Economic Analysis of High Speed Rail

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Purpose and Methodology

This research is carried out to take a wider look at the economic aspects of high speed rail, mainly in Europe, and its contribution to the economy, society and etc. The main purpose of this research is to explore and analyze the main costs of building a high speed rail line such as infrastructure costs, operational costs, rolling stock investments and other relative costs that may occur. This report also aims to identify the intermodal and socio-economic impacts of high speed rail and also take a look at some indirect and wider impacts of high speed rail such as increase in total welfare and growth of the GDP. Finally, this reports looks at the Channel Tunnel that links the United Kingdom to France as a case study.

Generally, this paper aims to answer the following questions:

- What are the costs of constructing and operating a high speed rail line?
- What impacts have high speed rail services had on the regional and European economy?
- Considering the extreme costs of building high speed rail infrastructure, is it possible to compensate these costs only from passenger revenues or is external support needed?

The research methodology in this report comprises comprehensive literature review, mainly internet material. These materials consist of books, journal articles, conference proceedings, reports published by different authorities and universities such as NSB Norway, Jerbaneverket, and actual cases from different countries around the world. I have tried to use a wide variety of literature to enrich this report as much as possible.
Introduction

There is lots of difference of opinion between different researchers regarding estimated and actual costs of transportation infrastructure. This difference is because every study uses a specific sample or samples which leads to even opposite opinions in different studies. For instance, Ubbels and Nijkamp (1999) believe that the estimations are almost correct, while Pickrell (1990) claims that cost estimates are highly inaccurate. Flyvbjerg (2002) argues that costs are underestimated in 90 percent of infrastructure projects. So the question arises that who is right and what policy and decision making procedures should be implied regarding transportation infrastructure development?

To answer this question, different aspects of transportation costs and the growing speed of high speed rail should be considered. According to Bruinsma (2008), high speed rail has developed rapidly since 1990. The ridership has increased 500 % between 1993 and 2003. This significant development requires the investor to consider reconnecting the urban system development to the railway network, which leads to the increase of transportation costs and makes the cost estimations more complex.

Cowie (2010) believes that while elasticity of demand impacts upon the demand side of the market, a major factor affecting the quality supplied is the cost of production. Transportation costs fall into different categories. For instance, there are costs referred to as public costs which affects the individual user of a transport mode who benefits directly from using that mode. Public costs are a significant factor in provision of transport services. There is also another category referred as financial costs. These costs are in terms of capital and operating costs, and they need to be in line not only against the financial gains, but also against wider public benefits.

We will study the Channel Tunnel as a case. According to Anguera (2005) from the London Strategic Rail Authority, the total size and growth of the cross channel market both in terms of passengers and freight was significantly overestimated. The authorities managed to predict the share of the market captured by the tunnel quite accurately. However, this was reached by engaging in a competitive battle with the ferry operators which led to reduced fees for
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both the tunnel and the ferry operators and decreased the revenues to a much lower level than estimated. Moreover, for technical and some other irrelevant reasons, the costs of constructing the tunnel doubled.
1. A Review of HSR Experiences around the World

High Speed trains are one of the most advanced modes of transport since the Second World War. However, construction of high speed rail lines are very expensive and have a significant sunk cost regarding the infrastructure, while estimating the financial and social impacts of it are rather difficult. So considering the studies undertaken on the economic, transport and regional development impacts of constructing a new line is necessary. In this thesis I review the development of the world’s HSR network, and summarize the literature which has examined this impact of technology.

The first high speed rail line in Japan called the Shinkansen was built around 47 years ago in time for the Tokyo Olympic games in 1964 (Hideo, 2003). The Shinkansen linked Tokyo to Osaka in approximately four hours at a speed of 220 KM/H. At the time, the Shinkansen was the first train linking Japan’s two most major cities with a speed above 200 KM/H (Cristopher, 2006).

Europe started following Japan’s achievement and presented a high speed rail proposal at the 1965 International Transport Fair in Munich, Germany (Briney, 2009). However, the first high speed line that started operation in Europe was the line that linked Rome to Florence in 1987. This line made the trip between the two large Italian metropolises to only four hours (North, 1993). In 1974, due to the oil crisis rising, the French prime minister decided to use electricity as the power source of trains. Later on, he instructed the construction of a high speed line between Paris and Lyon. The first French TGV is launched in 1981, beating a world record by achieving a speed of 380 KM/H. Having seen the French and Japanese experiences, most European countries such as Belgium, Finland, Germany, Portugal, Romania, Turkey and Spain are competing to reach the fastest high speed line to generate user benefits (Briney, 2009). According to the US Congress report (2009), China is now the leader of high speed rail with a current 6000 KM network and a planned 16000 KM network for 2020.
First of all, the significant variety of railway infrastructure, type of provided service, maximum and average speed of trains should be considered. There is a clear difference between the speed that the train reaches on test tracks and the actual speed that is offered to the public.

Service requirements apply significant limitations to new high speed lines, because the attractiveness of a new high speed line is not only in its speed, but also lies in its capacity, reliability, frequency and comfort. These facts attract developed economies to set up an appropriate transport provision which is a requirement for linking densely populated and congested cities. These attractions increase in places where land is expensive and environmental benefits can be achieved in comparison with road and air transport. According to the French Rail Authority, SNCF (2009), high speed rail can compete with road and air travel in journeys up to 800 Kilometers and a 4 hour time frame.

High Speed has been a relative concept through time. When railways were invented, a speed of 50 KM/H was seen as fast. In 1845, Britain launched the fastest train at the time reaching maximum speed of 70 KM/H. Then the ‘Flying Dutchman’ was introduces which ran at an average speed of 90 KM/H. In the beginning of the twentieth century, British and American operators were able to reach a speed of 160 KM/H. In 1938, the ‘Mallard’ train covering the eastern coast of England achieved a speed of 203 KM/H (Allen 1992). Before the World War, operators increased their speed by improving rolling stock technologies using the existing tracks. After the World War, both improved track and train technologies were presented. Campos and de Rus (2008) have identified four types of HSRs:

1) A completely different track from other rail services such as the Shinkansen

2) A mixed high Speed system which trains can be operated on both high speed and upgraded conventional tracks such as the French TGV. The TGV can use the existing tracks in places where constructing a TGV is not justifiable.

3) A mixed conventional system such as the Spanish AVE. The AVE trains run on the new line, while others run on both tracks.
4) A fully mixed system such as the German ICE trains. In this system all types of passenger and freight trains can use the same infrastructure.

There are also other systems such as the tilting trains which are used in Italy and Sweden, and the rising magnetic levitation or MAGLEV technology. Most countries have decided to increase traveling speed either by using improved rolling stock on conventional lines or upgrading the current infrastructure since construction of a dedicated high speed track can be very expensive. However, Japan was the first country that introduced a new, dedicated high speed line between Tokyo and Osaka in 1964 which was later followed westbound to Kyushu and eastbound to Morioka and Niigata.

In Europe, the French have been a pioneer of developing high speed lines by introducing a dedicated high speed track from Paris to Lyon which used the existing infrastructure for approaching main stations. Later on, both the French and Japanese turned their concentration on improving links between large metropolises and remote areas of the country (Vickerman, High-speed Rail in Europe: Experience and Issues for Future Development 1997). However, other European countries decided to optimize the existing infrastructure, especially in areas where the networks were denser. Therefore, the first British high speed line run at as speed of 200 KM/H using and improved Diesel locomotive in 1976. Sweden and Italy developed a new technology which used an advanced improved tilting train in their X2000 and Pendolino Trains.

Investment pace in some countries such as Germany and Spain was rather slower than others. In Germany, the primary emphasis was upgrading existing trains to accommodate both passengers and freight which had a slow process. Investments in infrastructure have improved significantly in Spain after joining the European Union. The pace of developing high speed lines has increased a lot in the past decade and several countries have started to catch up with the pioneers. According to Preston (2009) high speed rail services are accountable for 25 percent of the total rail passengers in the European Union.
1.2. Main Models of High Speed Trains

As I have mentioned in the previous section, different types of high speed trains have evolved based on the specific needs and requirements of different countries. According to Givoni (2006), the Japanese Shinkansen can be indicated as the pioneer of high speed trains. The main differences between the four models can be described in their highest achievable speed, construction and operating costs and compatibility with existing infrastructure. In this section I will look into the four main types of high speed trains in more detail.

1.2.1. The Japanese Bullet Train (Shinkansen)

The name Shinkansen comes from Japan’s exclusive features of having large metropolitan areas which have a few hundred Kilometers distance and have a high passenger rate traveling between them. For instance, Tokyo, Osaka, and Nagoya which are large metropolitan cities, have a few hundred Kilometer distance, and have a high travel demand between one another are connected to each other via the Tokaido line. Having a new dedicated track just for itself is one of the Shinkansen’s unique features, since the other Japanese conventional tracks are narrow gauge and high speed trains are not able to operate on them. This feature of the Shinkansen totally separates it from the rest of the railway system. To be able to operate high speed trains, the route must be without tight curves and steep turns. Because of the Japanese geographic characteristics, the Japanese authorities had to construct lots of tunnels and bridges along the Shinkansen route which has led to significantly higher construction costs. According to Okada (1994), 30 percent of the Shinkansen line goes through and above tunnels and bridges. Moreover, leading the high speed trains into the city centers increase the construction costs even more, since the price of land in the city centers are very high.

1.2.2. The French TGV

The TGV is different from the Shinkansen to some extent. The French have tried to overcome the disadvantages of the Shinkansen and optimize it according to their own needs. The main difference between the Shinkansen and the TGV is that the TGV is able to operate on
existing conventional infrastructure as it enters the city centers. This unique feature has led to significant cost savings for the French. Moreover, the TGV is able to operate in cities which have no high speed rail infrastructure or in regions where construction of a new dedicated high speed line cannot be justified.

For example, the Spanish AVE is a combination of the Shinkansen and TGV. The AVE runs on a dedicated track because Spanish conventional infrastructure cannot host high speed trains, but uses the same type of rolling stock as TGV. This feature allows the Spanish high speed network to connect with the cross European network.

Another example could be the German ICE trains. The ICE primarily uses the TGV model. The difference is that ICE uses the same line for both passenger and freight trains which has led to higher construction costs in order to support the load of freight trains and lower usage of the line because of the low speed of freight trains.

1.2.3. The Tilting High Speed Train

The previous modes of high speed trains all used a new dedicated track specifically designed for achieving high speeds which led to significant construction costs. For the routes that construction of a dedicated high speed track cannot be justified, the tilting model of high speed trains can be used, but it comes at the price of lower speeds. The train has an advanced tilting mechanism that tilts as it goes through sharp curves and turns and it compensates the centrifugal forces that the passengers may experience. This is a very cheaper way to reach higher speeds on tracks in comparison with the Shinkansen and TGV models. The Swedish X2000 and the Italian Pendolino are using the tilting mechanism to avoid high costs of constructing a new dedicated line, which allows them to reach the maximum speeds of 210 and 250 KM/H. The TGV and Shinkansen trains will also start using tilting trains in near future.

1.2.4. The Magnetic Levitation Train (MAGLEV)

The magnetic levitation model is an upgraded model of the Shinkansen and TGV models. The MAGLEV technology was firstly introduced in the 1970s, but has not yet been in wide
operation. It uses electromagnetic forces to drive the rolling stock forward and can reach unlimited speeds in theory. The commercial goal for the MAGLEV technology is reaching the speed around 500 KM/H. The first magnetic levitation train was tested in 2003 and was able to reach the outstanding speed of 580 KM/H. The MAGLEV technology requires specially developed tracks and infrastructure which leads to extremely high construction and operating costs. There are existing magnetic levitation test tracks in Germany and Japan. The Japanese have planned to eventually continue the test track between Tokyo and Osaka which will make the trip short to one hour instead of the current two and a half hours. In 2003, China opened a magnetic levitation line from Shanghai Airport to the city financial district which reached the maximum speed of 430 KM/H. The success of the magnetic levitation is highly dependent on its success in Germany and Japan.
2. The Cost of Building and Operating a High Speed Line

High speed trains have been one of the most important technology enhancements in passenger and freight transportation in the 20th century. According to UIC (2005), in 2006 there will be around 9000 Kilometers of newly built and dedicated HSR routes in operation, and more than 20000 Kilometers of tracks have been modified to provide higher speeds for passengers traveling around the world that are looking for a transport mode which provides safe and convenient journeys. Since the introduction of the first Shinkansen high speed line in Japan, more than four billion passengers have used this service, while the number of passengers in Europe has been growing at a constant pace and has reached the amount of 1.5 billion since 1981. Currently, more than 15 countries in the world have put high speed trains in operation and with the great pace of growth, it is expected that more than 25000 Kilometers of new tracks will be constructed by the year 2020.

2.1. An Economic Definition of High Speed Services in Railways

Before, the rail industry saw the high speed concept only from a technical point of view which was the maximum achievable speed of a train on a specific track. In 1996, the European commission (1996) issued a directive that defined three types of high speed rail infrastructure. These types are new dedicated tracks specially built for high speed trains for minimum speed of 250 KM/H, specially modified conventional tracks for speeds around 200 KM/H, and specifically modified conventional tracks which have unique urban and geographical features, so the speed must be considered separately for each case.

