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Expansion Options for the Port of Durban: An Examination of Environmental and Economic Efficiency Costs and Benefits.

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Declaration

I declare that this dissertation is my own work, except where acknowledged in the text, and that it has not been submitted for a degree at any other university.

Sean Ross

Dedication

To my parents, John and Antoinette Ross

I dedicate this dissertation to both of you as an infinitesimally small showing of appreciation from me. You both have through the years, given me absolutely everything for which I am eternally grateful. I may not have been the smartest, kindest, most devoted or hardest working but I have always tried.

Know that nobody could ever ask for more giving and nobler parents. Most people look in books, companies, movies and history to find their heroes and saints. Fortunately, I only have to look in my own home...

Your Son, now and always
Sean

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Abstract

The port of Durban is currently suffering under severe capacity constraints. This has negatively affected efficiency resulting in queuing and berthing delays. If Durban wishes to remain the premier hub status port of the region and Southern hemisphere, then it needs to adequately address the current supply constraints. Shipping vessel operators and owners will not tolerate these inefficiencies indefinitely and if the port does not seek to address the situation, it runs the very real risk of losing patronage in the medium to long term.

The obvious response to the supply side constraint is to increase container handling capacity. This dissertation will analyse the expansion options available to the port in this regard. Beside simply increasing capacity, the port needs to increase draught depth at the berths since container vessels are continually migrating to larger sizes to benefit from economies of scale. A key challenge is the fact that the port serves other purposes beyond that of being a gateway for traded goods such as ecological functions and subsistence fishing. This is compounded by the significant environment degradation which the bay has suffered over the last century or so. The port, however, generates significant economic benefits for the city in terms of economic linkages and employment, and for its wider national and regional hinterland, by holding down the generalised cost of the transport of goods. By not expanding capacity, there are significant opportunity costs for Durban and for the port's wider hinterland. The best way of analysing the benefits and costs of the various options is to conduct a public CBA analysis which monetises and discounts streams of benefits and costs to arrive at a NPV.

Several expansion options are examined and include Bayhead, the old DIA site and Richards Bay. An NPV was calculated for each option where environmental externalities were included. The CBA yielded three options with positive NPV's out of the seven examined. The Southern Access routes, 3CA and 3DA, were both rejected since the effective removal of port sites used presently for the handling and storage of petrochemicals was considered infeasible. One of the Northern Access routes, 1AB, was also rejected since the option yielded a negative NPV. Even though DIA1 had a positive NPV; it was rejected based on mutual exclusivity with option DIA2. Richards Bay was rejected since it had a penalty cost of R89 billion over Durban, due primarily to higher logistical costs. On balance the Bayhead option 1AA and airport option DIA2 were chosen as the projects of choice primarily on the basis of the CBA results. Both these options yielded significantly positive NPV's and the port should seriously look into their construction as they would provide several years of spare capacity as well as being able to accommodate Post Panamax vessels.

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List of Abbreviations:

ARCH- Autoregressive Conditional Heteroscedasticity

ARDL - Autoregressive Distributed Lag

ARIMA- Autoregressive Integrated Moving Average

CBA - Cost Benefit Analysis

CVM- Contingent Valuation Method

DIA - Durban International Airport

DPP- Discounted Payback Period

DOT- Department of Transport

DWT- Deadweight Tonnes

EIA- Environmental Impact Assessment

IEM- Integrated Environmental Management

IRR- Internal Rate of Return

MPB- Marginal Private Benefit

MPC- Marginal Private Cost

MSB- Marginal Social Benefit

MSC- Marginal Social Cost

MPC- Marginal Propensity to Consume

NPV- Net Present Value

SAPO - South African Port Operations

SD- Sustainable Development

SS- Strong Sustainability

TEMPI- Transnet eThekwini Municipality Port Initiative

Teus- Twenty Foot Equivalent Units

TPT- Transnet Port Terminals

TNPA- Transnet National Ports Authority of SA

TCM- Travel Cost Method

UNCTAD- United Nations Conference on Trade and Development

VAR- Vector Autoregressive

WCED- World Commission on Environment and Development

WS- Weak Sustainability

WTAC- Willingness to Accept Cost

WTP- Willingness to Pay

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Chapter One: Introduction

1.1 Introduction

The port of Durban is a vital economic cog in the region in terms of employment and as a gateway for essential goods. However, due to rapid growth in container volumes over the past two decades, the port is facing severe capacity constraints, berthing delays and inefficiencies. The supply side response to the increased demand has been slow and limited. At present, the container-handling capacity of the port stands at around 2.5 million teus[1]. Considering that throughput in 2009 was just over 2.3 million teus, it can be seen that the capacity situation is indeed a desperate one.

1.2 Motivation for study

The obvious solution to the port's lack of capacity is to create additional container-handling capacity. The crucial question becomes the location, cost and benefits of this additional capacity. Investments in port infrastructure are extremely expensive and there are many factors to consider besides the financial cost. There has been much publicity around the uses of the old Durban International Airport site being used as an industrial hub, new airport or conversion of the site into a container-handling port. Added to this is the option of creating additional container-handling berths and terminal space in the Bayhead area of the existing port complex. This has been given much coverage in the confidential Tempi studies. The Tempi report, though, excluded benefit calculations and construction times for the various options.

Based on the above, it was thought interesting to embark on a study whereby, firstly the benefits of the expansion options were calculated and secondly, a CBA study was undertaken which included not only the financial costs but also the ecological ones. As such, the port had to be examined in terms of its environmental contribution to the bay as well as the ecological functions it provided. A suitable discount rate would also have to be determined in order to accurately reflect the streams of benefits and costs. Also analysed was the possibility of Richards Bay becoming the region's principal site for expanded container-handling capacity.

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[1]- Teu is an acronym for Twenty-foot Equivalent Unit and is the standard international term used to signify container traffic volumes. One teu is equivalent to one standard 20 foot freight container.

1.3 Aims and objectives

Objective

The overall objective of this dissertation is to ascertain whether any of the expansion options for the port of Durban are economically viable in terms of a wider conception of costs.

In pursuit of this objective, the principal aims of this exercise are to:

- Examine the current container capacity situation in the port of Durban as well as growth forecasts.
- Examine the economic relevance of the port of Durban to the city and country.
- Examine the various expansion options in terms of financial costs, capacity gained and environmental damage.
- Construct a 50 year Cost-Benefit Analysis and Sensitivity Analysis on the various expansion options which includes an environmental constraint.
- Provide suggestions, based on the CBA results, as to the ranking of the expansion options for potential implementation by the port administration.

1.4 Methodology

The research method undertaken will primarily be of a secondary data type. Various relevant journals and research articles will be collected, through a range of databases, library sources, published resources and websites. This approach is the most practical as there is an abundance of literature on the subject, albeit quite broad in focus. Some interviews were conducted with key colleagues within Transnet Group Planning, from which confidential information was made available.

Secondly, a CBA analysis will be done on the expansion options. The CBA will be a public type approach thereby internalising factors which would be excluded in a private CBA. The options will then be ranked accordingly. Since port marine infrastructure is by its design intended for long term usage, the CBA analysis was done over a 50 year time span so as to present a realistic stream of benefits which would accrue to the port.

1.5 Structure of Dissertation

This dissertation is composed of five separate chapters.

Chapter One provides a broad introduction, sets out the research problem, establishes a motivation and explains the basic methodology to be used in the study.

Chapter Two is the literature review whereby the basic conceptual material that will be relevant for the dissertation is covered. This chapter will lay the theoretical foundation for the central analysis in Chapter Four. Topics introduced here include discounting, cost benefit analysis, maritime economics, sustainability, port economics and general economic theory.

Chapter Three looks at the port of Durban in an economic context whereby the history, capacity, growth models, ecology and significance of the port are discussed. The port's early development and infrastructural changes are presented as well as its migration into a "hub" type port. The container handling capacity is shown and analysed as well as growth models. The ecological importance of the port is discussed whereby the port's role, besides being a gateway for trade, is analysed.

Chapter Four is where the actual CBA calculations are undertaken and where the conceptual base established principally in Chapter Two is applied. These calculations are quite long (each CBA calculation is 2 pages) and as such only a portion of the calculations are shown in the chapter. Benefits and costs are streamed and discounted accordingly to arrive at an NPV for each option. The reader can refer to the appendix for the full calculations. The calculations include the environmental cost of each of the expansion options in an attempt to provide a social outlook and internalise the environmental externalities.

Chapter Five presents the conclusions of the dissertation as well as recommendations. A brief outline of each of the preceding chapters is given so as to aid the reader in the summation of the dissertation. Also presented are the limitations of the dissertation and suggestions for future research.

Chapter Two: Literature Review

2.1 Introduction

The literature review covers theory relevant to the dissertation. It will lay the foundation for the subsequent chapters, by firstly providing a grounding upon which the latter chapters can expand and thus gain more insight. Secondly, it will provide a more concise, holistic view on the topic by exploring and linking various factors relating to the topic. Often, these factors are not obvious and the purpose of the literature review is to bring these factors to the fore.

2.2 Economics of Ports

2.2.1 Economic Function and Purpose of Ports

Ports have been a part of human endeavours for millennia and have functioned as conduits of wealth and prosperity for many of the world's cultures, both ancient and modern. They seamlessly allow trade of necessary, valuable, costly and rare items from otherwise unreachable regions. But what is the definition of a seaport and what is its exact function? Goss defines a seaport as "…acting as a gateway through which goods and passengers are transferred between ships and the shore" (Goss, 1990, pg. 208). Goss expands on the above by later stating that it is in fact too narrow a definition and adds that "the basic function of a port is to minimise the generalised costs of through transport" (Goss, 1990, pg. 210). Goss goes on to state that the economic purpose of seaports is "…to benefit those whose trade passes through them, i.e. through providing increments to consumers' and producers' surpluses" (Goss, 1990, pg. 207). The rest of this section will seek to examine and explain the role and purpose of ports, using the above quotations as starting points.

The demand for the services of ports is a multi-derived function, since ports are not demanded as a utility-satisfying good in themselves but rather as a means to an end. Ports serve a broader function and purposes and, as such, their need is derived from the aptly described "double derived demand". Ports exist only to serve ships and more importantly their cargoes; hence the demand for seaports is closely linked to the demand for shipping services. The first and probably most significant of the demands affecting the shipping function is Gross Domestic Product (GDP) growth, from both a national and international aspect. An increase in GDP is synonymous with an increase in productive capacity which, ceterus paribus would lead to more goods being in circulation. This would result in more goods being exported, via increases in production as well as more goods being imported, due to an increase in local income. More transport space would consequently be demanded to transport the increase in goods, leading to an increase in demand for shipping services. Other factors affecting the demand for shipping function will be examined in the next section, among these being technology and industrialisation (Goss, 1999; Jones, 2002).

Port economics is no different to any other branch of economics in terms of the continuous debate between the neo-classicalists and the reformists. These differing views span over issues such as the economic role of ports, government intervention, employment generation, location, subsidization and pricing too name a few. The Anglo-Saxon or neo-classicalist's have an unswerving faith in the price signalling mechanism of the market and feel that government intervention should be kept to an absolute minimum. Ports are considered as ordinary commercial models and, consequently, profit maximization should be their primary goal. They have a clear preference for ports being self-financed entities whereby users have to pay the full cost of the services they utilise (Goss, 1990). In this light, subsidies are frowned upon, as distorting trade, competition and costs and per se would reduce the scope for efficiency gains. In opposition to this is the European model that subscribes to the reformist or social democratic school of thought whereby profit maximisation is not the primary object and the ports' broader economic impacts are considered to be as important i.e. not more so. The European model acknowledges the presence of market failures such as externalities, public goods and imperfect competition. Government intervention in the form of administration and subsidies is considered necessary since ports are considered drivers of economic activity and precursors to social development whereby employment and infrastructure additions are led by the port (Goss 1990; Jones, 2002). From this angle, ports can be considered to be instruments of regional policy that are a cog in a greater machine that is the economy. Robinson (2002) concurs with this point of view and defines the role of ports as "links in supply chains" which help deliver and sustain value for ships. In line with this thinking pattern is Notteboom & Winkelmans (2001), who state that Port Authorities should move beyond the facilitator role and become a the catalyst to social development by using "value-added logistics" that facilitate greater interaction with the logistic chains of port users.

2.2.2 Port Models

Port models can take varying forms depending on factors such as pricing, administration, industry, structure, and subsidies. Jones (2002) defines ports in a hierarchical format according to their characteristics. The first and most primitive is the industrial port. The characteristics include one commodity shipped, bulk orientation and strong location advantage. The next step of port evolution is the common user port which is more diversified and has more bulk lines and maybe some general cargo. The next stage is that of a liner port which incorporates a more diversified traffic base and multiple terminals. The fourth stage of the evolution is the transhipment hub port which mainly focuses on container operations and can accommodate very large vessels. The fifth and final stage is that of a main port and this version has regional dominance, highly diversified traffic, advanced superstructure and infrastructure, competitive advantage and numerous supporting industries in close proximity to the port. Van Klink (1998) on the other hand defines ports according to four stages of development. The first is that of the port city and here the port is a centre of trade, has little intercontinental transport, is general cargo and labour intensive and there is a limited port authority role. The second stage is the port area and has the port functioning as an industrial complex and is characterised by increased intercontinental trading, increased bulk trade, capital intensive port operations and a limited port authority role. The third stage or port region contains most of stage two plus containerised transport, increased interport competition, increased port authority functions and increased demand for space. The fourth stage is the port network and is envisioned as a hub port in a seamless globalised world that emphasises logistic management, cost reductions, environmental considerations, societal concerns, diverse port ancillary industries and greater network linkages (Van Klink, 1998; Jones, 2002).

Jones (2002) names a three level taxonomy according to port authority control, and these are named landlord, tool and operating ports. The table below illustrates the various port models based on port authority control.

Table 1: Port Types According to Public Ownership

	Control by Port Authority		
Port type	**Infrastructure**	**Superstructure**	**Cargo-handling operations**
Landlord port	Yes	No	No
Tool port	Yes	Yes	No
Operating port	Yes	Yes	Yes

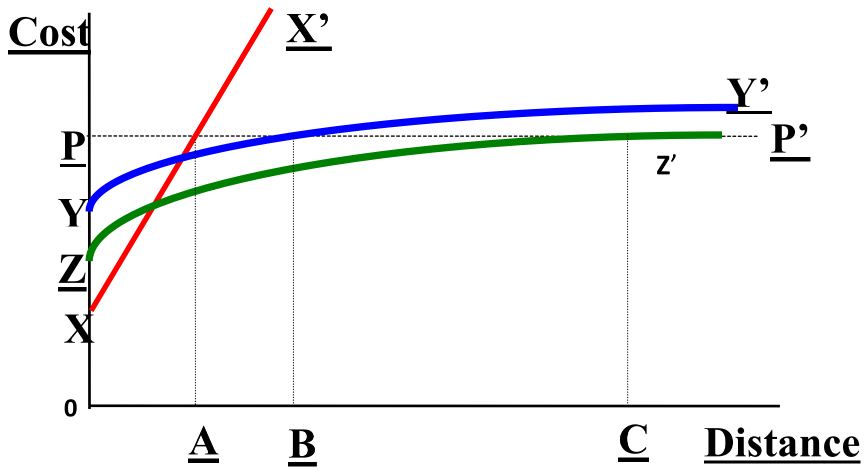
Source: Jones, 2002

In theory, the division between public-private operation of infrastructure and services may seem easy to assign on an economic efficiency and costing basis, however in the real world it is rarely so. The first type of port is that of a Landlord port and it has the most restricted form of public sector involvement. The port authority's jurisdiction covers only the marine infrastructure, which is the seaward side of the quay edge, thus allowing for private enterprise to control landside activities like cargo handling and superstructure, examples include Rotterdam and Antwerp. The second port is a Tool or Hybrid port and is structured so that the port authority controls both the marine infrastructure as well as the superstructure on land. In this model the private sector controls cargo handling and stevedoring and the port authority remains in control of fixed equipment and storage facilities. The last model of port governance is the Operating port where the port authority controls the full range of port activities. Brooks (2004) presents similar port governance models to that of Jones. The one exception is that of the 'private service port', which is described as an entirely private operation. On the international scene, various forms of the above models are incorporated in ports. For example, in the United Kingdom, ports more closely represent a fully private sector model, whereas in South Africa there is far more government intervention (Brooks, 2004; Jones, 2002).

2.2.3 Port Cost's and Efficiency

Total port costs account for only a fraction of the total costs associated with the logistics chain. This combined with the double derived demand phenomena, normally resulting in an inelastic demand schedule for port services and infrastructure with the possible exception of a single port in a competitive environment. By reverting again to a port's primary function of minimising general costs, it can be seen that if a port improves on its efficiency in the form of lower costs, the result will be increased welfare (Goss, 1990). Figure 1 below illustrates how a decrease in costs, or an increase in efficiency, can reduce the cost of sea transport. The red line signifies land based transport cost and the green/blue line signifying sea based transport costs. On the y axis is the cost variable and on the x axis is the distance variable. It is evident that although sea transport has higher fixed costs than land base costs, as the distance travelled increases, so does it become more economical to use sea transport. The green line represents a situation whereby an increase in transport efficiency occurs. As a result of this increase in efficiency, sea transport becomes even more attractive. Even though port costs are a relatively small part of the transport cost chain, they should not be overlooked. Radelet & Sachs (1998) illustrate this point by showing that high shipping costs can decrease the growth rate of manufactured exports and GDP per capita. The authors claim that by doubling the shipping cost, a decrease in annual growth of half a percent is realised (Suykens & Van de Voorde, 1998 and Radelet & Sachs, 1998).

Figure 1: Comparison of Sea and Land-Based Costs



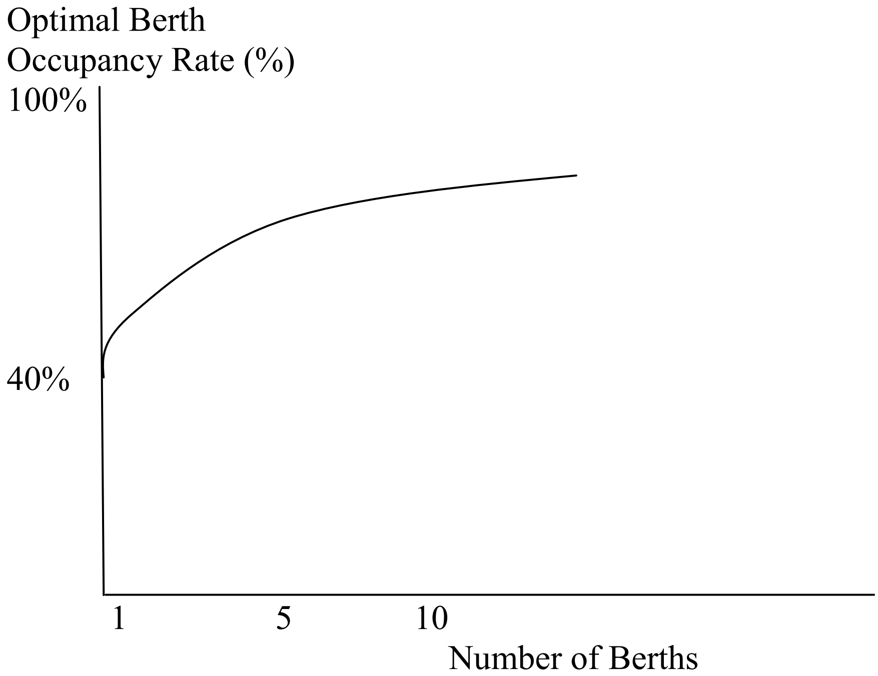
Source: Goss, 1990

Does an increase in port efficiency lead to a decrease in costs and which are the most relevant transport costs? Clark et al (2004) conduct an empirical analysis in an attempt to identify the key determinants of cost in relation to sea transport and ports. The first factor is that of geography or more specifically distance. Intuitively, the further the distance between two locations, the higher the expected transport cost for that voyage, though average cost may decline with distance. The authors find that an extra 1 000 km raises transport costs by 8%. Additionally, travelling an extra 1 000 km by sea increases costs by $190, whereas travelling the same distance by land raises costs by $1 380. The next factor is that of directional imbalance and this occurs when many carriers haul empty containers back, resulting in price distortions and either imports or exports becoming more expensive. An example is given between the USA and Caribbean in 1998, where 72% of containers sent from the Caribbean to the US were empty, resulting in costs that were 83% above average cost for the goods being transported. The maritime sector, like any other economic sector, faces increasing return to scale in the long run. The economies of scale occur both at the vessel level and at the port level. The port of Buenos Aires in Argentina is a prime example of this, whereby the cost of using the port is $14 per container for a 1 000 teu vessel but five times more for a 200 teu vessel at $70 per container (Clark et al, 2004).

The second factor is that of containerization. The development of containerized transport has resulted in large cost reductions in cargo handling and this exhibits a significant positive effect on transport costs. This phenomenon has, firstly, induced an increase in sea transport and, secondly, hastened the creation of hub ports. Both of these reasons further enhance increasing return to scale. The end result is that containerization has led to a reduction in cargo handling and total maritime charges. The availability and quality of land infrastructure is another crucial determinant of transport costs and the authors find that it constitutes 40% of transport costs for coastal countries, and as much as 60% for landlocked ones. Clark et al (2004) use an instrumental variable to capture economies of scale, namely the level of trade that goes through a shipping route. This instrumental variable, exhibits a significant and negative coefficient. Limao & Venables (2001) show that a 10% increase in transport costs is correlated with a 20% drop in volume traded. But what of causality? De & Ghosh (2003) find that improved port efficiency and lowered costs causes improved traffic flow as well as volume traded and not vice versa. Estache et al (2002) establish that ports which operate autonomously performed more efficiently in the short run. The authors state that private port ownership increases productive competition between ports which enhances efficient operation. The authors further illustrate that decentralisation and competition amongst Mexican ports enhanced efficiency. Brooks (2004) concurs with this view and states that privatisation has a propensity to improve efficiency. Clark et al (2004) find that regulations at the port level influence port effectiveness in a non-linear way, implying that a certain level of regulation can be beneficial and increase efficiency, but only up to a point (Clark et al, 2004; Brooks, 2004; Estache et al, 2002; Limao & Venables, 2001).

Bennathan & Wishart (1983) illustrate that as the number of general cargo berths increase, so too does the average occupancy rate. The reason for this phenomenon is the randomness in arrivals of both ships and cargoes. So, as the number of berths increases, the probability or likelihood of a ship finding an empty berth increases, even in high traffic ports. This decreases the waiting time of ships at sea and since ships are chartered on a daily rate, this decreases the ships' opportunity costs. Ports by their nature and, purpose try to gain maximum berth occupancy, whereas ships try to secure minimal waiting time. Increasing the number of berths serves to meet both these requirements more effectively, hence moving the port closer to a Pareto efficient solution. The authors show that a typical 1 berth facility operates at approximately 50% tenancy, a 5 berth facility at 65% tenancy and a 10 berth facility at 80% tenancy. Additionally, a higher numbers of berths have economies of scale effect on port output (Bennathan & Wishart, 1983).

Figure 2: Economies of Scale in Berth Occupancy



Source: Bennathan and Wishart, 1983

2.3 Maritime Economic Theory

2.3.1 Demand and Supply for Sea Trade

At their core, ports exist to service ships with respect to the movement of goods and, thus, maritime theory and ports theory are closely interlinked. The demand for shipping is a derived demand whereby ships are a means to an end, in terms of being a mode of transport for products, and not an end in themselves. Consequently, the demand for ports is a double derived demand since ports exist to service ships and their cargo. As such, maritime economic theory will be analysed with the aim of providing further insight, understanding and clarity on ports. Additionally, the seaborne industry is of particular significance to South Africa since approximately 95% of its trade volume is transported by sea and the country constitutes 6% of global tonne miles (Stopford, 1997; Jones, 2004; Jones, 2002).

As stated above, the demand for sea trade is a derived demand and thus its demand function is determined by a preceding demand, with GDP growth probably being the most significant. Since the mode of preference for the mass transport of goods is the shipping industry, for reasons of cost, speed and predictability, the consequent demand for shipping services is closely linked to that of GDP. The second factor that drastically affects the demand for shipping is the globalization and industrialization process whereby developing countries, undergoing industrial migration and greater trade openness, have an ever increasing demand for raw materials, finished products and semi-finished products. Figure 3 below illustrates the strong growth trajectories of developing countries like India and China as well as the continual growth of most other countries. This bodes well for the shipping industry, since there is a strong correlation between GDP growth and the demand for shipping services for reasons stated above (Stopford, 1997; Jones, 2004).

Figure 3: World GDP Growth Figures 2005-2008

Region/country	2005	2006	2007	2008
WORLD	3.4	3.9	3.8	2.9
Developed economies	2.4	2.8	2.5	1.6
of which: United States	3.1	2.9	2.2	1.4
Japan	1.9	2.4	2.1	1.4
European Union (27)	1.8	3.0	2.9	1.9
of which: Germany	0.9	2.9	2.5	2.0
France	1.9	2.2	2.1	1.6
Italy	0.0	1.7	1.5	0.5
United Kingdom	1.9	2.8	3.0	1.7
Developing economies	6.6	7.1	7.3	6.5
of which: China	10.4	11.1	11.4	10.0
India	8.8	9.2	9.7	7.6
Brazil	3.2	3.7	5.4	4.2
South Africa	5.1	5.4	5.1	4.1
Transition economies	6.6	7.5	8.4	7.4
of which: Russian Federation	6.4	6.7	8.1	7.5

Source: UNCTAD Development Report, 2008

Whereas the demand for sea transport is exogenous, being driven by factors outside its control, the supply of sea transport is endogenous. The most important factor is the size and growth of the world fleet. Shipbuilding is a long and expensive venture and can have a lag effect of between one to four years. In 1970, there was 326 million DWT (Dead Weight Tonnes) of ships available worldwide. This figure has increased to 1 043 million DWT by the beginning of 2007. In 2008, vessel orders were at their highest level ever, culminating in 10 053 on order. The continual addition of new tonnage into the world fleet, at a rate exceeding that which vessels are withdrawn from operation, is the primary factor leading to declining average age of the world fleet. The supply of the world's ships is fairly predictable, since it is not a situation that can change drastically in a short period of time. In recent years the demand supply ratio has been very tight, declining from a surplus of 11.2% in 1990 to 1% in 2005. The financial crisis, though, disrupted the ordering trend since numerous orders have been cancelled and shipbuilders have been focusing on increasing value from existing contracts. However, as a result of the lag effect of construction, many ships could not be cancelled which resulted in shipping supply increasing by 6.7% year on year in January 2009 despite an increase in trade activity of only 3.7% for the same period. This increase in supply, combined with a decrease in demand, resulted in freight rates dropping substantially. The figure below illustrates demand, supply and surplus tonnage of the world merchant fleet and shows the increasing trend in surplus vessels over the last four years. (UNCTAD, 2008; UNCTAD, 2009)

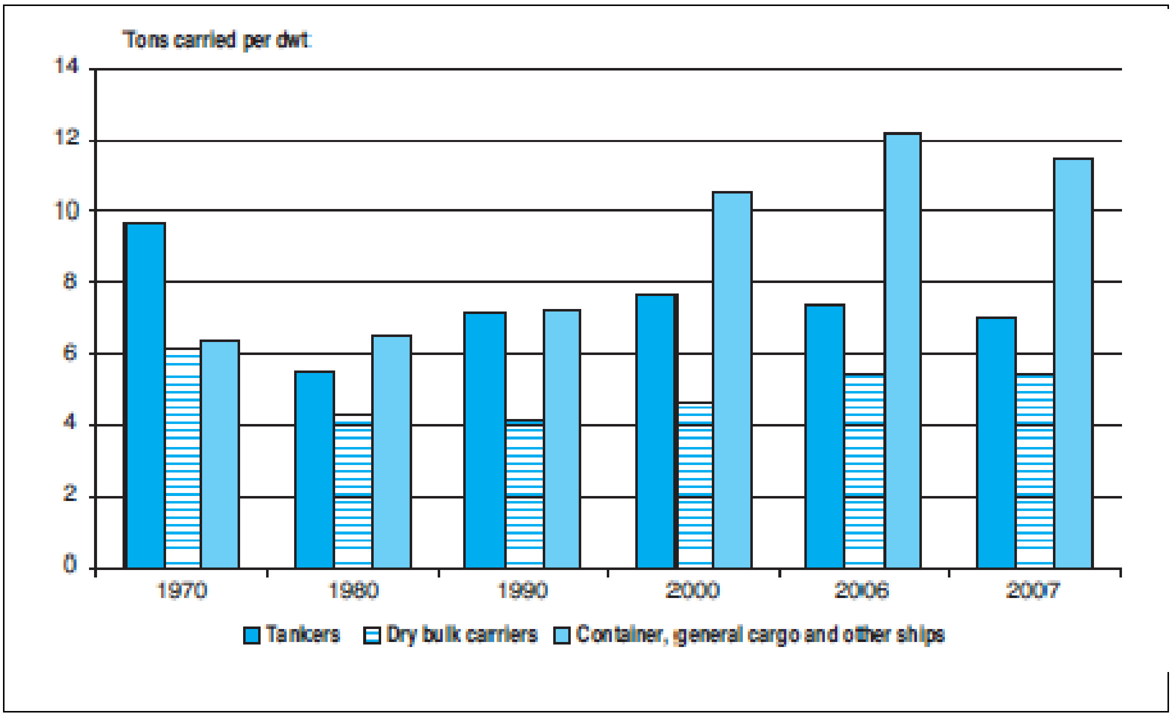
Figure 4: Supply and Demand of World Fleet (selected years)

	1990	2000	2004	2005	2006	2007	2008	1 Apr. 09
	Million DWT							
Merchant fleet, three main vessel types	558.5	586.4	667.0	697.9	773.9	830.7	876.2	896.2
Surplus tonnage	62.4	18.4	6.2	7.2	10.1	12.1	19.0	25.9
Active fleet	496.1	568.0	660.8	690.7	763.7	818.6	857.2	870.4
	Percentages							
Surplus tonnage as percentage of merchant fleet	11.2	3.1	0.9	1.0	1.3	1.5	2.2	2.9

Source: UNCTAD Development Report, 2009

Another important factor is the changing composition for the world fleet whereby, due to various fundamentals, the type of vessels being demanded and consequently being produced, can change from one decade to the next. Over the past few decades, there has been substantial growth in containerised cargo movements. Containerised cargo represented 54% of world general cargo trade in 1999, compared with 48% in 1995 and 37% in 1990. The phenomenal revolution of the container industry is testament to this fact, whereby container growth is expected to reach 287 million teu by 2015. Containers are rapidly becoming the mode of choice especially for heterogeneous and break-bulk goods for reasons of safety, predictability and manageability. The increase in efficiency brought on by containers allows more goods to be transported more often at lower rates. Figure 5 below illustrates the growth in container ships, across all teu classes, for selected years versus that of tankers and dry bulk cargo (UNCTAD, 2008; Stopford, 1997).

