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The future of Irish access transport: investigation, modelling and appraisal

(2 volumes)

Volume I: Main Text

Warren James Whitney

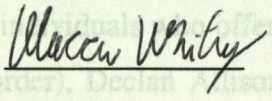
Thesis submitted to the University of Dublin, Trinity College, in fulfilment of the requirements for the award of the degree of Doctor of Philosophy

Transport Study and Research Group
Department of Civil, Structural and Environmental Engineering

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I apologise to anyone I may have overlooked in this list. All opinions expressed are my own, and any errors or omissions my responsibility.

SUMMARY

This thesis aims to examine in detail a variety of possible strategies for the development of the Irish access transport system. The Irish access transport system is considered as being the system (passenger and freight) linking the island of Ireland (Northern Ireland and the Republic of Ireland) with Great Britain and the remainder of the European Union.

Specific aims of the research project include:

- To examine possible alternative strategies for the development of the Irish access transport system up to the year 2020, with an important sub-objective in this regard of investigating technological and other measures which might form part of such strategies.
- To develop a means of predicting future transport demand under alternative strategies.
- To develop an appraisal framework allowing the comparison of different strategy options.

A number of alternative future strategies for the transport system were developed by reviewing available technological and other measures, identifying those appearing most promising, developing these latter in greater detail and combining them into consistent strategies. A future background scenario, embracing population and economic developments in the period to 2020 and forming the basis against which the strategies were assessed, was developed with reference to available information and current projections.

In order to assess the strategies, it was necessary to develop a set of demand prediction models for passenger and freight traffic and an appraisal framework permitting comparison of various different strategies' performance. In each of these areas, an extensive review of available techniques was carried out, leading to the identification of appropriate methodologies for the present purpose.

The chosen approach to passenger demand modelling uses a quasi-direct demand framework, while freight traffic is predicted using simple econometric models. Both types of traffic are assigned to networks represented using the University of Montreal's STAN model.

The appraisal framework in its final form concentrates primarily on multicriteria analysis, with a contribution from cost-benefit analysis. The criteria applied cover a wide range of environmental, economic, social and technical issues. Information from the demand models forms an important input to the appraisal process.

A number of alternative strategies were investigated in the first stage of the modelling and appraisal process. These were:

- Strategy 01: Do-Minimum, involving no transport provision additional to that likely to take place in any case by 2020.
- Strategy 02: Air/Sea, High Investment, involving significantly increased air and sea transport capacity (without attempting to alter the distribution of traffic).
- Strategy 03: Air/Sea, Managed Demand, again concentrating on air and sea transport, but directing investment to peripheral regions and using pricing measures to further encourage traffic to divert from congested facilities in the core regions.
- Strategy 04: Fixed Link, centring on a rail tunnel across the Irish Sea and its associated transport service alterations.
- Strategy 05: Buoyant Air, involving the provision of buoyant air transport (airship or partially-buoyant hybrid craft) services for both passengers and freight on principal Irish access routes.

A simplified analysis of these strategies was carried out initially, and it was identified that Strategies 04 and 05, possibly coupled with certain elements from Strategy 03, were the most promising. Modified versions of Strategies 04 and 05- designated 06 and 07 respectively- were developed and analysed in greater detail. Conclusions marginally favoured a buoyant air strategy (06), but, considering the technological risks involved, it is not possible to favour it unequivocally over minor modifications and optimisation of the existing system.

It has also been possible to review, in the light of results, the approaches taken in the fields of demand modelling and appraisal, and to identify possible further modifications which could increase their utility.

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I shall only enumerate by Rules generally known, and never contradicted, what are the true Causes of any Countries flourishing and growing rich; and then examine what effects arise from those Causes in the Kingdom of *Ireland.*

The first cause of a Kingdom's thriving, is the Fruitfulness of the Soil…

The Second, is the Industry of the People…

The Third, is the Conveniency of Safe Ports and Havens, to carry out their own goods, as much manufactured, and bring in those of others, as little manufactured, as the Nature of mutual Commerce will allow.

The Fourth is, that the Natives should, as much as possible, export and import their Goods in Vessels of their own Timber, made in their own Country.

JONATHAN SWIFT, *A Short View of the State of Ireland*, 1727.

Also, without being actually positive, it struck him a great field was to be opened up in the line of opening up new routes to keep pace with the times …

A great opportunity there certainly was for push and enterprise to meet the travelling needs of the public at large, the average man, i.e. Brown, Robinson and Co….