These definitions are based on the reachable speed of trains and seem to include all types of infrastructure which can accommodate high speed trains. But practically, speed cannot be an appropriate indicator in many cases, since operational speed can be limited in densely urbanized areas because of noise pollution and decreasing accident risks, or for example in tunnels and on bridges where the speed has to decrease due to safety reasons.
High speed and conventional rail are a lot similar with each other and have the same basic engineering aspects in which they both use a hard metal track that minimizes the energy consumption and friction between the wheels as the train moves along it. Although they look very similar in the first look, they have some major technical differences from the operational point of view. For instance, they use completely different signaling systems, which conventional lines use external electronic signals, while the high speed line signaling system is in-cab integrated that eliminates the need for the operator to look for signals along the track. Another difference between high speed and conventional lines is their electrification. High speed lines need at least 25000 Volts to able to operate, but conventional lines may use much lower voltages to generate enough power for operation.

These operational and technical differences indicate that the relationship between high speed and conventional lines and the way the infrastructure can be utilized play a much more effective role in achieving an economic definition of high speed services rather than speed. Campos, de Rus, and Barron (2006) have identified four different development models for high speed rail services:

1) The first model is the exclusive development model which demands a complete differentiation between high speed and conventional tracks and requires each mode to have its own dedicated track. The exclusive model was first use by the Japanese Shinkansen mainly for two reasons. The first reason was that the Japanese conventional tracks had exceeded their operational capacity, and the second reason was the government decision to construct a standard gauge track for high speed services. A significant benefit using the exclusive model for the Japanese was that they could completely separate the operation of the high speed and conventional services which turned out to be a wise choice after the bankruptcy of the national rail authority and privatization of the high speed and conventional services.

2) The second model is the mixed development model in which the trains run on both newly built dedicated high speed tracks and modified portions of the existing conventional tracks. The French have adopted this model in their high speed TGV trains which can run either on new tracks or on conventional tracks where building a new track cannot be justified. Using this model has led the French to significantly reduce infrastructure costs.
3) The third model is the mixed conventional model which is mainly used in the Spanish AVE trains. In this model the conventional trains can run on dedicated high speed lines as well. Since the Spanish tracks are narrow gauge and different from the rest of European countries, to make the Spanish network be able to connect with the growing European network, they developed an adaptive technology as in the TALGO trains, which was able to operate both on narrow and standard gauge tracks. Using this model allowed the Spanish to reduce rolling stock and maintenance costs significantly, and also allowed them to offer a higher speed service compared to conventional trains.

4) The last model is the fully mixed model which is used in the German ICE and Italian Pendolino trains. This model allows both conventional and high speed trains to use either type of infrastructure. Germans use this feature to operate freight trains on high speed tracks at night while passenger trains are diverted on to conventional tracks.

Choosing the right development model for high speed rail requires very careful and sensitive comparison of the pros and cons of constructing a new dedicated high speed line or upgrading the existing conventional infrastructure to provide high speed services; hence, the decision should be seen from an economical point of view as well as a technical point of view.

Some other factors can be considered for an economic definition of high speed rail services. The first factor is the specific and technical features of the rolling stock used in high speed rail services. The operation and maintenance cost of these advanced rolling stock require a long term investment up to 20 years for the operating companies and demands significant provision of HSR services. The second factor can be the financial support that the governments are willing to offer in expanding and developing their high speed rail network. The Europeans see high speed rail as a mean to achieve balance between different modes of transport and justify the investments made in terms of lower external cost of high speed transportation regarding safety and pollution. Another factor can be the demand for high speed rail services. Having adequate demand for high speed services is a critical factor regarding the survival of the operating companies. Nowadays, high speed rail has started introduce itself as a new mode of transport with its own infrastructure and advanced technology by introducing significant innovations over the conventional rail services in terms of convenient time table and reservation.
systems, catering, wireless internet and etc on board which will lead to additional value for its customers.

2.2. The Cost of Building a High Speed Rail Infrastructure

Constructing a newly built and dedicated high speed rail line demands some specific requirements and characteristics that restrict the operational speed of trains to below 250 KM/H. The track designed for high speed operation needs to avoid surface level junctions with roads and highways, have limited stops along the route, advanced signaling and electrification systems, and priority for high speed trains over slower conventional and freight trains.

All high speed infrastructures should have as many as the above features as possible, but this does not mean that all are constructed in the same way. Construction costs of infrastructure in different high speed rail projects may vary depending on special characteristics of each case. These characteristics can be in geographic, topographic, and technical terms of each case. UIC (2005) defines three major cost categories for constructing a new high speed infrastructure:

1) The first category is planning and land costs, which consist of both economic and technical feasibility studies, purchase of land and the relative fees such as legal and administration fees, public taxes, permits, and etc. The planning and land costs can rise significantly in cases where the land has an extremely high value, but it usually represents around five to ten percent of the investment.

2) The second category is infrastructure construction costs which consist of path preparation and construction of the platforms. These costs can be different regarding each case with respect to terrain characteristics, but usually constitute about ten to twenty five percent of the total costs of a newly built high speed infrastructure. In projects with difficult geographic conditions, these costs can easily rise to twice the normal price.

3) The third category is superstructure costs which consist of technical railway components such as the tracks, sideways, communication, safety, signaling and electrifying systems and some more. Each of these components can compensate between five to ten percent of the total infrastructure cost.
All high speed rail infrastructure projects include these three major types of costs, but the total infrastructure costs are significantly dependent on the relationship between the existing conventional infrastructure and the new dedicated infrastructure that is going to be built in each case. Again UIC (2005) has categorized high speed infrastructure projects in 5 categories regarding the mention criteria.

These categories are large separated corridors, for example the Madrid-Seville or the Paris-Lyon line, integrated corridors like the Madrid-Barcelona which is integrated with the Madrid-Seville corridor or the Paris-Lille which is integrated with the Paris-Lyon corridor, small portions of existing routes in order to link average sized cities, significant single projects such as the Channel Tunnel, and small projects using upgraded conventional lines mainly used for linking airports to the city centers such as the Oslo Airport Flytoget.

Campos and de Rus (2006) have collected data of 166 high speed rail projects worldwide, which consists of projects of all the five categories mentioned above. They have eliminated significantly large singular and small projects using upgraded conventional lines to avoid the complexity brought by their specific construction features. They have not considered projects in the early planning stage and those with incomplete financial data, since according to Flyvbjerg (2003), at early planning stages the actual costs may become much more than the amount estimated.

Figure 1 shows the average investment required to build one Kilometer of high speed rail infrastructure in their database. These costs are presented in million Euros and exclude the planning and land costs, but consists of infrastructure and superstructure costs. They have found out that the total construction cost for one Kilometer can vary between six and forty five million Euros which leads the average cost of eighteen million Euros. Their analysis reveal that the cost of building a new high speed rail infrastructure in Asian countries such as Japan, Taiwan and South Korea except for China, is slightly higher than European Countries.
The figure shows that among the European countries, Spain and France have quite lower construction costs in comparison with Belgium, Italy and Germany. These lower construction costs are the result of specific geographic conditions and having low populated areas outside major urban cities, and also construction techniques and procedures used in these countries. The French have reduced the cost by using steeper grades instead of constructing expensive tunnels and bridges. In order to construct straighter lines, more expensive lands need to be purchased, but this additional cost will be returned in the long run by the reduced operation and maintenance costs. Other European countries as well as Japan have higher construction costs since they have large densely populated areas and most of their country is surrounded by mountainous terrain which requires the construction of expensive tunnels, bridges, and viaducts.
The analysis reveals that the projects which are under construction and expected to be opened soon have had almost the same construction costs as the projects already in operation. An interesting fact is that there is no indication of the success of countries which have lots of experience in high speed rail technology in reducing their construction cost compared to the countries which are rather new to the technology. The construction costs of the newer Shinkansen and TGV lines have been much higher than the initial lines, sometime up to four times the initial investment.

2.3. The Costs of Operating High Speed Rail Services

After the construction phase, the operation phase of high speed rail services arrives which consists of two major types of costs which are the costs required for provision of transportation which benefit from the infrastructure, and the costs of development and maintenance of the infrastructure constructed. The European Union has issued a directive requiring all the countries that provide and operate high speed rail services to differentiate the organizations or create separate divisions in an organization which manage the infrastructure with organizations that manage high speed rail operation. However, some other countries outside Europe are still handling both infrastructure and operational aspects under one single organization.

2.3.1. Infrastructure Operating Costs

Infrastructure operating costs mainly consist of human resource costs, maintaining the operability of the track, guide ways, electrification, communication and safety systems, as well as traffic management costs. These costs may be constant or may become dependent on technical and safety factors regarding routine operation and performance. For instance, the number of trains which use the track or the traffic density can be a factor in measuring the maintenance costs of the tracks, electric traction installations and the catenary. According to the UIC (2006) database, the maintenance of electric traction installations can represent fifty five percent of labor costs of maintenance operations, while track maintenance and maintenance of equipment will represent 45 and 50 percent respectively.
Campos and de Rus have used their empirical findings and have focused more on five European countries which are Italy, France, Belgium, Spain, and the Netherlands. They have divided the infrastructure maintenance costs of a new high speed rail line in these countries into five categories of tracks, signaling, electrification, telecommunication and other costs. Figure 2 shows the total infrastructure maintenance costs of a new high speed rail line in these five countries compared with the total infrastructure maintenance costs of existing conventional line in the same countries.

![Figure 2: Comparison of maintenance costs of new lines](image)

Source: Campos and de Rus (2006)

The figure reveals an interesting fact that the maintenance costs of high speed rail infrastructure in France, Italy and Belgium are between fifteen to twenty five percents lower than the maintenance costs of conventional lines. This fact is because of the significantly lower traffic on high speed lines in comparison with conventional lines. It is also because the freight trains mostly run on conventional lines which will make more damage to the infrastructure and significantly increase their maintenance costs. The Netherlands is a totally different case since
the signaling and electrification costs are much higher than other countries. As it can be seen, the total maintenance costs in Italy are the lowest, whereas the Netherlands has the highest maintenance costs among these countries.

Generally, 40 to 65 percent of the total maintenance costs in conventional and high speed lines are compensated by maintenance of tracks and infrastructure, while 10 to 35 percent is compensated by signaling costs in high speed rail lines, and 15 to 45 percent by signaling costs in conventional lines. The electrification costs are almost the same in all of these countries.

2.3.2. Service Operating Costs

The service operating costs of high speed rail can fall under costs of maintaining rolling stock and equipment, energy and electrification costs, shunting and train operating costs, and ticketing and administration costs. The ticketing and administration costs consist human resource costs of ticket sales and setting information centers in the stations and may vary from one operator to another depending on their expected traffic levels. The other categories can be different depending on each project and their specific technical and operational characteristics.

Each European country has elaborated its own technical specifications in order to solve the issues regarding their own transportation system. Regarding the rolling stock used for providing high speed rail services, the French have used the TGV Reseau and THALYS for international routes operating between Belgium, Netherlands, and Germany and has recently introduced the double deck TGV Duplex. The Italians have used ETR-480 and 500 models, while the Spanish have acquired the AVE and ALARIS train types. Germany has the widest variety in the types of trains used for providing high speed rail services comprising of five different types of ICE-1, ICE-2, ICE-3, ICE-Polycourant and ICE-T. These types of trains are different regarding their length, material, mass, energy and electrification needs, and tilting features. Table 1 compares these different types regarding their capacity and speed.
Table 1: Types of Trains Used in Europe

<table>
<thead>
<tr>
<th>Country</th>
<th>Type of train</th>
<th>Years of first service</th>
<th>Capacity (seats)</th>
<th>Capacity (seats-km per year)</th>
<th>Maximum speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>TGv Resesu</td>
<td>1992</td>
<td>377</td>
<td>186.615</td>
<td>300/320</td>
</tr>
<tr>
<td></td>
<td>TGV Duplex</td>
<td>1997</td>
<td>510</td>
<td>267.750</td>
<td>300/320</td>
</tr>
<tr>
<td></td>
<td>THALYS</td>
<td>1998</td>
<td>377</td>
<td>167.785</td>
<td>300/320</td>
</tr>
<tr>
<td>Germany</td>
<td>ICE1</td>
<td>1990</td>
<td>627</td>
<td>313.500</td>
<td>280</td>
</tr>
<tr>
<td></td>
<td>ICE2</td>
<td>1998</td>
<td>368</td>
<td>174.300</td>
<td>280</td>
</tr>
<tr>
<td></td>
<td>ICE3</td>
<td>2001</td>
<td>415</td>
<td>174.300</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>ICE3 Poly.</td>
<td>2001</td>
<td>404</td>
<td>168.680</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>ICE/T</td>
<td>1999</td>
<td>357</td>
<td>128.520</td>
<td>230</td>
</tr>
<tr>
<td>Italy</td>
<td>ETR 500</td>
<td>1998</td>
<td>590</td>
<td>212.400</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>ETR 480</td>
<td>1997</td>
<td>480</td>
<td>138.240</td>
<td>250</td>
</tr>
<tr>
<td>Spain</td>
<td>AVE</td>
<td>1992</td>
<td>329</td>
<td>154.630</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>ALARIS</td>
<td>1998</td>
<td>161</td>
<td>44.275</td>
<td>200</td>
</tr>
</tbody>
</table>

Source: Campos and de Rus (2006)

The shunting costs also depend on the distance between the stations and the depot and the time required for rolling stock to stay at the depot, regardless the type of the rolling stock. The other costs regarding train operations are servicing, driving, operations and safety which mainly are human resource costs and are different in each country regarding the operator’s policy and technical procedures.

