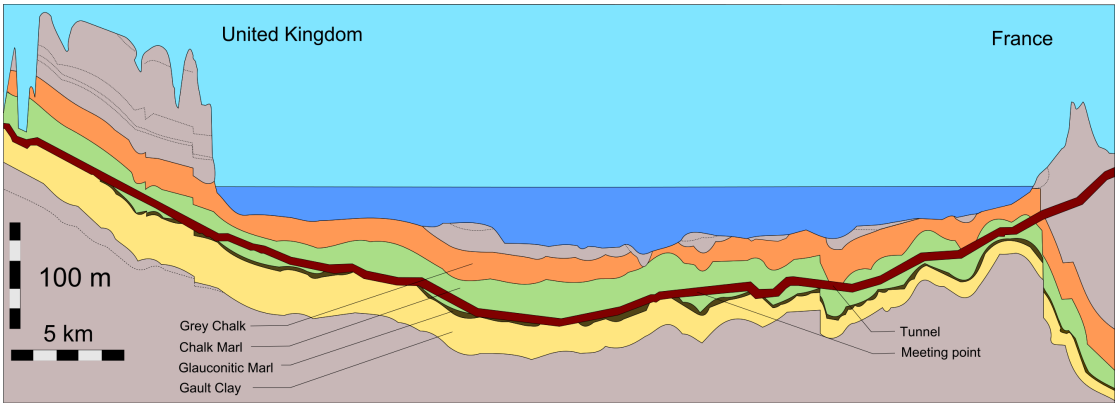

Figure 2: Channel Tunnel geological profile.

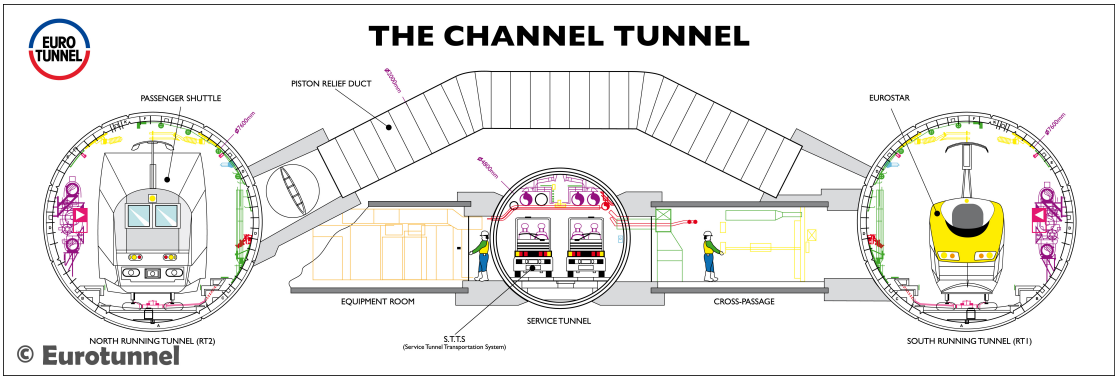

Figure 3: Channel Tunnel cross-section.

Figure 4: Englishman Graham Fagg and Frenchman Phillippe Cozette shaking hands through the breakthrough point, December 1 1990.

in geologically risky areas.

The breakthrough occured rather unceremoniously on October 30 1990, when a two-inch-diameter pilot hole joined the French and English service tunnels. The official connection of the two tunnels was performed on December 1 1990 by Englishman Graham Fagg and Frenchman Phillippe Cozette, who shook hands through the hole in front of the media.

The tunnel was completed and the rail service was officially opened on May 6 1994 by Queen Elizabeth II and French President François Mitterand. The full public service commenced several months later.

The spoil removed from the tunnel was put to use by both sides. The English dumped 4.9m cubic metres of the chalk marl into the sea near Dover, which even-

Figure 5: Englishman Graham Fagg and Frenchman Phillippe Cozette at the 20 year anniversary of the Tunnel's opening.

tually became Samphire Hoe, a 300,000m^2 County Park.[9] The French piled their spoil up to create a new hill.

3 Business Operations

As stated in section 1, there are three services provided by the Channel Tunnel:

- Le Shuttle, a shuttle service for road vehicles provided by Channel Tunnel owners Eurotunnel
- Passenger trains provided by the international high-speed rail operator Eurostar.[6]
- Freight trains operated by DB Schenker Rail (UK).[7]

Eurotunnel's commissioned traffic forecasts for the passenger services, which were used to analyse the costs and benefits of building the tunnel, proved to be overly optimistic. Figure 6 is taken from an analysis of the Channel Tunnel's

fiscal accomplishments made in 2003[8], and it shows that the actual number of passengers ended up only about a half to a third of the forecasted numbers.