Interesting to fathom, it seemed to him, from a motive of curiosity pure and simple, was whether it was the traffic that created the route or vice-versa or the two sides in fact.

JAMES JOYCE, *Ulysses*, 1922.

1 INTRODUCTION

1.1 OVERVIEW OF THE PROJECT

1.1.1 Background

Work on this research project began in October 1998, with the general objective of examining a variety of possible strategies for the development of the Irish access transport system. The Irish access transport system is considered as being the system (passenger and freight) linking the island of Ireland (Northern Ireland and the Republic of Ireland) with Great Britain and the remainder of the European Union.

1.1.2 Objectives

In more specific terms, the objectives of this project include:

- To examine possible alternative strategies for the development of the Irish access transport system up to the year 2020, with an important sub-objective in this regard of investigating technological and other measures which might form part of such strategies.
- To develop a means of predicting future transport demand under alternative strategies.
- To develop an appraisal framework allowing the comparison of different strategy options.

1.2 WORK PROGRAMME

This research project was conducted as a series of five "tasks". Although the original intention was that the tasks would be completed sequentially, practical considerations led to a decision to allow some tasks to run in parallel at various points. The tasks, and their corresponding sections of the thesis, were:

- Task 1: Predicting demand for Irish access transport in 2020 (corresponds to chapter 6 and part of chapter 3 of this thesis).
- Task 2: Modes, technologies and instruments for the Irish access transport system in 2020 (parts chapters 2, 3).
- Task 3: An appraisal framework to evaluate strategic options for the Irish access transport system in 2020 (chapter 7, part chapter 3).
- Task 4: Scenarios and strategies for the Irish access transport system in 2020 (chapters 4, 5).
- Task 5: Modelling strategic options for Irish access transport in 2020 (chapter 8).

A printed report was produced for each of Tasks 1-4 upon completion; this was not done for Task 5, since its completion coincided with preparation of the thesis itself. Figure 1.1 below gives an indication of the relationship between the various tasks. The arrows show how the outputs from one task feed into others.