Figure 3 shows the operations costs regarding each types of rolling stock presented in table 1. According to empirical findings of Campos, de Rus and Ignacio (2006), the average cost of operation per seat is around 53 Euros. Their database also shows that the average operating costs in France are between 10-20 percent cheaper than other European countries.
They have also compared the costs of maintaining rolling stock and equipment in each country. According to their empirical findings, a train is used for 500000 Kilometers every year, so the cost of maintaining a single high speed rail train is estimated to be one million Euros every which is equivalent to 2 Euros per Kilometer. Figure 4 shows the exact values of maintenance cost depending on consumption in each country. It shows that the German ICE trains have the lowest maintenance costs, while the Italian ETR-500 has the highest maintenance costs which can be explained by different policies of different operators.

Source: Campos and de Rus (2006)
Energy costs can be calculated by calculating the average energy consumption for each Kilometer which is a specific technical feature for each type of rolling stock. According to Levinson (1997) energy consumption is a relative factor and depends on the speed of the train and will increase significantly for speeds over 300 KM/H; but the price of energy and the payment options for the operator may vary. The total energy and electrification costs of high speed rail in France is around five percent lower than other countries such as Germany, since the energy is cheaper because of nuclear power technology and it is directly adopted by the operator which leads to the fact that the operator is able to negotiate with the energy supplier and reach higher energy savings.

2.3.3. External Costs of High Speed Rail

High speed rail can have some external negative effects which mainly are air pollution, noise and incidents. The emissions that are created to supply power for a high speed train is dependent on the trains energy consumption and the emissions that the electricity plant which powers the train produces. Since there are different types of producing electricity to power high
speed trains in different countries, it is rather difficult to make numerical emission comparisons between different countries. The general opinion among transportation experts is that high speed rail generates much less pollution than other transportation modes such as air travel and private cars. INFRAS/IWW (2000) states that high speed rail consumes much less primary energy compared to road and air. It also produces much less CO2 emissions, as low as 25 percent of car and air travel, since it does not use crude oil products.

High speed rail generates less noise than other transport modes, but the noise emissions are not that much in favor of high speed rail. The noise generated by high speed trains depends on each country’s specific technology and track characteristics and can be categorized in wheel and rail noise, pantograph noise, and aerodynamic noise. The noise generated lasts for only a short time period and depends on the speed of the train passing. The faster the speed, the higher the noise generated. Measurement of noise emissions in high speed rail have been carried out. The average noise level of a high speed rail line may vary between 80 and 90 decibels which can be annoying in populated areas. According to Levinson (1997), to be able to maintain the standard noise emission of 55 decibels at the speed of 280 KM/H, there must be a 150 meter corridor for trains passing by. For instance, residents alongside the TGV route in France have complained in several occasions regarding its noise which has led to the construction of acoustic fences in large sections of the infrastructure.

By comparing statistics of different transport modes, it is clear and obvious that high speed rail and air travel are the safest transportation modes nowadays. It has had the lowest passenger fatalities per billion passengers per Kilometer. This is due to the fact that high speed rail has limited the possibilities of having an accident by including advanced safety features in the infrastructure and rolling stock along with separating the routes from one another. The costs of enhancing safety on high speed rail are categorized under construction and maintenance costs instead of accident costs.

There are some other external costs regarding high speed rail such as alteration of landscapes and visual intrusion. These costs will be considered in planning and preparation costs rather than being considered separately. However, considering these costs cannot change the economic position of high speed rail regarding external costs, but it can lead to increasing
opposition to new projects. For example, in 1990 while the French were building the TGV Mediterranee line, an environmental protest was held by environmental activists in whom they blocked a bridge along the route. They believed that constructing a new dedicated line for this route is not necessary and the trains can use the same conventional tracks, since the demand for this route was low and mainly served business travelers. Similar protests have taken place along the Lyon-Turin line that connected the TGV to the TAV network, and also in the United States and the United Kingdom.

2.4. Revenue Analysis of High Speed rail

Constructing a high speed rail line can be very expensive, since it includes large sunk costs in fixed and unsustainable assets. The revenues generated from a high speed rail line may vary in different projects depending on the demand of travel, and specific technical and environmental aspects. Calculating revenues can be harder to carry out. According to Gourvish (2009), the only high speed line that was able to achieve financial success in Japan has been the Tokaido line while other lines across the country are still dependent on government support. The Tokaido line managed to generate the revenues required for infrastructure costs in only three years after starting operation. The French TGV line between Paris and Lyon managed to generate revenues with the internal rate of return of fifteen percent and was able to make up for the capital investments in twelve years. However, these routes had a significant demand of travel for about ten million passengers per year, while other lines such as the Madrid-Seville line with less demand than estimated have not been able to generate sufficient revenues and are dependent on government support to a large extent.

The European Union requirements for separation of organizations that provide high speed rail infrastructure and the operators have made it harder for the operators to generate revenues. This requirement leads to more access charges that the operator has to pay to the organization providing the infrastructure hence decreases the financial revenue generated. However, the social rates of return for high speed rail have been significantly higher than the financial rates of return. According to Vickerman (2009), the TGV network has generated the social rate of return of thirty percent for the Sud-East, fourteen percent for the Paris Interconnexion, twelve percent for
the Atlantique, and five percent for the Nord line. Generally, high speed rail has been able to generate financial revenue, but it cannot be considered as a complete financial success except for the early and high demand investments. High speed rail has been partially profitable, especially regarding social profits. It is unlikely that future projects could attract the private sector for investing in them since they are unlikely to generate significant financial revenues.

For example, in Spain, the main profits generated from high speed rail services can be categorized in time savings of the passenger using high speed trains and total profits generated from new traffic. Inglada and de Rus (1997) have carried out a cost benefit analysis of the Spanish high speed rail network. Table 2 presents their findings on the benefits generated from high speed rail in Spain. In order to carry out the calculations, they have used surveys from the respected corridors and also have used real data provided by the national railway company, the national airline, and local bus companies. They have assumed that during the forty years of the project life cycle, Spain will have an annual GDP growth of 2.5% and a social discount rate of 6%.
To calculate the increase in demand, they have presumed that the Gross Domestic Production will grow with the rate of 2.5 percent during the project’s forty year lifetime. Estimating benefits using sensitivity analysis along with the negative net present value indicated in the table above suggest that introducing high speed rail in Spain cannot be justified economically in Spain.

Another case that is different with other high speed rail projects in other countries is the case of Taiwan which has used private financing for infrastructure rather than requesting assistance from the government. Although the private investors estimated a large and profitable
demand for the Taiwanese high speed rail, the actual ridership after starting operation has not been satisfactory for the operators and related authorities. However, the ridership is increasing gradually but the traffic quantity is still not sufficient. It is suggested that the government of Taiwan can issue more flexible pricing rules to enable the operator to attract more passengers leading to ridership increase. According to Wardman (2006), innovative pricing has been used and has had significant effects in increasing ridership in France and Britain. So the high speed rail operator in Taiwan has to use more innovative marketing solutions in order to increase its ridership and meet expectations of different types of travelers such as business, leisure and group travelers.

Yung-Hsiang Cheng (2009) has carried out an ex post cost benefit analysis of the high speed rail project in Taiwan which shows that the high speed rail project in Taiwan has generated considerable social profits in terms of reduced travel times, road accidents, and external costs. According to this study, the social profits generated by the high speed rail project in Taiwan can be accountable for seventeen percent of its total revenue in 2009. However, the gradual descent of the social profit ratio along with the large extent of loans acquired by the operator and underestimated passenger demand will only lead to a positive net present value in later stages of operation. In order to make the high speed rail project in Taiwan more profitable, Cheng suggests that the government should negotiate with the banks to decrease their interest rate on loans given to the Taiwan high speed rail operator.

The demand for high speed rail in Taiwan has not been as sufficient as expected. Cheng suggests that the operators of high speed rail in Taiwan should use more innovative strategies such as creating alliances with hotels and car rental companies to increase the demand for high speed services. They should also try to create specific regional attractions in order to draw more passengers towards high speed rail by using rail transport’s mobility.

According to Nash and de Rus (2007), justifying the construction of a new high speed line depends on its ability to produce social and economical profits in order to reimburse infrastructure, maintenance and operational costs. The decision on constructing a new high speed line cannot be made by pure economic analysis since other factors such as social profits, time saving, regional and environmental impacts must be considered as well.
The social profitability of investing in a high speed rail line is significantly dependent on specific local conditions which uncover the true scale of costs, demand levels and external profits in terms of decreasing pollution and congestion generated from other modes of transport. With respect to high construction costs of high speed rail, the profitability in investing in high speed rail significantly depends on the number of passengers including diverted passengers from other modes and the traffic intensity of the planned corridor. High speed rail projects need a large degree of demand that can generate adequate economic and financial values to reimburse the extremely high infrastructure and maintenance costs. It should encourage passengers from other transport modes to start using high speed rail and increase their willingness to pay for an improved and safe journey.

Nash and de Rus believe that only under special situations such as minimal construction costs, existence of infrastructure, spectacular time savings, and exceptionally poor services on other transportation modes may investment in a new high speed rail line be financially acceptable with a less than an annual nine million passenger demand.
3. Intermodal and Socio-Economic Impacts of High Speed Rail

High speed rail can either behave as a complement or an alternative for other transportation modes. It can behave as a rival for other transportation modes in providing services in journeys either served by airlines, ferry operators in cases like the Channel Tunnel, private or public transport, and conventional rail lines. It may also behave as a complement for other transportation modes such in interchange points of other modes such as airports, ports and terminals.

The major benefit of high speed rail for a specific route can be providing lower travel times, especially for medium distance journeys, since longer journeys are mainly considered to be taken by air travel and short distance routes are usually dominated by road or conventional rail services. For trips including more than one transportation mode, choosing high speed rail is significantly dependent on its incorporation with the entire transport system. According to SDG (2004), the extent of trips which can make high speed rail competitive is dependent on airport access time, check in, and etc. However, the price, quality, and reliability of other transportation modes as well as the incorporation of high speed rail with the entire transport system may affect the market advantage of high speed rail.

3.1. Intermodal Effects of High Speed Rail

3.1.1. Summary of Empirical Findings

The decision made by the passengers to choose a particular transportation mode is dependent on the generalized cost of each mode. These generalized costs not only includes the ticket price, but may also include, factors such as total travel time, accessibility, reliability, quality of services on board and etc. When seen from a wider perspective, the incorporation of high speed rail with the transportation system can also affect the quality of each mode and the passenger choice. For instance, railway stations are normally located in city centers and largely populated areas which makes them more accessible, while airports are mostly outside densely
populated urban regions which makes them less accessible. Railways also have a competitive advantage over the other modes for serving large urban centers.

3.1.2. The Effect of Travel Time

A competitive advantage of high speed rail is reducing the total travel time. However, this advantage is highly dependent on the distance of the journey that high speed rail serves. According to SDG (2004), high speed rail does not have a significant advantage over other transportation modes and can be even less favorable in comparison with conventional rail services in journeys less than 150 Kilometers, since the location of the stations may be a factor for passenger’s decisions. For journeys between 150-400 Kilometers, railways even conventional rail may be faster than other modes such as air travel, since air travel demands spending additional time on airport access, check in and baggage procedures. In these journeys high speed rail can have more advantage since it can reduce the travel time even more. In journeys over 400 Kilometers, high speed rail may be significantly faster and is able to divert passengers from other modes such as road and air to high speed rail. For journeys over 800 Kilometers air travel has advantage over other transportation modes regarding the total travel time, even compared to a dedicated high speed rail line.

Yao and Morikawa (2003) believe that the distances where high speed rail is favorable to other transport modes can be different for different routes along their lifetime. For example, in the initial stages of the Tokaido line operation when its speed only reached 220 KM/H, it wasn’t able to offer significant advantage over air travel, while after several modifications and technology enhancements during time, it became the first train in the world with the ability to reach the speed of 590 KM/H and offered a largely considerable advantage over air travel especially for shorter routes. This has led the airlines to reduce their services in the 370 Kilometer Tokyo-Nagoya line, since traveling with high speed rail was able to decrease the total travel time of this journey from two and a half hours by air to only one hour by high speed rail.

De Rus et.al (2009) has presented the relationship between time and distance in high speed rail services in table 3. The table has taken the total travel time including access and waiting times into account and shows that high speed rail can have significant advantage over air
Economic Analysis of High Speed Rail

Transport in only in medium range journeys between 100 to 500 Kilometers. Generally, air transport can only compete with high speed rail services significantly in journeys more than 500 Kilometers and is not able to be an effective competitor in medium and short range journeys.

Table 3: Travel time and rail market share on selected corridors

<table>
<thead>
<tr>
<th>Corridor (km)</th>
<th>Year</th>
<th>Travel time</th>
<th>Rail share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tokyo-Osaka (515)</td>
<td>2005</td>
<td>2h 30min</td>
<td>81%</td>
</tr>
<tr>
<td>Tokyo-Okayama (643)</td>
<td>2005</td>
<td>3h 16min</td>
<td>57%</td>
</tr>
<tr>
<td>Tokyo-Hiroshima (814)</td>
<td>2005</td>
<td>3h 51min</td>
<td>47%</td>
</tr>
<tr>
<td>Tokyo-Fukuoka (1069)</td>
<td>2005</td>
<td>4h 59min</td>
<td>9%</td>
</tr>
<tr>
<td>Paris-London (257)</td>
<td>2005</td>
<td>2h 40min</td>
<td>66%</td>
</tr>
<tr>
<td>Paris-Amsterdam (514)</td>
<td>2004</td>
<td>4h 10min</td>
<td>45%</td>
</tr>
<tr>
<td>Brussels-London (204)</td>
<td>2005</td>
<td>2h 20min</td>
<td>60%</td>
</tr>
<tr>
<td>Paris-Geneva (339)</td>
<td>2003</td>
<td>3h 30min</td>
<td>35%</td>
</tr>
<tr>
<td>Paris-Brussels (183)</td>
<td>2006</td>
<td>1h 25min</td>
<td>100%</td>
</tr>
</tbody>
</table>


Total travel time can be considered as a significant factor in studying the intermodal effects of high speed rail and the modal share comparison between air and rail travel. Table 3 shows that in journeys with the total travel time of less than three hours, high speed rail has been able to capture most of the market share, while the modal share of high speed rail decreases drastically when the total travel time exceeds three hours. It is interesting to note that the Paris-Brussels corridor’s market share has been totally captured by high speed rail services and there are very few flights operating between the two cities.

