IMIA WGP 32(03)

HIGH-SPEED RAILWAY CONSTRUCTION PROJECTS

> ***"Whilst all passenger transport modes will reduce speed in the 21st century to save energy, only trains will reasonably be able to travel faster than today. High-speed rail travel will no doubt be the defining innovation of the 21st century"***
>
> ***Jean Albert GREGOIRE, Automobile engineer, in VIVRE SANS PETROLE (LIVING WITHOUT OIL), 1979***

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IMIA CONFERENCE 2003

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CHAPTER 1 - INTRODUCTION

All over the world high-speed rail systems are either being planned, are already under construction or are in operation.

Due to significant improvements in the quality of services the new railways have acquired substantial numbers of additional customers. In Europe train load factors are reaching remarkable levels, i.e. 65% in France, 66% in Spain and 51% in Germany. On core routes the new trains have even been able to overtake air traffic in terms of market share, for example 60% on the Paris – London route with the Eurostar.

There is no universal definition of ‘high-speed rail’. The term can mean anything from true high-speed operations on dedicated track to enhancements on existing track and can also include new technologies such as tilting trains.

Today, the 250 km/h threshold is maybe the right speed to name a train as a high-speed train.

The “High-speed” qualification really depends on the period under observation. For instance, the fastest London-Paris journey time has decreased by 50 % from 1914 to 2002.

Besides train-sets being able to run at high speeds, straight track or at least large radii are a prerequisite of high-speed operation over long distances. Maintaining the design criteria for the longitudinal gradient, track super-elevation and alignment are also important for successful and comfortable operations.

Examples:	Shinkansen	TGV	ICE	TAV
Operationnal Speed in km/h	260	300	250	300
Gradient in %	1.5	3.5	1.24	1.8
Min Radius in km	4	4	5	4

The existing railroad lines typically follow the existing topography and are characterised by tight curves and a mixture of freight and passenger traffic. The latter can also severely hamper high-speed operations.

Therefore, whenever possible and economically feasible new dedicated lines are the preferable alternative. In hilly or mountainous areas this leads to the necessity of the construction of numerous civil structures, such as tunnels, bridges, embankments and cuttings. Where the construction of new routes is not possible higher speeds can be achieved by upgrading of the existing line and the introduction of tilting trains.

Key factors for developing high-speed trains are safety aspects, ecological priorities and “door to door” concept.

In any event considerable construction work is necessary which requires significant investment.

CHAPTER 2 - OVERVIEW OF HIGH-SPEED TRAINS

High Speed in Europe

High-speed traffic is an important segment of the European railway system and is of great importance for the future. Rail services have been expanded greatly, in particular over the last years. In Europe, as of 2002, over 3260 kilometre new lines were in operation. In addition to the new lines, the European high-speed network also consists of upgraded lines and connecting lines. The existing networks will be developed further, with the emphasis on new line projects and inter-connections of the national networks. It is expected that by the year 2020 over 10,000 kilometre of new lines will have been put into service. More than 50 % of the high-speed network is operated in Europe.

The increasing number of links between high-speed systems will create a network effect. Work is well under way on the network linking Paris, London, Brussels and Amsterdam/Cologne. This also includes the important new line from London Ebbsfleet to the Channel Tunnel which should be completed this year. Integration of the individual networks is heavily dependent on projects in France. The extension of the South-East TGV (Train à Grande Vitesse) as far as the French-Spanish border will bring Spain into the network, whereas the planned Alpine crossing between Lyons and Turin will connect the French and Italian networks.

Extending the railroad network to Scandinavia will require building complex tunnels and bridges. An essential element is upgrading the Hamburg-Copenhagen line with a fixed link across the ‘Great Belt’. The decision in favour of a fixed link between Copenhagen and Malmö means that the high-speed network can be extended to Stockholm and Oslo.

France

In France, commercial operation of high-speed trains began in 1981 with the opening of the southern section of the newly-built South-East line. French National Railways (SNCF) started revenue service on the Atlantic Train à Grande Vitesse (TGV) line designed for 300 km/h in two stages (1989/1990). The Paris-Arras section of the new North TGV line was opened on 23 May 1993, followed in September 1993 by the extension to Lille and Frèthun/Calais at the entrance to the Channel Tunnel, adding 330 km of new line to SNCF’s high-speed network. Since 1994, this route is used by the new high-speed train Eurostar through the Channel Tunnel linking London with Paris and Brussels. The Eurostar belongs to the TGV family, but differs from the original version by its capability to use both British and French energy supply and signalling systems. In the future the East TGV will establish a link with the German ICE Network in Strasbourg.

For the future the operation of a double-deck TGV is being planned, which will offer 45 % more seating capacity without the need to upgrade infrastructure. This will substantially reduce operation costs per seat-kilometre. The operating speed will probably rise above 300 km/h.