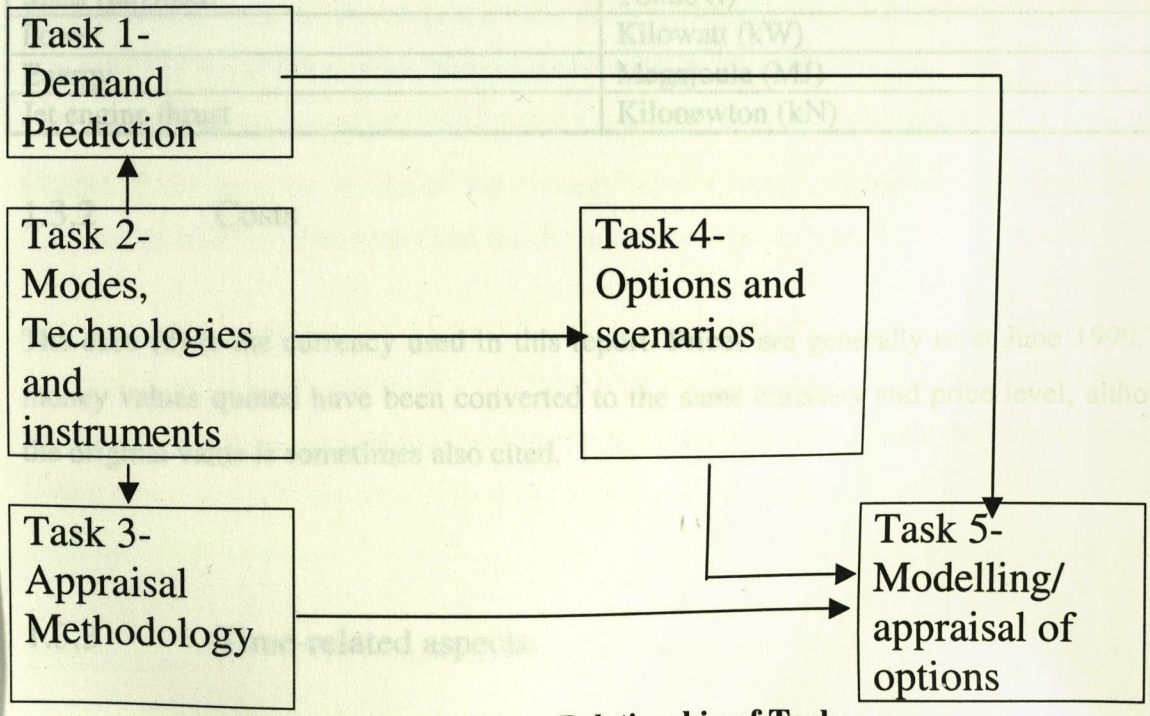


Figure 1.1 Relationship of Tasks

1.3 GENERAL PRINCIPLES

1.3.1 Units

SI units (including derived and multiple units) are used throughout this report. Where it is necessary to use a non-standard unit, the SI equivalent is given. Table 1.1 outlines the units used.

Table 1.1 Units used in this thesis

Quantity	Unit
Length (vehicle dimensions, wave heights)	Metre (m)
Length (distances)	Kilometre (km)
Time	Hour (h)
Volume	Cubic metre (m^3)
Mass (emissions)	Gram (g)
Mass (payload)	Tonne (t)
Power	Kilowatt (kW)
Energy	Megajoule (MJ)
Jet engine thrust	Kilonewton (kN)

1.3.2 Costs

The euro (€) is the currency used in this report. Prices are generally as at June 1999. All money values quoted have been converted to the same currency and price level, although the original value is sometimes also cited.

1.3.3 Time-related aspects

All references to the present-day position in this report have been updated to autumn 2001. The future horizon year is assumed to be 2020. 2015, 2016 and 2017 were assumed at various stages of the work, but all information has now been updated to a 2020 horizon year. 1995 is the base year for demand modelling.

1.4 STRUCTURE OF THIS THESIS

Chapter 2 gives a brief overview of the scope of the Irish access transport system and its background (including historical, economic, climatic and other factors, as well as current developments). Chapter 3 is a literature review covering the existing system, current policies, possible technological developments and methodologies for demand prediction and option appraisal.

Chapter 4 deals in more detail with possible measures for the future development of the system. Chapter 5 describes how the measures from Chapter 4 were synthesised into a number of alternative future strategies, and how alternative background scenarios against which to test the strategies were developed from a variety of available projections.

Chapter 6 describes the development of a demand forecasting methodology and Chapter 7 that of an appraisal framework, both rooted in the results of the Chapter 3 literature review.

Chapter 8 outlines the results of the strategy tests. Chapter 9 discusses these results and Chapter 10 draws conclusions from the discussion.

2 BACKGROUND

2.1 GENERAL OVERVIEW

Ireland is, in some respects, unique in Europe in terms of the elements of its transport system which link it with other countries, i.e. the access transport market. If the island is considered as a whole, there are no land links (road or rail) to any other part of Europe. It is by far the largest island in Europe without fixed links to the mainland. Furthermore, the nearest land mass is itself an island (Great Britain)- though one which has (comparatively recently) acquired a fixed link to the mainland. This poses further transport problems and, when taken together with Britain's large population, its common language with Ireland and strong political connections, has helped distort Irish trade patterns somewhat in favour of Britain.

Dependence on air and sea transport modes for both passenger and freight movements between Ireland (which hereinafter is understood to mean both the Republic of Ireland and Northern Ireland) and the remainder of Europe is therefore total. This may impose higher freight costs on Irish firms than their counterparts elsewhere in Europe. Furthermore, the heavy dependence on air transport for passenger movement must significantly increase the energy intensity of such traffic over that of countries with road and rail links available.

The distribution of development within the country also reflects access transport characteristics. The east and south coasts have traditionally dominated in terms of both population and industrial development; this has been the central issue in regional policy for many years. Attention is currently being focused on this aspect in connection with the 2000-2006 National Development Plan and the preparation of the National Spatial Strategy.

The need for investment in transport infrastructure in order to sustain economic growth is now widely recognised in Ireland. Access transport represents a significant portion of this need when road and rail improvements intended primarily to facilitate access to ports and airports are taken into account, but it is important to note that the principal needs lie elsewhere, particularly in urban transport.