The European commission has indicated in the COST318 (1998) report that the total market share of high speed rail cannot always be a linear function of the total travel time, but can also be dependent on different types of passengers using high speed rail services. It presents business travelers as an example who will rarely prefer using high speed rail services in cases of
medium ranged journeys if they cannot make a return trip in one day. In order to achieve this goal, the return journey should only consume an overall six hour time with significantly low access and waiting times. However, SNCF, the national high speed rail operator in France has been able to capture nearly half of the total market share regarding business travelers. According to Bernard (2006), high speed rail has managed to capture nineteen percent of the total market share regarding business travelers and seven percent regarding non leisure journeys in France in 2005 and 2006.

High speed rail has had a serious effect on the total market share of the airlines in the initial stages of operation. This impact has become worse during two to five years after high speed rail has been operational. According to COST318 (1998), the opening of the high speed AVE line between Madrid and Seville has led to significant loss of market share for airlines as much as twenty percent as well as reducing the number of flights between the two cities from seventy flights per week to only forty. Similarly, the introduction of the first TGV line between Paris and Lyon had an instant impact on the market share of the airlines. By introducing more short and medium range high speed lines in France the market share of the airlines has drastically decreased to half the amount before introduction of high speed rail services, especially in medium range corridors. Introduction of high speed rail has also had major intermodal impacts in longer corridors, leading to at least ten percent loss of market share for the airlines in Paris-Marseille and Paris-Nice corridor.

It has been discussed that economizing, environmental and overcrowdancde of airports can lead to increase in the demand for high speed services in a long term time frame. According to Wilken (2000), the launch of high speed rail services in France has led to a significant drop in the number of domestic flight and also forced the airlines to use smaller planes which reduced noise and environmental emissions.

According to Givoni (2005), trains have managed to win the demand battle from aircraft in the Paris-London corridor and acquire almost seventy percent of the total market share. However, although airlines are likely to lose this battle, but they are still operating more than sixty daily flights between London and Paris, since these two cities are major European hubs and
airlines need to drive passengers in them in order to generate profit from long distance, transatlantic and pacific flights.

Launching high speed rail has had considerable effects on the modal shares of road and conventional rail services. However, comparison between the market share of each mode is difficult since there has not been detailed studies on number of users regarding road travel. But de Rus et.al (2009) have calculated the deviation of road users to other modes in some corridors that high speed rail services have been introduced. They have found out that high speed rail has managed to capture a drastic volume of the market share form conventional rail services in Europe. This drastic loss of market share for conventional rail services can be due to the fact that most of the corridors that they serve are now served by new high speed rail services providing a faster and more convenient journey for passengers, except for people with low salaries who cannot manage or are reluctant to pay for high speed rail services. The empirical findings of de Rus et.al of modal market share before and after introduction of high speed rail are presented in table 4.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>29%</td>
<td>21%</td>
</tr>
<tr>
<td>Rail</td>
<td>40%</td>
<td>3%</td>
</tr>
<tr>
<td>HSR</td>
<td>0%</td>
<td>70%</td>
</tr>
<tr>
<td>Air</td>
<td>31%</td>
<td>6%</td>
</tr>
<tr>
<td>Road</td>
<td>44%</td>
<td>30%</td>
</tr>
<tr>
<td>Rail</td>
<td>16%</td>
<td>1%</td>
</tr>
<tr>
<td>HSR</td>
<td>0%</td>
<td>61%</td>
</tr>
<tr>
<td>Air</td>
<td>40%</td>
<td>8%</td>
</tr>
<tr>
<td>Road</td>
<td>57%</td>
<td>45%</td>
</tr>
<tr>
<td>Rail</td>
<td>23%</td>
<td>3%</td>
</tr>
<tr>
<td>HSR</td>
<td>0%</td>
<td>48%</td>
</tr>
<tr>
<td>Air</td>
<td>10%</td>
<td>4%</td>
</tr>
</tbody>
</table>

Source: de Rus, Campos, et al. (2009)
In Korea and Japan, road travel had a significant share in many corridors before introduction of high speed rail. However, according to Yao and Morikawa (2003), introduction of high speed rail services along with enhancements of speed and frequencies of high speed rail has had a significant impact on road demand and has decreased the number of road travelers by almost ten percent across the country. Park and Ha (2006) have stated that launching high speed rail between the Korean major cities such as Seoul, Busan, and Deagu has led to a twenty five percent reduction in bus services between these cities. High speed rail has also had intermodal effects on the demand for air travel in Korea and Japan, but this impact has not been as significant as Europe.

3.1.3. The Intermodal Effect of Prices

While the major advantage of high speed rail on other transportation modes such as road and conventional rail is the reduced travel time offered by high speed rail services, there are also some other factors affecting its competitiveness with other modes of transport.

High speed rail services have become really common on most countries in Europe since they offer appealing ticket fares, higher reliability, and superior comfort in terms of on-board facilities and more comfortable seats. Lopez-Pita and Robuste (2005) shows that regarding ticket fares, high speed rail services have always been favorable compared to air travel. Table 5 presents the air and rail fare relation for some specific corridors which indicates that railways are regularly around fifty percent cheaper than air travel.

The existence and growth of low cost airlines during the previous years has posed a major threat to high speed rail services regarding the attractive pricing especially in the holiday market. Nevertheless, according to UIC (2003) low cost airlines have been only able to capture the market share conventional rail rather than high speed rail. It is believed that the market share captured from the emerging low cost airlines have been captured from traditional airlines. However, high speed rail operators have responded to this threat by introducing low fare services by means of reducing services and amenities they offer.
### Table 5: Airfares/ HSR Fares on selected European corridors

<table>
<thead>
<tr>
<th>Ratio: Airfare/Railfare</th>
<th>Business (First class)</th>
<th>Non-business (Second class)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Paris-Marseille</strong></td>
<td>1.77</td>
<td>2.63</td>
</tr>
<tr>
<td><strong>Madrid-Seville</strong></td>
<td>1.29</td>
<td>1.81</td>
</tr>
<tr>
<td><strong>Frankfurt-Hamburg</strong></td>
<td>1.43</td>
<td>2.17</td>
</tr>
<tr>
<td><strong>Rome-Milan</strong></td>
<td>2.32</td>
<td>2.00</td>
</tr>
</tbody>
</table>

Source: Lopez-Pita and Robuste (2005)

A major and significant advantage of high speed rail is its frequency compared to other transportation modes. High speed rail has the advantage that it has the flexibility over its tracks and infrastructure to schedule its services according to different demand situations. High speed train can operate services in any desirable frequency as short as 2 every two minutes, while other modes such as air travel cannot meet this demand due to traffic congestion and airport limitations.

### 3.1.4. High Speed Rail as a Complement to Other Transportation Modes

In order for the high speed rail service to be a complement for other transportation modes, the extent of intermodality that it allows should be considered. There has been a long term relationship between railways and airline regarding airport accessibility. Railways have been used to connect the cities to the airports for a long time now. Recently, the collaboration between high speed rail services and the airline industry has started after the French government came to the decision of constructing an interconnection high speed rail line connecting the TGV Atlantic, Sud-East, and North lines to Paris Charles de Gaulle airport.

Air travel and high speed rail can be a complement for each other only if the users prefer or are obliged to use both these services in order to travel between two cities. From the operators’ perspective, high speed rail and air transport can be complementary if the high speed rail network is able to replace the short range flights which are connected to long distance flights of major hubs by using flexible train services. Three different complementary networks of air transport and high speed rail can be recognized according to de Rus et.al (2009):
1) High speed rail can partly substitute air travel gathering and delivering passengers to main airport hubs such as the Frankfurt airport case in which short range internal flights have been substituted by high speed rail services.

2) High speed rail can entirely substitute air services by gathering and delivering passengers to major airport hubs such as the Paris to Rome corridor which have been totally substituted by high speed rail services.

3) Air travel can link major hub airports together whereas high speed rail services can offer exclusive links between the hub airport such as the link connecting between Paris and Lyon airports.

High speed rail services have been introduced in lots of European airports nowadays and have started to exploit intermodality between different transportation modes; however, in order to achieve better operational integration between railways and air transport, enhanced connections should be developed between these two modes of transport.

The passenger travel market has gone through significant changes regarding modal distribution of demand in the past years. The demand for conventional rail services has dropped drastically since people have started preferring air transport for long range and road transport for short range journeys. This fact has made the conventional rail services less competitive with other transportation modes especially regarding the total travel time. To overcome this problem, high speed rail services were first introduced in the 1989s in order to create a new breakthrough for railway operator to provide fast, reliable and sustainable transportation. Nowadays, high speed rail services have become one of the premier choices for large number of passengers in a large number of routes offering services with lower generalized costs.

As de Rus et.al (2009) states “The effects of HSR on other transport modes are one of the key factors to account for when evaluating this apparent success. The interaction between high speed rail and other modes may take place in the form of competition and complementarity. Both types are relevant although the second one has attracted more attention so far. Intermodal competition usually results in substitution of operations between modes, driven by their commercial viability, relative market strength and different institutional and environmental
Economic Analysis of High Speed Rail

constraints. Alternatively, modal substitution may also improve the internal efficiency of each particular system (substitution through competition) and may reduce, in the broadest sense, the systems’ cumulative burdens/emissions on the environment (substitution through complementarity).

3.2. Socio-Economic Impacts of High Speed Rail

3.2.1. User Benefits

User benefits generated from a transportation system are an essential element in the justification of the investment made in that particular transportation mode. Travel time and travel cost savings are the two fundamental user benefits associated with high speed rail services. Secondary user benefits can be identified for high speed services such as reduced car accidents, reliability, increased comfort, increase in demand, economic development, regional and local impacts, property values, and etc.

3.2.2. Travel Time Savings

High speed rail services have led to significant time savings in most of the corridors that is has been operational. However, the degree of the time savings is dependent on the investment goal and whether it the goal is sound time savings or enhancing the transportation capacity. According to Gourvish (2009), the Tokaido line has reduced the travel time between Tokyo and Osaka for three hours in the initial phase and to thirty percent of the original time in the next phases. Similarly, high speed rail has reduced the travel time between Madrid and Seville for four hours. Also, the Channel tunnel has achieved significant time savings as much as fifty percent in the London-Paris route and even more in the London-Brussels corridor. However, in some corridors the time savings have been more moderate such as the Koln-Frankfurt route and the west coast main line of Britain.
3.2.3. Demand

The introduction of high speed rail services has led considerable increase in demand across Europe. Campos and de Rus (2009) have calculated the traffic demands in Europe by gathering empirical data on high speed rail projects in different European countries. Their results are presented in table 6. The table indicates that France has experienced the lowest demand increase, whereas Italy and Spain have achieved the highest.

Table 6: Growth in HSR traffic in Europe, 1994-2004 (billion passengers-Kilometers)

<table>
<thead>
<tr>
<th>Year</th>
<th>France</th>
<th>Germany</th>
<th>Italy</th>
<th>Spain</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>21.9</td>
<td>8.2</td>
<td>0.8</td>
<td>0.9</td>
<td>32.1</td>
</tr>
<tr>
<td>1999</td>
<td>32.2</td>
<td>10.2</td>
<td>4.4</td>
<td>1.7</td>
<td>52.7</td>
</tr>
<tr>
<td>2004</td>
<td>41.5</td>
<td>19.6</td>
<td>7.9</td>
<td>2.8</td>
<td>75.9</td>
</tr>
<tr>
<td>Growth 1994-2004</td>
<td>89%</td>
<td>139%</td>
<td>888%</td>
<td>222%</td>
<td>136%</td>
</tr>
<tr>
<td>% Share of Europe’s traffic in 2004</td>
<td>55%</td>
<td>265</td>
<td>10%</td>
<td>4%</td>
<td></td>
</tr>
</tbody>
</table>

Source: Campos and de Rus (2009)

Vickerman (2009) has calculated the share of high speed rail services in Europe’s total rail traffic. The results are presented in table 7. The table consists of data only regarding new high speed rail lines and does not include conventional upgraded services. It shows that between 2000 and 2006 the share of high speed rail has increased from sixteen to twenty three percent of total rail market in which France has achieved the highest share, with Spain and Italy in the next rankings, while the United Kingdom has achieved the lowest share compared to other countries.