Italy

High-speed traffic in Italy is provided by ETR 450 trainsets at a speed of 250 km/h. Its tilting body enables it to negotiate curves at higher speeds by “leaning into” the curve reducing need for new infrastructure. A hydraulic system governed by acceleration and gyroscopic sensors ensures that the passenger coaches make corresponding lateral inclinations in the transition bends. Shifting the train’s centre of gravity onto the inside of the bends partially counteracts the transverse acceleration so that higher speeds can be attained in bends. In this way, the speed can be increased by 30 % on parts of the existing network with much less investment than required for building new track.
These trains have been operating since 1988 on the new Direttissima line from Rome to Florence. A 90 kilometre extension to Bologna is under construction. 72 kilometre of this extension are in tunnels. Part of the connecting Turin-Milan-Verona-Venice new line is also under construction.

Spain

High speeds era began in Spain in April 1992 with the first traffic on the 471 km Madrid-Seville line. Unlike the rest of the Spanish rail network, this line was built to the standard 1,435 mm gauge. Consequently, all European high-speed lines have the same gauge. The Spanish high-speed train, the AVE (Alta Velocidata Española), is based on the TGV. Besides this train system, the locally developed Talgo trains also are operated on this line. The advantage of Talgo is that they can use the high-speed line for a fast run and then continue on conventional line because their wheel distance can be adjusted to the Spanish broad or standard European gauges. The Talgo system has a top speed of 220 km/h, the AVE has a top speed of 300 km/h. Partially completed and in operation is the new line between Madrid, Barcelona and the French border. This will connect to the South-East TGV, creating a link between Spain’s high-speed services and the European high-speed rail network.

Germany

High-speed rail service began in Germany in June 1991 with the market launch of the InterCityExpress (ICE) and the full opening of the two lines connecting Hamburg and Munich, one line going via Würzburg and Nürnberg and the other via Frankfurt and Stuttgart. On the newly built sections Intercity Express trains travel at scheduled top speeds of up to 250 km/h. The Berlin to Hannover high speed line was opened in 1998 and in August 2002 operations on the important 177 kilometre new line Cologne-Rhine/Main were inaugurated. With its 4% gradient it is dedicated to high-speed traffic only. Other lines presently under construction are Nurnberg-Ingolstadt, Karlsruhe-Offenburg and Cologne-Aachen routes. The ICE runs onto a network of 2000 kms. Only half of this network allows speed more than 250 km/h.

Although the ICE was only introduced in 1991, it has undergone further developments since then and has been considerably improved. The first trains had two locomotives and up to 14 passenger cars with a seating capacity of 723. The newly developed ICE 2.2 has a performance of 8,000 kW and reaches a scheduled top speed of 330 km/h. The innovation in the design of this new train is that there are drive units in all the cars, which distributes the weight evenly and permits greater acceleration. Some of these trains are built to use various power systems for international runs. The latest development is The ICE 3.

Germany has also developed a new high-speed train concept: this is the Transrapid. This technology comes from magnetic levitation. It needs pure dedicated track without the possibility to connect with the standard or high-speed European network. This concept has been successfully implemented in China, not in Europe, even if 2 projects exist in Germany (Ruhr and Baviera).

Japan

In the late 1950’s, the Japanese National Railways (JNR) launched a massive investment programme to increase its trunk line capacity, including construction of the Tokaido Shinkansen which was opened on 1. October 1964. It was the world’s first high-speed passenger railway, running between Tokyo and Osaka (515 km). With trains running at 210 km/h, the Shinkansen opened a new era by demonstrating the inherent advantage of high-speed rail transport.

The success of the Tokaido Shinkansen prompted its extension to western Honshu and northern Kyushu. The Sanyo Shinkansen was opened on 15 March 1972, and to Hakata on 10 March 1975. On 23 June 1983, the Tohoku Shinkansen was opened from Omiya (30 km north of Tokyo) to Morioko, and from Omiya to Niigata on 15 November 1983. The Omiya-Tokyo (Ueno) link was completed on 14 March 1985, and the Ueno-Tokyo link was finally opened on 20 June 1991.

The Shinkansen network today consists of four lines, totalling 1,800 km. It carries nearly 300 million people every year (810,000 every day). The maximum speed remained at 210 km/h for a long period, mainly because of noise problems. Today - after several technical improvements – the maximum speed on the Tokaido and Sanyo lines is 270 km/h.

New developments outside of Japan and Europe

In the Asian region, around 2,000 kms of high-speed roads are projected.

China

If there is one country that is concerned by transrapid technology, it is clearly China.

As stated above, the technology of magnetic levitation does not fit with the current other technologies. Indeed, China does not have any dense railway network, so investors can decide to set up new tracks without thinking about connections with existing tracks.
The first Transrapid line was inaugurated at the end of 2002 in Shanghai between the airport to the city centre. It is a 30 kms line and top speed reaches 430 kms/h. The total investment represents 1.3 billion Euros, i.e. more than 40 million Euros per km.
A second 180 kms line is foreseen between Shanghai and Hangghou, main city of the Zhejiang Region

Australia

In October 1993, the Australian Ministry of Transport announced that they would initiate a feasibility study on a high-speed railway between Sydney and Canberra. In the meantime, it has been finalised that the trains for this high-speed project will be standard TGV trains, the only exception being a new body shape (Thalys) for the power cars. The route is 326 kms long and includes part of the rapid transit railway planned and surveyed previously to connect Sydney with Melbourne. The new line starts from Sydney station, runs on an existing New South Wales line, and then on a completely new line to reach Canberra in 1 hour and 15 minutes instead of 4 hours and 40 minutes as at present. Nevertheless, this project has been delayed to at least the end of 2004.