2.2 GEOGRAPHY

2.2.1 Physical situation

Ireland is an island of area approximately 84,000 km^2 situated in the North Atlantic Ocean to the northwest of the continent of Europe and the west of Great Britain. Politically, it is divided into the Republic of Ireland, a constituent country of the European Union with a population (in 1996) of approximately 3.6 million, and Northern Ireland, part of the United Kingdom- itself a constituent country of the European Union- with a population of approximately 1.6 million. There is a heavy concentration of population along the east coast, particularly in the Dublin and Belfast metropolitan areas.

Physically, the island consists of a central plain which is generally no more than 150m above sea level, surrounded by coastal mountain ranges which rise to (on average) around 600m, the highest peak being 1,041m. Neither mountains nor rivers present significant barriers to transport other than on a local, intraregional, scale.

The area of greatest interest to this study consists of the islands of Ireland and Britain (the Isle of Man and the Channel Islands being ignored, principally due to small size) and the continent of Europe, with particular reference to France, Belgium, the Netherlands, Luxembourg and Germany.

2.2.2 Regional aspects

The island of Ireland is divided politically into two units, as described above. For long, these units have been regarded as regions themselves (at the NUTS 0-2 levels) in the European Union context. At the NUTS 3 level, a system of "planning regions" was established in the Republic of Ireland in the 1960s for strategic purposes, although no political power was devolved to this level. In recent times, there has been a trend towards greater recognition of regional issues in the Republic. This has led to a higher regard for the role of the NUTS 3 regions (currently eight in number), though not so far to the establishment of meaningful regional authorities, and to a greater availability of regional statistics. For the purposes of the forthcoming National Development Plan, the country has been divided into two "super-regions" (NUTS 2 level in EU terminology). The

eastern/southern NUTS 2 region (known as the "S&E" (southern and eastern) region) comprises the regions of Dublin, Mid-East, Southeast, Southwest and Mid-West and the western one ("BMW" for Border, Midlands and West) the regions of Midlands, West and Border. The latter qualifies, by virtue of its lower GDP, for the higher "Objective 1" level of EU Structural Funds while the former does not- apparently the primary reason for this unusual division.

In any closer examination of the characteristics of the regions, the first point of note is that all the major terminals for access transport facilities- that is to say, the three State airports and the Eastern Corridor, Southern Corridor and direct Continental ro-ro and lo-lo ports- are situated within the S&E super-region, as is the major deep-water bulk port of the Shannon Estuary. This suggests that the exports and imports of these regions will generally incur lesser direct transport and indirect time costs than those of the "poorer" western regions, with a very likely (judging from the literature, e.g. Culliton (1992)) downstream effect on the locational decisions of firms. The BMW super-region possesses a few ports, most of which are small and devoid of scheduled unitised services; the main exception, Drogheda (a minor lo-lo terminal) is actually located on the *east* coast, close to Dublin and just inside the Border region (reflecting the vagaries of regional definition). There are some small regional airports in the West and Border regions, only one of which (Connacht Regional/Knock) possesses any international services at the time of writing; even these are far less frequent and serve far fewer destinations than those from the State airports.

In addition to the peripherality of certain regions, there may also be special problems suffered by individual regions. For example, the economy of the Border region has suffered from the "knock-on" effects (particularly on image) of political instability and violence in Northern Ireland and also from "border effects" on local trade. Problems of urban deprivation particularly (but not exclusively) affect Dublin. Virtually all regions have their own particular problems.

Northern Ireland, in contrast to the Republic, is treated as a single region. This is sensible in relation to the size of the other statistical regions in the UK (of which it is the smallest in population terms) but makes it much larger in both area and population terms than any of the Republic's planning regions. It also tends to obscure the effects of internal social, economic and physical differences, particularly between east and west. However, because virtually all available statistical sources treat Northern Ireland as a single region, the present analysis will follow that convention.

2.2.3 Climate

Climatic factors are of interest from the point of view of this study purely because they affect the operability of sea and air-based transport systems, which account for all traffic to and from Ireland at present and are likely to in most possible future systems. Even if a fixed link (bridge or tunnel) were to be provided, it is likely that a large proportion of both passengers and freight would continue to use air and sea modes.

For the purposes of this study, the aspects of climate considered most important include wind speeds and directions, sea conditions (particularly wave heights) and visibility or icing problems where these may affect airports or other terminal facilities.