Table 7: High speed rail share of the total European rail market, 2000-2006 (%)

<table>
<thead>
<tr>
<th>Year</th>
<th>Europe (EU27)</th>
<th>France</th>
<th>Germany</th>
<th>Spain</th>
<th>Italy</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>16.0</td>
<td>49.7</td>
<td>18.5</td>
<td>9.6</td>
<td>10.8</td>
<td>0.0</td>
</tr>
<tr>
<td>2006</td>
<td>23.4</td>
<td>57.2</td>
<td>27.4</td>
<td>38.3</td>
<td>19.2</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Source: Vickerman (2009)
3.2.4. Economic Development

The introduction of high speed rail services can change the nature of the economic activities in a region which it serves by using its lower travel time to incorporate individual markets and create a dynamic economic zone. By promoting transportation throughout the region, high speed rail can lead to the effectiveness of the transportation network and enhance the excellence of life.

High speed rail services can assist different businesses using the reduced travel time in order to ease the accessibility for employees and improve the efficiency of different businesses as well as improving accessibility to suppliers and required material. High speed lines can reduce the airlines’ operational costs by providing high speed and reliable transportation for passengers to the major airports. These features allow high speed rail services to promote the economic growth of different regions and enable them to attract different business sectors that could not have been active without the accessibility provided by high speed rail services.

However, according to Gourvish (2009), although high speed rail can enhance the efficiency and competitiveness of different business sectors in regions connected by high speed rail by improving accessibility, they should not be considered as a significant economic growth engine. He states that the ten major high speed networks in Europe have only been able to increase the total European Gross Domestic Production (GDP) by only 0.25 percent and the employment rate by 0.11 percent which is not considered significant.

3.2.5. Regional and Local Economic Impacts

The introduction of high speed rail services has decreased the locational imbalance between major cities and the suburbs by easing the access of the capital to other cities, but has added to the economical imbalance between the center and the periphery. There is lots of difference of opinion regarding whether high speed rail services generate regional and economic benefits or not. The conditions are various depending on the location of the major and minor stations along the route and the train’s service patterns. For instance, according to Bonnafous
(1987), the introduction of the TGV line between Paris and Lyon became a concern for the hotel owners in Lyons, since people from Paris could do their business in one day using the TGV and return to Paris the same day. This fact led to economic loss for Lyon hotel owners; however, the tourism industry was able to generate profit in other regions that were connected to Paris with the same TGV line. The TGV line has also enabled the large and medium sized businesses to make their way into the Parisian market. However, according to Meunier (2002), the locational pattern of different industries were created by wider economic factors and high speed rail services have had much less important influence on the regional and economic developments in France.

The Japanese have been much more optimistic about the benefits and developments generated by the Shinkansen high speed rail services. According to Okada (1994), the Shinkansen has increased the employment rate by eight percent in the city of Kakegawa which is located 230 Kilometers away from Tokyo. However, others are less confident about these regional impacts; although they believe that services provided by the Shinkansen have increased these effects, but they are not only due to Shinkansen and other reasons may have played a role.

Although high speed rail services can enhance regional and urban regeneration, they can not merely generate economic development by their own. Vickerman (1999) denies the belief that high speed rail services can independently unravel the transportation and regional development issues. He believes that high speed rail services have mostly made changes to the distribution of economic activities rather than generating them.

### 3.2.6. Land and Property Values

High speed rail services can lead to increased land and property values depending on the locations of the stations along its serving route. Evidence from Japan and Europe show that when the stations are located in the same place of current rail stations they are unlikely to have considerable impacts on land and property values. But when new stations are built in areas far from the city center and provide easy access to the major urban areas and airports, they are able to increase land and property values. Newly constructed high speed rail stations built in smaller urban areas along the served route can generate considerable economic and commercial development; however, this is dependent on the characteristics of that area, changes in travel...
times and passenger demands that the high speed rail service generates. High speed rail services can also attract people and different businesses and industries to an area because of the increased accessibility provided by high speed rail which will further lead to increased land and property values.

### 3.2.7. Social Benefits of High Speed Rail

High speed rail services are able to generate social benefits mainly reducing the car accident rate by deviating road passengers to high speed rail and abolishing surface junctions, thus improving safety. It may also redistribute economic progress and development in a better way.

As an example, the highway between Calgary and Edmonton has experienced an eleven percent reduced accident rates due to introduction of the Calgary-Edmonton high speed rail line by diverting road passengers to rail and elimination of surface crossings. According to the Van Horne Institute report (2004), using an average cost per accident of $4.4 million per fatality, $30,000 per serious injury and $10,000 for collisions and property damage, the high speed rail alternative yields $215 million in net present savings over the 30 year life of the project. The road safety benefits on the Calgary-Edmonton high speed rail line are presented in table 8.

#### Table 8: Road safety benefits of the Calgary-Edmonton high speed rail

<table>
<thead>
<tr>
<th></th>
<th>Fatalities</th>
<th>Persons Injured</th>
<th>Collisions</th>
<th>Property Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hwy 2 Avg # per year:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>existing</td>
<td>10</td>
<td>296</td>
<td>883</td>
<td>698</td>
</tr>
<tr>
<td>estimated with HSR</td>
<td>9</td>
<td>264</td>
<td>786</td>
<td>621</td>
</tr>
<tr>
<td>Net benefit</td>
<td>-1</td>
<td>-38</td>
<td>-118</td>
<td>-91</td>
</tr>
<tr>
<td><strong>Rail Crossing Avg # per year:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>existing</td>
<td>2</td>
<td>3</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>estimated with CPR</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Net benefit</td>
<td>-2</td>
<td>-3</td>
<td>-3.5</td>
<td></td>
</tr>
</tbody>
</table>

3.3. The Environmental Impacts of High Speed Rail

The constructional and operational aspects of high speed rail services create a range of environmental issues. The most negative aspects regarding constructing and operating high speed rail lines are land possession, visual interruption, sound and air emissions. It is agreed in most cases that the noise pollution is the most significant disadvantage of high speed rail services.

According to Strohl (1993), resistance has been experienced regarding the construction and operation of high speed rail services in almost every project either by its opponents such as road and air travel operators to land owners, farmers, and residents alongside the route. These resistances have led to different ranges of delays in all projects and have been more influential in some countries such as Germany, regardless of their optimistic or pessimistic planning. For example, in France, the usage of agricultural land for the TGV Atlantique line became a major conflict between project owners and environmental activists. In Japan, the noise pollution impact was misjudged in the first place, but later on the new regulations forced the future line to comply with the standard noise pollution allowance.

It is believed that the noise generated from high speed trains is tolerable for speeds around 300 KM/H, particularly when the infrastructure is separated with the surrounding are for about one hundred and fifty meters. For speeds above 300 KM/H more strict environmental measures must be taken due to more aerodynamic noise generated by trains running with a speed above 300 KM/H. As the environmental standards get more and more strict, the construction costs of high speed line increase in terms of noise reduction fences and tunneling to comply with the new standards.

The amount of CO2 produced by high speed rail services is dependent on several factors such as the degree of traffic diverted from other contaminating transportation modes, the degree of new traffic produced, the demand for the new high speed rail services, and the nature and approach of energy consumption of high speed rails and competing transportation modes. High speed rail also generates SO2 and NOx contaminations to the environment while operating; however, these emissions are not acknowledged as significant environmental effects. Generally,
Economic Analysis of High Speed Rail

High speed rail is considered as a more environmentally friendly transportation mode with reduce operational and energy costs, compared to other transportation modes such as road and air travel.

According to Campos and de Rus (2009), “energy consumed by high-speed railways, measured in liters of petrol per 100 passenger-Kilometers, was 2.5, comparing favorably with 6 for the private car and 7 for airplanes. Furthermore, CO2 emissions were reported to be 4 tons per 100 passenger-Kilometers for HSRs, 14 for cars and 17 for air. Greater disparities have been claimed by some of the rail operators. Thus, as we have seen, SNCF has put its fuel consumption at 0.7 liters of diesel fuel per 100 passenger-Kilometers, compared with 3.3 liters for private road transport, and 7.14 liters for domestic air lines. Its CO2 emissions are put at 5.7 grams per passenger-Kilometer, which it notes are much lower than the 111 grams for road and 180 gram for air. Load factors and the method of generating electricity (France has substantial nuclear power plants) may explain these variations. Japanese sources have also reported positively on the CO2 effects of their trains, quoting, in one calculation, 19 grams per passenger-Kilometer, compared with 111 grams for airplanes and 173 grams for the private car”.

In the Høyhastighetsutredningens open seminar held by Jernebaneverket in December 2010 in Oslo, the likely energy sources for high speed rail services were discussed in presentations by representatives of different companies and authorities such as ATKINS, Statens Offentliga Utredningar, Swedish Royal Institute of Technology, and Asplan Viak Consultants, and etc. They stated that countries which use hydropower energy as their major energy source such as the Scandinavian countries are able to operate high speed rail services with zero CO2 and greenhouse gas emissions. Hydropower energy has some advantages over other types of energy such as fossil and nuclear energy. It is cost effective once the infrastructure is available, it can have positive effects on the wildlife and agriculture, it is much safer than other types of energy sources, and it is renewable. However, it does have some disadvantages as well such. Hydropower dams are very expensive to construct, lots of fish will be killed while the turbines are in operation, it doesn’t produce as much energy as other sources such as nuclear power, and the construction of the dams may lead to local ecosystem disruption.

Overall, it is obvious that high speed rail is an environmental friendlier mode of transport compared with other transportation modes such as road and air; however, some other factor
should be considered while comparing the environmental impacts of different modes such as the production method of energy used in different modes, and the amount of pollution generated by the construction of a new high speed rail line. According to Gourvish (2009), in some cases the environmental benefits generated cannot compensate for the amount of infrastructure investment, however the calculations are still in favor of high speed rail.
4. Indirect and Wider Economic Impacts of High Speed Rail

Indirect economic effects are referred to the impacts generated by high speed rail projects such as enhanced commercial and financial performance that can be used to justify a high speed rail project in circumstances when it cannot be justified on sound user profits. Local authorities often support the indirect and wider economic impacts of high speed rail projects in order to approve the construction of high speed rail projects with uncertain performance, since launching a new high speed rail project can lead to other urban developments such as eliminating disadvantages of existing railway infrastructure. Given that high speed rail projects are often financed by state or European commission support, local authorities try to justify it using indirect and wider impacts as an argument in order to get the project launched.

It is assumed by regional and local authorities that travel time savings and enhanced accessibility created by high speed rail projects can lead to direct economic and financial outcomes such as increase in business productivity as a reason of a newly connected zone, increased attraction for tourists and new residents. However, these assumptions may lead to misjudgments in prospective demand and generated benefits, as well as ignorance of the redistribution that is caused by alteration of the existing accessibility model.

Whether the construction of a high speed rail line or network generates economic improvement in a region is dependent on the unique characteristics of each region, as well as the modification that it implies on accessibility patterns and other policies affecting the transportation enhancement.

4.1. The European High Speed Rail Network

Early high speed rail projects in Europe were able to generate demand and also divert traffic from other transportation modes such as road and air to high speed rail. This fact led to region’s will to be included in the developing European network. They were able to generate significant economic benefits; however, later projects needed producing indirect and social profits in order to be justified for allocating finance.
As the network began to develop and expand, it became more complex, making it more difficult to identify the actual economic benefits it generated. The early experience of high speed rail in France indicated that high speed rail is not only a competitor for road and air travel, but can also completely drive them out of the market for journeys of 400-500 Kilometers range and even higher distances. As a consequence, high speed rail turned to a complement for other modes instead of being a competitor by connecting different airports in a region or province.

The Europeans decided to build a new high speed rail network called the trans European network or TEN as a dedicated and independent network from existing conventional rail services. According to Campos and de Rus (2009), “The major problems of the TEN are the duplication between networks, and the desire of cities and regions to ensure they are connected to each network—their perception is that it would be a serious disadvantage for them not to be connected when other cities were. In fact the amount of central EU funding for each TEN link is relatively small, and although dedication can give rise to eligibility for Structural and Cohesion Funds, national, regional and local governments (and the private sector) have to find the bulk of the finance; and this can prove to be a long-term burden on the public sector’s commitments.”

According to the European Commission (2003), the Trans European network was prioritized among European infrastructure projects in its early phases since it was promoting a new and environmentally friendly mode of transportation. However, intentional effects of high speed rail services such as produced traffic have not been as significant as anticipated. For instance, while rail services have captured seventy percent of the total Paris-London-Brussels market, Eurostar has only managed to serve one third of its original anticipated passengers after ten years of operation. According to Vickerman (2006), from the European Union point of view, the main challenge is identifying the economic benefits and added value generated by the Trans European network regarding strategic cross border aspects and crucial connections between cities of the European countries.

### 4.2. Definition of Wider Impacts of High Speed Rail

Although the main inspiration of the initial high speed rail lines was improving capacity, the escalated speed ranges that it provided has led to significant impacts on the competitiveness of...
high speed rail services and the traffic that it has produced. The increased speed has led to lower travel costs and impedance of distance providing improved accessibility and economic capacity for regions using high speed rail.

4.2.1. The impacts of Accessibility Change

Primary studies indicate that the introduction of the French TGV has improved the traffic generated between urban centers; however its effects on regional economies are yet uncertain. It cannot be concluded that high speed rail services have led to significant economic improvements and increased development rates in cities served by the TGV.

Although the TGV has led to significant traffic growth between Paris and the cities served, its effect on business traffic is more complex to analyze. The TGV has had a considerable effect on the mobility model of the Paris-Lyon corridor since lots of businesses along the route change their working patterns in order to get more use out of the improved accessibility which later led to growth in the travel demand between the two cities. The centralizing impact of high speed rail has not had a net economic impact on the major cities, but has led the businesses to concentrate their economic activities in main cities from the local surrounding areas. The same impacts were predicted in Nantes, but it mostly turned out in terms of increase in land and property value with little economic activity improvement; however, the tourism industry gained a significant benefit after introduction of the TGV in Nantes leading to a considerable increase in hotels and other tourist services.