Figure 5: Tonnes Carried by Ship Type 1970-2007

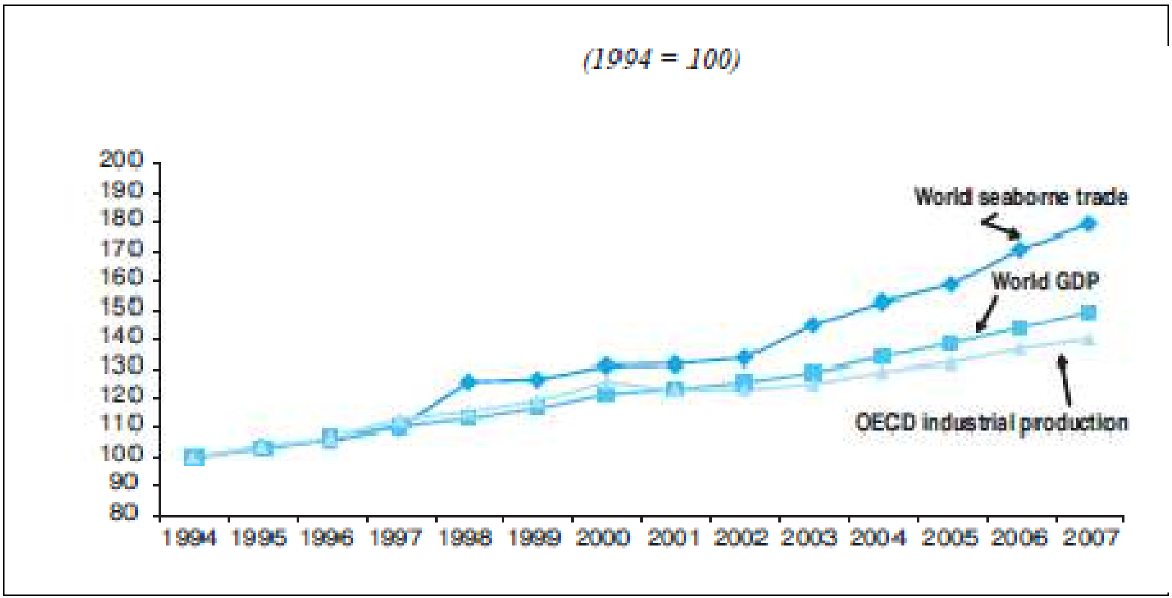


Source: UNCTAD Development Report, 2008

2.3.2 The Growth in Sea Trade

Worldwide seaborne trade surpassed 8 billion tonnes in 2007. This was largely due to spectacular growth of developing economies such as China and India. The strong performance of the world economy over the past few years has more than proportionately affected sea trade growth. The figure below illustrates the strong link between GDP growth and sea trade activity. The year 1994 is the base year, with the preceding and succeeding years being indexed against it. The worldwide recession aka "the credit crunch" resulted in global GDP growing by only 2.5% in 2008 and contracting by -1.7% in 2009, thereby leading to a decrease in trade activity from 4.5% in 2007 to 3.7% in 2008. Since the demand for ships is a derived demand, an international depression would have a negative effect on consumption goods and industrial production and by consequence decrease the demand for shipping vessels (UNCTAD, 2008; UNCTAD, 2009).

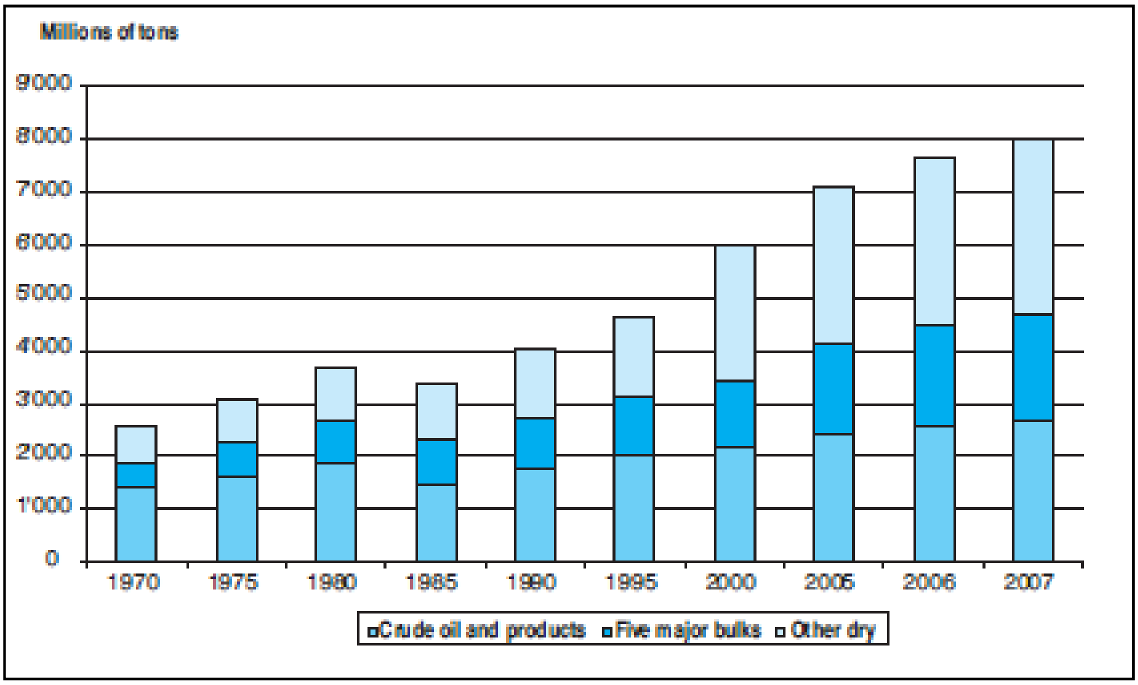
Figure 6: Tonnes Carried by Ship Type Compared to GDP



Source: UNCTAD Development Report, 2008

The 17 years leading up to 2007 have seen a doubling of tonnage transported, from 4 008 million tonnes in 1990 to 8 022 million tonnes in 2007. The figure below illustrates the total tonnage shipped for various years. The trend represented in both the above and below diagram is that of an upward one (UNCTAD, 2008).

Figure 7: Total Tonnage for Selected Years

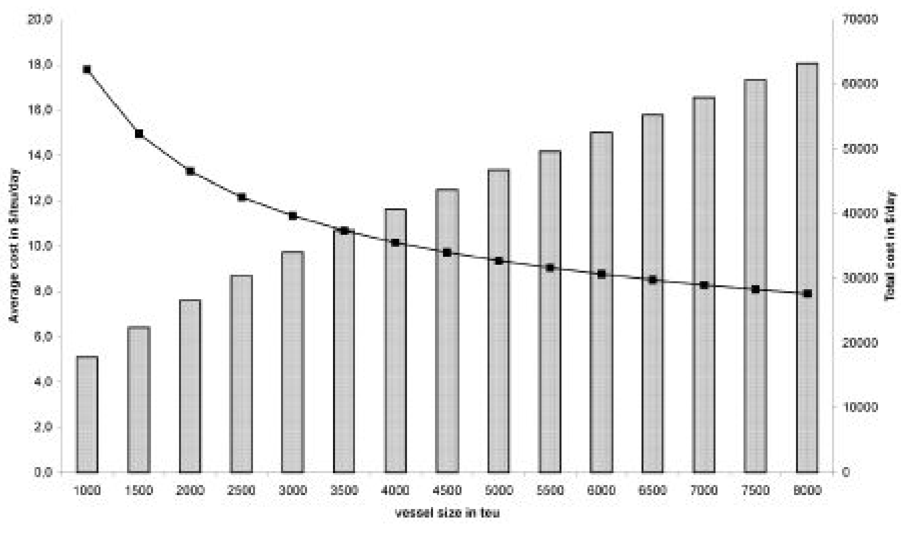


Source: UNCTAD Development Report, 2008

2.3.3 Behaviour of Shipping Costs

The shipping industry is not exempt from economic forces and, consequently can also benefit from economies of scale implying a decreasing LRAC curve, whereby one can lessen the average and marginal costs of vessels operations as the vessel size increases. As a consequence, there is an international trend of increasingly bigger vessels being both ordered and produced, with 36% of all containers ships scheduled to be built being larger than 7 400 teus, with post-Panamax vessels now representing approximately 75.8% on the container ship order book. The reason for the migration to larger vessels is because of economies of scale whereby larger vessels have lower associated average total costs. There is already a 14 000 teu ship, the Emma Maersk, in operation and a South Korean shipbuilder, Samsung Heavy Industries, has completed testing for a 16 000 teu ship (American Shipper*,* 2005). The new breed of larger ships will require specialized infrastructure such as deeper and wider approach channels and berths as well as larger container terminals. The South African Department of Transport has stated that increasing the average vessel size up to 3 100 teu could decrease the costs of sea transport by up to 17%. The diagram below illustrates the falling average costs as a vessel gets larger although, as can be seen, the returns to scale become quite small from the 6 500 teu mark (www.wikipedia.com, 2010; ISL Bremen, 2004; MSA, 1998).

Figure 8: Total and Average costs for Container Ships



Source: Cariou and Haralambides, 1999

2.4 Micro and Macro Economic Theory

2.4.1 Perfect Competition Theory

Perfect Competition is an ideal process in economics where the markets function efficiently. This means that resources are utilised in a way that is Pareto efficient and thus allow an economy to be distributive and rationing efficient. Prices are disseminators of information and guide the factors of production towards society's most beneficial point. The diagram below illustrates what conditions are necessary in order for a state of perfect competition to exist.

Figure 9: Conditions for Perfect Competition

MSB=MPB=MPR=MRC=MPC=MSC

Where: MSB= Marginal Social Benefit

MPB= Marginal Private Benefit

MRP= Marginal Revenue Product

MRC= Marginal Resource Cost

MPC= Marginal Private Cost

MSC= Marginal Social Cost

Source: Tewari and Singh, 1994

If all of these conditions occur, then the result will be an environment of perfect competition. Under perfect competition there are many buyers and many sellers and no economic participant can influence the price level. Additionally, there are no barriers to entry and information is freely available. However, if even one condition is not met the consequence can be partial or total market failure. If free market forces are allowed to interact freely via the price signalling mechanism, then a Pareto efficient situation will, in theory, be reached. Although, when the free market is not functioning properly, social welfare is not maximised and public intervention might be needed. It is important to remember that sometimes not all effects are shown by market prices. This phenomenon is known as market failure, which is a total or partial failure in the price signalling mechanism. The types of market failure analysed will be public goods, externalities and monopolies (Parkin et al, 2006).

An example of a public good is the earth's atmosphere which is a global, open access resource that is both non-rival and non-excludable in disposition thereby making it a public good. In a port context, a lighthouse would be a classic example, whereby one cannot prevent a ship from enjoying its usage and the use of it by a ship does not prevent other ships from using it in the same instance. Because it lacks well-defined property rights, a free rider situation arises whereby the lighthouse can be used without paying compensation. With rights and responsibilities difficult to outline, and agreements a challenge to reach, markets will not develop and, as such, a situation of market failure arises. It may, therefore, fall to governments and other organizations to develop direct interventionist policies for addressing the situation. As the causes and consequences of such change are often complex in nature, effective policies will require extensive cooperation among countries and industries with diverse conditions and priorities. Governments are not immune to inefficiency and may themselves fail to effectively allocate resources. Cross border disputes and interest only further compound this problem, making international cooperation a tricky affair (Stern et al, 2006).

2.4.2 Externality Theory

The next form of market failure is that of externalities. An externality is defined as a cost or benefit, arising from the production/consumption of a good or service, which is accrued to someone who is not directly involved in the production/consumption of that good or service. Externalities can be broadly divided into two sections, namely negative externalities and positive externalities. Negative externalities or external diseconomies impose an external cost on individuals who are not directly involved in that activity. An example of a negative externality is that of an individual smoking a cigarette and nearby people having to breathe second hand smoke. Positive externalities or external economies impose an external benefit on individuals who are not directly involved in that activity. An example is that of one's neighbour employing a security guard, which will undoubtedly benefit both their safety needs (Pearce, Hamilton & Atkinson, 2002).

External costs can be detrimental to global economic, social and environmental optimisation goals since they prevent market mechanisms from operating efficiently by interfering with price signals. Economists, in the context of sustainable development goals, increasingly acknowledge the relevance of recognising, assessing and internalising external costs. In a purely competitive market, where externalities do not exist, prices represent the instrument for efficient resource allocation, both on the production and consumption sides of the economy. External costs resulting from market imperfections, as is the case for clean air and fresh water, prevent optimal resource allocation. Market prices cannot give the right signals to economic agents and policy makers as long as externalities exist. The equations below describe the notion of externalities in mathematical for (Pearce, Hamilton & Atkinson, 2002).

From the below figure, the following equations can be derived:

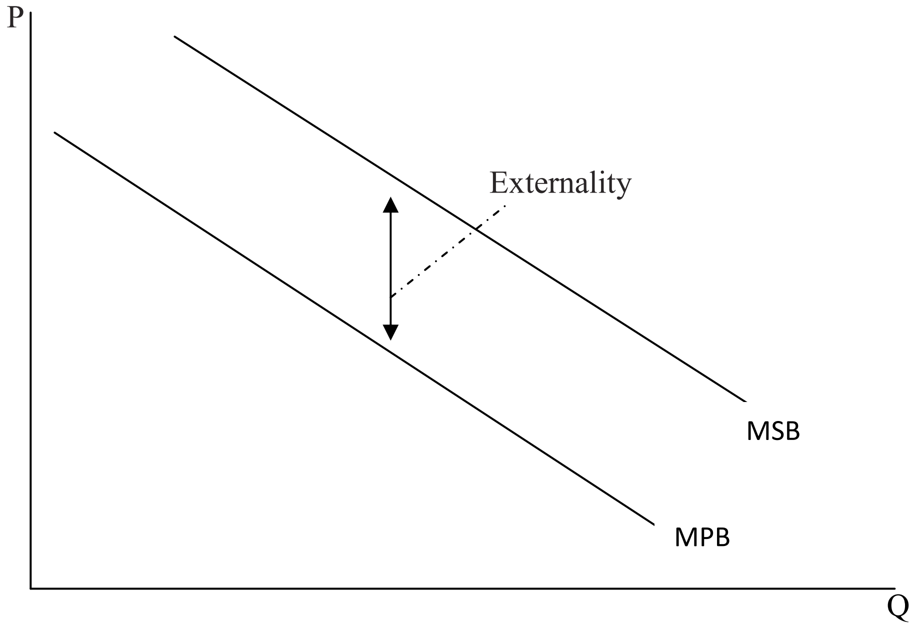
MSB= MPB + Externality (E) (1)

and

MSC=MPC+ (E) (2)

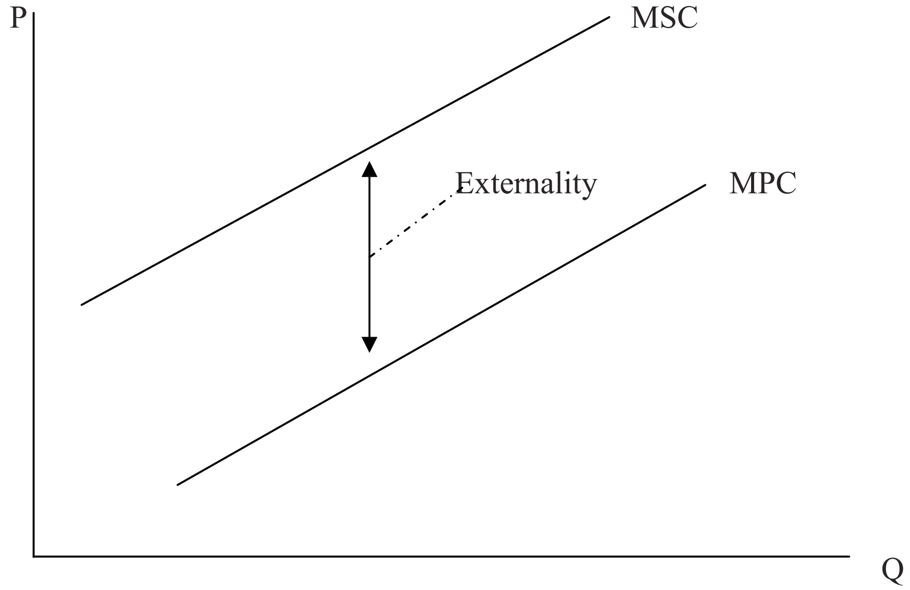
Equations (1) and (2) are two conditions that pertain specifically to externalities. Equation (1) pertains to externalities in consumption and shows that an externality exists when MSB exceeds the MPB. However, if there are no externalities involved then MSB=MPB. A consumption externality is illustrated in the diagram below, where it is assumed that the externality is constant and therefore does not vary with output.

Figure 10: Consumption Externality



Equation (2) pertains to externalities in production and shows that an externality exists when MPS exceeds MPC. This is related to the true cost reflection for a product or service. If the free market is operating efficiently, then MSC=MPC, however if there is market failure then an externality will exist equal to MSC less MPC. The figure below illustrates the difference between the MSC and MPC.

Figure 11: Production Externality



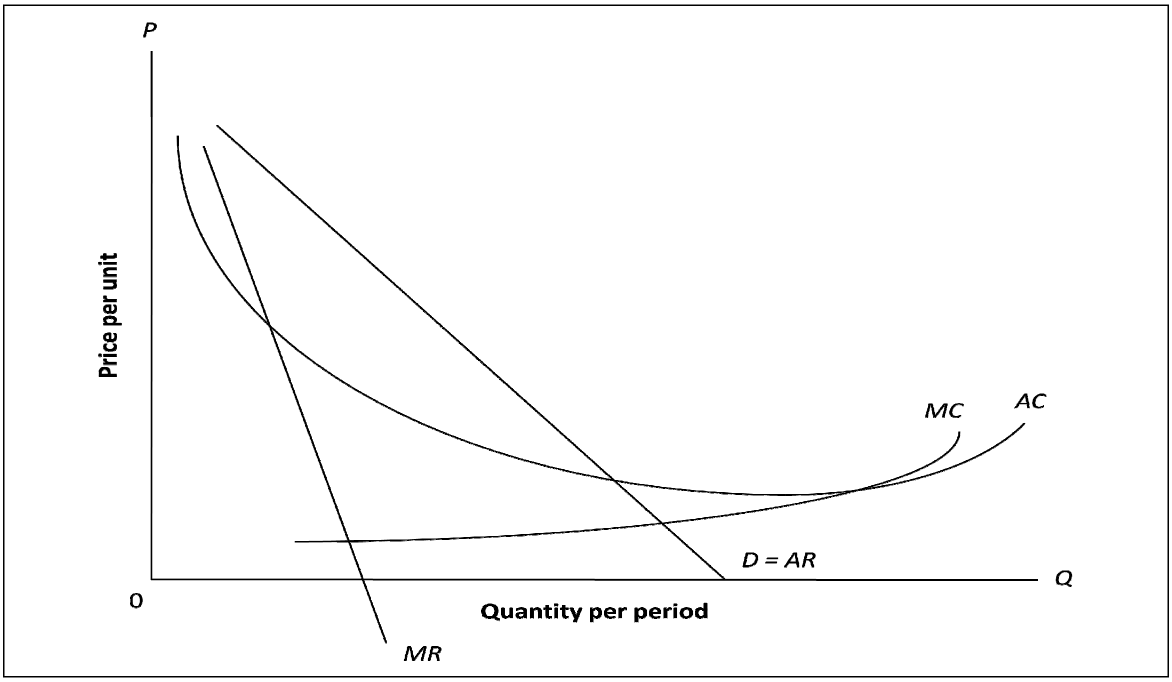
Thus, social costs are comprised of private and external cost and represent a true account of the cost of a good or service. External costs are the uncompensated side effects of a good or service but are nonetheless relevant.

2.4.3 Monopoly Power

The last form of market failure is that of a monopoly or single firm. The key defining point about a monopoly is that it has absolute market power and can practice selling products at a point where the price exceeds the marginal revenue and more importantly marginal cost. All firms produce at an output point where marginal revenue is equated to marginal cost. In a perfect competitive setting, this point coincides with price being equal to marginal revenue which in turn equals marginal cost. However, in a monopoly setting, this point coincides with price exceeding marginal revenue and hence marginal cost. This enables it to earn abnormally high profits which decreases social welfare. The two primary reasons that allow a monopoly to operate are barriers to entry and no close substitutes. Barriers to entry are factors which make it difficult for other firms to operate. These are wide ranging and could be anything from financial factors to legal constraints. No close substitute simply means that a firm has a unique product and for some reason other firms cannot imitate this product (Parkin et al, 2006).

A special form of monopoly that sometimes arises is that of a natural monopoly whereby the long run average cost curve is beneath the demand curve for the entire region of operational output i.e. there are economies of scale for the entire region of output. In addition this, the long run average cost curve is above the marginal revenue curve and marginal cost curve. This means that a single firm can supply the entire market at a lower price than two or more firms operating under perfect competition conditions. Consequently, a natural monopoly experiences economies of scale at every point along the demand curve. Examples of natural monopoly industries include electricity, telecommunications and marine infrastructure in ports. Conditions which bring about a natural monopoly are primarily high fixed costs and examples in a port include breakwaters, berths and approach channels (Parkin et al, 2006; Bennathan & Wishart, 1983).

Figure 12: A Natural Monopoly



2.4.4 Keynesian Multiplier

The distinction between the short and long run is an important theoretical consideration in economics. The long run has all inputs as being variable whereas the short run has at least one input as being fixed. There are no criteria for the time duration of the long and short run and this transition period can be as little as a year or, as in the case of ports a 100 years or more (Jones, 2004).

A useful short-run tool that can help quantify the final income amount from an initial investment or spending impetus is called the Keynesian multiplier. The ratio between the eventual change in income and the initial investment is called the multiplier. The size of the multiplier depends on the fraction of the additional income generated in each round that is spent in the next round and this fraction is known as the marginal propensity to consume. As will be shown in Chapter Three and Chapter Four, the construction of a multiplier is often an important step in economic impact studies. The box below illustrates the mathematical equation of the Keynesian multiplier. It is important to understand the philosophy behind Keynesian economics and the consequent application of it. Keynesian economics is based in a world of excess supply, underutilized resources and where the price level is fixed or at the most, very slow to adjust. Additionally, demand is deemed to create supply which is in direct opposition to Says Law. With prices fixed, it remains in the realm of the short run world. Subsequently, an increase in investment or spending can be multiplied throughout an economy without prices adjusting to maintain market equilibrium. There are few trade-offs to an increase in spending or investment in the short run world and the short run supply curve is very elastic (Parkin et al, 2006).

Figure 13: Keynesian Multiplier

$$Yo = \frac{1}{1 - c(1-t)} (C + I + G)$$

Or more simply,

$$Yo = \alpha A$$

Where:

Yo - Equilibrium level of income

α – Multiplier

t-taxes

A -Total autonomous spending

C-Consumption I-Investment G-Government

c- Marginal propensity to consume

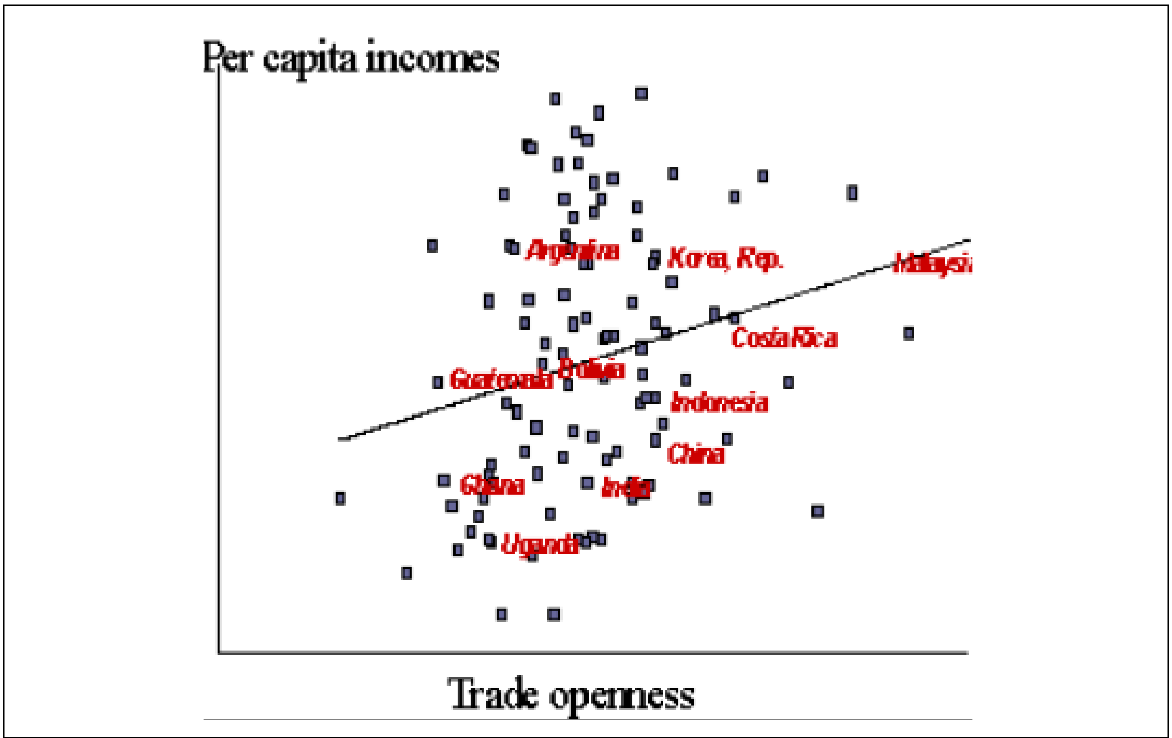
Source: Parkin, 2006

2.4.5 Trade Liberalisation

Though not essential for the purposes of this dissertation, the concept of trade liberalisation provides a further contextual framework in which one can analyse the port. Decreased tariffs and quotas have definitely been prominent in post apartheid South Africa and by deduction, this would have led to cheaper goods and consequently more demand. Tariffs are defined as a tax on importing a good or a service, thereby artificially increasing costs, for an economic or political objective. In an increasingly globalised and liberalised world, taxes on trade are definitely decreasing and South Africa is no exception to this trend. Between 1994 and 2002, South Africa reduced its average tariff rate from 11.7% to 4.9%. Complementing these tariff reductions was a focus on exports as a mean to decrease poverty in South Africa (Cassim, 2002). It is not hard to fathom the link between trade, shipping and ports and, as a result, trade liberalisation is an important topic with regards to a country's maritime sector. Whether trade liberalisation benefits or harms an economy in a dynamic way is beyond the scope of this dissertation but a brief analysis of trade theory will be undertaken. Trade liberalisation is a highly contested area of economics with numerous opponents and supporters on both sides of the debates. Intuitively, trade allows an economy to be more efficient since with no trade a country must be self-sufficient and must then maximise its wellbeing based only on local production. Thus trade increases a country's production possibilities. The reduction in tariffs encourages more trade which consequently promotes the flow of raw materials and finished goods. Additionally, the process of globalisation encourages and aids the sourcing of materials from around the globe. These goods need a cheap, efficient mode of transport and that is where the sea transport industry fits in (Bhagwati, 2004).

As shown previously, growth in GDP is the primary driver of the demand for sea trade since the demand for sea trade is a derived demand. Consequently, if trade liberalisation can be shown to be growth inducing, then this will increase the demand for ships as well as ports. There are many economists who view trade liberalisation as growth inducing and some of their papers will now be discussed. The results of Frankel and Romer's (1999) tests show that trade opening raises income. A rise of one percentage in the ratio of trade to GDP is shown to cause a one-half percent increase in income. Income is positively affected through the accumulation of physical and human capital. The possibility of reverse causation, from growth to trade, is eliminated by the use of instrumental variables. Sachs & Warner (1995) examine the experience of countries that have liberalised their trade since 1975, and conclude that higher growth occurs two years after liberalisation relative to the pre-liberalisation years. Harrison (1996), using time series data finds that openness is indeed a robust and significant factor in relation to growth. Strong and continuous liberalization periods produce rapid growth of exports and real GDP. Dollar (2001) shows that increased trade is related to accelerated growth. He controls for changes in other policies and addresses reverse causation with internal instrumental variables. Overall, there seems to be sufficient evidence that trade liberalisation does indeed cause growth. The diagram below, as taken from a World Bank study, shows the close positive relationship between trade and growth (Sachs & Warner, 1995; Harrison, 1996; Dollar, 2001; Frankel & Romer, 1999).

Figure 14: Trade Openness and Per Capita Income



Source: World Bank, 2002

2.5 Sustainable Development

2.5.1 Defining Sustainable Development

There are many definitions of sustainable development (SD) but the one used for this dissertation, is the 1987 statement by the World Commission on Environment and Development. The statement is as follows: "Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Mason, 1988, pg. 8). Thus, if non-decreasing welfare is maintained throughout time periods or generations, with a given stock of factor endowments, then a sustainable path can be identified. The report emphasised that significant and internationally threatening environmental problems were the joint consequence of poverty in the developing world and excessive consumption in the developed world. Issues of intra- and inter-generational equity were introduced, whereby intra-generational equity is equity within generations and intergenerational equity is equity between generations (Mason, 1988).