South Africa

What principally distinguishes South Africa from other sub-Saharan countries, is its infrastructure system. It has more paved roads, railways, and generates more electricity than the rest of Africa combined.

Undoubtedly South Africa could greatly benefit from high-speed travel. At this stage they are concentrating more on freight logistic solutions and often use slow diesel trains, sometimes even steam engines, which are polluting and are inefficient. Perhaps passenger transport would be the key to getting development going in the high-speed field. Contrary to the existing relatively slow passenger trains (e.g. the luxury Blue Train), high-speed cruises could be offered in the future. Business people could also use this high-speed infrastructure with the fares going directly into infrastructure, enabling further developments.

In 1988 feasibility studies on two high-speed railway systems, namely between Pretoria/Johannesburg to Cape Town and Johannesburg to Durban were carried out. The travelling time from Johannesburg to Cape Town would be reduced to 4 hours, but not being economically viable (US$ 35 bn), is was archived, hopefully to be revived in the near future.

Taiwan

With a population of approximately 20 million Taiwan is in severe need of state of the art public transportation systems. The country has only 1,000 km of existing railway services and the express trains now in operation are old and not fast (120 km/h).

To overcome the lack of capacity on the vital route between Taipei and Kaohsiung, construction has now begun on a 345 kilometre high-speed line connecting both cities in 90 minutes in October 2005. The invested amount is around 4.6 billion US Dollars, i.e. around 13 million Euros per km.

The rolling stock technology is based on the Shinkansen with planned maximum up to 300 km/h. An interesting aspect of this project is that 157 Kilometres will be on a continuous viaduct and 61 kilometres in tunnels. The total cost of this project is estimated at US$ 17 bn.

Korea

The most important transport route in Korea is the Seoul-Pusan axis, of which the railway has a high share. Many large and medium-size cities are scattered along this route, and the number of railway passengers is increasing remarkably every year. The existing train on this line connects Seoul to Pusan in 4 hours and 12 minutes. The passenger cars are hauled by a diesel locomotive at 105.8 km/h scheduled speed (maximum speed: 140 km/h). Because the Seoul-Pusan line is operating at almost full capacity, construction of a high-speed railway with a maximum speed of 300 km/h has begun. The first phase from Seoul to Taegu is scheduled for completion in 2004 with completion of the whole line expected by 2008.

CHAPTER 3 – HIGH-SPEED RAILWAY PROJECTS AND EXPERIENCE

3.1. Building a high-speed railway step by step

➢ Average construction costs

The average construction cost for a new high-speed railway is from Euros 10 Millions to Euros 40 millions. It depends not only on the technology but mainly on the relief of the landscape. If there are a lot of hills and mountains, then there will be more tunnels and bridges to be built.

Average construction costs for tunnels are the 8 millions per km, Euro 16 millions per km for bridges, Euro 1 million per km for superstructures, Euro 1,5 millions per km for signalling systems and Euro 1.2 million per km for Power supply.

In average, the amount of money invested in a high-speed railway project can be divided as follows:

40 % for civil works
20 % for tracks and railworks
15 % for earthworks
10 % for electrification
10 % for signalling and communication
5 % for other

Of course this split depends on the relief of the landscape.

➢ Earthmoving

Earthmoving is the first step of a high-speed railway construction. Initially, preliminary analyses are carried out using thousands of test bores to identify the geological nature of the ground, its geo-technical characteristics and the presence of cavities. Hydraulic studies are run on the catchment areas of all water courses, regardless of their size, in order to measure the impact the high-speed line would have on waterflows, and remedy it.

To build embankments, the material extracted from cuttings is generally recycled as far as possible, treating it where necessary. This limits the number of new quarrying operations, which are always difficult to manage in environmental terms. Compressible zones, where embankments (especially the very high ones) can settle to a considerable extent, call for special treatment in the form of preloading and drainage.

Flood risk areas, where the high-speed line could be subject to flooding, require a large number of bridges and viaducts to be built so that there is no measurable impact on water-flows at these locations. Million of tonnes of armour rock also have to be deployed, and many reservoirs built.

In seismic areas, special measures need to be taken to cope with the liquefaction of certain types of soil formation during earthquake.

In the limestone massifs, natural cavities have to be detected and treated.
Special structures to enable the passage of wild animals have to be built.

Ballast

Ballast is anything but ordinary stones you break up, especially when you are talking about TGV ballast. It provides the durable elastic support for dynamic interaction between soil and train loads. It is an aggregate with specific characteristics and is the outcome of an industrial manufacturing process. This provides the ballast with its geometrical characteristics (shape, maximum and minimum size) and very precise cleanliness characteristics that are standardised and set within strict tolerances. But even that is not enough to manufacture TGV ballast. In addition to all of this, the quality of the rock used to make the ballast has to give it, as part of its so-called “intrinsic” characteristics, very high hardness and resistance to abrasion, also in compliance with a very detailed specification.

