UNIVERSITY OF BIRMINGHAM

GENERALISED COST BENEFIT ANALYSIS FOR LARGE INFRASTRUCTURE PROJECTS: THE CASE OF THE CHANNEL TUNNEL RAIL LINK

A thesis submitted in fulfilment of the

requirements for the degree of

DOCTOR OF PHILOSOPHY

by

MOHAMMAD HOSSEIN NAGHASHIAN

School of Mechanical Engineering

University of Birmingham

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This thesis is dedicated to my parents,

Fatemeh Javaherian and Hamid Reza Naghashian

for their continual support throughout the years.

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Abstract

Even in the absence of specific evidence it is surely unthinkable to imagine Napolean Bonaparte himself, when considering the potential benefits of invading England, failing to weigh against them the costs of building a tunnel under *La Manche*. In the light of the considerable literature of cost benefit analysis (CBA) and by gathering together several analyses that have been performed on the Channel Tunnel in more recent times, this thesis demonstrates that a comprehensive 'big picture' CBA framework is missing, and then provides one: a new methodology, represented in Data Flow Diagram (DFD) form, for the generalised cost benefit analysis of large infrastructure projects.

Now, almost two hundred years after Napoleon's death, the world spends nearly $40 trillion (almost £24 trillion) on constructing and upgrading roads, railways, power plants and other infrastructures so as to keep up with demand. Such huge investments require realistic plans, clear deadlines and tight budgets for the best allocation of resources but cost overruns and delays are all too frequent. What exactly causes the cost overruns or delay is difficult to identify, but better planning and focus on the accuracy of the appraisal is one way to reduce the problems.

The new model presented herein should prove useful in assisting decision-makers for all large infrastructure projects, and as a foundation for developing an appropriate decision making tool for different categories of projects too, based upon the experience of the

Channel Tunnel. This, after all, was a project that the Government had financed through the private sector with high investment risks and significant degrees of uncertainty and had then put out for construction and operation in two different tenders. In spite of never being viable for the private sector, the Eurotunnel Company looks in a better shape now and the tunnel is working properly, but the construction cost and deadlines were clearly exceeded.

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Chapter 1

INTRODUCTION

1 INTRODUCTION

1.1 Background

The American Heritage Dictionary states that “The term infrastructure has been used since 1927 to refer collectively to the roads, bridges, rail lines, and similar public works that are required for an industrial economy, or a portion of it, to function. The term also has had specific application to the permanent military installations necessary for the defence of a country. Perhaps because of the word's technical sound, people now use infrastructure to refer to any substructure or underlying system.” (The American Heritage® Dictionary of the English Language, 2009)

Richard Threlfall, the UK Head of Infrastructure in 2010 said that “the need for infrastructure development is one of the great global challenges of our time.” Failure to invest is equal to failure to grow and failure to improve socially and economically. Some Specialist’s assessment is that nearly $40 trillion (almost £24 trillion) is required worldwide to construct or upgrade roads, railways, power plants and other infrastructures so as to keep up with demand. As stated by the Treasury, the UK infrastructure’s spending could require £40bn to £50bn each year up to 2030 (Threlfall, 2010). Investment in infrastructure is crucial for the modern economy. Infrastructure investment will simply boost economic development if it is distributed to high value plans and they are built in a cost effective way. Most of the infrastructures in the USA are provided by the private companies. As stated by national income accounts data in 2012 gross fixed private investment was $2 trillion. Total federal, state and local government infrastructure investment in 2012 was $472 billion (Edward, 2013). The following graph from the Private Infrastructure Projects Database (PIPD) of World Bank shows trends of investment in infrastructure projects in low and middle income countries by primary sector (PPID, 2013). The graph shows the increase of investment in infrastructure projects from 1990 to 2012. As the investment and number of projects grow the importance of the plan and risk of the project will increase.

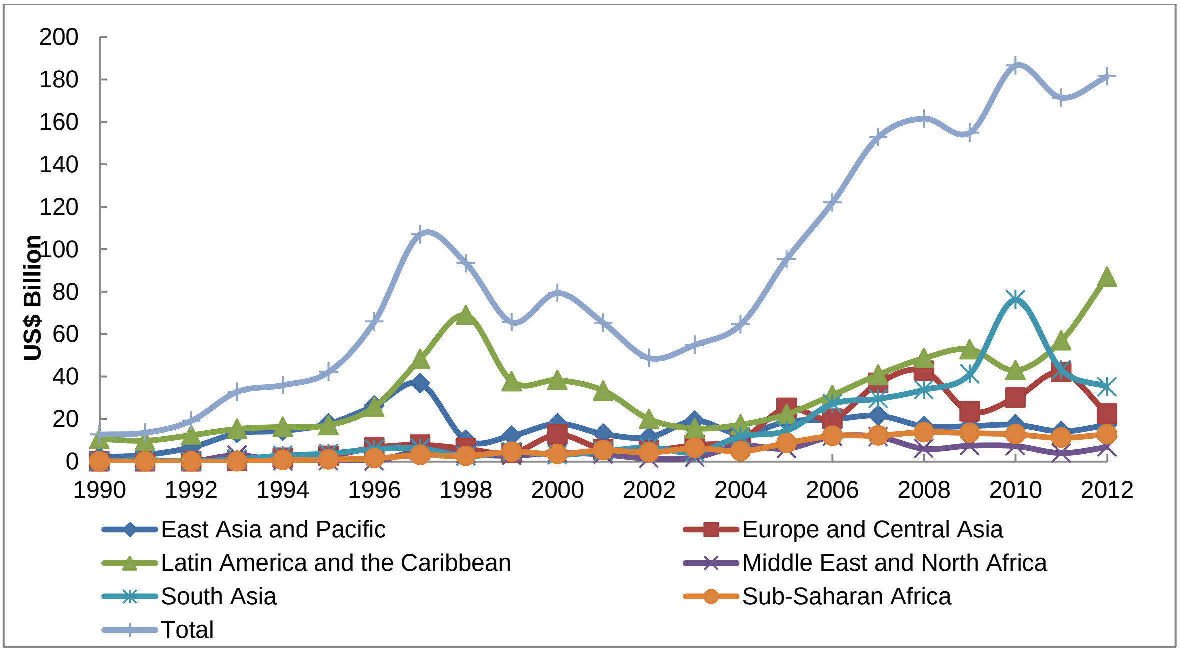

Figure 1: Infrastructure projects in low and middle income countries by primary sector (PIPD)

In terms of size, a large infrastructure project means a cost per project from hundreds of million to several billion dollars (Flyvbjerg and Cowi, 2004). Such huge investments should have a plan, deadline and tight budget to use the best allocation of resources; but with years of practise, trial and error methods and learning, there is still a long way to perfection. Unfortunately cost overruns and delays are habits in mega projects' setup. In the past there have been a vast number of projects with cost overruns and delays, all for different reasons. What exactly causes the cost overruns or delay is difficult to forecast, but better planning and focus on the decency of the appraisal is the way to reduce the problems (Flyvbjerg et al, 2005). Some famous examples of cost overruns in large transport projects have been gathered by Flyvbjerg (2003) and can be seen in Table 1 below.

Table 1: Some famous examples of cost overruns in large transport projects (Flyvbjerg, 2003)

Project	Cost Overrun (%)
Boston's artery/tunnel project	196
Humber Bridge, UK	175
Boston-Washington-New York rail, USA	130
Great Belt rail tunnel, Denmark	110
A6 Motorway Chapel-en-le-Frith/Whaley bypass, UK	100
Shinkansen Joetsu rail line, Japan	100
Washington metro, USA	85
Channel Tunnel, UK, France	80
Karlsruhe-Bretten light rail, Germany	80
Öresund access links, Denmark	70
Mexico City metro line	60
Paris-Auber-Nanterre rail line	60
Tyne and Wear metro, UK	55
Great Belt link, Denmark	54
Öresund coast-to-coast link, Denmark/Sweden	26

Transport, as an example of large infrastructure projects, is costly and frequently faces large cost overruns. Work can be more expensive than in the original primary calculation; therefore extra budget is needed. This will cause other problems such as delay and the project might stop for long time to get the extra budget approval (Flyvbjerg et al 2005). Accordingly the budget cannot afford the other projects because the overall budget for infrastructure is fixed and tight in general. Consequently it will not only damage the project under consideration, but also other planned project as well (Cantarelli et al., 2012). This problematic situation is even more alarming seeing that the "cost escalation has not decreased over the past 70 years." (Flyvbjerg et al., 2003) This can affect the whole country or region if the cost escalation goes out of hand. Examples of the Suez Canal (1900%) and Sydney Opera House (1400%) show how much cost overruns can damage an economy (Flyvbjerg et al., 2003). Large infrastructure projects have special characteristics that the planner should take into account (Flyvbjerg and Cowi, 2004):

- These projects are naturally risky because of long term planning and complex boundaries,
- Decision making and planning of such projects are related to different sections with conflicting interests,
- The scope or motivation level might change a lot over time,
- Statistical calculations demonstrate that unexpected events are mostly not considered in budget planning,
- Therefore misinformation of costs, benefit and risk is happening all the time.

The outcome is cost overruns and/or benefit shortages with most of the projects. These vast amounts of investments and the problematic history of this category proves that there is a need to have a direct path that everyone can learn from, use, understand and be able to compare their results together. A method called cost benefit analysis (CBA) has been used for decades. It has advantages and shortcomings that will be explained in this thesis. Although it has been used for many years there is still no comprehensive framework that all can use for planning and decision making. There are various examples of using CBA in financial regulation (Cochrane, 2004), crime prevention (Dossetor, 2011), healthcare benefits (Eichler, 2004), cloud computing (Konodo et al., 2009).

In a way that no study to date has done, this thesis introduces a generalised CBA process model for large infrastructure projects, taking into account that any such model must be based on actual experience from real projects. The purpose is to guarantee a realistic consideration of the problems and difficulties as well as suggestions that are practically required and possible to implement in a real situation.

1.2 Aims and Objectives

The aim of this thesis is to produce a generalized cost benefit analysis model for large infrastructure projects based on the channel tunnel case study and the objectives are:

1. Review the use of established concept for cost benefit analysis.
2. Determine whether the Channel Tunnel Rail Link (CTRL) was justified; was it really on time and on budget; did it deliver the fare reductions and travel time savings?
3. Present an improved methodology/framework for cost benefit analysis including hitherto neglected items.

1.3 Research Methodology

Whatever the answers to the second objective above, it was realised that there would then be further questions about the extent to which they could be generalised, whether to other tunnelling projects, other infrastructure projects or even any other projects in any sphere of human activity. In some senses the Channel Tunnel was atypical, it being the largest such project of its time, funded by private investors and involving international collaboration; furthermore there was considerable uncertainty about the costs, what demand might be realised and how its competitors might react. In others though, the Tunnel was ideal: most importantly there been a handful of reasonably independent studies conducted at different times, by different people and using different methods. It was envisaged that the thesis would be predominantly quantitative and, unlike in so many other cases where the data and calculations are veiled in commercial confidentiality, availability of detailed information from the public domain would be guaranteed. This was essential in that the research was intended to expose the single “truth” of the matter i.e. a set of measurable dimensions of the Channel Tunnel project’s costs and benefits that could be quantitatively and independently calculated using exact quantitative approaches and frameworks (Creswell, 2003).

Central to the research would thus be to establish the quantitative nature of the relationships between the costs and the benefits of large infrastructure projects using Cost Benefit Analysis. Proof has been found from the literature on related studies about the use of such an approach (see Ministry of Transport, 1963; Coopers & Lybrand Associates Ltd., 1973; Channel Tunnel Advisory Group, 1975; UK/French Study Group, 1982 and Anguera, 2006).The basics of a qualitative method were also combined to deliver further insight into the costs and Benefit of the Channel Tunnel and benefits of the project.

The study started with a literature review, which illustrates an opportunity to improve a suitable theoretical approach for the study and a generalised CBA process model for all large infrastructure projects.

Then the introduction of the CBA case study for the Channel Tunnel project has been studied. The information such as the history of the project in terms of reasons that led to the construction of the project, Past appraisals of the project, comparison of them together and information about the construction, finance and capital cost of the project, the current operation data and the procedure for collecting data is discussed.

Afterward a complete research strategy adopted for the case study is given. Further assessment to categorize differences in the costs and benefits of the Channel Tunnel throughout different categories, the calculation of generated traffic, user benefit, comparisons with old studies, payback period, net present value, internal rate of return, sensitivity analysis and capacity of the tunnel is studied.

In order to examine costs and benefits, it is required to have a theoretical and generalised model that brings together, in a logical routine, all the crucial features to be considered; and offers proper parameters and ideas of reference for the analysis. Therefore the next section addresses the development of a generalised CBA framework of any large infrastructure project. This supports the identification of proper theories, data collection and a former CBA case study of the Channel Tunnel. The suggested DFD framework is a base for all inclusive Cost Benefit Analysis of any project based on the experiment on the Channel Tunnel case study. The consideration for the flow chart looks at the big picture and making CBA, a step by step procedure. The new perspective for applying the IRR is recommended later on.

1.4 Layout of the Thesis

This thesis contains six chapters including the introduction and conclusion. Chapter 1 is the introduction and outlines the background within which this research has been carried out and the validation for the study; and then points out the aims and objectives. The key research questions have been discussed and the research methodology to address these questions has been explained. The reason for choosing the Channel Tunnel project asa case study is also covered.

Chapter 2 illustrates a review of the literature focusing on the current methods and process of cost benefit analysis and comparison of different models and methods. The chapter hints about the practice of CBA and how it has developed within its theoretical foundations. Additionally it will be discussed why most of the projects have cost overruns and delays. It will be shown why there is a need for a new comprehensive framework for cost benefit appraisals. It then shows how this method is modifiable for application in large infrastructure projects.

Chapter 3 is the introduction of the CBA case study for the Channel Tunnel project. This chapter will demonstrate the history of the project in terms of reasons that led to the construction of the project. Past appraisals of the project, comparison of them and information about the construction, finance and capital cost of the project will be discussed afterwards. In addition, the current operation of the Eurotunnel Company and all the required background data to conduct the CBA for the project is demonstrated. Opinions are shown modifying this choice of method and the explicit study approaches applied for collection of data. The procedure for collecting the data is explained in this chapter.

Chapter 4 presents the data analysis section. A complete research strategy adopted for the case study is given. The chapter also presents a study of the data on costs and benefits of the Channel Tunnel case. Further assessment to categorize differences in the costs and benefits of the Channel Tunnel throughout different categories is also offered. This chapter will go through the calculation of generated traffic, user benefit, comparisons to old studies, payback period, net present value, internal rate of return, sensitivity analysis and capacity of the tunnel. It also completes with thoughts on the findings and the recommended suggestions.

In order to examine costs and benefits, it is required to have a theoretical and generalised model that brings together, in a logical routine, all the crucial features to be considered; and offers proper parameters and ideas of reference for the analysis. In Chapter 5 the discussion addresses the development of a generalised CBA framework of any large infrastructure project. This supports the identification of proper theories, data collection and a former CBA case study of the Channel Tunnel. This chapter is dedicated entirely to the development of the practical model concerning the costs of the infrastructure and the benefits accruing from such costs. Although there are lots of cost benefit research and publications in the literature review; a comprehensive big picture framework is missing. The suggested DFD framework is a base for all inclusive Cost Benefit Analysis of any project based on the experiment on the Channel Tunnel case study. The consideration for the flow chart looks at the big picture and making CBA, a step by step procedure. The new perspective for applying the IRR is recommended in this chapter as well.

Chapter 6 goes through the conclusions and recommendations drawn from the whole study. The objectives and research questions are reviewed and highlighted. The main conclusions from the research for the Channel Tunnel case study, generalised cost benefit analysis model and future areas of research are also presented. Recommendation of analysis for the new UK high speed 2 rails is provided as well.

Finally, the references show the details of the literature used in this thesis and the appendices are an enhancement of some sections providing more detail.

Chapter 2

LITERATURE SURVEY

2 LITERATURE SURVEY

2.1 Introduction

This chapter will explain about the current methods and process of cost benefit analysis and provides a comparison of different models and methods. Additionally the reason why most projects have cost overruns and delays will be discussed. It will be explained why there is need for a new comprehensive framework for cost benefit appraisals.

2.2 Cost Benefit Analysis

In life everybody should decide between choices. Business analysts', investors' and governments' decisions are more important because of the scale and impact of their choices. They regularly study diverse means to develop performance and outcomes. "Sometimes, the "means" are alternative project approaches; sometimes, the means are acquisition of competing products or services" (RMS, n.d.). The most difficult aspect each time is the response to the questions: "What is the best option?", "Should you undertake this project?" or "When a project should start?". The cost benefit analysis will help to find the answer.

Cost Benefit Analysis (CBA) definition is "Process of quantifying costs and benefits of a decision, programme, or project (over a certain period), and those of its alternatives (within the same period), in order to have a single scale of comparison for unbiased evaluation" (Business Dictionary). Harberger and Jenkins' (2002) definition of CBA is a set of tools for guiding judgments on whether or not to take a specific course of action. Another definition says that CBA is a methodology of valuing costs and benefits that allows comprehensive comparisons to be made and recommends benefits and costs for consideration, measurements and approaches for combining them together (Pearce, 1988 and Snell, 1997 and Preez, 2004). Carcoba (2004) defined CBA as a method designed to calculate the viability of a plan by quantifying the costs and benefits which are to be used to assess the social costs and benefits of an investment. Watkins' (2006) definition is the course of weighing the entire anticipated costs against the entire anticipated benefits of one or more activities, so as to select the best or most profitable. CBA is mostly used for the comparison of projects i.e. if a project pays a net economic profit to the public welfare. It is intended to carry enough information to decision makers, to see if the plan can make society better off than the status quo. It has been used either for a yes or no conclusion on whether a course of action is going to be undertaken. Also it has been used to pick among two or more opposite courses of actions (Harberger and Jenkins, 2002). CBA is a method of "assessing the economic worth of an investment, which is judged over its life-time using the discounted values of all current and future flows of costs and benefits associated with the project" (DFID, 2004). It means that all impacts of the process will be calculated by an economic view. CBA will usually pay attention to economic benefits that can be translated as a monetary value. Therefore, the non-quantifiable benefits and costs are regularly denoted as social and/or environmental benefits and costs. The separation among economic, social and environmental impacts is often not obvious. In a practical sense, the benefits and costs of a plan are usually narrowed down to a chain of unconnected categories that can be calculated in monetary values. Additionally non-quantifiable impacts can be weighed in qualified terms. In this situation the CBA can be improved to use more complex “ranking methods”. Various environmental impacts can be assessed and in numerous circumstances, for roads or railways, they must be considered to meet strict environmental standards. On the other hand, the understanding of the ‘social’ impacts are less clear cut, and therefore slight or no consideration has been given to this type (A Guide to Pro-poor Transport Appraisal, 2004). In addition, CBA should be comprehensive but simple. Manteiga & Sunyer (2000), with their experiences in the improvement of environmental assessment methodologies, concluded that “to achieve the main evaluation objectives a much more simple methodology was needed”. While the simplicity is important, the new CBA method should still be comprehensive (Brooks and Tobias, 1996).

2.3 Types of CBA

There are three types (or class) of CBA in the literature: ex-ante, in medias res and ex-post. ex-ante is the most common method which takes place before the project and at the time of the project’s consideration. Forecasts have a big impact for this type of CBA. In medias res happens during the project and helps to modify the ex-ante analysis to help the further decisions. Ex-post will be conducted at the end of each project. The ex-post works as a learning device for the decision makers as it can measure the effectiveness of the CBA calculations (Boardman et al, 2001). “Ex-post evaluation aims to compare the plan and the actual results, to analyse the reason for any differences, and to draw out lessons learned, which contribute to holding smooth evaluations in future” (Li et al, 2010, pp 3).

In addition, some literature (Boardman et al, 2001) mentions a comparison of all CBA’s after the project is finished and includes it as the fourth option. This thesis assumes the comparison as a part of ex-post, to calculate the effectiveness of the first two types’ effects with the ex-post result. Table 2 compares all types of CBA in different aspects for transport projects. As can be seen in the table, everything is changeable “ex-ante” but it is hard to change most of the things “in medias res” and impossible “ex-post”. On the other hand the learning factor is the main point of “ex post”, a minor one for “in medias res” and impossible “ex ante”.

Table 2: Types of CBA (Boardman et al., 2001 and Anguera, 2006 and Li et al, 2010)

	Ex-Ante	In Medias Res	Ex Post
Resource Allocation	Helps to select best project	If low sunk costs, can still shift resources	Too late, project is over
Traffic	Forecast based on other competitors' work or estimate of market	Forecast based on actual values from the start of project	Actual values after the project finished
Price, Revenue, Costs, Benefits	Forecasts based on forecasted traffic and forecast willingness to pay by consumer	Forecast based on actual data gathered from the start of the project and reaction of market. Therefore the result is more reliable and accurate and errors are less.	Actual values after the project finished
Ability to Make a Change	Yes - Every change is possible because the project is not started yet	Yes but limited - Change is limited because the project is in operation but PM will be able to have actual calculation about the situation and decide to proceed to the original plan or change.	No - The project life time is finished
Learning about Actual Value of the Project	Poor estimate - high uncertainty about future of cost and benefits	Better estimate - learn from errors in the ex-ante CBA to prevent them happening again during the life time of the project	Excellent - Provides information about errors and the accuracy of both ex ante and in medias res CBA

2.4 Why Decisions Go Wrong

Funnily enough Murphy's Law (*Anything that can go wrong will go wrong*) does apply to large projects. There is even some research that proves "whatever can go wrong will" unless there is a way to prevent it (Warnera & McCarthy, 2013).

Cost overruns and delays are one of the major risks of big projects According to Flyvbjerg et al. (2002) study of 258 cases. In the study the average cost of overruns for railway projects was 45%; for bridges and tunnel projects it was 34% and for roads was 20%. The overruns happened in 5 continents and 20 countries. Although each type should be treated separately, because of the difference in their overrun percentages, they still create major problems for planning such projects (Flyvbjerg et al., 2002). The problems which occur because of these cost overruns are:

- Inefficient allocation of resources (waste)
- Delays and further cost overruns because of the above
- Destabilizing the policy, planning, implementation and operation of projects.

A project gets bigger and therefore the problems get bigger (Flyvbjerg et al, 2003). Flyvbjerg (2005) explains two reasons for failures in financial appraisals. The first is the wrong forecast of cost, benefits and risks by promoters and planners; and the second is the optimistic forecasts for a project to get approval. He recommends finding a better methodology for appraising the project to avoid the forecasting mistake of the first problem. In addition, he indicates that the second problem is hardest to solve and the solution is to “improve incentive structures, with the latter being the more important.” This will lead to underestimating the costs and overestimating the benefits in order to get permission to start the project.

$$Underestimated\ Cost + Overestimated\ Benefits = Project\ Approval$$

Using this formula means showing the project at its best on paper and not in reality. This will cause the selection of the “unfittest” project that will produce the most problems and inaccuracy (Flyvbjerg, 2005).

This thesis is focused on solving the first issue, as the second issue is usually happening in the policy makers divisions. Flyvbjerg and Cowi (2004) showed different examples of how planners “intentionally” choose the optimistic view to get the approval and explained briefly on how to solve this problem.

Priemus et al. (2008) categorized the problems that prevent the implementation of megaprojects from being successful into two types of “pitfalls” i.e. ones that are:

- “Unmanageable in terms of time or money”: there are many reasons for this such as technical complexities like uncertainties and social complexities like disagreement between the parties involved on design, cost, etc.

- “Impoverished as to its substance”: the project not being “sufficiently future oriented and to prevent unmanageability it has too little ambition.”

They recommend the following three possible explanations for these:

1. Inaccuracies in the decision-making process leading to pitfalls such as wrong cost estimations
2. The nature of the project such as differences between the completeness of technology for different project that lead to more or less uncertainty.
3. The implementation of the project such as projects facing little opposition being quicker to implement than ones facing more. (Priemus et al., 2008)

Short and Kopp’s (2005) study of mega-projects identified 6 main improvements for better investment decision making:

1. Better data collection for policy and research
2. More in depth analysis of investment allocations between different modes
3. Increasing transparency of national investment planning
4. Better analysis and clearer understanding of where international planning may apply
5. Improving the strategic appraisal from a neutral perspective including ex-ante and ex-post

6. Research into planning and decision-making processes in order to improve the value of investment to society

This thesis will focus on the 5th of these items.

2.5 Approach to Cost Benefit Analysis

The important aspect of CBA is the identification and calculation of all relevant costs and benefits related to the suggested project (Briscoe, 1993). Brent’s (2003) definition of cost is everything that imparts a loss and a benefit is any gain to an individual. Lindqvist and Lindholmn (2001) defined costs as the values of the actual used resources. These resources should be used in the best possible way to avoid waste. In order to achieve the Pareto optimality or Kaldor-Hicks efficiency in decision making, the ideal decision models should have the best degree of quantification as well as level of richness (Barr, 2012 and Scitovsky, 1941). The level of richness is the extent to which factors are included. Therefore effective choices have to be made - and usually they are made implicitly - about the appropriate level of detail to employ. For example, in discrete simulation, it is more or less at one extreme of the full range of modelling approaches actually available within management science. It is characterised by high levels of quantification being applied to a small set of supposedly pertinent features and (without much formal justification) to the neglect of everything else. Discrete models typically have high levels of detail but low richness (Figure 2). Of course predictions can be horribly wrong if anything important is omitted (Tobias, 2014).

Examples of models with a high degree of quantification are models that use only simple quantified investment appraisal tools such as payback period, NPV and IRR. Examples of models with a good level of richness but not enough quantification use the management insight and expert's managerial instinct. Complex tools try to get the best out of both the richness and quantification to achieve the Pareto efficiency. Achieving the Pareto efficiency means the best allocation of resources in decision making and avoids waste (Flyvbjerg et al, 2005).

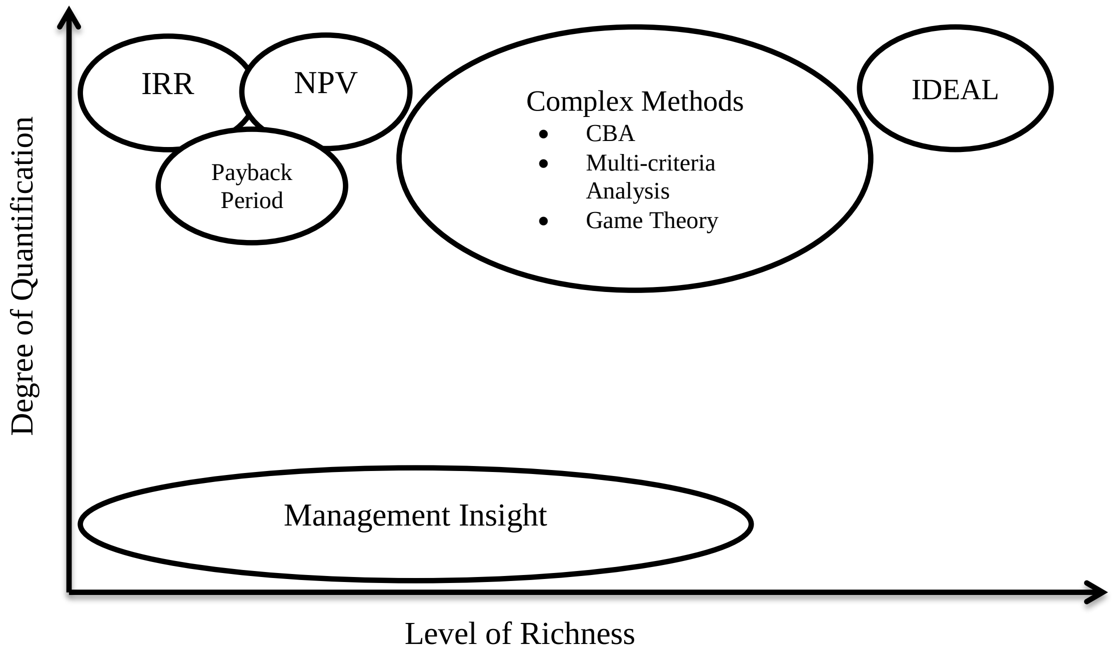

Figure 2: Examples of models with degree of quantification versus level of richness

In order to discuss CBA some basic definitions should be explained. Willingness and capability of a user to buy a product or service under certain conditions is called **demand**. Demand figures have been used to evaluate behaviours in competitive markets. Sometimes a **Supply** figure has been added as well to evaluate the equilibrium price. The equilibrium price is the price that suppliers are willing to sell at for a product or service which matches the price the consumers are willing to pay (Brent, 2006). In cost and benefit calculations, the analyst should "consider all costs and benefits to society as a whole". The net benefit of society (NSB) equals the total society benefit (B) minus total social costs (C) (Boardman, 2006).

$$NSB = B - C$$

2.6 Surplus

The highest price that the consumer is happy to pay for a service or product is the willing to pay price. Therefore, the difference of actual price, up to the willing to pay price, is the consumers' benefit. As this price is different for different consumers, the equilibrium price will be calculated as mentioned previously to maximise the suppliers' benefit. The monetary gain for the consumers who pay less than their willing to pay price is the **consumer surplus**. The monetary gain by selling at the actual price (or market price), which is more than the minimum price at which they would be willing to sell is the **producer surplus** (Brent, 2006 and Boardman et al, 2001). The Figure 3 shows the consumer and producer surpluses in a supply demand figure example.

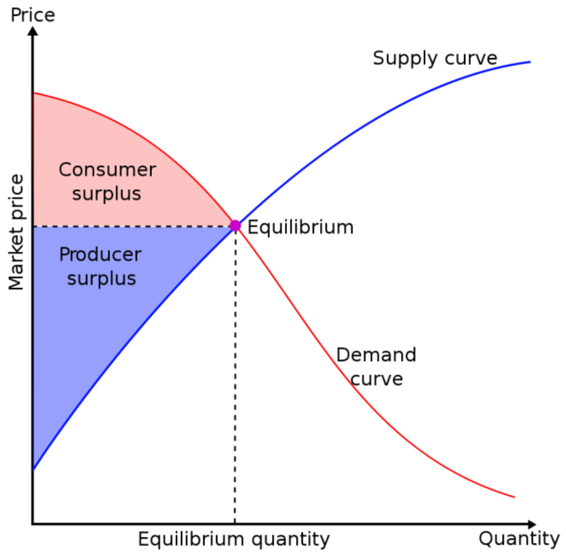

Figure 3 : Standard Supply/Demand curve to calculate surplus

2.7 Discounting

There is one problem of adding all benefits and costs together. The value of money is different for different years. CBA must take into account the sum of benefits and costs of a project for different years over a period of time. All the forthcoming benefits and costs must be discounted relative to the present value. Different methods use different tools in order to have the same scale for comparison. Two major tools of CBA are NPV and IRR. Preez (2004) included the Benefit Cost Ratio (BCR) as well as the first two and discussed that one or more of the three can be used for decision making.

2.7.1 NPV

The main type of tool that has been used for many years is the Net Present Value. The present value (PV) is:

$$PV(CB) = \sum_{t=0}^{n} \frac{CB_t}{(1+d)^t}$$

- t is the year of cost and benefits occurrence
- d is the discount rate
- CB_t is the benefit or cost in year t
- n is the life time period of the project.

The NPV is the difference of the present value of Benefit ($PV(B)$) and the present value of Cost ($PV(C)$).

$$NPV = PV(B) - PV(C)$$

In this method a project is viable if the NPV is positive and the option with the bigger value of NPV is better. There are some downsides to this method, which will be explained later sections (Brent, 2006 and Boardman et al, 2001 and Layard and Glaister, 1994).

2.7.2 IRR

There is another method that is irrelevant to the discount rate and to a certain degree calculates the speed of returning the investments. It is called the Internal Rate of Return (IRR). The Internal Rate of Return or Economic Rate of Return is the discount rate when the NPV becomes zero.

$$NPV(CB) = \sum_{t=0}^{n} \frac{CB_t}{(1+r)^t} = 0$$

- t is the year of cost and benefits occurrence
- r is the rate of return
- CB_t is the benefit or cost in year t
- n is the life time period of the project.

The advantages of IRR are that it is independent of the discount rate, inflation and interest rates and also can be used to compare projects with different start times and different lengths.

2.7.3 BCR

The Benefit Cost Ratio (BCR) is the ratio of the present value of the benefits relative to the present value of the costs (Preez, 2004):

$$BCR = \frac{PV(Benefit)}{PV(Cost)} = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}}$$

In this formula for the acceptance of a project, the discounted BCR should be more than one and for comparison between the projects the higher BCR is better.

2.8 CBA Tools

Different tools have been discovered for solving a decision problem. It is not an easy job to choose a suitable tool. It depends on the actual decision problem and also the objectives of the decision makers. “Sometimes the simpler the method the better, but complex decision problems may require complex methods, as well” (Fülöp, 2005). In capital budgeting or investment appraisals as well as NPV and IRR, which have been explained previously, there are many tools to use; such as accounting rate of return; payback period; profitability index; modified internal rate of return. In this thesis these methods are called simple measures because they use only one formula to generate the result. There are more complex methods as well as CBA in the literature. Fülöp gathered most of these complex methods in his paper and briefly explained them (2005). Table 3 shows well-known simple measures and complex methods used for decision making.

Table 3 : Examples of simple measures and complex decision making tools (Fülöp, 2005)

Simple Measures	**Complex Methods**

• Payback Period (PP)
• Return on Investment (ROI)
• Accounting Rate of Return (ARR)
• Profitability Index (PI)
• Net Present Value (NPV)
• Internal Rate of Return (IRR)
• Modified Internal Rate of Return (MIRR)
	• Cost Benefit Analysis
	• Multi-Criteria Analysis
	  • Utility theory
	  • Goal programming
	  • Outranking methods
	  • Analytic hierarchy process
	• Cost Effectiveness
	• Cost–Utility Analysis
	• Economic Impact Analysis
	• Social Return on Investment (SROI)
	• Game Theory

2.9 Period of Analysis

The period of analysis should regularly cover the useful life of the project, such as the life time of a bridge. On the other hand, it is impossible to find a finite life cycle for some calculations such as many health and social policies. In those cases a similar medium to long term period can be chosen to have a single scale for alternatives (New Zealand Treasury, 2005). In addition, an operational contract can be the base for the period of analysis as the project might have a life cycle of more than the contract. The perspective of the analyst would be the operational time that the company will benefit from the project, such as BOT contracts (Build-Operate-Transfer) for railway projects (Delmon, 2010).

2.10 Short Comings of CBA

Underestimated costs and overestimated benefits: As discussed in Section 2.4, one of the main weaknesses of financial appraisal is getting the project approved by any means. There have been numerous examples in the literature that have caused an over running or over timing of big projects (Flyvbjerg, 2006). This will lead to underestimating the costs and overestimating the benefits in order to get permission to begin the project. This means showing the projects at its best on paper and not in reality. This will cause the selection of the “least fit” project that will produce the most problems and inaccuracy (Flyvbjerg, 2005).

Identifying incorrect cost and benefit: All costs and benefits should be identified and quantified appropriately. Unfortunately the uncertainty of future projects and human error to assign an appropriate monetary value to intangible impacts, results in an incorrect cost benefit analysis (Plowman, 2011).

Monetising errors: As some impacts are not naturally monetary, they frequently need to be assigned a monetary value. This approximation is frequently based on past experiences that can be biased; which can cause an incorrect cost and benefit result (Plowman, 2011).

Inaccuracy, unsuitability or insufficiency of tools used for calculation: Each tool has its short comings that might affect the whole CBA. For example, the calculation of the present value balances all present and future costs and benefits, but the estimation of the discount rate is not going to be realistic. Also the NPV tool is not suitable for the comparison of projects with different capital investment. Moreover, using the same tools in isolation is insufficient for informing decisions (as covered in Section 5.6.3.1) and cannot reflect all of the aspects of the project (Plowman, 2011 and Boardman, 2001).

2.11 CBA Framework

More or less all the frameworks use the following steps to implement CBA:

I. Specify the set of change **alternatives** (if there is more than one)

II. Find **data** regarding the operation of the project

III. Decide **whose cost and benefit** should be recognized

IV. Set the **framework** for CBA

V. Identify and categorize cost and benefits (**Impact**)

VI. **Forecast** cost and benefit over life time of the project

VII. **Monetize** and quantify all impacts

VIII. **Discount** cost and benefit to achieve the present value

IX. Perform **sensitivity** analysis

X. **Decide** on continuation, closure or making changes on the operation of the project or choose between change alternatives.

The keywords for each step are highlighted and will be used throughout this thesis.

2.12 Selected Approaches to CBA

Table 4 shows a comparison of the more complex frameworks and models found in the literature. Their differences have been shown in terms of their style, name and most importantly, what each stage includes.

As can be seen in the table, although all the frameworks have different titles and names for different CBA steps, all can be categorized in 4 different stages. These stages are: Setting the Framework, Technical Analysis, Economic Evaluation and Evaluation of Result. This thesis will use this new categorize to introduce the new approach for the proposed CBA.

Table 4 : Selected Approaches to CBA

		Cellini & Kee	Boardman	Minnesota	South East High Speed Rail	Scotland
Style		List of 10 steps	List of 9 steps	4 stage single level flowchart	Hierarchy of Benefits	2 level flowchart with feed back
Name		CEA or CBA	CBA	BCR /BCR	CBA Framework	BCA
Stages	Setting The Framework	1. Set the framework 2. Decide whose CBA?	1. Specify alternatives 2. Decide whose CBA?	Planning the Analysis	–	Define the Problem Eliminate Unreasonable Option
	Technical Analysis	3. Identify & Categorize cost benefits 4. Project cost benefit	3. Catalogue the Impacts 4. Predict The Impacts	Engineering Analysis	User benefits Non user benefits Operating impacts Capital cost Engineering cost Operating and Maintenance cost	Determine the Benefit and Cost
	Economic Evaluation	5. Monetize Costs 6. Quantify Benefits in term of effectiveness or Monetize benefits 7. Discount Cost and Benefits 8. Compute Cost-effectiveness ratio or NPV	5. Monetize all impacts 6. Discount benefits and costs 7. Compute NPV	Economic Valuation	Annual benefits Annual costs Discount stream of benefits and costs	Compare Option Benefits and Costs Choose the best Option
	Evaluation of Result	9. Sensitivity Analysis 10. Make a recommendation	8. Sensitivity Analysis 9. Make a recommendation	Evaluating Results	Evaluation criteria Preferred alternatives	Test the robustness of the choice Select preferred Option

2.13 Conclusion

This chapter explained how the use of CBA has developed and its theoretical foundations, current methods and process; together with a comparison of different models and methods. Additionally, it has been discussed as to why most of the projects have cost overruns and delays. It has been shown why there is a need for a new comprehensive framework for cost benefit appraisals. As can be seen in the literature, there are none or limited models related to cost benefit analysis. Most of the literature materials use the steps of CBA and some that have introduced a framework, methodology or chart are not comprehensive or have errors. The introduction of a generalised CBA model can help contribute to better decision making and help to achieve a greater rate of productivity. If used effectively it is capable of improving decisions in the infrastructure industry.

In order to have a better understanding of the application of CBA, the next chapter introduces the case study of the Channel Tunnel. Following on, a new simple and comprehensive CBA model will be proposed.

Chapter 3

THE CHANNEL TUNNEL

3 THE CHANNEL TUNNEL

3.1 Introduction

The Channel Tunnel has been chosen for the case study because it was one of the largest, if not the largest, infrastructure mega projects in Europe of its time (Gourvish, 2006). The project has been a big challenge for decades with lots of uncertainties. There are still different opinions about whether it should have been built (Anguera, 2006 and Gourvish 2006). There were various proposals and appraisals that led to the construction of the project and comparison of these with the actual operation of the project is the main purpose of the case study with the hope of helping decision makers makes better judgments on future projects.

This chapter is the introduction of the CBA case study for the Channel Tunnel project. The history of the Channel Tunnel will be included as well as past appraisals of the project for comparison. Information about the construction, finance and operation of the project will be discussed afterwards. These are all the data required to conduct the CBA for the project in Chapter 4.

3.2 History of the Channel Tunnel Rail Link (CTRL)

Gourvish's work (2006) has been used as the main literature for the history of the tunnel with the addition of some other references.

The idea for building the tunnel was recommended to Napoleon Bonaparte during a short-term peace between France and England in 1802. Albert Mathieu Favier, who was a French mining engineer, drafted the first plan to Napoleon. He designed a two level tunnel to be used paved and lit by oil lamps; the top one to be used by horse-drawn carriages and the underside for groundwater flows. However war soon started again and the plan was abandoned. In addition, the lack of technology for building the tunnel was a big problem. They did not have the necessary geological science for building the structure.

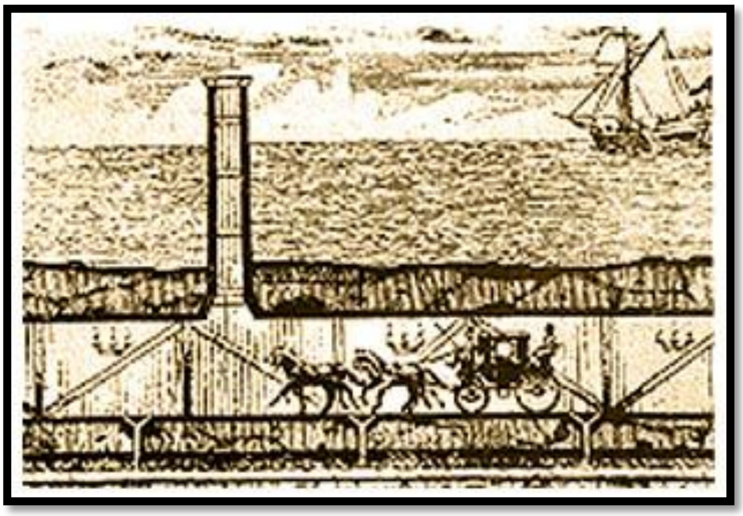

Figure 4 : Cartoon of 1802 tunnel designed by Albert Mathieu Favier (Unmuseum website)

Steam trains were invented in the 1820s and by 1850 the railways started to run from Paris to Calais and from London to Dover. Passengers used small ferries to cross the water with fear of death. By this time, engineers had more experience on tunnelling jobs and the French and English engineers now approached the task of planning to build a 25-mile undersea tunnel. They faced several problems and needed to find a good path for tunnelling; this required geology science. The rock had to be suitable for tunnelling and in addition they had a problem with ventilation of the tunnel, because of the steam from the locomotives. Moreover, both countries were afraid of building a route that could be used for war.