Additionally, the commission stated that the escalating threats and consequences of development on the environment could not be solved without considerable international collaboration. It stated that the future welfare of developed countries was not only dependent upon them changing their development path towards more sustainable practice, but would fail unless developing countries were also prepared to adapt and make the necessary changes. The commission believed that the global economy had to meet people's needs and desires, but growth had to simultaneously engage with the planet's limits and carrying capacity. The report identified two key concepts: Firstly, the needs of the poor should be a priority and policy should not further disadvantage them; the second point was the idea of limitations that technology and social organization impose on the environment's ability to meet present and future needs (Mason, 1988).

Another way of looking at the sustainable development approach is the term *"security of intergenerational access to resources."* The meaning of intergenerational is quite clear in the South African context where the resources in question are for the benefit of both the present and subsequent generations. Security refers to a reasonable certainty that the future will not involve a significant reduction in people's access to resources. Access implies three qualities: that the resource remains available in terms of both sufficient quantity and quality; that the people can use it as needed or to the same extent as in the past and that equity exists in regulations governing its use and distribution. Resources, means natural resources such as bays, mangroves, streams, lakes, agricultural lands, fisheries or anything in nature that has or could have a productive potential and/or provide ecological services (Pearce, Hamilton & Atkinson, 2002).

Though Sustainability Theory is quite broad in scope, it can be broadly divided into two approaches, namely the neoclassical approach and the Ecological approach. The neoclassical approach will be presented first, followed by the ecological approach.

2.5.2 Different Approaches to Sustainable Development

The Hartwick rule is considered a suitable starting point for the neoclassical approach and was devised by John Hartwick in 1977. The rule guarantees non-declining consumption through time when an exhaustible resource, such as coal, uranium, forestry and gas is utilised in the production of a good or service. The rule states that as long as the stock of capital is non-decreasing through time, then non-declining consumption was also possible. The stock of capital could be held constant by reinvesting the rents received from the natural capital stock into man-made capital stock. Thus, as the natural capital stock falls the man-made stock replaces it. The rents received are stated to be Hotelling rents whereby rent increases at the current rate of interest and a single distinctive path will maximize social well being. This distinctive path is found by using the terminal condition, which will ensure that the stock is efficiently extracted over time so that none is left and the stock constraint (Hanley, Shogren, & White, 1997).

The assumptions of the Hartwick model are, firstly that natural and man-made capitals are perfect substitutes. This implies that the elasticity of substitution is equal to one. Secondly, as the natural resource depletes we can use continually smaller quantities of it assuming of course that technology improves. This implies that as the amount of non-renewable resource decreases to zero, its average product goes to infinity, thus creating a situation where natural resource exhaustion does not act as a restraint on growth. Also, preferences are determined exogenously in the model and market prices are assumed to operate as accurately as disseminators of information across time. This approach presupposes that as long as there is a proper functioning price-signalling mechanism and a free interaction of buyers and sellers then scarcity will be reflected by prices in the economy. The last assumption is that discount rates are positive (Hanley, Shogren, and White, 1997).

Given the above assumptions that man-made and natural capital are infinitely substitutable, the Hartwick or Neoclassical approach is usually termed the weak sustainability (WS) approach to Sustainable Development. WS focuses on maintaining the overall stock of capital, irrespective of whether it is natural or man-made. The degree of substitutability of natural and man-made capital is the key principle, which clearly separates the weak and strong sustainability (SS) approaches (Hanley, Shogren, & White, 1997).

Any economist who generally shares a reservation regarding the standard neoclassical interpretation of SD would likely fall into the ecological school of thought. They represent a loosely assembled body of thoughts and ideas that criticize the inability, or perceived inability, of the neoclassical school to integrate ecological essentials into their welfare measures. The common thread uniting the alternate approaches is the perception that the neoclassical approach has too many impractical assumptions. The ecological school proposes that the extraction of a non-renewable resource should be synonymous with substitute development and reinvestment, in strict accordance with the Hartwick rule for non-renewable resources. Ecological economists do not view capita as a homogenous entity and focus on non-declining *natural* capital, as opposed to man-made capital, to achieve SD. A greater sense of caution is emphasised under this approach, since there is a high level of ignorance about how ecological systems work, thereby increasing the risk of causing irreversible damage. The crucial difference between the ecological approach and the neo-classicists is the level of substitution between man-made and natural capital (Hanley, Shogren, & White, 1997).

The ecological school of thought also wants to keep the stock of capital constant through time, but they emphasis the constant use of natural capital. According to ecologists, natural capital is different to man-made capital because some assets are essential for human life and well being and cannot be replaced by man-made capital. Capital that is of high importance is given the name, critical natural capital. Because of this, the ecological approach is labelled as the SS approach, since man-made and natural capital are not perfect substitutes and under some circumstances can even be considered complements. The reason the school is more concerned about non-declining natural capital is the perception of irreplaceable natural capital. By safeguarding this critical natural capital, the future generation is not disadvantaged in terms of natural resource availability, thereby protecting against irreversible ecological damage. SS also stresses a discontinuity about many ecological functions as well as the external costs realised through environmental stress. Thus, SS is concerned with maintaining critical components of the natural capital, in conjunction with the overall capital level. Other assumptions of the ecological school are that discounting is unethical and that the environment should not only be viewed as an input but also as a source of utility in itself (Hanley, Shogren, & White, 1997).

2.5.3 Discounting

Discounting is an important element of sustainable development theory as well as other branches of economics such as Cost Benefit Analysis and Econometric Forecasting. In the context of this dissertation, it will be seen that various discount rates are used in the cost calculation process. Thus, a basic understanding of the logic and application of the discounting process is needed.

Discounting is an extremely contentious issue because of its broad scope of application, which can include aspects of ethical, philosophical and economic particulars. These aspects can involve the environmental and resource needs of both present and future generations. To understand the process of discounting properly, one must first grasp the concept of compounding. Compounding is the process whereby an initial amount, a principle, is grown by a certain interest rate and where the interest earned on the initial investment is continually reinvested (Pearce; Hamilton & Atkinson, 2002).

The discount rate is, in essence, the reversal of compounding. It involves obtaining the present value from a future value. Discounting allows a comparison of two different future values, whereby they are both discounted to their present value, and then compared directly. It is thus, the rate used to calculate the present value of future cash flows. By ignoring discounting, a loss or benefit in the present is valued the same as a loss or benefit in the future. In addition to this, the higher the discount rate the less the future is valued (Pearce; Hamilton & Atkinson, 2002).

There are two reasons for discounting, namely the Social Opportunity Cost of Capital (SOC) and the Social Time Preference Rate (STPR). The SOC states that because capital grows over time, people will be expecting some form of additional compensation if they are to forgo current consumption. By implication, the SOC approach means that we could invest an amount equal to the present value of future cash flows and if it accrues at the current interest rate, the future and present values will be the same. Thus, the SOC is simply how much society benefits from saving in the present in order to gain higher utility in the future. The second reason for discounting is that of STPR. It is generally considered that people have a preference for present consumption as opposed to future consumption. The reason is based on the uncertainty of one's life span. Thus, it would be logical to maximise one's utility now, since there is no guarantee of our existence tomorrow. Since we only have one lifetime, this approach would be rational. However, since saving is merely delayed gratification, people expect to be compensated for not consuming in the present. Accordingly, it can be seen that the preferences of people are crucial since it dictates their behaviour and we cannot just ignore them. If people's preferences can be shown to be important, then it can be stated that people prefer the present to the future. Society as a whole also has a time preference; it is simply the cumulated time preference rate applied to individuals and then averaged. However, this is more than just a pure time preference and may be a sign of a concept that future societies will be richer than the present day societies due to among other things technological improvements and GDP growth. Thus R1 gained today is worth more in utility terms than R1 gained in 10 years time. We thus have a situation of diminishing marginal utility of consumption and this forms another reason for discounting (Pearce, Hamilton & Atkinson, 2002).

There are, however, objections to using discounting when appraising investments. The higher the discount rate, the more society favours the present as opposed to the future. By this reasoning, many advocate lowering the discount rate as a means of being considerate of future needs. Models that are said to account for future generations' utility are more accurately accounting for what the current generation believes is important. It is argued is that investment now should be done with the goal of allowing future generations the maximum scope of choice. The problem is then how to ensure the future's utility is not negatively affected. One view of countering this problem is to purposefully lower the discount rate. The question thus becomes, by how much should the discount rate be lowered? One argument is to install a zero discount rate, so that consumption today will be valued the same as consumption tomorrow. This approach seems illogical because it takes no account of the opportunity cost of capital or time preference theory. A negative discount rate would also be nonsensical, since consumption would be continuously postponed for future generations (Pearce, Hamilton & Atkinson, 2002).

Since discount rates are primarily determined by the interaction of current market forces, they are said to reflect current generation needs at the exclusion of the futures needs. However, the opposite side of this argument states that the determination of interest rates is reflected by the preferences of economic agents, who may have a innate concern for the future and that will be reflected the current decision making process. Therefore, lowering the discount rate will be a pointless exercise, since we are already considering the future with the current interest rate. Another argument against lowering the discount rate would be the effect on consumption that it could have. Since consumption is inversely related to the interest rate, lowering it could lead to increased current consumption at the expense of the future. Also, the current interest rate is determined by the monetary authorities or the Central Bank. They use it as a targeting tool, normally to keep inflation under control, but also in some cases to manipulate the exchange rate or to affect employment. Thus, interfering with the discount rate to manipulate consumption for the future could be counterproductive and cause havoc in an economy. Environmental economists are often very critical of discounting; stating that it discriminates against future generations, since the higher the discount rate the more a future cost is reduced. A common example is that of decommissioning a nuclear power plant. If the cost is estimated to be R1billion today, then, depending on the discount rate employed, the amount in 50 years can be quite miniscule. The figure below illustrates the powerful influence discounting can have on a projected cost (Bruggink & Van der Zwaan, 2001; Sinden & Thampapillai, 1994).

Figure 15: Discounting Example

At 5%

$$\frac{R1{,}000{,}000{,}000}{(1.05)^{50}} = R87{,}203{,}726$$

At 10%

$$\frac{R1{,}000{,}000{,}000}{(1.1)^{50}} = R8{,}518{,}613$$

Goodin (1982) more succinctly explains the above with the proposition of four reasons for discounting. These are broadly listed as psychological, uncertainty, diminishing marginal utility and the opportunity cost reasons. The psychological reason is defined as "people's psychological propensity to attach less importance to future payoffs" (Goodin, 1982, pg. 54). The next approach is that of the uncertainty reason, which states that uncertainty is closely linked to temporal distance. Thus, as a future benefit or cost becomes further away in time, there will be less certainty of its magnitude or impact. The third reason is that of diminishing marginal utility and is based on the concept that an economy is dynamically efficient and, as such, will always have positive GDP growth. Hence, future generations will be always be better off than current generations. As a consequence, the current, poorer generation will obtain more fulfilment from the consumption of a good or service than the future, richer generation since they have less. Because of this, saving, which is merely delayed consumption, should be discouraged since it would further cause inequality between the future and the present. The fourth approach is the opportunity cost reason which asserts that the discount rate is "the opportunity cost in terms of the potential rate of return on alternative uses on the resources that would be utilised by the project" (Goodin, 1982, pg. 58). Thus, it is necessary that the rate of return on a CBA is greater than the opportunity cost of undertaking that project or else the project should be rejected since higher returns would be available elsewhere in the market (Goodin, 1982).

2.6 Cost Benefit Analysis

2.6.1 The CBA Process

Due to the scarcity of resources and infiniteness of wants, decisions must be constantly made between which goods and services are to be produced. Many of these decisions have far reaching and complicated consequences across time and space. One way of assigning weightings to various gains and losses is via the Cost Benefit Analysis (CBA) process. CBA is an economic tool that is used to evaluate the economic merits of a particular project. CBA is intended to improve the quality of public or private policy decisions, by assigning a monetary figure to the aggregate change in individual or societal welfare. This dissertation will comprise two distinct sections. Firstly, the CBA process and its rationale will be discussed and explained. After which, road accident literature will be examined with emphasis on the CBA approach.

CBA entails the appraisal of an investment whereby benefits and costs are assigned monetary values. CBA project evaluation can be broadly divided into economic or public and financial or private analyses. A financial CBA uses market prices as its benchmark whereas an economic CBA include the total economic value of the effects that a project has such as externalities and opportunity costs. In addition, an economic CBA also includes direct and indirect effects in the hope of providing a fuller economic analysis. Neoclassical welfare economics appraises developments on the basis of changes in net social welfare, which implicitly assumes that societal welfare is the aggregate of all individual welfares and that welfare can in fact be measured. Additionally, with a constrained income, individuals choose a basket of goods that maximises their utility or welfare i.e. they are rational. It is normally also assumed marginal utility of income is identical for all individuals, whereas often in reality, the marginal utility of income normally decreases as income rises (Kopp, Krupnick & Toman, 1997).

The CBA process can be broadly divided into four areas. These are: the identification of costs and benefits, valuation of each cost and benefit, discounting future streams into present value terms and finally calculating the net social benefit using a suitable investment criterion. In the initial phase of identification various benefits and costs are only included if they are extra outcomes of the project. That is to say, if their effects would occur only if the project was embarked on, then the outcomes should be included in the analysis. Sunk costs are those that were incurred before the project and do not change the net social benefit of new projects. As a consequence of this, sunk costs are excluded from the analysis. By the same token, fixed costs are also excluded from the analysis, since they apply to all alternatives under consideration. With regards to costs, all changes of costs, both negative and positive, must be included. Importantly, a benefit may arise from a project in the form of reduced costs and vice versa. In all cases, it is necessary to ensure that the costs included are truly opportunity costs rather than just transfer payments since transfers do not measure benefits/costs from goods or services. Double counting is also an issue that must be avoided and occurs when an impact of a project can be measured in two or more ways. In all cases it is necessary to ensure that the costs included are truly opportunity costs rather than just transfer payments since transfer payments do not measure net social benefit from costs and benefits. Taxes and subsidies are market distortions that can artificially lower or raise the market price of a good or service. However, the decision to exclude or include them is project specific. CBA can be used both in the private and public domain but with differing applications and perspectives. In a public CBA externalities are included but not in a private CBA. The public CBA focuses on societal well-being whereas the private CBA focuses on firm/individual welfare maximisation (Sinden & Thampapillai, 1994).

Once all the costs and benefits have been identified, the next step involves converting them into monetary measures. CBA indicates that an investment should be undertaken if the benefits are larger than the costs. In order to compare benefits and cost, all factors must be converted to a common scale, which is usually monetary. In a competitive market, prices are disseminators of information and indicate the true worth of a good or service. When market prices govern customers' purchases, it reveals that their willingness to pay (WTP) for a good and that that good is at least as valuable to them as the money they abandon. The utility gained from a good by the individual concerned is the maximum he or she would be WTP for the use or ownership of that good (Sinden & Thampapillai, 1994).

Consumers will increase their consumption of a good or service up to the point where the benefit of an extra unit is equal to the marginal cost to them of that same good or service. The marginal benefit will decline with the amount consumed, since the utility gained decreases as the amount of that product increases. The market's answer to this is to decrease prices to allow consumers to obtain a greater quantity of the commodity. This association between the market price and the quantity consumed is illustrated by the demand schedule or the WTP. This makes the CBA process easier since all values are already in the form of their true economic worth. Under a market situation, Pareto efficiency is guaranteed since trade is governed by choice and no rational person chooses to become worse off. However, not all goods have market prices and the term to describe this situation is market failure. Examples include the atmosphere, oceans and human life (Sinden & Thampapillai, 1994).

A public CBA analysis, as shown above, includes externalities and, as a result, the total economic value (TEV) that a project has on society as a whole, irrespective of it being reflected in the market or not, is measured and analysed. Sometimes, due to market failure, market prices do not reflect accurately or completely and therefore cannot be used directly for valuation. When this occurs, it is sometimes possible to use surrogate market techniques. Goods without market prices cannot be excluded; since the lack of an organised market does not imply that consumers place no value on them but rather that there is a failure in the price signalling mechanism. Selecting an appropriate valuation technique depends on many factors, including the project to be valued and the availability of financial resources, data, model and time. The primary objective is to identify all the effects of the relevant project, value them correctly and then incorporate the stream of their benefits and costs into the analysis (Sinden & Thampapillai, 1994; Kopp, Krupnick & Toman; 1997).

2.6.2 Surrogate Market Techniques in CBA

Unfortunately, market prices are not always available due to externalities, monopolies and a lack of well defined property rights. Some of the non-market valuation methods will now be discussed. This process can take many differing routes depending on data, the econometric model and status of the commodity or resource being analysed. The final model choice will depend on various factors such as direct value, indirect value, options value, single observation, group observation and existence value. An important starting point to the concept non-market values is the concept of WTP and willing to accept compensation (WTAC). The utility gained from a good is the maximum a person would pay to acquire the good if they did not already have ownership of it. By the same token, the WTAC is the minimum a person would accept as compensation for loss of a good and, as such, it is the amount that would return the individual to his utility level prior to the loss of the good. In theory, WTP and WTAC should be congruent in scale for goods which are substitutes and for which the income effect is negligible. However, empirical evidence illustrates that WTP is approximately two to five times smaller than the WTAC for the same good or service. Garrod & Willis (1999) propose six reasons as to why there may be a divergence and these will be briefly explained. Firstly, the discrepancy between the two measures may be a result of poor empirical procedures used to calculate WTP and WTAC, in the form of badly designed questionnaires and biased interviewing techniques. Secondly, that the WTAC measure is incomplete, since the actual ownership of a good increases its value resulting in a higher selling price or WTAC. Thirdly, consumers may act strategically and selfishly when formulating their WTP or WTAC bids, especially with the WTAC, so as to try and obtain as much as possible. A fourth reason is that the difference between WTAC and WTP might be authentic. Irregularity of importance is created by the situation whereby people demand more to sell an object than they would offer to purchase it. The fifth reason is that the discrepancy can be explained when there is a lack of alternatives for the good being valued. The last argument is that the discrepancy between WTAC and WTP may arise because of a lack of financial incentives and experience (Hanley & Spash, 1993; Garrod & Willis, 1999).

The contingent valuation method (CVM) is an example of a technique that is used when market prices are not available and is one of the most popular non-market valuation techniques. CVM is a survey technique that attempts to extract information about individual preferences for a good or service by asking individuals how much they are willing to pay (WTP) for that good or service. A CVM can be split into a number of well defined steps. The CVM falls under a set of methods which subjectively evaluate possible damages which can be seen within actual or theoretical market behaviours. The first stage entails the creation of an in depth description of the project that the participants are being asked to value creating. All pertinent facts should be given to the respondents to assist them in fully understanding the consequences of their valuation decisions. Of tantamount importance is the reason or motivation for valuing the good or service and the impact it will have on them. Stage two of the CVM relates to the acquisition of bids from the respondents. The sample size selection for the exercise will be pivotal in the accuracy of the outcome. Generally, the greater the sample size the smaller the disparity in the mean WTP and/or WTAC. The survey can be conducted in a personal interview which will provide the widest range of information to the person being interviewed but has the risk of interview bias. This partiality can take place when the respondent's WTP or WTAC is influenced by indirect signals. The third method that is applied is known as trade-off games where respondents must select between different bundles of goods. A combination of money and varying amounts of a good will be offered in an attempt to decipher the consumers WTP. Another offer is made after the first offer and entails the good involved being increased and the money involved being decreased. This decrease in money will, by deduction, be the price paid for the good. The increased price of the good is then adjusted until the respondent is indifferent between the two alternatives, thereby producing the consumer's WTP (Hanley & Spash, 1993).

Another approach is the travel cost method (TCM), which is a method for valuing the non-market benefits of outdoor recreation resources, which require expenditure for their consumption or enjoyment. These recreation resources can therefore have their user values estimated based on WTP. If the good is a recreational resource, this approach provides useful information. However, the degree of substitutability is crucial, as in a zoo not being a perfect replacement for seeing animals in the wild. Therefore, surrogate marketed goods can provide partial estimates of the benefits from many goods or services, but cognisance must be taken with regards to non-marketed or intangible benefits that are also linked to these goods or services. Hanley & Spash (1993) state that the TCM places a value on a non-market good or service by using consumption behaviour in related markets. These consumption costs will include travel costs, entry fees, in site expenditure and outlay on capital equipment necessary for consumption (Hanley & Spash, 1993).

The hedonic price method states that a good or service is not a single object but rather a bundle of particular characteristics. In other words, the value of the good or service is the aggregate value of the individual characteristics or attributes found in that good or service. Since a good or service consists of a collection of attributes or characteristics, these different characteristics illustrate disparities in prices of those same goods or services. For instance, the value of a house will be made up of the value of the standard components of the house, such as the amount of bedrooms, size of the land as well as additional characteristics that can go into the house such as a Jacuzzi, pool, internet or additional parking spaces. So one might pay a certain amount, X, for a three bedroom simplex, but will pay X plus a premium for the same simplex with air conditioning units installed. The premium will be the extra value of the air conditioning unit, ceteris paribus. Consequently, the price of a good or service is a function of the vector of characteristics. By differentiating the price of a good or service with respect to the level of the required characteristic, the implicit price of that particular characteristic can be derived (Hanley & Spash, 1993).

The next method is the replacement cost approach, which assesses the value of a natural resource according to the cost to replace it once it has been damaged or altered. This approach weighs up whether is it more cost effective to let damages happen and repair them after the project or alternatively not let the damages happen at all. The necessary conditions for this model to be used are that the magnitude of the damage is measurable, the replacement cost is measurable, the existing environment structure is optimal and that there are no secondary benefits associated with the expenditures. An example of the replacement cost approach would be the estimated cost of replanting the mangroves in Durban Harbour after they have been removed. The relocation cost approach is a modification of the replacement cost technique and uses estimated costs of relocating a natural or physical asset (Hanley & Spash, 1993).

Once all the costs and benefits have been converted to monetary terms, they need to be converted to present value figures. The method of doing this is called discounting. As stated above, the discount rate is, in essence, the reversal of compounding. Discounting allows a comparison of two different future values, whereby they are both discounted to their present value, and then compared directly. It is thus the rate used to calculate the present value of future cash flows. As shown above, by ignoring discounting we are saying that there is no distinction between future and present costs and benefits. CBA is normally interested in dynamic efficiency as opposed to static efficiency and for this the discounting process is crucial. As the discount rate rises, so will discrimination against future projects increase, assuming that the majority of the benefits occur in the future since for a given discount rate, costs and benefits are smaller the more in the future they occur. Alternatively, when costs occur in the future and benefits occur in the present, these are more likely to pass the CBA test for a given discount rate, ceterus paribus (Krupnick, Toman, & Kopp, 1997).

2.6.3 Selection of Investment Criterion

The final step of CBA is to calculate the net social benefit using a chosen investment criterion. The most commonly used tool of analysis is the net present value (NPV) method. The NPV is simply the discounted benefits less the discounted costs of a project as is shown in the equation below. If the NPV is positive then the project should be accepted and if it is negative then the project should be rejected. The standard NPV rule is stated in mathematical form below.

Figure 16A: Standard Net Present Value Equation

$$NPV = \sum(B_t - C_t)(1+i)^{-t}$$

NPV-net present value

B-revenue

C-cost

i-interest rate/discount rate

The standard CBA rule, excludes environmental considerations or damages. To compensate for this, an additional parameter is added to the standard CBA case. The result is the extended CBA rule and is shown in the box below. E is net environmental damage. E is a positive value ($+E_t$) if there are net environmental benefits. B and C would be non-environmental benefits and costs respectively.

Figure 16B: Environmental Constraint with Net Present Value

$NPV = \sum(B_t - C_t - E_t)(1+i)^{-t}$

NPV > 0 to pass the CBA test

Other evaluation methods include the Discounted Payback Period (DPP) and the Internal Rate of Return (IRR). The DPP analyses the time it will take for a project's cash flows to recover the costs of that project. This method is easy to understand but requires an arbitrary cut off point and is biased towards short term projects and thus is only useful for rough or quick decisions or in conjunction with other methods. The IRR is the rate at which the project's NPV is exactly equal to zero and, as such, will provide the breakeven point for a project to be deemed worthwhile. The acceptance condition with the IRR method is that the IRR has to be greater than the going market interest rate. Generally, an IRR which is higher than the social discount rate indicates a desirable investment project. The IRR method is problematic for non-conventional cash flows and is complicated and cumbersome to calculate. Both these methods are inferior to that of the NPV method but may be used in conjunction with the NPV method to provide more information (Hanley & Spash, 1993).

Lastly, a popular variant of CBA which is used as a means to analyse uncertainty is that of sensitivity analysis. Future consequences derived from present day decisions are not always definite. Often, the available information with regards to decisions is unavailable, unreliable or incomplete. Making decisions in the face of uncertainty can result in irreversible damages such as the permanent loss of revenue or species extinction. In addition, even if a negative effect is predicted, there can still be uncertainty about the scale of the effect. There are three primary methodologies to coping with uncertainty. First is to simply ignore or assume away the uncertainty. Secondly, the uncertainty can be reduced to an ignorable or minimal level. The third approach is to include the uncertainty in its entirety into the cost-benefit analysis. There are many methods that factor in uncertainty such as simulation and decision trees but sensitivity analysis is the most common and simplest method. Sensitivity analysis helps mitigate uncertainty, by specifically varying crucial information which is inserted into a CBA model thereby altering the possible outcomes. Key variables and their inferences are inserted in the model and are therefore forced to be recognised. Sensitivity analysis can be divided into two broad areas, namely the variable by variable approach and the scenario approach. The variable by variable approach assumes the independence of the variables involved and categorises the results into most likely, optimistic and pessimistic. Only one variable is changed at a time, using a ceterus paribus approach. The scenario approach takes into account the interdependence among variable and identifies numerous consistent combinations of the variables (Zerbe & Dively, 1994; Sinden & Thampapillai, 1994).

Sensitivity analysis, however, is not without its flaws. There are no explicit rules for choosing values for variables, and, as such, this can be subject to selection bias. Additionally, obtaining key information on the uncertainties can often be very difficult. The interdependent interactions among variables are incorporated in scenario analysis. The results can point out disadvantages in a project, and areas where further clarifying research should be undertaken. The advantages and disadvantages illustrate that sensitivity analysis is most suited for projects that require quick decisions, limited accuracy or are relatively simple (Zerbe & Dively, 1994).

2.6.4 Issues and Challenges in CBA

Cost benefit analysis is not without its ethical and theoretical dilemmas. A crucial ethical challenge is the question of the valuation of human life which often occurs in cost benefit analysis. There is significant disagreement in civil society, charity organizations and indeed the general public to the idea of placing a money value on human life. However, economists emphasise that it is unattainable to fund every project that promises to save a human life and that some realistic foundation is needed to filter the projects that would yield the greatest social benefit. One approach to this end is to calculate the present value of a person's expected future income streams. This seems logical, since a person's income is indicative of their marginal revenue product, which in turn shows their economic contribution to society. Additionally, there are many cases in which people willingly agree to enlarged risks in return for elevated pay, such as working on Alaskan fishing trawlers, participating in covert operation work, or for time-savings in driving faster on highways. Personal choices which people make can be used to estimate the personal price they place on increased risk and by deduction the worth to them of reducing that risk. This calculation is comparable to placing an economic value on the predicted amount of lives saved. Estimates of the value of a statistical life are widely used and multiplied by expected deaths avoided to obtain the mortality benefits from a particular program. The idea of placing a value on a human life may appear unpleasant and even ridiculous, but it must be remembered that this is not an arbitrary exercise. Economists value life so that more lives can be saved or improved, so, by deduction, it is the reduction in the probability of death which is trying to be accomplished. This concept can be better explained through the use of an example: If there was a pollution reduction policy that would affect 100 people and this group was willing to pay R10 per person to reduce the chance of dying by 0.01. The WTP of the group is therefore R1000 (100 x 10) to reduce the chance of death by 1(100 x 0.01) (Sinden & Thampapillai, 1994).

The fundamental question with regards to the above becomes, is it ethical for an amount of pollution to remain if the group cannot afford the total cost of pollution reduction? The answer may be yes, since, as shown above, if compensation is paid to the loser there is no economic reason why there cannot be an optimal level of pollution. The problem with this, however, is the distinction between willingness to pay and ability to pay, a concept that is explored more fully later. So, if a group wants pollution reduced but are unable to pay, they are discriminated against due to their lack of income. The below example illustrates the morality of grouping everyone's utility together. Taking the example from above, if instead of all 100 people being willing to pay R10, assume that a quarter of the group, 25, are so opposed to the mere possibility of dying that they are willing and able to pay R40, thereby removing all of the pollution. However, the other 75 are indifferent and are willing to pay nothing to avert the risk. Consequently, the overall WTP of the group is still R1000 (25 x 40) resulting in the same pollution level.

CBA bases its ethical standard on utilitarianism which is a social philosophy that assumes each individual's utility counts equally and so, by deduction, the welfare function for society is the aggregation of all the individual utilities. In this case, it is ethical if one person's utility diminishes as long as another's utility increases by an equal amount. The answer must be no as this is in opposition to the Pareto optimality criterion which is a point where it is impossible to make one person better off without simultaneously making another worse off. To move beyond this conundrum, Kaldor-Hicks assumes that the marginal utility income of all individuals to be the same. The Kaldor-Hick criterion does not take into consideration income distribution in the society aka the Gini coefficient, yet welfare appraisal of a policy depends on that very distribution since the value of the goods or services is based on WTP, which in itself is normally based on ability to pay. The ignoring of distributional effect has led to general disapproval of Kaldor-Hicks, but even though most economists claim to use the Pareto criterion, the use of Kaldor-Hicks is still more common in making welfare judgements (Zerbe & Dively, 1994).

As mentioned previously, an important consideration in a CBA is that of distributive effects, since even if an outcome is efficient it may disproportionately affect certain segments of society. This is especially important in a developing economy with skewed welfare and resources. Efficiency can be defined in terms of the maximization of the total utility of society, with the crucial assumption that utility can be measured. However, when a market is not efficient, total societal utility is probably not at its maximum and there is an opportunity for improving welfare without making someone worse off. It must be emphasised, however, that the marginal utility of an extra rand is not the same for the poor and rich. Consequently, some assumptions are made regarding the broad comparison of individuals' utility. A key concept with regards to this is that of Pareto efficiency which is a point where it is impossible to make someone better off without making someone worse off. A Pareto superior move occurs when a policy makes someone better off without making someone else worse off. By definition, a policy is only efficient if there are no losers. Alternatively, if there are losers, they need to be fully compensated for their loss by the winners thus making it consistent with the Pareto principle. A CBA can thus have positive distributional and efficiency gains and yet still be rejected since the redistribution costs may be larger than the gains. The full compensation approach is not always ideal though, as it may in some instances require compensation of the rich (Zerbe & Dively, 1994).