Prevailing winds over Ireland are southwesterly in direction; wind speeds in exposed coastal locations average around 8m/s in winter and 7m/s in summer, and those inland 5-6m/s in winter and 4-5m/s in summer. Mean annual speeds recorded at weather stations range from 3.3m/s to 8.1m/s. Gales in typical locations (i.e. major cities and airports) occur on between 2 and 17 days per annum; at exposed coastal sites, the corresponding figure is 10 to 40 days. The highest gust speeds recorded are generally in the region of 40-50m/s. 200-600 hours of fog per annum are typical. Annual mean daily air temperature is in the range 9-10°C; summer temperatures lie generally around 14-16°C and winter 9-10°C (Rohan 1986).

Sea states are proportional to wind speed; the author has referred to the table provided by Phillips (1999) in this respect. Each sea state corresponds to a "force" on the Beaufort scale of wind strength; in turn, a force represents a range of speeds. A range of wave heights can be equated to the sea state. On this basis, the typical significant wave heights likely to be encountered in Irish coastal waters would be around 1.1m in summer and 1.4m in winter. Under moderate gale conditions, the significant wave height would reach at least 4.3m. Bryce (1997) observes that the significant wave heights assumed for the safety certification of high-speed ships are 2.8m in the Irish Sea, 3.0m in the North Channel, 3.4m in St. George's Channel, 3.7m in the Cork-Bristol Channel corridor and 4.0m in the Atlantic.

2.3 HISTORY

2.3.1 General historical background

It is not the purpose of this project to examine in any detail the history of Ireland, but some points are worthy of note in the transport context. Human settlement on the island dates from at least 6000-8000 BC. While Norse and (in parts of the island) French influences were strong at one time or another, the defining factor over much of the island's history, and in its access transport system, has been its relationship to Britain.

In particular, the country was colonised by Anglo-Normans from the twelfth century onward and gradually incorporated into a political unit with Britain, the countries' parliaments ultimately being merged by the Act of Union in 1801. Closer political connections brought about an increase in travel between the countries. However, famine in the 1840s led to a decline in population and a long-term economic stagnation. Following a violent campaign for independence, the island was partitioned in 1922 into the independent Irish Free State and Northern Ireland, a part of the UK. Although the Free State (which became the Republic of Ireland in 1949) was no longer as politically dependent on Britain as before independence, close economic links continued (a currency union was maintained until the 1970s). In spite of this, closer links did begin to be forged with Continental Europe; access transport reflected this, as in the development of a ro-ro shipping service to France in the 1960s.

In the early 1970s, both the Republic of Ireland and the UK entered the then European Economic Community (now the European Union); this led to further development of economic and trade connections between the Republic and Continental countries. By the 1980s, this affiliation had another dramatic effect on transport in the form of the Cohesion and Structural Funds provided for investment in infrastructure. The significant improvements thus brought about were amongst the factors contributing to the Republic of Ireland's unprecedented economic prosperity in the late 1990s.

Northern Ireland had suffered severe economic setbacks since the end of the 1960s as a result of politically-motivated violence. However, this declined in the 1990s, eventually leading to ceasefires and a political agreement, though political instability and uncertainty

continue to some degree. The reduction in violence was accompanied by a renewed economic confidence.

2.3.2 History of the access transport system

Transport figured heavily in the early history of Ireland; colonisation by Norse and Anglo-Norman peoples reflected in its spatial distribution the ease of access by sea to various points along the coast and their adequacy as harbours; the dominance of the east and south coasts appears to have begun at this stage. Indeed, it is probable that all the various peoples who settled in Ireland since prehistoric times arrived by sea, as the island's separation from Britain predated the first known human settlement (de Courcy Ireland 1986). Trading by sea was also a very important aspect of the economy from earliest times (de Courcy Ireland 1986).

However, regular scheduled shipping services for the carriage of passengers and freight did not evolve until the 16th and 17th centuries, when the British government's need for efficient postal communication with its representatives in Ireland led it to encourage the development of such services. The evolution of the public postal services in the 18th century gave further impetus to access transport development. The 19th century saw the introduction of steamships; the development of the railways around the same time rendered the ports more easily accessible, favoured shorter sea crossings (because of this ease of access) and led to railway companies taking financial interests in the shipping services (Gilligan 1988).

Further evolution of sea transport followed in the 20th century, with unitised roll-on-roll-off (ro-ro) and lift-on-lift-off (lo-lo) services developing by the late 1960s and rapidly coming to dominate the freight market. However, by now, passenger services were facing increased competition from airlines. Ro-ro services and rising car ownership also brought about an increase in the number of ferry passengers travelling with a car at the expense of "classic" passengers travelling to and from the ports by rail. Longer sea routes (e.g. Dublin-Liverpool) went into decline, partly as a consequence of the latter trend.