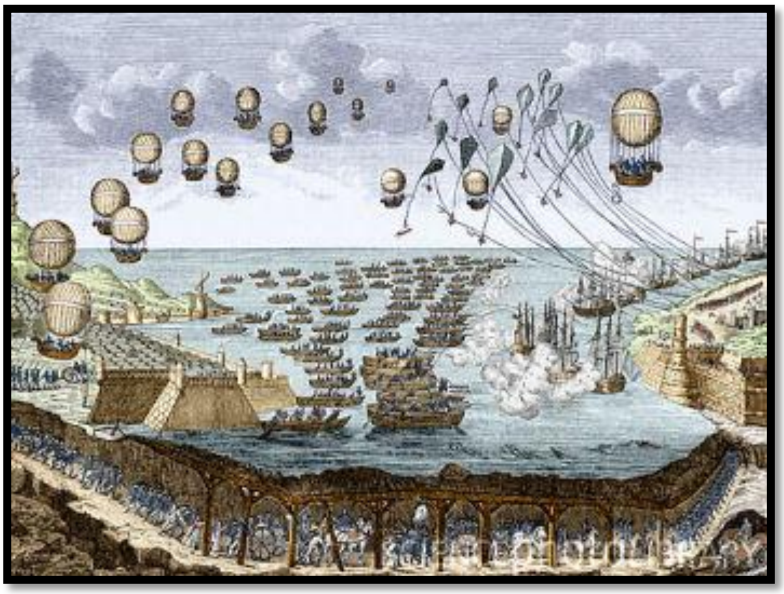

Figure 5 : A political cartoon showing a French invasion using balloons, boats and a tunnel. Fear of this caused the British to cancel the project. This cartoon was drawn in 1804, after the resumption of war between England and France in 1803 (Science Photo).

A French mining engineer called Thomé de Gamond was working on the project for decades, with the help of a few English engineers such as William Low and John Brunlees, to produce the first serious plan between Calais and Dover. His scheme in 1857 was accepted by both sides. He proposed a rail tunnel bored through the chalk, which he thought ran underneath the sea-bed. His plan had an international gate on an artificial island in the middle of the tunnel and ventilation was provided in his plan. His marketing proposal mentioned that 350,000 passengers per year were using ferries for crossing the water and he estimated that the appeal of 25 minutes under the water, crossing with no sickness would double the usage.

Around the time of the Franco-Prussian war (1870-1871), the English and French grew closer and the first serious attempt to build the tunnel was in 1870. Boh countries agreed to build a joint tunnel scheme and tunnel companies started to find the best geological area for the tunnel. In 1881 companies started to dig the tunnel with the newly invented tunnel boring machines; but once again, because of the fear of war, the construction decision was postponed (Gourvish, 2006, pp 6-7).

In the wake of the Second World War, objections to military usage of the tunnel weakened. The Channel Tunnel Company that was established a few decades earlier in 1929, restarted its work and formed a Channel Tunnel study group on the recommendation of Shawcross the Labour MP at a dinner party he attended with three members of parliament and others related to the project (Gourvish, 2006, p 19). The initial cost of the tunnel reported by the study group in 1947 was estimated at £45-65 million depending on the choice of lining material (Gourvish, 2006, p 19). In addition, another group somewhat confusingly called "Channel Tunnel Study Group" was formed and they published a small report in 1960. They assumed a bored tunnel, immersed tube, bridge and bridge-tunnel combination and also engineering and financial support for each type. Return on capital was not mentioned, but an investment of £130 million would be needed. Another report was conducted by the French government in the same year and these two groups then worked together on another proposal, publishing it in 1963. They conducted a full evaluation of two competing proposals for the fixed link: a bridge, or a tunnel. Both would need 6 years for construction and would reduce London-Paris journey times from the original 7 hours to 4.5. In 1962 the bridge would cost £298.5M, the tunnel £143M (Gourvish, 2006, p 35). Either way there were to be "clear long term savings over established transport modes, 'realistic' economic benefits, 'acceptable' financial returns and compatibility with Britain's European policy" (Gourvish, 2006, p 42).

Both governments agreed to have three phases and had worked on two agreements by 1972 (Gourvish, 2006, pp 100-101). Coopers & Lybrand conducted a cost benefit study of the Channel Tunnel for the UK under the direction of British and French project managers and governments in 1973. It was a much updated and clearer report and had a better evaluation of the project (Gourvish, 2006, p 111 and Coopers & Lybrand Associates Ltd., 1973). In the same year the UK finally joined France in the common market and the governments agreed to build the tunnel. The private funding of the project was discussed and more experimental work was done but Labour Prime Minister Harold Wilson cancelled construction in 1975 on financial grounds because of the oil crisis (Gourvish, 2006, p44, p 165 and Eurotunnel Group website).

The Channel Tunnel and Alternative Cross Channel Services report was published in the same year by the Channel Tunnel Advisory Group (CTAG, 1975), discussing whether the various earlier studies were sufficient for deciding to invest in the tunnel rather than in air and sea transport; and comparing four different projects with more updated fuel prices. The study shows that the capital and operating cost would be less if the tunnel were constructed instead of expanding the existing air and ferry services (Gourvish, 2006, pp 179-184).

However when the Conservatives came back into power in 1979, the UK Government decided it would have nothing to do with the funding of the plan; Margaret Thatcher the British Prime Minster saying that “she had no reservations (about) the project being independently subsidised” (Channel Tunnel website and Wilson, 1991, pp 14 -21 and Gourvish, 2006).

In September 1981 a United Kingdom/French summit meeting took place and both agreed to build “a joint study by experts of the type and scope of possible fixed links, taking account of interests of maritime transport, with a view to advising both governments on whether a scheme for fixed cross-Channel link can be developed which would be acceptable to and in interests of both countries” (Department of Transport, 1982). Therefore the study was carried out and they published a report in June 1982 explaining their methods of analysis, results and the conclusions of the study group (Department of Transport, 1982).

In 1984 both sides agreed to fund the project privately and promoters were sought. The banking report was published and there were arguments between the banks, promoters and governments about funding the project and government guarantees (Gourvish, 2006, pp 238-258).

After an invitation from the governments in 1985, four submissions were proposed:

1. Channel Tunnel Group/ France-Manche: a rail proposal based on the 1975 plan by (CTG/F-M) with twin 7.3 metre bored rail tunnels and a third service tunnel.

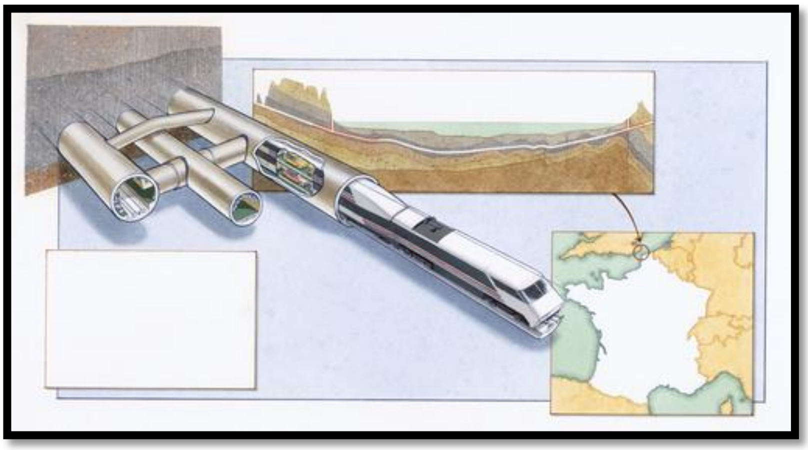

Figure 6 : CTG/FM option with two bored rail tunnel and a service tunnel

2. Euro Bridge studies group (Euro Pont): a multispan suspension bridge with a 12-lane roadway and optional rail link in an enclosed tube based on untried techniques.

Figure 7 : Europont included a rail tunnel and 12-lane motorway within a vast tube suspended from half kilometre spans by Kevlar cables.

3. Euro route: a 21 km tunnel between artificial islands approached by bridges.

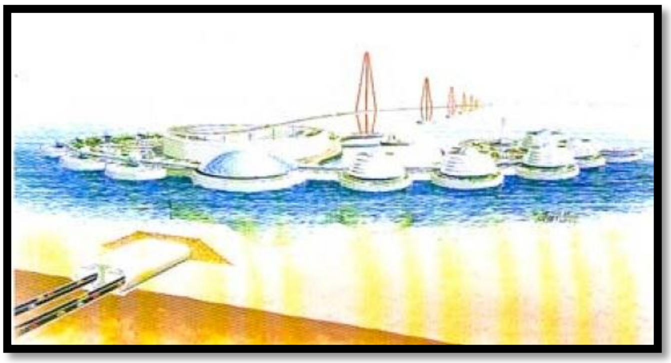

Figure 8 : Artificial Island connected by an underwater Tunnel

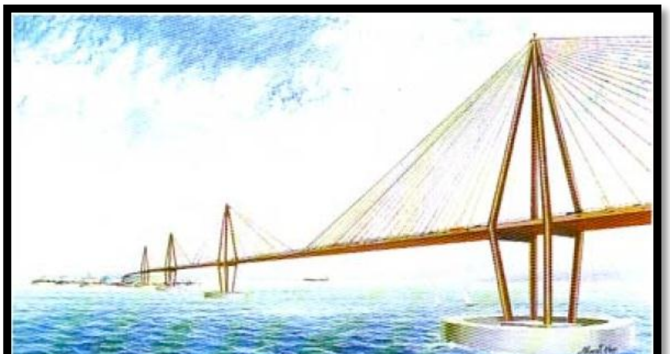

Figure 9 : Bridge towards one of the Artificial Islands

4. Channel Expressway: 11.3 metre bored road and rail tunnels with mid-channel ventilation towers (Wilson, 1991 and Gourvish, 2006, p 263 and Commolli et al, 1986, pp 261-269).

On 20 January 1986 Thatcher and Mitterrand said that the Eurotunnel bid had been nominated and on 12 February 1986 the Foreign Affairs Ministers of the two countries signed the Franco-British Treaty in Canterbury (Eurotunnel Group Website).

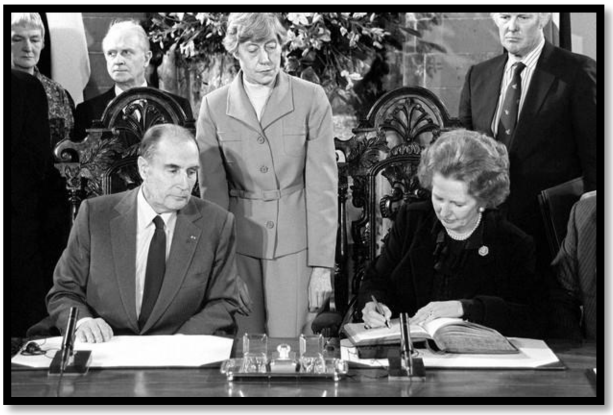

Figure 10 : French President François Mitterrand (L) and British Prime Minister Margaret Thatcher (R) sign, 12 February 1986, in Canterbury Cathedral, the Canterbury treaty between France and Britain on the construction of a double rail tunnel under the English Channel

On 14 March 1986 it was the Channel Tunnel Company that won the votes. The Concession Agreement was awarded for a period of 55 years between the two concessionaires, the Channel Tunnel Group Ltd and France-Manche SA. They were delighted to win the concession and confident to finish the project by the spring of 1993 (Eurotunnel Group website, Gourvish, 2006, p 277).

On 15 December 1987 boring of the service tunnel started on the UK side and on 28 February 1988 on the French side. On 1 December 1990 they completed the first breakthrough, in the service tunnel, 22.3 km from the UK and 15.6 km from France. Englishman Graham Fagg and Frenchman Phillippe Cozette broke through the service tunnel. Eurotunnel completed the tunnel boring on time (Flyvbjerg pp 96-97). The other breakthrough was on 22 May 1991 in the North rail tunnel and on 28 June 1991 in the South rail tunnel. The handover from TML to Eurotunnel was on 10 December 1993 and equipment installation and testing was completed by 1994 (Eurotunnel Group website).

The tunnel was officially started its operation with one year delay compared to original plan by Queen Elizabeth II and French President Francois on 6 May 1994. A full public operation did not start for some months. The first international freight train in commercial service went through the Channel Tunnel on 1 June 1994.

Figure 11 : Official opening by Queen Elizabeth II and French President François Mitterrand on 6th may 1994

3.3 Past Appraisals of the Channel Tunnel

The Channel Tunnel is a 50.5 kilometre under water rail tunnel linking the United Kingdom to northern France. Predictions before the construction of the Channel Tunnel mainly and methodically overestimated the scales of the construction costs and the enlargement of the number of cross channel passengers and freight markets.

Anguera, in his paper, stated that "the construction cost of the tunnel has been doubled" and "cost benefit appraisal of the Channel Tunnel reveals that overall the British economy would have been better off if the Tunnel had never been constructed, as the total resource cost has been greater that the benefits generated" (Anguera, 2006).

As mentioned in the history of the tunnel, the idea of building a tunnel between the UK and France started over 200 years ago; therefore, there have been different types of analysis previously. A large amount of research had been carried out in the last 25 years prior to the construction of the tunnel. This thesis will investigate four major ex-ante analyses and one economic evaluation after the tunnel has been built and operated for a few years; also there will be a comparison of the studies.

3.3.1 Proposals for a Fixed Channel Link (Ministry of Transport, 1963)

On 17th November 1961 both governments decided to work on a report about a fixed tunnel or bridge link between the two countries. They needed to understand if the project was “technically adequate and practicable”. They worked on “Traffic, technical problems and matters of international law, costs, economic implications and financing” (MoT, 1963 report p 1). The base year for this study is 1969 and the discount rate is of 7% for 50 years until 2019.

3.3.2 The Channel Tunnel: A United Kingdom Transport Cost Benefit Study (Coopers & Lybrand Associates Ltd., 1973)

This report shows the cost benefit analysis for a double track rail facility from Cheriton near Folkestone to Sangatte near Calais (C&L, 1973, p 14). Their assumptions for the growth rate of traffic and revenue are:

Table 5 : Percentage of growth rate and traffic in C&L study

	Central Case % p.a.	Low Case % p.a.
1991 - 2000	5	3.5
2001 - 2010	3	1.5
2011 - 2030	1	0.5

In this report five sets of costs and benefits have been calculated:

1. The UK share of the tunnel capital costs.
2. Other infrastructure costs added because of the tunnel.
3. The British owned transport companies’ loss as an outcome of the tunnel construction.

4. The net benefits to passengers' resident of the United Kingdom from the improved service that the tunnel will produce (fares, journey time reduction and extra service frequencies).
5. The reduction in freight costs that the tunnel will create in the interests of the UK (C&L, 1973, p 1).

The base year for this study is 1973 and the discount rate is of 10% for 50 years until 2030.

3.3.3 The Channel Tunnel and Alternative Cross-Channel Services (Channel Tunnel Advisory Group, 1975)

This report is produced by the Channel Tunnel Advisory Group presented to the Secretary of State for the Environment in 1975. They have calculated just the UK's share of the project and chose a 50% share for most of the investments and revenue. The report shows the cost benefits of the tunnel itself against dependence on ferries and also a tunnel with a development of the current air and ferry services (CTAG, 1975 pp 28-29).

The base year for this study is 1973 and the discount rate is of 10%. The appraisal period is 50 years until year 2030 (CTAG, 1975).

3.3.4 Fixed Channel Link Report (UK/French Study Group, 1982)

The Department for Transport joined with the French government to build a UK/French study group and calculated a broad range of possibilities for an extra service for the

Channel market. This is the main study that resulted in the construction of the tunnel with three scenarios: A, which favoured the tunnel; B, the base case and C, which favoured the improvement of the existing services (DOT, 1982, p 18).

They calculated all the benefits and costs for:

- Single 6 metre rail tunnel
- Single 7 metre rail tunnel
- Single 7 metre tunnel with vehicle shuttle facilities
- Double 7 metre rail tunnel with vehicle shuttle facilities
- Road bridge
- Road bridge and 6 metre rail tunnel
- Composite scheme.

They made four assumptions for each of the projects to which the various scenarios related:

- Traffic forecasts
- Capital costs and finish dates
- Size and utilisation rate of ferries for the future
- Costs of aviation.

(DoT, 1982, pp 80-81)

The base year for this study is 1981 and the discount rate chosen is 7%. However for each option there are different construction times and appraisal periods. In Table 5 the closest options to the actual project have been selected.

3.3.5 The Channel Tunnel; an Ex-Post Economic Evaluation (Anguera, 2006)

There is one study carried out after construction of the tunnel, in which Ricard Anguera outlines his calculations of the economic evaluation of the project. He concludes that the project was not viable and the tunnel should not have been constructed. His approach and data will be discussed in this thesis.

He studied a short term appraisal until the year 2003 and also forecasted the benefits of the tunnel until the year 2052. He mentioned two scenarios:

1. If the current debt and size of the tunnel remains the same, therefore the market should grow by 10% to achieve a positive NPV; but the capacity of the tunnel is not enough for that.
2. If the whole tunnel debt is written off, the tunnel can compete with ferry companies and will be able to achieve a £2billion NPV (Anguera, 2006 p 313).

The base year for the study is 2004 with the discount rate of 3.5% as in the HM Green Book and the final appraisal period of 2003 for a short version and 2052 for a longer version.

3.4 Comparison

The comparison of different CBA's is difficult because there are different approaches and methods that researchers have used for their different studies. However, Table 5 shows the summary of former tunnel CBA approaches and differences. In addition there have been differences on appraisal period, forecasted traffic, difference in price base etc. Some of these differences are because of the time period when the studies were carried out; for instance, the discount rate varies at different times. Some differences are because of different assumptions and some are because of different approaches that have been used in each study.

Table 5 shows the detailed comparison of the older studies. As can be seen in the table there are significant differences between the methods of CBA calculation in different studies. Some of the differences are obvious such as base year and construction period but some are strangely different such as taking different impacts into account. Some of the studies calculate the producer's loss and some include the "avoided investment" or "avoided benefits".

Table 6 : Detailed comparison of the older studies

Study Name	MoT (1963)	C&L (1973)	CTAG (1975)	DoT (1982)	Anguera Thesis	Anguera Paper
Different Scenarios	Very high, upper, lower, very low	Low-forecast, central-forecast	Tunnel with different investment in existing services	Scenario A, central B, scenario C	Short term, long term	Short term
Comments		Just UK share	Just UK share			
Base Year	1969	1973	1973	1981	2004	2004
Start Year	1963	1973	1975	1991	1987	1987
Discount Rate	7.0%	10.0%	10.0%	7.0%	3.5%	3.5%
Construction Period	5	7	5	11	7	7
Operation Period	50	50	50	39	9	9
End of Contract	2018	2030	2030	2041	2003	2003
End of Contract if Starts at 1987	2042	2044	2042	2037	2003	2003
Channel Tunnel Costs	Capital costs, operating costs	Capital costs	Capital costs, operating costs		Capital costs, operating costs	Capital costs, operating costs
Capital Cost Avoided		Shipping, ports, roads	Other services			
BR Investment Costs					Infrastructure, passengers and freight rolling stock	Infrastructure, passengers and freight rolling stock
Channel Tunnel Benefits	Revenue, consumer surplus	Total user benefit from fares, journey time reduction, extra service frequencies	Revenue, travel time savings, consumer surplus	Travel time savings	Revenue, travel time savings, consumer surplus	Revenue, travel time savings, consumer surplus
Avoided Benefit/Cost		Reduction in transport operators' costs	Benefit/costs from the avoided investment in other services	Avoided cost/benefit of existing service		
Producers' Losses		Decrease in transport operators' revenues				Decrease in ferries' revenue

3.5 Eurotunnel

Groupe Eurotunnel S.A. is the company that manages and operates the Channel Tunnel. The company is based in Paris. It includes the shuttle services and produces revenue on other trains from DB Schenker freight and Eurostar passengers through the tunnel. The company is on both the Euronext Paris and the London Stock Exchange.

The first year of operation did not go as planned; the company lost £925m because of a disappointing amount of revenue and huge interest charges from the debt (Eurotunnel annual report, 1995). After all the first years' problems and disagreements of the board and shareholders, a dissident shareholder group took control of the board in 2004 with a so-called "boardroom coup" because of the disagreements. They appointed Raymond as chief executive but he resigned the next year and Jacques Gounon took control of the company as chairman and chief executive in 2005 (Norris, 2005). In 2006 the shareholders voted on a deal that would have exchanged half the reduced debt of £6.2bn for 87% of the equity (BBC, 2007 and Harrison, 2006). However, the plan did not work out and the company were given protection from bankruptcy by a French court for six months (BBC, 2006). After a month of work a new plan for restructuring was accepted by the shareholders, which included share swapping and waiving travel benefits. Deutsche Bank, Goldman Sachs and Citigroup were approved to provide £2.8bn long term loan (BBC, 2007). Eurotunnel announced a net profit of €1 million for the first time in its history after the restructuring in 2007 (BBC, 2008). In 2008 the company paid its first dividend of €0.04 per euro value because of a €40 million net profit (Le Figaro, 2009).

3.6 Construction

Although the construction of such a huge and cutting edge project is an important challenge, as this thesis is focused on the decision making and appraisal of the project, technical details and history of the construction of the tunnel are not covered. This detailed information can be seen in Gourvish (2006 pp 320, 266, 373, 383, 384), Flyvbjerg (2003, pp 6 and 14), Eurotunnel website, Eurotunnel right issue (1994) and DOE Report (2001).

3.7 Lifetime (Life Span)

The construction of the main section of the tunnel which explains its potential lengthy lifetime is made from very high strength and dense concrete to add extra protection to the steel reinforcements. To guarantee no feature of the plan was overlooked, 18 design development studies were carried out. The lining was also produced with a lifespan of 120 years; it had to be tough enough as not to deteriorate within that timeframe (John Neerhout, 1995). Although the lifetime of the project has been designed to be at least 120 years, for the sake of this thesis, the 99 years of the Eurotunnel contract has been assumed in calculating the CBA based until the end of contract and to give a private company perspective. After this length of time, probably another invitation to tender will take place to choose the next operator. The extra maintenance needed after this time span will probably be more than normal and the new company should take this into account. This thesis assumed normal maintenance costs increase every year until the end of the contract.

3.8 Financing

The concession was for a period of 55 years originally but then it extended to 65 years and extended again later on to 99 years until 2086 because of the changes that the Government made to the original plan (Flyvbjerg, 2003). The Channel Tunnel project had two challenges: financing and construction. Therefore the two groups of promoters and construction companies worked together closely in order to achieve the best result. A consortium of ten contractors operated together with the name of the Trans Manche Link (TML), with five banks that invested the initial equity of £47 million (Equity 1) (Grant, 1997). In 1986 the ten construction companies negotiated with five banks on two of the key contracts: the construction contract and the detailed term sheet for the credit facilities. A private placement of shares with organizations (Equity 2) was launched later on (Grant, 1997). Co-financier of the project, The European Investment Bank's (EIB) contribution was an important indication of European backing for the project. An arrangement was signed that helped the loan syndication that should have been finalized before the Equity 3 issue launch. 50 banks together, who guaranteed the agreement, syndicated it productively to over 200 banks (Grant, 1997); £770 million was gathered by selling 220 million units of £3.50 shares as a public offer (Gourvish, 2006, p 297). The rights issue (Equity 4) was postponed until the first breakthrough of the tunnel. It was accomplished two days before the last closing day of the equity issue. The syndication of the scheduled extra £2 billion credit was only achieved with substantial support from the four agent banks (Natwest, Midland, Banque Nationale de Paris and Credit Lyonnais) (Grant, 1997). In 1992 there were more financial complications. The TML Company asked for extra construction costs of about £1.5 billion. It was obvious that Eurotunnel had appropriate capitals to open the tunnel, but there would be a requirement for extra after opening to pay the banks' interest fees until the breakeven point. A condition for the presentation of the rights issue in 1994 (Equity 5) was gaining the initial functioning licence from the IGC (Intergovernmental Commission). Investors wanted to know that the structure was working. The two governments approved an extension of the concession by another 10 years and it was the signal for the banks to approve the equity launch (Grant, 1997).

Table 7 : Channel Tunnel Equity

Financing	£ Million	Date
Equity 1 (Founder shareholders)	47	Sep-86
Equity 2 (Private institutional placement)	206	Oct-86
Equity 3 (Public Issue)	770	Nov-87
Equity 4 (Rights Issue)	566	Nov-90
Equity 5 (Rights Issue)	793	May-94

Eurotunnel lost about £925 million in the first year (Eurotunnel annual report, 1995) because of a delay in operation, huge debt interest owed to the banks and not enough traffic and revenue (Gourvish, 2006, pp 370-373). The risk of construction did not pay off and Eurotunnel shares dropped. The original price was £3.50 per share in 1987. The share price increased up to £11.00 in the middle of 1989 because of the over-optimistic projections about the project before, due to cost overruns and delays, the shares dropped dramatically to £1.42 in 1995. This resulted in the suspension of interest payments to prevent bankruptcy (Flyvpjerg, 2003, p 32 and Vilanova, 2006, p 26).

After the first restructuring in 1997, due to the small revenue and big debt interest the trust did not produce for the investors and the shares traded for the price of 65 pence, almost 95 percent of the pick value (Flyvbjerg, 2003, p 33). Figure 12 shows the peaks and throughs of Eurotunnel's share price from the start of construction to the first year of operation.

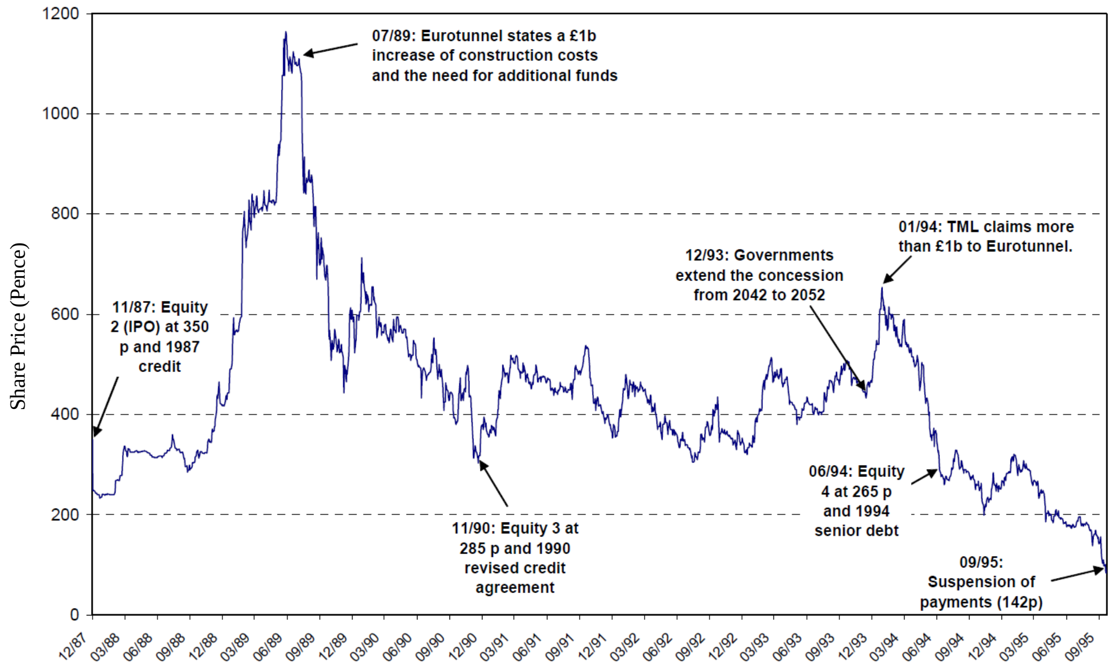

Figure 12 : Eurotunnel share price from the start of construction until 1995 (Flyvbjerg)

3.9 Capital Costs

The total cost of construction of the Channel Tunnel and equipment in 2012 prices was £11,932 million. Table 8 shows the different forecasts, the concession award (CTG-FM) and the actual cost of the tunnel in the base year and also at 2012 prices.

Table 8 : Forecasted and actual capital cost of the tunnel (£M)

Study Name	TG 1960	MoT 1963	C&L 1973	CTAG 1975	DoT 1982	CTG-FM 1985	Actual 1994
Base Price	1962	1962	1973	1973	1981	1985	1985
Tunnel	80	103	246		1296	1329	2110
Terminals	14	15	80			448	553
Fixed Equipment						688	1200
Railway Installation	10	11					
Project Development Including Start-up Cost			32				
Highway construction (France)	2	2					
Rolling Stock	6	7	31		257	245	705
Engineering and Management			37				
Contingencies			42			132	
Portal Infrastructure					581		
Inland Infrastructure					187		
Subsequent Investment					671		
Bonuses							46
Direct work							36
Total	£ 112	£ 138	£ 468	£ 458	£ 2992	£ 2842	£ 4650
Total In 2012 Price	£ 2024	£ 2488	£ 4793	£ 4691	£ 9712	£ 7292	£ 11932

As well as the tunnel construction cost, which was financed privately, the British Government invested in new services and upgrading of the current railway network from 1987 to 1994. Gourvish (2002) gathered and published a list of related investments to the Channel Tunnel in his book. Table 9 shows the detailed investments of British Rail related to the Channel Tunnel.

Table 9 : Investments of British Rail related to the Channel Tunnel (Gourvish, 2006, p324)

Item	Investment (2012 Prices)
Infrastructure: Phase I	1273.5
(Waterloo International Terminal, Waterloo associated work, North Pole International Depot, west London line electrification, Tonbridge-Redhill electrification, Dollands Moor Freight Operation Centre, other freight terminals, Chiselhurst -Folkestone resignalling, route upgrading, structural/clearance work and other.	
Infrastructure: Phase II	174.2
Ashford International station, north London line electrification and other.	
Total Infrastructure	1447.5
Rolling stock: Phase I	1119.3
Class 373 trains (Eurostar), night service stock, class 92 locomotives, intermodal wagons and other.	
Rolling stock: Phase II	217.5
North of London train sets, class 92s - included in Phase I	
Total rolling stock	1336.8
Total	2784.3

3.10 Why the forecast went wrong

In the 1987 financing package, a 25% cushion was considered which most parties believed was more than enough (Grant, 1997). What were the important causes/effects in the cost overruns of the Tunnel and also do they suggest failure in this context? Every mega-project has some uncertainties that may occur in its construction and the Channel Tunnel was no different. The Channel Tunnel construction cost almost doubled, but the project was nearly on time compared to other mega projects. The comparison shows that it is in the middle range of the mega projects' over budget list (Flyvbjerg book, p 14). Nonetheless, there are some mega projects that were hugely over time and budget; for instance, both the Suez and Panama canals were more than 50 times over budget; the Concorde project was more than 7 times over budget and had unsatisfactory returns; and the Seikan tunnel in Japan had a 14 year delay (Gourvish, 2006, p 366).

Grant (1997) mentions three problems: first, tunnelling progress was not as fast as planned. The contractor misjudged the challenge of getting the logistical backing for the boring machinery and the cost control was not satisfactory. Second, several changes occurred in the terminal and fixed equipment plan. Third, there was the underestimation of rolling stock costs. TML asked for a large claim of extra expenses.

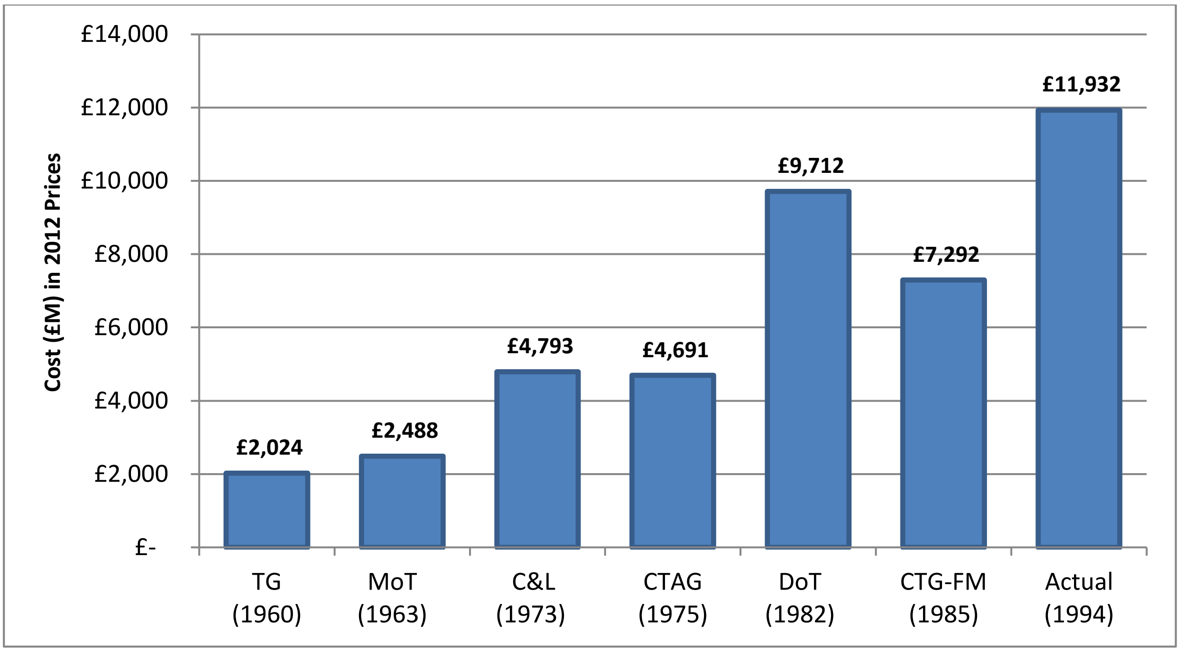

Figure 13 : Forecasted and actual capital cost of the tunnel

Flyvbjerg et al (2003) explains that the reasons for the cost over runs of the tunnel were firstly, the enhancement in safety, security and environmental requirements and the changing of regulations by the governments and secondly, the lack of a clear owner for the scheme.

Gourvish and Anson (2006) published a table that summarises the additional investment costs to safety related investments, safety related operating, security-related investments and environment-related investments. They also calculate the cost of these extra capital investments in net revenue over the life time of the concession (Gourvish, 2006, p 361).

Carmen Li et al. (2000) mention that the difficulties involved in building and commissioning of the equipment are in different stages; such as tunnelling, rolling stock and design changes. In reality, on the British side, the ground conditions showed to be far worse than predicted with salt water in the rock reducing the capability of the boring machines and this initiated delays and forced costly adjustments to the equipment. This was one of the reasons that the tunnelling stage started more slowly than in the forecasted timetable. As well as tunnelling problems, the unforeseen rises in the cost of the rolling stock followed and added to the cost of the construction. Furthermore, the Inter-Governmental Commission group, which was liable for permitting Eurotunnel an operating authorization, made some design changes. For instance, they required fire doors linking the shuttle wagons to be enlarged by 10cm, which seems very small, but as Carmen Li et al. discussed, required significant and expensive re-engineering. The original proposal did not consider any cooling system; therefore another design change had to be conducted to reduce the temperature caused by the friction of the trains and electrical equipment. This problem could increase the tunnel temperature up to 50°C and finally, a cooling system was added, moving cold water through many hundreds of kilometres of piping (Li, 2000, pp 5-6).

With the extra capital cost as resulting from the changes, Eurotunnel tried to obtain money from governments or expand the period of the concession. Morton the co-chairman of the tunnel at the time revealed that a ten year extension of the contract might be worth £200 million in NPV (Gourvish, 2006, p 360). In December 1993 the governments had decided to extend the original end period of the concession from 2042 to 2052. In addition in 1997 Eurotunnel was able to achieve an arrangement from the French and UK governments for a considerable extension to the end period of the concession from 2052 to 2086 (Li, 2000)

3.11 Operation

The tunnel is used 24 hours a day, 365 days a year. Eurotunnel offers the fastest cross-channel service; the passenger shuttle takes almost 35 minutes to cross the strait without even having to get out of the car. This value amounts to almost 90 minutes for truck shuttles from motorway to motorway. The Eurotunnel 2008 Reference document (2009) shows that the Eurotunnel Group earned 98% of its income from two main sources:

1. Le Shuttle freight that carries trucks and Le Shuttle passengers that carries cars, motor homes, caravans, coaches, motorcycles and trailers; and also

2. Tolls from the railway services for use of the tunnel by Eurostar and the through rail freight services. (ET 2008 Reference Document, 2009, p 21).

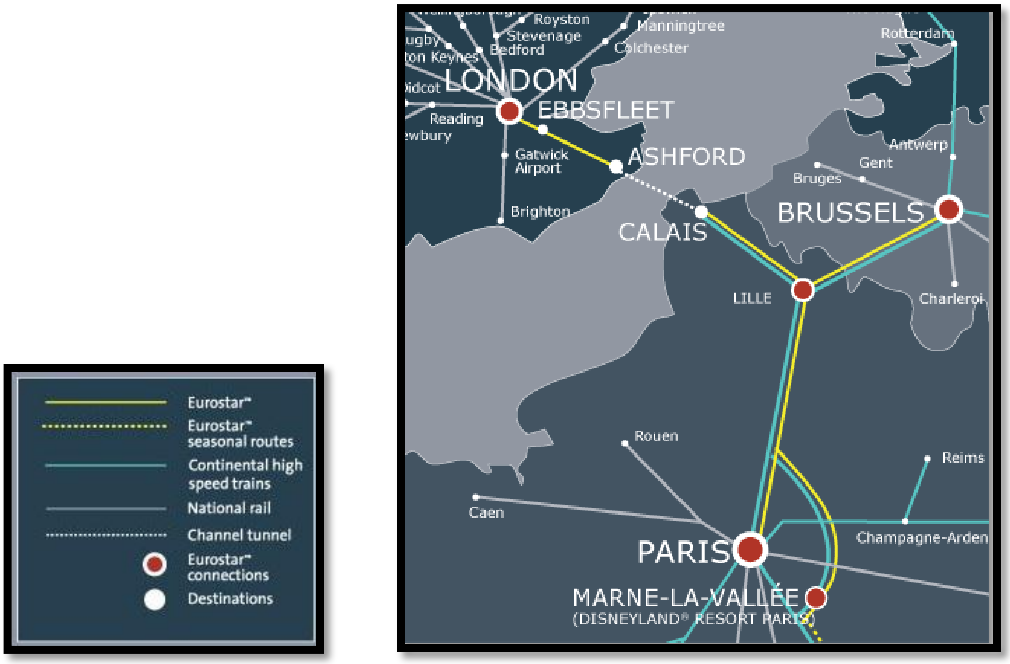

Figure 14 : Channel Tunnel Map of Destination (Eurotunnel)

3.11.1 Eurostar

Eurostar is a high-speed railway passenger service owned by the Eurotunnel Company connecting London to Paris and Brussels via the Channel Tunnel. Eurostar fares were considerably more in the past than nowadays. The cheapest price in 1994 was £99 and to win back the customers they reduced the price; the cheapest price in 2003 was £59 (Trend, 2004).

The first UK part of the Eurostar route called High Speed 1, runs from London to the Tunnel. There are other plans to expand the network to Birmingham, Manchester, Sheffield and Leeds called High Speed 2. The first phase that connects London to

Birmingham is planned to finish by 2026 and the whole project is going to finish by 2032 (HS2, 2014). Eurostar competes directly with the air passenger market from all London airports to Paris and Brussels.

Eurostar reached its record breaking 9.9 million passengers transported in 2012. The Eurostar market share in 2012 was more than 80%, in competition with the airlines according to the Eurotunnel annual report of that year (ET 2012 annual review, 2013, p 15).

3.11.2 Le Shuttle

The Eurotunnel shuttle (Le Shuttle) service transports vehicles between two heads of the Channel Tunnel (Folkestone and Calais) by a different type of train to the Eurostar. It has a motorway to motorway access, 4 departures every hour, the trip is just 35 minutes and the price starts from £23 per car and £302 per coach each way (Eurotunnel website).

Le Shuttle freight uses semi-open wagons to carry lorries and trucks for crossing through the tunnel. The trip is just 35 minutes, it has up to 6 departures every hour and its price starts from £126 per vehicle each way (Eurotunnel freight website).

Le Shuttle competes with ferries that cross the channel in both the passenger and freight markets. The passenger Le Shuttle's market share by 2012 was 51%, in competition with the ferries which had 49%. Le Shuttle Freight's share was still less than half the market with 43%, in contrast with 57% for the ferries (ET 2012 Annual Review, 2013, p 14).

3.11.3 Through Rail Freight Service

There are some services using the tunnel between the UK and central Europe operated by companies such as SNCF and DB Schenker. The Eurotunnel Group does not operate them and cannot impact on the operations of through rail freight services; but an important share of the Eurotunnel Group's income consequently is dependent on the progressive operation of these services, over which it has no operational control (ET 2008 Reference Document, 2009, p 9 and 21).