2.7 Conclusion

This concludes the literature review, whereby all the relevant theory has been covered. Important port and economic issues have been explained with the aim of enhancing the proceeding chapters and adding to their academic richness. The function and purpose of ports was explained, as well as the presentation of port models and costing. Maritime economic theory has been explained in terms of the demand and supply functions of ships as well as global trends in the shipping industry. Sustainability was introduced and included the two schools of thought as well as the important concept of discounting. CBA theory was covered in some detail whereby non market and market based techniques were explained. Added to this, was more general economic theory such as market failure, Keynesian multiplier and international trade. This chapter along with Chapter Three will provide a contextual framework for the CBA calculations in Chapter Four.

Chapter Three: The Port of Durban

3.1 Introduction

This chapter will examine the port of Durban from an economics perspective and will seek to expand on the general theory presented in the literature review and apply it specifically to the Port of Durban. This chapter will also serve as a foundation for the proceeding chapter which will analyse the various CBA options and data for Durban. The port's significance and impact will be examined in the context of the South African and local economy through its income and employment generating effect. Though the quantity of cargo moving through a port is important, of more interest is the type of cargo that a port focuses on.

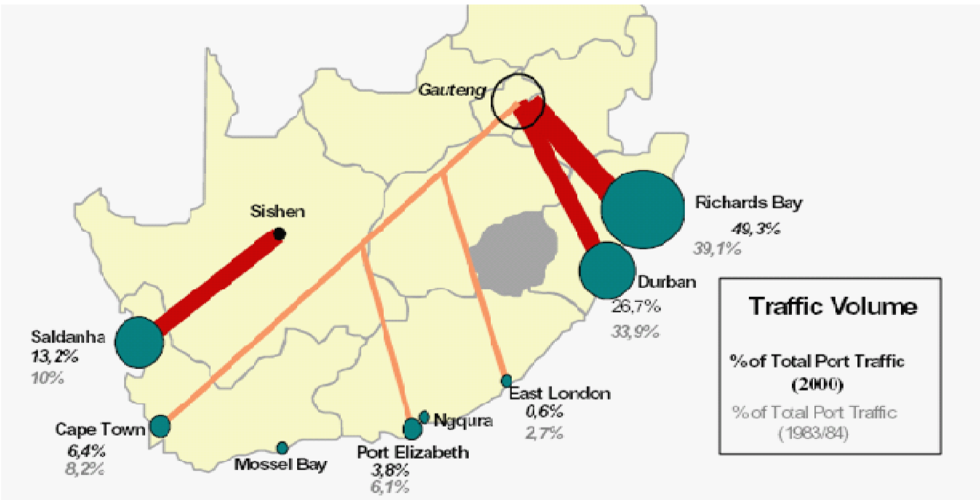
3.2 The South African Port Sector

Before examining the port of Durban in isolation, it would be prudent to briefly discuss the South African port scenario in a broader sense. In South Africa, ports are considered national assets and as such are under the control of the government-owned utility Transnet. Previously, the ports division of Transnet, Portnet, performed the various port duties and services. However, this monolithic structure, in the interest of efficiency and transparency (and in line with international best practice) , was divided into the National Ports Authority (NPA) which focused on the provision of basic marine infrastructure and marine services as well as South African Port Operations (SAPO) which focused on the operation of terminals under Transnet's jurisdiction. A basic landlord-operator distinction thus emerged, again in line with international best practice. The NPA later became Transnet National Port Authority of South Africa (TNPA) and SAPO became Transnet Port Terminals (TPT) (Jones, 2003; www.ports.co.za, 2010).

South Africa is heavily reliant on maritime transport with its port infrastructure comprising eight principal commercial ports, namely, Durban, Richards Bay, East London, Port Elizabeth, Mossel Bay, Cape Town, Saldanha and the newly-commissioned port of Coega, which is exceeding expected volumes). The country has evolved into a major sea-trading nation over the last four or so decades and in 2002 handled 3.6% of world sea trade by volume. In terms of tonne miles or real activity, this figure increases to 6% of global trade, placing the country within the top 12 globally and resulting in a global maritime activity share that is more than 20 fold its global GDP share. Sea trade constitutes more than 90% of total trade in South Africa and ports play a critical social and economic role both nationally and regionally. The majority of the port activity is concentrated on the east coast of South Africa. A stark illustration of this fact is that Durban and Richards Bay together make up 76% of sea trade in the country (Chasomeris, 2005; www.ports.co.za, 2010).

Traffic growth in the 1990's was derived from two primary regional points and sources, namely Durban from a general cargo perspective and Richards Bay from a raw materials perspective. Richards Bay, which deals primarily in bulk goods, such as coal, ore and minerals, has seen its annual tonnage increase from 55 million tonnes in 1989 to in excess of 90 million in 2000. Viewing perceived value in terms of tonnage is a flawed approach since in terms of economic linkages and value adding, processing a tonne of coal is not the same as handling a tonne of refined goods (Jones, 2002). The figure below illustrates the breakdown of sea trade activity by port in South Africa. It can be seen clearly that Durban and Richards Bay are giants in comparison to the other ports. Of late, however, there has been the rapid growth in Saldanha Bay which has seen its share of cargo tonnage, excluding containers, increase from 32 million tonnes in 2003 to 56 million tonnes in 2009. These figures become even more impressive when they are transformed into percentages whereby it can be seen that Saldanha had 11% of the market in 2003 and only six years later has 19%. The key factor driving the growth has been the completion of an 800km railway line which connects the port to the Sishen mines in the Northern Cape (Chasomeris, 2003; www.ports.co.za, 2010).

Figure 17: Total Traffic Volume in South Africa



Source: Department of Transport, 1998 and Jones, 2001

The South African ports sector experienced significant capital intensive investment in the 1970s and 1980s, which was biased towards the bulk shipping sector. However, world trends have seen a migration towards containerisation and unitisation and South Africa is no exception, with the country installing dedicated container-handling facilities for the first time in 1977. Up until 1990, the available capacity could easily cater for national traffic levels of approximately 1 million teus level. After this, however, the lack of adequate container capacity, combined with growing demand, brought with it a multitude of problems. On the demand side, South Africa became a democracy and re-entered the globalised world, resulting in a noticeable rise in seaborne container volumes, due to liner carriers returning to the South African trades and increased trade liberalisation. The upsurge in volumes produced inevitable negative consequences of delays and vessel queues. By 2000, the combined amount of annual teus handled in South African ports was 1.8 million and this was achieved using with the same container quays which were constructed in 1977. There was some limited capital investment in strategic areas in the 1990s, such as cargo extensions to facilities in Richards Bay (Lawrance, 2000).

The new millennium brought with it bolder and more ambitious port investment initiatives. A new industrial hub status port in the Eastern Cape, which was earlier envisioned but never acted upon, has now been commissioned. Secondly, the Durban general cargo infrastructure has received significant upgrades and extensions such as extensions to landside facilities, deepening and extending cargo handling superstructure and infrastructure as well as deepening and widening the harbour entrance. Due to the age and mismatch of the cargo handling infrastructure, productivity has lagged that of international levels, resulting in congestion that is a constant feature of local ports. There were also supply side issues to deal with such as liner routes becoming more specific and centred around hub status ports. As such, hub status ports have to provide capacity that exceeds national demand, making attainment of hub port status difficult in capacity constricted scenarios. South African ports' relative competitive stance with their southern hemisphere counterparts can be gauged from the table below. Looking at both indicators, South African ports emerge as clear leaders on both the African and Southern Hemisphere front. Richards Bay is ranked first on the table in terms of total traffic, as it has a large amount of coal and other bulk cargoes passing through its doors. Durban, although ranked 3rd overall, is ranked 1st in the container category thus it is clear that Durban is the leading multi-purpose port in South Africa and indeed the Southern Hemisphere (Jones, 1997; Jones, 2003; Department of Transport, 1998).

Table 2: African and Southern Hemisphere Port Traffic

Port	Total Port Traffic (m tonnes)	Rank	Container Traffic (teus 000s)	Rank
Richards Bay	91.5	1	5	15
Newcastle	73.9	2	9	14
Durban	49.7	3	1291	2
Santos	43.1	4	945	4
Sydney	24.6	5	999	3
Melbourne	22.3	6	1322	1
Casablanca	19.8	7	311	9
Abidjan	14.6	8	434	7
Auckland	13.3	9	561	6
Cape Town	11.8	10	395	8
Lagos	9.1	11	178	11
Mombasa	8.9	12	219	10
Buenos Aires	7.8	13	716	5
Dakar	7.2	14	149	13
Port Louis	4.7	15	161	12

Source: **ISL, Bremen, 2001 and Jones 2003 (**Selected ports, 2000**)**

3.3 History of the Port of Durban

Durban is the largest city in KwaZulu-Natal, the third largest city in South Africa and is also home to the country's busiest port. The city has a pleasant subtropical climate which along with its beautiful beaches makes it a leading tourist destination. The port is situated on the east coast of South Africa at coordinates 31° 02'E in longitudinal and at 29° 52'S in latitudinal terms and being a natural harbour, is a very rare commodity. Trading activities in the port of Durban can be traced back to 1824, with the port quickly gaining a favoured status among seafarers and traders due to its attributes (Jones, 2002; www.ports.co.za, 2010).

Interest in Durban Bay grew tremendously in the early years of its operations, with imports doubling between 1849 and 1850. Towards the end of the 1800s, the sugarcane industry in Natal flourished and consequently so did sugar exports increase, making Durban the busiest sugar terminal in the world, while the exploitation of coal reserves in northern Natal made the port a strategic bunkering point and secured its position as a crucial economic cog in the British Empire's maritime activities. A key problem, however, was that larger vessels were unable to access the port due to the "battle of the bar" constraint (www.ports.co.za, 2010). Prior to 1904, the port was severely limited in terms of allowing larger vessels in, since the sand bar hindered the main channel of the harbour entrance, consequently limiting deeper draught vessels. After 1904, through the use of improved dredging techniques and infrastructure, the sand bar struggle had been won. After this defining event, the port expanded and developed primarily along the

Point, Bluff and Maydon Wharf areas. The next few decades, between and after both world wars, were characterised by upgrading of current facilities and a focus on improving infrastructural quality as opposed to infrastructural expansion. During this period, oil and petroleum trade and usage increased dramatically, overtaking coal as the staple energy source of the world. In the 1960s and 1970s, two piers were constructed, to help alleviate congestion. Today, Durban has 63 berths and 6 repair berths, which can be broadly separated into five main segments of the port. The first segment is made up of Pier 1 and Pier 2 and is engaged principally in the handling of containerised/unitised cargoes, and therefore represents the current "commanding heights" of the port. The second segment of the port is located in the Salisbury Island/Island View area, and handles the port's strategic liquid-bulk trades in petroleum products and chemicals. A third segment is the Maydon Wharf area, which contains private terminals as well as terminals controlled by Transnet and is engaged primarily in the handling of dry-bulk and break-bulk (conventional) cargoes. The Point terminal area and the Bayhead area are the fourth segment and fifth segment respectively. Figure 18 below provides an aerial representative of the port of Durban that illustrates the five segments discussed (Jones, 2002; www.ports.co.za, 2010).

Figure 18: The Current Layout of Durban Port

Source: Google Earth, 2010

3.4 Economic Significance of the Port of Durban

As can be seen in Figure 17, on page 40 above, the logistical strength of the national shipping infrastructure, rests primarily in KwaZulu-Natal. The port of Durban is an example of a port under national jurisdiction of Transnet. As shown above, Transnet eventually evolved to become the Transnet National Port Authority of South Africa (TNPA) and Transnet Port Terminals (TPT). Durban is a port of choice because its current infrastructure enables it to be a full service general cargo and container port. In addition to this, Durban is well serviced by an adequate rail and road infrastructure, which links it to the economic hub of South Africa, Gauteng. In addition to this, the KZN region is a large economic region in itself and is second only to Gauteng in South Africa (www.ports.co.za, 2010).

Table 3 below, illustrates a snapshot of the South African port sector for 2009. In terms of cargo tonnes handled, excluding containers, Durban has 20% of the market and is dwarfed by Richards Bay which has more than double Durban's tonnage handled, at more than 40%. Durban is in fact only ranked third behind both Saldanha Bay and Richards's bay. Richards Bay, which was constructed in the 1970s, has had an enormous impact on Durban's port planning and functions. The primary reason for its existence was to serve as high-mass export point for raw materials such as coal. Richards Bay also diversified its goods base to include, at a lower cost, some commodity types that were traditionally the domain of Durban such as neo-bulk cargo like steel, ferro alloys and forest products. At the time of Richards Bay construction, Cape-sized bulk vessels were too large to enter Durban (Jones, 2003; NPA, 2009).

Table 3: Port Cargo Statistics in South African Ports

	RICHARDS BAY	DURBAN	CAPE TOWN	SALDANHA BAY	TOTAL SA PORTS	Durban as a % of Total
Cargo Handled (excluding containers)	77,631,154	37,419,282	3,058,601	56,475,625	182,735,369	20%
Total Teus Handled	6,273	2,395,175	1,382,052	NA	4,334,612	55%
Tonnage of Teus	84,686	32,334,863	18,657,702	NA	58,517,262	55%
Total Tonnage (including containers)	77,715,840	69,754,145	21,716,303	56,475,625	241,252,631	29%

Source: NPA, 2009 (Note table has been edited)

However, when the full traffic base is calculated, by including container tonnage, Durban's share of total tonnage increases quite substantially and according to www.ports.co.za, a teu is on average 13.5 metric tonnes. Multiplying the teu figure of 2 395 175 by 13.5 yields a tonnage of just over 32 million tonnes. As shown in the table above, the addition of container tonnage increases Durban's total tonnage quite substantially and moves it past Saldanha Bay and just behind Richards Bay. Additionally, it is evident that Durban is the leader in terms of teus handled. As will be shown below, containers offer the richest economic impact of all types of cargo, thereby enhancing Durban port's economic significance. Looking again at Table 4 below, it can be observed that even though Durban lags Richards Bay in gross tonnage of cargo it still has by far the most number of vessels docking. One of the major reasons for this is the substantial growth in container trade, through which Durban has been a major beneficiary. Another reason was the absolute tonnage growth in bulk cargo which Richards Bay dealt in. This forced Durban to concentrate on lower-volume bulk, break-bulk and liquid-bulk. This enabled great diversity within the port in terms of cargo type as well as vessel type and quantity. Additionally, vessels that carry break-bulk are traditionally smaller than that of traditional bulk, explaining why more vessel dockings are in Durban than Richards Bay for the same amount of cargo ceteris paribus. However, as shown in the literature review, container vessels are continually becoming larger, so there is no telling if this particular relationship will hold in the medium to long term. Recent reasons for Durban's high amount of callers include the avoidance of the Suez Canal due to Somali pirates, thereby making Durban a transitional stop. With reference to the table below, it can be observed that Durban has 43% of total general cargo vessels, 42% of total tankers and 44% of total container vessels. The most important figure, in relation to Durban, is that of teus handled since this is where its dominance and significance come to the fore. Durban already has the established infrastructure, superstructure and logistical networks to handle containers and since Richards Bay has inadequate structure for containers, Durban's dominance in containers has, to date, been unchallenged (NPA, 2009; www.ports.co.za).

Table 4: Port Vessel Statistics in South African Ports

	RICHARDS BAY	DURBAN	CAPE TOWN	SALDANHA BAY	TOTAL SA PORTS	Durban as a % of Total
Total General Cargo	247	705	220	373	1,648	43%
Total Bulk	1257	930	320	921	3,603	26%
Total Containers	42	1883	897	784	4,233	44%
Total Tankers	184	646	159	344	1,542	42%
Grand Vessel Total	1874	4848	2440	3489	15,879	31%

Source: NPA, 2009 (Note table has been edited)

Jones (2003) shows that there is a growing international trend for the major container shipping lines to attempt to organise trade and activities around so called "hub" ports which meet and cross at "sub-regional transhipment nodes". The logical response to this arrangement would be the establishment of a single hub port of the eastern seaboard of South Africa. Since Durban is the country's major container port, is well frequented by major shipping lines and has terminal and hub status, it is quite reasonable for it to remain South Africa's primary container port. The other alternatives on the eastern sea board are not really competitors when it comes to containers. Richards Bay is primarily a bulk port and does not have the adequate infrastructure to extend its activities beyond this scope. Maputo has large deviation costs from traditional shipping lines as well as limited depth and capacity. Port Elizabeth has weak land side links to Gauteng as well as having limited local demand to justify a major port there. Another possibility is the new port of Coega which is situated at the mouth of the Coega River, 20km from Port Elizabeth. It began operations in October 2009 and is South Africa's 8^{th} commercial port. The port is part of a broader economic initiative, the Coega Industrial Development Zone, which seeks to focus on export driven activities which should help alleviate unemployment and chronic poverty in the region. Coega can easily accommodate post-Panamax vessels since it has a depth of -18m and was originally touted as a deep water bulk port. Now, its area of focus is on containers and some minerals, which would be transferred from Port Elizabeth. The final port configuration will have 32 berths but whether the port will become a serious contender as a container or hub port will remain to be seen (Jones, 2003; www.ports.co.za, 2010).

Even though Durban lags Richards Bay in terms of pure tonnage, this in itself is a poor yardstick of economic impact and significance since no account is taken of cargo value or employment propensities of infrastructure required (Jones, 2003). Generally, in terms of economic and employment impacts, general cargo provides the most followed by dry-bulk cargo and lastly liquid-bulk. Bearing this in mind, comparing two ports only on the basis of tonnage is frivolous and, more specifically in Durban's case, it can be seen that from a port's perspective, it handles higher valued cargo than Richards Bay. This is especially evident when one considers one job is created per 47 000 tonnes of cargo handled at Richards Bay, whereas in Durban, one job is created per 7 500 tonnes of cargo handled (Jones, 1998). Additionally, in 2004 an average container vessel spent R2.94 million per port call, far exceeding the R1.8 million for a break-bulk cargo vessel as well as exceeding the R1.3 million for a bunker vessel. The economic richness present in containers is not limited to Durban and, as Table 5 below illustrates, is present in other ports such as Fremantle in Australia (Suykens, 1984; Tempi, 2006).

Table 5: Port of Fremantle's Economic impact by Cargo Type

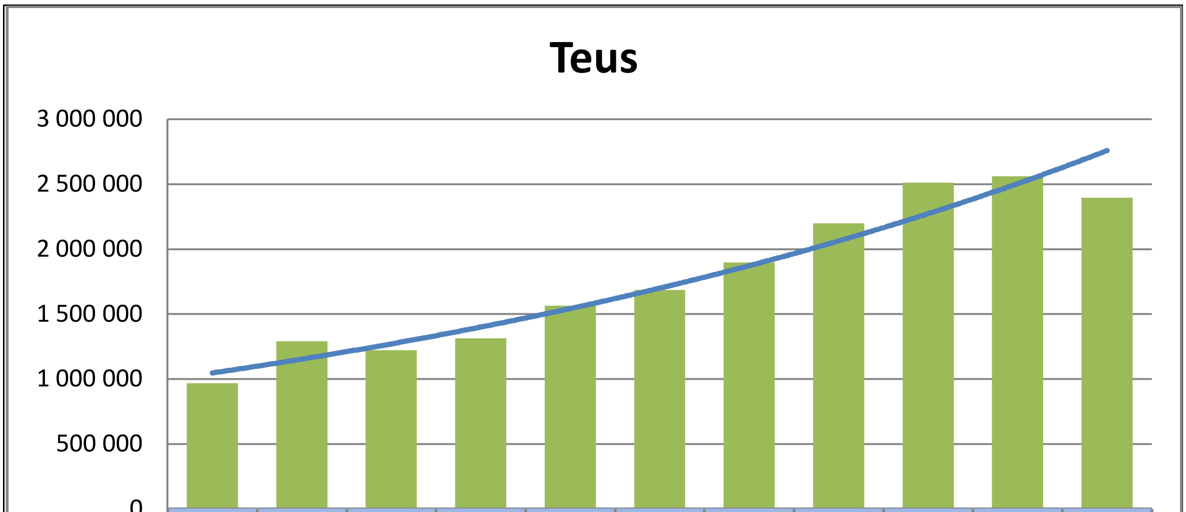
Cargo Type	Output ($m)	Value Added ($m)	Household Income ($m)	Employment (no.)
Direct Effects				
Containers	177	121	73	1331
Other General Cargo	45	30	18	340
Liquid-Bulk	35	20	8	158
Dry-Bulk	83	44	25	459
Other	1	1	0	7
Total	341	215	124	2294
Direct + Indirect Effects				
Containers	382	240	125	3195
Other General Cargo	96	59	31	800
Liquid-Bulk	67	38	17	441
Dry-Bulk	181	100	50	1339
Other	2	1	1	19
Total	728	440	223	5792

Source: Bureau of Economic Transport Economics Australia, 2000

As is the case with South African ports, the port of Fremantle in Australia, shown in Table 5 above, derives the most economic prosperity from containers from both a direct and indirect perspective. Even though containers account for only 13% of activity in the port, they contribute 55% to economic activity. Consequently, containers have the greatest employment generating effects, followed by dry-bulk and liquid-bulk. Though dynamics differ from port to port in terms of infrastructure, administration, socioeconomics and geography, commonsense and observation lead one to a simple "rule of thumb" approach. As such, containers offer the most economic opportunity for a port and since Durban already focuses on this area, it would be prudent to continue with this trend. From the above, it is quite evident that both the present and future comparative advantage of Durban port rests in the realm of containerised cargoes due to reasons already shown. Also, since the port is already the leader in terms of container volumes, it has significant infrastructure suited to containers and is quite dependant on containerised cargo for its economic benefits, hence the removal of this great economic magnifying source would be particularly devastating on the Durban region as a whole (Criddle, 2000; Jones, 2003).

Looking at Figure 19 below, it can be seen that the Durban port has seen an extraordinary increase in containers, with annualised growth of between 8% and 10% for the last decade. As was shown above, containers form an integral cog in the Durban port machine from an economics and social perspective since they provide a source of trade, income and employment. Container growth is affected by a myriad of factors such as increased volumes of world trade, lower trading restrictions, the substitution to containers from other transport systems, and South Africa's recent economic performance and rising per capita incomes. Growth between 2002 and 2007 is nothing short of spectacular, but this growth has not come without costs and constraints. Needing containers and providing adequate space for them are two entirely different things and this will be explored below. Also, we have seen that general cargo is the richest form of cargo and has the largest employment benefits. South Africa needs extended general cargo capabilities and in this respect, Durban's needs are similar to national needs. It is thus clear that Durban needs the container industry for continued survival and prosperity, but whether the container industry needs Durban as much remains to be seen (Jones, 2003).

Figure 19: Total Teus for Durban Port (in thousands)



	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Teus	969 0	1 291	1 223	1 313	1 565	1 686	1 899	2 198	2 512	2 560	2 395

Source: NPA, 2008 and www.ports.co.za, 2010

Durban's greatest strengths, namely its ideal location, good economic linkages and strong infrastructure, have also developed to be its Achilles heel, since its popularity, especially for containerised cargo, has seen demand surge in a context of largely fixed physical infrastructure. With the growth of sea trade demand, the real problems of Durban are not necessarily the lack of adequate marine infrastructure in the form of berths or quay walls, but rather a lack of terminal-handling and back-of-port cargo storage and distribution space as well as a critical shortage of managerial capacity and ability to operate the present container terminal at satisfactory operational levels. The supply side reaction by the authorities to these escalating demand pressures has been slow and inadequate. The growth of containerised cargo volumes has put the port's container terminal under sustained pressure since the mid-1990s, resulting in available capacity being sometimes overwhelmed capacity (Jones, 2001). The consequences have been congestion, queuing, high berth occupancy, and overall delays to container ships. The port area is saturated with industrial and commercial development, making space an expensive premium for all cargo types, above all for containerised cargo, but also for neo-bulk, space-intensive cargoes like steel and forest products. This forces the port to confront a hierarchy of cargoes, with a greater focus on the retention of cargoes that are richest in economic terms. These are identified in this study as containerised cargoes, and hence the migration of some neo-bulk and break-bulk cargoes to Richards Bay, where space is more readily available, is both entirely understandable and is also consistent with a greater focus on Durban's part on cargoes where it enjoys the greatest comparative advantages. The Durban-Gauteng rail route itself is dominated by inefficiency and poor management and this is further exacerbated by operating problems associated with Transnet which reduce the availability and reliability of rail even more. Of course, the more reliant on rail the cargo is, the more delays that cargo type will encounter, especially the bulk cargoes for which rail is the cheapest and most efficient form of transport. Previously, Durban's major economic disadvantage was its inability to host post-Panamax-sized ships due to its lack of depth. However, after recent capital investments, the entrance width has been increased from 110m at its narrowest to 220m and the depth in the outer channel from 12m to approximately 19m. The depth at berth level though, still remains a problem at only -12.8m. This is far from adequate, with many of the bigger container vessels requiring far greater depth as can be seen in Ircha (2006) which states that hub status type ports must have the following in order to remain relevant:

- Container-stacking densities of 2 000-4 000 teus per hectare;
- Sustained ship-to-shore gantry crane productivity of 50 moves per hour;
- Three day dwell times;
- 30-minute truck turnaround times;
- On-dock rail service; and
- Water depths by the berth of 15m and more.

Currently, Durban satisfies none of these parameters, and if it wishes to become efficient and remain productive and relevant, the authorities should address all of them. Doing so would require significant capital investments such as infrastructure expansions as well as innovative and efficient management (Jones, 2003; Transnet, 2010).

3.5 Multiplier Model

The theory of the Keynesian multiplier, which was covered extensively in the literature review, helps quantify the final income effect from an initial investment or spending impetus. The ratio between the eventual change in income and the initial investment is called the multiplier. The size of the multiplier depends on the fraction of the additional income generated in each round that is spent in the next round and this fraction is known as the marginal propensity to consume. Table 5 above touched on the multiplier process for the port of Fremantle, but the concept will now be explored and applied in far more detail. The economic impact of port activities on the local economy can be subdivided into three broad areas. The first area is that of directly port-related or port generated activities, that would cease to exist if the port were to close. The second area is that of indirectly port-related activities and pertains to backwardly-linked services and infrastructure. The third and final broad category is termed induced effects, and is in fact the multiplier effect from other inputs. It arises as those employed in the previous two categories re-spend their money in the local economy, thereby increasing the original economic impact. Jones (2003) examined the port of Durban's economic impact on the local economy. Table 6 below is taken from that same study and as can be observed, 24 000 direct port related jobs from approximately 360 businesses are created through first round inputs. Of the 24 000 jobs, approximately 8 500 are from Transnet, which is an indication of the significant role that the institution plays in the local region. The 24 000 figure translate into a wage bill of approximately R950 million rand in 1994 wage level. Assuming an inflation rate of 10% per annum, this figure would equate to approximately R4 billion in 2010 terms! Coupled with this, many port activities were in fact excluded from the above calculation such as insurance, financial services, medical services and legal services (Jones, 2003).

Another reason why the employment figure is conservative is that it fails to account for the induced or multiplier effect. As shown in the literature review, the economic or employment effect is extended far beyond the initial spending impetus such that the final round of total expenditure normally far exceeds the initial input. The multiplier varies from region to region depending on the marginal propensity to consume (MPC), taxes, and how much respending is retained within the local region. Jones assumes that the majority of port employees are in fact low to middle income earners, which is not an unreasonable assumption. Bearing this in mind, an average tax rate of 20%, MPC of 0.85 and a retention rate of 0.85 is used to formulate the multiplier value. The data is substituted into the multiplier equation from the literature review and yields a multiplier value of 2.4. The port of Seattle conducted an economic impact analysis and depending on which assumptions they used, the multiplier ranged from 2.9 to 4.4. The port of Lake Charles Harbour also conducted an economic impact study and calculated a multiplier of 2.6 and the port of Hastings derived a multiplier of 1.58. Thus, the figure used by Jones is in no way over the top when one looks at other port economic impact papers and it even falls on the lower end of the spectrum. The box below illustrates the calculations that were used to obtain the multiplier for the port of Durban. At 1994 prices, the total income generated by the port is approximately R2.3 billion. Once again, if we assume a 10% increase per annum, in 2010 price terms, this would equate to R9.6 billion (Jones, 2003; Martin Associates, 2007; Meyrick Associates, 2007).

Figure 20: Multiplier for Durban (1994 prices)

$$\alpha = \frac{1}{1 - c\,[(1-t)\,r]}$$

Substituting the various values

$$= \frac{1}{1 - 0.85[(1-0.2)0.85]}$$

$=2.4$

Calculating Equilibrium income for wages only:

$Yo = \alpha A$

$Yo = 950 \text{ X } 2.4$

$= R2.3$ Billion

Calculating Equilibrium income for all expenditures:

$Yo = (950+500) \text{ X } 2.4$

$= R3.5$ Billion

Source: Jones, 2003

Even with the multiplier effect, the regional economic impact of the port is under-estimated since wages and salaries are not the only costs in a port. Industries which provide inputs and services to port establishments are excluded. In the same paper, Jones (1998) attempts to calculate these very costs and some of the examples include paper, ropes, cranes, hooks and property costs. Jones does this by showing that on average 48% of total costs are non-wage costs and based on this assumption, a 1994 figure of R500 million is generated from port related expenditure which is not linked to wages. This amount extrapolated to regional labour elasticities, generated an additional employment figure of approximately 7 000 jobs. The refineries around the port employ around 1 800 people and the Island View area about 500 as well. Thus, as Jones rightly says, the port and port related activities generate approximately 40 000 jobs in the local economy, a figure which www.eThekwinionline.org.za concurs with. Looking at the box above, it can be calculated that the total economic impact of the port is R3.5 billion in 1994 prices. In 2010 monetary terms, this equates to roughly R14.62 billion. Additionally, www.eThekwinionline.org.za states that the port and related industries contributes over 20% of Durban's GDP and approximately 1.5% of national GDP! Thus, it is quite evident that the port and its related clusters are integral to the Durban community in terms of employment and social stability (Jones, 2003; www.eThekwenionline.org.za, 2010).