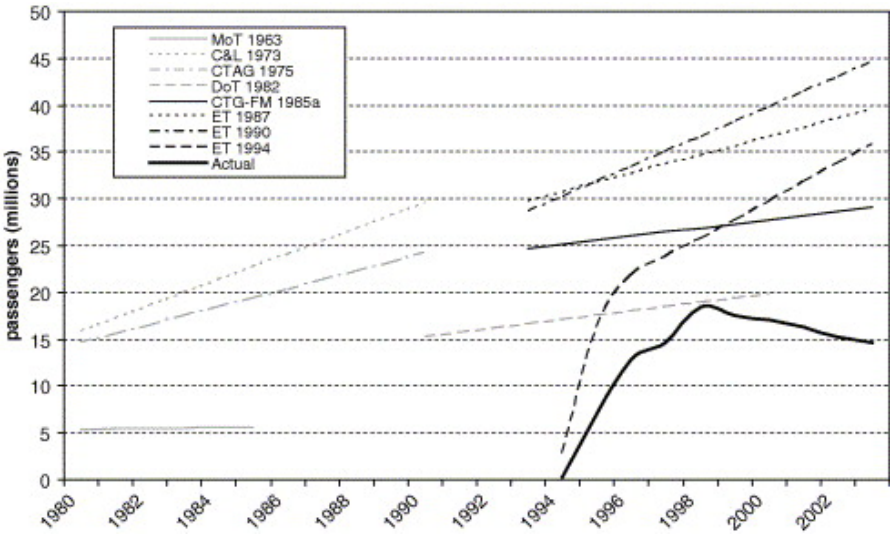

Figure 6: Channel Tunnel passenger traffic forecasts and actual results (millions of passengers).

The study remarks:

> *After the opening of the Channel Tunnel, the total number of cross-Channel passengers grew at a considerable pace up until 1998, at which point duty free was abolished. The market then began a process of regression, which continues to the present day.*

Luckily, as Figure 7 shows, the market began to improve again after this dip in 2003 due to the completion of Section 1 of High Speed 1, the high-speed railway connecting the British end of the tunnel to London. By 2014 the 20m passenger mark had been broken, but this is still far lower than what even the most pessimistic pre-construction forecasts by ET had predicted.