In Spain, it is expected that high speed rail will lead to two major impacts, diverting passengers from air travel to high speed rail and integrating small and medium urban centers located alongside the route. Urban development is expected to happen in the surroundings of new high speed rail stations.

4.3. Wider Economic Benefits of High Speed Rail

According to de Rus et al (2009), wider economic benefits of high speed rail can be seen in two different tracks. One track is the improvement they make in the total welfare by
Economic Analysis of High Speed Rail

generating reduced travel time, reduced accidents and etc. Another track is the profits generated in terms of increased Gross Domestic Production or GDP as a result of improved economic activities provided by new transportation services. These benefits can be measured in different ways which leads to different results generated. For instance, the travel time savings gained through commuting and leisure travel are welfare benefits to the user, but do not have direct impacts on the Gross Domestic Production; nevertheless, when travel time savings improve productivity, it may have a considerable impact on the GDP.

Wider economic impacts can be implied in different ways according to each individual region’s specific characteristics. For example, the increase in welfare can occur in one area and the increase of GDP in another. Primary and secondary regions may experience different impacts depending on the effects that the new transportation mode has on concentration of employment.

Wider benefits are the benefits that cannot be captured from passengers in monetary terms such as ticket sale, but they present themselves in various ways such as improvements made in the labor market, productivity, increasing competition in different markets and etc. According to Jara Diaz (1986), if true competition rises in markets using transportation then the user benefits can represent the total profits generated by improved transportation accurately.

Regarding the effects of high speed rail on the labor market, it is agreed that improved transportation is able to ease the access to occupations that were not feasible before. According to the Department for Transport (2005) it enables work force to find jobs in regions which need labor instead of regions where there are less job opportunities available, which will lead to generated benefit achievable for employees, employers, as well as the public. Improved accessibility may lead to persuading the labor to work for more hours which is favorable to the employees, employers, and the public; however, the labor would rather use these gained extra hours for leisure rather than work. Perhaps the most significant impact of high speed rail can be the improvement in productivity which is achieved by enabling labor to transfer from less to more productive jobs by providing easier access to different regions. High speed rail can improve and increase the opportunity for long time commuting for competent labor in cases where personal issues may restrict temporary relocation.
4.4. Total Economic Impact

Three major elements should be considered in order to assess the total economic impacts of high speed rail service. These elements are high speed rail’s effect on competition in the served areas, its impact on generating benefits by using the market change by means of agglomeration, and its impacts on linkages such as the labor market.

High speed rail’s impact on competition in perfect and imperfect competitive markets is uncertain, but it is considered that the escalated competition has had a neutral impact on the markets and the impacts can be categorized under direct user benefits. The direct user benefits are significantly higher in imperfect competition markets rather than perfect competition markets due to increase in productivity in imperfect markets. The major direct benefits generated in most high speed rail projects are travel time savings related to the salary levels which reveal increase in productivity. The benefits produced in imperfect competition markets are due to creation of a greater market size which enables businesses to improve their scale and productivity. Reduced transportation costs and commuting times enables the businesses to have access to a greater labor market which will generates profit for firms by reduced salary levels and access to skilled human resources which will lead to increased productivity.

It should be considered that the scale of the infrastructure project is not the only factor affecting the extent of wider economic benefits of high speed rail. Larger infrastructure projects are expected to generate higher direct benefits for users, but wider economic impacts cannot be linked only to direct user benefits. Experiences reveal that some smaller infrastructure projects have managed to have greater indirect economic impacts in terms of productivity and linkage, while larger projects have been unable to do so.

4.5. Evidence of Wider Economic Impacts of High Speed Rail

According to findings of Laird et al. (2005), although the development of the Trans European Network has led to major improvements in transportation costs and accessibility, it has not been able to contribute significantly to the growth of GDP and welfare in Europe. These
findings reveal that the Trans European Network has only managed to increase the total GDP around four percent. They also show that the Trans European Network has had both positive and negative impacts, but the major positive impacts were experienced in poorer and more peripheral areas; hence, it cannot be strongly concluded that the Trans European Network has made a significant contribution to the economy improvement of regions it served, considering its substantial investment cost. However, the wider economic impacts and added value generated by high speed rail services may vary depending on each region’s specific characteristics.

Although investment in high speed rail infrastructure and services has increased significantly and became a priority for European states, the motivation and underlying principle of these investments have been unclear to some extent. It is not transparent whether the purpose of these investments are increasing the transportation capacity and maintaining the market share of rail services, or it is a competing transportation mode for air travel in medium ranges, or it is a more primary and basic mean for economic growth and territorial equilibrium with impacts on competitiveness and cohesion. As Campos and de Rus (2009) state in their report of empirical findings, “Analysis of different projects suggest that whilst the wider economic effects of HSR can be significant, they are not always obvious or predictable and can vary significantly between different high speed rail projects. The analysis needs, however, to go further. Most of the analysis does not deal adequately with the dynamic effects, which the development of a completely new network could have on patterns of trip making and economic behavior. These may go beyond the simple network effects as evidenced by the rapid growth of that other new network of low-cost airlines. The next stage in the development of high speed rail is the joining up of the major international networks with the developing of national networks, and this could imply a step-change in effects even greater than that experienced by the first high speed rail links. Such a step-change does, however, carry implications for pricing and interconnection with other modes, including local and regional rail which need careful consideration.”
5. Case Study: The Channel Tunnel

5.1. History of the tunnel

The idea of linking Britain and France through a tunnel has been discussed for more than 200 years. The idea was first presented by Albert Mathieu in 1802. He proposed a link between Cap Gris Nez and Eastwell Bay, which turned out to be quite the same route as the tunnel was constructed later. According to Slater and Barnett (1957), the first effort to build the tunnel was by Colonel Beaumont in 1880 which was refused by the government because of national security issues; furthermore, inadequate engineering techniques held back the construction for a further 100 years.

Because of the vast traffic increase between the UK and Europe after the Second World War and the forecasts of more traffic growth in the following years, relevant authorities came to a conclusion that the construction of the tunnel is feasible and details of executing it should be completely examined.

In 1957, consideration of building the Channel Tunnel turned serious and the Anglo-French Channel Tunnel study group was established. The French government established an alternative study group to study the feasibility of a channel bridge instead of a tunnel. An official joint working group of the British and French was set up to analyze the two proposals. According to the Ministry of Transport Report (1963), the joint working group voted in favor of the tunnel, so the British and French prime ministers made a joint decision to find a solution for the construction on mutually acceptable terms, which none of their solutions was acceptable to the other. Therefore, another joint group was established to revise the proposals, and finally in March 1970, both prime ministers agreed to the new scheme.

Financing and construction arrangements of the project went along at a slow pace. This led the Labor government to set up a Channel Tunnel Advisory Group (CTAG) to reassess the project. The reassessment led the government to abandon and withdraw from the project. In March 1980, following the government’s announcement that it was looking forward to receive
proposals for a fixed link across the channel, a joint British-French study group published its report (Department of Transport, 1982), which favored the tunnel instead of a bridge.

The early estimations suggested significant financial benefits; however, the capital markets were not prepared to support any of the proposals. Finally, in 1985 the British and French governments invited promoters to propose a scheme for developing, financing, constructing and operating a fixed link across the English Channel. The governments refused to give any support from the public funds or financial guarantees and stated that the link should be constructed and operated completely by the promoter’s own risk.

In 1986, the British and French governments agreed to facilitate the construction of the tunnel by the Channel Tunnel Group-France Munch (CTG-FM) Consortium, after assessing the four proposals received.

5.2. Traffic Forecasts

Traffic forecasts and diversion have been a fundamental part of the studies undertaken prior to the construction of the tunnel. The CTG-FM and Eurotunnel reports have estimated the total demand of the cross channel traffic and the likely passenger and freight diversion through the channel link.
Table 9: CTG-FM Passenger and Unitised Freight forecasts - Total demand (1993) and tunnel share (1993 and 2003) (millions of passengers and millions of tonnes)

<table>
<thead>
<tr>
<th></th>
<th>1993</th>
<th></th>
<th></th>
<th>2003</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Demand</td>
<td>Tunnel passengers</td>
<td>Market share (%)</td>
<td>Tunnel passengers</td>
<td>Market share (%)</td>
</tr>
<tr>
<td>Car passengers</td>
<td>9.5</td>
<td>6.3</td>
<td>66%</td>
<td>7.3</td>
<td></td>
</tr>
<tr>
<td>Coach passengers</td>
<td>8.4</td>
<td>4.4</td>
<td>52%</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>Day trip passengers</td>
<td>3.2</td>
<td>3.1</td>
<td>97%</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td>Other foot passengers</td>
<td>46.1</td>
<td>10.9</td>
<td>24%</td>
<td>12.9</td>
<td></td>
</tr>
<tr>
<td>TOTAL passengers</td>
<td>67.2</td>
<td>24.7</td>
<td>37%</td>
<td>29.1</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>1993</th>
<th></th>
<th></th>
<th>2003</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Demand</td>
<td>Tunnel freight</td>
<td>Market share (%)</td>
<td>Tunnel freight</td>
<td></td>
</tr>
<tr>
<td>Roll on/roll off freight</td>
<td>24.2</td>
<td>6.0</td>
<td>25%</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>Containers and Rail wagon</td>
<td>7.9</td>
<td>4.0</td>
<td>52%</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>32.1</td>
<td>10.0</td>
<td>31%</td>
<td>14.3</td>
<td></td>
</tr>
</tbody>
</table>

Source: Channel Tunnel Group Limited and France Manche SA CTG-FM (1985)

Table 9 indicates that Eurotunnel’s goal was to capture two third of the road market within the first year of operation.
Table 10: Eurotunnel (1987, 1990) passenger and freight forecasts (million of trips/tons)

<table>
<thead>
<tr>
<th></th>
<th>1993</th>
<th></th>
<th>2003</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Traffic Volumes</td>
<td>Tunnel market share</td>
<td>Traffic Volumes</td>
<td>Tunnel market share</td>
</tr>
<tr>
<td>Total passenger demand</td>
<td>67.1</td>
<td></td>
<td>93.6</td>
<td></td>
</tr>
<tr>
<td>Channel Tunnel traffic</td>
<td>29.7</td>
<td>44%</td>
<td>39.5</td>
<td>42%</td>
</tr>
<tr>
<td>Total unitized freight market</td>
<td>42.4</td>
<td></td>
<td>62.5</td>
<td></td>
</tr>
<tr>
<td>Channel Tunnel traffic</td>
<td>14.8</td>
<td>35%</td>
<td>21.1</td>
<td>34%</td>
</tr>
</tbody>
</table>

1987 update

<table>
<thead>
<tr>
<th></th>
<th>1990 update</th>
<th></th>
<th>2003 update</th>
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<tbody>
<tr>
<td></td>
<td>Traffic Volumes</td>
<td>Tunnel market share</td>
<td>Traffic Volumes</td>
<td>Tunnel market share</td>
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<tr>
<td>Total passenger demand</td>
<td>84.2</td>
<td></td>
<td>125.2</td>
<td></td>
</tr>
<tr>
<td>Channel Tunnel traffic</td>
<td>28.6</td>
<td>34%</td>
<td>44.6</td>
<td>36%</td>
</tr>
<tr>
<td>Total unitized freight market</td>
<td>47.2</td>
<td></td>
<td>74.5</td>
<td></td>
</tr>
<tr>
<td>Channel Tunnel traffic</td>
<td>16.2</td>
<td>35%</td>
<td>36.8</td>
<td>36%</td>
</tr>
</tbody>
</table>

Source: Eurotunnel (1987, 1990)

Table 10 indicates a higher estimation for the passenger and freight markets by increasing the total transport market. The passenger market for 2003 was estimated to be 35% higher in 1990 than it was in 1987. Anguera (2005) states “The combined effect of the changes in the total market and assumed diversion rates was, both for the passenger and freight markets, a considerable increase in the absolute projected traffic through the Tunnel.” Flyvbjerg (2003) believes that this is because of the need to preserve confidence of the shareholders and banks when new cost overruns appeared in the project.
### Table 11: Eurotunnel (1994) passenger and freight forecasts (million of trips/tons)

<table>
<thead>
<tr>
<th>Year</th>
<th>Traffic volumes</th>
<th>Tunnel market share</th>
<th>Traffic volumes</th>
<th>Tunnel market share</th>
<th>Traffic volumes</th>
<th>Tunnel market share</th>
<th>Traffic volumes</th>
<th>Tunnel market share</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total passenger demand</td>
<td></td>
<td>Total unitized freight market</td>
<td></td>
<td>CT traffic</td>
<td></td>
<td>Total unitized freight market</td>
<td></td>
</tr>
<tr>
<td></td>
<td>71.7</td>
<td></td>
<td>77.7</td>
<td></td>
<td>82.5</td>
<td></td>
<td>107.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.9</td>
<td>4%</td>
<td>16.3</td>
<td>21%</td>
<td>21.8</td>
<td>26%</td>
<td>35.8</td>
<td>33%</td>
</tr>
<tr>
<td></td>
<td>43.8</td>
<td></td>
<td>47.4</td>
<td></td>
<td>50.2</td>
<td></td>
<td>73.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.6</td>
<td>6%</td>
<td>11.1</td>
<td>23%</td>
<td>16.0</td>
<td>32%</td>
<td>25.3</td>
<td>33%</td>
</tr>
</tbody>
</table>

Source: Eurotunnel (1994)

It seems that Eurotunnel has considered the slower market growth than predicted in 1994, but the estimations are still higher than the 1985 estimate.