Table 6: Durban Port Employment and Output (all data at 1994 levels)

Industry/Sector	Number	Employment	Wage bill (R million)
Portnet	1	5400	240
Portnet dredging	1	112	6
Spoornet	1	3217	115
Terminal operators	11	2213	90
Liquid-bulk terminals	3	275	16
C&F agents	138	3600	135
Ships agents	37	1350	65
Ship chandlers	17	400	ns
Container depots	3	366	13
Container parks	7	260	ns
Container logistics	3	140	6
Ship owners & operators	5	11002	ns
Ship repairers & builders	5	9603	34
Stevedores	24	1650	45
Cargo equipment suppliers	2	200	ns
Road haulers	>75	15001	ns
Bunker services	2	110	5
Offshore services	3	80	3
Tallying services	5	1204	ns
Security	3	3001	ns
Marine contractors	2	114	5
Customs & Excise	1	300	ns
Other State	3	1001	ns
TOTAL	**>360**	**23867**	**~R950**

Source: Jones, 2003

3.6 Constraints to Expansion

As shown in Table 2, on page 42, Durban is the largest general cargo port in Africa and the second largest in the southern hemisphere. As a major port city, Durban will benefit from any growth in international trade volumes especially of the general cargo type. Although Durban's port infrastructure is extensive, at present it suffers from critical capacity limitations. The port currently provides 63 berths that can be used for cargo related activities as well as repair facilities for a further 8-9 vessels. These capacity constraints are found in the port's marine infrastructure, cargo-working facilities, its interaction with the landside logistics networks and most facilities in the port. The constraints are indicated in Table 7 below, which illustrates the situation for Durban in 2004/5. Bearing in mind that annual container volumes reached 2 395 175 teus for 2009; it becomes clear how grave the capacity situation is. Considering how desperate the capacity circumstances are, it is indeed surprising that only short term capital investments have been undertaken over the last two decades. Towards the end of the previous century, there were some capital expenditure on gantries, larger container areas and straddle carriers. In 2002, more gantries were added as well as 20 straddle carriers. The second part of the 2002 project was the relocation and specialisation of areas within the port, namely Pier 1 resulting in increased capacity of approximately 700 000 more teus. All these short term improvements will result in the port having a present day capacity of 2.5 million teus. Already in 2005, the container terminal were operating at 90% capacity and now five years hence, with teus handled being 2.4 million in 2009 or 96% capacity, there is a pressing need for Durban to increase and improve its container handling operations (Muller, 2004; NPA, 2009).

Table 7: Port of Durban Capacity Constraint

Terminals	Current traffic M tonne	Theoretical capacity M tonne	Spare Capacity	Percentage used
Bulk Liquids	23,800,000	Unlimited	Unlimited	-
Motor vehicles units	171,365	220,000	48,635	77.89
Coal	1,800,000	2,500,000	700,000	72
City	2,400,000	5,200,000	2,800,000	46.15
Containers	1,724,218	1,900,000	175,782	90.75
Break-bulk	4,200,000	6,300,000.00	2,100,000	66.67
Total excl vehicles	**33,924,218.00**	**16,120,000.00**	**5,824,417.00**	

Source: NPA, 2006

Though this paper views the port from an economics perspective, it must be borne in mind that this is only one of the uses for the port. Figure 21 below, taken from Tempi 2006, illustrates some of the other uses of the port of Durban. These include disease management, recreation, food production, bird refuge and conservation. Thus, there is always an opportunity cost for any form of expansion in the port and this must be balanced against developmental conditions of the region. Ports which are located in urban areas, as is the case of Durban, have a great public demand to access the port for leisure-based activities such as sailing, fishing, paddling, water skiing and canoeing. However, if the land around the port has become a trendy place to frequent, the other developments such as restaurants, nightclubs and shopping areas would also bid for the valuable land space. Besides port development directly competing with these activities for space, the already established developments can impose a negative externality in terms of noise, traffic congestion, negative aesthetics, property devaluation and pollution. Applying the above to Durban, one can see that the significant Point developments fall quite clearly in this category. There are many conflicting activities happening simultaneously in the port of Durban and the recreation versus commercial activities is one of them. A prime example of this is the development of a multi-billion rand waterfront adjacent to the harbour that includes luxurious property developments, an aquarium, a water world and various water sports facilities. Thus, by implementing infrastructure to develop the port to handle further cargo, an opportunity cost is created in the form of lost recreational activities. In addition to this, are security issues that limit public interaction in zones deemed to be sensitive (IEM, 2006; Ircha, 2006).

Figure 21: Port of Durban Attributes

Scale	ROLES/SERVICES
Municipal	Waste assimilation and dilution
	Disease management
Provincial/National roles	Landscape character
	Food production
	Recreation and leisure
	Landscape conservation
	Provides regional ecological resilience
	One of only three estuarine bays in South Africa
	Nursery for fishery
	Refuge for birds
	Landscape conservation
	Research and knowledge creation
International role	Education (at all levels, particularly critical at the tertiary level)
	Bird refuge

Source: Tempi, 2006

Referring again to the figure above, it can be seen that the environment and ecological role of the port is quite significant. Before commercial harbour developments overtook Durban Bay, it was a pristine estuarine lagoon that was abundant in wild life, plants and swamps. From the 1800s onwards, after the port became a popular trading destination, the port gradually ceased to be a natural haven due to dredging and construction. Thus, even though there are still plentiful bio-organisms in the port, this amount pales in comparison to what the bay held in its prime and as such there is increasing environmental pressure to not do any further damage to the natural habitat. Most of the original sand banks have been lost through dredging, resulting in the remaining sandbanks being considered quite essential and valuable, due to rarity and their function of nutrient contribution to the neighbouring biomass. A factor contributing to their existence value is their rarity in terms of this type of habitat being only available in Richards Bay and Durban Bay. A key feature of the sandbanks is their stability which is created by the contribution which microscopic organisms and macro-benthic invertebrates make through enhancing resilience and increasing surface area of the sandbank. A higher surface area from the sandbank benefits the bay via the filtrating mechanism that it provides, which ensures that the water entering the bay is somewhat cleansed or filtered. Besides the sandbanks, there are also the heritage site status mangroves of which approximately 15 hectares are remaining in the bay. These are vital to the bay for biodiversity and sustainability and also share the same body of water as the grasslands and sandbanks, thereby participating in the energy transfer properties of the water medium. There are numerous activities that depend on the proper functioning of this ecological area, with the most obvious being the angling industry, be it for subsistence or recreational purposes, which resulted in 16 000 angling outings in 1987. The second activity is that of bait collecting which generated a harvest of 2.5 tonnes in 1995. Bird watching and academic research are also frequent activities which depend on a well functioning ecological system. Forbes & Demetriades (2007) show that the water area of the bay has been reduced by 57%, the sandbank by 86%, sea grass by 100%, bird species by 94% and the mangroves by 97%. The complexity of the ecosystem means that a simple linear correlation between habitat and species loss is virtually impossible. Figure 22 below illustrates the ecological losses of habitat and bird life for selected time periods. Figure 18, on page 43, illustrated, on an overhead satellite photograph, the location and extent of the sandbanks and mangroves (Forbes & Demetriades, 2006; Mander, 2007).

Figure 22: Port of Durban Habitat Loss

Period	Habitat loss (%)	Palaearctic wader loss (%)	Ratio (Habitat: PW)
1964 – 1967	28	74	1:2.6
1967 – 2006	41	79	1:1.9
1964 – 2006	57	94	1:1.7

Source: Tempi, 2006

An ecosystem by definition is interlinked and, as such, changes in one part of an ecosystem can have drastic consequences in another part. Deeper and wider channels, brought on through commercial port expansion, could have a detrimental effect on the sandbanks and via interlinked systems on the entire ecosystem. This would be further exacerbated by larger post-Panamax vessels, whose more powerful propellers and somewhat greater resultant wash/turbulence could cause disturbances in the ecosystem as well. According to the environmental section of the Tempi process, there is no feasible scenario under which the partial or total removal of the sandbanks can be justified. Additionally, the option of rehabilitation, relocation or replacement is stated to be a poor substitute for the natural sandbanks as the sandbank type and quality is stated to be quite unique. This is firstly due to the fine sediments of the Silt Canal and, secondly, to the physico-chemical nature of the ecosystems in the bay. The Silt Canal in the bay is directly affected through the inflow of freshwater via rivers thereby influencing salinity, oxygen levels and turbidity. This in turn determines the amount and ratio of the various micro and macro organisms in the bay and replicating this balance in another location would prove near impossible. The 1996 Integrated Environmental Management (IEM) study concurs with this view and shows that removing the sandbanks for infrastructural purposes would have a detrimental effect on the ecosystem would also result in a 60 hectare loss of water area. The IEM study also describes the possible negative externalities that would arise as a result of port expansions such as traffic congestion in Glenwood and the Berea, the compromising of capital investments on Victoria Embankment and the obstruction of sea views in surrounding areas (IEM, 1996; Tempi, 2006).

The above constraints are absolute constraints in terms of physical obstacles that may hinder expansions. An often overlooked constraint is that of efficiency lost or relative constraints. In a survey conducted in 2003 by Jones, various firms were asked for comments and opinions with regards to this very issue. The results were that not a single respondent viewed the terminal and cargo handling services provided by the port as good. Additionally, rail services were seen in the same light, which is a worrying occurrence considering how crucial rail is to bulk services. The survey also illustrated the lack of confidence in the managerial competence of the NPA in particular, with 64% of responding reporting a lack of necessary skills in the port authority management as a major problem. Thus, in a way, the inefficiency of the management structure is itself a constraint on the port's expansion and even current workings. This has come to the fore recently because the situation is further exacerbated by the capacity constraint of the port (Jones, 2003).

3.7 Growth Forecast for Durban Containers

It has been shown above that Durban is South Africa’s foremost container port. Durban accounts for some 65% of the total South African containerised port traffic and the port of Durban, having terminal status, is by far the best adapted port for this function. It has also been shown that though containers offer the best return on investment in the form of economic linkages, Durban is suffering from severe capacity constraints. As shown previously, the port management’s response to these capacity constraints has been slow, limited and short sighted. To accurately predict what kind of additional capacity is needed for the future, one must first calculate the actual cargo volumes for the related periods through some form of demand forecasting. Econometric forecasting involves estimation of a quantitative value about the probability of a future event occurring using underlying fundamentals and can be broadly divided into three categories, namely, cross sectional, time series and panel data. Cross sectional data analyses a group of data points at a single moment in time. For the purposes of forecasting, time series econometrics is the most conventional approach; here forecasting is based on data taken across time intervals. Panel data is a combination of both cross sectional and time series data and involves analysing a specific group of data over a period of time In order for an econometric model to be meaningful, it must be relevant, rational and significant. Achieving these requirements means that model and data selection are of the utmost importance and this selection depends on available resources. Time series models vary according to data availability and manipulation and some of the more common models are autoregressive integrated moving average (ARIMA), autoregressive distributed lag (ARDL), vector autoregressive (VAR), autoregressive conditional heteroscedasticity (ARCH) and generalised autoregressive conditional heteroscedasticity (GARCH). Looking at time series in detail is beyond the scope of this dissertation, but the first three models listed above will be briefly examined as they are the most commonly used. After which, we will briefly look at some container forecasting models for the port of Durban (Gujarati, 2003; Stopford, 1997).

The ARIMA model is based on two components, namely an autoregressive component and a moving average component. The autoregressive component means that a current value, say Y, is dependent on a previous or lagged value of Y. The moving average component relates to how the error term and its lagged values contribute to the dependent variable, say Y. The term integrated relates to how many times the model must be differenced in order to become stationary. In time series, a model is considered stationary if its mean and variance are constant over time and the covariance value is dependent on the distance between the two time periods and not on when the time periods are. If a model is not stationary, the regression results will be spurious and inaccurate. See below an example of an ARIMA model which has a constant, a lagged value of Y and a lagged value on the error term to help explain the outcome of Y_t (Gujarati, 2003; Muller, 2004).

Figure 23: ARIMA Model

$$Y_t = \delta + \phi_{1_t} Y_{t-1} + \varepsilon_t - \theta_1 \varepsilon_{t-1}$$

The ARDL model has two parts to it as well, an autoregressive component which was explained above and a distributed lag component. The distributed lag component is simply lagged independent variables that are used to explain the dependant variable as well as lagged values of the dependent variable. When a model uses both present and lagged values of its explanatory variables, it is a dynamic model. The reason that lags are used is that many economic reactions take time to be processed in an economy, an example of which is the interest rate impact in South Africa which takes approximately 18 months to be felt in the real economy. There are three main reasons for lags. The first is the psychological reason and relates to habitual behaviour, fear, optimism and perception. The next is the technological reason and involves the use of capital and technology in the economy. The last is institutional reason and contractual obligations. See below an example of an ARDL model where Y is the dependent and explanatory variable, U is a constant term, X is the independent variable and E is the error term (Gujarati, 2003; Muller, 2004).

Figure 24: ARDL Model

$$y_t = \mu + \sum_{i=1}^{p} \gamma_i y_{t-i} + \sum_{j=0}^{r} \beta_j x_{t-j} + \delta w_t + \varepsilon_t$$

The VAR models are atheoretic, meaning they do not have any theoretical underpinnings, and use simultaneous endogenous variables only. In all time series models, to a varying extent, the past data and relationships between data flows is extrapolated to the future. It is this very condition that sometimes leads models to be entirely wrong and an example of which is the current world recession which no model predicted. However, by including a big enough data set with lagged GDP, previous recessions should be included, thereby calculating the probability of a recession occurring in a given period. Predicting any future event with certainty is impossible, but models help by assigning probabilities, and this is why econometrics is often considered more art than science. The results of some econometric times series studies for the port of Durban's containers demand as well as the actual number of teus for selected years are illustrated in Table 8 below. A key structural problem, which none of these models address, is that between the years 2007 – 2009, the World encountered its worst recession since the 1930s depression. As such the actual number of teus in 2009 is in fact less than the 2007 figure, providing the city with much needed "breathing space" much akin to ESKOM's situation whereby the decrease in demand caused by the recession actually led to fewer blackouts and less load shedding (Gujarati, 2003; Muller, 2004).

Muller (2004) uses ARDL, ARIMA and VAR models to calculate future container volumes for the port for the period 2004 – 2013. However, since the ARDL had the lowest errors, the estimates from that model were used. The 2006 and 2007 predictions are underestimated, whereas the 2009 figure, probably due to the non-prediction of the recession, is overestimated.

Floor & Van Niekerk (2001) use a straight linear equation which depicts the number of teus as a function of GDP. Their prediction runs from 2000 – 2020 and it is evident from the comparison with the actual teus that their model is not very accurate. This is a clear example of how more dynamic models, such as those outlined above, are better suited for time series type data and predictions. The official model used by the Tempi process and Transnet has been based on a demand-forecasting exercise undertaken by Graham Muller & Associates. For the purpose of forecasting of container traffic demand, this exercise extended the earlier Muller (2003) approach and also utilised an ARDL model. The model predicts that that by 2013 Durban will have almost 5 million teus passing through it, whereas the earlier Muller model predicted a traffic level of 3.75 million teus for the same year. Table 8 below compares the predictions of the various models which were discussed (Floor & Van Niekerk, 2001; Muller, 2004; Transnet, 2006).

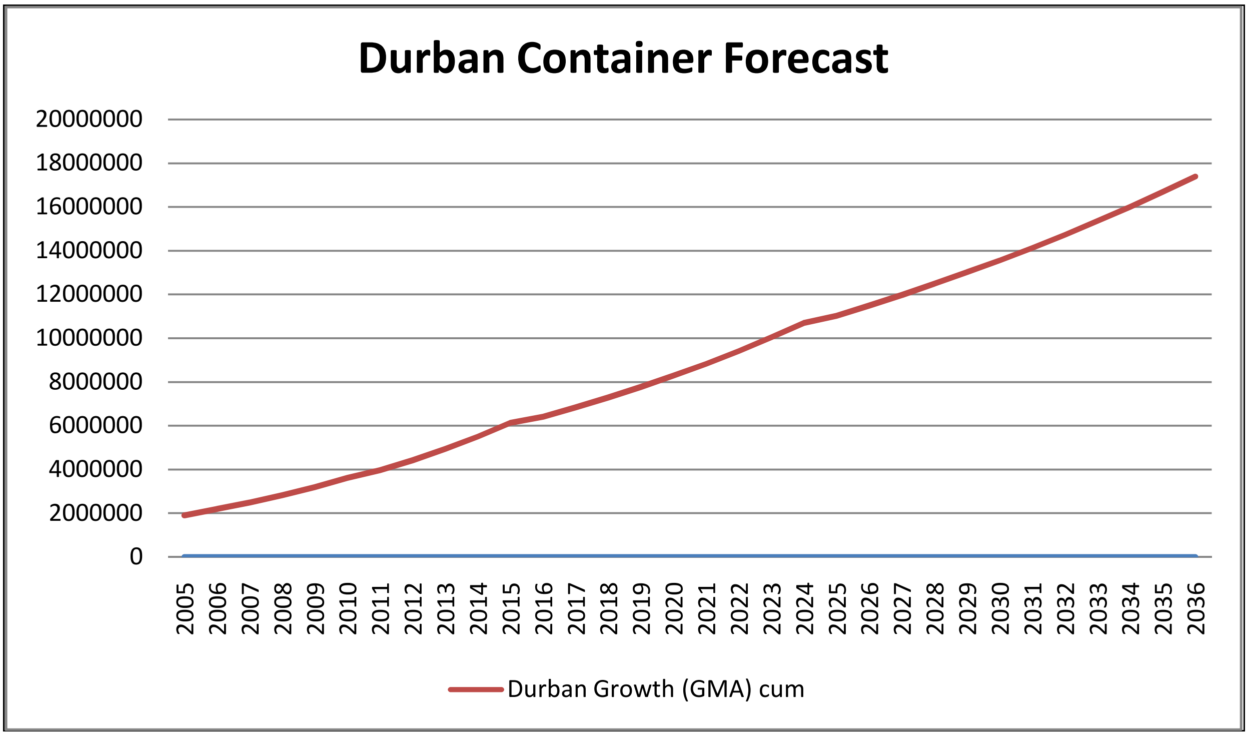
Table 8: Comparative Results of Forecasting Models

Comparative Years	Muller (2004)	Transnet (2006)	F&V (2001)	Actual
2005	1843403	1898483	1553661	1898483
2006	2014839	2198523	1639112	2202841
2007	2202220	2485731	1729263	2480223
2009	2772436	3189633	1924713	2395175
2013	3751631	4928918	2384382	NA
2020	NA	8280853	3287688	NA

Source: Floor and Van Niekerk, 2001; Muller, 2004 and Transnet, 2006

The model used by Transnet provides a forecast until the year 2036 where the expected teus will be in the region of 17 million. It must be noted that the model which Transnet used was a medium growth type scenario and if the high growth scenario was used the amount of teus in 2036 container traffic would reach 25 million teus. The near future consequences of growth without an increase in supply will be congestion, increased costs and delays in the port. In the long term, this could even lead to Durban losing its dominant container status.

Figure 25: Durban Container Long Term Forecast (Medium Growth)



Source: Transnet, 2006

3.8 Conclusion

This chapter has focused on the port of Durban and has examined issues of capacity, growth, ecology and economics. The costs and opportunities of increasing port capacity have many perspectives, conflicts and problems. Questions of development and sustainability as well as environmental parameters all compete to become the dominant perspective. From the above, it is clear that stop-gap, short term measures are not going to alleviate pressure for very long and, as such, large expansion options must be considered if Durban is to remain relevant in the medium term as a hub port. Durban is currently at a crossroads in terms of where to locate additional container-handling capacity. The theory of CBA was covered in the literature review and it is through this methodology that this dissertation will attempt to answer these fundamental questions.

Chapter Four: CBA Options for Durban Port

4.1 Introduction

This section of the dissertation will examine the various expansion scenarios available to Durban as well as their associated CBA proposals. It must be emphasised that the data was referenced from various research papers and sources where often the underlying assumptions differ markedly. As such, sometimes heroic assumptions are made so that a complete model could be constructed. This is often the case with economic and CBA studies where only incomplete data is available. The primary sources that will be used in the CBA are the Tempi documents (2006), Jones (2004), papers sourced from Imani Development (2006) and Vancometrics (2006) as well as many others.

4.1.1 Methodology for Benefit and Cost Calculations

As shown in the literature review, a NPV with an environmental constraint can be constructed to form the equation below where the NPV is a function of benefits less financial and environmental costs and discounted accordingly. The philosophy behind discounting and CBA, along with their possible failings, was covered extensively in the literature review.

$$NPV = \sum(B_t - C_t - E_t)(1+i)^{-t}$$

$NPV > 0$ to pass the CBA test

As shown in Chapter Three, Durban harbour has numerous ecological and recreational functions, in addition to its key economic function as a gateway for seaborne trade. These include: disease prevention, nutrient dispersal, flood mitigation, leisure activities and a food source. The Tempi process attached financial and environmental costs to various expansion options for the port of Durban but not the proposed economic benefits of each of the options. The environment costs were ascertained by using a mixture of a hedonic and CVM approaches in order to evaluate the current environmental benefits that the bay provides. This approach was used since for the most part the services provided by the bay are non-market in nature and as such, market values must be estimated. The cumulative environmental benefit of leaving the bay untouched is approximately R1.4 billion per annum (See Appendix 1 for a detailed breakdown of bay benefits and costs for the various expansion options). The expansion options were then measured and evaluated against this figure according to how the environmental benefits of the bay increased or decreased under the different expansion options. The environmental impact of the different expansion options differs quite noticeably in range. The values range from a cost of R849 million to a benefit R31 million per annum, showing that some expansion options decimated the environment whilst others actually improved on the status quo (Tempi, 2006).

Since the economic benefits were not provided for in the Tempi process, some sort of proxy or calculation had to be used to derive them. As such, the benefits of each of the expansion options had to be identified, valued, discounted and streamed accordingly. A possible way of doing this is to look at the positive effects that a larger and deeper port would have on vessels in general and container vessels in particular through cost savings. As shown in the literature review, vessel sizes are on the increase since, through economies of scale, they provide cheaper unitised transport. All the expansion options examined in the dissertation increase the berth depth to -16.5m, from the current -12.5m. For example, a 4 500 teu vessel has a 30% lower average unit cost than a for a 2 500 teu container. These cost savings would eventually flow through to end users, ceteris paribus, in the form of lower freight rates and charges. As such, ports must adapt to this trend by installing infrastructure that can cater for these large vessels. One can thus quantify the benefits derived from port extensions in this way, as Erskine did in her unpublished 2008 honours dissertation (Benachio, Cariou & Haralambides, 2002; Tempi, 2006).

An alternate approach will, however, be used in this dissertation in order to quantify the benefits of port expansions. This approach was initially done by Jones in 1995 and 1998 whereby the expenditure that a typical container ship experienced was calculated. Jones (1998) rightly states that this approach should be considered as an "impressionistic indication rather than a detailed description of economic activity" (Jones, 1998, pg. 24). In 1994, the average container ship contributed R788 000 per port call in Durban or R1 970 per container. If the regional multiplier, which was calculated in Chapter Three, is applied then the economic impact becomes approximately R1.9 million. The Tempi process of 2006 used an adaptation of the Jones methodology whereby the expenditure was calculated for a typical container ship as seen below. Here it can be seen that in 2006, a typical container vessel per call spent just over R2.9 million in the port and if the multiplier is applied, the figure per a typical vessel per call becomes just short of R 7 million (Jones 1995; Tempi, 2006).

Table 9: Expenditure of a Typical Container Vessel Per Call

Service	Expenditure	Percentage
NPA marine infrastructure & services[1]	135 000	4.6.
SAPO Terminal charges	675 000	22.9
Stevedoring & Tallying	13 300	0.5
Ships Agency	33 000	1.1
Ship Chandlers	45 000	1.5
Clearing & Forwarding	616 000	21
Container depots, logistics etc	125 000	4.3
Road haulage	430 000	11.9
Rail charges	100 000	3.4
Ship repair services	77 000	2.6
Bunkers & fuel	772 000	26.2
TOTAL EXPENDITURE PER CALL	2 941 300	100

Source: Tempi, 2006 and Jones, 1995

1- This excludes payments for Cargo Dues

The R2.9 million figures above was derived using a 900 teu container ship and assuming a 70:30 road to rail ratio of cargo distribution and 35:65 ratio of container volumes across Durban to non-Durban cargo owners. As Figure 32 below illustrates, this yields expenditure of R3 222 per container or R7 732 when using the regional multiplier. By making a large assumption, that the benefit per teu is constant across types, it can be established that economic benefit for 2006, when multiplied by the 2.2 million teus, was just over R7 billion or just over R17 billion if the multiplier is used. However, since many containers are 12 metre boxes, it is perhaps more accurate to multiply the average spend per vessel by the amount of vessels per annum but when this was done it had a minimal impact on the outcome. The above illustrates what benefits can be derived from the attraction of additional container traffic in the port of Durban. The benefit figure per teu shall be used when calculating the stream of benefits for the various expansion options. The figure below illustrates the above calculations. The expansion options analysed will be Bayhead, DIA and Richards Bay. Each option will be explained in the context of the port and then analysed using CBA methodology. For a detailed explanation of CBA methodology, environmental economics, discounting and their applications, please refer to the literature review (Tempi, 2006).

Table 10: Expenditure of Typical Container Vessel

	Typical Vessel Spend Per Call	Rand Per Teu	Rand per Teu with Multiplier	Container Economic Contribution	Multiplied Economic Contribution
2006	2 900 000	3 222	7 732	7 098 043 222	17 035 303 733

Source: Tempi, 2006 (Data in Rands)

The crucial question then becomes: can the secondary or multiplier effects be used in the CBA analysis? On this point, the literature is mixed. Sinden & Thampapillai (1994) state that "in a competitive market, there are no real secondary benefits and cost and so none should be included. But equally, in a non-competitive market secondary outcomes can exist and so should be identified and included" (Sinden & Thampapillai, 1994, pg. 36). As was illustrated in the literature review, ports do not operate in a perfectly competitive environment but they do exhibit some forms of competition. It is very tempting to include as many benefits as possible for a given project, thereby skewing the CBA decision in favour of the project. If this approach is taken, then so should secondary losses in order to give a more balanced account. The Department of Environmental Affairs states that the multiplier effect should only be used in an economic report and not a CBA study where only the first round effects are relevant. As such, it was thought that only the direct benefits of the cash flows would be used and not their multiplied effects (DEA, 2009).

Before proceeding with the CBA, some critical foundations need to be established. As with any economic analysis, certain assumptions are made out of necessity or convenience. The higher the discount rate, the more society favours the present as opposed to the future. One view of counteracting this problem is to purposefully lower the discount rate. Miles Mander, of Future Works, proposes using a negative discount rate with regards to "critical natural capital", since the future will require a larger capital stock to offer the same level of utility because of population growth. This approach is virtually identical to the strong sustainability approach shown in the literature review. The above is thought to be nonsensical, since the two primary reasons for discounting, the opportunity cost of capital and time preference, are not addressed by this approach. In light of this, a weak sustainability clause and the Hartwick model are assumed where man-made capital and natural capita are deemed to be near perfect substitutes. The rule states that as long as the stock of capital is non-decreasing through time, then non-declining consumption is also possible. The stock of capital could be held constant by reinvesting the rents received from the natural capital stock into man-made capital stock. The Hartwick model also assumes a positive discount rate. As such, a discount rate of 8% was used for two reasons. Firstly, this is the rate used by the DEA as well as in the Tempi process.

Secondly, this rate closely reflects South Africa's long-term interest rate. Some other assumptions were also made for the CBA in this dissertation and include:

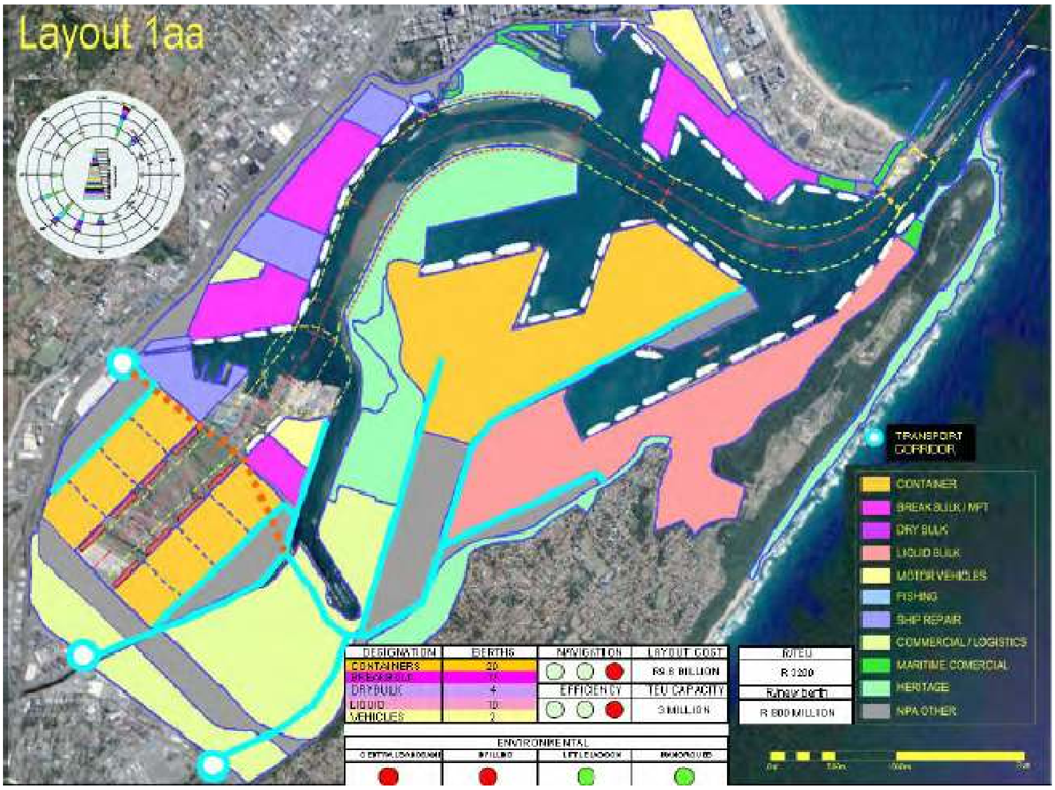
- The first two-thirds of construction project time involve no economic benefits.
- The last one-third of the construction period involves 50% economic benefit per annum. The reason for this assumption, as well as the previous assumption, is that intuitively one would expect a construction project of such a large nature to start yielding benefits before final completion. The primary reason for this is that construction normally happens in phases and as long as the phases are independent of each other, then operations can begin at completed phases.
- Full environmental costs are calculated from the first year.
- A 50 year time horizon is used.
- Construction times are inferred and adapted from a Transnet Technical Report.
- The benefit of an additional teu is constant across all construction options.