The first scheduled air services from Northern Ireland commenced in 1933 and from the then Irish Free State three years later, both somewhat late by European standards (Byrne 1979; Corlett 1981). Significant development only took place after World War II, when the availability of ex-military aircraft and pilots facilitated expansion on a large scale. The

arrival of faster, more comfortable turboprop aircraft in the 1950s led to a significant increase in passenger numbers. The gradual evolution of the services brought about a steady rise in carryings over the 1960s and 1970s, though economic setbacks such as the 1973 oil crisis slowed or temporarily reversed growth. Air freight was rather slower to evolve, but dedicated freight services developed rapidly in the 1950s and 1960s.

For most of their history, air services were dominated, under a restrictive licensing system, by large government-owned carriers. This changed in the Republic of Ireland-Great Britain market in the mid-1980s (slightly earlier on Northern Irish routes) when new carriers were licensed to compete on the principal routes for the first time. The result was- particularly on Republic of Ireland routes- intense competition and the withdrawal of several established carriers from the market. Fares were dramatically lowered, particularly as low-cost "budget" carriers (Ryanair being the most notable) entered the market, leading to modal shift from shipping services, coupled with an increase in overall demand (Burke 1990).

In the passenger market, sea carriers fought back against this increased airline competition through both the introduction, in the early 1990s, of high-speed passenger-orientated services, with a concomitant trend back towards longer routes, and the replacement of most remaining conventional vessels with large multi-purpose (passenger/freight) "superferries" offering an increased standard of passenger amenities.

2.4 ECONOMY

2.4.1 National

Any assessment of transport needs in Ireland must necessarily take account of the degree to which economic factors increasingly shape the demands and constraints on the transport system. Recent economic growth in the Republic of Ireland has far outstripped projections, although it is now beginning to slow markedly, and consequent transport demand growth- freight transport volumes, for instance, are closely correlated with GDP- has also exceeded the predictions of previous studies (such as the KPMG Access Transport Study described below). Although it is very unlikely that exceptionally high growth will continue to 2020, the base level of GDP is likely to remain high by previous Irish standards, and transport

demands likewise. The potential for growth in the Northern Irish economy must also be considered in the light of reduced political instability.

Ireland as a whole has traditionally been a small, relatively poor, agriculturally-based economy with very few significant industries; the principal exceptions were the linen, shipbuilding and engineering industries of northeastern Ulster. Widespread industrialisation only came to the Republic of Ireland post-1960, and light industry such as electronics and pharmaceuticals, predominantly subsidiaries of large multinational firms, dominated this process. More recently, there has been a trend towards the services sector (as might be expected in a maturing economy).

After periods of modest growth in the 1960s and 1970s, the Republic of Ireland's economy underwent a prolonged recession in the first half of the 1980s. Wage moderation (through national agreements), European capital investment, improved education and labour force growth contributed to renewed economic growth in the early 1990s, increasing to levels never before seen in Ireland by the middle of the decade and outperforming many major European economies (Fitzgerald et al. 1999). Sectoral shares of GDP are considered in greater detail below.

Northern Irish GDP has remained more or less constant as a percentage of UK GDP in recent years. In sectoral terms, 4.8% is accounted for by agriculture, 25.5% industry and 68.3% services. Relative to the UK as a whole, the region is more dependent on agriculture and less on industry and services. Relative to the Republic of Ireland (see also 2.4.2 below), it is less dependent on industry and more on services (presumably due to its more advanced position in the "development cycle"- i.e. it industrialised first and shifted from industry to services first- and possibly also to the high level of reliance on the public sector).

2.4.2 Regional

The importance of regional accounts and other regional economic measures has only come to be recognised within the past few years in the Republic of Ireland (as Northern Ireland constitutes a single region, it is not considered in this discussion). However, regional accounts for the years 1991-1997 are now available (Central Statistics Office (CSO), 1999b).

These reveal that the highest per capita GVA (regional GDP) is found in the Dublin region, followed by South West, Mid West, South East, Mid East, Border, West and Midlands. Only the Dublin and South West regions exceed average EU GDP; they are also the only ones to exceed the State average (which, in 1998, was 108% of the EU average).