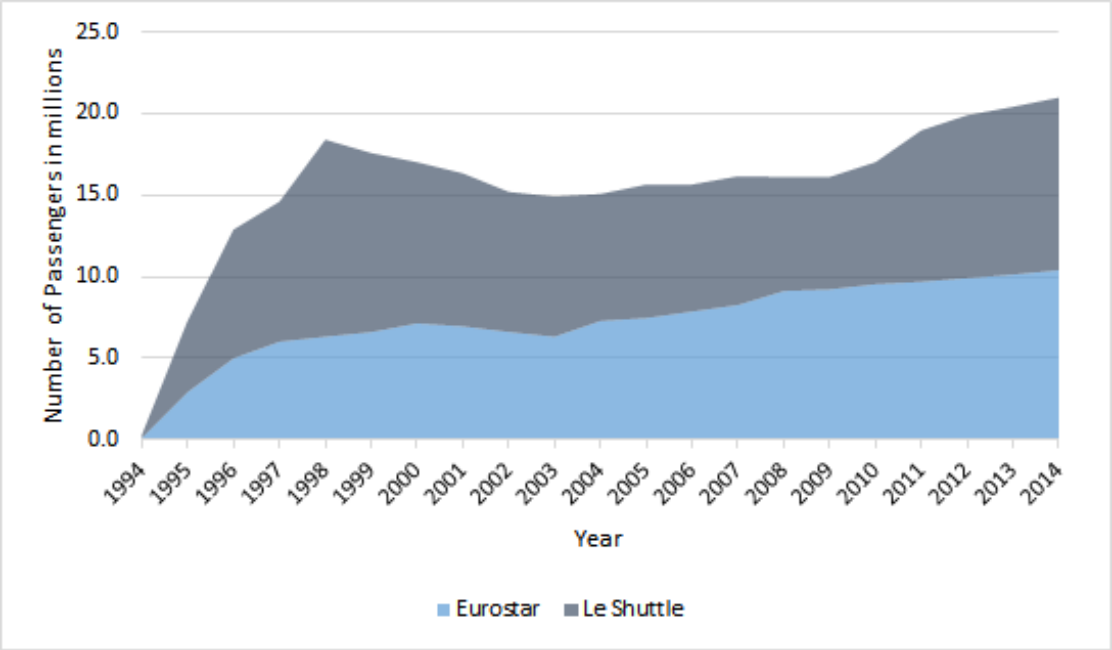

Figure 7: Actual Channel Tunnel passengers, 1994—2014

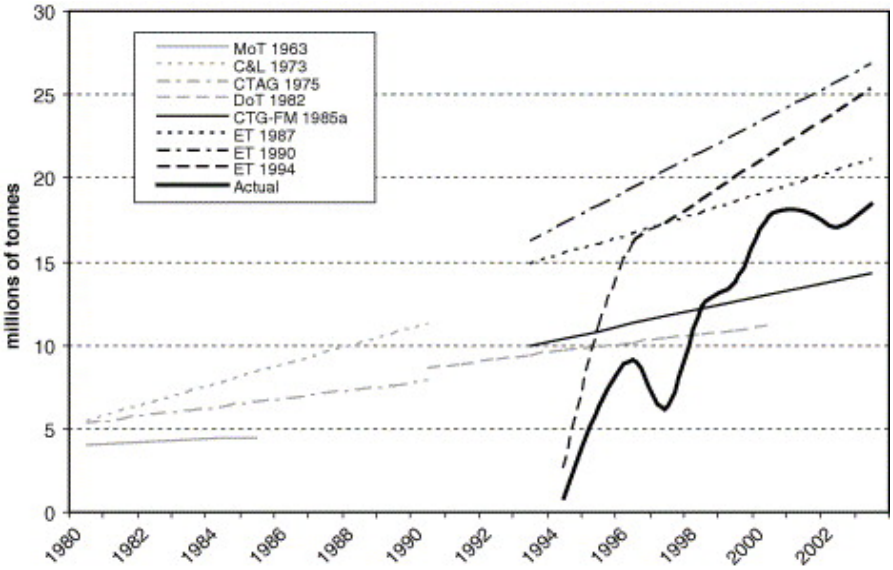

Figure 8: Channel Tunnel freight forecasts and actual results (million tonnes).

Figure 9: Actual Channel Tunnel freight results, 1994—2014

The erratic growth patterns of the freight figures compared to forecasts until 2003 can be seen in Figure 8. The drop in 1997 is due to a shuttle fire that closed shuttle sevice for a time. The volumes passed initial predictions in 1998 and approach 1987 estimates by 2003. They do not, however, reach the updated predictions of 1990 and 1994.

Examining the more recent figures in Figure 9, we see that growth has been relatively slow since 2003. Apart from the cutback following another shuttle fire in 2008, numbers have remained largely unchanged, barely surpassing the 20Mt mark in 2014.

Figure 10 shows Eurotunnel's revenue figures, both from its own Le Shuttle service and the money they receive from Eurostar's use of their rail line. This graph closely follows Figure 7 for the most part, especially in recent years.

Notable events include the termination of a contract in 2007 which provided Eurotunnel with approximately 70 million Euros per year as a guarantee of minimum income from Eurostar, and in 2012, the liquidation of SeaFrance, a trans-Channel ferry operator, and the redistribution of demand across the market along with aquisition of its assets by Eurotunnel.[10]

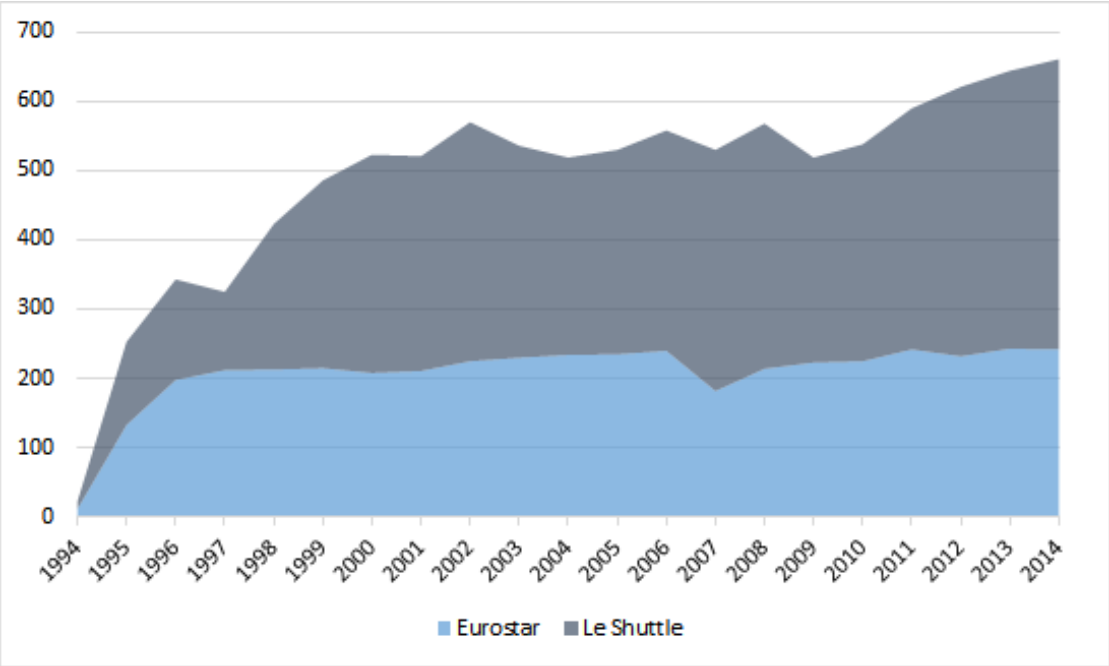

Figure 10: Eurotunnel revenue from CT-related sources, 1994—2014

4 Impact

In this section the effects of the Channel Tunnel on transport infrastructure and operations in both England and France will be examined.

4.1 England

The paper *The Impact of the Channel Tunnel on Kent and Relationsips with Nord-pas-de-Calais* by Hay et al. looks at the effects of the new transport link from an English perspective.

4.2 France

5 Conclusion

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