3.11.4 Europorte

Europorte is a European rail freight company founded in 2003 and is part of the Eurotunnel Group, operating between France and the United Kingdom using the Channel Tunnel (Europorte website). The company started to receive revenue in 2009 and achieved 170 million pounds of revenue by 2012 (ET 2012 Annual Review, 2013). Europorte services are:

- Traction for rail freight trains at a national
- Local rail services
- Management of private branch lines and rail hubs
- Contracted infrastructure management on rail networks in ports and on industrial sites
- 1st level maintenance service on wagons

3.11.5 Who uses the Tunnel?

As can be seen in the graph below, Eurotunnel utilities up to 55% of the tunnel capacity; Eurostar uses 13%, the Truck Shuttle 21%, through rail freight 1%, Le Shuttle 10% and maintenance 10% of the capacity.

Figure 15 : Who uses the tunnel? (Picture Reference : 2012 Annual Review, 2013, p 8)

Eurotunnel should use 50% of the capacity because of its contract and the only reason that they are using the extra 5% can be the maintenace percentage that should be attributed to all users of the tunnel.

3.12 Operating Costs

The figure below shows the operating costs during the operation of the tunnel. It is obvious that the operating costs start with a high value but they settled during the operation of the tunnel because the management tried to optimize everything. But it is hard to discuss whether this drop was normal or not. Another point arising from the graph is that the employee benefit expenses almost doubled from 1994 to 2012.

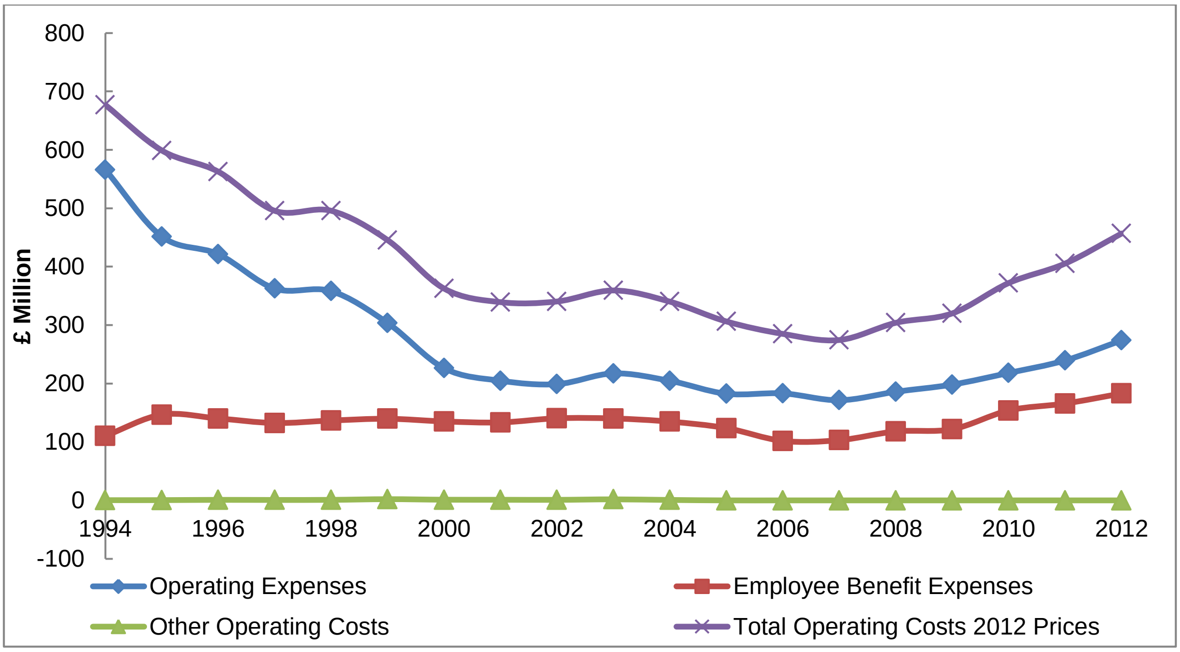

Figure 16 : Operating Costs

3.13 Total Cost

Figure 17 shows all costs together. The purple figure is the added value of all costs as a total. The investment of the British Government, capital cost of the tunnel and operation costs are all included.

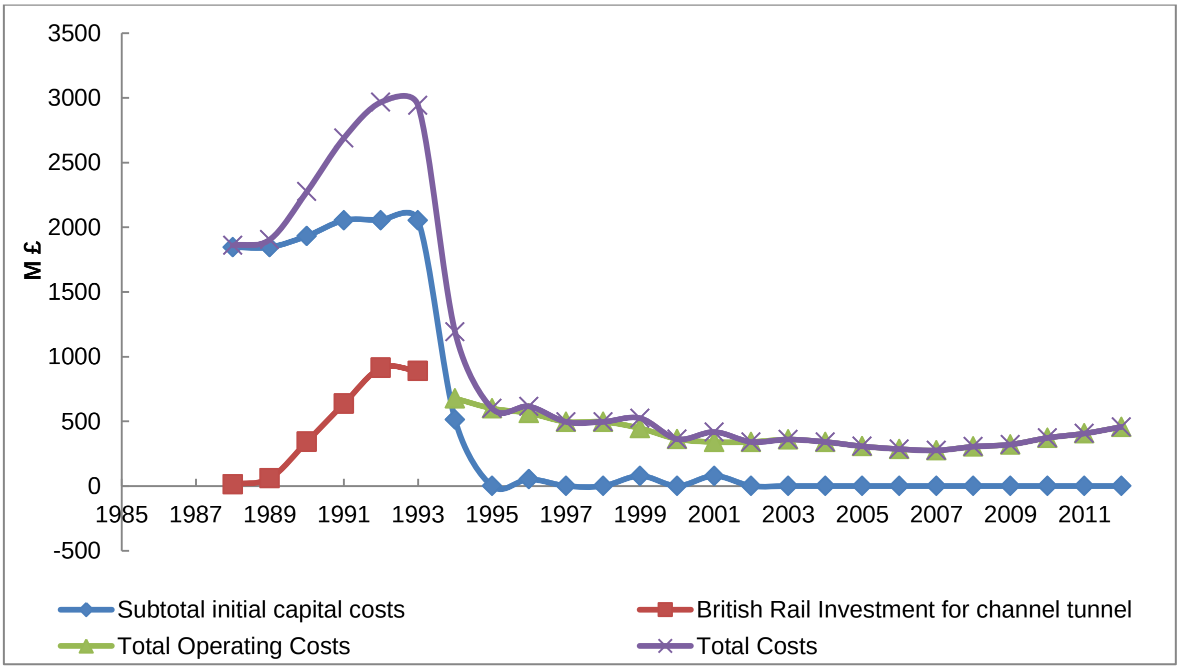

Figure 17 : Total Costs

It can be seen that British investment gradually increased until the start of the Channel Tunnel operation but that Eurotunnel spent almost the same amount every year until the completion of the project. Operation cost per year is almost fifth of the average of the capital cost per year.

3.14 Traffic and Demand

One of the most important parts of these studies is traffic and traffic forecasts because of their importance in calculating the benefits. The following sections show the actual traffic transported through the Channel Tunnel.

3.14.1 Eurotunnel Passenger Service

The Eurotunnel passenger service consists of passengers carried by Eurostar between London and Paris or Brussels and passengers who use the tunnel to cross the channel with Le Shuttle in cars or coaches. Figure 18 shows the actual traffic carried by this service.

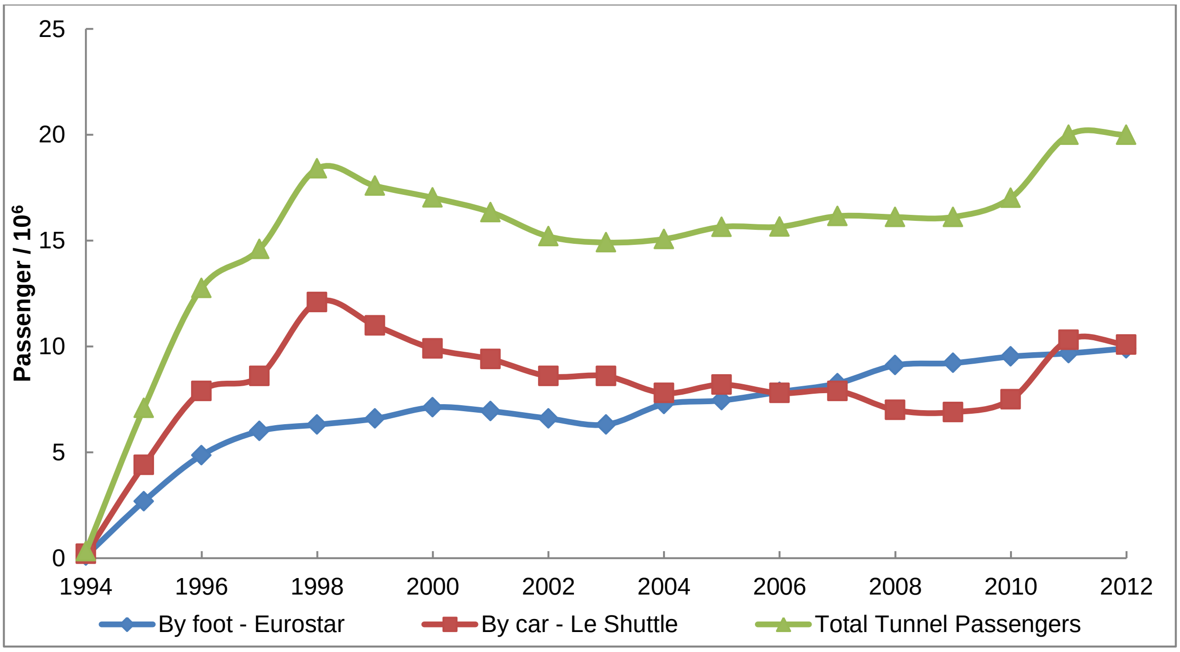

Figure 18 : Eurotunnel Passenger Service traffic

3.14.2 Eurotunnel Freight Service

The freight service consists of trucks that use the Le Shuttle Freight wagons or the through rail services which have been explained in the Operation Section 3.10. Figure 19 shows the actual traffic using this service.

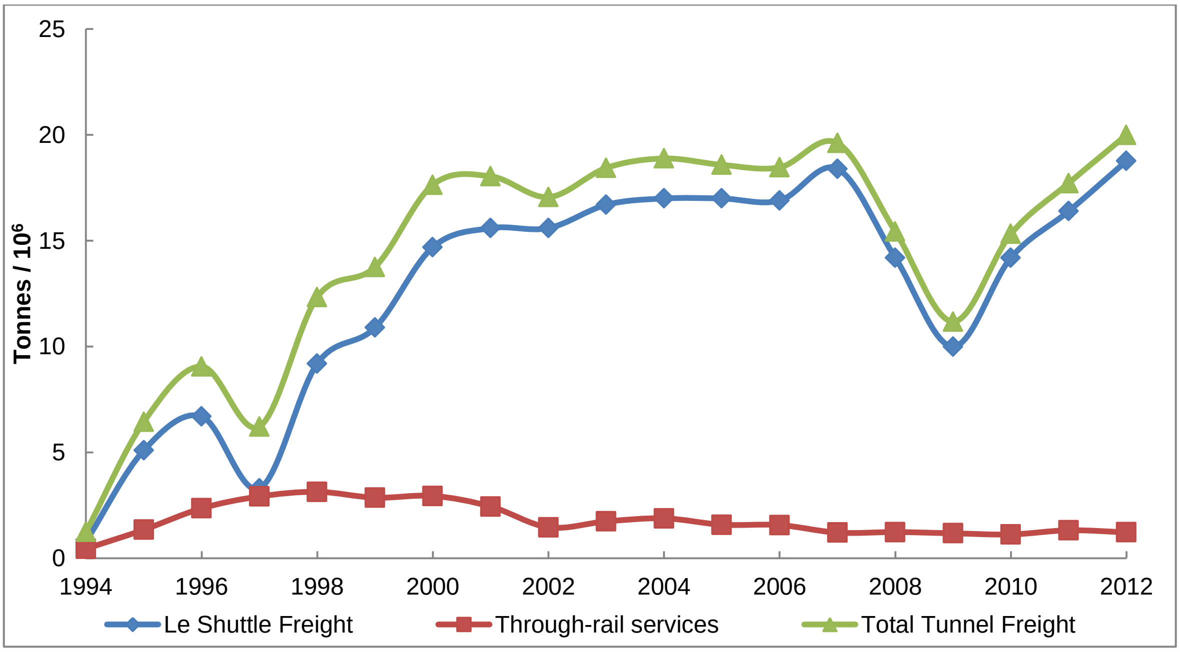

Figure 19 : Eurotunnel Freight Service traffic

As can be seen in the graph through rail services have increased in first few years of operation, possibly because of the excitement that the new service generated in the market. After 1998 it started to decrease until 2002 but was almost steady thereafter. There were two big drops in Le Shuttle freight in 1997 and 2008/2009, both being because of fires, one in November 1996 and one in 2008. More time was required to recover from the second drop probably because it had happened at the same time as the financial crisis. The shuttle market in 2012 reached its peak value after the large drop of 2008.

3.14.3 Sea Traffic

The Eurotunnel's main competitors, the ferry companies, are using the port of Dover to cross the Channel. The Dover traffic is shown in Figure 20. There are many competitors such as Portsmouth that could have been included as well but the principal competitor is the Dover Strait. The assumption is that the other English ports are not in direct competition with the Channel Tunnel because of their locations and destinations.

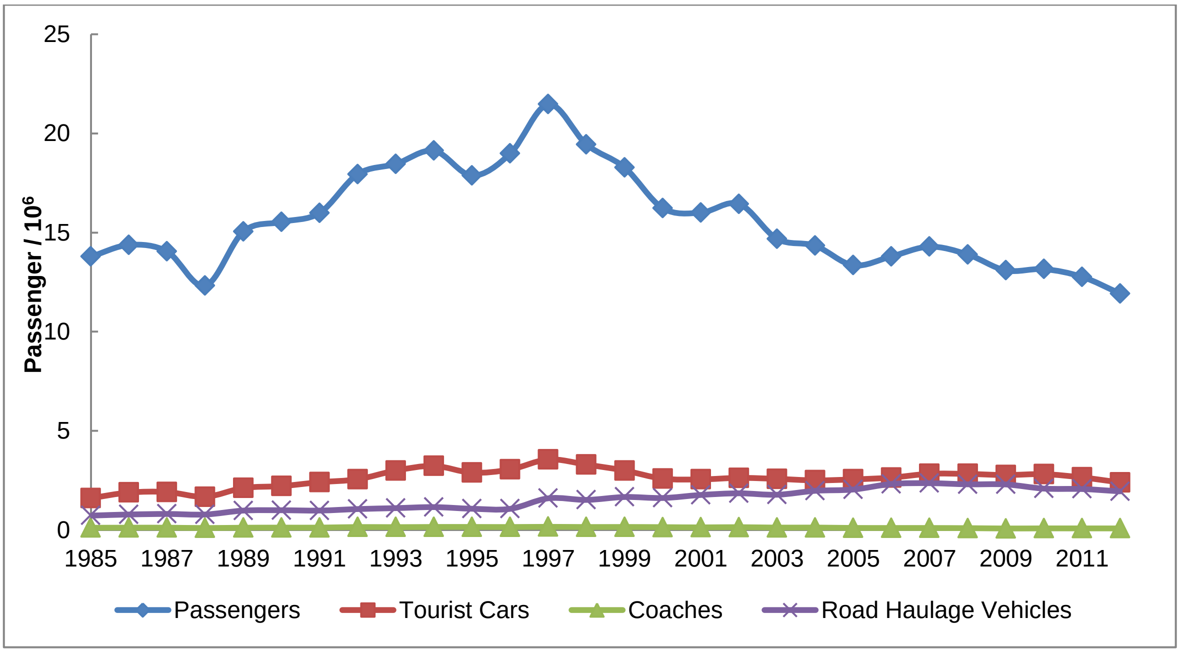

Figure 20 : Sea Traffic

3.14.4 Air Traffic

The air traffic data is collected from the UK Civil Aviation Authority (CAA). The data is from all London airports such as Heathrow, Gatwick, Luton and Stansted to Brussels airport and Charles de Gaulle, Le Bourget and Orly airports in Paris. Figure 21 shows the passengers.

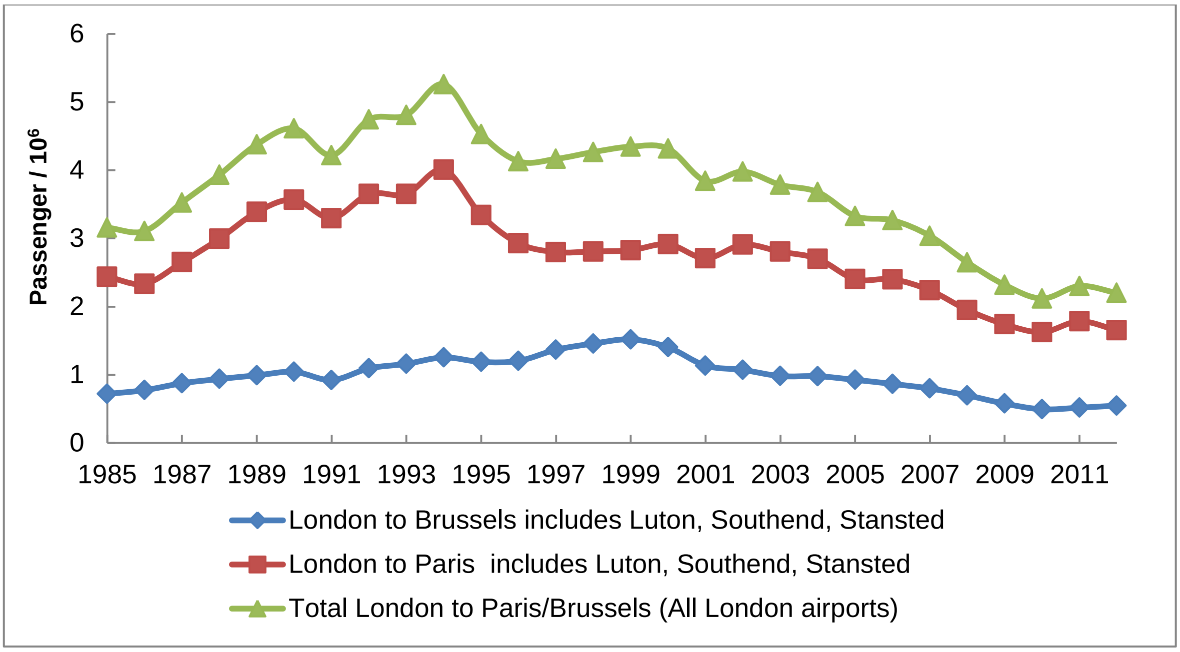

Figure 21 : Air Traffic

3.14.5 Forecasted Traffic

The figures below show the comparison of the forecasted total cross channel market in the old studies versus the actual total market and also the comparison of the forecasted tunnel demand compared to the actual data after the operation of the tunnel. The actual traffic is shown in light blue. The comparison for the total passenger market can be seen in graph below. Most of the forecasts before the tunnel are up to 60 Million passengers per year except the Eurotunnel estimations for 1987, 1990 and 1994. These overestimations may be attributable to inflating traffic forecasts so as to offset huge capital cost increases and hence control share prices.

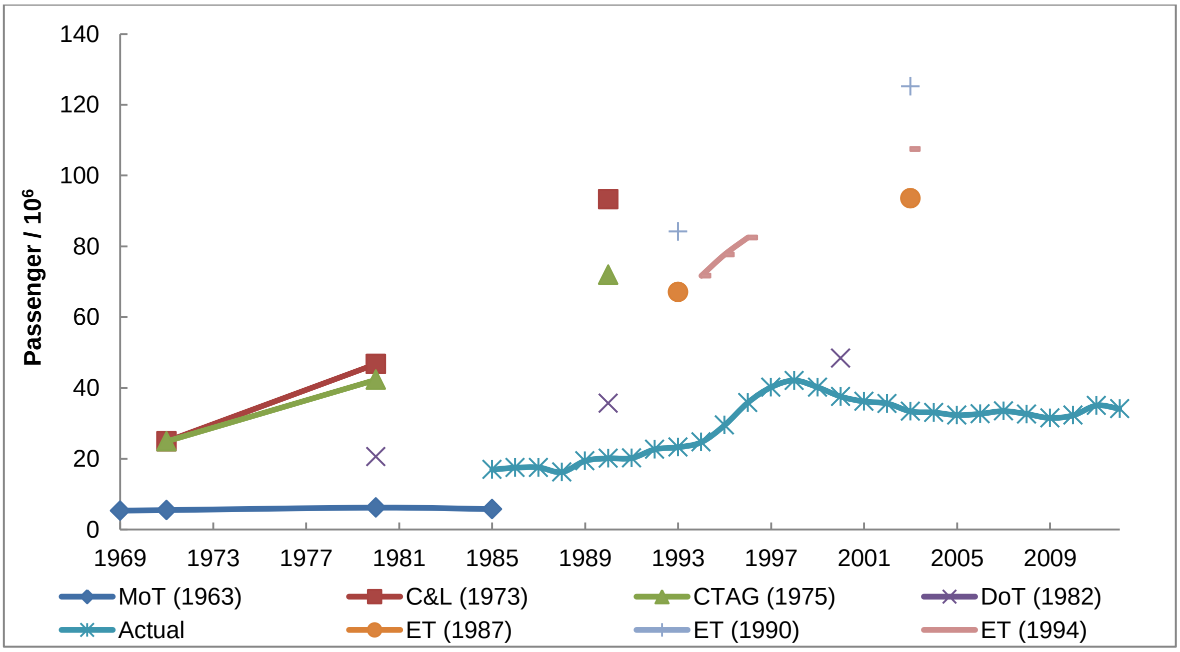

Figure 22 : Total cross channel passenger market

The comparison for the tunnel passenger market can be seen in the graph below. The overestimation of Eurotunnel traffic data is evident.

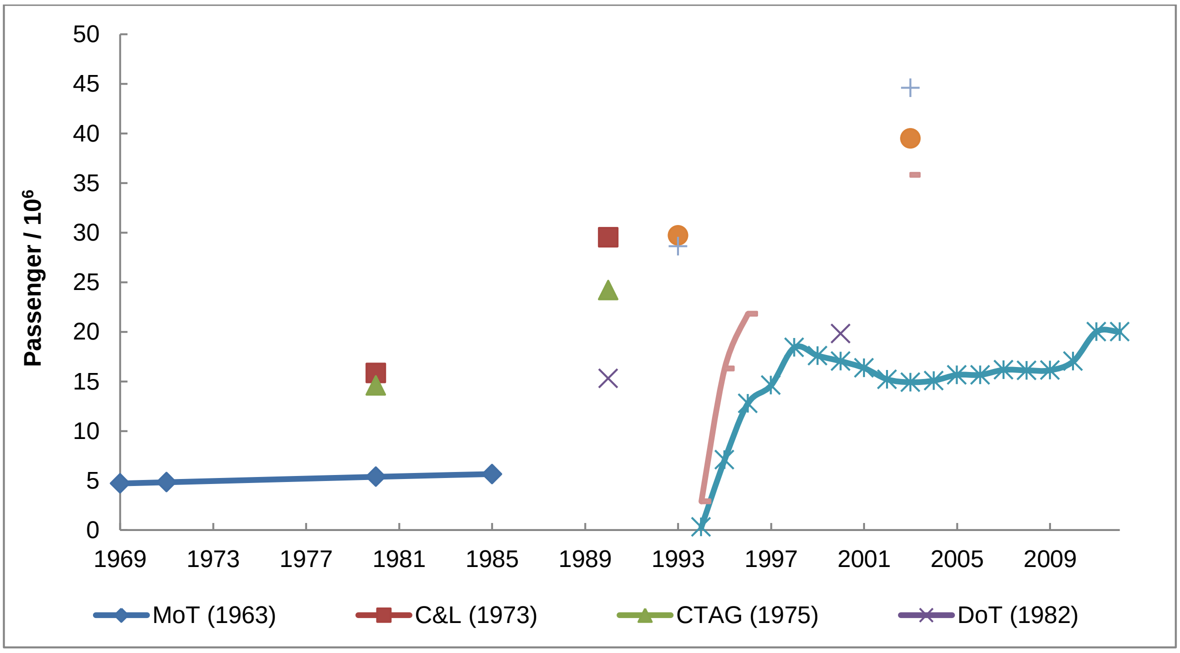

Figure 23 : Tunnel passenger market

As can be seen in the passenger traffic graphs (Figure 22 and 23), there was a boost in expectations in the Eurotunnel forecasts in 1987 and to an even larger extent in 1990. For example, the estimated passengers in the DoT's (1982) study in 2000 is 19.8 million, the Eurotunnel's (1987) estimation for 2003 is 39.5 million and Eurotunnel's (1990) for 2003 is 44.6 million passengers. Compared to the actual tunnel's operational data, which is 17.3 for 2000 and 15.2 for 2003, the Eurotunnel's prediction shows a huge overestimation. The Eurotunnel's forecasted number of estimated tonnage of freight was not available, but a comparison of estimated units of freight compared to the actual operational data proves the same point. This considerable increase in forecasted data happened at the time of the cost overruns. Flyvbjerg et al (2003) mentioned that "by the need to preserve the confidence of the shareholders and of the banks when new cost overruns became apparent in the project". Although Eurotunnel (1994) reduced the overestimation a little, there is still a big gap between the estimation and the actual traffic.

This amount of overestimation may have occurred because of either overestimation of the whole cross channel market, or by calculations inaccuracy of the actual portion of the market caught by the new service, or by both (Anguera, 2006).

The comparison for the tunnel tonnage freight market can be seen in the graph below. Unfortunately the total market comparison is not presented due to the unavailability of data.

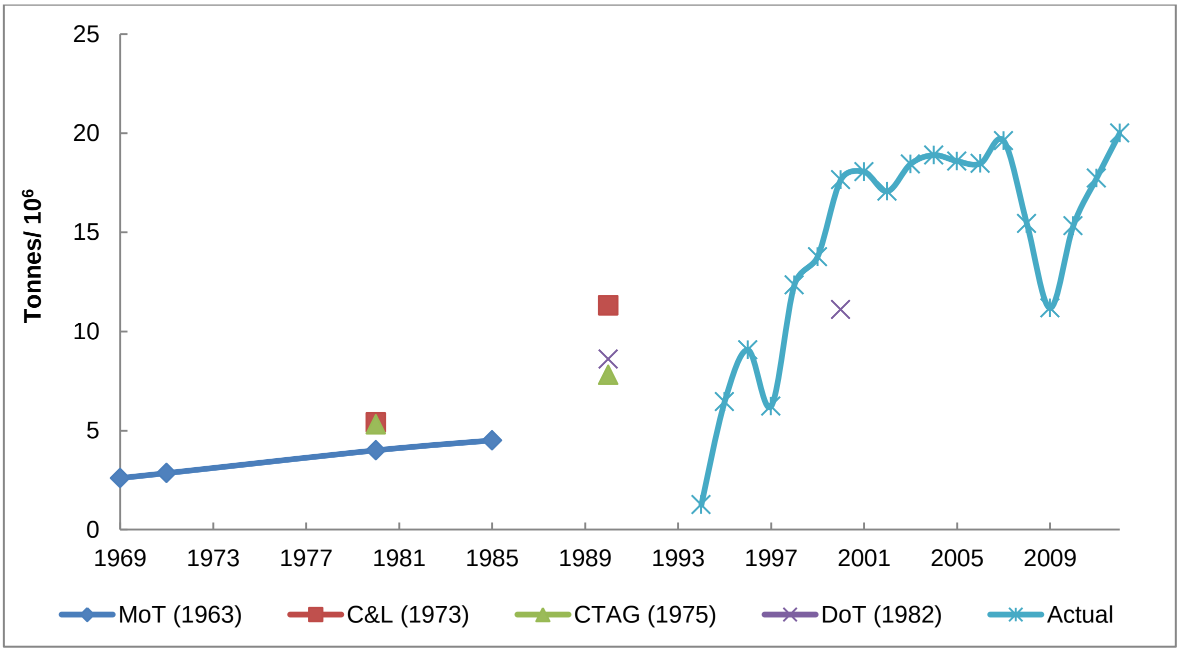

Figure 24 : Tunnel tonnage freight market

The comparison graph shows the differences between the data presented by Eurotunnel compared with the older studies and actual traffic. The huge overestimation of the Eurotunnel traffic forecasts suggests that the calculations had indeed been biased so as to retain the banks and shareholders' confidence and keep the share price high.

3.15 Revenue

Figure 25 shows the Eurotunnel actual revenue at current prices. It includes Le Shuttle, Eurostar, Europorte and other revenues. Other revenues consist of (a) revenue from retail shops in the terminals on both countries, (b) revenues in respect of the maintenance of telecommunication lines in the Tunnel, and (c) revenue from property activities. Note that all prices are actual prices.

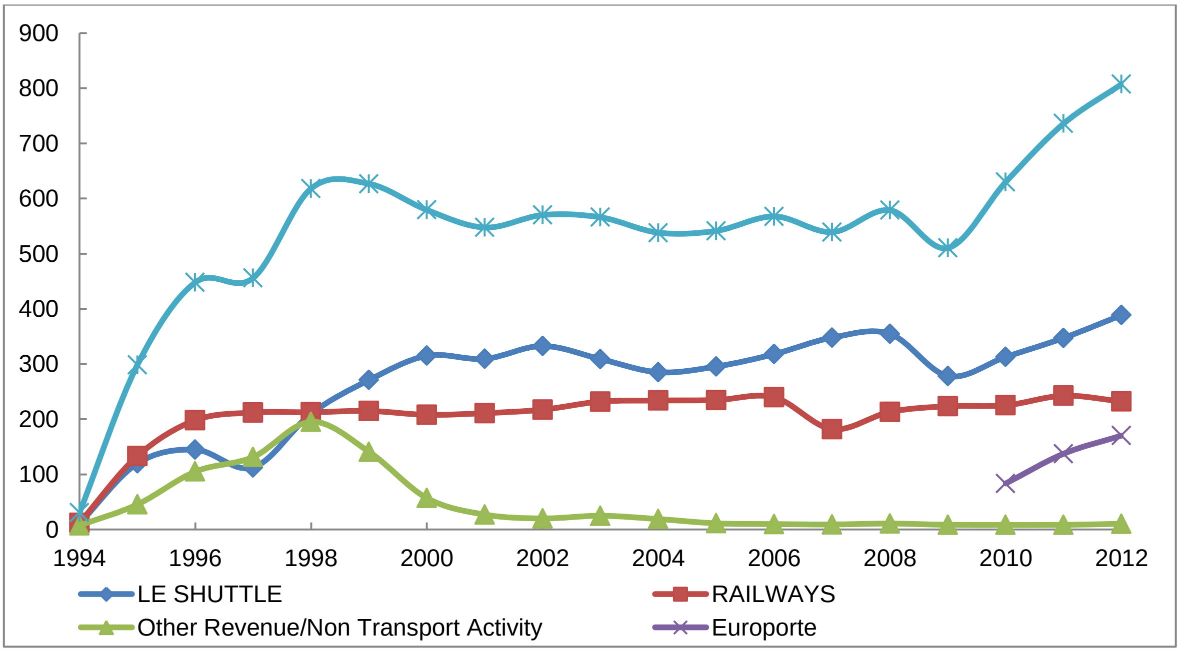

Figure 25 : Eurotunnel Revenue

The Channel Tunnel revenue was not as expected, due to the previously mentioned reasons. Figure 26 shows the forecasted revenues just before the operation. The overestimation of the projected value versus actual revenue of the tunnel can be seen in the figure. The purple figure is the actual result. Considering the difference from the estimated traffic and the actual operation result, this difference between the total revenue is understandable. As it can be seen, the forecast of revenue in 1990 is more than twice the actual outcome.

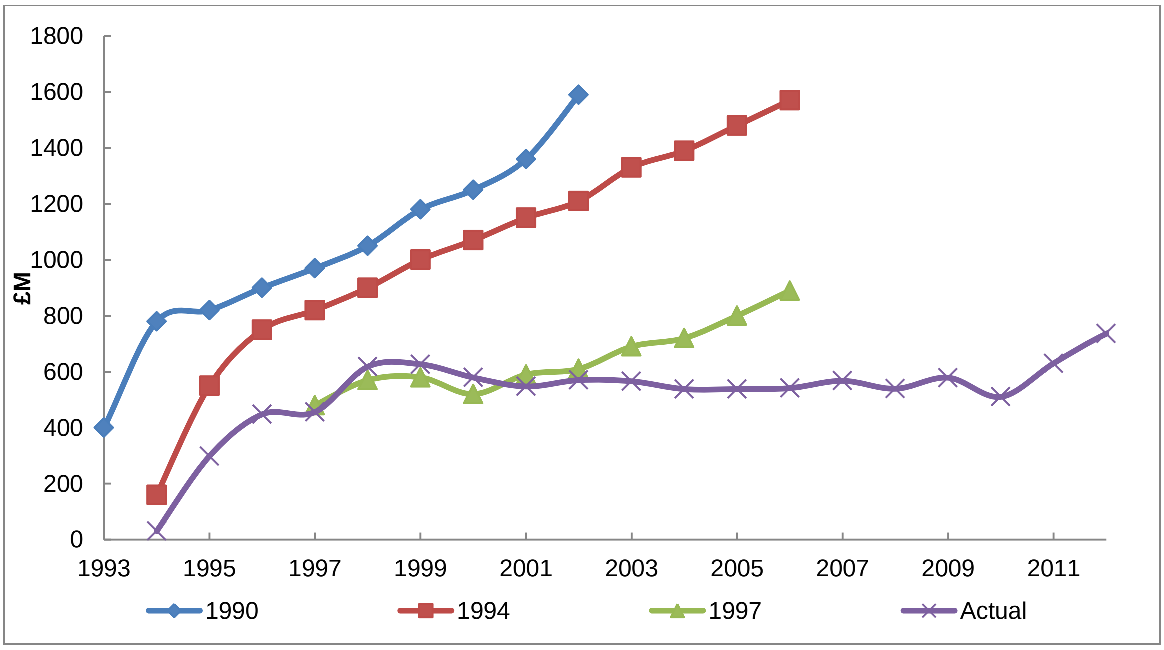

Figure 26 : Forecasted and actual Revenue

The 1997 forecast was good for 5 years but again the actual revenue did not increase the same as the forecasts. The Actual revenue kept steady until 2010, rising again after the recession.

3.16 Conclusion

This chapter explained about the Channel Tunnel project, one of the biggest, if not the biggest self-financed project of the time. The escalation in costs and the delay resulting from the misjudgement of the challenges of getting the logistical support for the boring machines and the cost control; some changes which occurred in the terminal and with the fixed equipment plan; the complexity and shortcomings of the rolling stock specified and delivered by TML; the enhancement in safety, security and environmental requirements and the changing of regulations by the governments; all caused more problems in the operation of the project. Moreover, the competitive cross channel market resulted in a reduction of prices charged by the ferry operators; Eurotunnel had not allowed for that in their estimations. This resulted in less than the forecasted traffic for the new services and therefore less than the forecasted revenue for the company. Having all these misjudgements and wrong calculations of the uncertainties, the question is "Was the Channel Tunnel a viable project? "

This chapter went through the decision making complexities, construction challenges, financing issues etc. Additionally, the operation of the tunnel with the exact operation value of traffic and a comparison of it with the channel market traffic; its revenue and its comparison with the forecasted revenue were studied. These data are the background for the next chapter; in which the viability of the tunnel is investigated via cost benefit analysis.

Chapter 4

CHANNEL TUNNEL COST BENEFIT ANALYSIS

4 CHANNEL TUNNEL COST BENEFIT ANALYSIS

4.1 Introduction

With the information about the operation of the tunnel gathered, the CBA could be conducted. This chapter uses the collected data and goes through the calculation and analysis of generated traffic, user benefits, comparison with older studies, payback period, the net present value, the internal rate of return, sensitivity analysis and the capacity of the tunnel. In addition the summaries and conclusion about the project are demonstrated.

4.2 Inflation Adjustments

The inflation adjustments needed for the study in this chapter were calculated with reference to the Office for National Statistics (ONS) and the CDKO tag was used, being a long term indicator of the prices of consumer goods and services (Jan 1974=100). All the GDP per capita adjustments needed for the study were calculated from the ONS and the GDP per person non-inflation (IHXT) was used.

4.3 Period of the Project

The period of the project for the construction was from 1987 to 1994 and operation from 1994 to the end of the contract in 2086.

4.4 Cost Benefit Model

The model that was used to start the cost benefit analysis of the Channel Tunnel is shown below, highlighting the different stages that were considered.

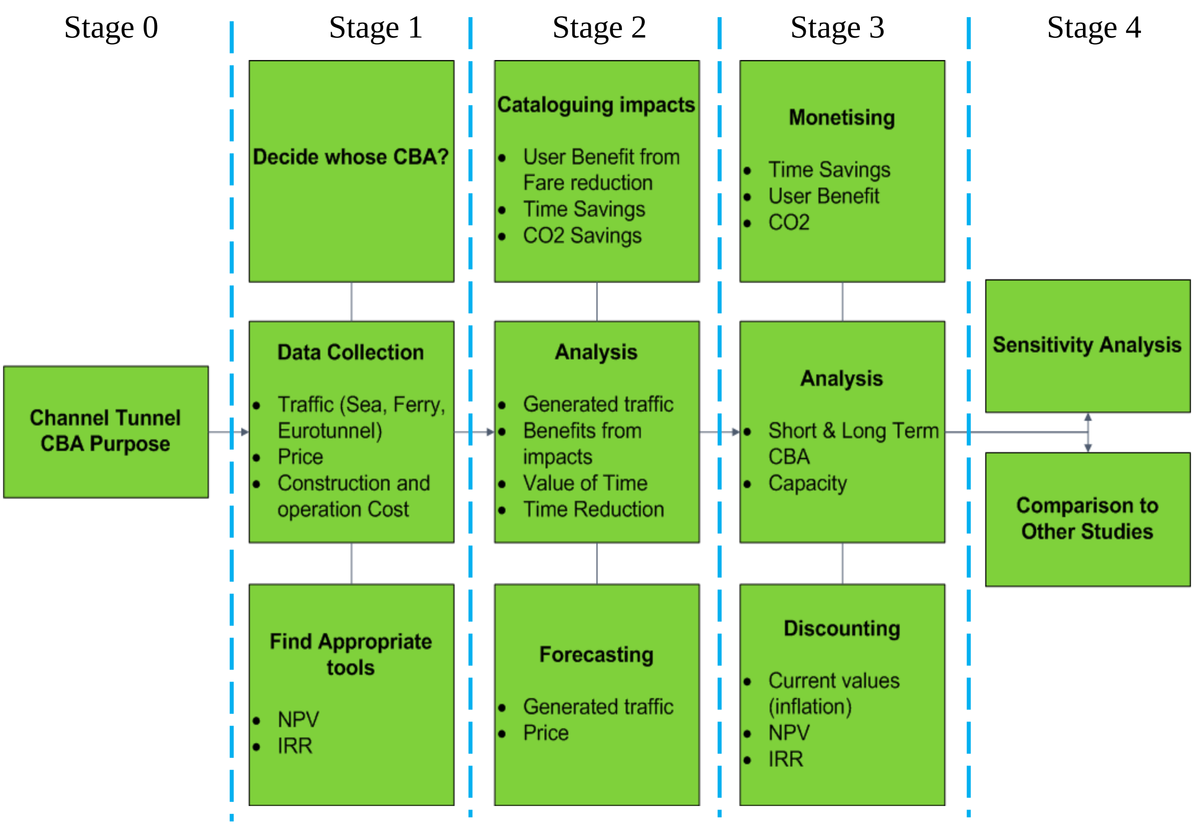

Figure 27 : Different Stages Considered in Conducting the CBA

4.5 Generated Traffic Calculation

Due to the extra supply for the cross channel market, a reduction in price and journey time, the demand for use of the service and crossings through the tunnel increased. This section shows the calculation of generated passengers for different market segments of the Channel Tunnel traffic.

To calculate the generated passengers, the traffic of the market without the tunnel is considered. As can be seen in all types of market segments, the growth of the market is almost steady, therefore a linear regression line will be sketched using Excel and the formula for the line will be generated.[1] As a result, the difference between the new actual market traffic data, minus the forecasted data without the tunnel, is the traffic generated for each year. The forecast base is air traffic from 1985 to 1993, a year before Eurostar started its operation.

4.5.1 Generated Eurostar Passengers

Figure 28 shows the generated passenger traffic between all London airports and Paris and Brussels.

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[1] Note that the small differences from the trend line are the error factor but that is neglected. Another error is the unpredicted sudden events that affect the traffic for one year which is impossible to predict in forecasts.