Rails

Rails are UIC standard section, 60kg/m.
As a safety factor, rails undergo very stringent testing and inspection.
Their chemical make up and dimensions are based on very strict specification and tolerance down to a few tenths of a millimetre.

It is now possible to turn out from factory continuous welded rails 400 meters long using standard 80 metre lengths of rail supplied by the steel industry.

Sleepers

Travelling at 300 km/h not only calls for a considerable mass, but also millimetre geometrical tolerances and a fastening anchor strength that can only be delivered by concrete sleepers. Not only that, but the sheer scale of the volume requires faultless manufacturing logistics to guarantee deadlines and flawless quality.
Sleepers are generally twin black reinforced concrete (2,4m wide), equipped with insets for fasteners and rubber pads.

Construction of the track

For the operation of a high-speed train, the most sensitive point is the track.
The track laying process is not particularly specialised to high speed lines: the same technique is applicable to modern track laying using continuous welded rails; TGV tracks, however, answer to stringent requirements for dimensions, materials and tolerances.
When most of the civil contractors have sufficient technical knowledge and equipment to bore tunnels, to build bridges or to compact a bank, there are only a few contractors all over the world to master the laying of an uninterrupted rail with lengths over hundreds of kilometres, or to incorporate points in such a track that a train may safely

negotiate at 220 kilometres per hour. The reason there are few contractors mastering the technology is there are very few trains all over the world operating at high speed. Consequently few contractors have gained experience. As the market is very limited, also only few contractors have invested in the proper equipment specific to high-speed track construction.

How do the contractors operate?

First of all, there is a taking over of the trackbed from the civil contractors to the track contractor after severe tests, such as hardness tests (the trackbed is compacted with improved gravel material).
Then a temporary track without ballast is installed directly on the bank, at the location of one of the two definitive tracks. This track measures 7 to 8 kilometres. This temporary track is used to unload the rails by lengths of 400 meters all along the 7 to 8 kilometres.

Then the temporary track is substituted by the definitive one and, using this new definitive track, the second definitive track is constructed. Rails are welded to each other without discontinuity. Laying of the ballast starts now by successive layers of 8 centimetres each with heavy compaction between each layer, up to a minimum thickness of 35 centimetres measured between the bank and the bottom of the sleepers.

Then a work train brings the sections of continuous welded rails and places them (by special crane) on each side of the temporary track; for the next step, a gantry train rides on these 2 rails and proceeds with unloading the temporary track elements and placing TGV Sleepers at proper spacing (60cm); a special gantry crane is then used to lift the rails and place them onto their final position on the sleepers.
Rails are welded together using thermite process (mix of aluminium powder and iron oxide) with aluminothermic welding machines equipped with a saw and a grinder.
Laying of the ballast starts now by successive layers of 8 centimetres each with a ballast train (temping/lining/levelling machine) which forces the ballast under the sleepers up to a thickness of 32 centimetres, with a millimetre precise alignment of the rails.
Before the rail is joined, its length must be adjusted very accurately to ensure that thermal stresses in the rail do not exceed certain limits. This operation (called “liberation of the rail”) consists of a simulation of a temperature rise of the rail up to 25° Celsius (this limit has been calculated for the western Europe climatic conditions). Of course, if the ambient temperature is equal to these 25° C, there is no mechanical action to apply to the rail before welding. If the ambient temperature is superior to this limit, one should wait until the temperature comes down at night. If the temperature is inferior to 25°C, the rail is elongated using hydraulic jacks with a force which is calculated to simulate the condition of the rail at 25°C , the rail is elongated using hydraulic jacks with a force which is calculated to simulated the condition of the rail at 25°C and the rail is clamped to the sleepers at a predetermined torque value.
Thus, thermal stresses due to variation of temperatures are absorbed without longitudinal strains allowing for the rail to be uninterrupted, one piece, for hundreds of kilometres without snaking despite changing weather conditions.
When the first track is complete, works begin on the adjacent track, directly with work trains running on the first track.

The points are also very critical to install. There are even fewer contractors mastering the fitting of the points than contractors able to lay tracks. The points are pieces 156 meters long allowing the train to negotiate a change in direction at 170 kilometres per hour or even longer, 222 meters long allowing a speed of 220 kilometres per hour (the train may run full speed on the straight line).

An incident without consequence had been reported long ago during the construction of the link Paris to Lyons. The quality of the ballast used on a small section did not conform to the specification in terms of hardness. This was due to a rupture in the supply of adequate ballast and the imperative date of inauguration of the line. A non-conform ballast had been used to allow the track to be delivered in due time. The defective ballast had been replaced without any damage having been reported. The insurers must be sure that the technology is well mastered by the contractors in charge of the track and the points.

Construction of the catenary

There is nothing particular in regard to the installation of the catenary. The technique used is the same as for a conventional train.

The contractors may work using the track after construction. Recently they have opted for an installation of the pylons supporting the catenary from a road aside the bank and prior to the construction of the track. The overhead contact line is pulled afterwards using a special train on the track recently built. No major loss has been reported regarding this activity

The catenary, which is in direct contact with the high-speed trains via its pantograph, demands watchmakers – precision for its settings.