4.1.2 Bayhead - Northern Layouts

The Tempi process initially had 11 expansion options and through a process of elimination, these were later reduced to four more serious and practicable possibilities. The four alternatives chosen, based on various criteria such as financial cost and environmental feasibility are 1AA, 1AB, 3CA, 3DA. These four options all provide access routes to a new container-handling basin at Bayhead and can be broadly divided into two separate categories, namely a Northern Access route via Maydon Wharf/Esplanade Channels in 1AA and 1AB as well as a Southern Access route via Island View Channel in 3CA and 3DA. All the Bayhead options will have a berth depth of -16.5m, thereby allowing post-Panamax vessels to access the port. As shown in the literature review, shipping vessel size is continually migrating toward to larger and deeper vessels to benefit from increasing returns to scale which larger vessels provide. From Chapter Three, it also became apparent that the current depth specifications of Durban port are wholly inadequate at -12.5m. In addition, it must be emphasised that the layouts are mutually exclusive, in that by choosing one you are in fact rejecting the other three. The NPV value, which is highlighted in yellow, is the most important factor and if positive means that the project makes economic sense. Other key variables like the Payback Period and IRR (see Appendix 5 for an example on how the IRR was calculated), which were also explained in the literature review, are also shown in the tables so as to provide further economic information on the expansion options (Tempi, 2006).

The first Northern Layout, 1AA, provides space for an additional 3.2 million teus and 12 additional berths with a total financial cost of R9.6 billion. This calculates at R800 million a berth or R3 200 per teu. The expansion involves filling in around Salisbury Island, deepening and widening the Esplanade and Maydon Wharf Channels, cutting back of the associated sandbanks, as well as a dig-out basin in the present Bayhead rail marshalling yard site. The positives of this option are that there is minimal interruption of cargo handling activities. A definite negative is that an estimated 10% loss of the sandbank will result if this option is used. Tempi (2006) estimate the negative environmental effects to be in the region of R749 million rand per annum. The CBA calculations are shown below whereby this option yields an NPV of R66 billion and a payback period of 8 years. The option also has an IRR of 26.4%, which is far above the discount rate, indicating that the project is profitable and has very little financial risk (Tempi, 2006).

Figure 26: Diagrammatic Overview of Option 1AA



Source: Tempi, 2006

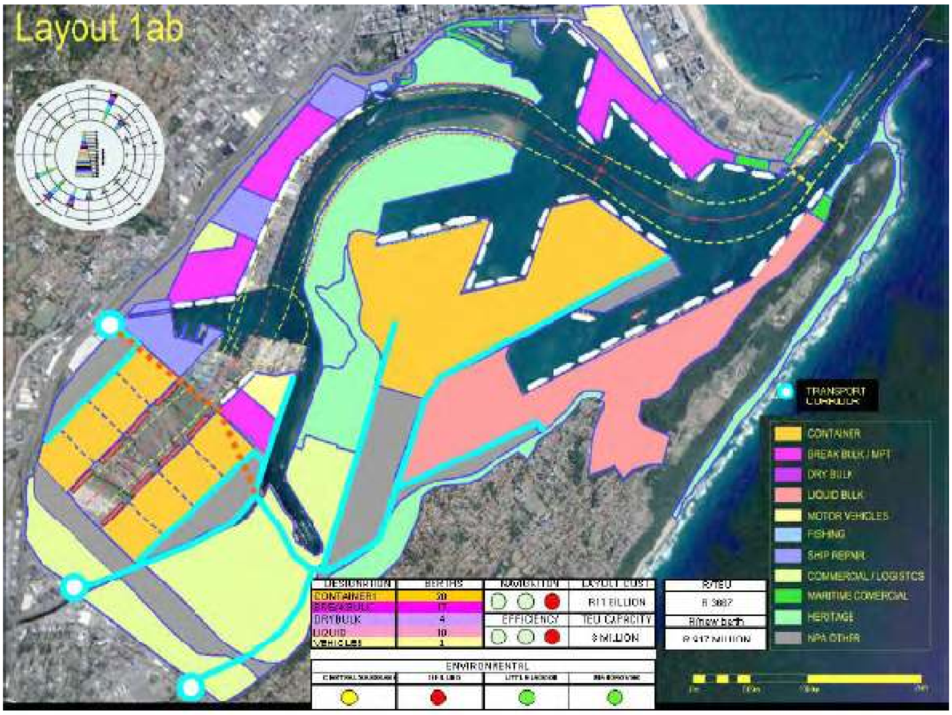
Table 11: CBA of Option 1AA (in millions of Rands)

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Infrastructure Cost		-9 600							
Environmental Cost			-749	-749	-749	-749	-749	-749	-749
Benefits			0	0	0	0	5 155.5	5 155.5	10 311
Total		-9 600	-749	-749	-749	-749	4 406.5	4 406.5	9 562
Discount Factor		1	1.08	1.17	1.26	1.36	1.469	1.59	1.7138
NPV	**66 465**	-9 600	-693.5	-642.15	-594.58	-550.54	2 999	2 776.84	5 579.3
Key Factors									
Additional Teus	3.2								
Construction Cost	9.6 billion								
Construction Time	6								
IRR	26.40%								
Payback Period	8								

(See Appendix 2 for full 50 year calculations)

In terms of capacity gained, layout 1AB also gains 3.2 million teus and 12 berths. The layout differs markedly from 1AA in terms of it leaving the sandbank largely untouched. Due to the sandbank avoidance, the environmental costs are thereby greatly reduced - at R459 million per annum as opposed to 1AA's R749 million- in environmental damages. The avoidance of the sandbank loss is accomplished by pushing back the Maydon Wharf quayside, resulting in the removal and setting back of the quay wall from its present position. The proposed cutting into Maydon Wharf comes at a great economic cost since this segment contains numerous businesses. Over 200 000 square metres of prime rental space are lost which translates to R419 million. The loss of vessel activity calculates at R1.69 billion and the loss of business activity calculates at R5.462 billion. The financial cost of this expansion option is R11 billion which calculates at R917 million a berth or R3 667 per teu. This option has a NPV -R22 billion, an IRR of 3.325%. This option would need an unrealistically low discount rate to make it profitable since the economic opportunity costs are so high and this is evident by the IRR being far below the discount rate of 8%.

Figure 27: Diagrammatic Overview of Option 1AB



Source: Tempi, 2006

Table 12: CBA of Option 1AB (in millions of Rands)

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Infrastructure Cost		-11 000							
Environmental Cost			-459	-459	-459	-459	-459	-459	-459
Opportunity Cost			-7 471	-7 471	-7 471	-7 471	-7 471	-7 471	-7 471
Benefits			0	0	0	0	5 155.2	5 155.2	103 10.4
Total		-11 000	-7 930	-7 930	-7 930	-7 930	-2 774.8	-2 774.8	2 380.4
Discount Factor		1	1.08	1.1664	1.25971	1.36049	1.46933	1.58687	1.714
NPV	**-22 786**	-11 000	-7 342.6	-6 798.7	-6 295.1	-5 828.8	-1 888.5	-1 748.6	1 388.94
Key Factors									
Additional Teus	3.2								
Construction Cost	11 billion								
Construction Time	6								
IRR	3.325%								
Payback period	0								

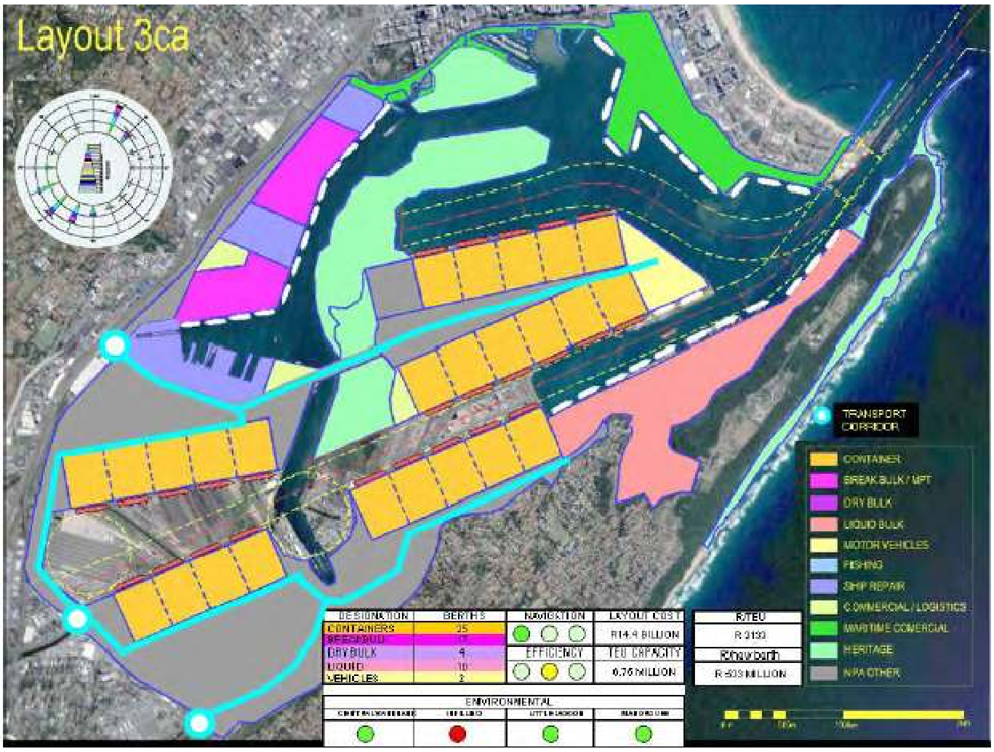
(See Appendix 2 for full 50 year calculations)

4.1.3 Bayhead - Southern layouts

These routes use a southerly channel to access Bayhead and as such the effect on the natural habitat like the sandbank is negligible. This change in channel routing is quite different to the northern access routes in that the Island View Channel, instead of the Esplanade and Maydon Wharf Channels, is extended to provide vessels to a new Bayhead basin. The financial cost of 3CA is R14.4 billion for a capacity of 6.75 million teus and 27 container berths. This calculates at R512 million per berth or R2 133 per teu gained. The table has been edited to omit year 1 to year 5 since the relevant calculations only happen from year 6. This option yields an NPV of R146 billion, a payback period of 8 years and a high IRR of 29.92%. The Southern layout routes yield far higher NPV's than their Northern counterparts owing to the positive environmental effect of these options which Tempi (2006) shows as being R31 million. These effects include improved flood mitigation and landscape character as well as better deep sediment assimilation, resulting in the Southern Access Route being highly favoured by environmentalists.

The Southerly Access routes, however, do have a major failing in that they require the removal of the petro-chemical installations. Port planners considered this an impossible notion since there is no other adequate location for the petro-chemical installations and, even if there was, the financial cost would be highly prohibitive. Exact financial figures were not calculated since the idea was considered too fanciful by port planners and as such the Southerly Access routes were both discarded. An interesting point though is that the best Island View option, 3CA, exceeds option 1AB by some R80 billion in benefits. Hence, if the cost of moving and rebuilding the petro-chemical installations and acquiring a suitable piece of land to rebuild them can be shown to be less than R80 billion, then these options should indeed be seriously considered. As such, it was thought prudent to calculate these flows of benefits and costs in the event of a costing being done on the removal of the petro-chemical installations (Tempi, 2006).

Figure 28: Diagrammatic Overview of Option 3CA



Source: Tempi, 2006

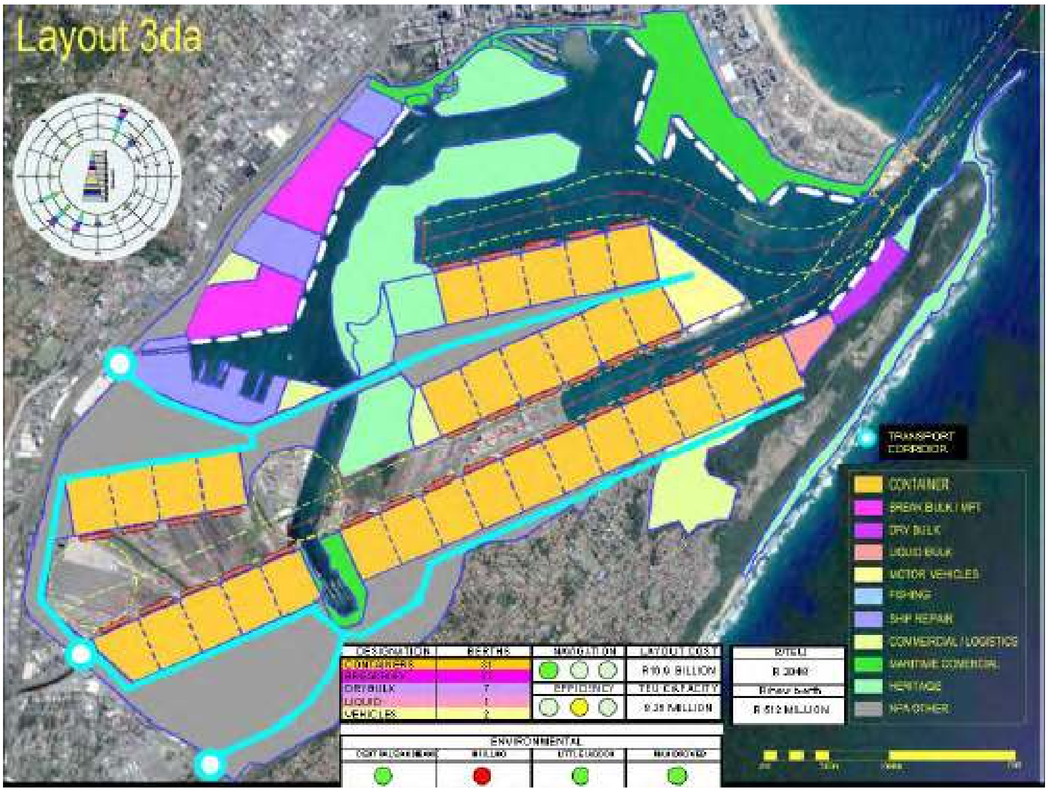
Table 13: CBA of Option 3CA (in millions of Rands)

	Total	Year 0	Year 1	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11
Infrastructure Cost		-14400							
Environmental Cost			31	31	31	31	31	31	31
Benefits			0	10874.3	10874.3	10874.3	21748.5	21748.5	21748.5
Total		-14400	31	10905.3	10905.3	10905.3	21779.5	21779.5	21779.5
Discount Factor		1	1.08	1.58687	1.71382	1.85093	1.999005	2.15892	2.33164
NPV	**146131.1**	-14400	28.7037	6872.16	6363.11	5891.77	10895.17	10088.1	9340.85
Key Factors									
Additional Teus	6.75								
Construction Cost	14.4 billion								
Construction Time	8								
IRR	29.92%								
Payback period	8								

(See Appendix 2 for full 50 year calculations)

Layout 3DA is quite different to the 3CA in terms of the extent of additional capacity. The financial cost is R16.9 billion for an additional capacity of 8.25 million teu or 33 container berths. This calculates at R583 million per new berth or R2 033 per teu. The increase in 6 berths over option 3CA is due to the conversion of liquid bulk berths to container berths. As shown above, although the two southerly routes are highly favoured by environmentalists, at present this is not considered a serious option by port planners or commercial port users because of the effective destruction of liquid-bulk sites and trades. The table below has some years missing for the same reasons as above. This option yields a NPV of R144 billion, payback period of 10 years and an IRR of 24.39%. Like option 3CA above, this is not being considered seriously due to the perceived difficulty of removing the petro-chemical installations.

Figure 29: Diagrammatic Overview of Option 3DA



Source: Tempi, 2006

Table 14: CBA of Option 3DA (in millions of Rands)

	Total	Year 0	Year 1	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14
Infrastructure Cost		-16900							
Environmental Cost			31	31	31	31	31	31	31
Benefits			0	13291	13290.8	13290.8	26581.5	26581.5	26581.5
Total		-16900	31	13322	13321.8	13321.8	26612.5	26612.5	26612.5
Discount Factor		1	1.08	1.999	2.15892	2.33164	2.518	2.71962	2.93719
NPV	**144585**	-16900	28.7037	6664	6170.55	5713.47	10568	9785.36	9060.52
Key Factors									
Additional Teus	8.25								
Construction Cost	16.9 billion								
Construction Cost	11								
IRR	24.39%								
Payback period	10								

(See Appendix 2 for full 50 year calculations)

4.1.4 Durban International Airport (DIA) Site

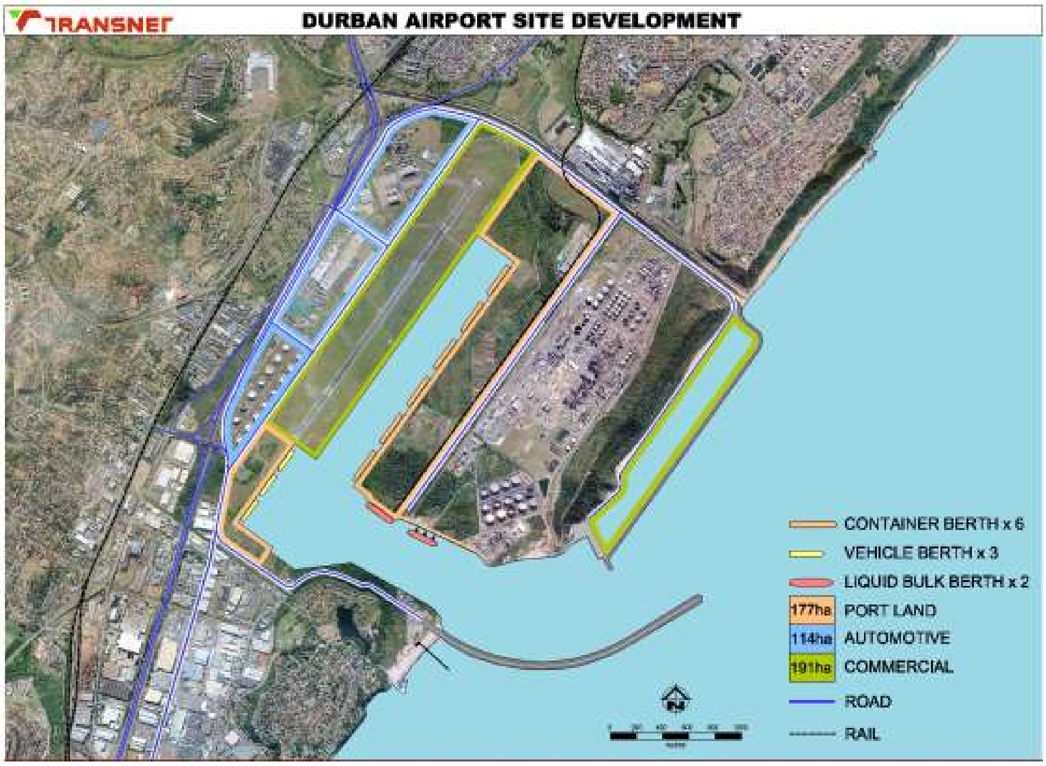
From May 2010, Durban's international airport has relocated to King Shaka International Airport at La Mercy. This area, which also includes the Dube Trade Port freight logistics hub, opens up new vistas for Durban as a strategic regional transport platform and hub. This brings to the fore pertinent questions about what will be done with the vacant space at the old airport site. The DIA site fundamentally differs to Bayhead in this regard, since even though the expansion options may generate a positive NPV, alternate uses for the land may generate an even higher NPV. These options include a second airport, whereby Virginia airport is relocated to the DIA site as well as an industrial logistics zone. The industrial zone includes suggestions for a petrochemical hub that will have a steam cracker, polyethylene plant, polypropylene plant and PVC plant. Added to this, is interest shown by Mondi for manufacturing and distribution of its many paper products as well as Shoprite who wish to develop it into an efficient supply chain site (Moloi, 2006).

The third option, most relevant to this dissertation, is the conversion of the site into a second port. The DIA site is situated in a flat low-lying area which is ideal for a harbour type development since it is over 600 ha in area, well serviced by road and rail, close to Durban port and has established linkages to inland and coastal regions. The purpose of this dissertation is not to look at the expansion alternative available from the DIA perspective, but rather to assess what options are available for port expansion. However, it would be a point of interest if a port serves the region best as opposed to the other options mentioned above. Such a study was done in a combined study by Vancometrics and Imani Development entitled “Durban International Airport, Decision Making Framework for Redevelopment of the Airport Site, 2006”. On balance the findings of the report were that the dig-out port would yield the most economic benefits if linked to a Petronet oil pipeline terminal and an expansion option for the automotive industry. A mixed industrial and logistics option which excludes the port ranks second and migrating Virginia airport to the DIA ranks last.

The DIA option will have a depth of -16.5m, thereby allowing post-Panamax vessels to access the port. There is no in-depth literature on the ecological and environmental consequences of developing the DIA as a port and a proper environmental impact assessment would need to be done with regards to breakwaters, access channel, the Isipingo river estuary, damage to mangroves, harbour basin and back of port logistics. The primary environmental concern is the destruction of the habitat of the black-headed dwarf chameleon which is quite rare in the province and in recent decades has suffered significant declines. The rarity of the chameleon is compounded by the fact that previous relocation attempts have failed. The DIA site also has the largest sub-population. Other considerations include the relocation of the market gardeners who use the area for farming and agriculture. As there is no adequate data with regards to environmental costs, it will be assumed that the environmental costs are the same as for the Bayhead option of the same capacity. This is admittedly a massive assumption that would normally have an impact on the results of CBA study. However, just as the Bayhead options were mutually exclusive amongst themselves, so are the options relating to the DIA. And since the environmental cost assumption is applied to both DIA options, it should still give a fairly accurate ordinal ranking (Moloi, 2006; Tempi, 2006).

The first option, DIA1, will increase the current teu capacity by 3 million teus at a cost of R14.9 billion and a construction time of six years. This option yields a NPV of R55 billion a payback period of nine years and an IRR of 20.72%. Unfortunately, no diagram for the DIA1 option could be found and as such, the one below is an impressionistic opinion taken from the Tempi document. The DIA options have far lower NPV’s than the comparable Bayhead options owing to their greater infrastructural costs and long construction times. It is these high initial costs which lead to very long payback periods indicative of the diminishing power of discounting on cash flows in the future.

Figure 30: Diagrammatic Overview of Option DIA1



Source: Tempi, 2006

Table 15: CBA of Option DIA1 (in millions of Rands)

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Infrastructure Cost		-14900							
Environmental Cost			-749	-749	-749	-749	-749	-749	-749
Benefits			0	0	0	0	4833	4833	9666
Total		-14900	-749	-749	-749	-749	4084	4084	8917
Discount Factor		1	1.08	1.1664	1.25971	1.36049	1.46933	1.58687	1.71382
NPV	**55836.1**	-14900	-693.52	-642.15	-594.58	-550.54	2779.5	2573.61	5202.98
Key Factors									
Additional Teus	3								
Construction Cost	14.9 billion								
Construction Time	6								
IRR	20.72%								
Payback period	9								

(See Appendix 2 for full 50 year calculations)

The second option, DIA2, will increase current teu capacity by 6.25 million teus at a cost of R25.1 billion and a construction time of twelve years. This option yields a NPV of R69 billion, a payback period of 15 years and IRR of 14.84%. The environmental costs have been derived by doubling the Bayhead 1AB environmental cost, based on the very simple logic that since this option yields roughly double the amount of capacity as 1AB, it should also yield double the environmental cost. The table has been edited so as to illustrate the more relevant years. DIA2, though it has much higher capital costs than DIA1, has a higher NPV due to the greater capacity which it provides. Since it has more than double the capacity of DIA1, the stream of positive benefits per teu eventually overcomes the initial high investment costs. Perhaps of some concern is the relatively low IRR, which indicates that should the opportunity cost of capital increase to this level then the project would no longer be feasible.

Figure 31: Diagrammatic Overview of Option DIA2

Source: Transnet, 2009

Table 16: CBA of Option DIA2 (in millions of Rands)

	Total	Year 0	Year 1	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13
Infrastructure Cost		-25100							
Environmental Cost			-1498	-1498	-1498	-1498	-1498	-1498	-1498
Benefits			0	0	10069	10069	10069	10069	20138
Total		-25100	-1498	-1498	8571	8570.75	8570.75	8570.75	18639.5
Discount Factor		1	1.08	1.85093	1.999	2.15892	2.33164	2.51817	2.71962
NPV	**69185.68**	-25100	-1387	-809.32	4288	3969.92	3675.85	3403.56	6853.7
Key Factors									
Additional Teus	6.25								
Construction Cost	25.1 billion								
Construction Time	12								
IRR	14.84%								
Payback period	15								

(See Appendix 2 for full 50 year calculations)

4.1.5 Sensitivity Analysis on Different Options

As shown in the literature review, sensitivity analysis illustrates how reactive the result of a CBA is to a change in a single variable, ceteris paribus. Sensitivity analysis allows informed decisions to be made by altering some assumptions and/or inputs that would consequently alter the final outcome. Under sensitivity analysis, it is understood that the future cannot be predicted perfectly and as such various outputs for a given project must be forecast in the event that they become the actual outcome. By using sensitivity analysis, a range of values are now exhibited, which can point out weaknesses in the project as well as areas where more research needs to be undertaken.

For this dissertation, the only dependable inputs that could be altered were that of the discount rate and the infrastructural costs. There was not enough reliable information to attempt altering the environmental costs, growth forecasts or benefit calculations. As shown above, the current official real social discount rate used in South Africa is 8%. The Development Bank of South Africa, however, uses a 5% discount rate for its projects, since the average long term rate of real interest rates over the past 15 years has been in the region of 5% since according to Conningarth Economists "If one uses the underlying theory of long-term real interest rates (i.e. the cost of funding to the State), the average long-term real interest rate in South Africa over the last 15 years has been approximately 5%." (Tempi, 2006, Definition and Application of a Hurdle Rate, pg. 6). Additionally, "...Walshe and Dafferen calculate that the STPR is slightly in excess of the growth rate of an economy. The long-term growth rate of the South African economy is in the order of 2.5% to 5%, which is substantially lower than the 8% social discount rate used in South Africa." (Tempi, 2006, Definition and Application of a Hurdle Rate, pg. 6).

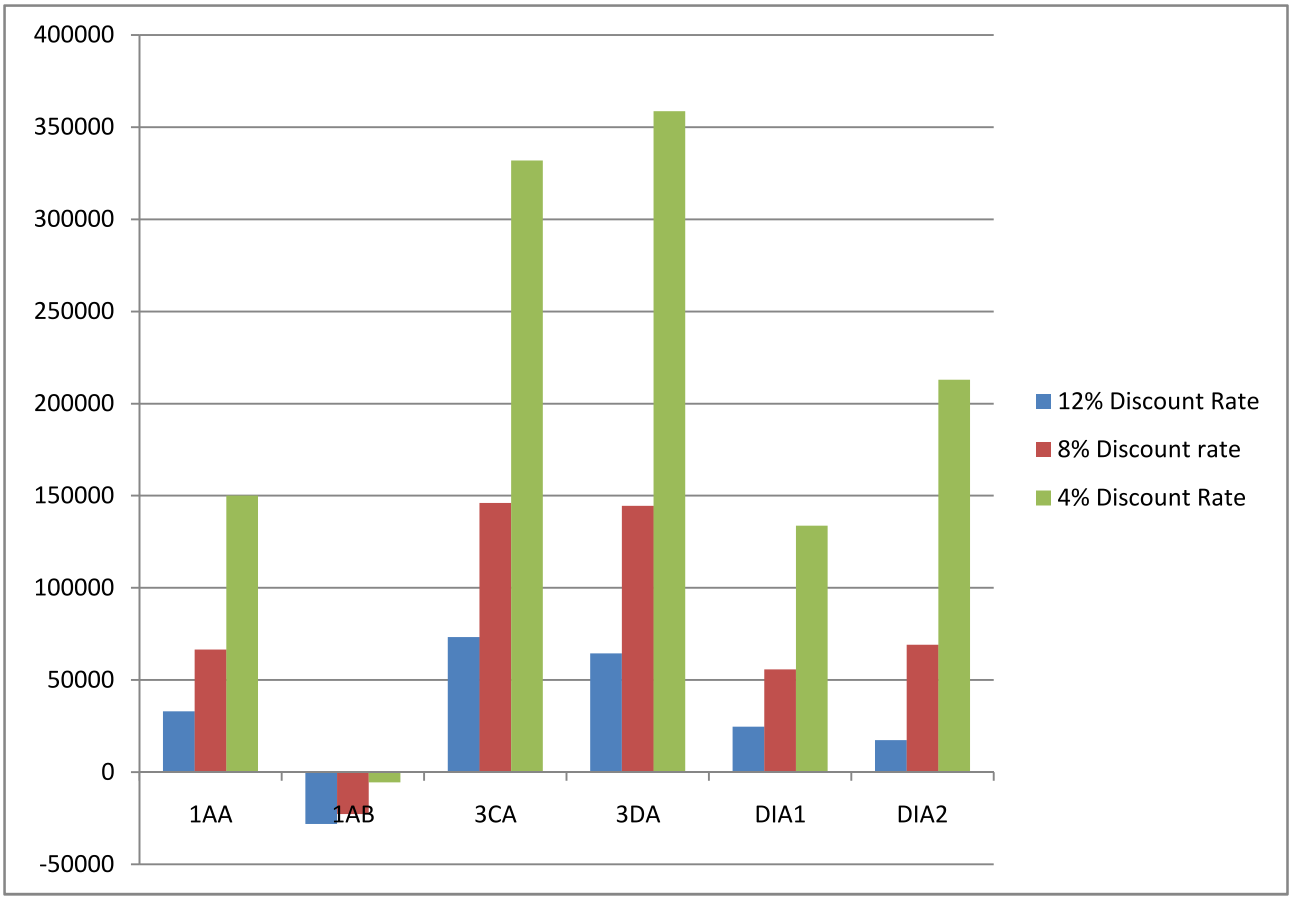
Based on the above, it was thought prudent to calculate a range of discount rates and as such the discount rate was altered to 4% and 12% and as was expected the NPVs increased and decreased respectively. Even though the NPVs changed under differing discount rates, the relative stance of the projects remained largely the same. The exception was that under a 4% discount rate, 3DA became the highest ranked option as opposed 3CA. Additionally, under a 12% discount rate DIA1 becomes more profitable than DIA2 because the additional cash flows are penalised more. As stated above, the Bayhead options are internally mutually exclusive and the same for the DIA options. A graph is also depicted below, illustrating the expansion options by discount rate. By varying the discount rate, it could be seen what the NPV would be under different circumstances thereby factoring in risk and uncertainty. As can be seen if the discount rate were to suddenly deviate from the long-term average of 8% to an extent of 4% or 12%, the NPV would still be positive for the relevant expansion options. Under the 4 % discount rate, option 1AB is close to its breakeven point of the NPV, which is 3.325 % as per the IRR calculation shown above. (A summary of the sensitivity analysis is shown here. The reader can refer to the Appendix 3 for full calculations.)