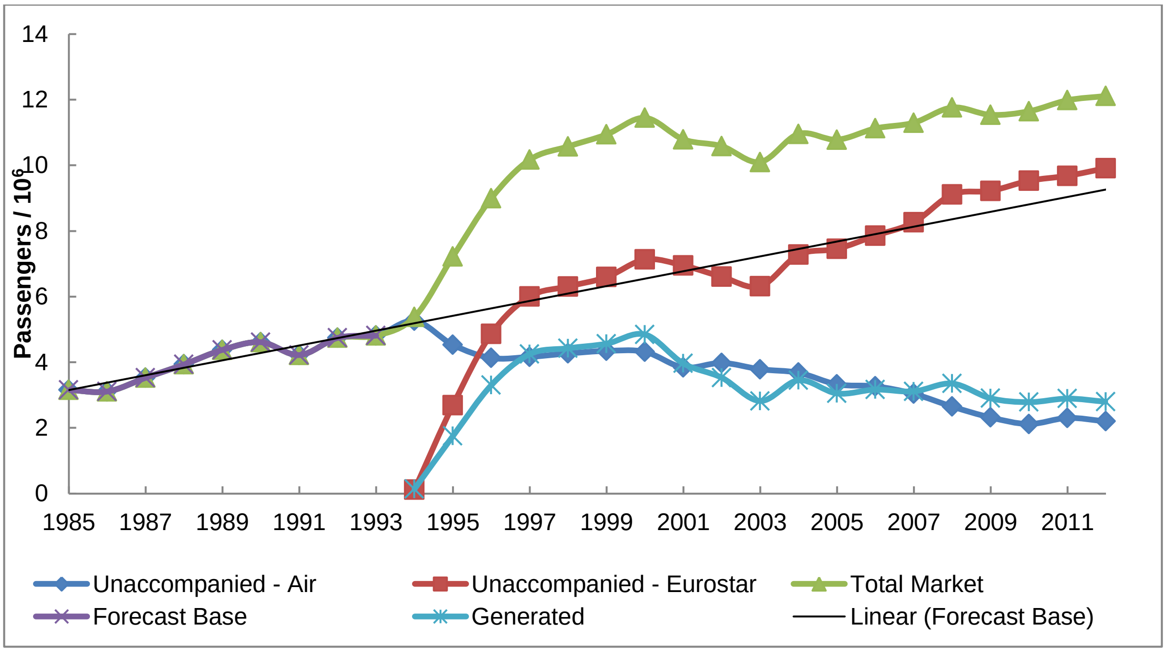

Figure 28 : Generated Eurostar Passengers

As it can be seen, there is a big shift in market after the tunnel operation had started and there has been an increase of generated passengers every year ever since. This is because of adding a new service to the market. The excitement increased the traffic noticeably for the first few years but thereafter the increase was almost steady. The peak time for the number of generated passengers for this market is the year 2000 with 4.8 million passengers generated by Eurostar. It is also obvious that many consumers moved from planes to Eurostar every year just by looking at the air data. The peak time for air planes are before the operation of Eurostar in 1993. Moreover, Eurostar is increasing its traffic every year and therefore their peak is the latest data in 2012, with traffic of 9.9 million passengers.

4.5.2 Generated Le Shuttle Passengers

Figure 29 shows the generated passenger traffic for the Le Shuttle service. It is the number of passengers using cars or coaches to cross the channel from the UK to France or vice versa. The forecast base is from 1985 to 1993 and it is almost steady with a small drop in 1988.

As can be seen in the graph, the first few years of the operation have an increasing trend for generated passengers, but the peak time is 1998 and then the generated number reduces every year until it reaches the zero point; after that, the ferries and Le Shuttle are just fighting for the existing customers. The total market is increased by the operation of the tunnel.

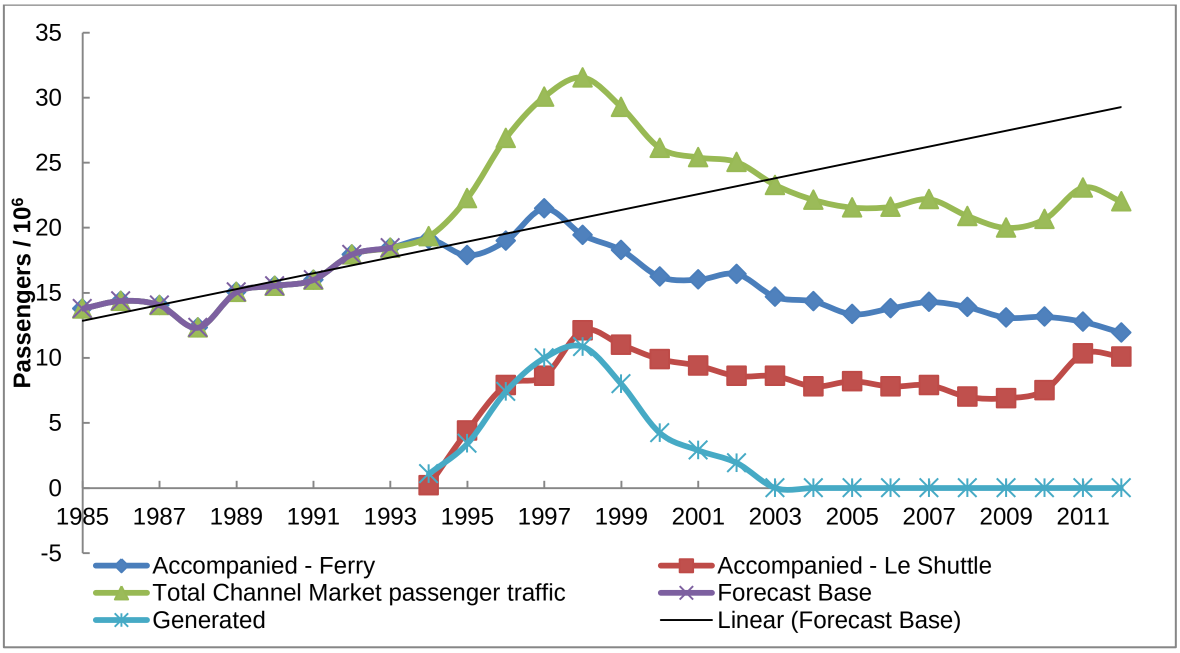

Figure 29 : Generated Le Shuttle Passengers

4.5.3 Generated Le Shuttle Cars

Figure 30 shows the generated car traffic for the Le Shuttle service. It is the number of cars crossing the channel from the UK to France or vice versa. The forecast base is almost steady with a small drop in 1988.

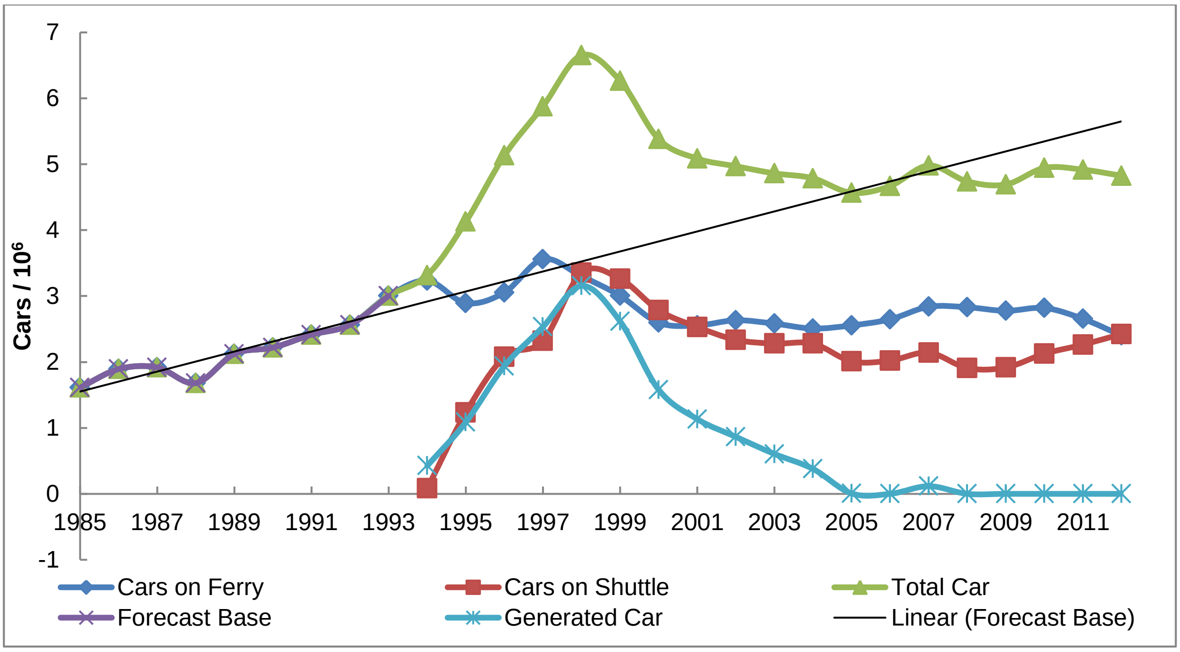

Figure 30 : Generated Le Shuttle Cars

The graph shows the generated car market flies in the first few years of operation until 1988 and then it starts to reduce. By 2005 there is almost no generated traffic added to the market and the total market is steady. The ferries and the tunnel are competing for the existing customers and the graph shows that Le Shuttle had the advantage in 1998 to 2000, but ferries got it back. For the first time in 11 years Le Shuttle reached 2.42 million cars in a year and passed the ferries' traffic of 2.40 million cars a year by 2012.

4.5.4 Generated Le Shuttle Coaches

Figure 31 shows the generated coach traffic calculation for the Le Shuttle service. It is the number of coaches crossing the channel from the UK to France or vice versa. The forecast base is almost steady with a small drop in 1988 and a small increase in 1992.

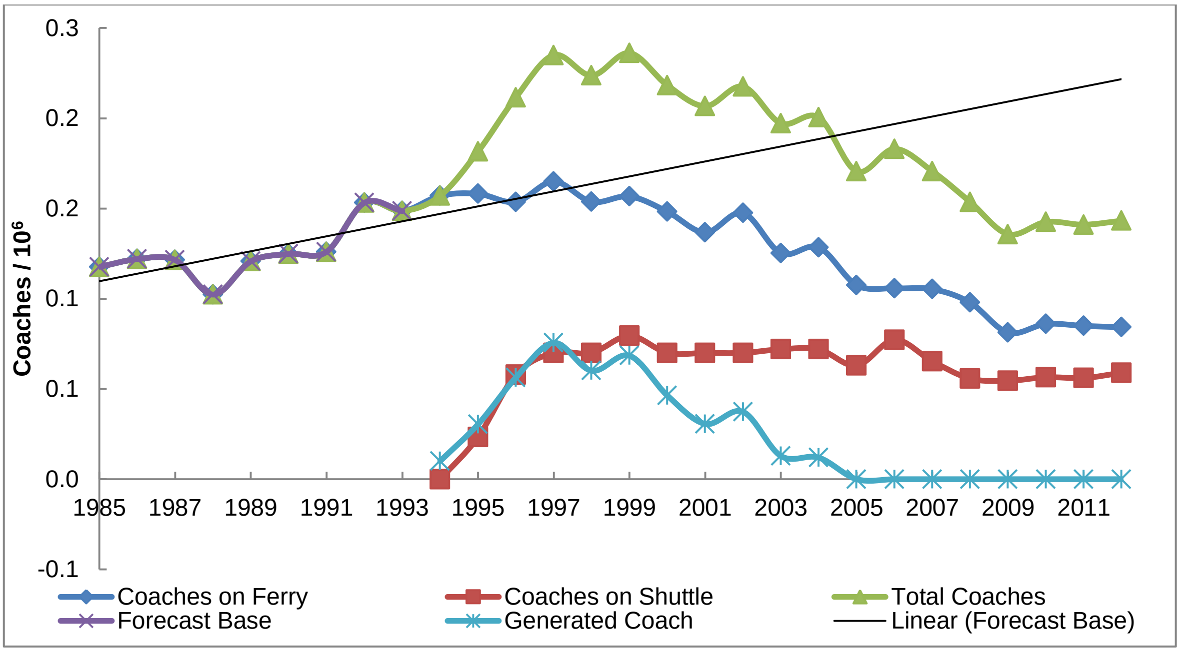

Figure 31 : Generated Le Shuttle Coaches

The data demonstrates that the coach market improved by the operation of the tunnel until 1999 with 240 thousand coaches crossing and then declined to reach 140 thousand in 2012. This reduction could be because of the better services available for passengers, such as cheap flights and the Eurostar. The generated traffic occurred between 1994 and 2004 and tends to zero by 2005. Le Shuttle coach traffic is almost steady from 1997 to the present, but ferries are losing their users almost every year after 1997. It also can be seen that the coach market is in decline, possibly because of cheap flights and cheaper rail transport.

4.5.5 Generated Le Shuttle Freight

Figure 32 shows the generated freight traffic calculation for the Le Shuttle service. It is the number of trucks crossing the channel from the UK to France and vice versa. This market is mostly business to business and very cost sensitive. The forecast base is very steady with a very small drop in 1988. The competition is between freight services and Le Shuttle in this market segment.

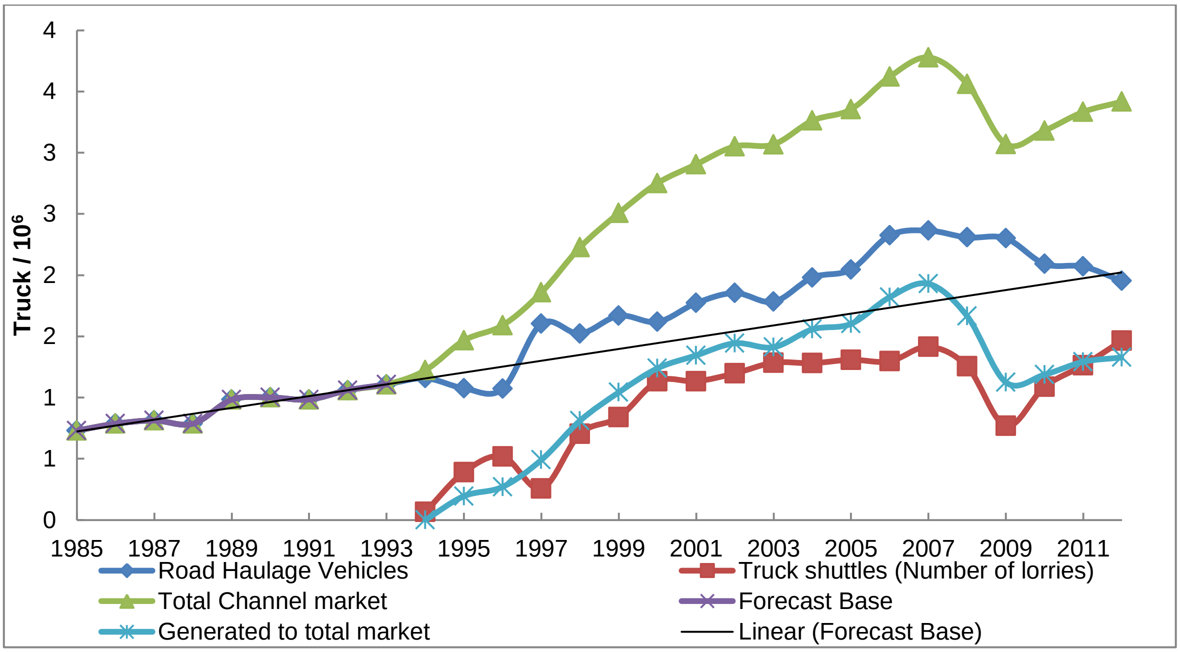

Figure 32 : Generated Le Shuttle Freight

The graph shows that the freight market crossing with Le Shuttle is still increasing every year and it is one of the main points and strengths of such a big construction project. The total market increased every year, except a big drop in 2008 and 2009 because of the world economic crisis. The generated truck line shows the effect of the Channel Tunnel to the market is still positive. This market looks optimistic for both competitors to benefit more every year; but it seems Le Shuttle started to come back better after the recession in 2008 with an increase in traffic, rather than the ferries' data that shows a reduction every year after the recession. Another important point that can be seen in the figures is that the generated data exceeds the shuttle services in most of the operational years. This means that the new service did not use any existing customers and has 100 percent generated customers for most of the years. Even the existing services had some generated customers because of the new prices. Anguera (2006) assumed there would be no generated market for Le Shuttle Freight; while the actual generated users are almost 100% on average until 2012.

4.6 User Benefits

There are a lot of benefits generated by the tunnel as well as the economic revenue. The two most important reasons for which the Tunnel was constructed were time-saving and passengers benefitting from fare reductions. Correspondingly, as well as the capital cost, operational cost and British Rail's investments in improvements and stations, there is another cost impact which is the producers' loss; this will be explained later in the thesis.

There are other factors that may affect the costs or benefit of large transport projects; such as distance to Station/Airport, ride (comfort, space, etc.), environmental impacts (emissions, sound pollution, etc.), safety and security, reliability, effect on employment and energy saving factors. It is never easy to include all the impact factors of benefit or cost to the economy due to a project and therefore some of the factors will be neglected.

This thesis will show the calculation of travel time saving, user benefits from fare reduction, producers' loss and CO_2 reduction as a benefit of the introduction of the tunnel.

4.6.1 Time Savings

One of the most important advantages of investing in transportation infrastructure is travel time saving. Metz's (2008) simple definition of travel time saving is that "there are better things to do than travel, so if travel time could be reduced by improving the infrastructure, then there would be a quantifiable economic benefit to set against the cost of the investment" (Metz, 2008). Gwilliam (1997) mentioned that 80% of the overall benefits of transport projects in developed countries comes from time saving (Gwilliam, 1997). On the other hand, the absence of enough information concerning the actual financial value of time saving means that it can occasionally be absent in evaluations (Institute for Transport Studies, University of Leeds, 2003).

Travel time saving is calculated for the customers who switched from sea and air to Eurostar and Le Shuttle and also for the generated customers.

4.6.1.1 Value of Time

The tag unit 3.5.6 report in April 2011 demonstrates the latest value of time recommended by DFT for use in the appraisal (DFT, 2011). The values needed for the current study are in Table 10 below.

Table 10 : Value of time per person

Value of time per person (£ per hour, 2002 prices) from DFT	
Rail passenger working time	30.57
Non-working time	4.46
Working lorry driver	8.42

Rail passenger working time is used for the business users of the service from the transport analysis guidance (DFT, 2011). The value of time for the business customer should be more than for those who use the tunnel for a leisure trip; this is also called 'passengers with non-working time values'.

For freight the assumption is that each truck has one driver and therefore the value of time for a lorry driver will be used. In addition, the study of freight users' benefits (BAH and ITS, 2004) shows the values of unitised freight for each truck or lorry and value of time for non-bulk freight, which is the value of time for each tonne of freight carried on through rail services.

The DFT guidance (DFT, 2011) shows a way of expanding the value of time for other years by adding a factor of GDP per capita (GDP growth per head). Using this same way for calculating the expanded value of time for different years and by adding inflation, the values used in the study in 2012 prices are as Table 12.

Table 11 : Freight value of time

Freight value of time (£ per hour, 2003 prices) from (BAH and ITS, 2004)	
Unitised freight	1.20
Other non-bulk freight	0.60

Furthermore, another significant piece of research in the value of time shows that customers would rather to pay extra to save **waiting time** and **walking** rather than paying for the same saving in ride time. Therefore, spending for walking to/from and waiting for a trip is normally valued a lot greater than the actual travel time. Consequently, the DFT recommends that the value of time for each category should be calculated as two and a half times the waiting time in the study (DFT, 2011).

Table 12 : Calculated Value of Time

	Non Work Leisure (£/hr)	Rail Passenger Working Business (£/hr)	Truck Driver (£/hr)	Truck (£/hr)	Tonne of Non-bulk Freight (£/hr)
1994	4.85	33.24	9.15	15.17	0.62
1995	4.96	34.00	9.36	16.45	0.63
1996	5.17	35.45	9.76	16.97	0.66
1997	5.33	36.53	10.06	17.47	0.68
1998	5.46	37.42	10.31	18.11	0.69
1999	5.68	38.90	10.72	18.74	0.72
2000	5.79	39.69	10.93	19.09	0.74
2001	5.94	40.72	11.22	20.78	0.75
2002	6.14	42.11	11.60	20.34	0.78
2003	6.30	43.20	11.90	20.88	0.80
2004	6.43	44.07	12.14	21.74	0.78
2005	6.48	44.38	12.23	21.44	0.76
2006	6.61	45.30	12.48	21.96	0.74
2007	6.66	45.63	12.57	22.07	0.70
2008	6.54	44.85	12.35	18.88	0.68
2009	6.31	43.24	11.91	20.90	0.68
2010	6.24	42.74	11.77	20.73	0.65
2011	5.88	40.32	11.11	19.47	0.62
2012	5.65	38.75	10.67	18.47	0.60

4.6.1.2 Journey Time

High Speed 1 has been constructed in two phases. The first phase from the tunnel and Fawkham Junction in north Kent was finished in September 2003; reducing London/Paris journey times to 2 hours 35 minutes (21 minutes reduction) and London/Brussels to 2 hours 20 minutes. The second phase was finished in 2007 and reduced the journey time of London/Paris by another 20 minutes to 2 hours 15 minutes and London/Brussels to 1 hour 51 minutes. The estimated journey time reduction used for future calculations are in Table 13. Appendix A shows the actual and estimated values that led to the calculations in Table 13. [2]

Table 13 : Journey Time Calculation

	1994 - 2003	2003 - 2007	2007 - 2012
In-Vehicle Journey Time Reduction - Sea By Car	55	55	55
Waiting Time Reduction - Sea By Car	30	30	30
In-Vehicle Journey Time Reduction - Sea By Foot	153	174	197
Waiting Time Reduction - Sea By Foot	15	15	15
In-Vehicle Journey Time Reduction - Air	-90	-69	-45
Waiting Time Reduction - Air	60	60	60

4.6.1.3 Passenger Time Saving

Passenger time saving is calculated for passengers who used to use air and sea transport and now use Eurostar and Le Shuttle instead. Figure 33 shows the formula relations used in Table 14.

For passengers without a car, the time saving is for the London to Paris/Brussels journey time by rail, in comparison to the former transport methods of rail-ferry-rail, coach-ferry-coach and air services. The travel time savings for passengers with cars and coaches have been estimated in relation to the ferries. Each time saving is separated in journey time and waiting time. The waiting time reduction values are 2.5 times the journey time reduction (ITS, 2004).

[2] The negative value in the table means extra time for the trip.

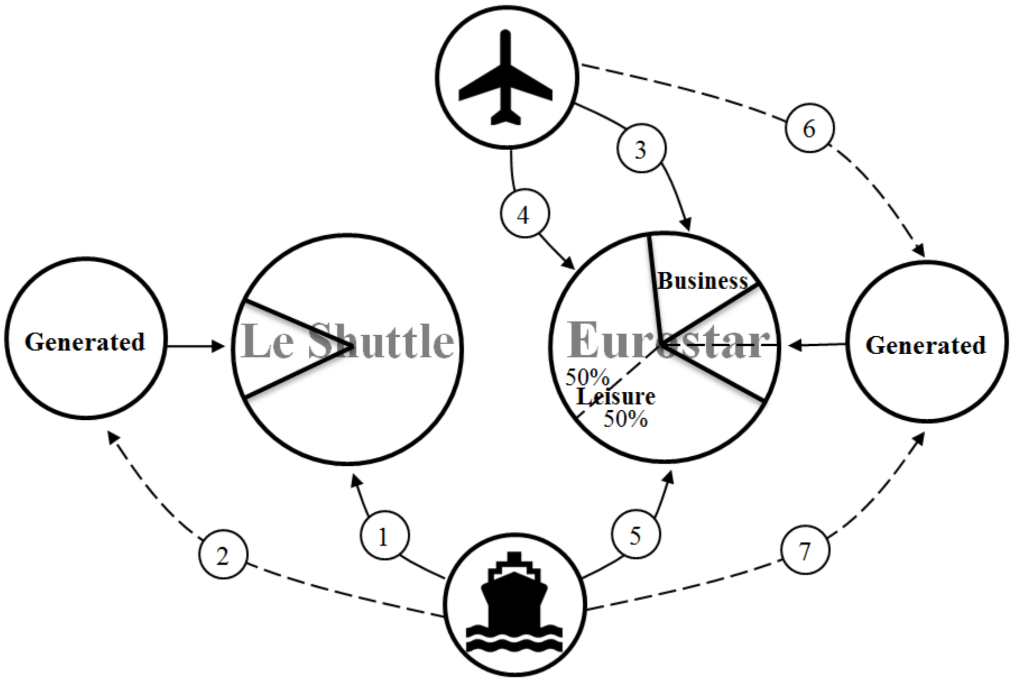

Figure 33 : Eurotunnel Generated Passengers

Following Anguera (2006) the assumptions for calculating time savings are:

- Both Le Shuttle and Eurostar generated users' benefit from time saving is half the value of the time savings because of rule of half.
- The existing users of Le Shuttle are expected to have been directed from ferry services.
- Eurostar business passengers are assumed to be 30% of the existing customers. All business users are assumed to be diverted from air services.
- The other 70% of existing Eurostar customers are assumed to be leisure passengers and 50% of them are assumed to be diverted from air services and 50% from ferry services.

- The generated traffic for Eurostar is assumed to be 50% from air and 50% from ferries.
- The waiting time for the ferries and tunnels is assumed to be the same.

Table 14 : Passenger Time Saving Formulas

	Passenger Time Saving Formulas
1	$TS = Existing\ Shuttle\ Passengers \times Sea\ Journey\ Time\ Reduction \times VoT_{Leisure}$
2	$TS = \frac{1}{2} \times Generated\ Shuttle\ Passengers \times Sea\ Journey\ Time\ Reduction \times VoT_{Leisure}$
3	$TS = 0.3 \times Existing\ Eurostar\ Passengers \times [(Air\ Journey\ Time\ Reduction + (Air\ Waiting\ Time\ Reduction \times 2.5)] \times VoT_{Business}$
4	$TS = \frac{1}{2} \times 0.7 \times Existing\ Eurostar\ Passengers \times [(Air\ Journey\ Time\ Reduction + (Air\ Waiting\ Time\ Reduction \times 2.5)] \times VoT_{Leisure}$
5	$TS = \frac{1}{2} \times 0.7 \times Existing\ Eurostar\ Passengers \times [(Sea\ Journey\ Time\ Reduction + (Sea\ Waiting\ Time\ Reduction \times 2.5)] \times VoT_{Leisure}$
6	$TS = \frac{1}{2} \times Generated\ Shuttle\ Passengers \times [(Sea\ Journey\ Time\ Reduction + (Sea\ Waiting\ Time\ Reduction \times 2.5)] \times VoT_{Leisure}$
7	$TS = \frac{1}{2} \times Generated\ Eurostar\ Passengers \times [(Air\ Journey\ Time\ Reduction + (Air\ Waiting\ Time\ Reduction \times 2.5)] \times VoT_{Leisure}$

It should be mentioned that the time reduction is underestimated because the ferry competitor assumed the shortest route from Dover to Calais. These assumptions will produce different and complicated formulas to calculate the travel time saving. The formulas are numbered the same as Figure 33. Ricard Anguera (2006) used similar formulas to find passenger time savings but he assumed that the generated passengers were 20% for Le Shuttle and 30% for Eurostar, which in reality is not true. Firstly, this is because the number of generated passengers is different to these estimates for each year and secondly, the generated passengers will become existing traffic after a few years of operation and the generation of passenger is not continuous for all periods of the project. The trends in Figures 28 and 29 suggest traffic increases in every year and furthermore that these would have occurred even without the tunnel; but in some cases, the rate of that growth escalated, which resulted in generated traffic. Moreover, there are some differences between Anguera's calculations and the calculations derived from Table 12 of the value of time, journey time's values and the waiting time's values. These differences have been discussed in their specific sections. Figure 34 shows the passenger time saving benefits resulting from the construction of the tunnel and they are adjusted to 2012 prices. As can be seen in the figure, the travel time saving increased in the first few years after construction of the tunnel and it became steady until 2006. The monetised value of time savings has continually risen since the start of operations, rising particularly sharply in 2003 and 2007.

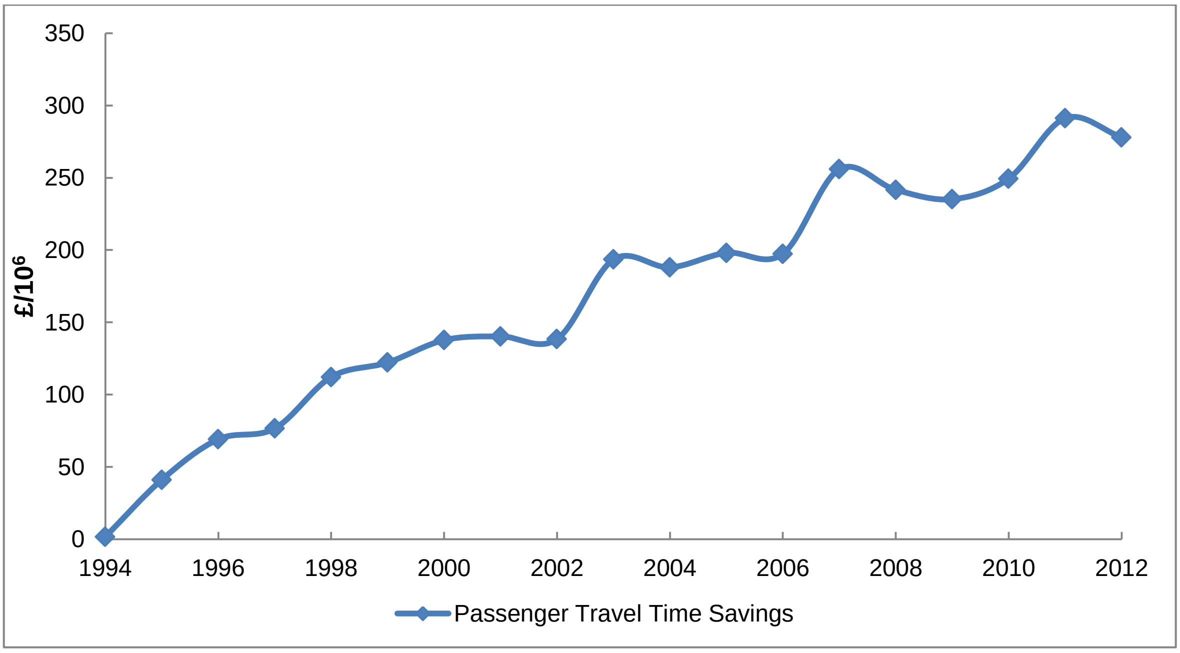

Figure 34 : Passenger Time Saving

4.6.1.4 Freight Time Savings

The calculation of freight time saving is similar but simpler to passenger time saving. The Eurostar is not in the freight market and therefore just Le Shuttle and through rail services' time savings will be calculated. For truck shuttle services, both truck driver and cargo time savings are calculated. Through rail freight time saving is only applied for cargo transported by the service.

The time savings are only applied for the cross channel journey, which is in direct competition between sea transport and the tunnel. The calculation is underestimated because the chosen route for the ferries is the shortest route in the channel market. Formulas used in the calculation are numbered the same as Figure 35.

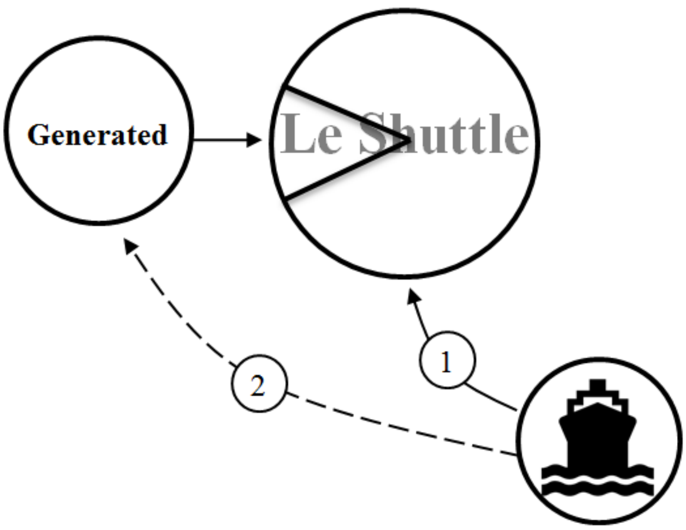

Figure 35 : Eurotunnel Generated Freight

The formulas used are the same as Anguera's (2006) framework but he assumed no generated passengers for freight, which is not true. As explained in Section 4.6.4 (Generated Le Shuttle Freight), the freight market is all generated and also there is some generated market for ferries in some years as well.

Table 15 : Freight Time Saving Formulas

	Freight Time Saving Formulas
1	$TS = Units\ of\ Truck\ \times Sea\ Journey\ Time\ Reduction \times VoT_{Track\ Load}$
2	$TS = Units\ of\ Truck\ \times Sea\ Journey\ Time\ Reduction \times VoT_{Driver}$
3	$TS = Tonnes\ of\ Freight\ \times Sea\ Journey\ Time\ Reduction \times VoT_{Non-Bulkt}$

Figure 36 shows the freight time saving benefits resulting from the construction of the tunnel and it is adjusted to 2012 prices.

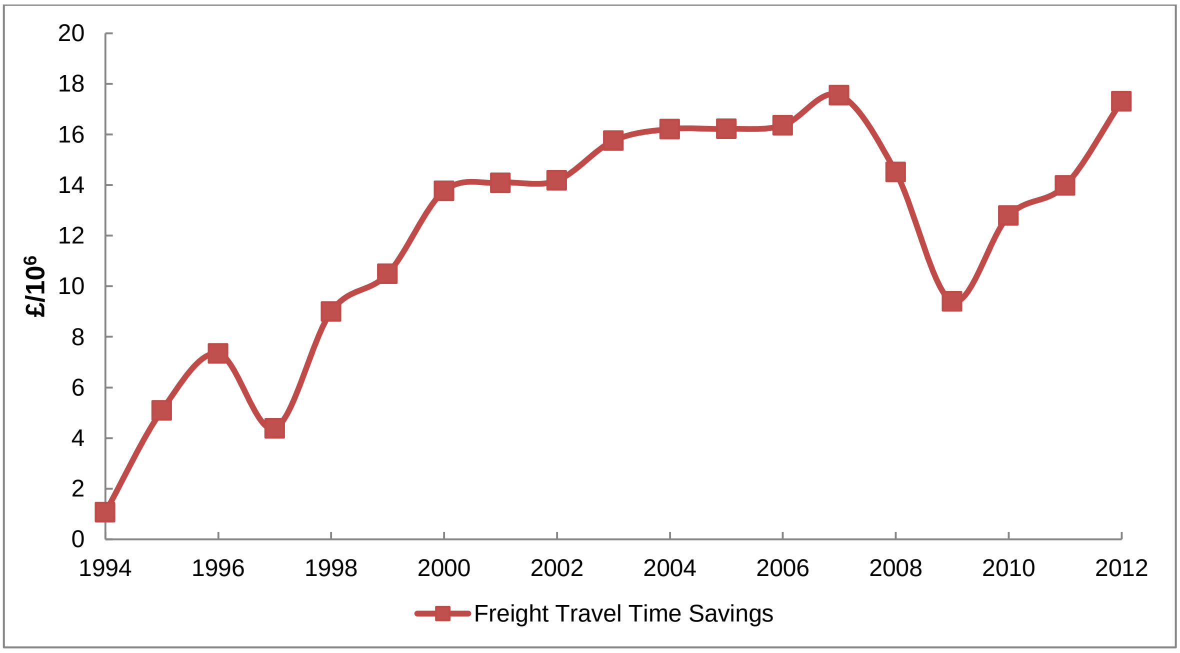

Figure 36 : Freight Time Saving

Now with all travel time saving calculations, it is possible to sketch the total time saving graph. The majority of the total of the travel time savings are for passenger travelling time. The reason for this is the high number of passengers using the service and also the greater journey time reduction in comparison to the freight services. Total time saving comparison can be seen in Figure 37.

Figure 37 : Total Time Saving

4.6.2 Fare Reductions' Savings

In a competitive market, the reduction in the price of a service or improving the quality of the service will increase the demand for that service or product. So the introduction of a new package into the competitive cross channel transport market will affect the market share and the usage of the existing services. The ferry services had had something of a monopolised cartel over the freight and car market for years and had been able to charge their customers more than the actual cost of their services. As demonstrated by the sudden reduction in ferry prices after tunnel opened. So the new option for the consumers with a better service, less journey time and a better price attracts them to change their operator and also attracts new customers as well. The following graph shows the effect of the new service added to the market and can be used to calculate the surpluses.

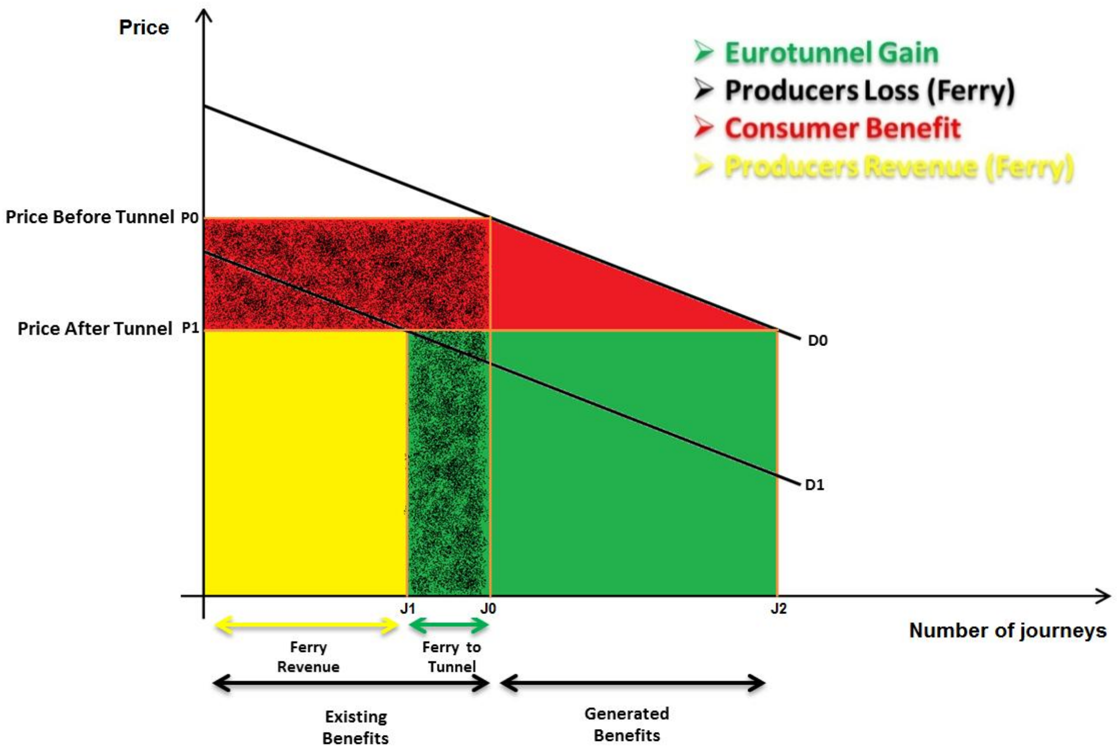

Figure 38 : Surplus Calculation

The consumer surplus is produced when there is a difference between what a customer wants to pay for a product (willingness to pay) and the actual price that they pay. There is usually a difference between different users; some will benefit from a huge surplus and some will benefit less. The Figure 38 shows the consumer surplus as a result of the new supply of the Channel Tunnel. The advantages of the new service such as time savings, better price and availability will change the consumer's behaviour. In this type of calculation, the surplus for users who used to use the service before (existing) but now enjoy the new advantages such as price, will gain the full value of the benefits; but the new customers that are using the service because of the new advantages (generated) will only benefit form half the total benefit because of the rule of half. Figure 38 shows the calculation of consumer benefits and producers' loss. Note that there is no need to include the supply curve because the price is known already. The calculation of the average price used to calculate the surplus for each year is explained in Section 4.6.2.1.

The horizontal axis is the actual number of journeys of the users and the vertical axis is the price of the service. The D_0 line is the total demand for consumers using the cross channel transport market since the opening of the tunnel and the D_1 line is the producers' (ferry) demand after the tunnel construction. Before the Channel Tunnel was invited to the market the price that the consumer used to pay was P_0 and the new lower price is P_1. Due to the lower price of the service more customers will be attracted so the number of journeys will be more. The number of journey for ferries used to be J_0 and because of the new demand will decrease and become J_1. The number of journeys for the whole market will be J_2. Therefore the ferry market will be 0 to J_1, existing customers moving to the new tunnel service will be J_1 to J_0 and the generated customers will be J_0 to J_2. Furthermore, the yellow area will be the producer's revenue, the green will be Eurotunnel's gain and the red zone will be the consumers' benefit. As can be seen, the generated consumer benefit is a triangle and will be half the value of the generated consumers multiplied by the price difference; this triangle will explain the rule of half. The black covered area in the red and green zone is the ferries' loss because of the new service or can be called the producers' loss. The calculation of each area for the cross channel market will be analysed and discussed in the following related sections.

4.6.2.1 Passenger Fare Reduction Benefit

The average fares are calculated from Eurotunnel's revenue and traffic data, as published by Eurotunnel in their annual reports. Revenue split data, numbers of trips per category and weighted averages (cars and coaches) have been used. Note that the ferries' average fares have been assumed to be equal to those of the tunnel. Figure 39 shows the change of average fares in 2012 prices for all the operational years.