Electrification work for the 2 x 25 kW system powering a high-speed line calls for a hundred percent rock solid organisation. The execution studies have to begin about a year before the actual electrification work starts so that the equipment used can be delivered and made ready at the assembly point before being set up on the line itself.

The foundations for the catenary masts, mast positioning and concreting the foundations all take place after the track has been laid using works trains custom-designed for this type of project.

The earth and feeder cables are paid out before the conductor configuration is completed, before the catenary and contact wires are strung and the final adjustment of droppers and catenary line tension. Electrification of isolated points such as road bridge and protection grilles is carried out off track.

Electrification work consists of six main operations that take place in a fixed sequence. First the foundations are dug and the masts erected (generally one beam each 63m). Next comes the simultaneous paying out of the earthing cable and the feeder, after which come the mast brackets and gantries, the paying out of the catenary (65mm 2/14 kN tension) and contact wires hard copper 120 mm2, the positioning of the headspan droppers, and the final adjustments.

Testing

High-speed railways are declared operational after a series of tests and trials have been performed, designed to ensure that plant and equipment are functioning properly. Above all, one must ensure that track laying and geometry meet the highest quality standards both for service safety and passenger comfort.
Also, power take-up must be good in order to ensure a constant supply of electricity to the High-speed transits. Consequently, to make any final adjustments and identify remaining defects, services are systematically being scheduled on all routes available on the new line at speeds above commercial operating speeds, for example, 330 km/h for a 300 km/h operating speed. Lateral and vertical acceleration sensors are fitted to the power car and trailers for recording “track” parameters. Surveillance cameras are mounted on the roof areas to monitor electricity collection quality. There are also tests on acoustics and wheel rail interaction stresses.

3.2. Experience with Heathrow Express Rail Link

Project Description

The Heathrow Express Rail Link provides a high-speed passenger service from Paddington Station in London directly to London Heathrow Airport. The link includes a new dedicated rail connection, mainly in tunnel, from a junction with the existing rail network to the airport terminals. The tunnels pass beneath runways, roads and buildings. The method selected to construct twin platform tunnels and access tunnels within the new Central Terminal Area was the New Austrian Tunnelling Method (NATM). Also included was compensation grouting in certain sections, aimed at limiting surface settlement.

Loss Experience

A major collapse occurred during the construction of the tunnels in October 1994. Workers were evacuated from the tunnel just before the first collapse and no injuries occurred. Major disruption was caused to the airport and the project was severely delayed as a result. Losses (including both insured and uninsured losses) are estimated to have been as high as 400 million GB Pounds (€600 million Euro). The tunnel collapse is considered to have been ‘one of the worst civil engineering disasters in the United Kingdom in the last quarter of a century’. The delay in start up was evaluated at around 14 months due to this event.

Extensive investigations were carried out following the tunnel collapse. The report prepared by the Health and Safety Executive (HSE)[1.] identified the direct causes as being: substandard construction over part of the tunnel length, damage to the tunnel by grout jacking, construction of a parallel tunnel in failing ground. These led to major structural failure in the tunnels and progressive failure in the adjacent ground.

Loss prevention - Lessons learnt and recommendations

The above HSE investigation concluded that the NATM tunnelling method itself was not at fault, taking into account the ground conditions at the tunnel location, and that tunnelling could have been carried out without incident.

The major reasons for the collapse were: ineffective quality and safety management systems, lack of adequate engineering controls and monitoring systems and lack of an adequate level of care.

New or unfamiliar technologies bring added risk, which needs to be assessed and managed. Production pressures need to be balanced with satisfactory checks and feedback from monitoring systems must be in time to prevent danger and losses. All parties responsible for the project’s success must have a strong commitment to maintaining high levels of health and safety management.

[1] – the collapse of NATM tunnels at Heathrow Airport – UK Health and Safety – Executive 2000 – ISBN 0 7176 1792 0)

Insurers need to be proactive at all stages in promoting, supporting and monitoring the risk management undertaken on High-Speed Rail Projects. With the insurance approach to loss prevention, experienced engineers from their risk services team provide input with the aim of securing high levels of risk management on insured projects; both when underwriting is carried out and during the construction period. Risk services engineers provide advice and support to insured clients, making visits to projects at key stages to carry out risk surveys. This allows insurers to gauge whether levels of risk management are adequate, and to take appropriate action. Assistance is provided to clients through loss prevention advice that is fed back to them by risk services engineers, following risk surveys.

Where tunnelling is involved, as is often the case on high-speed rail projects, then the associated risks require particular attention. For instance, the new Tunnelling Code of Practice, being published by the Association of British Insurers and the British Tunnelling Society [2.] provides guidelines for achieving the high levels of risk management needed on these projects. This Code aims to promote and secure best practice for the minimisation and management of risks associated with the design and construction of tunnels and other underground structures. The Code sets out practice for the identification of risks and their allocation between the various parties and contract insurers, and also how these risks are to be managed and controlled.

In conclusion, the Heathrow Express tunnelling incident highlights how safety and control of risk are intimately bound up in quality, engineering, management, procurement, organisational arrangements and consideration of human factors. High levels of risk management, by which all risks to projects are identified, analysed and properly handled, are essential.