Table 17: Varying Discount Rates for Different Options

		Bayhead	**Options**			**Airport**	**Options**
Discount Rate	**1AA**	**1AB**	**3CA**	**3DA**		**DIA1**	**DIA2**
12%	32951	-28085	73249	64531		24601	17304
8%	66465	-22786	146131	144585		55836	69186
4%	150068	-5601	331847	358590		133778	213031

(See Appendix 3 for full 50 year calculations)

Figure 32: Options under Different Discount Rates



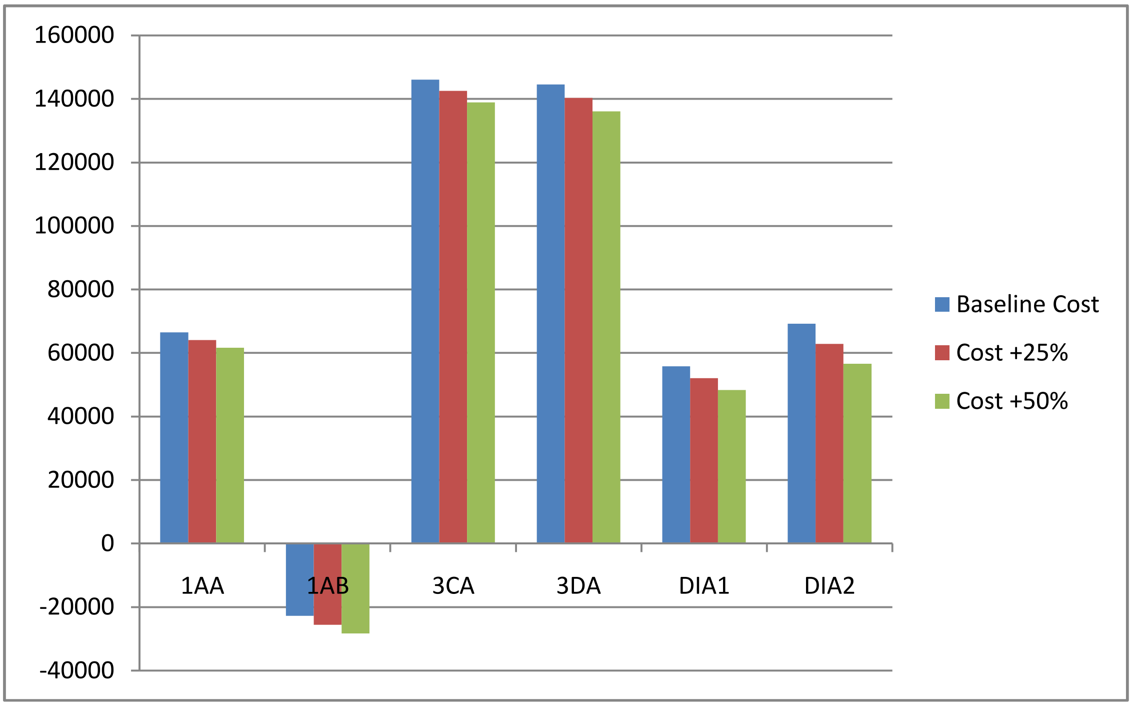
The infrastructural cost of a project is also very unpredictable with many large capital projects deviating from their initial predicted costs. This can be due to anything from exchange rate fluctuations to raw material cost increases. As such, it is prudent to establish the effect on the project of increased infrastructural costs. The scenarios tested were that of 25% above the baseline cost and 50% above the baseline cost. The table below illustrates the findings whereby even though the infrastructural costs are increased substantially, the effect on the NPV is negligible indicating that the cost and benefit flows as well as the discount rate has a far more relevant effect on the NPV.

Table 18: Varying Infrastructure Cost for Different Options

		Bayhead	Options			Airport	Options
Infrastructural Cost	**1AA**	**1AB**	**3CA**	**3DA**		**DIA1**	**DIA2**
Normal Cost	66465	-22786	146131	144585		55836	69186
Cost+25%	64065	-25536	142531	140360		52111	62911
Cost+50%	61665	-28286	138931	136135		48386	56636

(See Appendix 4 for full 50 year calculations)

Figure 33: Options under Different Infrastructure Costs



4.1.6 Richards Bay Port Option

The last expansion option to be considered is that of Richards Bay, primarily because of its close proximity to Durban. Richards Bay, like Durban, is also located on the east coast of South Africa and is approximately 180 kilometres from Durban. The port was originally created to act as an export point for coal sourced from Mpumalanga. Though the port was primarily created for coal, it has since evolved to a more diversified traffic base. The port now deals with minerals, steel, aluminium, ferro alloys, forest products (woodchips and paper products), phosphates and sand products. Richards Bay has a depth of -18.5 metres, thereby allowing it to comfortably accomodate post-Panamax vessels and as shown in the literature review, international trends are definitely migrating towards larger vessels. Additionally, the immediate area around the port is relatively undeveloped and as such, there is ample space is available for cargo handling activities. Further to this, there are opportunities for capital widening and deepening to promote capacity and to bring about efficiency-enhancing initiatives. The port also has an established railway line with the Gauteng, which as South Africa's economic hub, receives a large proportion of both finished and unfinished goods from the country's ports. Though the port has established rail links, it does not have adequate road links with the Gauteng hub and as such, goods travelling by road must go via Durban first. The additional travelling cost would consequently affect final throughput costs, thereby negatively affecting competitiveness (Lawrance, 2000; Jones, 1997).

Table 19: Costing Analysis between Durban and Richards Bay

	Durban Primary	Richards Bay Primary	Difference	% increase of Durban Cost
Items	**Total PV**	**Total PV**	**Total PV**	
Capital Costs	R 24,845	R 30,368	R 5,523	22.2%
Supply Chain Costs	R 857,404	R 935,140	R 77,736	9.1%
Economic Opportunity Costs	-R 67,241	-R 61,270	R 5,970	-8.9%
Environmental Cost	R 5,717	R 5,717	R 0	0.0%
Net Cost	R 820,725	R 909,955	**R 89,229**	10.9%

Source: Tempi, 2006 (in millions of Rands)

The Tempi process included a costing analysis of Richards Bay becoming the primary regional container port instead of Durban. The information that was obtained about this costing approach was very limited in terms of literature but financial data were adequate. In favour of Durban remaining the region's primary container port was that it is easier for industry and shipping lines to access as well as options on developing the integrated connection between the port, city and the province. With regards to Richards Bay's advantages, these include the port having a depth of -18.5m as well as naturally migrating to become a multi-purpose terminal port. However, even though the port handles neo-bulk, it still has quite a way to go before it can seriously handle large container volumes. At present, Richards Bay lacks the manufacturing capacity to generate substantial volumes of general cargo, the market demand to consume general cargo and the logistical infrastructure to transport general cargo efficiently. As seen in the table above, the costing analysis compares capital costs (infrastructure), supply chain costs (distribution), environmental cost and opportunity costs between Durban and Richards Bay. The penalty incurred by moving to Richards Bay in 2007 prices is R89 billion. The large cost differential is mainly due to the diversion of the road traffic base via Durban to reach Gauteng. The additional supply chain costs alone contribute a R77 billion penalty. The capital costs are also higher in Richards Bay due to the lack of a cargo-handling infrastructure suitable for containerised general cargo-handling operations. In terms of economic opportunity costs, Durban's are higher than Richards Bay's, due to construction on productive quayside land. Hence, until there is a direct road link to Gauteng from Richards Bay, there will always be a diversionary penalty for containers. As such, any CBA analysis will be negatively affected by this diversion premium by at least R89 billion. Bearing in mind that that the NPV's calculated for the expansion options in Durban were less than R89 billion, it can be seen that the expansion options in Durban are far more financially sound (Tempi, 2006).

4.1.7 Final Ranking of Expansion Options

The table below illustrates the final ranking of the various options using the baseline financial costs and 8% discount rate. Out of the initial seven options, only three were shown to be economically beneficial; however, the nature of a CBA is to find the most beneficial outcome. Option 2 of the DIA options is the best, followed by 1AA and then DIA1. Richards Bay, for reasons stated above, has been listed as a last resort for becoming a container focused port. Because of the mutual exclusivity of some of the options, the best workable combination is that of 1AA and DIA2, which are both highlighted in red. The combined gain in potential container traffic from 1AA and DIA2 is 9.45 million teus, and when this is added to the current port capacity of 2.5 million teus the total capacity becomes 11.95 million teus. According to the official Transnet forecasts for Durban, this will be sufficient until at least 2027 and more likely closer to 2030. In addition to this, there are speculative construction ventures that Transnet is exploring which could provide a few million more teus. Considering that that 1AA has a far shorter construction time, this option should be constructed first, thereby alleviating capacity constraints more quickly and allowing Durban to benefit from the economic benefits.

Table 20: Final Ranking of Expansion Options

Rank	Option	NPV	Comments
1	3CA	146131	Rejected since Petro-Chemical removal is difficult
2	3DA	144585	Rejected since Petro-Chemical removal is difficult
3	DIA2	69186	Accepted-this option should begin construction after 1AA
4	1AA	66465	Accepted-this option should be constructed first
5	DIA1	55836	Rejected since DIA2 has a higher NPV (mutual exclusivity)
6	1AB	-22786	Rejected-negative NPV and very low IRR
7	Richards Bay	Unknown	Rejected since this option has R89 billion penalty over Durban

4.1.8 Conclusion

This chapter has shown that three expansion options will yield major economic benefits to the Durban region. By process of elimination, two options were accepted based on their NPV's and these were DIA2 and 1AA. The various economic theories explained in the literature review were applied in the CBA analysis in the hope of providing a complete social outlook. Externalities such as environmental implications were internalised so as to provide a social economic outlook as opposed to a private one. Discounting was applied to all streams of benefits and costs so as to calculate a NPV and a weak sustainability clause was assumed in all calculations. The Keynesian multiplier, even though it was not used, proved useful in measuring a regional economic impact. If Durban is to remain South Africa's premier port, then it must proceed with expanding its capacity. By not doing so, the city will incur large opportunity costs in terms of employment and development.

Chapter Five: Conclusion

5.1 Final Conclusion

This paper sought to economically analyse the various expansion options available to the port of Durban and then rank them according to certain criteria. The primary means of doing this was via the construction of a CBA which included the benefits, financial costs and ecological costs of various expansion options available to the port.

The literature review provided the key concepts that the CBA would apply. The demand for ports was shown to be a double derived demand since ports exist firstly to serve ships and their cargo which in turn depend on commodity trade growth and GDP growth. Ports were shown to generally have an inelastic demand function due to the double derived demand function as well as port costs being a small percentage of total supply chain costs. Sea transport was also shown to be ideally suited for long-distance freight transport, because of the high incidence of high fixed costs. Maritime economic theory showed that vessel size and draught is continually increasing due to the economies of scale which these vessels provide. There are already 14 000 teu ships in operation and 16 000 teu ships in design testing, which places additional pressure for ports to provide the adequate infrastructure to accommodate these large vessels or risk becoming redundant. Increased containerisation has been a global trend over the last few decades as containers increase efficiency both in logistics and carrying capacity. CBA theory was introduced whereby market and non-market techniques, for the calculation of benefits and costs, were explained as well as the crucial concept of discounting. Public CBA was shown to include externalities and opportunity costs whereas private or financial CBA only takes into account market signals. The tools of NPV, IRR and DPP were explained along with their advantages and disadvantages. Lastly, the concept of sensitivity analysis was introduced as a means of incorporating uncertainty into a model.

Chapter Three looked at the port of Durban from an economics context. The port's historical underpinnings were presented as well as its relevance in the South African economy. Durban was shown to be the premier container port in the country, in the Southern African region and indeed in the southern hemisphere. Even though Durban lags Richards Bay in pure tonnage terms, containers have more of an impact than pure bulk cargo in terms of employment and economic activity. The port has seen sustained high growth rates in container volumes over the last two decades, resulting in substantial congestion and inefficiency for vessels. The various ecological and environmental functions of the bay were also examined as it is important to remember that the port serves other functions besides being a gateway for goods. It was shown that over the last few decades, significant environmental degradation occurred, which in turn compromised the bay's ability to perform its crucial ecological functions. The multiplier concept, which was explained in the literature review, was shown for the port of Durban as well as other international ports. Various forecast growth models were examined so as to better understand the growth situation in the medium term.

Chapter Four sought to construct and implement the CBA calculations whereby the concepts in Chapter Three and Four were to be applied. The Tempi process provided financial and ecological costs for the original eleven expansion options for the port. These were later reduced to four more practical options. The economic benefits for each option had to be calculated, since the Tempi process did not include any benefits calculations. It was decided that the average vessel spend per call would be divided by the amount of teus it carried thereby yielding spending per teu. Construction times were taken from a combination of the Tempi report as well as a Transnet technical report which were not available to the public. The CBA was then setup over a 50 year horizon, since ports are by their nature long term entities. The long term interest rate for South Africa, 8%, was then applied to the various streams to convert into present values. An NPV, IRR and DPP were then calculated for each option. A sensitivity analysis was also done in an attempt to incorporate uncertainty into the model. Some rather large assumptions were made so that a complete CBA could be calculated. For the DIA calculations, the environmental costs were assumed to be the same as the Bayhead options of the same capacity.

The CBA yielded five options with positive NPV's. The Southern Access routes, 3CA and 3DA, were both rejected since though they had high NPV's and positive environmental benefits, the removal of the only sites in the port suitable for the handling and storage of liquid-bulk petroleum products and chemical cargoes was considered infeasible. In this respect, the CBA was incomplete since the costing of the removal was not included but since these options were discarded the consequence for the dissertation was minimal. One of the Northern Access routes, 1AB, was also rejected since the option yielded a negative NPV. This was primarily because of the opportunity costs of this option, which saw significant business and leasing losses due to the setting back of the Maydon Wharf quayside, and the consequent reduction of cargo-handling and commercial space. Of the expansion options associated with the dig out of the former airport site, even though the first of these, DIA1, had a positive NPV, it was rejected based on mutual exclusivity with option DIA2. Richards Bay was looked at briefly and this option was also rejected since it had a total cost penalty of R89 billion over Durban, due primarily higher logistical costs. On balance the Bayhead option 1AA and airport option DIA2 were chosen as the projects of choice primarily on the basis of the CBA results. Both these options yielded significantly positive NPV's and the port should seriously look into their construction. Also, since these options are fully independent of each other, they can be built in tandem or separately. If they are to be built separately, then 1AA should be embarked on first since its construction time is half that of DIA2.

5.2 Limitations

The primary limitation in the actual CBA was the assumption of the DIA environmental costs. Ideally, each expansion option should have costs that are uniquely assigned to it so as to better reflect reality. This dissertation also failed to analyse the effect on back of port operations and logistics in terms of congestion and delays to road users. The Bayhead and Maydon Wharf areas are extremely busy with hauliers of every kind. Increasing the amount of traffic throughput in these zones will no doubt impose a negative externality on residents and businesses alike.

5.3 Suggestions for further Studies

To add to this work, a CVM study on the DIA environmental costs would be very interesting. This in itself would be a complete dissertation as the probit econometrics for this exercise can be quite complex.

A study of the effect on traffic congestion would also be of benefit since this would undoubtedly impose a negative externality on the local community.

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Internet Source 5

www.wikipedia.com

Appendices:

Appendix 1A: Summary of Environmental Costs and Benefits for Expansion Options

Development options	Ranked in terms of least costs	Percentage change in benefits	Change in economic value of benefits supplied per year	Average change in benefit values to user households per year (assuming 2m users)
3ca, 3d, 3da	1	+3%	+ R31 million	+ R77
3b	2	-7%	- R116 million	- R290
3a, 3c	3	-9%	- R151 million	- R378
1ab	4	-32%	- R459 million	- R1 148
1a, 1aa	5	-52%	- R749 million	- R1 872
1b	6	-54%	- R774 million	- R1 935
2	7	-59%	- R849 million	- R2 123

Source: Tempi, 2006

Appendix 1B: Detailed Breakdown of Environmental Costs and Benefits for Expansion Options

	Status Quo	SERVICES SUPPLIED AS A PERCENTAGE OF THE *STATUS QUO*									CHANGES IN THE ANNUAL VALUE OF BENEFITS SUPPLIED – IN MILLIONS								
ECOSYSTEM SERVICES SUPPLIED BY DURBAN BAY	**INDICATIVE ANNUAL VALUE**	**1a**	**1aa**	**1ab**	**1b**	**2**	**3a**	**3b**	**3c**	**3ca,3d, 3da**	**1a**	**1aa**	**1ab**	**1b**	**2**	**3a**	**3b**	**3c**	**3ca,3d,3 da**
Waste assimilation	R 100,000,000	25.75	25.75	56.65	22.75	20	79.1	80.35	79.1	100	R -74.3	R -74.3	R -43.4	R -77.3	R -80.0	R -20.9	R -19.7	R -20.9	R -
Waste assimilation-Heavy metals	R 50,000,000	72.9	72.9	80.315	72.65	64	100.15	104.15	100.15	103	R -13.6	R -13.6	R -9.8	R -13.7	R -18.0	R 0.1	R 2.1	R 0.1	R 1.5
Flood mitigation	R 20,000,000	90	90	90	90	80	120	125	120	120	R -2.0	R -2.0	R -2.0	R -2.0	R -4.0	R 4.0	R 5.0	R 4.0	R 4.0
Mitigating regional disasters	R 100,000,000	22.7	22.7	49.35	20.8	17.6	58.18	59.28	58.18	84.4	R -77.3	R -77.3	R -50.7	R -79.2	R -82.4	R -41.8	R -40.7	R -41.8	R -15.6
Nursery for marine fisheries	R 27,000,000	8	8	40.6	5.5	4	47.75	48	47.75	81	R -24.8	R -24.8	R -16.0	R -25.5	R -25.9	R -14.1	R -14.0	R -14.1	R -5.1
Refuge for birds	R 10,000,000	13	13	50.55	9.5	8	69.2	69.7	69.2	92	R -8.7	R -8.7	R -4.9	R -9.1	R -9.2	R -3.1	R -3.0	R -3.1	R -0.8
Genetic, species and landscape conservation	R 40,000,000	16.75	16.75	47.2	14.25	12	59.5	60.25	59.5	88	R -33.3	R -33.3	R -21.1	R -34.3	R -35.2	R -16.2	R -15.9	R -16.2	R -4.8
Landscape character	R 500,000,000	60.25	60.25	76.4	58.75	52	102.3	105.55	102.3	108	R -198.8	R -198.8	R -118.0	R -206.3	R -240.0	R 11.5	R 27.7	R 11.5	R 40.0
Disease management	R 474,000,000	47.25	47.25	68.4	45.25	40	92.65	95.15	92.65	105	R -250.0	R -250.0	R -149.8	R -259.5	R -284.4	R -34.8	R -23.0	R -34.8	R 23.7
Fishery-angling	R 13,000,000	16.25	16.25	41.5	14.75	12	43.8	44.55	43.8	78	R -10.9	R -10.9	R -7.6	R -11.1	R -11.4	R -7.3	R -7.2	R -7.3	R -2.9
Fishery-bait	R 1,000,000	3.5	3.5	38.06	0.1	0	56.58	56.58	56.58	98	R -1.0	R -1.0	R -0.6	R -1.0	R -1.0	R -0.4	R -0.4	R -0.4	R -0.0
Sport and outdoor adventure activities	R 10,000,000	29.75	29.75	56.15	27.25	24	77.25	78.75	77.25	101	R -7.0	R -7.0	R -4.4	R -7.3	R -7.6	R -2.3	R -2.1	R -2.3	R 0.1
Education, sight seeing, research	R 1,000,000	25.25	25.25	50	23.75	20	55.3	56.55	55.3	80	R -0.7	R -0.7	R -0.5	R -0.8	R -0.8	R -0.4	R -0.4	R -0.4	R -0.2
	R 1,346,000,000									**TOTALS**	**R -702.4**	**R -702.4**	**R -428.8**	**R -726.9**	**R -800.0**	**R -125.8**	**R -91.7**	**R -125.8**	**R 39.9**
										% CHANGE	-52%	-52%	-32%	-54%	-59%	-9%	-7%	-9%	3%

Source: Tempi, 2006

Appendix 2: CBA Calculations for Expansion options (in millions of Rands)

Bayhead Option 1AA

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-9600										
Environmental Cost			-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits			0	0	0	0	5155.5	5155.5	10311	10311	10311	10311
Total		-9600	-749	-749	-749	-749	4406.5	4406.5	9562	9562	9562	9562
Discount Factor		1	1.08	1.17	1.26	1.36	1.469	1.59	1.7138	1.85	1.999005	2.158925
NPV	**66465**	-9600	-693.52	-642.15	-594.58	-550.537	2999	2776.842	5579.3	5166	4783.214	4428.902

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311
Total	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562
Discount Factor	2.331639	2.51817	2.719624	2.937194	3.172169	3.425943	3.700018	3.996019	4.315701	4.660957	5.033834	5.43654
PV	4100.835	3797.069	3515.805	3255.375	3014.236	2790.959	2584.222	2392.798	2215.554	2051.438	1899.48	1758.778

	Year 23	Year 24	Year 25	Year 26	Year 27	Year 28	Year 29	Year 30	Year 31	Year 32	Year 33	Year 34
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311

Total	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562
Discount Factor	5.871464	6.341181	6.848475	7.396353	7.988061	8.627106	9.317275	10.06266	10.86767	11.73708	12.67605	13.69013
PV	1628.498	1507.868	1396.175	1292.754	1196.995	1108.328	1026.23	950.2129	879.8268	814.6544	754.3097	698.4349

	Year 35	Year 36	Year 37	Year 38	Year 39	Year 40	Year 41	Year 42	Year 43	Year 44	Year 45	Year 46
Infrastructure Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Environmental Cost												
Benefits	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311
Total	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562
Discount Factor	14.78534	15.96817	17.24563	18.62528	20.1153	21.72452	23.46248	25.33948	27.36664	29.55597	31.92045	34.47409
PV	646.699	598.7953	554.4401	513.3705	475.343	440.1324	407.53	377.3426	349.3913	323.5105	299.5467	277.3581

	Year 47	Year 48	Year 49	Year 50
Infrastructure Cost				
Environmental Cost	-749	-749	-749	-749
Benefits	10311	10311	10311	10311
Total	9562	9562	9562	9562
Discount Factor	37.23201	40.21057	43.42742	46.90161
PV	256.8131	237.7899	220.1758	203.8665

Bayhead Option 1AB

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-11000										
Environmental Cost			-459	-459	-459	-459	-459	-459	-459	-459	-459	-459
Opportunity Cost			-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471
Benefits			0	0	0	0	5155.2	5155.2	10310	10310.4	10310.4	10310.4
Total		-11000	-7930	-7930	-7930	-7930	-2774.8	-2774.8	2380.4	2380.4	2380.4	2380.4
Discount Factor		1	1.08	1.1664	1.25971	1.36049	1.46933	1.58687	1.714	1.85093	1.999	2.15892
NPV	**-22786**	-11000	-7342.6	-6798.7	-6295.1	-5828.8	-1888.5	-1748.6	1388.9	1286.06	1190.79	1102.59
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459
Opportunity Cost	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471
Benefits	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4
Total	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4
Discount Factor	2.331639	2.51817	2.719624	2.937194	3.172169	3.425943	3.700018	3.996019	4.315701	4.660957	5.033834	5.43654
PV	1020.913	945.2896	875.2681	810.4335	750.4014	694.8161	643.3482	595.6928	551.5674	510.7106	472.8801	437.852
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year 30**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459
Opportunity Cost	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471
Benefits	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4

Total	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4
Discount Factor	5.871464	6.341181	6.848475	7.396353	7.988061	8.627106	9.317275	10.06266	10.86767	11.73708	12.67605	13.69013
PV	405.4185	375.3875	347.581	321.8343	297.9947	275.921	255.4824	236.5578	219.035	202.8102	187.7872	173.877
	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year 42**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459
Opportunity Cost	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471
Benefits	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4
Total	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4
Discount Factor	14.78534	15.96817	17.24563	18.62528	20.1153	21.72452	23.46248	25.33948	27.36664	29.55597	31.92045	34.47409
PV	160.9973	149.0715	138.0292	127.8048	118.3378	109.572	101.4556	93.94036	86.98181	80.53872	74.57288	69.04897

	Year 47	**Year 48**	**Year 49**	**Year 50**
Infrastructure Cost				
Environmental Cost	-459	-459	-459	-459
Opportunity Cost	-7471	-7471	-7471	-7471
Benefits	10310.4	10310.4	10310.4	10310.4
Total	2380.4	2380.4	2380.4	2380.4
Discount Factor	37.23201	40.21057	43.42742	46.90161
PV	63.93423	59.19836	54.8133	50.75305

<u>Island View Option 3CA</u>

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-14400										
Environmental Cost			31	31	31	31	31	31	31	31	31	31
Benefits			0	0	0	0	0	10874.25	10874.25	10874.25	21748.5	21748.5
Total		-14400	31	31	31	31	31	10905.25	10905.25	10905.25	21779.5	21779.5
Discount Factor		1	1.08	1.1664	1.259712	1.360489	1.469328	1.586874	1.713824	1.85093	1.999005	2.158925
NPV	**146131.06**	-14400	28.7037	26.5775	24.6088	22.78593	21.09808	6872.157	6363.109	5891.767	10895.17	10088.12
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5
Total	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5
Discount Factor	2.331639	2.51817	2.719624	2.937194	3.172169	3.425943	3.700018	3.996019	4.315701	4.660957	5.033834	5.43654
PV	9340.854	8648.939	8008.277	7415.071	6865.807	6357.228	5886.323	5450.299	5046.573	4672.753	4326.623	4006.132
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year 30**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5

Total	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5
Discount Factor	5.871464	6.341181	6.848475	7.396353	7.988061	8.627106	9.317275	10.06266	10.86767	11.73708	12.67605	13.69013
PV	3709.382	3434.613	3180.197	2944.627	2726.506	2524.543	2337.54	2164.389	2004.064	1855.614	1718.161	1590.89
	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year 42**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5
Total	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5
Discount Factor	14.78534	15.96817	17.24563	18.62528	20.1153	21.72452	23.46248	25.33948	27.36664	29.55597	31.92045	34.47409
PV	1473.047	1363.932	1262.9	1169.352	1082.733	1002.531	928.2692	859.5085	795.8412	736.89	682.3056	631.7644
	Year 47	**Year 48**	**Year 49**	**Year 50**								
Infrastructure Cost												
Environmental Cost	31	31	31	31								
Benefits	21748.5	21748.5	21748.5	21748.5								
Total	21779.5	21779.5	21779.5	21779.5								
Discount Factor	37.23201	40.21057	43.42742	46.90161								
PV	584.967	541.6361	501.515	464.3657								

Island View Option 3DA

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-16900										
Environmental Cost			31	31	31	31	31	31	31	31	31	31
Benefits			0	0	0	0	0	0	0	13290.8	13291	13290.8
Total		-16900	31	31	31	31	31	31	31	13321.8	13322	13321.8
Discount Factor		1	1.08	1.1664	1.25971	1.36049	1.46933	1.58687	1.71382	1.85093	1.999	2.15892
NPV	**144585**	-16900	28.7037	26.5775	24.6088	22.7859	21.0981	19.5353	18.0882	7197.33	6664	6170.55
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	13290.8	26582	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5
Total	13321.8	26613	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5
Discount Factor	2.33164	2.518	2.71962	2.93719	3.17217	3.42594	3.70002	3.99602	4.3157	4.66096	5.03383	5.43654
PV	5713.47	10568	9785.36	9060.52	8389.37	7767.94	7192.53	6659.75	6166.44	5709.66	5286.73	4895.12
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year 30**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5

Total	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5
Discount Factor	5.87146	6.34118	6.84848	7.39635	7.98806	8.62711	9.31727	10.0627	10.8677	11.7371	12.676	13.6901
PV	4532.52	4196.77	3885.9	3598.06	3331.53	3084.75	2856.25	2644.68	2448.78	2267.39	2099.43	1943.92
	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year 42**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5
Total	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5
Discount Factor	14.7853	15.9682	17.2456	18.6253	20.1153	21.7245	23.4625	25.3395	27.3666	29.556	31.9204	34.4741
PV	1799.92	1666.6	1543.14	1428.84	1323	1225	1134.26	1050.24	972.443	900.41	833.713	771.957
	Year 47	**Year 48**	**Year 49**	**Year 50**								
Infrastructure Cost												
Environmental Cost	31	31	31	31								
Benefits	26581.5	26581.5	26581.5	26581.5								
Total	26612.5	26612.5	26612.5	26612.5								
Discount Factor	37.232	40.2106	43.4274	46.9016								
PV	714.775	661.828	612.804	567.411								