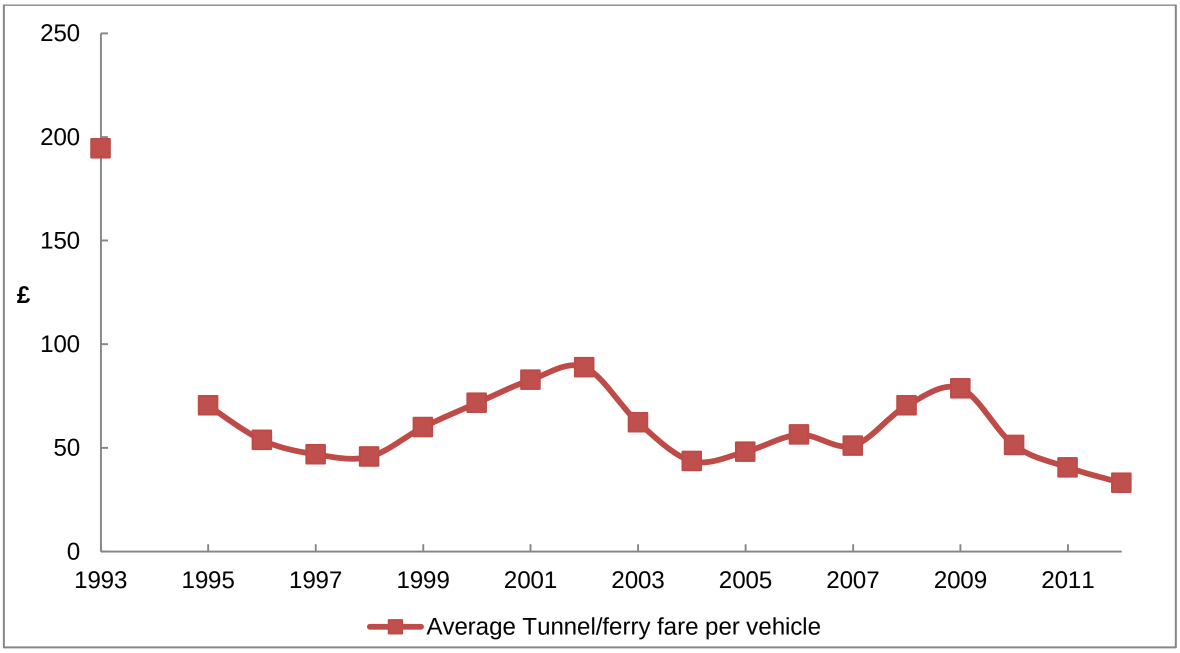

Figure 39 : Average Tunnel/Ferry Fare per vehicle

The amount of passenger traffic has been discussed in Section 3.14. There are two types of passengers using the new service and those should be considered in order to calculate the benefit resulting from the fare reduction for passengers. They are customers who are using coaches to cross the channel and those who use their own cars. The number of generated passengers (new customers) and the number of consumers who are changing their mode of transport to the tunnel (existing customers) are calculated in section 4.5.

In addition, the rail-sea-rail and walking passengers are not calculated in this analysis because the connected service ceased before the tunnel operation and the walking passengers are neglected because of the very small amount that uses the service. Moreover, the passengers using air transport are neglected because there is no evidence to show the effect of the tunnel on air price and the price of air transport is very complicated (Anguera, 2006).

Figure 40 : Total Passenger User Benefit

The average price reduction for each year from the start of operation is used to calculate the user benefit for existing consumers. The generated consumer benefit is half of the average price reduction multiplied by the number of new consumers for each year.

Figure 40 shows the estimated passenger user benefits from the fare reduction in 2012 prices. The amount of user benefits varies, but the drop after 1998 is because of the abolition of duty free; which increased the price of both the ferries and the tunnel. Another drop in 2000 was because of the recession, which occurred in that year and the number of trips decreased.

4.6.2.2 Freight Fare Reduction Benefit

The calculation of the consumers' benefits was approached in the same manner as the passengers' benefits, due to the fare reductions. The analysis just took unitised freight into account, due to the unavailability of data and the small size of through-rail market relative to unitised freight.

The generated traffic calculation has been discussed in Section 4.6 and amounts to half the benefit because of the rule of half. [3] Note that Eurotunnel's freight market after 1997 is generated traffic and calculated by the rule of half. Moreover, there is some generated

[3] Eurotunnel's freight market after 1997 is generated traffic until 2011.

traffic carried by producers as well, because of the new reduced prices. The generated traffic carried by the ferries is using the benefit by rule of half as well. [4]

The result of unitised freight surplus is shown in Figure 41. The data of the benefits from the opening of the tunnel is highlighted. The freight market is mostly a business to business market and therefore very price sensitive. It is obvious that the opening of the new service helped the growth of the transport market. The calculation shows that as the market is growing every year, the benefit is growing with a good pace annually. It also shows how ferry operators used to use their monopolised cartel to increase the price in the market. If they could not compete with Eurotunnel they would have vanished from the market.

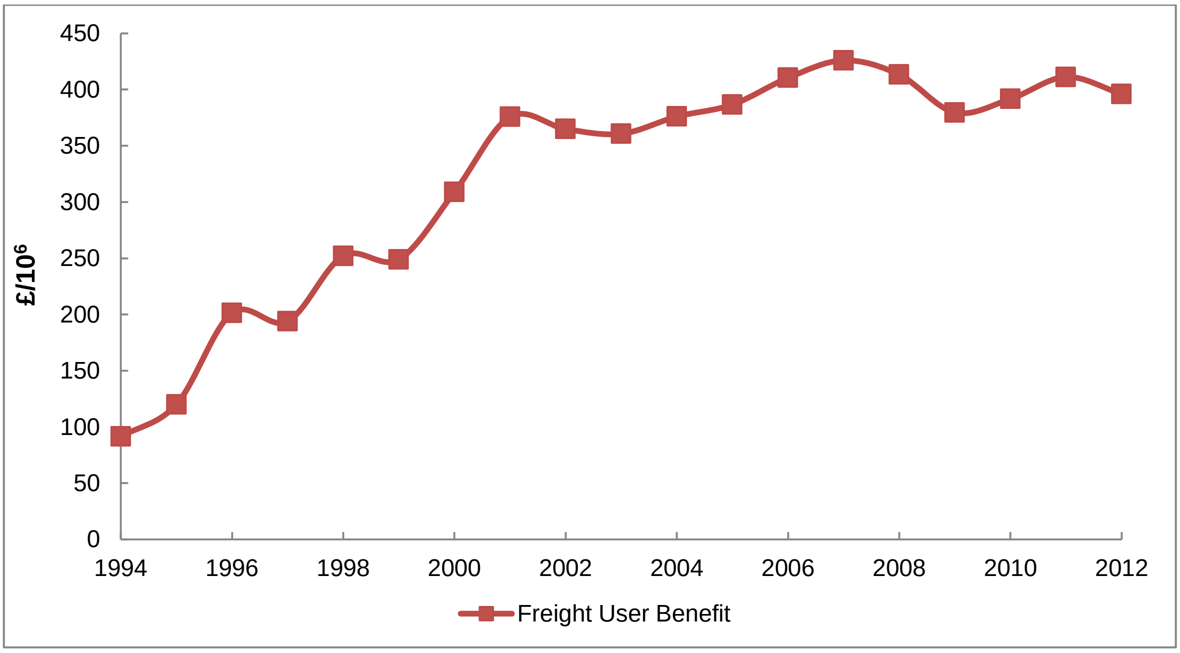

Figure 41 : Total Freight User Benefit

[4] Ferries (Producers) freight market has generated traffic from 1997 until 2011.

4.6.3 Producers' Losses

Producer's loss is the loss of the ferry operators as a result of the opening of the new transport service. The new service resulted in a loss of the producers' customers and also forced them to reduce the fare in a price competition with the tunnel. Figure 42 shows the producers' loss resulting from the opening of the tunnel.

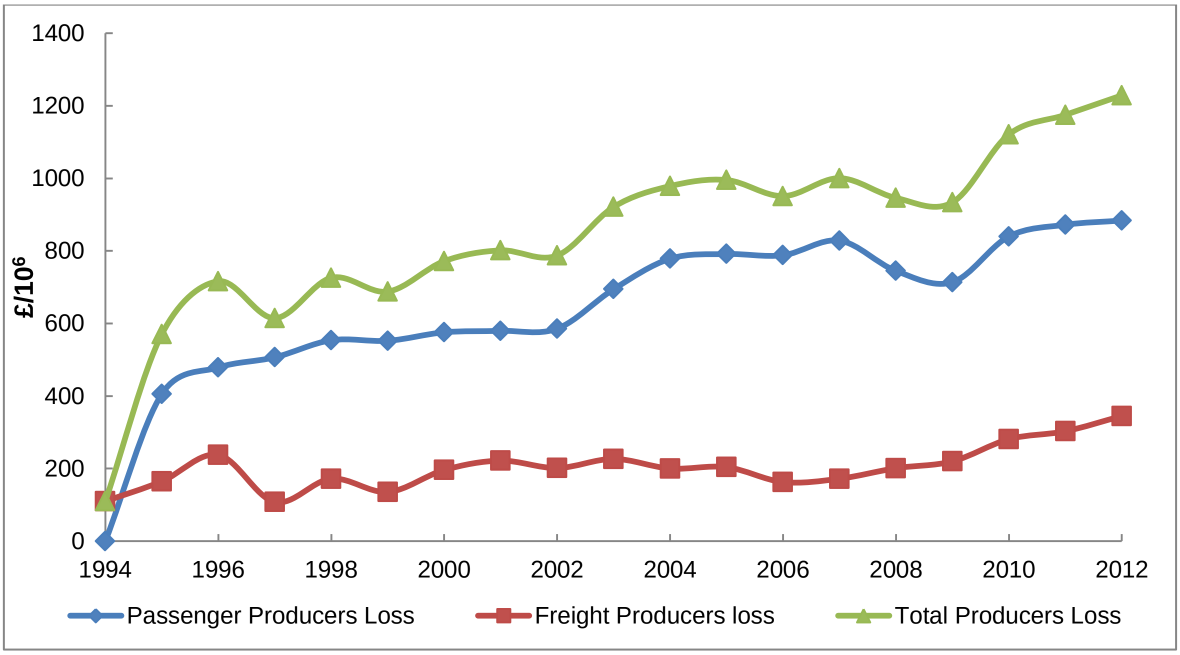

Figure 42 : Total Producers' Losses

4.6.4 CO_2 Emission Savings

It is important in urban areas with a high population and vehicle density to reduce emissions of substances that can affect health and the environment. Every growing industry is required to lower the emissions from its industrial processes and improve energy efficiency (Rail Transport and Environment, 2008). Moreover there is pressure from customers for green services including businesses using greener freight services.

As a result the governments are trying to increase public transportation with fewer emissions and are trying to build green vehicles such as electric trains. This will result in taxing companies more every year and the effect on revenues will rise. Therefore the importance of green transport is going to grow every year.

The estimated production of CO_2 produced by the channel market transport companies is calculated. The following graphs show the differences between Eurotunnel production and the competitors. The CO_2 savings are also calculated as if the Channel Tunnel had never been built. Unfortunately it is not easy to calculate the monetised savings of CO_2 reduction, due to the inconsistency of the monetised effect of CO_2 emissions in different research. The research shows different values for the cost of a carbon footprint, such as $5 to $100 per tonnes of CO_2 (Litterman, 2013); $25 per tonne (Morgenstern, 2002); $348 per tonne (Vandoren, 1999).

The average CO_2 emissions per person from travel by air is derived from the annual average CO_2 emissions per person from London-Paris and London-Brussels flights and the proportion of passenger trips. The return trip emissions are calculated in the same way because the external factors affecting the emissions are negligible. The average CO_2 emissions for Eurostar are 14.6 Kg per trip (calculated from Eurostar's website) and are split in a 50 percent proportion between London-Paris trip and London-Brussels. The estimation of CO_2 savings for Eurostar and the air travel market is calculated and is shown as Figure 43.

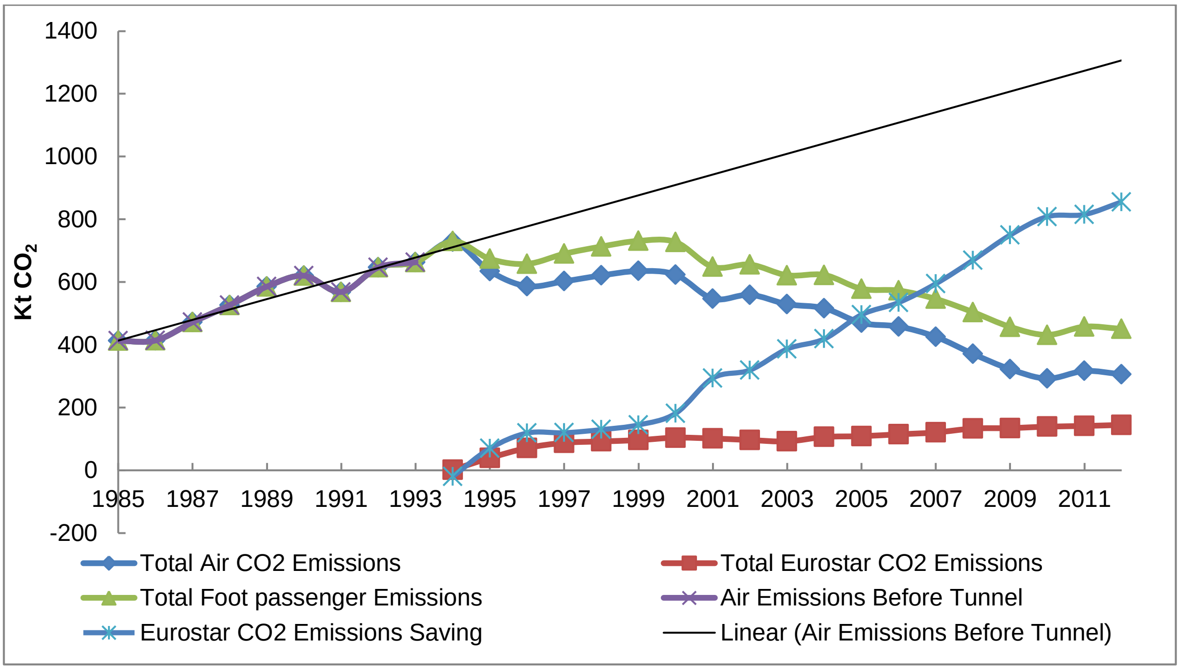

Figure 43 : Air/Eurostar CO_2 Emissions Calculation

As can be seen in Figure 43 the CO_2 emissions are reduced every year after the tunnel construction. The tunnel CO_2 saving line shows the saving is increasing every year compared to the market forecast without the tunnel. The estimated total savings until 2012 for the Eurostar passenger market is 7.7 Mt of CO_2 emissions.

Average CO_2 emissions per passengers on ferries (Dover-Calais) are estimated at 5Kg per passenger trip (Richard Hammond, 2007). Average CO_2 emissions per passenger on Le Shuttle (Dover-Calais) are estimated at 4.4 Kg per passenger trip (UIC Ecopassenger website, 2014). The estimation of CO_2 savings for the passenger shuttle and the ferry market are calculated and are shown in Figure 44.

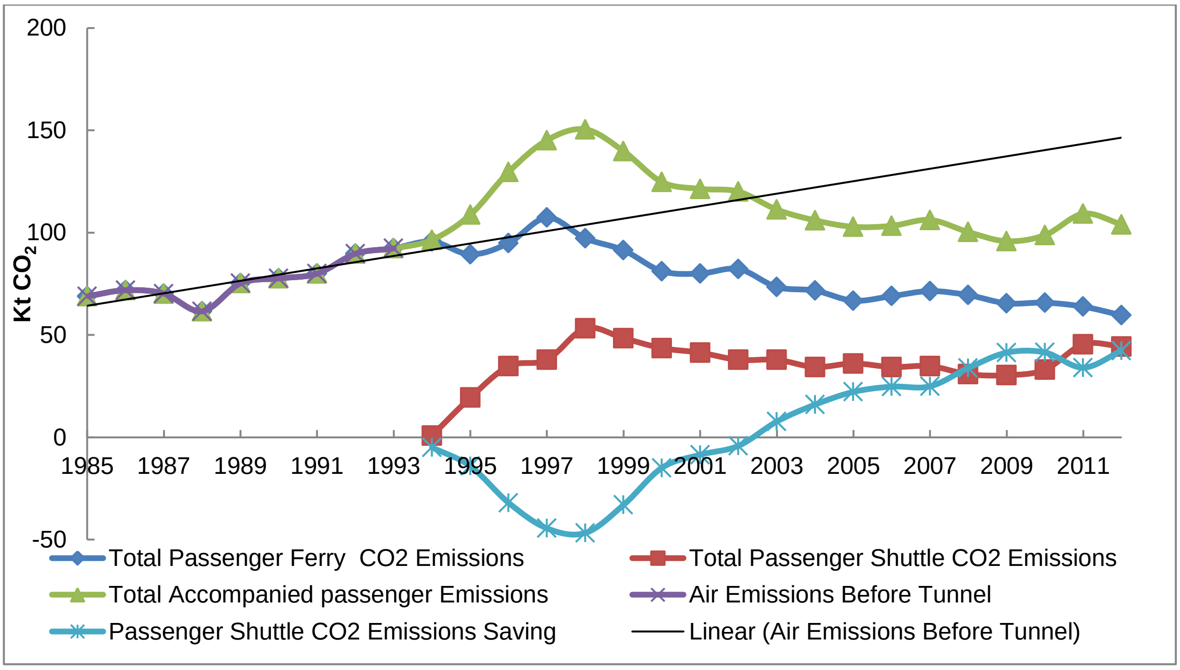

Figure 44 : Ferry/Shuttle Passenger CO_2 Emissions Calculation

As shown in Figure 44 the first few years of the shuttle operation caused more CO_2 production rather than savings until 2002, because of more generated passengers to the market and the number of existing ferry users. After that the savings start to build until the present. The total estimated savings of the shuttle passenger service is 85.6 Kt until 2012.

Average CO_2 emissions per truck on the ferries (Dover-Calais) are estimated at 158Kg per trip (Eurotunnel Carbon Counter). Average CO_2 emissions per truck on the shuttle (Dover-Calais) are estimated at 8.8 Kg per trip (Eurotunnel Carbon Counter). The estimation of CO_2 savings for the freight shuttle and the ferry market are calculated and shown as Figure 45.

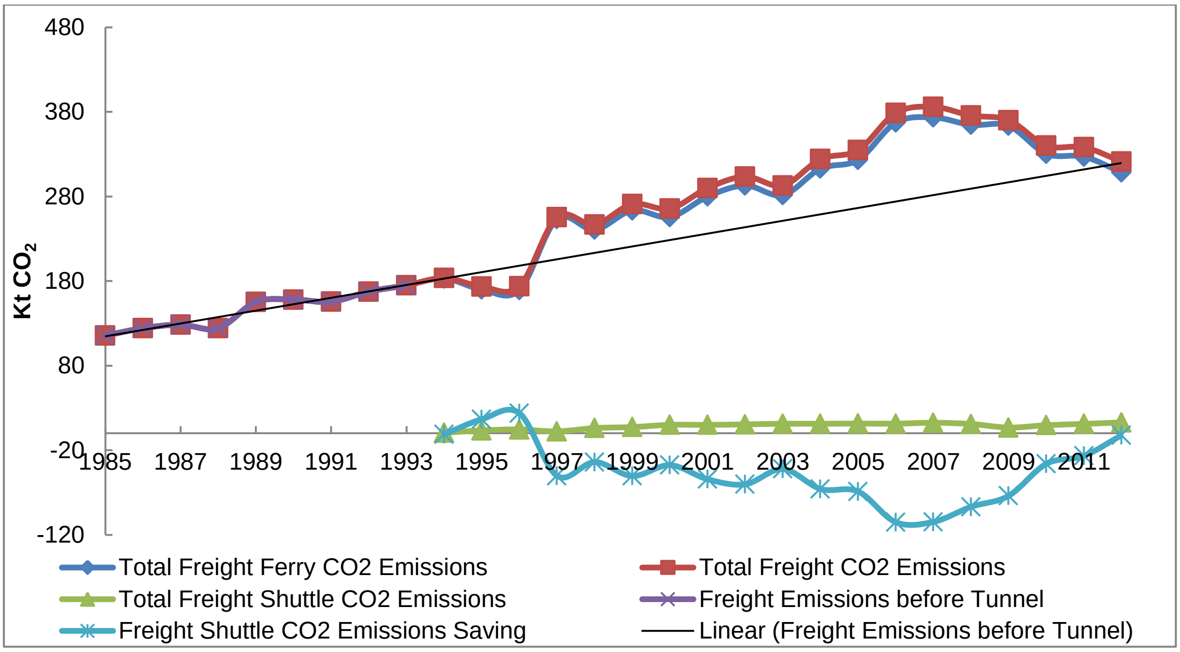

Figure 45 : Ferry/Shuttle Freight CO2 Emissions Calculation

Figure 45 shows that there is mostly production of CO_2 emissions in the freight market due to the huge number of generated customers using the new freight services. The emissions' saving line shows that although there are no savings now, as the market is steady and also more existing customers are going to use the new service, therefore the savings are going to be positive in the next few years. The total CO_2 production because of the new service until 2012 is 6.9 Mt and it is increasing every year.

4.6.4.1 CO_2 Comparisons

Figure 46 shows the estimated total emissions' saving because of the operation of the tunnel. The saving increases every year on comparing it to the old monopolised market.

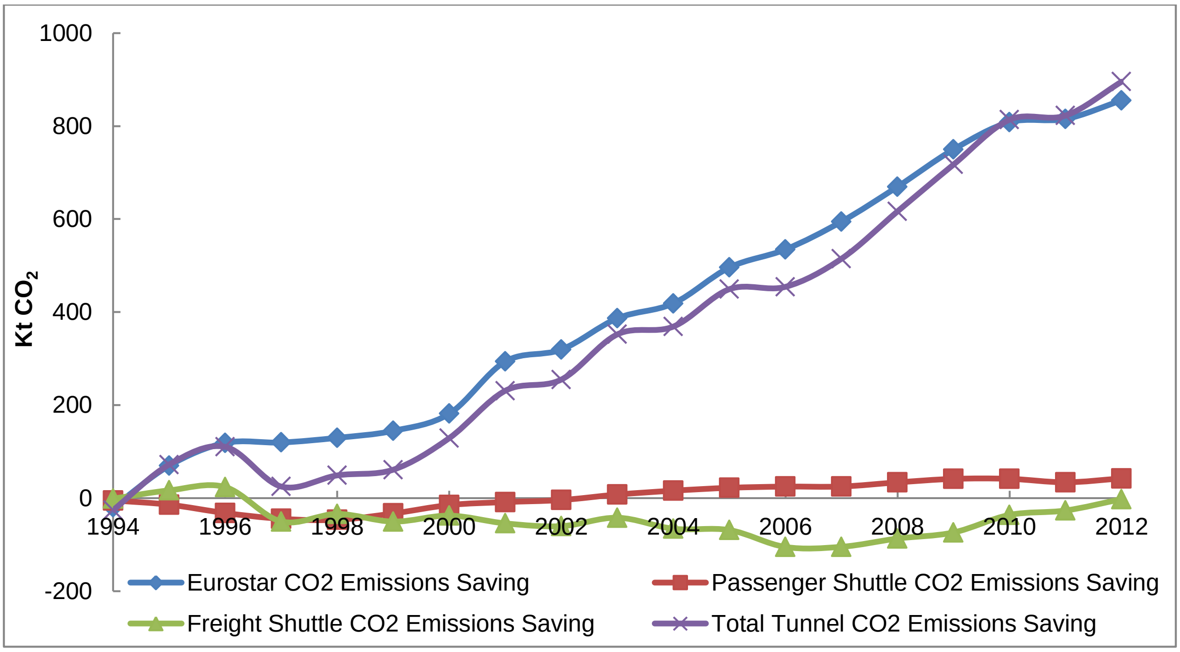

Figure 46 : Emissions Saving Comparison

Figure 47 shows the amount of CO_2 production by the tunnel's competitor. As can be seen the air travel's emissions are more than both the freight ferries' and the passenger ferries' emissions.

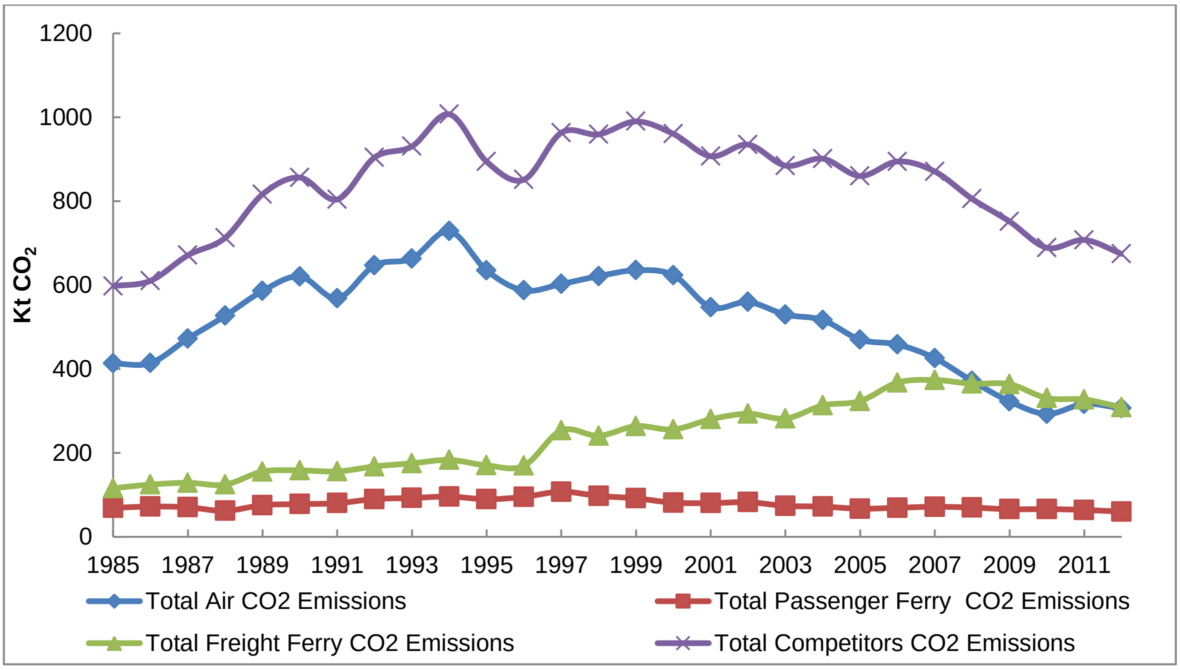

Figure 47 : Comparison of CO_2 Emissions by Competitors

Figure 48 shows the comparison of emissions' savings with the tunnel and the competitors' emissions production annually.

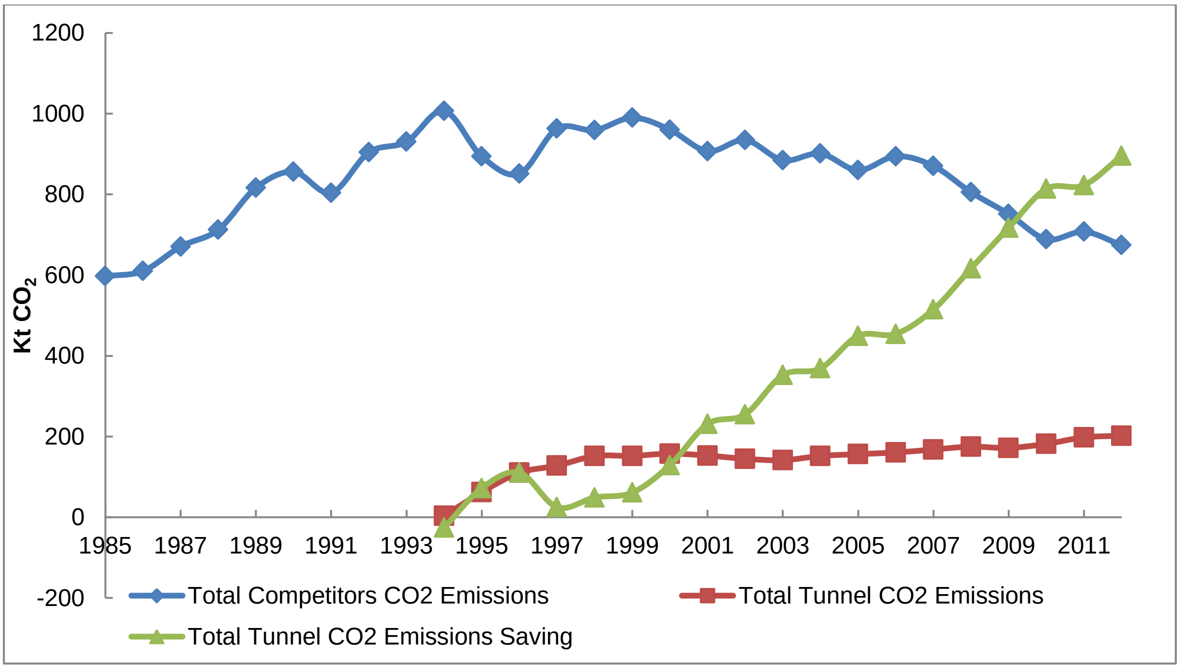

Figure 48 : CO2 Emissions Savings by Tunnel

Unfortunately this huge amount of saving cannot be added to the user benefit because still there is no approved research to monetise the savings in emissions.

4.6.5 Total Users' Benefits

Figure 49 shows the comparison of all unitised benefits because of the tunnel's construction. As can be seen, passenger users' benefit from fare reduction has the highest saving every year with the total benefit of £12.4 Billion. Freight time saving has the lowest saving of £230 million. Passengers' travel time saving saved £ 3.2 Billion in total and freight users' benefit from fare reduction saved £6.1 Billion. All savings are based on 2012 prices and calculated until 2012. It can be seen that the benefit of the fare reduction is almost 5.5 times the benefit of time savings. Due to the competitive nature of the market, this shows the impact of the opening of the tunnel was enough to break the monopolised cartel of the ferries in the cross channel market.

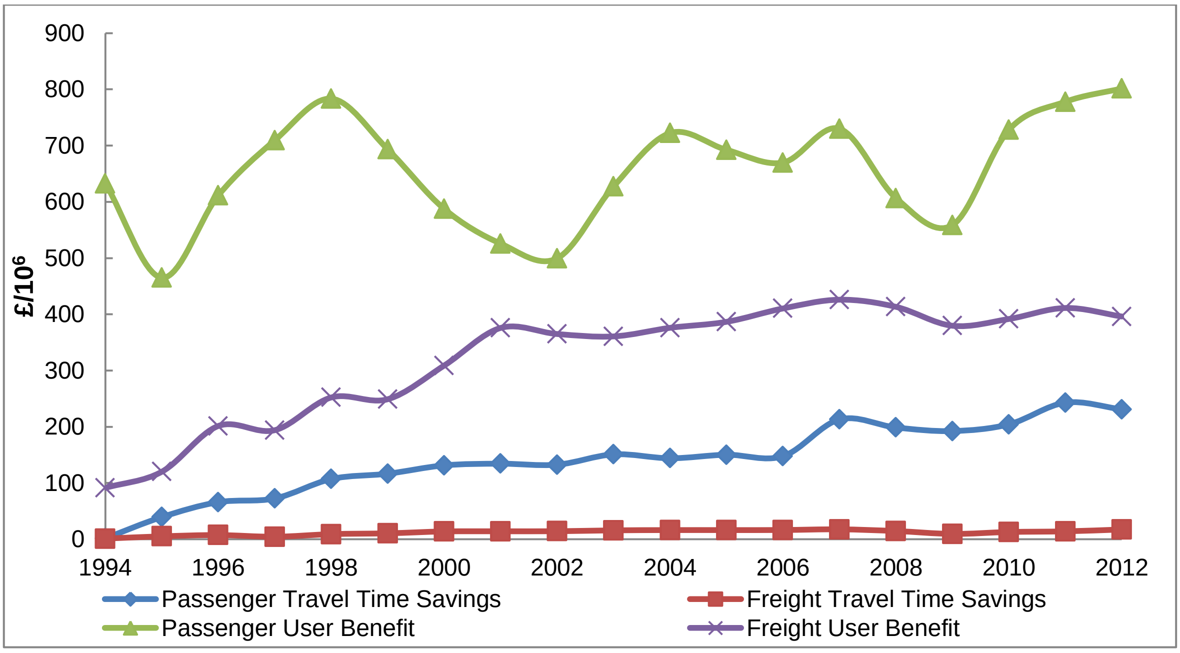

Figure 49 : Total Users' Benefits

4.7 Cost Benefit Analysis

Channel Tunnel costs, revenues and benefits have been calculated and analysed. Therefore it is now appropriate to commence a transport cost benefit analysis and financial calculation to examine the project's worth in the short and long term. The analysis is applied exclusively based in transport relations, with the scope of the study being narrowed to the direct supply costs concerned with the construction and operation of the rail link.

The cost benefit analysis (CBA) has been applied to all transport terms such as time savings, fare reduction benefit and producers' loss with the range of the study limited to the direct supply costs including construction and operation of the new service. The CBA excludes the broader impacts such as environmental factors, employment, regional effects and energy savings, due to the unavailability of data.

4.7.1 Cost Benefit until Now

The cost benefit analysis neglects any financing costs (interest charges, etc). All figures are in 2012 prices and millions of pounds (£M). The figure below shows the costs, producers' loss, benefits and the sum of them for each year in 2012 prices. As can be seen, after the operation of the tunnel from 1995, the benefit makes the total positive, although the producer's loss hugely affects it as a negative factor. Now the effect of the construction cost should be calculated to see if the project is viable in the longer term.

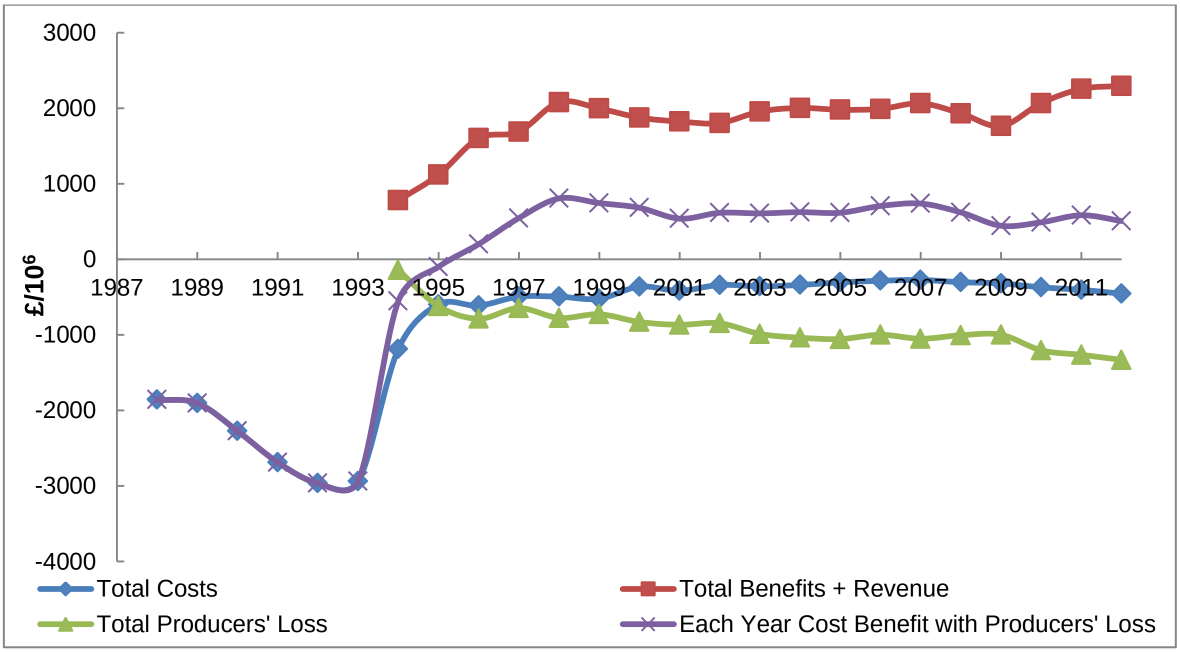

Figure 50 : Cost Benefit until Now

In addition the internal rate of return (IRR) is calculated until the year 2012. Moreover, the NPV and IRR have been calculated with and without the producer's loss. The net present value (NPV) uses the discount factor of 3.5% from the HM Treasury Green Book (2003). In the sensitivity analysis section the other discount rate has been calculated as well.

4.7.2 Payback Period

The simplest way of looking at a project is the payback period method. The payback period method is easy to use, suitable for short-term decision making, suitable if returns are precise, but the income stream is not time related. The length of time taken to repay the initial capital cost is the result of this method.

In the case of the Channel Tunnel the capital cost including British Rail's investment, in 2012 prices is £15.1 Billion and so the three plotted results are:

- Pure Financial Profit of Each Year (Revenue – Operating Cost)
- Financial Profit plus Benefits
- Financial Profit plus Benefits minus Producers' Loss.

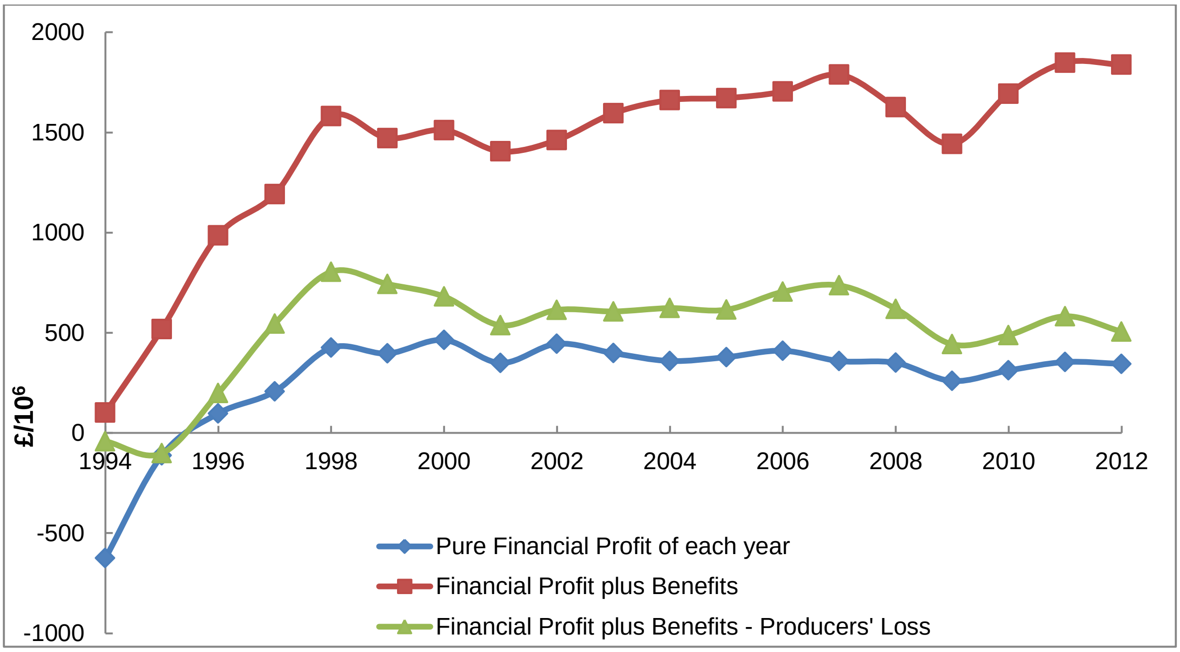

Figure 51 : Tunnel Benefits in 3 Perspectives

The graph illustrates that the benefits help to show that the investment is more rational. The next figure shows the analysis of the payback period for each type of assumption.

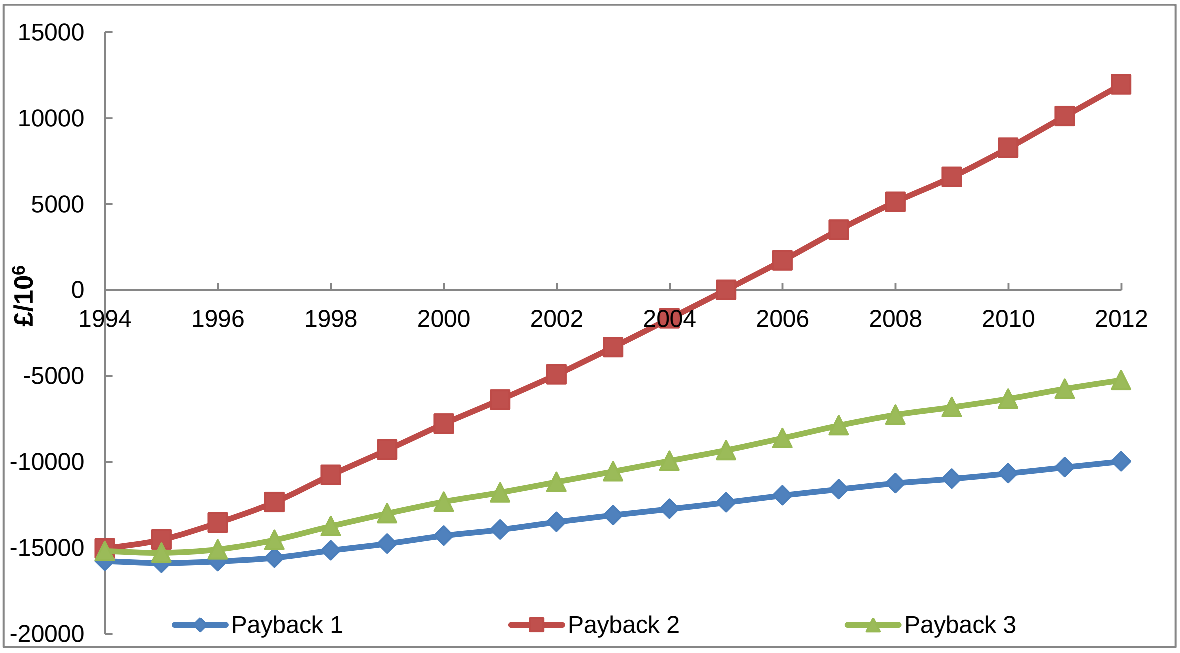

Figure 52 : Payback Period Calculation

Figure 52 shows the huge investment costs relative to the revenue and benefits of the service. The payback 1 line (green) shows only the benefit from a financial point of view. It shows that the investment is not returned yet and the forecast of the payback period is the year 2040. The payback 2 line (red) shows all other monetised benefits added to the financial benefits. As can be seen, the return on the investment is in the year 2005 as the graph changes from negative to positive. The payback 3 line (blue) includes the producer's loss as well. The trend of the line shows that the payback period is going to be in the year 2018.