General loss experience from tunnels building

From a study of Munich Re about 107 important tunnel claims during the last 10 years, 10 % of the loss amounts come from fire, 50 % are issued from natural events, 25 % come from construction methods, and only 10 % come from design defaults. Another study about the last 20 years shows that the average amount of important claims is around Euros 2 millions.

The most important tunneling claims coming from high-speed railway projects are the Heathrow Express Link Claim (presented above) the 2 claims from the TAV Bologne-Florence link (Euro 3.6 million in 1999 and Euro 5.6 million in 2000)

[2] – Joint Code of Practice for the Procurement, Design and Construction of Tunnels and Associated Underground Structure – 2003 – The Association of British Insurers and the British Tunnelling Society.

3.3. Channel Tunnel Rail Link – Section 1 the Channel Tunnel to Fawkham Junction.

Project Description

The Channel Tunnel Rail Link (CTRL) is being built by London and Continental Railways Ltd. who hold the Government franchise to build and operate the CTRL. It is the United Kingdom's first major new railway in over a century and provides a high-speed line running between the Channel Tunnel and St Pancras station in London. The CTRL is being constructed in two sections. The 74 km long Section 1 of the CTRL passes through mainly rural areas of Kent, between the Channel Tunnel and Fawkham Junction. Begun in October 1998, Section 1 is due to be completed in 2003 at a cost of 1.9 billion GB Pounds (€ 2.8 billion Euros), almost Euros 40 million per km.

Loss Experience from Section 1 of the CTRL

Whilst the first section of the project has generally gone well, there have been some insured losses. These were mainly from damage whilst earthworks were underway during a period of particularly high rainfall. The winter of 2000/2001 was the wettest since records began 200 years before. In this period, prolonged rainfall led to ponding in some partly constructed earthworks sections, causing damage to completed formations; there was also erosion of slopes in some places. Due to strict environmental requirements, some flooded areas could not be drained quickly due to the effects that floodwater and silt would have on local watercourses. Resultant claims, which have included certain consequential costs, have been in the tens of millions (Euros).

Loss Prevention - Lessons Learnt on Section 1 of the CTRL

With increased environmental performance comes a corresponding need to include environmental compliance in the risk management that is undertaken. Planning of earthworks needs to minimise exposures to storm damage and ensure that slopes are protected as early as possible with earthworks formations left exposed for minimum durations where these are susceptible to storm damage. Temporary earthworks drainage needs to be carefully planned to take account of likely storm flows and be designed to meet environmental requirements under peak storm flows.

High levels of risk management have generally been achieved by the various parties involved in this very large and complex project. The Client's approach to properly handling risk at all stages including: advance detailed planning (including construction methods), careful selection of Contractors, non-adversarial partnering arrangements with a form of Contract encouraging high levels of risk management, active supervision of the design and construction processes, has contributed to the success of the CTRL project to date. Insurers have supported the risk management undertaken during Section 1 of the CTRL, providing risk control specialists to carry out risk surveys and advice on loss prevention measures.

CTRL Section 2

Progress is already well advanced on the 3.3 billion GB Pounds (€4.8 billion Euros), 39 km long Section 2, i.e. more than Euros 100 million per km (because of building 3 new stations) which will take the CTRL beneath the River Thames and through North London to St Pancras (mainly in tunnel). This section is scheduled for completion in 2007. When all sections are opened, the journey times from central London to the Channel Tunnel will be halved. There will also be high-speed connections for commuters in and around London, with the creation of three new international stations at St Pancras and Stratford in London, and at Ebbsfleet in North Kent.

3.4. French TGV in the North of France

Project description

The North region of France has sustained heavy sapping and bombing during the 2 world wars. Theatres of operation were mostly in the Champagne and the Picardy areas. After the wars, the trenches and bombs craters were filled with all kind of stuff, from old guns and canons to military cars and trucks. In and around Paris, the subsoil has been extensively worked, not always legally, to extract limestone or clay and many galleries have been abandoned without caring about what could happen above later. It is above those kinds of subsoil that the High Speed Line from Paris to the cities of Lille, Brussels, Amsterdam, but also Calais and the UK, has been constructed. Geological soundings have been conducted according to a predefined grid probably too wide meshed and some reinforcing works have likely been executed.

Loss experience

In 1993, while running at the full speed of 300 km/hr, the passenger train had suddenly left the track and heeled over. Fortunately, thanks to the technology used for this train, the full train remained assembled and no fatal injury was involved. A sudden subsidence of the bank had been found to be the cause of the accident. As some people were injured, a legal case was opened and the experts have concluded to a fault from the owner, the French national railways company (SNCF). The French State being its own insurer, the Contractor’s CAR insurance policies were not damaged. The subsidence was due to a decompacted subsoil. The area escaped to the geological soundings. The photos taken by the pilots of the RAF during and after the wars show craters from heavy bombings at the exact location of the accident. More than soundings, a better public enquiry should have avoided this spectacular and costly damage

Loss prevention – lessons learnt and recommendation

The lesson to gain from this accident is that in addition to the soundings, the inhabitants in the areas covered by a project must be questioned on what could have happened in the past in their region. Have quarries been exploited legally or not, have heavy bombings being endured, have floods been observed, and so on. All kind of archives have to be examined.