#### 5.2.1. Actual Traffic Volumes

**5.2.1.1. Passengers**

Table 12 presents the actual Channel Tunnel passengers between 1994 and 2003.

### Table 12: Actual Channel Tunnel passengers, 1994 – 2003 (millions of passengers)

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<tr>
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<th></th>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Eurostar passengers</td>
<td>0.1</td>
<td>2.7</td>
<td>4.9</td>
<td>6.0</td>
<td>6.3</td>
<td>6.6</td>
<td>7.1</td>
<td>6.9</td>
<td>6.6</td>
<td>6.3</td>
</tr>
<tr>
<td>Le Shuttle passengers</td>
<td>0.2</td>
<td>4.4</td>
<td>7.9</td>
<td>8.6</td>
<td>12.1</td>
<td>11.0</td>
<td>9.9</td>
<td>9.4</td>
<td>8.6</td>
<td>8.6</td>
</tr>
<tr>
<td>CT passenger</td>
<td>0.3</td>
<td>7.1</td>
<td>12.8</td>
<td>14.7</td>
<td>18.4</td>
<td>17.6</td>
<td>17.0</td>
<td>16.3</td>
<td>15.3</td>
<td>14.7</td>
</tr>
</tbody>
</table>


By comparing the demand forecasts and the actual number of passengers, it’s clearly obvious that the Eurotunnel’s forecasts were very optimistic, since they had predicted the number of passengers to be between 2 to 3 times of the current number of passengers.
This large overestimation of the passenger traffic of the tunnel may be caused either by miscalculation of the actual share of the market captured by the tunnel, or the overestimation of the total cross channel market, or both.

**Total Cross Channel Passenger Market**

The total number of the tunnel passengers grew at a convenient pace till 1998 after the tunnel’s opening, but since the duty free got eliminated the market began to fall which continues to the present day. Table 13 shows this market regression by presenting the total channel tunnel passengers from 1994 to 2003.

**Table 13: Total cross-Channel passengers, 1994 – 2003 (millions of passengers)**

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<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>Unaccompanied</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air passengers</td>
<td>4.4</td>
<td>4.0</td>
<td>4.0</td>
<td>4.3</td>
<td>4.3</td>
<td>4.4</td>
<td>4.3</td>
<td>4.0</td>
<td>4.3</td>
<td>4.1</td>
</tr>
<tr>
<td>Eurostar passengers</td>
<td>0.1</td>
<td>2.7</td>
<td>4.9</td>
<td>6.0</td>
<td>6.3</td>
<td>6.6</td>
<td>7.1</td>
<td>6.9</td>
<td>6.6</td>
<td>6.3</td>
</tr>
<tr>
<td>Classic passengers subtotal</td>
<td>7.0</td>
<td>6.7</td>
<td>8.9</td>
<td>10.3</td>
<td>10.6</td>
<td>10.9</td>
<td>11.5</td>
<td>10.9</td>
<td>10.9</td>
<td>10.4</td>
</tr>
<tr>
<td><strong>Car accompanied</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferry service</td>
<td>23.7</td>
<td>21.5</td>
<td>22.4</td>
<td>23.8</td>
<td>20.4</td>
<td>19.0</td>
<td>16.6</td>
<td>16.0</td>
<td>16.5</td>
<td>14.8</td>
</tr>
<tr>
<td>LE Shuttle</td>
<td>0.2</td>
<td>4.4</td>
<td>7.9</td>
<td>8.6</td>
<td>12.1</td>
<td>11.0</td>
<td>9.9</td>
<td>9.4</td>
<td>8.6</td>
<td>8.6</td>
</tr>
<tr>
<td>Car accompanied subtotal</td>
<td>23.9</td>
<td>25.9</td>
<td>30.3</td>
<td>32.5</td>
<td>32.5</td>
<td>30.0</td>
<td>26.5</td>
<td>25.3</td>
<td>25.1</td>
<td>23.5</td>
</tr>
<tr>
<td><strong>Total cross Channel passengers</strong></td>
<td>30.9</td>
<td>32.5</td>
<td>39.2</td>
<td>42.8</td>
<td>43.1</td>
<td>40.9</td>
<td>38.0</td>
<td>36.3</td>
<td>36.0</td>
<td>33.9</td>
</tr>
</tbody>
</table>

Source: Anguera (2005)

The deviations of the estimations for the total market are even higher than the estimations of the passenger section. However, the share of the market that has been achieved by the channel tunnel has exceeded all projections since 1998 and is close to the estimations of 1987.
5.2.1.2. Freight

According to Eurotunnel’s annual reports the freight volume through the tunnel has increased significantly since freight operations have begun. The current freight volume is higher than Eurotunnel’s predictions in 1987. Table 14 presents the actual freight tonnages from 1994 to 2003.

<table>
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<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Le Shuttle freight</strong></td>
<td>0.8</td>
<td>5.1</td>
<td>6.7</td>
<td>3.3</td>
<td>9.2</td>
<td>10.9</td>
<td>14.7</td>
<td>15.6</td>
<td>15.6</td>
<td>16.7</td>
</tr>
<tr>
<td><strong>Through rail services</strong></td>
<td>1.3</td>
<td>2.4</td>
<td>2.9</td>
<td>3.1</td>
<td>2.9</td>
<td>2.9</td>
<td>2.4</td>
<td>1.5</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td><strong>Total Tunnel freight</strong></td>
<td>0.8</td>
<td>6.4</td>
<td>9.1</td>
<td>6.2</td>
<td>12.3</td>
<td>13.8</td>
<td>17.7</td>
<td>18.0</td>
<td>17.1</td>
<td>18.4</td>
</tr>
</tbody>
</table>


Eurotunnel published updated forecasts in 1990 and 1994 which predicted 30% higher freight volume than the actual volume in 2003.

**Total Cross Channel Freight Market**

According to Eurotunnel’s annual reports, the cross tunnel freight market has stabilized since 2001, after experiencing continuous growth since it began operation. This has led to loss of the freight market share for the ferry operators. Eurotunnel estimated the cross channel freight market almost twice the size of its actual market.

The main reason that the freight and passenger market predictions have not been reached has been the very high overestimation of the cross channel market, both in terms of passengers and freight. As stated in the National Audit Office (2001) report and the Civil Aviation Authority figures, this fact has been the result of the unpredicted existence and emerging of low cost airlines which offer very competitive prices to passengers for a very wider range of destinations across whole Europe rather than the single route from London to Paris. Regarding the freight market, the channel tunnel has achieved a higher share of the market than predicted which has been the result of the great performance of Eurotunnel’s Le Shuttle service.
5.3. Channel Tunnel Costs and Revenue Analysis

In this section a cost and revenue analysis of the tunnel will be presented. The actual costs and revenues will be compared with the initial estimations and the main reasons for miscalculations in terms of cost overruns and revenue shortfalls will be presented.

5.3.1. Costs

Eurotunnel has broken down the actual costs of constructing the channel tunnel in the following categories: tunnels, terminals, fixed equipment, rolling stock, bonuses and direct works. They have stated in their report that the total costs for constructing the channel tunnel has been 9456 million Pounds. The highest portion of the costs is associated with the tunnel boring and fixed equipment costs. According to Gourvish (2002), the British Railway invested significantly in development of its international passenger and freight services which included construction of several stations, rebuilding and upgrading 94 bridges, purchasing passenger and freight rolling stock, and constructing new freight terminals.

Several studies have been carried out for estimating the costs of constructing the tunnel. The project was awarded to the CTG-FM proposal in 1985 which proposed 4740 million pounds. Eurotunnel estimated the total costs to be nearly 5000 million Pounds in 1987; however, the construction costs kept rising in the following years which led the final construction costs of the tunnel to 9500 million Pounds, which indicates nearly 100% cost increase over the original proposal.

Flyvbjerg (2003) believes that the reasons behind this significant cost increase are twofold; enhanced safety, security and environmental requirements which can affect construction policies and lack of a clear owner of such a large project. By creating an independent company, which was Eurotunnel, from the construction consortium, the risk was allocated between Eurotunnel and the contractors in three different ways (fixed cost, target cost, and cost plus) for separate parts of the job.
Unpredicted problems and delays in the execution of the project caused further labor and financing costs; furthermore, unforeseen ground conditions on the British side made the team carry out expensive modifications to the tunnel boring machines. These facts led to significant cost overruns, additional financing problems and loss of expected operational revenues for Eurotunnel.

### 5.3.2. Revenues

Eurotunnel’s actual revenues are presented in table 15. The highest revenue achieved was in 1999 and 2000. The actual revenues show that Eurotunnel clearly has overestimated their incoming revenues. A reason for this misjudgment is that they expected the cross channel market to grow much faster than it actually did. Another reason was that they misinterpreted the alternative services’ competiveness to respond to their services. It turned out that the ferry operators and low cost airlines offered very competitive prices which led to smaller revenues for Eurotunnel. Anguera (2005) gives another reason for revenue shortfalls: “The simple “toll road” operating concept appeared to be highly vulnerable to peak demand overload. In the peak days, long queues formed on both sides of the Tunnel and extended into the motorways. The design configuration did not allow Eurotunnel the management of demand; neither could it encourage off-peak use. As a result, ET was suffering from peak overload whilst at the same time losing further potential revenue by failing to price discriminate. “

**Table 15: Eurotunnel’s actual revenue (£m, out turn prices)**

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Le Shuttle</td>
<td>11</td>
<td>120</td>
<td>145</td>
<td>113</td>
<td>210</td>
<td>271</td>
<td>315</td>
<td>310</td>
<td>333</td>
<td>309</td>
</tr>
<tr>
<td>Railways</td>
<td>12</td>
<td>133</td>
<td>198</td>
<td>212</td>
<td>213</td>
<td>215</td>
<td>208</td>
<td>211</td>
<td>217</td>
<td>232</td>
</tr>
<tr>
<td>Other</td>
<td>7</td>
<td>51</td>
<td>141</td>
<td>206</td>
<td>243</td>
<td>168</td>
<td>77</td>
<td>43</td>
<td>31</td>
<td>43</td>
</tr>
<tr>
<td>Total</td>
<td>31</td>
<td>304</td>
<td>483</td>
<td>531</td>
<td>666</td>
<td>654</td>
<td>600</td>
<td>564</td>
<td>581</td>
<td>584</td>
</tr>
</tbody>
</table>


The strong reaction from the ferry operators forced Eurotunnel to lower its prices. This price reduction had direct effect on Eurotunnel’s traffic volume, leading to decreased revenues compared to the estimated level. Castles (2003), categorizes the cross channel passenger market...
largely a leisure market which is dependent on the customers’ taste. Furthermore, there are several alternatives for the customers to cross the channel. A lot of people may choose ferries to enjoy the sea while crossing the channel. The failure to notice this by Eurotunnel led them to believe that the price levels would be maintained. The underestimation of its competitors caused Eurotunnel’s expected revenue to fall way short of its expectations. On the other hand, ferry companies started competing against each other as well as with Eurotunnel by cutting costs to maintain their market share. They started to invest significantly in upgrading their fleet during the tunnel construction to prepare for the competition. One great option that gave advantage to the ferries over than the railway was the possibility to purchase duty free goods on board. Eurotunnel lost a great amount of passengers by eliminating this option.

5.4. The Economic Appraisal of the Channel Tunnel

Anguera (2005) has calculated the total user benefits that the tunnel has produced in terms of fare reductions and travel time savings. These calculations show that the benefits have increased up to 1998 and then stop growing at a rate of 500 million Pounds. They show that fare reduction benefits are about four times the travel time savings. These analyses are presented in table 16.

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</thead>
<tbody>
<tr>
<td><strong>Total travel time savings</strong></td>
<td>2.2</td>
<td>41.6</td>
<td>75.6</td>
<td>90.0</td>
<td>77.0</td>
<td>80.2</td>
<td>87.3</td>
<td>87.6</td>
<td>84.8</td>
<td>84.7</td>
</tr>
<tr>
<td><strong>Total consumer surplus</strong></td>
<td>113.7</td>
<td>170.9</td>
<td>321.7</td>
<td>347.9</td>
<td>458.7</td>
<td>406.7</td>
<td>392.5</td>
<td>462.9</td>
<td>419.8</td>
<td>409.9</td>
</tr>
<tr>
<td><strong>Total user benefits</strong></td>
<td>115.8</td>
<td>212.5</td>
<td>397.3</td>
<td>437.9</td>
<td>535.7</td>
<td>486.9</td>
<td>479.7</td>
<td>550.5</td>
<td>504.6</td>
<td>494.7</td>
</tr>
</tbody>
</table>

Source: Anguera (2005)

His calculations show a large negative net present value which indicates that this project has not been a viable one. The main reasons for this negative NPV can be the limited operational time of the tunnel and extremely high capital costs. Regarding long term analysis and taking the
debts size into account, the tunnel will need a ten percent of passenger and freight volume increase each year to generate a positive net present value. This rate of growth is unlikely to happen due to the size of the market and limited capacity of the channel tunnel.