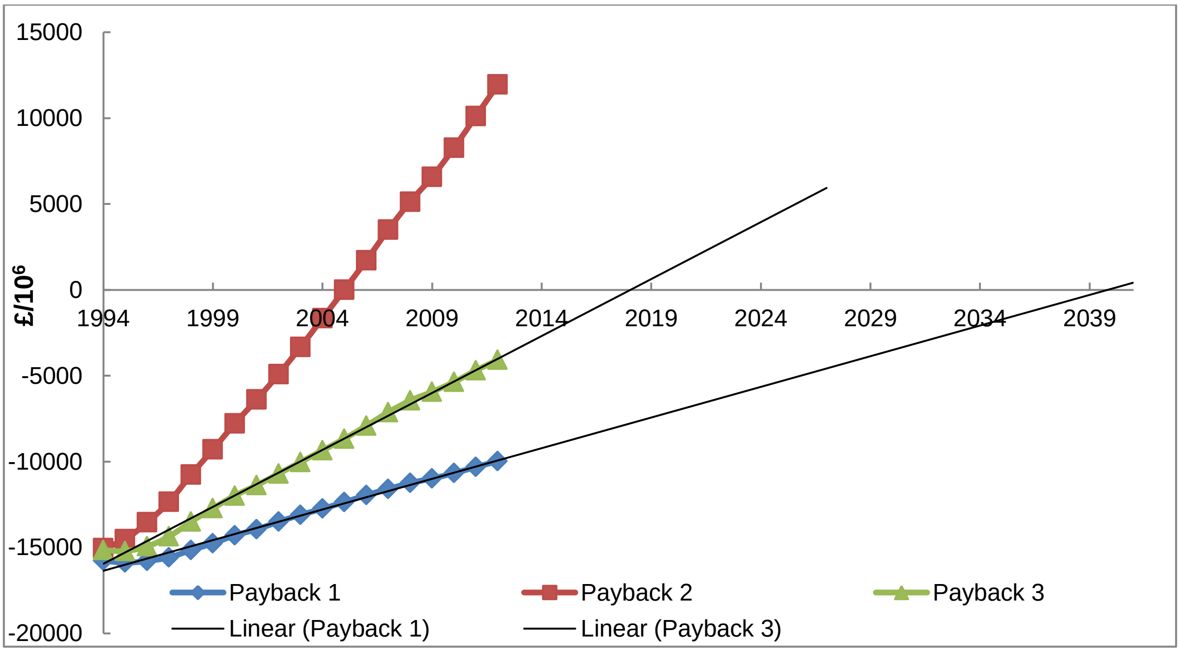

Figure 53 : Payback Period Calculation with Forecasts

4.7.3 Net Present Value

NPV is defined as the sum of the present values (PVs) of the individual cash flows of the same unit. NPV gets rid of the changing value of money over time problem and allows consideration of comparisons at different interest rates. NPV is useful for comparing similar projects with the same capital cost. Positive NPV is necessary for each project.

In the case of the Channel Tunnel there are two timeframes to calculate the NPV. The first one is to consider just the actual operation of the tunnel until 2012 with real numbers to see if the tunnel is on track. The second considers the whole period of the contract with different assumptions on benefits. This is the main purpose of the analysis to see if the project is viable considering the same operation of the company through the period of the contract.

4.7.3.1 NPV Short Term

The short term NPV shows the net present value with real data for the actual operation of the project. The same three aspects as the payback period: pure financial profit of each year (revenue – operating cost); financial profit plus benefits and financial profit plus benefits minus producers' loss will be considered for the NPV.

The result of the NPV until 2012 for each type of consideration is in Table 16 below.

Table 16 : NPV until 2012

NPV (Until 2012, 3.5% Discount Rate, 2012 Prices, £M)

Pure Financial Profit of Each Year (Revenue – Operating Cost)	-10526
Financial Profit plus Benefits	1899
Financial Profit plus Benefits minus Producers' Loss	-7043

Table 16 shows the differences from the assumptions are huge. For better understanding of the Channel Tunnel project's viability and also in order to expand the data for the long term period, a yearly NPV is calculated as well. Figure 54 shows the NPV for each perspective in every year of the project's operation.

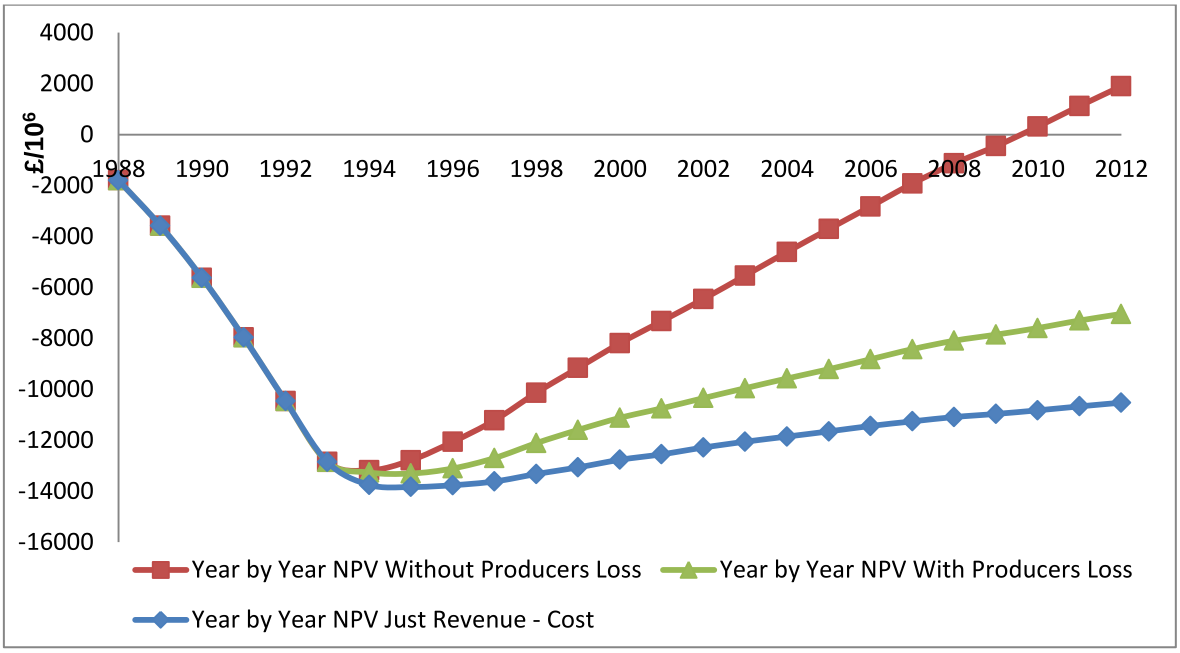

Figure 54 : NPV until 2012

As can be seen in the figure, in the construction zone (years 1987 to 1994), the NPV reduces every year as the cost of the tunnel is added annually and no profit or benefit is generated. After 1994, this is the start of the operation, the slope of the graph changes to positive because of revenues and benefits being generating. Just considering the revenues, the blue plot line shows that there are not any returns until 2012. In addition, the trend of this plot does not show a good positive slope to expect a good return soon. In the section concerning the long term NPV, the time will be forecast when the NPV of this perspective is going to be positive. Looking at the benefit added plot (red), the slope is quite good and there is a good return every year and as can be seen in the graph, it is positive after 2010. The middle plot (green) is with the producer's loss added and it does not have a return on the investment yet, but the trend is better than the first plot.

4.7.3.2 NPV Long Term

To be able to see when the project will have a return and also to compare the actual operating of the tunnel to the studies, the trend of the project should be calculated and then the NPV forecasted to the end of contract. Forecasting the NPV on a yearly basis will demonstrate a good trend of each perspective. To forecast the NPV the trend of the yearly cost benefit can be used and then it is possible to calculate the NPV of the forecast. The long term NPV on a yearly basis and a comparison to other studies is shown in Figure 55 below.

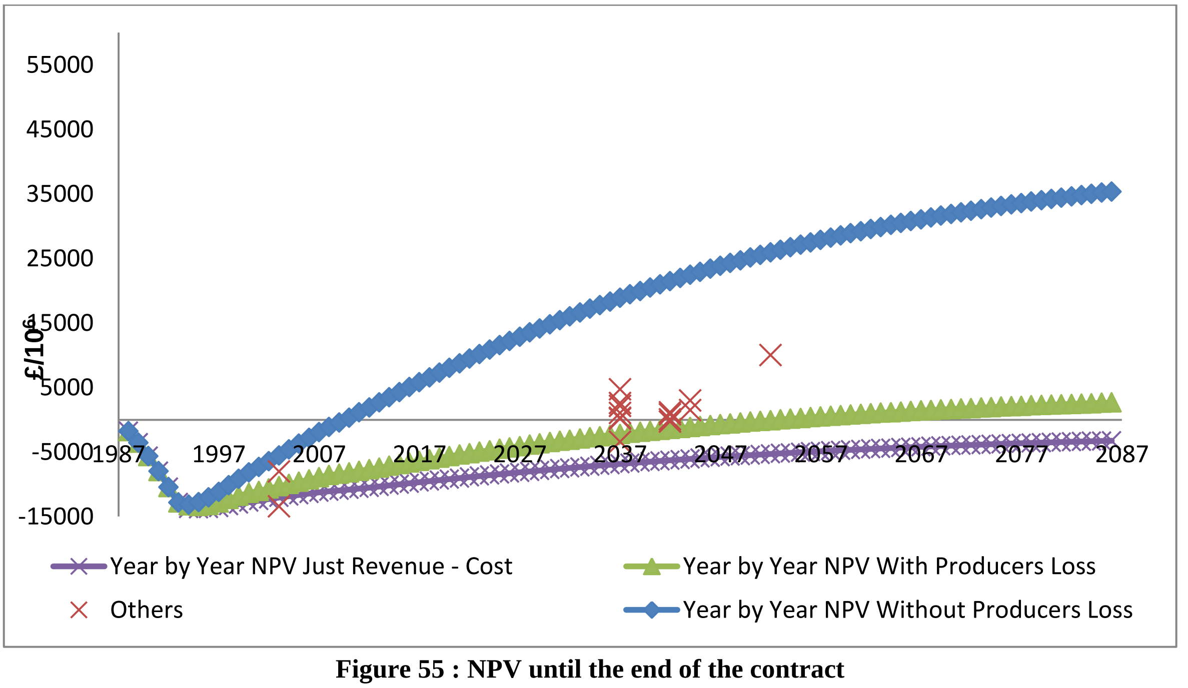

Figure 55 : NPV until the end of the contract

As can be seen in the figure the “only financial” perspective (purple) is not reaching positive for the whole period of the contract. This is because of the huge capital cost of the tunnel so that the revenue coming from the operation is not enough to produce a return on the investment. The “plus benefit” perspective (blue) is in good shape and shows a huge NPV for the whole time of the contract. The “minus producers’ loss” perspective (green) is starting better and reaches the zero point before the end of the contract time in the year 2042. It is the closest to the previous mentioned studies in Section 3.3 because of the chosen impacts. The final NPV of all types in 2086 are in Table 17 below.

Table 17 : NPV until the end of the contract

Forecasted NPV until the end of the contract (Until 2086, 3.5% Discount Rate, 2012 Prices, £M)	
Pure Financial Profit of Each Year (Revenue – Operating Cost)	-3254
Financial Profit plus Benefits	35370
Financial Profit plus Benefits minus Producers’ Loss	4771

The figure shows the huge benefit for the customers for the whole period of the contract. The meaning of each perspective will be discussed later.

4.7.4 Internal Rate of Return

IRR is a rate of return to measure and compare different investments. It is the discount rate where the NPV is equal to zero. It is time value related and enables a comparison of projects with different values.

In the case of the Channel Tunnel, the IRR needs to be calculated as well as the NPV. The NPV is a good comparison to see the profitability of same capital cost size projects; but it is bigger if the project is bigger. Therefore there is a need to calculate the IRR as well to complement the NPV and to be able to compare the project to other sized projects.

The figure below shows the IRR calculation. The calculation until 2012 is from real data and afterwards is from the cost benefit forecast as explained in the long term NPV section. This figure shows the effect of time on IRR.

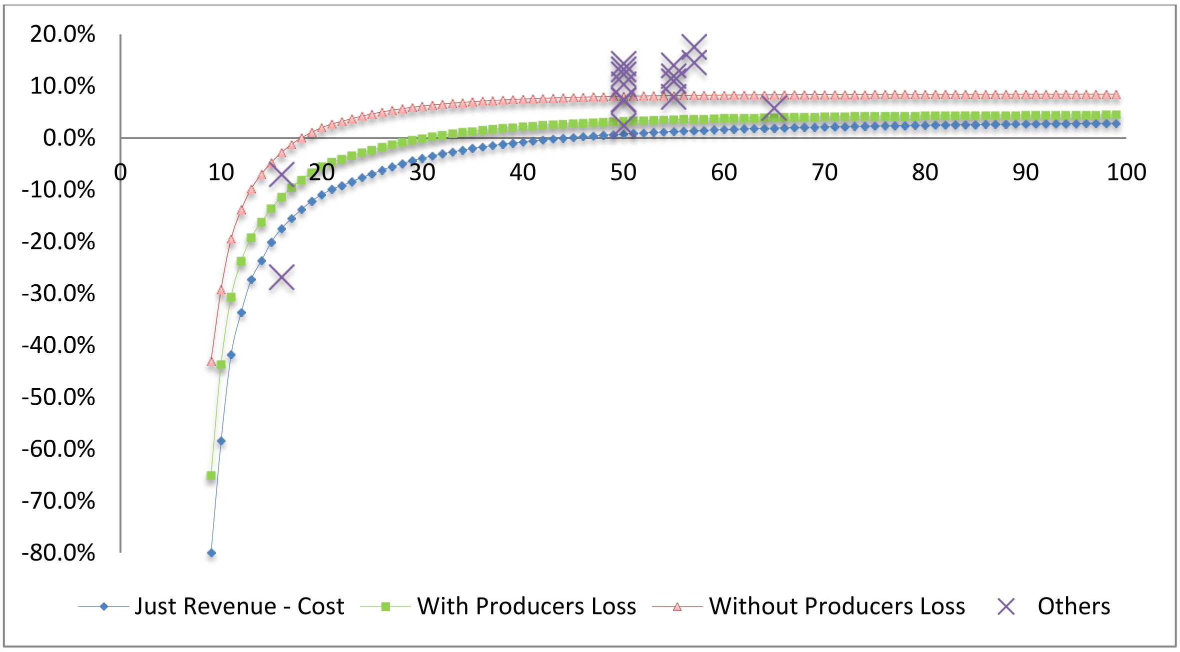

Figure 56 : IRR until the end of the contract

Each point in the graph shows the calculation of the IRR from the start of construction until the year of that point. As can be seen, all three perspectives start negative because of the big capital cost, but as the operation continues the IRR gets better and it will settle on a number after different years of operation. Table 18 below shows the real IRR until 2012 and the forecasted IRR until the end of the contract.

Table 18 : IRR Results

	2012	2086
Pure Financial Profit of Each Year (Revenue – Operating Cost)	-6.9%	2.8%
Financial Profit plus Benefits	4.6%	8.4%
Financial Profit plus Benefits minus Producers' Loss	-2.3%	4.4%

As is shown, all figures are positive in the long term, but these figures are not usually seen as a good return on an investment for a private company. The private sector usually invests in a project with an IRR of 12% or higher in the UK (Vecchi et al., 2012 and Anguera, 2006).

4.8 Ex post Financial Appraisal

The "Pure Financial" perspective in the last section includes both capital cost of the project and also British Rail's investment because of the Channel Tunnel. Therefore an actual financial appraisal for showing the return on investment for the private company of Eurotunnel can be calculated as well, to see if the extension of the contract helped to return enough profit for shareholders. Therefore the same calculation has been applied without the investment of British Rail and the results can be seen in Figure 57. Note that all of the axes in this Section have been chosen the same for better visual comparison of the figures. The starting year is 1987 so as to match the start of construction.

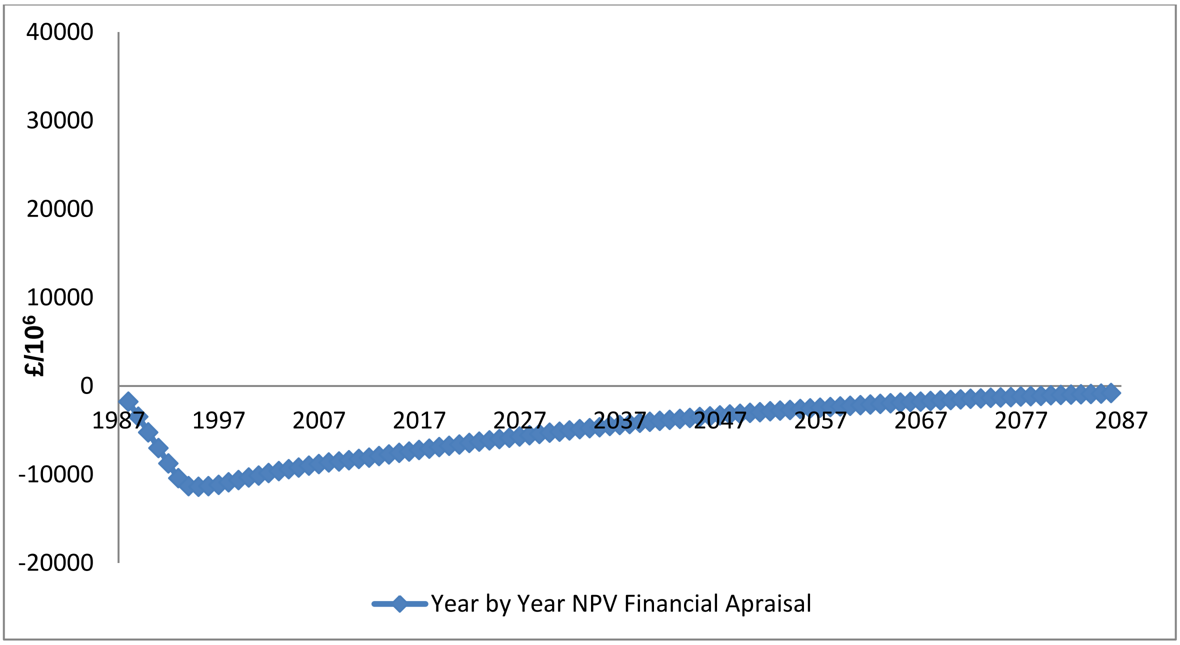

Figure 57 : Ex Post Financial Appraisal NPV

The long term NPV figure shows that the NPV will not be positive until the end of the contract; although it is closer than the figure based purely on the financial perspective. The

NPV in the year 2012 is £-8103 and in the year 2086 at the end of the contract is forecast at £-831.

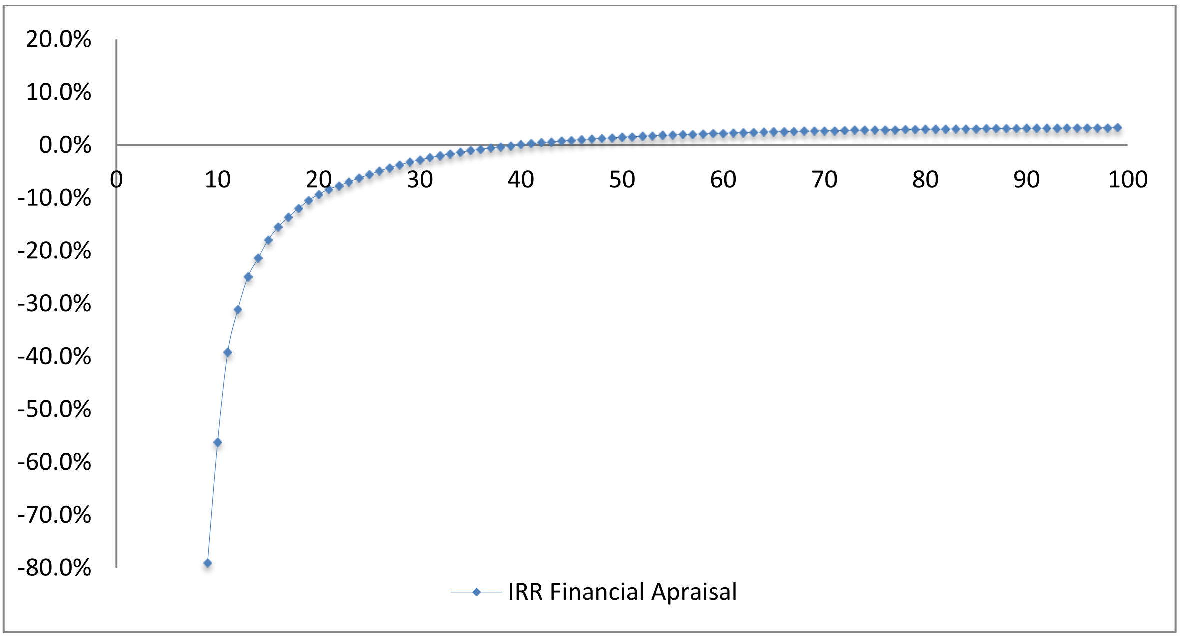

Figure 58 : Ex post Financial Appraisal IRR

The IRR is a bit higher than the "pure financial" figure but is still not a good rate of return. The IRR in the year 2012 is -5.6% and in the year 2086 at the end of the contract is forecast at 3.3%.

4.9 Subsidy Option

In terms of financial appraisal for a private company the operation of the tunnel does not look like a viable project; although looking at the huge benefit for the consumers, the project looks really convincing for the government to invest. Therefore the assumption of a full capital cost subsidy from the government is applied and the results can be seen as Figure 67 below.

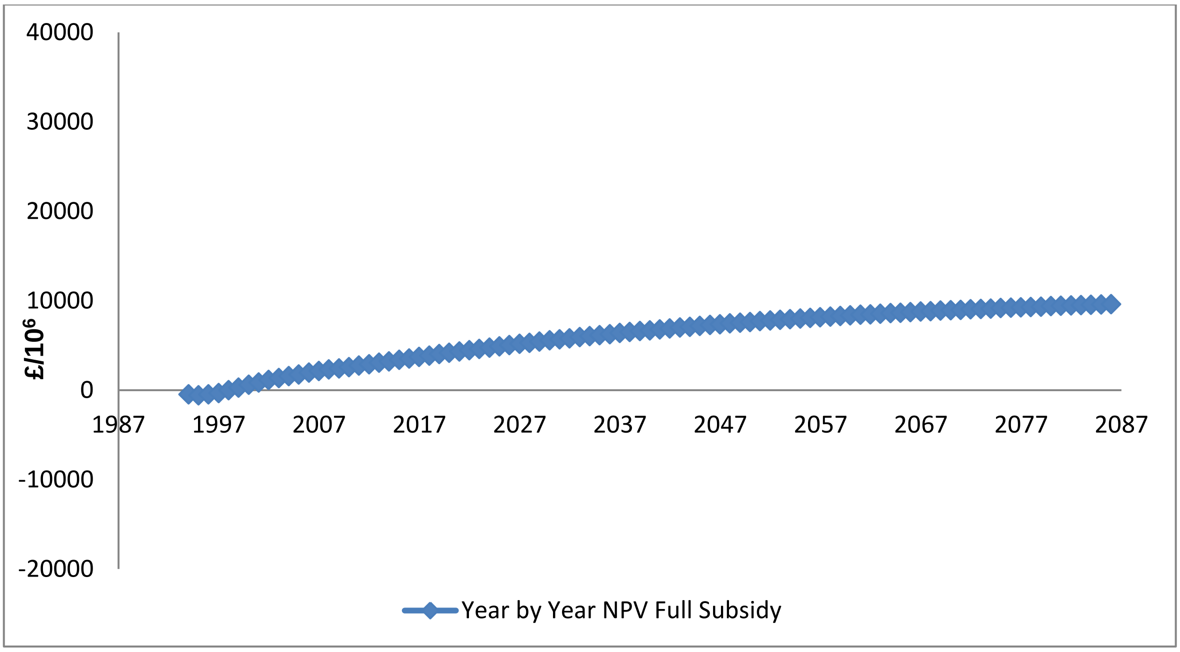

Figure 59 : Subsidy Option NPV

Figure 59 shows the NPV forecast without capital cost until the end of the contract. As can be seen, the operation of the tunnel is generating a good NPV value of £2874 M until 2012 and the forecasted NPV until the end of the contract is £9591 M.

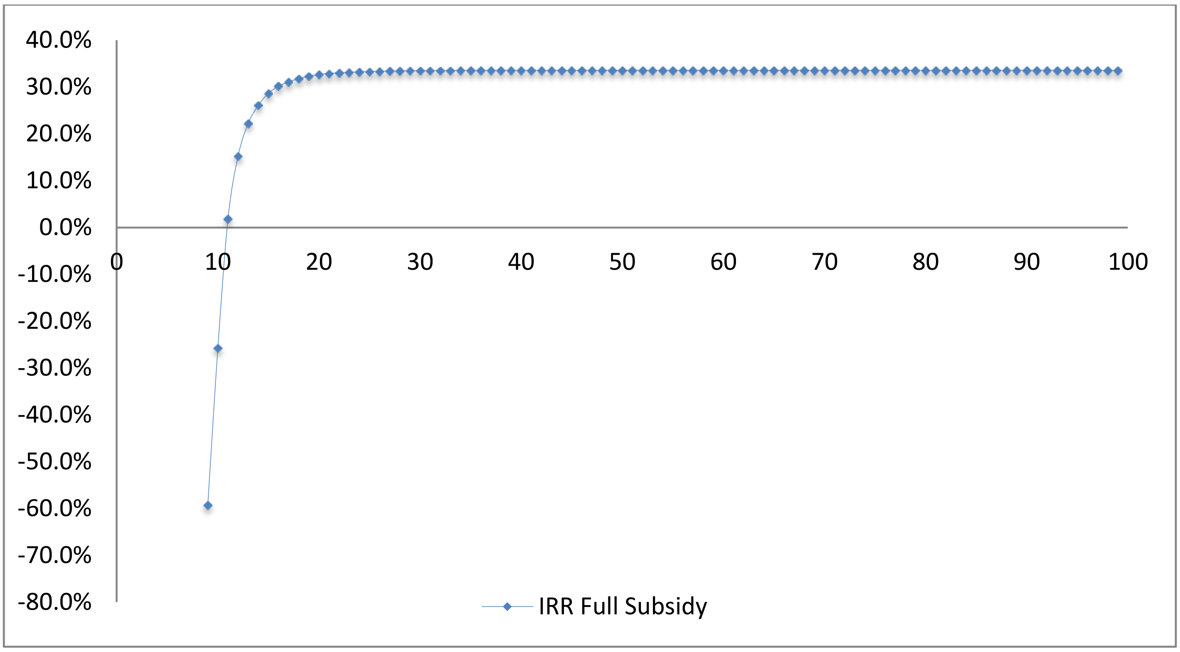

Figure 60 : Subsidy Option IRR

The IRR figure (Figure 60) is stable sooner than the other figures because there is no capital cost. The IRR until 2012 is 33.3% and is forecast at 33.5% at the end of the contract.

4.10 Comparison

The comparison between the historical users' benefits and current results is quite difficult. There has been a lack of consistency in analysis in the past that makes it hard to compare the exact results. The lack of consistency in choosing the discount rate, appraisal periods, benefits' and costs' impacts shows the different approaches used by different groups to calculate the project's benefits at different times. Moreover, the difficulties also increase with the way the results have been offered over the years. The next two tables show the differences between the previous studies and the most recent. An attempt has been made to show the obvious differences and similarities in the best possible way. The first table (Table 19) summarises the result of the costs and benefits. The second table (Table 20) is focused on differences between the CBA results of the studies presented in NPV and IRR. Table 19 compares the impacts for the current analysis with the other studies. It also shows the differences in base year used for each analysis, proposed start year of the project, chosen discount rate, projected construction period, suggested operation period and the differences in anticipated end of contract used in studies. The comparison of the last result is more difficult but it is the base for calculation of NPV and IRR in the next table.

Table 20 compares the NPV and IRR. The 2012 base year was used for ease of comparison. The comparison shows the values from the other studies that are shown in Figures 55 and 56. It can be seen that although there are differences between the assumptions of the project and the studies had been conducted in different years but the value of IRR has been from 2.4% to 17.6% in the ex-ante studies. The ex-post studies including the current analysis show the value of IRR for the long term from 4.4% to 8.4%. The NPV value is between £-3.3 Billion and £4.7 Billion in 2012 prices for ex ante studies. The ex-post studies including the current analysis show the value of NPV for long term from £4.7 Billion to £9.9 Billion but the ex post have used longer period of analysis and therefore larger NPV is produced. Note that assuming the same appraisal period for ex-post will produce negative NPV.

Table 19 : Comparison with other studies

Studies Name	MoT (1963)	C&L (1973)	CTAG (1975)	DoT (1982)	Anguera Thesis	Anguera Paper	Naghashian
Scenarios	Very High, Upper, Lower, Very Low	Low-Forecast, Central-Forecast	Tunnel with Different Investment in Existing Services	Scenario A Central B Scenario C	Short & Long Term	Short Term	Short Term, Long Term, Without PL
Comments		Just uk Share	Just uk Share				
Base Year	1969	1973	1973	1981	2004	2004	2012
Start Year	1963	1973	1975	1991	1987	1987	1987
Discount Rate	7.0%	10.0%	10.0%	7.0%	3.5%	3.5%	3.5%
Construction Period	5	7	5	11	7	7	7
Operation Period	50	50	50	39	9	9	92
End of Contract	2018	2030	2030	2041	2003	2003	2086
End of Contract if starts at 1987	2042	2044	2042	2037	2003	2003	2086
Channel Tunnel Costs	-	-158.4	-	-2020	-10885	-10885	-15692
	-208	-159.5	-				
	-199		-439				
	-		-				
Capital Cost Avoided		129.9	136				
		156.1					
BR Investment Costs					-1784	-1784	-2423
Channel Tunnel Benefits	-	374.8	-	-	6367	6333	20015
	362	518	-	2107	-		
	273		387	-			
	-		-				
Avoided Benefit/Cost		246.6	-194	1924			
		347.1					
Producers' Losses		-99.9				-3669	-8942
		-121.5					

Table 20 : NPV/IRR Comparison with other studies

Studies Name	Unit	MoT (1963)	C&L (1973)	CTAG (1975)	DoT (1982)	Anguera Thesis	Anguera Paper	Naghashian
Scenarios		Very High, Upper, Lower, Very Low	Low-Forecast, Central-Forecast	Tunnel with Different Investment in Existing Services	Scenario A Central B Scenario C	Short Term, Long Term	Short Term	Short Term, Long Term, Long Term without PL
Comments			Just UK Share	Just UK Share				
Base Year		1969	1973	1973	1981	2004	2004	2012
Start Year		1963	1973	1975	1991	1987	1987	1987
Discount Rate		7.0%	10.0%	10.0%	7.0%	3.5%	3.5%	3.5%
Construction Period		5	7	5	11	7	7	7
Operation Period	Years	50	50	50	39	9	9	92
End of Contract		2018	2030	2030	2041	2003	2003	2086
End of Contract if starts at 1987	1987	2042	2044	2042	2037	2003	2003	2086
Net Present Value	£ Million 2012 Prices	2593	1515	-297	4726	-8195	-13009	-7043
		2147	2989	61	282	9995		4771
		1031		860	-3431			35370
		153		1157				
IRR	%	14.4%	14.6%	8.0%	12.3%	-7.0%	-26.8%	-2.3%
		13.3%	17.6%	11.0%	7.3%	5.8%		4.4%
		10.4%		12.0%	2.4%			8.4%
		7.4%		14.0%				

4.11 Sensitivity Analysis

Uncertainty in cost benefit analysis can be assessed with a sensitivity analysis that demonstrates in what way results respond to the parameter changes. Although a type of sensitivity analysis has been conducted in the previous sections (e.g. having every year's NPV and IRR, using different scenarios), there is still a need to work on some other types of sensitivity to reduce the uncertainty of the analysis.

4.11.1 NPV-Discount Rate

With the intention of certifying that the discount rate used in the calculation is appropriate and is not exclusively accountable for the result of the analysis, the following sensitivity analysis is implemented. An "NPV-Discount rate" sensitivity analysis is beneficial where there is uncertainty over the discount rate. Although The Green Book offered 3.5% for short term calculations and 2.5% for long term, this can be used to improve the CBA robustness. Four discount rates are used with four different graphs to show the differences between the NPV values. The discount rates used are 2.5% and 3.5% as per DFT guidelines, 7% and 12% for comparison with old studies. Note that while having less effect on the capital costs a higher discount rate decreases the present value of benefits that are accrued over time (CBA Builder, 2011).

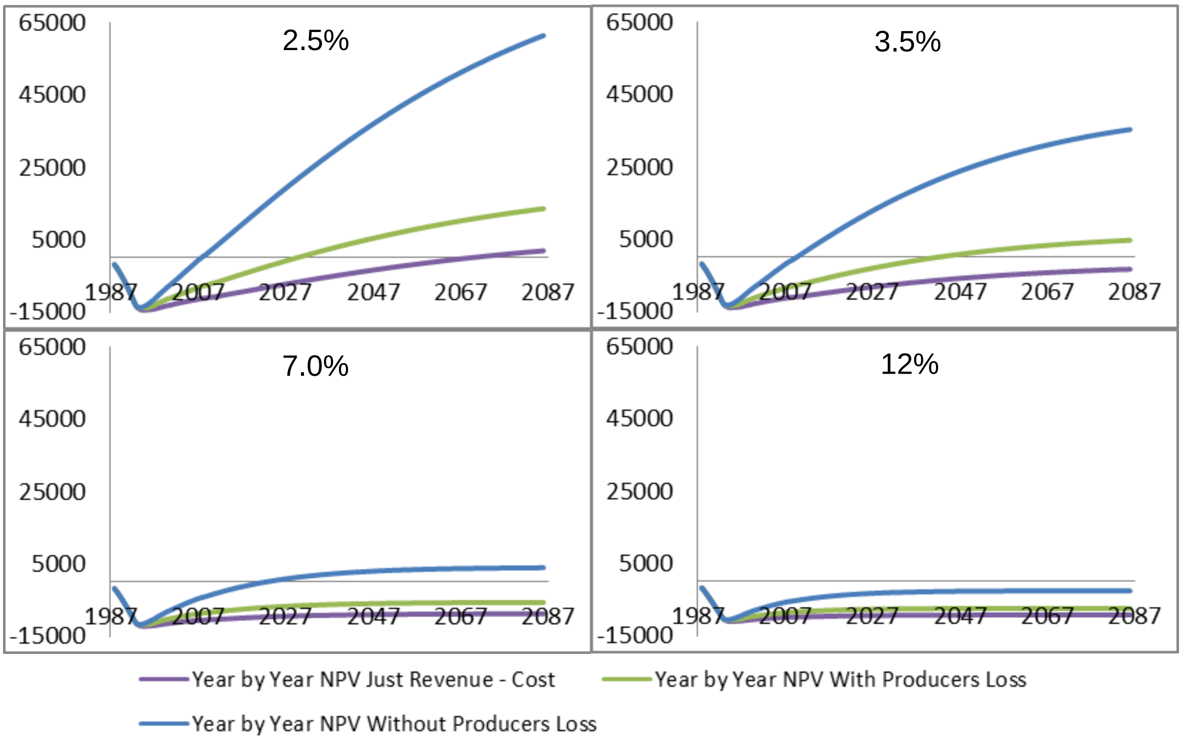

Figure 61 : Sensitivity Analysis on Discount rate

The sensitivity analysis shows the effect of discount rate on the NPV figures. The first graph with 2.5% discount rate shows a really good NPV figure for all perspectives. Even the "Pure Financial" perspective is positive at the end for this discount rate. This shows the effect of discount rate on present values is less and makes the graph more positive. The discount rate of 3.5% is shown as the second graph to compare the others to the actual calculation of the analysis. The third uses 7% as the discount rate. The only positive figure will be the benefit figure and the other two are showing negative NPV. The 10% discount rate affects greatly the present values of benefits and revenues. All graphs remained negative with this discount rate; although the 7% and 10% are not realistic, they show the risk of the project with different discount rate values.

Table 21 : Discount Rate Sensitivity Analysis Result

NPV-Discount Rate Sensitivity Analysis (End of Contract)	2.5%	3.5%	7%	10%
Pure Financial Profit	1993	-3254	-8747	-9207
Financial Profit plus Benefits	61469	35370	3989	-2525
Financial Profit plus Benefits minus Producers' Loss	13630	4771	-5594	-7376

4.11.2 Capacity

The quantity of trains or shuttles that can pass through the tunnel is limited. Therefore an analysis is needed to see if the current analysis has not overestimated the capacity of the tunnel. The capacity of the tunnel is analysed by calculating the quantity of standard trips per hour in each direction. The standard path defined by Eurotunnel is "the time it takes a shuttle train operating at 140 km/h to proceed over that portion of the system that, under normal operating condition, is used by all other trains using the tunnel". Signalling is one of the important factors that change the capacity in a railway network. By 2012 the system authorizes 20 standard paths per hour in each direction. There are some differences between types of trains, but at peak times speed can be adjusted to increase the number of trains and shuttles to travel through the tunnel in each direction. Eurotunnel can use only 50 % of the tunnel capacity by its current contract and therefore their maximum trips in 2012 were 10 per hour in each direction. Eurotunnel suggests the following options to increase the tunnel capacity in the short term and long term future:

- Choosing a uniform operating speed for all trains

This will allow more trains to run on the same number of standard paths. [5] The different operating speeds are increasing the intervals between trains and therefore reduce the capacity.

- Increasing the power of the locomotive for shuttles

This will increase the ability of each locomotive to pull a longer train.

- Reducing the distance between trains

Currently the distances between trains are 3 minutes. If the authorities reduce that to 2 minutes and 30 seconds the capacity of the tunnel will increase to 24 paths per hour.

- Improving the signalling system (Eurotunnel reference document 2012)

The capacity of the tunnel needed for the current study uses the following formula:

  – Paths per Hour in each direction (PPH):

$$PPH = \frac{Passengers,\ Cars\ or\ Trucks\ Per\ Year}{Days\ Per\ Year \times Hours\ Per\ Day \times Tunnel\ Availability(\%) \times Passengers,\ Cars\ or\ Trucks\ per\ Path \times 2}$$

The figure below shows the estimated capacity of the tunnel until 2012 and the forecast based on the CBA analysis until the end of the contract. The tunnel limits per hour are 20

[5] At the time of the registration document of 2012 by Eurotunnel, passenger trains could reach 160 km/h compared to freight trains that could travel at 100 to 120 km/h. (Eurotunnel reference document, 2012)

paths per hour in each direction at the moment and Eurotunnel limits per hour are 10 paths per hour in each direction.

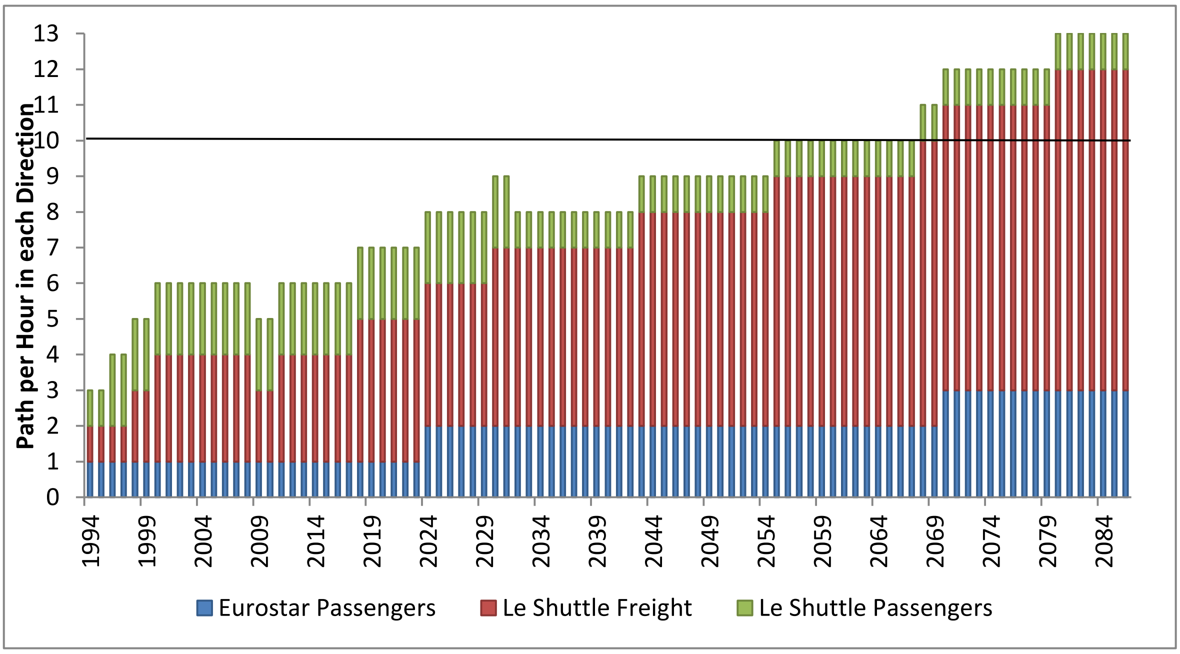

Figure 62 : Capacity Calculations

As can be seen in the figure, there is no need for improving the capacity until 2067 and the capacity needs to increase to 13 by the end of the contract; which is achievable by Eurotunnel's suggestions, as discussed. Note that this is not the whole capacity of the tunnel because Eurotunnel can only use half of the tunnel's capacity by the current contract. Also it is necessary to mention that there should be differences between peak times and off peak times, but this study assumed that Eurotunnel will manage that by using more paths for passengers in peak times and more freights paths in off peak.