To avoid reoccurrence of this type of accident which could be disastrous, the French Railways have developed a system of surveillance from an helicopter. The fresh movements of the soil can be detected and preventive measures to avoid accident may be undertaken.

The construction of a bank crossing a wide area and, like a dam, preventing the rain to be drained from the upper lands to the sea may cause heavy problems if not sufficiently taken into consideration. Actually, without proper drain works, the side of the bank exposed to the flow of water will be sapped by the water while the other side will dry and the soil will lose volume which will lead to subsidence of that other side of the bank. To prevent this double negative effect, rainwater passages must be provided all along the bank.

CHAPTER 4 - UNDERWRITING ISSUES

The underwriting of high-speed rail projects involves an understanding of a multitude of different exposures. This, combined with the sheer size of some of these projects, provides a distinct challenge to the underwriter in ensuring a clear picture of the risk is formed.

Underwriting profit is the goal. If this is to be achieved then the approach must be to involve all areas of expertise available to the underwriter. This means using risk management engineers to help the underwriter assess technical risks, PML scenarios, experience of the project team and the inherent risk management culture of the project. Claims colleagues may also provide valuable experience of losses on past projects.

The following aspects represent key underwriting issues:-

1. Duration of project

- Usually in excess of 5 years therefore exposing the project to multiple repeat seasons and thus an enhanced natural perils risk which should be factored into rating.
- Consider the exposure to an insurer’s balance sheet of risks written in an earlier underwriting cycle when reduced rates, wider coverage, lower deductibles and weak risk management may have been prevalent. This, combined with the potential volatility of losses presented by large exposures to the modest Engineering accounts of insurers means that review clauses should never be discounted as a prudent underwriting measure.
- Reinsurance treaties will usually provide protection on a ‘contracts attaching’ basis and will help to smooth the net result, the extent of which will depend upon whether proportional or non-proportional cover is obtained. Reinsurance costs and conditions will need to be factored into the underlying terms for the project.

2. Experience of project team and Risk Management culture

- These are arguably the most important factors when underwriting a high speed rail project.
- The experience of the contractors in high risk works such as tunnelling is paramount.
- At the same time there should be a partnership approach to risk management rather than contractors operating in isolation. An effective project manager should be in place to coordinate implementation of risk management protocols between the various contractors and sub-contractors. The insurer will support this by concentrating on technical implementation.

3. Structures

Modern high-speed rail transport calls for large radii or track that is almost completely straight (although tilting train technology will help to reduce this requirement and, in turn, the cost).

This makes it necessary to construct new routes comprising many civil engineering structures or features such as bridges, tunnels, embankments and cuttings, the extent of which depends upon how uneven the topography is and any environmental considerations.

4. Natural perils

Earthmoving and ballasting works are particularly prone to storm and flood. The extent of temporary works protection is key, particularly for works in proximity to water with 1 in 20 years frequency protection a recognised minimum requirement of insurers.

Projects located in high intensity earthquake zones and tropical storm areas will undoubtedly test natural catastrophe capacities available to insurers. Sub limits will usually apply combined with specific deductibles. Tracking of exposure is important as ‘nat cat’ accumulation reinsurance will invariably be written on an annual ‘losses occurring’ basis.

5. Tunnelling risks

- The experience of insurers and reinsurers with various tunnelling collapses has led to the development of the ‘Joint Code of Practice’ in the UK (see previous comment). Risk registers are an important feature and provide a valuable tool in support of insurers’ risk management monitoring.
- Prudent underwriting should support a joint risk management approach. The level of deductibles and rates will be determined by the exposure presented by ground conditions, tunnelling method and loss limit The latter point is a recent development and recognises the fundamental problem with underwriting tunnelling risks ie. recognising the exposure with respect to additional reinstatement costs in the rating, such exposure traditionally representing the major part of past claims. Munich Re clause 101 seeks to apply a percentage limit of the area immediately damaged to cater for the additional costs of reinstatement but this in itself does not provide an easy mechanism for rating.
- An alternative approach would be to request that the client establishes the most likely reinstatement method in the event of a catastrophic collapse and the associated likely cost. A monetary loss limit can then apply which recognises both damage to the tunnel and the additional costs of reinstatement. This way, a proper assessment of exposure has been agreed and the underwriter has a sum on which to charge for the additional reinstatement as well as for the actual physical damage to the tunnel represented by the contract value.
- Tunnel boring machines (TBMs) represent another major exposure. The risk of plant becoming immobilised due to unforeseen ground conditions / operator error and possibly abandoned as a result is a trade risk usually excluded by

insurers. Fire is another key hazard and the quality of fire suppression systems should be investigated.

6. Track laying

This can involve specialist equipment and the use of rolling stock to transport ballast and other materials.

7. Fire

The heavy civils exposure should not detract from the fire risk, principally at stations (but also with respect to TBMs, as mentioned above). Again, in response to various high profile fires in the UK including the London Underwriting Centre loss of circa 100m GB Pounds, a joint industry / Association of British Insurers' risk management initiative resulted in the development of a Joint Code of Practice document on fire prevention, issued in 1992. Non compliance with the code's requirements allows insurers to suspend or withdraw cover. The principles of this document have also been used on international projects.