The execution of the channel tunnel project has been very complicated, since it involved two governments, lots of different organizations, and complex relations. It has experienced several financial difficulties during all phases of the project. The market size and revenue estimations have been far too optimistic, since they didn’t consider the rising of cheap ferry operators and low cost airlines. The freight shuttle service has been the most profitable service of the channel tunnel; however, the fierce competition between the shuttle and the ferry companies which led to reduced fares has had a significant impact on the tunnel revenues. Furthermore, due to technical and some financial reasons, the construction costs of the tunnel increased significantly and combined with the reduced tariffs caused trouble for Eurotunnel’s finances. The studies carried out on economic aspects of the channel tunnel show that constructing this tunnel has not had any economic benefits since the huge amount of financial and labor resources invested in it are much greater than the generated benefits. The tunnel could have been profitable for the producers if it had been able to operate without its financial depts. On the other hand, the channel tunnel has generated large amounts of benefit for its consumers with reduced fares, both passengers and freight. The price of these benefits is a huge loss for both tunnel and ferry operators. In other words, the consumer benefits are highly insignificant compared to huge producer losses. While its current operation creates some benefits, but its huge accumulated dept makes in unsustainable financially. The channel tunnel is a state of the art engineering masterpiece with a poor economic performance. However, John Kay (1989) believes that the channel tunnel will provide significant social benefits gained through lower prices for consumers that outstands the producers’ losses, but also criticizes the UK and French governments for leaving the private sector to finance the project.

5.5. The Regional Development Impacts of the Channel Tunnel

According to a study carried out by Alan Hay (2004) from Kent University predicted that operation of the channel tunnel will lead to increasing traffic on Kent roads, so the government
took action to improve road schemes. The construction of the channel tunnel has also had impacts on the employment within the transport operation sector. It has led to increase of employment rates of Eurotunnel; however, this came to the price of reduction in employment of the ferry industry which has been the effect of the port’s reduced market share and profits.

Regarding the environment, the channel tunnel has not been able to meet expectations than had been hoped for. In some cases it has had negative effects on the environment. Transferring traffic from road to rail was hoped to be improved by operating the channel tunnel, but it is evident that this goal has not been achieved.

However, the construction and operation of the channel tunnel has had some broader impacts rather than construction and transport operations such as impacts on the investments made, the tourism, retailing, manufacturing, road freight, warehousing and logistics industries.

The construction of the channel tunnel has encouraged investors and foreign businesses to invest their money and do business in the UK. According to the Kent University study, lots of French and other European companies have been registered in the United Kingdom due to this fact. The tunnel also has had positive impacts on the tourism industry especially in south east England. Increased tourist numbers has led to the construction of new infrastructure such as hotels, restaurants and other entertainment facilities and has created a positive employment rate for the region. The tunnel has led to significant improvements in the retail and manufacturing sectors by providing enhanced freight and logistics services to these sectors.

David Smith (1994) believes that the channel tunnel creates development opportunities not only for the south east region, but also certain peripheral UK regions experiencing gains in relative accessibility similar to the South East. As stated by Smith “As a result of the British Government’s commitment to free enterprise, with priority being attached to deregulation, competition, privatization and commercialization, British Rail appears unable to provide the regions with an international service capable of maximizing the opportunities offered by the Channel Tunnel. The British Government’s commitment to market-led solutions is likely therefore to result in a missed opportunity to help revitalize the economic well-being of the regions and may peripheralize further British manufacturers from the continental market-place.”
6. Discussion and Conclusion

High Speed trains are one of the most advanced modes of transport since the Second World War. However, construction of high speed rail lines are very expensive and have a significant sunk cost regarding the infrastructure, while estimating the financial and social impacts of it are rather difficult.

In Europe, the French have been a pioneer of developing high speed lines by introducing a dedicated high speed track from Paris to Lyon which used the existing infrastructure for approaching main stations. Investment pace in some countries such as Germany and Spain was rather slower than others. In Germany, the primary emphasis was upgrading existing trains to accommodate both passengers and freight which had a slow process.

Constructing a newly built and dedicated high speed rail line demands some specific requirements and characteristics that restrict the operational speed of trains to below 250 KM/H. The track designed for high speed operation needs to avoid surface level junctions with roads and highways, have limited stops along the route, advanced signaling and electrification systems, and priority for high speed trains over slower conventional and freight trains.

All high speed infrastructures should have as many as the above features as possible, but this does not mean that all are constructed in the same way. Construction costs of infrastructure in different high speed rail projects may vary depending on special characteristics of each case. These characteristics can be in geographic, topographic, and technical terms of each case. UIC (2005) defines three major cost categories for constructing a new high speed infrastructure:

1) The first category is planning and land costs, which consist of both economic and technical feasibility studies, purchase of land and the relative fees such as legal and administration fees, public taxes, permits, and etc. The planning and land costs can rise significantly in cases where the land has an extremely high value, but it usually represents around five to ten percent of the investment.

2) The second category is infrastructure construction costs which consist of path preparation and construction of the platforms. These costs can be different regarding each case with respect to
terrain characteristics, but usually constitute about ten to twenty five percent of the total costs of a newly built high speed infrastructure. In projects with difficult geographic conditions, these costs can easily rise to twice the normal price.

3) The third category is superstructure costs which consist of technical railway components such as the tracks, sideways, communication, safety, signaling and electrifying systems and some more. Each of these components can compensate between five to ten percent of the total infrastructure cost.

All high speed rail infrastructure projects include these three major types of costs, but the total infrastructure costs are significantly dependent on the relationship between the existing conventional infrastructure and the new dedicated infrastructure that is going to be built in each case.

As discussed, economic impacts and added value generated by high speed rail services may vary depending on each region’s specific characteristics such as economy improvements of the region (de Rus et al, 2009), the effect on competition in the served areas, the impact on labor market (Jara Diaz, 1986) and so on. But the question is are the high speed rail projects in planning and operation worthwhile from a cost and revenue perspective or not?

According to empirical findings, high speed rail systems are generally more economic when higher traffic use these services. This concludes that high speed rail should be constructed wherever traffic volumes are high. The traffic on the new system can be boosted if it is possible to construct a network such that passengers travelling between a number of city pairs use at least part of the same route, with services then branching off on to different high speed or conventional lines.

Although investment in high speed rail infrastructure and services has increased significantly and became a priority for European states and other regions (Laird et al, 2005), but different cases have different economic records around the world.
A cost and revenue analysis of some high speed rail projects including the Channel Tunnel are presented in Table 17 and the reasons for miscalculation of actual costs and revenue shortfalls are explained. Eurotunnel estimated the total costs to be nearly 5000 million Pounds in 1987, however, the final construction costs of the tunnel rose up to 9500 million Pounds, which indicates nearly 100% cost increase over the original proposal. Eurotunnel's actual revenues clearly show overestimation of their incoming revenues because of misjudgment of the cross channel market growth according to Anguera (2005). However, building, maintaining and operating high speed rail lines are expensive and involve a significant amount of sunk costs and may substantially compromise both the transport policy of a country and the development of its transport sector for decades.

In France or Spain, for example, high speed divisions are the only business units within the rail companies that can reasonably recover their operating costs according to the SDG report (2004). There are two groups of countries in Europe. France and Spain have slightly lower building costs than Germany, Italy and Belgium. This is explained not only by the similar geography and existence of the less populated areas outside the major urban centers, but also by construction procedures. In France, for example, the cost of construction is minimized by adopting steeper grades rather than building tunnels and viaducts.

In Japan, the cost per kilometer (excluding land costs) in the Tokyo-Osaka Shinkansen was relatively low (€5.4 million in 2005 values), but in all the projects carried out during the following years, this figure was tripled or quadrupled. Also as it could be seen in Table 17, the estimated costs of the Tokyo-Osaka Shinkansen project have been misjudged and cost overruns have been experienced.

In contrast with the French and Japanese high speed rail networks, the German ICE operated using the existing network in order to access major cities, because new construction would be difficult. The Cologne-Frankfurt high-speed railway is a 177-kilometre (110 mile) long railway line in Germany, connecting the cities of Cologne and Frankfurt. It was constructed between 1995 and 2002 at a total cost of 6 billion Euros according to Deutsche Bahn’s reports.
According to Cox and Vranich (2008), “the Californian High-Speed Rail project is a planned future high-speed rail system in the state of California and headed by the California High-Speed Rail Authority (CHSRA). The total cost is estimated by the CHSRA to be US$42.6 to 45 billion, while other estimates put the cost at US$58.8 billion or more. An implementation plan approved in August 2005 estimates that it would take eight to eleven years to develop and begin operation of an initial segment of the California high-speed train. In September 2008 the report projected that the final cost for the complete high-speed rail system would be $65 to $81 billion. This is significantly higher than estimates made for the CHSRA by Parsons Brinckerhoff, a British owned construction firm.”

At 23 million people, Taiwan has a much smaller population than Japan, Europe, and other places with high speed rail networks. Business traffic volume is considered the main revenue source of Japanese and European high speed rail operations, but the Taipei–Kaohsiung business trip growth has not been as much as expected according to Cheng (2009). The Taiwan high speed rail project is one of the world’s largest high speed projects executed using private financing. With construction managed by a private company and the Taiwan High Speed Rail Corporation (THSRC) operating the line, the total cost of the project was US$18 billion.
Table 17: Summary of some high speed rail projects' financial data

<table>
<thead>
<tr>
<th>Project</th>
<th>Estimate Cost</th>
<th>Actual Cost</th>
<th>Estimate Revenue</th>
<th>Actual Revenue</th>
<th>Estimated Passengers</th>
<th>Actual Passengers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro Tunnel</td>
<td>5000 million Pounds</td>
<td>9500 Million Pounds</td>
<td>839 (Million Euro)-Year 2010</td>
<td>736.6(Million Euro)-Year 2010</td>
<td>13.3 Million-Year 2010</td>
<td>9.5 Million Year-2010</td>
</tr>
<tr>
<td>Paris-Brussels-Amsterdam-Cologne(France)</td>
<td>1560 Million Euros</td>
<td>3330 Million Euros</td>
<td>967 Million Euro</td>
<td>876 Million Euro</td>
<td>83.2 Million-Year 2010</td>
<td>65.5 Million-Year 2010</td>
</tr>
<tr>
<td>Tokyo-Osaka Shinkansen(Japan)</td>
<td>200 Billion Yen</td>
<td>400 Billion Yen</td>
<td>100,079 Million Yen -Year 2011</td>
<td>76,224 Million Yen -Year 2011</td>
<td>351.18 Million-Year 2011</td>
<td>418 Million-Year 2011-Annually</td>
</tr>
<tr>
<td>Cologne-Frankfurt(Germany)</td>
<td>6.4 billion Dollar</td>
<td>8.7 Billion Dollar</td>
<td></td>
<td></td>
<td></td>
<td>31.5 Million-Year 2010</td>
</tr>
<tr>
<td>California High Speed Rail</td>
<td>45 Billion Dollar</td>
<td>65-81 Billion Dollar( it is a current Project)</td>
<td>190 Million Dollar-Year 2011</td>
<td>105 Million Dollar-Year 2011</td>
<td>176 Million-Year 2010</td>
<td>91-95 Million Per Year 2010</td>
</tr>
<tr>
<td>THSR(Taiwan)</td>
<td>11.5 Billion Dollar</td>
<td>18 Billion Dollar</td>
<td>23,323,712 Million Dollar</td>
<td></td>
<td></td>
<td>36,939,596 Million (2010)</td>
</tr>
</tbody>
</table>

Sources: Various

It is seen that the Channel Tunnel Rail Link is much more expensive than any other high speed line that has been constructed. This is because of the construction of routes through tunnels or over viaducts which is four to six times more expensive per kilometer than construction over flat land.

The Utah Foundation Report (2010) states that “funding for HSR systems almost always depends on external capital contributions. This is because HSR almost always requires significant financial resources. While some HSR systems are able to cover the cost of operations and maintenance from the revenue received from fares alone, the capital costs of infrastructure
are very expensive and cannot be paid without the central government’s assistance. For instance, all the well known private companies in Japan were previously owned by the government. Also in Europe, the independent operators own and run their own trains on the tracks that were initially paid for by the government.” This theory is backed up by the United States Congress Report (2009) which indicates that high speed rail infrastructure investments can rarely be covered by the incoming revenues.

However, high speed rail may not be justifiable in most cases regarding sound financial analysis; it has proven to be profitable in socio economic and environmental aspects of transportation. High speed rail services around the world have managed to generate user benefits such as reduced travel time and cost, improved accessibility, regional and local economic developments, reduction in car accidents, and etc as well as providing a more environmental friendly mode of transport in terms of noise, CO2, SO2, and NOx emissions. Although these social benefits have been significant in some cases and overestimated in most, they have never been able to compensate for the extremely high costs of infrastructure investments.

To sum up, high speed rail experiences around the world have not been worthwhile in terms of Cost-Revenue analysis. This is mainly because according to findings, in the next 20-year interval, accumulated demand growth has halved and therefore traffic volumes of high speed train would not grow as expected. This study also shows that most European high speed rail projects and also United States projects are still in their “first 20-year period” and therefore it is natural to expect high growth rates at least until the high speed transport markets start to mature as in Japan. So, high speed rail operating costs in comparison with their revenue is still questionable for many countries. The analysis in this report suggests that high speed rail can be justifiable to some extent mainly in 100-500 Kilometer corridors connecting densely populated regions to local areas.

This study also concludes that the high speed rail introduction has led to a significant social benefit from travel time savings, reduced road accident rates, and reduced external costs. Though the ratio of social benefits to operation revenue in different high speed rail projects will
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decrease gradually, but the huge amount of financial loans and under estimated ridership will cause the NPV to become positive only in the final stages of the project if the traffic volume increases as expected.
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