4.12 Summaries

Chapter 4 is concerned with the Cost Benefit Analysis of the Channel Tunnel. The calculation of generated traffic, user benefits, comparison with previous studies, payback period, net present value, internal rate of return, sensitivity analysis and the capacity of the tunnel have been part of the study. The comparison of different situations shows that the Channel Tunnel project could never have been economically viable for a private company. Even the longer period of the contract did not help because of the huge capital cost of the project. The Eurotunnel Company had to start thinking 'outside the box' by adding Europorte and the 'My Ferry Link' section to increase their revenue. On the other hand, the project is helping the economy because of its huge benefits. The results show that without considering the producer's loss, the customers are the big winners in this competitive market. This market has given customers a choice of services, reduced prices for the service, reduced journey times, more environmentally friendly options, safety and a better quality of services because of the competition. Existing services such as the ferries are the losers in this situation. The significant amount of producer's loss demonstrates this, but they have had a long run enjoying the monopolised cartel market before the tunnel opened. The other losers are Eurotunnel's shareholders who lost money because of miscalculations of the project in terms of capital costs and traffic and revenue overestimation.

4.13 Conclusions

The Channel Tunnel construction has been one of the big challenges of its time in terms of engineering, investment, financing and operation. This chapter explained the result of the project from different views and perspectives.

The comparison of different situations shows that the Channel Tunnel project is not an economically viable project for a private company. Even the longer period of contract did not help because of the huge capital cost of the project. The Eurotunnel Company had to 'start thinking outside the box' by adding Europorte and the 'My Ferry Link' section to increase their revenue.

On the other hand, such a project is helping the British economy because of its huge benefits. The results show that without considering the producer's loss, the customers are the big winners in this competitive market. This market gives customers the choice of services, reduced prices for the service, reduced journey times, more environment friendly options, safety, a better quality of services, because of the competition etc…

Existing services such as ferries are the big losers in this situation. The big amount of producer's loss proves this statement, but they have had such a long run enjoying the monopolised cartel market before the tunnel's operation. Other losers are Eurotunnel shareholders who lost lots of money because of miscalculations of the project in terms of capital costs and traffic and revenue overestimation. The banks obtained their loan interest from shareholders money when the shares reduced from £3.50 to £1.42 after 1 year of operation. Such events will reduce the publics' trust in governments and can have important effects on the economy.

Considering the full subsidy option, suggests that the Government finances the project instead of spreading the risk to the shareholders. The Government could finance the project with the high risks of investment and a big degree of uncertainty and then put the construction and operation in two different tenders.

The project has been a piece of engineering but at an expensive cost. With all the problems after starting the operation, the Eurotunnel Company looks in a better shape now and the tunnel is working properly.

Chapter 5

TOWARDS BETTER COST BENEFIT ANALYSIS

5 TOWARDS BETTER COST BENEFIT ANALYSIS

5.1 Introduction

The first task for a potential project is to check its feasibility. Performing a cost benefit analysis is important to any project. Performing a CBA means making a relative analysis of all the benefits expected from the project and also all the costs produced by the project. A CBA helps to choose whether to undertake a project or not. It structures the suitable project's objectives and develops a 'before and after' measure of the project's accomplishments. It also calculates the approximations of the resources needed to accomplish the project, the amount of risk of the project and the speed of returning the investment. As discussed in Section 2.12 although there are lots of cost benefit research and publications in the literature, a comprehensive 'big picture framework' is missing. The following suggested framework is a DFD base for all inclusive Cost Benefit Analyses of any project; based on the experience of the Channel Tunnel case study. The consideration for the flow chart (Figure 63) looks at 'the big picture' and making a CBA, a step by step procedure.

5.2 Generalised CBA Process Model

To demonstrate the framework in the best way the DFD (Data Flow Diagram) technique has been used. DFD is an understandable, simple graphical method and beneficial as a communication system giving information to the users. The Gane-Sarson DFD method was used to demonstrate the CBA framework because their approach is one of the most common systems for organized analysis and design of a system since the late 1970s. Their technique is based on the construction of a logical framework of the system; by sketching graphical methods to allow users and designers to get a clear and mutual image of the system and understand in what way its different parts connect together to meet the user's requirements (IBM Website). The designed stages of the CBA considering the literature and experiment of the Channel Tunnel case study are:

- Stage 0 - Project identification
- Stage 1 - Setting the framework
- Stage 2 - Technical analysis
- Stage 3 - Economic evaluation
- Stage 4 - Evaluation of results and decision making.

Figure 63 shows the complete flow chart with the relationship between each stage.

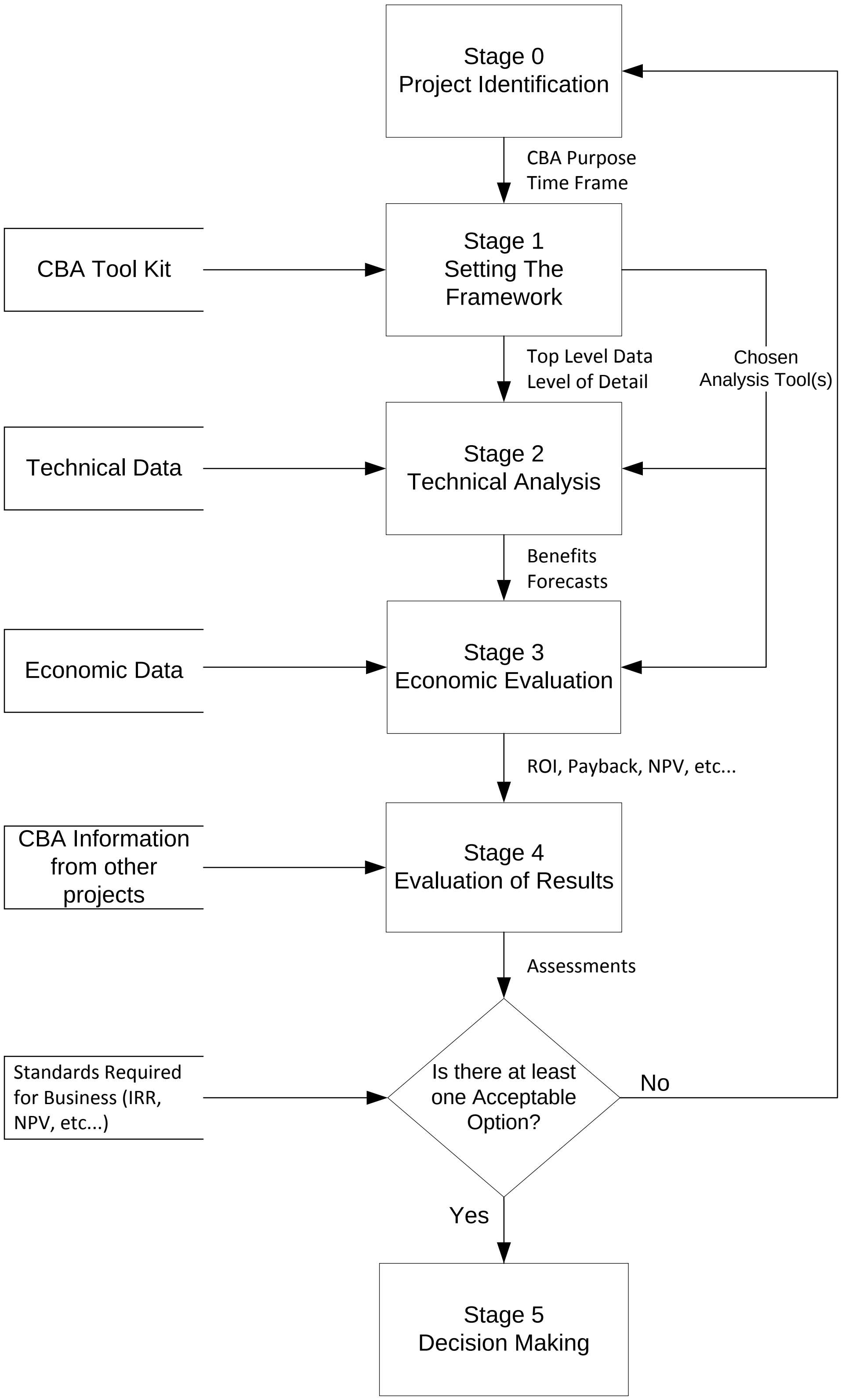

Figure 63 : Generalised CBA Process Flowchart

5.3 Stage 0 – Project Identification

To start the CBA process there is a need for project identification. This stage has been assumed as stage 0 because the actual cost benefit analysis has not started yet, but this stage is required for a CBA process. In this section the project goal (aim) and objectives are to be defined. The goal of the project is a high level statement that provides the general context for what the project is going to achieve. The objectives are lower level statements that describe the precise and tangible products and services that the project is going to provide.

5.4 Stage 1 - Setting the Framework

As can be seen in the Channel Tunnel case study the first stage of starting a CBA is setting the framework. Setting the framework includes the following and each one is explained later; bear in mind that to be able to set the framework the analyst needs to know the purpose of the CBA and to have an idea of the timeframe:

- Decide whose cost and benefit,
- Data collection,
- Choose the appropriate tool for analysis of the project.

Figure 64 is the DFD for this section.

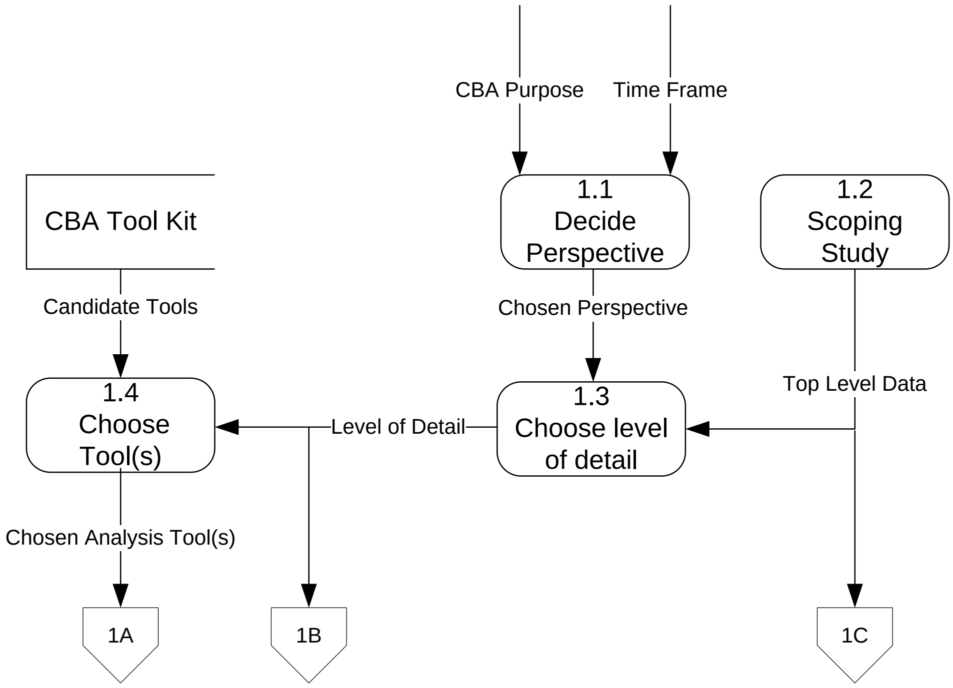

Figure 64 : Stage 1 - Setting the Framework

5.4.1 Decide Perspective (1.1[6]) - Whose Cost Benefit Analysis?

The perspective means deciding whose cost and benefit should be considered. The case of the Channel Tunnel showed that different perspectives play a huge part in cost benefit analyses. As a matter of fact, some events can be a benefit for one perspective and a cost to another. The analyst's duty is to choose who has standings; this means whose benefit and costs must be calculated. Typically the perspective refers to the investor's point of view, but sometimes a bigger perspective like the consumers', the country's, the regional or

[6] Note that these values are referring to the same value in DFD diagrams.

global is used to attempt to substantiate' here the viability of a project. An example is the environmental factors that are a consequence of global climate change.

5.4.2 Scoping Study (1.2)

The gathering of and measurement of information needed for the CBA should happen in this section. One of the main starting points of a CBA is finding the correct and comprehensive information needed. The accuracy of the data is really important. Note that a sensitivity analysis will be carried out for the unsure and assumed collected data for the ex-ante and in medias res.

5.4.3 Choose Level of Detail (1.3)

Brooks and Tobias (1996) have an extended paper on level of detail and complexity. The level of detail of a project, when applying it on a model, "usually means an assessment of the extent to which the observable system elements and the assumed system relationships are included in the model." Of course the level of detail refers to the structure that the model symbolizes (for instance, in the case of the Channel Tunnel, the number of business travellers and leisure travellers, should be included in the model), instead of the exact way that the model is applied (for example just considering the train loads or differentiating between whether to consider the average mix or separate them, or the time frame). "Models are often described as being detailed; meaning that the model contains most of the elements and interactions thought to exist in the system being modelled" but "the trick is not simply to create an artificial copy of the system under study." To be able to build a framework for the study the analyst should be “motivated by wanting insight and understanding (rather than skill or expertise)”. Also the focus should be on “simplification and abstraction” rather than “just realism”. Additionally the analyst should pay more attention to the behaviour of the organization as a whole, rather than to that of its components. “In model building, we therefore need to take account very carefully of whatever connectedness and interactions are at play but without including absolutely everything.” (Brooks and Tobias, 1996)

5.4.4 Choose Tool(s) (1.4)

CBA tools have been explained in Section 2.8. The appropriate tool for the project type, period of construction, period of operation, sometimes the recommendations of the top management team (senior executives or even board members) are going to be chosen at this point. Note that sometimes some tools have been chosen to be able to compare the project with the alternative projects, because that project used a specific tool the analyst has to choose the same CBA tool as well.

5.5 Stage 2 - Technical Analysis

The next stage is Technical Analysis which includes:

- Cataloguing the impacts
- Forecasting

- Analysing the benefits.

The DFD for this stage is as shown in Figure 65.

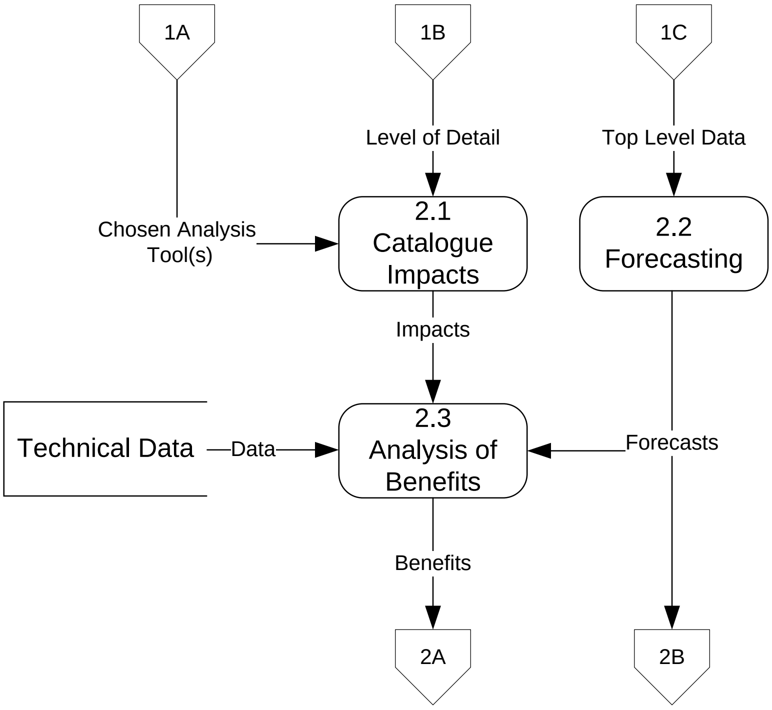

Figure 65 : Stage 2 - Technical Analysis

5.5.1 Catalogue Impacts (2.1)

Cataloguing the impacts is listing the physical impacts as benefits or costs from the start of the project and specifying the unit of each impact. The impacts' list depends on the project and it should be measurable. Usually impacts on people will be calculated. They should have a cause and effect relationship to project the outcome and they should not be too general. Note that some impacts can be a cost to some and a benefit to others. In addition the choice of measurement indicator depends on data availability and ease of monetization.

This thesis's case study is a railway project; therefore, the explanation of the impacts uses the same field as an example. As railways affect most sectors of society, it was considered that this general objective could be further specified from the following general viewpoints: economic, safety, ride, environmental impact, speed, reliability, resilience, socio-political factors etc. From the economic viewpoint, the main objective is the minimisation of the total transport costs. Therefore the project can be comparable to others and the operator can have a competitive fare. The main objective from the environmental viewpoint is the minimisation of all the unwanted effects on the environment caused by building and operations. Either engineers or social scientists have not sufficiently dealt with the socio-political impact of transport operation. Each factor can be in different categories of passenger, freight, infrastructure and vehicle. Note that some factors can be related to all types of transport modes.

5.5.2 Forecasting (2.2)

Forecasting is always difficult, supply-demand figures are generally unknown and this makes it tough to calculate a good estimation of the impacts. Generally it is more challenging to forecast impacts if the project has a long period of construction and operation or if the connections between variables are not simple; but to make good forecast the analyst should:

- Analyse the operation data
- Forecast current operation data to the end of the project's life time

- Forecast benefits and costs
- Forecast alternative data, costs and benefits.

The difficulties are:

- Different individual behaviour
- Policy can have different effects on behaviour of third parties that can change the CBA and it is hard to predict. This is called the spill over effect in the literature (Boardman et al., 2001).
- Scientific knowledge can be uncertain.

5.5.3 Analysis of the Benefits (2.3)

This step is to calculate the benefits of the project. The input of the impacts, forecasting and technical information of the project will enable the analyst to calculate the benefits and costs. This is not the end result of the benefit because it should go through the next stage to calculate the value of the benefit in time, considering the economic aspects of it.

5.6 Stage 3 - Economic Evaluation

The next stage is Economic Evaluation which includes:

- Monetising and quantifying

- Discounting
- Cost Benefit Analysis.

The DFD figure for this stage is shown as Figure 66 below.

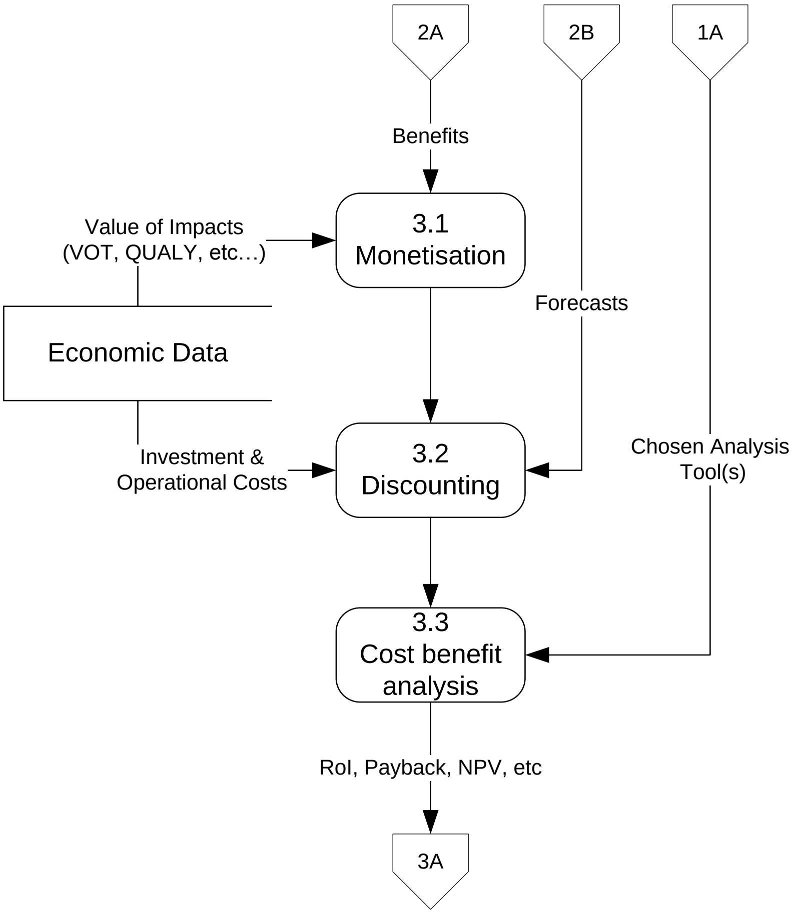

Figure 66 : Stage 3 - Economic Evaluation

5.6.1 Monetisation (3.1) - or Quantifying

Monetizing means attaching a money unit to all impacts (Pounds sterling in CT case). In a CBA, the value is calculated in terms of willingness to pay. Willingness to pay is explained in Section 2.5. Several impacts are difficult to value in currency as they do not trade in markets (i.e. life, safety, time) and if no one is willing to pay for an impact then its value will be zero. In some CBA's, a comparable way for non-monetised impacts will be produced as explained in Section 2.8.

5.6.2 Discounting (3.2)

After monetising all the benefits and costs, all the monetised values should be discounted to the present values. Investopedia explains discounting as "The process of determining the present value of a payment or a stream of payments that is to be received in the future. Given the time value of money, a dollar is worth more today than it would be worth tomorrow given its capacity to earn interest. Discounting is the method used to figure out how much these future payments are worth today" (Investopedia, 2014). The analyser should use discounting as practically everyone prefers to consume now rather than in the future (Caplan, 2005). There are different discounting methods in the literature and it has been discussed extensively in Section 2.7.1. Note that all the alternatives should use the same discounting value and methods for comparison. Usually the discount rate is instructed by a government agency accountable for economic and financial oversight for other agencies.

5.6.3 Cost Benefit Analysis (3.3)

Now that the analyser has everything in hand in the present value, the CBA should be performed. Therefore the analyser should calculate the net present value of the project as the first step. NPV is usually the first step and the main result of a CBA, but it is not usually enough. The question that the decision maker is going to ask is “which of these many methods to apply in a CBA of large infrastructure projects?” Using the NPV brings up the question of the suitable discount rate. However, the NPV illustrates an effective technique to be used as it is both consistent and satisfactory. Although a CBA focuses just on either the mean or mode of the NPV, Barker and Button (1995) argued that it struggles to deliver sufficient evidence for an effective conclusion when there are big uncertainties for projects. On the other hand, there are some improvements to the NPV and IRR which makes them a better measure to compare projects in different situations.

5.6.3.1 Net Present Value (NPV)

As discussed in Section 2.7.1, the net present value (NPV) equals the present value of all benefits minus the present value of all costs:

$$NPV = PV(B) - PV(C)$$

The option with the biggest NPV illustrates a more capable allocation of resources at least; there is a need to mention that it is not the best allocation, because not all probable options are necessarily investigated in the CBA.

The idea is the larger the NPV, the better the project is in which to invest; but there are some down sides, to which the analyzer should pay attention. Although net present value (NPV) analyses are beneficial when you are valuing investment opportunities, the process is by no means perfect. The first important disadvantage of the NPV is that the bigger the investment equals the larger the NPV value. This means the comparison is only rational if the options have the same investment budget in hand, otherwise the other CBA tools should be used in order to compare projects with different investment needs. The second big disadvantage is that the NPV is hugely dependent on the discount rate, as seen in the case study. This makes a huge difference for different projects. Consequently, the NPV is suitable to value investments at an initial stage; however, it is not a conclusive result for the investor to be able to rely on for all investment judgments. On the other hand, there are some suggestions for improvements to the NPV which will be explained next (Sinha, 2008).

To avoid the first problem - comparing projects with different initial investment, the recommendation is to compare the rate of NPV/Capital Cost. In this case this rate can be the measure for the comparison of the projects. To avoid the second problem - the sensitivity analysis for different discount rates is the solution. Also having an NPV graph can show the trend and slope of the NPV for all years of operation. A comparison of this graph can make the judgments a lot easier.

5.6.3.2 Internal Rate of Return (IRR)

As discussed in Section 2.7.2, there is another method that is irrelevant to the discount rate and calculates the speed of returning the investments: it is called the Internal Rate of Return (IRR). The Internal Rate of Return or Economic Rate of Return is the discount rate when the NPV becomes zero.

$$NPV(CB) = \sum_{t=0}^{n} \frac{CB_t}{(1+r)^t} = 0$$

- t is the year of cost and benefits occurrence
- r is the rate of return
- CB_t is the benefit or cost in year t
- n is the life time period of the project.

The advantages of the IRR are that it is independent of the discount rate, inflation and interest rates and also can be used to compare projects with different start times and life times.

The shortcoming of the IRR is that it might produce inconsistent results when related to the NPV. This problem will be solved by using the rate of NPV method as discussed previously. Also having an IRR graph for all years of operation can show the trend and slope of the IRR and that can make the comparison of projects a lot easier. Note that this method has been used in the Channel Tunnel case study. Another problem with the IRR is that some literature (e.g. Rousse, 2008) suggests that it should be used for projects with the same duration, but sketching the graph will solve the problem by showing the trends of each project and comparison will be made possible.

5.7 Stage 4 - Evaluation of Results

The next stage is Evaluation of Results which includes:

- Sensitivity analysis
- Comparison between the alternatives.

The DFD figure for this stage is as Figure 67 below.

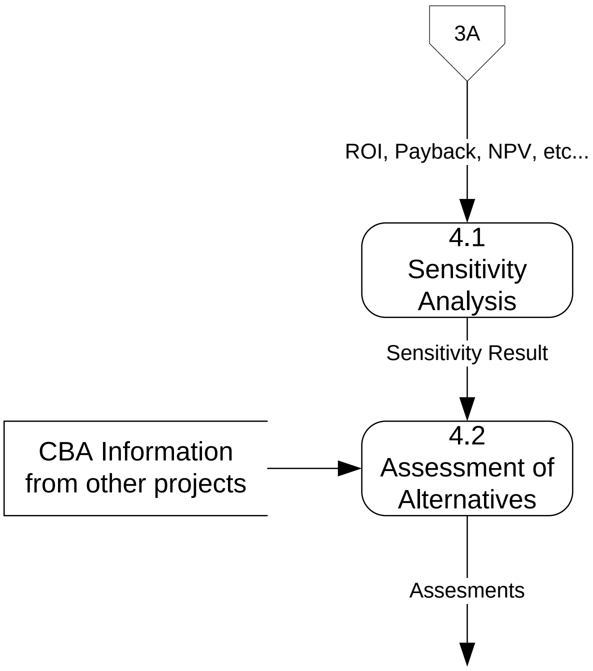

Figure 67 : Stage 4 - Evaluation of Results

5.7.1 Sensitivity Analysis (4.1)

Sociologists such as Ulrich Beck (1992) and Anthony Giddens (1990) have argued that in modern society, risk is increasingly playing a big part in human affairs. They say this 'risky society' will fail in any aspect of life if does not take risk into account.
"Sensitivity analysis is a way to predict the outcome of a decision if a situation turns out to be different compared to the key prediction(s)" (Investopedia, 2014). There is typically some uncertainty about projected impacts, the monetary calculations, forecast of the project etc. To make it clear for decision makers and the uncertainties' effects on the CBA results, a sensitivity analysis should be performed.

Two types of sensitivity should be performed in the CBA analysis:

- When there is a level of uncertainty in one section the special sensitivity will be carried through that part to show the effect on the end result.
- Making different scenarios to show the risk of the project at different situations in all sections.

A sensitivity analysis can include approximately all variables and assumptions, but time and resource restrictions will pressure the analysts to pay attention to the most important. Note that the "level of detail" Section should clarify the need for sensitivity analysis items as well.

5.7.2 Assessment of Alternatives (4.2)

To compare the alternatives fairly the included impacts should be the same. It can be said that the perspectives should be the same. They should all use the same CBA tools as well; otherwise the comparison will be impossible. The case of the Channel Tunnel showed that comparison of the studies was not possible because the different perspectives and chosen impacts.

5.8 Stage 5 - Decision Making

After the comparison the alternatives that pass the minimum requirement (eg. Standard minimum IRR for private company) for an investment will go through the decision making process. In its simple definition: 'Decision Making is the action of picking among two or more paths of actions'. The decision making result is not perfect and the decision maker might have to have a better choice that is not considered, or the correct data might not have been accessible at the time but the best decision should be made with the information and alternatives available. Decision making necessity is getting the broadest information and analysing it at the quickest time (Harris, 1980).

CBA models generally recommend the option with the best NPV, but also take into account the sensitivity analysis as well (Boardman, 2006). As shown in the Channel Tunnel case study, only considering the NPV is not enough. Also there are different backgrounds of calculation of the NPV for different projects. The ‘must have item’ for choosing between the alternatives is the same approach and calculation for all options.

With the proposed model the decision maker can compare the alternatives easily with a straight forward path. The new methods for the NPV and IRR can be used to show the better projected performance for all the alternatives. This will ease the calculation of the CBA and also the decision making process.

5.9 Conclusions

As explained in this chapter, although there are lots of cost benefit research and publications in the literature, a comprehensive ‘big picture’ CBA framework is missing. This chapter introduced a generalized cost benefit analysis model for large infrastructure projects. The suggested framework is a DFD base for all inclusive Cost Benefit Analyses of any projects; based on the experiment of the Channel Tunnel case study.

Chapter 6

CONCLUSIONS

6 CONCLUSIONS

6.1 Introduction

This chapter provides the conclusions and summaries of the entire thesis. The objectives and research questions of the study are reviewed and the answers are summarised. In this chapter, the research recommendation for High Speed 2 is proposed. The thesis closes with recommendations for future works and the future adoption of the outcomes in practice.

6.2 Research Conclusions

CBA is a broad range of methodologies to help decision making for investment in projects before, in the middle and at the end of the operation to measure costs and benefits. This thesis presented a new methodology for a generalised cost benefit analysis process for large infrastructure projects. In order to achieve the new methodology a proper case study for the Channel Tunnel project has been chosen and the following objectives needed to be dealt with:

1. Review the use of the established concept for cost benefit analysis.
2. Determine whether the Channel Tunnel Rail Link (CTRL) was justified; was it really on time and on budget; did it deliver the fare reductions and travel time savings?
3. Present an improved methodology/framework for cost benefit analysis including hitherto neglected items.

A summary of the findings and conclusions of the above objectives are as follows.

- Review the Use of the Established Concept for Cost Benefit Analysis.

The literature review chapter of the thesis explained about the current methods and process of cost benefit analysis and provided a comparison of different models and methods. Additionally, the reasons why most projects have cost overruns and delays have been identified. It has been explained why there is a need for a new comprehensive framework for a cost benefit model.

- Determine Whether the Channel Tunnel Rail Link (CTRL) was justified; - was it really on time and on budget; did it deliver the fare reductions and travel time savings?

The chosen case study was a CBA assessment of the Channel Tunnel, one of the biggest projects in the 20th century between the UK and France. This thesis described the stormy history of the project from the fears of invasion the early 19th century, when the idea came to mind for the first time, to today's concerns about financial viability, actual traffic and future forecasts.

The Channel Tunnel project was completed successfully although the construction cost and deadlines were exceeded. Chapter 3 described the Channel Tunnel project, one of the biggest, if not the biggest self-financed project of the time. The escalation in costs and the delay resulting from the misjudgement of the challenges of getting the logistical support for the boring machines and the cost control; some changes which occurred in the terminal and with the fixed equipment plan; the complexity and shortcomings of the rolling stock specified and delivered by TML; the enhancement in safety, security and environmental requirements and the changing of regulations by the governments; all caused problems in the operation of the project. Moreover, the competitive nature of the cross channel market resulted in a reduction of prices charged by the ferry operators; Eurotunnel had not calculated for that in their estimations. This resulted in less than the forecasted traffic for the new services and therefore less than the forecasted revenue for the company. Having all these misjudgements and wrong calculations of the uncertainties, the question is - was the Channel Tunnel a viable project? The chapter went through the decision making complexities, construction challenges, financing issues etc. Additionally, the operation of the tunnel with the exact operational value of the traffic and a comparison of it with the channel market traffic; its revenue and its comparison with the forecasted revenue, were studied.

Chapter 4 basically went through the Cost Benefit Analysis of the Channel Tunnel. The calculation of generated traffic, user benefits, comparison to previous studies, payback period, net present value, internal rate of return, sensitivity analysis and the capacity of the tunnel have been part of the study. The comparison of different situations demonstrated that the Channel Tunnel project is not an economically viable project for a private company. Even the longer period of the contract did not help because of the huge capital cost of the project. The Eurotunnel Company had to start thinking 'outside the box' by adding Europorte and the 'My Ferry Link' section to increase their revenue. On the other hand, such a project is helping the economy because of its huge benefits. The results showed that without considering the producer's loss, the customers are the big winners in this competitive market. This market has given the customers a choice of services, reduced prices for the service, reduced journey times, more environmentally friendly options, safety and a better quality of services because of the competition. Existing services such as the ferries are the big losers in this situation. The big amount of producer's loss proved this statement but they have had such a long run enjoying the monopolised cartel market before the tunnel's operation. Other losers are Eurotunnel shareholders who lost lots of money because of miscalculations of the project in terms of capital costs and traffic and revenue overestimation. The banks obtained their loan interest from shareholders money when the shares reduced from £3.50 to £1.42 after 1 year of operation. Such events will reduce the publics' trust in governments and can have important effects on the economy. Considering the full subsidy option, suggests that the Government finances the project instead of spreading the risk to the shareholders. The Government could finance the project with the high risks of investment and a big degree of uncertainty and then put the construction and operation in two different tenders. The project has been an outstanding piece of engineering but at great expense. With all the problems after starting the operation, the Eurotunnel Company looks in a better shape now and the tunnel is working properly.

- Present an Improved Methodology/Framework for Cost Benefit Analysis including Hitherto Neglected Items.

It is not an easy task to provide a response on whether a project is successful or unsuccessful. It is dependent on many factors such as perspective and timing. Nonetheless, it is also dependent on with what you compare it. Frequently there is a tendency to compare success with the anticipated outcomes; although, that speaks more about the anticipation rather than the success of the projects. Projects are different - but in what ways do they differ? Different frameworks and models have been recommended in this thesis for analysing differences among projects. Generally frameworks express the necessity to adapt project management to the situation (Söderlund, 2011). This thesis tried to gather all the aspects that are important for decision making in large infrastructure projects. Chapter 5, or the main results of this thesis, presented the new model. As clarified in the chapter, although there are lots of cost benefit research and publications in the literature, a comprehensive ‘big picture’ CBA framework was missing. This chapter introduced a generalized cost benefit analysis model for large infrastructure projects. The suggested framework is a DFD base for all inclusive Cost Benefit Analyses of any projects based on the experiment of the Channel Tunnel case study. The designed stages of the CBA considering the literature and experiments on the Channel Tunnel case study include:

project identification; setting the framework; technical analysis; economic evaluation; evaluation of results and decision making. Each section has its own DFD diagram with linked but separated subsections. Each subsection has been explained and the link to the next section is clarified.

As noted throughout the thesis, effective cost benefit analysis models are helpful for improvement in project performance. The new model can, therefore, be used to assist promoters in their decision making of all large infrastructure projects. This finding could be used as a foundation for developing an appropriate decision making tool for different categories as well.

6.3 Recommendation for High Speed 2

The Channel Tunnel can be considered to have been beneficial to the economy l when including its benefits and long term of operation. Although it had its own ups and downs, generally it is a very long term project and future generations will continue to use it. The expansion of the tunnel route from different parts of the UK to different parts of Europe will increase the closeness of Britain to continental Europe and will help both economies. The project helped to break the monopoly of the ferry service and made the market competitive, which lowered the price of the cross-channel service.

High Speed 2 is the plan for the extension of High Speed 1 from London to Birmingham and then Leeds and Manchester. Although the plan looks promising, the Government should not repeat the mistakes of HS1 and the Channel Tunnel. The best option is to use the proposed generalised cost benefit analysis process model for large infrastructure projects. The forecasts (including cost, traffic, revenue etc.) should be as accurate as possible with an error factor in order to avoid overestimations. The project can increase the use of the other 50% of the tunnel and can compete with planes in the passenger market and even more in the freight market. The cost is another big factor which should not be as difficult as the Channel Tunnel to calculate because the uncertainties are not that great and similar projects have been handled previously.

6.4 Contribution to Knowledge

The significant concern in any doctoral study is an original contribution to knowledge. The difficulty is that the idea of originality might be arbitrary (Fellows and Liu, 1997). Walker (1997) recommended numerous originality examples; for instance, new methodology development, tools and/or techniques, new fields of investigation, new explanation of existing material and new application of current theories. Based on this definition, the contribution to knowledge for the current study can be regarded in respect of its direct influence and the future potential as/if additional work is carried out.

It was realised from the literature review that a generalized CBA model for large infrastructure projects needs to be developed for the use of promoters, researchers etc. Whereas wide research on cost benefit in different industries has been commenced, it seems that no effort has focused on the comprehensive model of a CBA to highlight the potential benefits that come from such research for investors, scientists and society as a whole. By paying attention to this specific gap, this research builds on the present knowledge of cost benefit analysis and highlights changes and different perspectives on the application of the present methods to a new area. Consequently, this demonstrates a major contribution to knowledge. A model has been proposed that can be useful for investors and researchers to calculate costs and benefits of a project systematically and that can be used for comparing different projects. The model will assist promoters to take proper measures, make appropriate decisions and allocate the resources necessary for projects. It can also be a base upon which to build comprehensive computer software for cost benefit analysis of large infrastructure projects. Some highlights of different contributions are as follows:

- ✓ Channel Tunnel cost benefit analysis
    - Ex-post CBA
    - 2012 prices
    - Actual value calculations until 2012
    - CO_2 emissions' calculations
    - New proposed generated traffic calculations
    - New NPV figure calculation
    - New IRR figure calculation
    - New perspective on sensitivity analysis by comparing graphs of NPV with different discount rates
    - Comparisons to previous studies
- ✓ New generalised cost benefit analysis model based on DFD

6.5 Future Work

Based on the outcomes of the study and its limits, three recommendations are proposed to deliver a path for attempted future studies in this area as follows.

1. Within the scope of this study, it was not possible to consider social costs and benefits such as environmental impacts, safety, effect on employment and energy savings. Future studies could helpfully be carried out in these mentioned areas. It is believed that these costs and benefits are noteworthy and can affect comparisons and future decision making; although, this needs additional data collection and research in each of the recommended areas.

2. This study has revealed a significant analysis and conclusions of the costs and benefits of the Channel Tunnel project and High Speed 1, for decision making. It is recommended that further studies can be undertaken for High Speed 2 projects with the proposed model.

3. The study can be advanced to develop generalised cost benefit analysis computer software.

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APPENDICES

APPENDIX A: Journey Time

The calculated and estimated journey times and waiting times in minutes can be seen in Table below.