8. Testing and commissioning

Technological advances inevitably increase the risk of defects in design, materials and workmanship. Careful risk assessment and underwriting to limit the insurer's exposure to serial losses and impact of train sets is important. Significant deductibles will usually apply.

9. Third Party Liability

- Environmental aspects form a major consideration with tunnels often the only option in ecologically sensitive areas.
- Tunnelling in urban areas has its own concerns in respect of potential damage to surface / sub-surface property including infrastructure and utilities. Vibration, subsidence and removal or weakening of support risks should be carefully assessed and schedules of conditions obtained.
- Consequential losses due to interruption of existing rail services can be considerable. The interface works will therefore require close examination.

10. Delay in Start Up

- The involvement of private finance in the funding of high speed rail projects in most countries has increased the demand for financial protection.
- Generally, financiers are dependent upon the completion of the project on time and the consequent revenue generated to service and repay the debt. For this reason they are frequently insured in joint names alongside the concession company / employer.
- Insurance against loss of revenue following physical loss or damage occurring during construction is therefore an important aspect in negotiations with the financiers to fund the project and forms a key element of the project cover.
- Factors such as adverse weather, unforeseen ground conditions, strikes and other factors can cause delay without any material damage loss. Progress monitoring is vital to examine the programme and critical path activities against progress to determine slippage due to insured or uninsured events.
- Lead times for TBMs and train sets inevitably present particular considerations with respect to critical path.

11. PML

- This will normally be represented by a station fire, tunnel collapse or natural catastrophe. The contract risk register may help in assessing key risks.
- An assessment of material damage / revenue stream scenarios is important. A worst case material damage loss eg. fire in a major station, may not necessarily have the worst result on revenue if trains can be routed elsewhere. However, the collapse of a bridge or tunnel on a remote country section may actually result in a lower works' PML but high revenue loss. An examination of contingency plans at an early stage will help determine a final combined PML.

To summarise the underwriting perspective it is clear that the size and duration of such projects with the accompanying mix of exposures presents a challenge to the most disciplined underwriter. Volatility of losses is the major danger to the achievement of an underwriting profit but by attending to the following basic disciplines insurers can hope to achieve acceptable loss ratios:

- Treat each part of the work as a sub-project for underwriting purposes;
- Pay attention to the above key underwriting issues;
- Demonstrate strength of rates, deductibles and conditions, that recognise technical exposures, past experience and reinsurance costs / cover;
- Develop an integrated risk management programme supported by all parties

CHAPTER 5 - CONCLUSION

The renaissance of the railways presents new opportunities for engineering insurances due to the new technologies, new construction methods, new structures and new types of machinery required.

However, much care is taken in the planning and building of these structures. There will always be a residual risk for the principal and the contractor. To assess and evaluate this risk is a difficult task – due to the large bridge spans and length of tunnels involved – and to provide cover for these risks is a challenge to the insurance industry.

On account of increasing privatisation, the insurers may be required to provide insurance cover not only for Contractor's All Risk, Machinery Breakdown and Third Party Liability, but also for Civil Engineering Completed Risks.

Despite the Speed Record by the French TGV of a whopping 515 km/h these speeds are not really viable commercially at the moment for a number of reasons. First of all, all pantographs have to make contact with an overhanging wire, when travelling at such speeds vibrations are immense. Also the dynamic pressures experienced by the track are overwhelming, and they would be worn out much faster, other than changing the physical size of the rails there is not a lot that could be done. Also there are a few other things, tracks and train wheels need to be absolutely perfect in order to run at such speeds. Already lasers are used in France to place sleepers millimetre by millimetre to ensure perfect straightness. However, wheels must be perfectly round too, and that is another problem. So going over 450 km/h in the near future seems unrealistic.

The problem is that the faster trains go, the greater the resistive force in terms of air resistance they face. The amounts of energy that have to be used to contract this force which at speeds over 320 km/h can amount to several tons. To counter this force vast amounts of energy must be consumed. The whole environmental point about trains is that they use up a lot less energy (and therefore pollute a lot less) than the equivalent number of cars on the road. If they go faster than 320 km/h they may start to lose this advantage and may even become more costly in terms of energy use than the car, like the aeroplane.

Many people see the future of transportation, being in Magnetic Levitation trains. These are trains that « float » on a magnetic field, and are propelled by electromagnets. This would eliminate physical contact anywhere, so no wearing out would occur, and there would be the capability of reaching aircraft speeds.

Germany, and Japan have both developed magnetic levitation systems. Their experiences suggest that magnetic levitation is technically feasible. China is the only country at this stage with an operational link.

Another technology is currently developed by Bombardier to be installed in North America. That is the Jet Train prototype. Equipped by a gas turbine, this tilting train can reach a speed of 240 km/h on non electrified railways, frequent in the United States (less than 1% of lines are electrified).

Development is never static. If the Transrapid system holds its own, there will be further major opportunities in store for the insurance market.