Old Airport Option DIA1

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-14900										
Environmental Cost			-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits			0	0	0	0	4833	4833	9666	9666	9666	9666
Total		-14900	-749	-749	-749	-749	4084	4084	8917	8917	8917	8917
Discount Factor		1	1.08	1.1664	1.25971	1.36049	1.46933	1.58687	1.71382	1.85093	1.999	2.15892
NPV	**55836.1**	-14900	-693.52	-642.15	-594.58	-550.54	2779.5	2573.61	5202.98	4817.58	4460.72	4130.3
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666
Total	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917
Discount Factor	2.33164	2.51817	2.71962	2.93719	3.17217	3.42594	3.70002	3.99602	4.3157	4.66096	5.03383	5.43654
PV	3824.35	3541.06	3278.76	3035.89	2811.01	2602.79	2409.99	2231.47	2066.18	1913.13	1771.41	1640.2
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year 30**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666

Total	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917
Discount Factor	5.87146	6.34118	6.84848	7.39635	7.98806	8.62711	9.31727	10.0627	10.8677	11.7371	12.676	13.6901
PV	1518.7	1406.2	1302.04	1205.59	1116.29	1033.6	957.039	886.148	820.507	759.729	703.453	651.345
	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year 42**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666
Total	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917
Discount Factor	14.7853	15.9682	17.2456	18.6253	20.1153	21.7245	23.4625	25.3395	27.3666	29.556	31.9204	34.4741
PV	603.097	558.423	517.059	478.758	443.294	410.458	380.054	351.901	325.835	301.699	279.351	258.658
	Year 47	**Year 48**	**Year 49**	**Year 50**								
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749								
Benefits	9666	9666	9666	9666								
Total	8917	8917	8917	8917								
Discount Factor	37.232	40.2106	43.4274	46.9016								
PV	239.498	221.758	205.331	190.121								

Old Airport Option DIA2

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-25100										
Environmental Cost			-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498
Benefits			0	0	0	0	0	0	0	0	10069	10069
Total		-25100	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	8571	8570.75
Discount Factor		1	1.08	1.1664	1.25971	1.36049	1.46933	1.58687	1.71382	1.85093	1.999	2.15892
NPV	**69185.68**	-25100	-1387	-1284.3	-1189.2	-1101.1	-1019.5	-943.99	-874.07	-809.32	4288	3969.92
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498
Benefits	10069	10069	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138
Total	8570.75	8570.75	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5
Discount Factor	2.33164	2.51817	2.71962	2.93719	3.17217	3.42594	3.70002	3.99602	4.3157	4.66096	5.03383	5.43654
PV	3675.85	3403.56	6853.7	6346.02	5875.95	5440.69	5037.68	4664.52	4319	3999.07	3702.84	3428.56
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year 30**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498
Benefits	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138

Total	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5
Discount Factor	5.87146	6.34118	6.84848	7.39635	7.98806	8.62711	9.31727	10.0627	10.8677	11.7371	12.676	13.6901
PV	3174.59	2939.44	2721.7	2520.09	2333.42	2160.57	2000.53	1852.34	1715.13	1588.09	1470.45	1361.53
	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year 42**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498
Benefits	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138
Total	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5
Discount Factor	14.7853	15.9682	17.2456	18.6253	20.1153	21.7245	23.4625	25.3395	27.3666	29.556	31.9204	34.4741
PV	1260.67	1167.29	1080.82	1000.76	926.633	857.994	794.439	735.591	681.103	630.651	583.936	540.681
	Year 47	**Year 48**	**Year 49**	**Year 50**								
Infrastructure Cost												
Environmental Cost	-1498	-1498	-1498	-1498								
Benefits	20138	20138	20138	20138								
Total	18639.5	18639.5	18639.5	18639.5								
Discount Factor	37.232	40.2106	43.4274	46.9016								
PV	500.631	463.547	429.21	397.417								

Appendix 3: Sensitivity Analysis-Varying Discount Rates

Bayhead 1AA with 4% Discount Rate

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-9600										
Environmental Cost			-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits			0	0	0	0	5155.5	5155.5	10311	10311	10311	10311
Total		-9600	-749	-749	-749	-749	4406.5	4406.5	9562	9562	9562	9562
Discount Factor		1	1.04	1.08	1.12	1.17	1.22	1.27	1.32	1.37	1.42	1.48
NPV	**150068**	-9600	-720.19	-692.49	-665.86	-640.248	3622	3482.521	7266.3	6987	6717.9	6459.519
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311
Total	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562
Discount Factor	1.54	1.60	1.67	1.73	1.80	1.87	1.95	2.03	2.11	2.19	2.28	2.37
PV	6211.076	5972.189	5742.489	5521.624	5309.254	5105.052	4908.704	4719.908	4538.373	4363.82	4195.981	4034.597
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year 30**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749

Benefits	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311
Total	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562
Discount Factor	2.46	2.56	2.67	2.77	2.88	3.00	3.12	3.24	3.37	3.51	3.65	3.79
PV	3879.42	3730.211	3586.742	3448.79	3316.144	3188.6	3065.962	2948.04	2834.654	2725.629	2620.797	2519.997

	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year 42**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311
Total	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562
Discount Factor	3.95	4.10	4.27	4.44	4.62	4.80	4.99	5.19	5.40	5.62	5.84	6.07
PV	2423.074	2329.879	2240.268	2154.104	2071.254	1991.59	1914.991	1841.337	1770.517	1702.42	1636.942	1573.983

	Year 47	**Year 48**	**Year 49**	**Year 50**
Infrastructure Cost				
Environmental Cost	-749	-749	-749	-749
Benefits	10311	10311	10311	10311
Total	9562	9562	9562	9562
Discount Factor	6.32	6.57	6.83	7.11
PV	1513.445	1455.236	1399.265	1345.447

Bayhead 1AA with 12% Discount Rate

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-9600										
Environmental Cost			-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits			0	0	0	0	5155.5	5155.5	10311	10311	10311	10311
Total		-9600	-749	-749	-749	-749	4406.5	4406.5	9562	9562	9562	9562
Discount Factor		1	1.12	1.25	1.40	1.57	1.76	1.97	2.21	2.48	2.77	3.11
NPV	**32951**	-9600	-668.75	-597.10	-533.12	-476.003	2500	2232.47	4325.4	3862	3448.033	3078.601
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311
Total	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562
Discount Factor	3.48	3.90	4.36	4.89	5.47	6.13	6.87	7.69	8.61	9.65	10.80	12.10
PV	2748.751	2454.242	2191.287	1956.506	1746.881	1559.715	1392.603	1243.395	1110.174	991.2271	885.0242	790.2001
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year 30**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311

Total	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562
Discount Factor	13.55	15.18	17.00	19.04	21.32	23.88	26.75	29.96	33.56	37.58	42.09	47.14
PV	705.5358	629.9427	562.4488	502.1865	448.3808	400.34	357.4464	319.1486	284.9541	254.4233	227.1637	202.8247
	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year 42**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311	10311
Total	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562	9562
Discount Factor	3.95	4.10	4.27	4.44	4.62	4.80	4.99	5.19	5.40	5.62	5.84	6.07
PV	2423.074	2329.879	2240.268	2154.104	2071.254	1991.59	1914.991	1841.337	1770.517	1702.42	1636.942	1573.983
	Year 47	**Year 48**	**Year 49**	**Year 50**								
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749								
Benefits	10311	10311	10311	10311								
Total	9562	9562	9562	9562								
Discount Factor	6.32	6.57	6.83	7.11								
PV	1513.445	1455.236	1399.265	1345.447								

Bayhead 1AB with 4% Discount Rate

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-11000										
Environmental Cost			-459	-459	-459	-459	-459	-459	-459	-459	-459	-459
Opportunity Cost			-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471
Benefits			0	0	0	0	5155.2	5155.2	10310	10310.4	10310.4	10310.4
Total		-11000	-7930	-7930	-7930	-7930	-2774.8	-2774.8	2380.4	2380.4	2380.4	2380.4
Discount Factor		1	1.04	1.0816	1.12486	1.16986	1.21665	1.26532	1.3159	1.36857	1.42331	1.48024
NPV	**-5601**	-11000	-7625	-7331.7	-7049.7	-6778.6	-2280.7	-2193	1808.9	1739.33	1672.44	1608.11
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459
Opportunity Cost	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471
Benefits	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4
Total	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4
Discount Factor	1.53945	1.60103	1.66507	1.73168	1.80094	1.87298	1.9479	2.02582	2.10685	2.19112	2.27877	2.36992
PV	1546.26	1486.79	1429.61	1374.62	1321.75	1270.92	1222.03	1175.03	1129.84	1086.38	1044.6	1004.42
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459
Opportunity Cost	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471

Benefits	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.	10310.4	10310.4	10310.4	10310.4
Total	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4
Discount Factor	2.46472	2.5633	2.66584	2.77247	2.88337	2.9987	3.11865	3.2434	3.37313	3.50806	3.64838	3.79432
PV	965.791	928.645	892.928	858.585	825.562	793.81	763.279	733.92	705.694	678.552	652.454	627.359
	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459
Opportunity Cost	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471
Benefits	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.	10310.4	10310.4	10310.4	10310.4
Total	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4
Discount Factor	3.94609	4.10393	4.26809	4.43881	4.61637	4.80102	4.99306	5.1927	5.4005	5.61652	5.84118	6.07482
PV	603.23	580.029	557.72	536.269	515.644	495.811	476.742	458.40	440.774	423.822	407.521	391.847
	Year 47	**Year 48**	**Year 49**	**Year 50**								
Infrastructure Cost												
Environmental Cost	-459	-459	-459	-459								
Opportunity Cost	-7471	-7471	-7471	-7471								
Benefits	10310.4	10310.4	10310.4	10310.4								
Total	2380.4	2380.4	2380.4	2380.4								
Discount Factor	6.31782	6.57053	6.83335	7.10668								
PV	376.776	362.284	348.35	334.952								

Bayhead 1AB with 12% Discount Rate

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-11000										
Environmental Cost			-459	-459	-459	-459	-459	-459	-459	-459	-459	-459
Opportunity Cost			-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471
Benefits			0	0	0	0	5155.2	5155.2	10310	10310.4	10310.4	10310.4
Total		-11000	-7930	-7930	-7930	-7930	-2774.8	-2774.8	2380.4	2380.4	2380.4	2380.4
Discount Factor		1	1.12	1.2544	1.40493	1.57352	1.76234	1.97382	2.2107	2.47596	2.77308	3.10585
NPV	**-28085**	-11000	-7080.4	-6321.7	-5644.4	-5039.7	-1574.5	-1405.8	1076.8	961.404	858.396	766.425
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459
Opportunity Cost	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471
Benefits	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4
Total	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4
Discount Factor	3.47855	3.89598	4.36349	4.88711	5.47357	6.13039	6.86604	7.68997	8.61276	9.64629	10.8038	12.1003
PV	684.308	610.989	545.526	487.077	434.89	388.295	346.692	309.546	276.381	246.768	220.329	196.722
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year 30**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459
Opportunity Cost	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471

Benefits	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4
Total	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4
Discount Factor	13.5523	15.1786	17.0001	19.0401	21.3249	23.8839	26.7499	29.9599	33.5551	37.5817	42.0915	47.1425
PV	175.645	156.826	140.023	125.021	111.625	99.6656	88.9871	79.4528	70.94	63.3393	56.5529	50.4937
	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year 42**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459	-459
Opportunity Cost	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471	-7471
Benefits	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4	10310.4
Total	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4	2380.4
Discount Factor	52.7996	59.1356	66.2318	74.1797	83.0812	93.051	104.217	116.723	130.73	146.418	163.988	183.666
PV	45.0837	40.2533	35.9404	32.0897	28.6515	25.5817	22.8408	20.3936	18.2085	16.2576	14.5157	12.9605
	Year 47	**Year 48**	**Year 49**	**Year 50**								
Infrastructure Cost												
Environmental Cost	-459	-459	-459	-459								
Opportunity Cost	-7471	-7471	-7471	-7471								
Benefits	10310.4	10310.4	10310.4	10310.4								
Total	2380.4	2380.4	2380.4	2380.4								
Discount Factor	205.706	230.391	258.038	289.002								
PV	11.5719	10.332	9.22501	8.23662								

Island View 3CA with 4% Discount Rate

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-14400										
Environmental Cost			31	31	31	31	31	31	31	31	31	31
Benefits			0	0	0	0	0	10874.25	10874.25	10874.25	21748.5	21748.5
Total		-14400	31	31	31	31	31	10905.25	10905.25	10905.25	21779.5	21779.5
Discount Factor		1	1.04	1.0816	1.124864	1.169859	1.216653	1.265319	1.315932	1.368569	1.423312	1.480244
NPV	**331847.46**	-14400	29.80769	28.66124	27.55889	26.49893	25.47974	8618.577	8287.094	7968.359	15301.99	14713.45
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5
Total	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5
Discount Factor	1.539454	1.601032	1.665074	1.731676	1.800944	1.872981	1.9479	2.025817	2.106849	2.191123	2.278768	2.369919
PV	14147.55	13603.41	13080.2	12577.12	12093.38	11628.25	11181.01	10750.97	10337.47	9939.879	9557.576	9189.977
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year 30**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5

Total	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5
Discount Factor	2.464716	2.563304	2.665836	2.77247	2.883369	2.998703	3.118651	3.243398	3.373133	3.508059	3.648381	3.794316
PV	8836.517	8496.651	8169.856	7855.631	7553.491	7262.973	6983.627	6715.026	6456.756	6208.419	5969.634	5740.033
	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year 42**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5
Total	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5
Discount Factor	3.946089	4.103933	4.26809	4.438813	4.616366	4.801021	4.993061	5.192784	5.400495	5.616515	5.841176	6.074823
PV	5519.262	5306.983	5102.868	4906.604	4717.888	4536.431	4361.953	4194.186	4032.871	3877.76	3728.616	3585.208
	Year 47	**Year 48**	**Year 49**	**Year 50**								
Infrastructure Cost												
Environmental Cost	31	31	31	31								
Benefits	21748.5	21748.5	21748.5	21748.5								
Total	21779.5	21779.5	21779.5	21779.5								
Discount Factor	6.317816	6.570528	6.833349	7.106683								
PV	3447.315	3314.726	3187.236	3064.65								

Island View 3CA with 12% Discount Rate

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-14400										
Environmental Cost			31	31	31	31	31	31	31	31	31	31
Benefits			0	0	0	0	0	10874.25	10874.25	10874.25	21748.5	21748.5
Total		-14400	31	31	31	31	31	10905.25	10905.25	10905.25	21779.5	21779.5
Discount Factor		1	1.12	1.2544	1.404928	1.573519	1.762342	1.973823	2.210681	2.475963	2.773079	3.105848
NPV	**73249.23**	-14400	27.67857	24.71301	22.06519	19.70106	17.59023	5524.939	4932.981	4404.448	7853.906	7012.416
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5
Total	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5
Discount Factor	3.47855	3.895976	4.363493	4.887112	5.473566	6.130394	6.866041	7.689966	8.612762	9.646293	10.80385	12.10031
PV	6261.086	5590.255	4991.299	4456.517	3979.033	3552.708	3172.061	2832.197	2528.748	2257.81	2015.902	1799.913
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year 30**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5

Total	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5
Discount Factor	13.55235	15.17863	17.00006	19.04007	21.32488	23.88387	26.74993	29.95992	33.55511	37.58173	42.09153	47.14252
PV	1607.065	1434.879	1281.142	1143.877	1021.319	911.8917	814.189	726.9545	649.0665	579.5237	517.4318	461.9927
	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year 42**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5	21748.5
Total	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5	21779.5
Discount Factor	52.79962	59.13557	66.23184	74.17966	83.08122	93.05097	104.2171	116.7231	130.7299	146.4175	163.9876	183.6661
PV	412.4935	368.2978	328.8373	293.6047	262.1471	234.0599	208.982	186.5911	166.5992	148.7493	132.8119	118.582

	Year 47	**Year 48**	**Year 49**	**Year 50**
Infrastructure Cost				
Environmental Cost	31	31	31	31
Benefits	21748.5	21748.5	21748.5	21748.5
Total	21779.5	21779.5	21779.5	21779.5
Discount Factor	205.7061	230.3908	258.0377	289.0022
PV	105.8768	94.53286	84.40434	75.36102

Island View 3DA with 4% Discount Rate

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-16900										
Environmental Cost			31	31	31	31	31	31	31	31	31	31
Benefits			0	0	0	0	0	0	0	13290.8	13291	13290.8
Total		-16900	31	31	31	31	31	31	31	13321.8	13322	13321.8
Discount Factor		1	1.04	1.0816	1.12486	1.16986	1.21665	1.26532	1.31593	1.36857	1.423	1.48024
NPV	**358590**	-16900	29.8077	28.6612	27.5589	26.4989	25.4797	24.4998	23.5575	9734.07	9360	8999.7
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	13290.8	26582	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5
Total	13321.8	26613	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5
Discount Factor	1.53945	1.601	1.66507	1.73168	1.80094	1.87298	1.9479	2.02582	2.10685	2.19112	2.27877	2.36992
PV	8653.55	16622	15982.8	15368.1	14777	14208.6	13662.1	13136.7	12631.4	12145.6	11678.5	11229.3
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year 30**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5

Total	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5
Discount Factor	2.46472	2.5633	2.66584	2.77247	2.88337	2.9987	3.11865	3.2434	3.37313	3.50806	3.64838	3.79432
PV	10797.4	10382.1	9982.8	9598.84	9229.66	8874.67	8533.34	8205.13	7889.55	7586.1	7294.33	7013.78
	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year 42**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5
Total	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5
Discount Factor	3.94609	4.10393	4.26809	4.43881	4.61637	4.80102	4.99306	5.19278	5.4005	5.61652	5.84118	6.07482
PV	6744.02	6484.63	6235.22	5995.41	5764.82	5543.09	5329.9	5124.9	4927.79	4738.26	4556.02	4380.79
	Year 47	**Year 48**	**Year 49**	**Year 50**								
Infrastructure Cost												
Environmental Cost	31	31	31	31								
Benefits	26581.5	26581.5	26581.5	26581.5								
Total	26612.5	26612.5	26612.5	26612.5								
Discount Factor	6.31782	6.57053	6.83335	7.10668								
PV	4212.29	4050.28	3894.5	3744.71								

Island View 3DA with 12% Discount Rate

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-16900										
Environmental Cost			31	31	31	31	31	31	31	31	31	31
Benefits			0	0	0	0	0	0	0	13290.8	13291	13290.8
Total		-16900	31	31	31	31	31	31	31	13321.8	13322	13321.8
Discount Factor		1	1.12	1.25	1.40	1.57	1.76	1.97	2.21	2.48	2.77	3.11
NPV	**64531**	-16900	27.6786	24.713	22.0652	19.7011	17.5902	15.7056	14.0228	5380.43	4804	4289.25
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	13290.8	26582	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5
Total	13321.8	26613	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5
Discount Factor	3.48	3.90	4.36	4.89	5.47	6.13	6.87	7.69	8.61	9.65	10.80	12.10
PV	3829.68	6831	6098.9	5445.44	4862	4341.08	3875.96	3460.68	3089.89	2758.83	2463.24	2199.32
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year 30**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5

Total	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5
Discount Factor	13.55	15.18	17.00	19.04	21.32	23.88	26.75	29.96	33.56	37.58	42.09	47.14
PV	1963.68	1753.29	1565.44	1397.71	1247.96	1114.25	994.862	888.27	793.098	708.123	632.253	564.512
	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year 42**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	31	31	31	31	31	31	31	31	31	31	31	31
Benefits	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5	26581.5
Total	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5	26612.5
Discount Factor	52.80	59.14	66.23	74.18	83.08	93.05	104.22	116.72	130.73	146.42	163.99	183.67
PV	504.028	450.025	401.808	358.757	320.319	285.999	255.356	227.997	203.569	181.758	162.284	144.896
	Year 47	**Year 48**	**Year 49**	**Year 50**								
Infrastructure Cost												
Environmental Cost	31	31	31	31								
Benefits	26581.5	26581.5	26581.5	26581.5								
Total	26612.5	26612.5	26612.5	26612.5								
Discount Factor	205.71	230.39	258.04	289.00								
PV	129.371	115.51	103.134	92.0841								

Old Airport DIA1 with 4% Discount Rate

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-14900										
Environmental Cost			-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits			0	0	0	0	4833	4833	9666	9666	9666	9666
Total		-14900	-749	-749	-749	-749	4084	4084	8917	8917	8917	8917
Discount Factor		1	1.04	1.0816	1.12486	1.16986	1.21665	1.26532	1.31593	1.36857	1.42331	1.48024
NPV	**133778.1**	-14900	-720.19	-692.49	-665.86	-640.25	3356.75	3227.64	6776.19	6515.56	6264.97	6024.01
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666
Total	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917
Discount Factor	1.53945	1.60103	1.66507	1.73168	1.80094	1.87298	1.9479	2.02582	2.10685	2.19112	2.27877	2.36992
PV	5792.31	5569.53	5355.32	5149.35	4951.29	4760.86	4577.75	4401.68	4232.39	4069.6	3913.08	3762.58
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year 30**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666

Total	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917
Discount Factor	2.46472	2.5633	2.66584	2.77247	2.88337	2.9987	3.11865	3.2434	3.37313	3.50806	3.64838	3.79432
PV	3617.86	3478.71	3344.92	3216.27	3092.56	2973.62	2859.25	2749.28	2643.54	2541.86	2444.1	2350.09
	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year 42**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666
Total	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917
Discount Factor	3.94609	4.10393	4.26809	4.43881	4.61637	4.80102	4.99306	5.19278	5.4005	5.61652	5.84118	6.07482
PV	2259.71	2172.79	2089.22	2008.87	1931.61	1857.31	1785.88	1717.19	1651.14	1587.64	1526.58	1467.86
	Year 47	**Year 48**	**Year 49**	**Year 50**								
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749								
Benefits	9666	9666	9666	9666								
Total	8917	8917	8917	8917								
Discount Factor	6.31782	6.57053	6.83335	7.10668								
PV	1411.41	1357.12	1304.92	1254.73								

Old Airport DIA1 with 12% Discount Rate

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-14900										
Environmental Cost			-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits			0	0	0	0	4833	4833	9666	9666	9666	9666
Total		-14900	-749	-749	-749	-749	4084	4084	8917	8917	8917	8917
Discount Factor		1	1.12	1.2544	1.40493	1.57352	1.76234	1.97382	2.21068	2.47596	2.77308	3.10585
NPV	**24601**	-14900	-668.75	-597.1	-533.12	-476	2317.37	2069.08	4033.6	3601.43	3215.56	2871.04
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666
Total	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917
Discount Factor	3.47855	3.89598	4.36349	4.88711	5.47357	6.13039	6.86604	7.68997	8.61276	9.64629	10.8038	12.1003
PV	2563.42	2288.77	2043.55	1824.59	1629.1	1454.56	1298.71	1159.56	1035.32	924.397	825.354	736.923
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year 30**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666

Total	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917
Discount Factor	13.5523	15.1786	17.0001	19.0401	21.3249	23.8839	26.7499	29.9599	33.5551	37.5817	42.0915	47.1425
PV	657.967	587.471	524.527	468.328	418.15	373.348	333.347	297.631	265.742	237.27	211.848	189.15
	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year 42**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666	9666
Total	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917	8917
Discount Factor	52.7996	59.1356	66.2318	74.1797	83.0812	93.051	104.217	116.723	130.73	146.418	163.988	183.666
PV	168.884	150.789	134.633	120.208	107.329	95.8292	85.5618	76.3945	68.2093	60.9012	54.3761	48.5501

	Year 47	**Year 48**	**Year 49**	**Year 50**
Infrastructure Cost				
Environmental Cost	-749	-749	-749	-749
Benefits	9666	9666	9666	9666
Total	8917	8917	8917	8917
Discount Factor	205.706	230.391	258.038	289.002
PV	43.3483	38.7038	34.557	30.8544

Old Airport DIA2 with 4% Discount Rate

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-25100										
Environmental Cost			-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498
Benefits			0	0	0	0	0	0	0	0	10069	10069
Total		-25100	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	8571	8570.75
Discount Factor		1	1.04	1.0816	1.12486	1.16986	1.21665	1.26532	1.31593	1.36857	1.423	1.48024
NPV	**213030.9**	-25100	-1440.4	-1385	-1331.7	-1280.5	-1231.2	-1183.9	-1138.4	-1094.6	6022	5790.09
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498
Benefits	10069	10069	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138
Total	8570.75	8570.75	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5
Discount Factor	1.53945	1.60103	1.66507	1.73168	1.80094	1.87298	1.9479	2.02582	2.10685	2.19112	2.27877	2.36992
PV	5567.4	5353.27	11194.4	10763.8	10349.9	9951.78	9569.02	9200.98	8847.1	8506.82	8179.64	7865.04
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year 30**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498
Benefits	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138

Total	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5
Discount Factor	2.46472	2.5633	2.66584	2.77247	2.88337	2.9987	3.11865	3.2434	3.37313	3.50806	3.64838	3.79432
PV	7562.54	7271.67	6991.99	6723.07	6464.49	6215.85	5976.78	5746.91	5525.87	5313.34	5108.98	4912.48
	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year 42**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498
Benefits	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138
Total	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5
Discount Factor	3.94609	4.10393	4.26809	4.43881	4.61637	4.80102	4.99306	5.19278	5.4005	5.61652	5.84118	6.07482
PV	4723.54	4541.86	4367.18	4199.21	4037.7	3882.4	3733.08	3589.5	3451.44	3318.69	3191.05	3068.32

	Year 47	**Year 48**	**Year 49**	**Year 50**
Infrastructure Cost				
Environmental Cost	-1498	-1498	-1498	-1498
Benefits	20138	20138	20138	20138
Total	18639.5	18639.5	18639.5	18639.5
Discount Factor	6.31782	6.57053	6.83335	7.10668
PV	2950.31	2836.83	2727.73	2622.81

Old Airport DIA2 with 12% Discount Rate

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Infrastructure Cost		-25100										
Environmental Cost			-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498
Benefits			0	0	0	0	0	0	0	0	10069	10069
Total		-25100	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	8571	8570.75
Discount Factor		1	1.12	1.2544	1.40493	1.57352	1.76234	1.97382	2.21068	2.47596	2.773	3.10585
NPV	**17304.17**	-25100	-1337.5	-1194.2	-1066.2	-952.01	-850.01	-758.93	-677.62	-605.02	3091	2759.55
	Year 11	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**	**Year 21**	**Year 22**
Infrastructure Cost												
Environmental Cost	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498
Benefits	10069	10069	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138
Total	8570.75	8570.75	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5
Discount Factor	3.47855	3.89598	4.36349	4.88711	5.47357	6.13039	6.86604	7.68997	8.61276	9.64629	10.8038	12.1003
PV	2463.89	2199.9	4271.69	3814.01	3405.37	3040.51	2714.74	2423.87	2164.17	1932.3	1725.26	1540.42
	Year 23	**Year 24**	**Year 25**	**Year 26**	**Year 27**	**Year 28**	**Year 29**	**Year 30**	**Year 31**	**Year 32**	**Year 33**	**Year 34**
Infrastructure Cost												
Environmental Cost	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498
Benefits	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138

Total	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5
Discount Factor	13.5523	15.1786	17.0001	19.0401	21.3249	23.8839	26.7499	29.9599	33.5551	37.5817	42.0915	47.1425
PV	1375.37	1228.01	1096.44	978.962	874.073	780.422	696.806	622.148	555.489	495.972	442.833	395.386
	Year 35	**Year 36**	**Year 37**	**Year 38**	**Year 39**	**Year 40**	**Year 41**	**Year 42**	**Year 43**	**Year 44**	**Year 45**	**Year 46**
Infrastructure Cost												
Environmental Cost	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498	-1498
Benefits	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138	20138
Total	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5	18639.5
Discount Factor	52.7996	59.1356	66.2318	74.1797	83.0812	93.051	104.217	116.723	130.73	146.418	163.988	183.666
PV	353.023	315.199	281.428	251.275	224.353	200.315	178.853	159.69	142.58	127.304	113.664	101.486

	Year 47	**Year 48**	**Year 49**	**Year 50**
Infrastructure Cost				
Environmental Cost	-1498	-1498	-1498	-1498
Benefits	20138	20138	20138	20138
Total	18639.5	18639.5	18639.5	18639.5
Discount Factor	205.706	230.391	258.038	289.002
PV	90.6123	80.9038	72.2356	64.4961

Appendix 4: Sensitivity Analysis with Increased Infrastructure Costs

For these calculations, the infrastructure costs were simply inflated by 25% and 50% respectively.

Example 1: Bayhead 1AA

The original capital cost was R9.6 billion.

This figure is inflated by 25% to obtain an amount of R12 billion.

The same figure is then inflated by 50% to obtain R14.4 billion

The result is a reduction in the NPV to R64 billion and R61 billion respectively.

Example 2: Old Airport DIA1

The original capital cost was R14.9 billion.

This figure is inflated by 25% to obtain an amount of R18.625 billion.

The same figure is then inflated by 50% to obtain R22.35 billion

The result is a reduction in the NPV to R52 billion and R48 billion respectively.

Appendix 5: Calculation of IRR for Expansion Options

These calculations are based on trial and error whereby one adjusts the discount rate until an NPV of zero is found. It is quite a cumbersome and long winded procedure but provides crucial information about the financial risk of a project. Bayhead 1AA is shown below as an example. The reader here should remember that under an 8% discount rate, the NPV for this option was R66 billion. As per the literature review, the higher the discount rate, the lower the future cash flows of a project. The breakeven or zero NPV point for 1AA is 26.401% or more than three times the long term interest rate for South Africa.

	Total	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Infrastructure Cost		-9600									
Environmental Cost			-749	-749	-749	-749	-749	-749	-749	-749	-749
Benefits			0	0	0	0	5155.5	5155.5	10311	10311	10311
Total		-9600	-749	-749	-749	-749	4406.5	4406.5	9562	9562	9562
Discount Factor		1	**1.26401**	1.60	2.02	2.55	3.23	4.08	5.16	6.52	8.24
NPV	**0**	-9600	-592.56	-468.79	-370.88	-293.41	1366	1080.42	1854.8	1467	1160.86

Interest rate required for a NPV of zero.

NPV of zero