Passenger Journey Time		1994 - 2002	2002 - 2007	2007 - 2012
Journey Time - Eurostar London-Paris	Min	176	155	135
Journey Time - Eurostar London-Brussels	Min	161	140	111
Journey Time - Eurostar London-Paris/Brussels Average	Min	173	151	128
Journey Time - Eurostar Dover-Calais	Min	35	35	35
Journey Time - Le Shuttle Dover-Calais	Min	35	35	35
Journey Time - Air London-Paris	Min	85	85	85
Journey Time - Air London-Brussels	Min	75	75	75
Journey Time - Air London-Paris/Brussels Average	Min	82	82	83
Journey Time - Coach London - Dover average	Min	160	160	160
Journey Time - Sea Dover-Calais	Min	90	90	90
Journey Time - Coach Calais-Paris	est	130	130	130
Journey Time - Coach Calais-Brussels	est	130	130	130
Waiting Time - Eurostar	Min	60	60	60
Waiting Time - Le Shuttle	Min	30	30	30
Waiting Time - Air	est	120	120	120
Waiting Time - Coach	est	30	30	30
Waiting Time - Sea	est	60	60	60

APPENDIX B: Passenger Travel Time Saving Calculation

Year		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Base Year	**2012**																			
Eurostar Passengers																				
Generated carried by Eurostar	**Millions**	0.1	1.8	3.3	4.2	4.4	4.6	4.8	4.0	3.5	2.8	3.5	3.0	3.2	3.1	3.4	2.9	2.8	2.9	2.8
Existing Eurostar	**Millions**	0.0	0.9	1.6	1.8	1.9	2.0	2.3	3.0	3.1	3.5	3.8	4.4	4.7	5.1	5.8	6.3	6.7	6.8	7.1
Business (Estimate)	**0.3**	0.0	0.3	0.5	0.5	0.6	0.6	0.7	0.9	0.9	1.0	1.1	1.3	1.4	1.5	1.7	1.9	2.0	2.0	2.1
Leisure (Estimate)		0.0	0.7	1.1	1.2	1.3	1.4	1.6	2.1	2.2	2.4	2.7	3.1	3.3	3.6	4.0	4.4	4.7	4.8	5.0
Shuttle Passengers																				
Passenger Generated carried by shuttle	**Millions**	0.2	3.4	7.4	8.6	10.9	8.0	4.2	2.9	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Passenger Existing Shuttle	**Millions**	0.0	1.0	0.5	0.0	1.2	3.0	5.7	6.5	6.7	8.6	7.8	8.2	7.8	7.9	7.0	6.9	7.5	10.3	10.1
Value of time per passenger																				
Value of Time per Person - Leisure (£/hr)	**2012**	4.8	5.0	5.2	5.3	5.5	5.7	5.8	5.9	6.1	6.3	6.4	6.5	6.6	6.7	6.5	6.3	6.2	5.9	5.7
Value of Time per Person - Business (£/hr)	**2012**	33.2	34.0	35.5	36.5	37.4	38.9	39.7	40.7	42.1	43.2	44.1	44.4	45.3	45.6	44.9	43.2	42.7	40.3	38.8
Travel Time Saving																				
Diverted from Air Service to Eurostar																				
In vehicle added	**min**	-90	-90	-90	-91	-91	-91	-90	-90	-90	-69	-69	-69	-68	-46	-46	-45	-45	-45	-45
Waiting time	**min**	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Existing Business Passengers		0.0	0.3	0.5	0.5	0.6	0.6	0.7	0.9	0.9	1.0	1.1	1.3	1.4	1.5	1.7	1.9	2.0	2.0	2.1
Existing Business Passengers Benefit/Loss per crossing																				
in vehicle added penalty	**£**	-49.9	-51.1	-53.4	-55.2	-56.6	-58.9	-59.9	-61.2	-63.0	-49.4	-50.4	-50.8	-51.7	-34.9	-34.2	-32.8	-32.3	-30.3	-29.3
waiting time saved benefit	**£**	33.2	34.0	35.5	36.5	37.4	38.9	39.7	40.7	42.1	43.2	44.1	44.4	45.3	45.6	44.9	43.2	42.7	40.3	38.8
Net journey time benefit/loss per crossing	**£**	-16.6	-17.1	-18.0	-18.7	-19.2	-20.0	-20.2	-20.4	-20.9	-6.2	-6.3	-6.4	-6.4	10.7	10.6	10.5	10.5	10.0	9.4
(3) Total Existing Eurostar business passengers from Air Annual benefit/loss	**£/10^6**	0.0	-4.8	-8.4	-9.9	-10.8	-12.2	-13.8	-18.3	-19.3	-6.5	-7.3	-8.5	-9.0	16.5	18.4	19.8	21.2	20.4	20.1
Existing Leisure Passengers		0.0	0.3	0.5	0.6	0.7	0.7	0.8	1.0	1.1	1.2	1.3	1.5	1.6	1.8	2.0	2.2	2.4	2.4	2.5
Existing Leisure Passengers benefit/loss per crossing																				
In vehicle added penalty	**£**	-7.3	-7.5	-7.8	-8.1	-8.3	-8.6	-8.7	-8.9	-9.2	-7.2	-7.4	-7.4	-7.5	-5.1	-5.0	-4.8	-4.7	-4.4	-4.3
waiting time saved benefit	**£**	12.1	12.4	12.9	13.3	13.6	14.2	14.5	14.9	15.4	15.8	16.1	16.2	16.5	16.6	16.4	15.8	15.6	14.7	14.1
Net journey time benefit/loss per crossing	**£**	4.8	4.9	5.1	5.3	5.4	5.6	5.7	5.9	6.2	8.5	8.7	8.8	9.0	11.5	11.4	11.0	10.9	10.3	9.9
(4) Total Existing Eurostar Leisure passengers from Air annual benefit/loss	**£/10^6**	0.0	1.6	2.8	3.2	3.5	4.0	4.6	6.2	6.6	10.5	11.7	13.5	14.7	20.8	22.9	24.3	25.7	24.4	24.6
Diverted from Sea service to Eurostar																				
In vehicle added	**min**	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
Waiting time	**min**	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30

Leisure Passengers		0.0	0.3	0.5	0.6	0.7	0.7	0.8	1.0	1.1	1.2	1.3	1.5	1.6	1.8	2.0	2.2	2.4	2.4	2.5
Leisure Passengers benefit/loss per crossing																				
in vehicle saved benefit	**£**	4.4	4.5	4.7	4.9	5.0	5.2	5.3	5.4	5.6	5.8	5.9	5.9	6.1	6.1	6.0	5.8	5.7	5.4	5.2
waiting time saved benefit	**£**	6.1	6.2	6.5	6.7	6.8	7.1	7.2	7.4	7.7	7.9	8.0	8.1	8.3	8.3	8.2	7.9	7.8	7.4	7.1
Net journey time benefit/loss per crossing	**£**	10.5	10.7	11.2	11.5	11.8	12.3	12.5	12.9	13.3	13.7	13.9	14.0	14.3	14.4	14.2	13.7	13.5	12.7	12.2
(5) Total Existing Eurostar Leisure passengers from Sea annual benefit/loss	**£/10^6**	0.0	3.5	6.1	7.1	7.8	8.7	10.0	13.4	14.3	16.7	18.7	21.6	23.5	26.0	28.6	30.2	31.9	30.3	30.5
Eurostar Generated passengers		0.1	1.8	3.3	4.2	4.4	4.6	4.8	4.0	3.5	2.8	3.5	3.0	3.2	3.1	3.4	2.9	2.8	2.9	2.8
(6) Eurostar Generated passengers as if from Air	**£/10^6**	0.1	2.2	4.2	5.6	6.0	6.4	7.0	5.9	5.4	6.0	7.5	6.7	7.1	9.0	9.5	8.0	7.6	7.4	6.9
(7) Eurostar Generated passengers as if from Sea	**£/10^6**	0.3	4.7	9.3	12.3	13.1	14.0	15.2	12.8	11.7	9.6	12.0	10.7	11.3	11.2	11.9	9.9	9.4	9.2	8.6
(6,7) Eurostar Generated passengers annual benefit/loss (1/2 benefit from rule of half)	**£/10^6**	0.5	6.9	13.5	17.9	19.1	20.4	22.2	18.6	17.2	15.7	19.5	17.4	18.4	20.2	21.4	17.9	17.0	16.6	15.4
Diverted from sea services to the Shuttle																				
In vehicle added	**min**	152	152	152	153	153	153	153	153	153	174	174	174	174	197	197	197	197	197	197
Waiting time	**min**	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
All are Leisure Passengers																				
Leisure Passengers benefit/loss per crossing																				
in vehicle time saved benefit	**£**	12.3	12.6	13.1	13.6	13.9	14.4	14.7	15.1	15.7	18.3	18.6	18.8	19.2	21.8	21.5	20.7	20.5	19.3	18.6
Existing Shuttle Passengers		0.0	1.0	0.5	0.0	1.2	3.0	5.7	6.5	6.7	8.6	7.8	8.2	7.8	7.9	7.0	6.9	7.5	10.3	10.1
(1) Existing Shuttle passengers annual benefit/loss	**£/10^6**	0.0	12.4	6.4	0.0	17.2	43.5	83.5	98.4	104.5	157.2	145.4	154.1	149.7	172.4	150.3	142.9	153.6	199.5	187.4
Shuttle Generated passengers		0.2	3.4	7.4	8.6	10.9	8.0	4.2	2.9	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2) Generated Shuttle passengers annual benefit/loss (1/2 benefit from rule of half)	**£/10^6**	1.2	21.5	48.7	58.3	75.4	57.7	31.2	21.9	15.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
All Leisure Passengers Annual Benefit/Loss	**£/10^6**	1.2	33.9	55.1	58.3	92.6	101.2	114.7	120.3	119.6	157.2	145.4	154.1	149.7	172.4	150.3	142.9	153.6	199.5	187.4
Total Travel Time Savings																				
Passengers diverted from Air to Eurostar																				
Business	**£/10^6**	0.0	-4.8	-8.4	-9.9	-10.8	-12.2	-13.8	-18.3	-19.3	-6.5	-7.3	-8.5	-9.0	16.5	18.4	19.8	21.2	20.4	20.1
Leisure	**£/10^6**	0.0	1.6	2.8	3.2	3.5	4.0	4.6	6.2	6.6	10.5	11.7	13.5	14.7	20.8	22.9	24.3	25.7	24.4	24.6
Total diverted from Air	**£/10^6**	0.0	-3.2	-5.6	-6.6	-7.3	-8.2	-9.2	-12.1	-12.7	3.9	4.4	5.0	5.8	37.3	41.3	44.1	46.9	44.8	44.7
Passenger diverted from Sea to Eurostar																				
Leisure	**£/10^6**	0.0	3.5	6.1	7.1	7.8	8.7	10.0	13.4	14.3	16.7	18.7	21.6	23.5	26.0	28.6	30.2	31.9	30.3	30.5
Passenger diverted from Sea to Shuttle																				
Leisure	**£/10^6**	0.0	12.4	6.4	0.0	17.2	43.5	83.5	98.4	104.5	157.2	145.4	154.1	149.7	172.4	150.3	142.9	153.6	199.5	187.4
Total diverted from Sea	**£/10^6**	0.0	15.9	12.5	7.1	25.0	52.3	93.6	111.9	118.8	173.9	164.1	175.7	173.2	198.4	178.9	173.1	185.5	229.7	217.9
(6,7) Eurostar Generated passengers annual benefit/loss (1/2 benefit from rule of half)	**£/10^6**	0.5	6.9	13.5	17.9	19.1	20.4	22.2	18.6	17.2	15.7	19.5	17.4	18.4	20.2	21.4	17.9	17.0	16.6	15.4
(2) Generated Shuttle passengers annual benefit/loss (1/2 benefit from rule of half)	**£/10^6**	1.2	21.5	48.7	58.3	75.4	57.7	31.2	21.9	15.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Passenger Generated	**£/10^6**	1.7	28.4	62.2	76.1	94.5	78.1	53.3	40.5	32.3	15.7	19.5	17.4	18.4	20.2	21.4	17.9	17.0	16.6	15.4
Total Passenger Travel Time Savings	**£/10^6**	**1.7**	**41.1**	**69.1**	**76.6**	**112.2**	**122.2**	**137.7**	**140.3**	**138.4**	**193.5**	**188.0**	**198.1**	**197.4**	**255.9**	**241.6**	**235.2**	**249.4**	**291.2**	**278.0**

APPENDIX C: Freight Travel Time Saving Calculation

Year	Unit	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Base Year	**2012**																			
Number of Lorries on Shuttle (CT)		0.1	0.4	0.5	0.3	0.7	0.8	1.1	1.1	1.2	1.3	1.3	1.3	1.3	1.4	1.3	0.8	1.1	1.3	1.5
Generated Le shuttle		0.0	0.2	0.3	0.3	0.7	0.8	1.1	1.1	1.2	1.3	1.3	1.3	1.3	1.4	1.3	0.8	1.1	1.3	1.5
Existing Le shuttle		0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Through Rail Freight (Tonnes)		0.5	1.3	2.4	2.9	3.1	2.9	2.9	2.4	1.5	1.7	1.9	1.6	1.6	1.2	1.2	1.2	1.1	1.3	1.2
£/hr per Truck Load	**£/hr**	15.2	16.5	17.0	17.5	18.1	18.7	19.1	20.8	20.3	20.9	21.7	21.4	22.0	22.1	18.9	20.9	20.7	19.5	18.5
£/hr for Working Lorry Driver	**£/hr**	9.2	9.4	9.8	10.1	10.3	10.7	10.9	11.2	11.6	11.9	12.1	12.2	12.5	12.6	12.4	11.9	11.8	11.1	10.7
£/hr per Tonne of Non-bulk Freight	**£/hr**	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.6	0.6
Values for Travel Time Saving (minutes)																				
Lorries on Shuttle	**min**	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Through Rail Services	**min**	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Benefit per Crossing (per lorry crossing on shuttles)																				
From Cargo	**£**	7.6	8.2	8.5	8.7	9.1	9.4	9.5	10.4	10.2	10.4	10.9	10.7	11.0	11.0	9.4	10.5	10.4	9.7	9.2
From Driver	**£**	4.6	4.7	4.9	5.0	5.2	5.4	5.5	5.6	5.8	5.9	6.1	6.1	6.2	6.3	6.2	6.0	5.9	5.6	5.3
Per Tonne on Through Rail Services	**£**	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.6	0.6
Total Travel Time Savings - Freight Carried in Lorries on Shuttles																				
Cargo Benefits from Generated		0.0	0.8	1.1	1.1	3.2	3.9	5.4	5.9	6.1	6.7	7.0	7.0	7.1	7.8	5.9	4.0	5.6	6.1	6.8
Cargo Benefits from Existing		0.5	1.6	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Total Cargo Benefits	**million £**	0.5	2.4	3.3	1.1	3.2	3.9	5.4	5.9	6.1	6.7	7.0	7.0	7.1	7.8	5.9	4.0	5.6	6.1	8.0
Driver Benefits from Generated		0.0	0.9	1.3	1.3	3.6	4.5	6.2	6.4	6.9	7.6	7.8	8.0	8.1	8.9	7.7	4.6	6.4	7.0	7.8
Driver Benefits from Existing		0.3	0.9	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Total Driver Benefits	**million £**	0.3	1.8	2.5	1.3	3.6	4.5	6.2	6.4	6.9	7.6	7.8	8.0	8.1	8.9	7.7	4.6	6.4	7.0	8.5
Subtotal Shuttle Benefits	**million £**	0.8	4.2	5.8	2.4	6.8	8.4	11.6	12.2	13.0	14.4	14.7	15.0	15.2	16.7	13.7	8.6	12.1	13.2	16.6
Freight Carried on Through Rail Services																				
Benefits	**million £**	0.3	0.9	1.6	2.0	2.2	2.1	2.2	1.8	1.1	1.4	1.5	1.2	1.2	0.9	0.8	0.8	0.7	0.8	0.7
Total Freight Travel Time Saving	**million £**	**1.1**	**5.1**	**7.3**	**4.4**	**9.0**	**10.5**	**13.8**	**14.1**	**14.2**	**15.8**	**16.2**	**16.2**	**16.4**	**17.6**	**14.5**	**9.4**	**12.8**	**14.0**	**17.3**

APPENDIX D: Passenger User Benefit from Fare Reduction Calculation

Year	Unit	Before	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Base Year	**2012**																				
Accompanied traffic																					
Number of cars on Dover Straits	**Million**		3.23	2.89	3.05	3.56	3.30	3.00	2.59	2.55	2.63	2.58	2.51	2.55	2.65	2.84	2.83	2.78	2.82	2.65	2.40
Number of cars on Shuttle	**Million**		0.08	1.23	2.08	2.32	3.35	3.26	2.78	2.53	2.34	2.28	2.28	2.01	2.02	2.14	1.91	1.92	2.13	2.26	2.42
Total channel car passenger market			3.32	4.13	5.13	5.88	6.65	6.26	5.38	5.08	4.97	4.86	4.79	4.56	4.67	4.98	4.74	4.69	4.94	4.92	4.82
Generated Cars			0.43	1.09	1.94	2.53	3.16	2.62	1.58	1.13	0.86	0.61	0.38	0.01	0.00	0.12	0.00	0.00	0.00	0.00	0.00
Existing Cars			2.89	3.04	3.19	3.34	3.50	3.65	3.80	3.95	4.10	4.26	4.41	4.56	4.67	4.86	4.74	4.69	4.94	4.92	4.82
Number of coaches on Dover Straits	**Million**		0.16	0.16	0.15	0.17	0.15	0.16	0.15	0.14	0.15	0.13	0.13	0.11	0.11	0.11	0.10	0.08	0.09	0.08	0.08
Number of coaches in Shuttle	**Million**		0.00	0.02	0.06	0.07	0.07	0.08	0.07	0.07	0.07	0.07	0.07	0.06	0.08	0.07	0.06	0.05	0.06	0.06	0.06
Total channel coach passenger market			0.16	0.18	0.21	0.24	0.22	0.24	0.22	0.21	0.22	0.20	0.20	0.17	0.18	0.17	0.15	0.14	0.14	0.14	0.14
Generated Coaches			0.01	0.03	0.06	0.08	0.06	0.07	0.05	0.03	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Existing Coaches			0.15	0.15	0.16	0.16	0.16	0.17	0.17	0.18	0.18	0.18	0.19	0.17	0.18	0.17	0.15	0.14	0.14	0.14	0.14
Average Tunnel/ferry fare per vehicle	**2012**	194.4	0.00	70.39	53.71	46.87	45.68	59.98	71.64	82.79	88.90	62.29	43.65	48.10	56.35	51.04	70.38	78.69	51.27	40.57	33.06
Benefit to existing Car passengers			561.71	377.15	449.25	493.49	520.04	490.44	466.54	441.11	432.98	562.27	664.48	667.06	644.57	697.21	587.64	542.95	707.68	756.32	778.53
Benefit to existing Coaches passengers			28.58	18.75	21.85	23.53	24.33	22.55	21.10	19.65	19.01	24.36	28.42	24.95	25.27	24.47	19.05	15.71	20.40	21.70	23.11
Total Existing traffic benefit			590.29	395.90	471.10	517.01	544.37	512.99	487.65	460.76	452.00	586.63	692.90	692.02	669.84	721.68	606.69	558.66	728.09	778.02	801.64
Benefit to generated Car passengers			41.44	67.33	136.42	186.85	234.65	175.79	96.92	63.23	45.61	39.98	28.53	0.43	0.00	8.35	0.00	0.00	0.00	0.00	0.00
Benefit to generated Coach passengers			0.98	1.89	3.96	5.57	4.47	4.60	2.85	1.71	1.97	0.85	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Generated traffic benefit			42.42	69.22	140.38	192.42	239.12	180.39	99.77	64.94	47.58	40.83	29.43	0.43	0.00	8.35	0.00	0.00	0.00	0.00	0.00
Total annual benefits			**632.70**	**465.12**	**611.48**	**709.44**	**783.49**	**693.39**	**587.41**	**525.70**	**499.58**	**627.47**	**722.34**	**692.45**	**669.84**	**730.03**	**606.69**	**558.66**	**728.09**	**778.02**	**801.64**

APPENDIX E: Freight User Benefit from Fare Reduction Calculation

Year	Unit	Before	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Base Year	**2012**																				
Number of units through the port of Dover	**Million**		1.16	1.08	1.07	1.60	1.52	1.67	1.62	1.77	1.85	1.78	1.98	2.05	2.32	2.36	2.31	2.30	2.09	2.07	1.95
Number of units on the shuttle	**Million**		0.07	0.39	0.52	0.26	0.70	0.84	1.13	1.13	1.20	1.28	1.28	1.31	1.30	1.41	1.25	0.77	1.09	1.26	1.46
Total unit of freight on the channel	**Million**		1.22	1.47	1.59	1.86	2.23	2.51	2.75	2.90	3.05	3.07	3.26	3.35	3.62	3.78	3.56	3.07	3.18	3.33	3.42
Average ferry/tunnel fare per unit	**£**	360.74	286.04	273.04	222.33	240.54	222.33	235.34	215.83	192.43	204.13	208.03	209.33	209.33	209.33	209.33	209.33	209.33	209.33	209.33	209.33
Benefit to existing customer	**£ Million**		91.35	111.50	182.64	164.40	195.95	183.57	219.10	262.58	251.85	252.93	258.06	265.34	272.62	279.90	287.19	294.47	301.75	313.40	295.56
Generated Freight	**£ Million**		0.00	0.20	0.27	0.49	0.81	1.04	1.24	1.34	1.44	1.41	1.56	1.60	1.82	1.93	1.67	1.12	1.19	1.29	1.33
Benefit to Generated customer	**£ Million**		0.00	8.56	18.75	29.51	56.18	65.39	89.78	113.18	113.05	107.77	117.90	121.29	137.80	146.08	126.07	85.15	89.90	97.82	100.52
Total Unitised Freight benefit	**£ Million**		**91.35**	**120.07**	**201.39**	**193.91**	**252.13**	**248.96**	**308.88**	**375.75**	**364.91**	**360.69**	**375.96**	**386.63**	**410.42**	**425.98**	**413.25**	**379.62**	**391.65**	**411.22**	**396.08**

APPENDIX F: Passenger Producers’ Loss Calculation

Year	Unit	Before	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	2012																				
Number of cars on Dover Straits	**Million**		3.23	2.89	3.05	3.56	3.30	3.00	2.59	2.55	2.63	2.58	2.51	2.55	2.65	2.84	2.83	2.78	2.82	2.65	2.40
Number of cars on Shuttle	**Million**		0.08	1.23	2.08	2.32	3.35	3.26	2.78	2.53	2.34	2.28	2.28	2.01	2.02	2.14	1.91	1.92	2.13	2.26	2.42
Total channel car passenger market	**Million**		3.32	4.13	5.13	5.88	6.65	6.26	5.38	5.08	4.97	4.86	4.79	4.56	4.67	4.98	4.74	4.69	4.94	4.92	4.82
Generated Cars	**Million**		0.43	1.09	1.94	2.53	3.16	2.62	1.58	1.13	0.86	0.61	0.38	0.01	0.00	0.12	0.00	0.00	0.00	0.00	0.00
Existing Cars	**Million**		2.89	3.04	3.19	3.34	3.50	3.65	3.80	3.95	4.10	4.26	4.41	4.56	4.67	4.86	4.74	4.69	4.94	4.92	4.82
Number of coaches on Dover Straits	**Million**		0.16	0.16	0.15	0.17	0.15	0.16	0.15	0.14	0.15	0.13	0.13	0.11	0.11	0.11	0.10	0.08	0.09	0.08	0.08
Number of coaches in Shuttle	**Million**		0.00	0.02	0.06	0.07	0.07	0.08	0.07	0.07	0.07	0.07	0.07	0.06	0.08	0.07	0.06	0.05	0.06	0.06	0.06
Total channel coach passenger market	**Million**		0.16	0.18	0.21	0.24	0.22	0.24	0.22	0.21	0.22	0.20	0.20	0.17	0.18	0.17	0.15	0.14	0.14	0.14	0.14
Generated Coaches	**Million**		0.01	0.03	0.06	0.08	0.06	0.07	0.05	0.03	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Existing Coaches	**Million**		0.15	0.15	0.16	0.16	0.16	0.17	0.17	0.18	0.18	0.18	0.19	0.17	0.18	0.17	0.15	0.14	0.14	0.14	0.14
Average Tunnel/ferry fare per vehicle	**£**	194.42	-	70.39	53.71	46.87	45.68	59.98	71.64	82.79	88.90	62.29	43.65	48.10	56.35	51.04	70.38	78.69	51.27	40.57	33.06
Car Producers Benefit Without Tunnel	**£ Million**		561.71	591.22	620.74	650.25	679.76	709.27	738.79	768.30	797.81	827.32	856.84	886.35	907.66	945.37	921.09	912.17	961.13	955.74	938.03
Car Producers Benefit After Tunnel	**£ Million**		0.00	203.71	164.07	166.78	150.76	180.15	185.90	211.54	234.01	160.79	109.40	122.88	149.17	144.82	199.20	218.39	144.49	107.63	79.35
Ferry Producer's loss on Cars	**£ Million**		561.71	387.51	456.67	483.47	529.00	529.12	552.88	556.76	563.80	666.53	747.43	763.47	758.49	800.56	721.89	693.78	816.64	848.12	858.67
Coach Producers Benefit Without Tunnel	**£ Million**		28.58	29.39	30.19	31.00	31.81	32.61	33.42	34.23	35.03	35.84	36.65	33.16	35.59	33.18	29.86	26.39	27.71	27.42	27.84
Coach Producers Benefit After Tunnel	**£ Million**		0.00	11.13	8.25	7.73	7.02	9.40	10.62	11.32	13.12	7.80	5.61	5.17	5.96	5.38	6.89	6.39	4.41	3.45	2.78
Coach Producers Loss	**£ Million**		28.58	18.25	21.94	23.27	24.79	23.21	22.80	22.91	21.92	28.04	31.04	27.98	29.63	27.80	22.98	20.00	23.30	23.97	25.06
Passenger Producers Loss	**£ Million**		**0.00**	**405.76**	**478.61**	**506.73**	**553.78**	**552.33**	**575.68**	**579.67**	**585.72**	**694.57**	**778.47**	**791.45**	**788.11**	**828.36**	**744.87**	**713.78**	**839.94**	**872.09**	**883.73**

APPENDIX G: Freight Producers' Loss Calculation

Year	Unit	Before	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Base Year	**2012**																				
Number of units through the port of Dover	**Million**		1.16	1.08	1.07	1.60	1.52	1.67	1.62	1.77	1.85	1.78	1.98	2.05	2.32	2.36	2.31	2.30	2.09	2.07	1.95
Number of units on the shuttle	**Million**		0.07	0.39	0.52	0.26	0.70	0.84	1.13	1.13	1.20	1.28	1.28	1.31	1.30	1.41	1.25	0.77	1.09	1.26	1.46
Total unit of freight on the channel	**Million**		1.22	1.47	1.59	1.86	2.23	2.51	2.75	2.90	3.05	3.07	3.26	3.35	3.62	3.78	3.56	3.07	3.18	3.33	3.42
Generated Freight	**Million**		0.00	0.20	0.27	0.49	0.81	1.04	1.24	1.34	1.44	1.41	1.56	1.60	1.82	1.93	1.67	1.12	1.19	1.29	1.33
Existing Freight	**Million**		1.22	1.27	1.32	1.37	1.42	1.46	1.51	1.56	1.61	1.66	1.70	1.75	1.80	1.85	1.90	1.94	1.99	2.04	2.09
Average ferry/tunnel fare per unit	**£**	360.74	286.04	273.04	222.33	240.54	222.33	235.34	215.83	192.43	204.13	208.03	209.33	209.33	209.33	209.33	209.33	209.33	209.33	209.33	209.33
Freight Producers Benefit Without Tunnel	**£ Million**		441.19	458.68	476.03	493.38	510.73	528.08	545.44	562.79	580.14	597.49	614.84	632.19	649.55	666.90	684.25	701.60	718.95	736.30	753.65
Freight Producers Benefit After Tunnel	**£ Million**		331.24	293.78	238.25	385.55	338.60	392.53	349.26	340.95	378.51	370.89	414.62	428.27	486.61	494.78	483.10	481.56	437.82	433.31	408.65
Freight Producers loss	**£ Million**		**109.94**	**164.89**	**237.78**	**107.83**	**172.13**	**135.56**	**196.18**	**221.83**	**201.63**	**226.60**	**200.22**	**203.93**	**162.93**	**172.12**	**201.15**	**220.04**	**281.13**	**303.00**	**345.01**

APPENDIX H: CO_2 Emissions Saving Result

Year		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total Air CO2 Emissions	**kg**	413	414	472	527	586	620	568	647	663	728	635	587	602	621	635	623	547	559	529	516	470	458	426	371	322	292	316	306
Total Passenger Ferry CO2 Emissions	**kg**	69	72	70	62	75	78	80	90	92	96	89	95	107	97	91	81	80	82	73	72	67	69	71	69	65	66	64	60
Total Freight Ferry CO2 Emissions	**kg**	115	124	128	124	155	158	156	168	175	183	170	169	253	241	264	256	280	293	282	313	323	367	373	365	363	330	327	308
Total Competitors CO2 Emissions	**kg**	597	610	671	712	816	856	804	904	930	1007	894	851	963	959	990	960	907	935	885	901	860	894	870	805	751	689	707	674
Total Eurostar CO2 Emissions	**kg**										2	39	71	88	92	96	104	101	96	92	106	109	115	121	133	135	139	141	145
Total Passenger Shuttle CO2 Emissions	**kg**										1	19	35	38	53	48	44	41	38	38	34	36	34	35	31	30	33	45	44
Total Freight Shuttle CO2 Emissions	**kg**										1	3	5	2	6	7	10	10	11	11	11	12	11	12	11	7	10	11	13
Total Tunnel CO2 Emissions	**kg**										3	62	110	128	152	152	158	153	145	141	152	156	160	168	175	172	182	198	202
Eurostar CO2 Emissions Saving	**kg**										**-20**	**70**	**119**	**120**	**130**	**145**	**182**	**294**	**319**	**387**	**419**	**496**	**535**	**595**	**670**	**750**	**808**	**815**	**855**
Passenger Shuttle CO2 Emissions Saving	**kg**										**-5**	**-14**	**-32**	**-44**	**-47**	**-33**	**-15**	**-9**	**-4**	**8**	**16**	**22**	**25**	**25**	**34**	**41**	**41**	**34**	**42**
Freight Shuttle CO2 Emissions Saving	**kg**										**-1**	**17**	**24**	**-50**	**-34**	**-51**	**-38**	**-54**	**-60**	**-42**	**-66**	**-69**	**-105**	**-105**	**-87**	**-74**	**-36**	**-27**	**-2**
Total Tunnel CO2 Emissions Saving	**Kg**										**-26**	**72**	**110**	**25**	**49**	**61**	**129**	**231**	**255**	**352**	**369**	**449**	**454**	**515**	**617**	**717**	**814**	**823**	**895**

APPENDIX I: Cost Benefit Analysis (Short Term, 3.5% Discount Rate, £Million)

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Resource cost of the Channel Link																									
Construction	-1567.5	-1567.5	-1473.4	-1341.6	-1341.6	-1341.6	-335.5																		
Inland Infrastructure	-278.0	-278.0	-246.6	-203.0	-203.0	-203.0	-50.7																		
Rolling Stock	0.0	0.0	-211.8	-508.4	-508.4	-508.4	-127.0		-52.0			-78.0		-78.0											
Subtotal initial capital costs	-1845.5	-1845.5	-1931.8	-2052.9	-2052.9	-2052.9	-513.2		-52.0			-78.0		-78.0											
Subtotal operating cost	0.0	0.0	0.0	0.0	0.0	0.0	-676.8	-598.9	-562.6	-495.7	-495.8	-445.4	-362.6	-339.3	-340.5	-359.3	-340.2	-306.2	-285.0	-274.5	-304.0	-320.1	-372.1	-405.4	-456.9
Total Tunnel cost	-1845.5	-1845.5	-1931.8	-2052.9	-2052.9	-2052.9	-1190.0	-598.9	-614.6	-495.7	-495.8	-523.4	-362.6	-417.3	-340.5	-359.3	-340.2	-306.2	-285.0	-274.5	-304.0	-320.1	-372.1	-405.4	-456.9
BR investments																									
Total other costs (BR investments)	-13.6	-59.0	-342.6	-636.3	-913.1	-888.4																			
Total Costs	-1859.1	-1904.5	-2274.5	-2689.2	-2966.0	-2941.3	-1190.0	-598.9	-614.6	-495.7	-495.8	-523.4	-362.6	-417.3	-340.5	-359.3	-340.2	-306.2	-285.0	-274.5	-304.0	-320.1	-372.1	-405.4	-456.9
Tunnel Revenue																									
LE SHUTTLE							18.5	195.1	230.1	173.5	313.0	397.7	449.0	433.3	458.4	413.7	370.8	373.7	389.6	408.8	400.7	316.2	339.8	358.5	388.7
RAILWAYS							20.5	216.9	315.1	326.8	316.8	315.5	296.5	295.6	299.4	310.6	304.1	296.8	293.7	214.0	241.0	253.9	244.5	250.3	232.2
Non transport Activities														38.0	27.7	33.5	24.7	14.2	12.1						
Other Revenue							12.5	74.1	167.1	202.7	291.3	206.9	81.2							10.8	12.3	9.8	9.0	8.8	10.5
Euro Porte																							90.8	141.9	170.3
Total Revenue							51.5	486.1	712.2	703.1	921.1	920.2	826.7	766.8	785.5	757.8	699.7	684.7	695.5	633.6	654.0	579.8	684.2	759.6	801.8
Travel time savings																									
Passenger travel time savings							1.7	41.1	69.1	76.6	112.2	122.2	137.7	140.3	138.4	193.5	188.0	198.1	197.4	255.9	241.6	235.2	249.4	291.2	278.0
Freight travel time savings							1.1	5.1	7.3	4.4	9.0	10.5	13.8	14.1	14.2	15.8	16.2	16.2	16.4	17.6	14.5	9.4	12.8	14.0	17.3
Subtotal travel time savings							2.8	46.2	76.5	81.0	121.2	132.7	151.5	154.4	152.6	209.2	204.2	214.3	213.7	273.5	256.1	244.6	262.2	305.1	295.3
Consumer surplus																									
Consumer surplus-accompanied passengers							632.7	465.1	611.5	709.4	783.5	693.4	587.4	525.7	499.6	627.5	722.3	692.4	669.8	730.0	606.7	558.7	728.1	778.0	801.6
Consumer surplus-unitised freight							91.4	120.1	201.4	193.9	252.1	249.0	308.9	375.8	364.9	360.7	376.0	386.6	410.4	426.0	413.3	379.6	391.7	411.2	396.1
Subtotal consumer surplus							724.1	585.2	812.9	903.3	1035.6	942.3	896.3	901.5	864.5	988.2	1098.3	1079.1	1080.3	1156.0	1019.9	938.3	1119.7	1189.2	1197.7

Subtotal benefits							726.8	631.4	889.3	984.3	1156.8	1075.0	1047.8	1055.8	1017.1	1197.4	1302.5	1293.4	1294.0	1429.5	1276.1	1182.9	1381.9	1494.4	1493.1
Total Benefits + Revenue							778.4	1117.5	1601.6	1687.4	2078.0	1995.2	1874.5	1822.7	1802.6	1955.2	2002.2	1978.0	1989.5	2063.1	1930.1	1762.6	2066.1	2254.0	2294.8
Producer's Loss																									
Passenger							0.0	-405.8	-478.6	-506.7	-553.8	-552.3	-575.7	-579.7	-585.7	-694.6	-778.5	-791.4	-788.1	-828.4	-744.9	-713.8	-839.9	-872.1	-883.7
Freight							-142.9	-214.4	-309.2	-140.2	-223.8	-176.3	-255.1	-288.4	-262.2	-294.6	-260.3	-265.1	-211.8	-223.8	-261.5	-286.1	-365.5	-394.0	-448.6
Total Producers' Loss							-142.9	-620.2	-787.8	-646.9	-777.6	-728.6	-830.8	-868.1	-847.9	-989.2	-1038.8	-1056.6	-1000.0	-1052.2	-1006.4	-999.9	-1205.5	-1266.0	-1332.3
Each Year Cost Benefit with Producers' Loss	**-1859**	**-1905**	**-2274**	**-2689**	**-2966**	**-2941**	**-555**	**-102**	**199**	**545**	**805**	**743**	**681**	**537**	**614**	**607**	**623**	**615**	**705**	**736**	**620**	**443**	**489**	**582**	**506**
Year by Year NPV With Producers Loss	**-1796**	**-3574**	**-5626**	**-7969**	**-10466**	**-12859**	**-13295**	**-13372**	**-13226**	**-12840**	**-12289**	**-11797**	**-11361**	**-11029**	**-10663**	**-10313**	**-9966**	**-9634**	**-9268**	**-8898**	**-8597**	**-8389**	**-8168**	**-7913**	**-7699**
IRR With Producers Loss									**-70%**	**-45%**	**-32%**	**-25%**	**-20%**	**-17%**	**-15%**	**-12%**	**-11%**	**-9%**	**-8%**	**-6%**	**-5%**	**-5%**	**-4%**	**-4%**	**-3%**
Year by Year NPV Without Producers Loss	**-1796**	**-3574**	**-5626**	**-7969**	**-10466**	**-12859**	**-13183**	**-12789**	**-12065**	**-11220**	**-10136**	**-9162**	**-8195**	**-7327**	**-6454**	**-5534**	**-4608**	**-3708**	**-2821**	**-1923**	**-1133**	**-456**	**312**	**1121**	**1899**
IRR Without Producers Loss								**-69%**	**-43%**	**-29%**	**-19%**	**-14%**	**-10%**	**-7%**	**-5%**	**-3%**	**-1%**	**0%**	**1%**	**2%**	**3%**	**3%**	**4%**	**4%**	**5%**
Year by Year NPV Just Revenue - Cost	**-1796**	**-3574**	**-5626**	**-7969**	**-10466**	**-12859**	**-13754**	**-13840**	**-13768**	**-13621**	**-13330**	**-13067**	**-12770**	**-12554**	**-12289**	**-12059**	**-11859**	**-11655**	**-11441**	**-11261**	**-11091**	**-10969**	**-10828**	**-10672**	**-10526**
IRR Just Revenue - Cost									**-80%**	**-58%**	**-42%**	**-34%**	**-27%**	**-24%**	**-20%**	**-17%**	**-16%**	**-14%**	**-12%**	**-11%**	**-10%**	**-9%**	**-8%**	**-8%**	**-7%**
Year by Year NPV Financial Appraisal	**-1783**	**-3506**	**-5248**	**-7037**	**-8766**	**-10436**	**-11331**	**-11416**	**-11345**	**-11198**	**-10906**	**-10644**	**-10347**	**-10131**	**-9865**	**-9636**	**-9435**	**-9232**	**-9018**	**-8838**	**-8668**	**-8546**	**-8404**	**-8249**	**-8103**
IRR Financial Appraisal									**-79%**	**-56%**	**-39%**	**-31%**	**-25%**	**-21%**	**-18%**	**-15%**	**-14%**	**-12%**	**-10%**	**-9%**	**-8%**	**-8%**	**-7%**	**-6%**	**-6%**
Year by Year NPV Full Subsidy	**0**	**0**	**0**	**0**	**0**	**0**	**-491**	**-577**	**-467**	**-320**	**-29**	**285**	**582**	**846**	**1112**	**1342**	**1542**	**1746**	**1959**	**2140**	**2310**	**2431**	**2573**	**2728**	**2874**
IRR Full Subsidy									**-59%**	**-26%**	**2%**	**15%**	**22%**	**26%**	**29%**	**30%**	**31%**	**32%**	**32%**	**33%**	**33%**	**33%**	**33%**	**33%**	**33%**

APPENDIX J: Cost Benefit Analysis (Long Term, 3.5% Discount Rate, £Million)

	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085
With Producers Loss																			
CB With Producers Loss	-102	681	615	489	689	748	808	867	926	986	1045	1104	1163	1223	1282	1341	1401	1460	1519
Cumulative CB With Producers Loss	-15291	-12318	-9321	-6329	-3209	414	4333	8550	13062	17872	22977	28379	34078	40073	46365	52953	59838	67019	74497
NPV for each year with Producer's Loss	-77	436	331	221	263	240	219	197	178	159	142	126	112	99	88	77	68	60	52
Year by Year NPV With Producers Loss	-13372	-11361	-9634	-8168	-6896	-5649	-4513	-3484	-2556	-1724	-980	-317	272	793	1254	1660	2018	2332	2607
IRR With Producers Loss		-20.2%	-9.0%	-4.2%	-1.6%	0.2%	1.3%	2.0%	2.5%	2.9%	3.2%	3.4%	3.6%	3.7%	3.8%	3.9%	3.9%	4.0%	4.0%
Without Producers Loss																			
CB Without Producers Loss	519	1512	1672	1694	2044	2281	2518	2754	2991	3228	3464	3701	3938	4174	4411	4648	4884	5121	5358
Cumulative CB Without Producers Loss	-14528	-7783	14	8270	17948	28880	40996	54295	68777	84442	101291	119323	138538	158937	180519	203284	227232	252364	278679
NPV for each year without Producer's Loss	394	967	900	768	780	733	681	627	574	521	471	424	380	339	301	267	237	209	184
Year by Year NPV Without Producers Loss	-12789	-8195	-3708	312	4265	8027	11538	14784	17759	20470	22925	25137	27122	28896	30476	31880	33124	34222	35191
IRR Without Producers Loss	-69.4%	-9.8%	0.0%	3.7%	5.6%	6.7%	7.3%	7.7%	7.9%	8.1%	8.2%	8.3%	8.3%	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%
Just Revenue - Cost																			
CB Just Revenue - Cost	-113	464	378	312	442	494	546	598	650	702	754	806	858	910	962	1014	1066	1118	1170
Cumulative CB Just Revenue - Cost	-15886	-14295	-12364	-10672	-8679	-6313	-3688	-803	2342	5748	9413	13339	17524	21970	26675	31641	36867	42353	48098
NPV for each year Just Revenue - Cost	-86	297	204	141	169	159	148	136	125	113	103	92	83	74	66	58	52	46	40
Year by Year NPV Just Revenue - Cost	-13840	-12770	-11655	-10828	-10015	-9201	-8441	-7737	-7090	-6501	-5967	-5485	-5053	-4666	-4322	-4016	-3744	-3504	-3293
IRR Just Revenue - Cost		-27.3%	-13.8%	-8.4%	-4.9%	-2.7%	-1.2%	-0.2%	0.5%	1.1%	1.5%	1.8%	2.0%	2.2%	2.4%	2.5%	2.6%	2.7%	2.8%
Financial Appraisal																			
CB Financial Appraisal	-113	464	378	312	442	494	546	598	650	702	754	806	858	910	962	1014	1066	1118	1170
Cumulative CB Financial Appraisal	-13033	-11442	-9511	-7819	-5826	-3460	-835	2050	5196	8601	12266	16192	20377	24823	29529	34494	39720	45206	50951
NPV for each year Financial Appraisal	-86	297	204	141	169	159	148	136	125	113	103	92	83	74	66	58	52	46	40
Year by Year NPV Financial Appraisal	-11416	-10347	-9232	-8404	-7592	-6778	-6017	-5313	-4667	-4078	-3544	-3062	-2630	-2243	-1899	-1592	-1321	-1081	-870
IRR Financial Appraisal		-24.9%	-12.0%	-7.0%	-3.7%	-1.7%	-0.3%	0.6%	1.3%	1.8%	2.1%	2.4%	2.6%	2.8%	2.9%	3.1%	3.2%	3.2%	3.3%
Full Subsidy																			
CB Full Subsidy	-113	464	378	312	431	474	516	558	601	643	685	728	770	812	855	897	939	982	1024
Cumulative Full Subsidy	-738	983	2992	4684	6651	8934	11429	14135	17053	20183	23525	27078	30843	34820	39008	43409	48021	52845	57880
NPV for each year Full Subsidy	-86	297	204	141	165	152	140	127	115	104	93	83	74	66	58	52	46	40	35
Year by Year NPV Full Subsidy	-577	582	1746	2573	3375	4161	4884	5544	6144	6686	7172	7608	7997	8343	8650	8921	9161	9372	9557
IRR Full Subsidy		22.2%	31.8%	33.1%	33.4%	33.5%	33.5%	33.5%	33.5%	33.5%	33.5%	33.5%	33.5%	33.5%	33.5%	33.5%	33.5%	33.5%	33.5%