In terms of sectoral shares of GVA, in the Republic of Ireland as a whole agriculture, forestry and fishing account for just under 5%, manufacturing and construction for 39% and services for nearly 57%. In regional terms, however, agriculture, forestry and fishing may account for up to 10% in some regions (Border, Midlands, West, South East). Manufacturing's share of GVA in most regions is relatively close to the State average, the principal exception being Mid East on 50%. Predictably for a capital city, Dublin has the greatest dominance of service activity (69%). In terms of the contribution each region makes to State GDP in the three sectors, South West, South East and Border dominate in agriculture and Dublin in manufacturing and services. Agriculture's share is declining, manufacturing's static or declining and services' rising in most regions. In Dublin and Mid East, manufacturing is growing at the expense of services; this is probably attributable to the inclusion of the construction industry, a notable beneficiary in these regions of the economic boom, in the manufacturing sector.

Relative to the State's GDP, regional GVA levels have fluctuated, but the principal trends in this respect over 1991-1997 were decline in the Border, Midlands, Mid West, and West regions (i.e. the GVA of these regions is now lower relative to State GDP), growth in Mid East and South West and stability in Dublin and South East. Relative to EU GDP, there was growth in all regions over this period.

2.5 ACCESS TRANSPORT

2.5.1 Scope of the access transport system

The access transport system comprises all transport links connecting the island of Ireland (Republic of Ireland plus Northern Ireland) with the rest of Europe (Britain and the European mainland). It encompasses passenger, unitised (container/trailer) freight and bulk freight services.

In strict terms, the access transport system proper is confined to the air and sea links which actually cross the water barriers separating Ireland from the rest of Europe. However, in this research project, attention is additionally given to "inland" links (principally road and rail) which carry passengers and freight to and from the terminals (ports, airports) of the access links, insofar as they affect the characteristics of the access system.

2.5.2 Principal components of the system

The Irish access transport system, as defined for the purposes of this thesis, is extensive and complex. Large parts of the network are shared with, often dominated by, other (local, domestic Irish, Britain-mainland Europe) traffic flows. Many sections are shared between passenger and freight traffic (roads, railways, ports, airports, some ferries and airliners). In practice, factors such as these obscure the true scale and characteristics of the system.

Sub-section 3.2.2 in the following chapter describes in greater detail the characteristics of the network and its main components, with particular attention to the "core" system consisting of air and sea links to and from the island of Ireland.

The system can be segmented into a number of sub-systems in a variety of ways. It is proposed to limit the description of the system in this chapter to an analysis of the various possible subdivisions of the system and their general characteristics. As described above, the following chapter of this thesis examines the system in considerably greater detail.

The different parts of the system can be segmented by purpose, i.e. the type of traffic they are intended to carry, as follows:

- Passenger: passengers unaccompanied by vehicles, as in the case of airlines, coaches, most passenger trains and foot passengers on ferries.
- Car-accompanied passenger: passengers travelling with a car or other vehicle, as on ferries.
- Unitised freight: travels in standardised units, usually lift-on-lift-off (lo-lo) containers (carried on specialised container ships) or roll-on-roll-off (ro-ro) trailers (carried on freight or passenger/freight ferries).

- Bulk freight: conveyed on bulk ships of a type appropriate to the particular cargo.

Segmented into different transport modes, the major components of the system are:

- Air passenger (further divides into main, regional and low-cost carriers).
- Conventional sea passenger (low operating speeds, may carry car-accompanied or foot passengers).
- Fast sea passenger.
- Conventional ro-ro freight (may be accompanied or unaccompanied, on freight-only or passenger/freight ships).
- Fast ro-ro freight (limited).
- Lo-lo freight.
- Bulk sea freight (includes liquid bulk traffic such as oil, dry bulk such as grain, break bulk such as timber).
- Air freight (may be on dedicated freighters or passenger aircraft; some nominal "air freight" traffic is actually road-hauled to British and other hubs for onward transport)
- Inland links (including rail, road, inland waterways, some air links).

The transport network can be divided into various geographical corridors. For surface transport these are:

- Northern Corridor: Northern Ireland to Scotland and northwest England.
- Central Corridor: Dublin Bay to north Wales and northwest England.
- Southern Corridor: South coast of Ireland to west and south Wales and western England.
- Landbridge: Route to continental Europe using the above corridors to Britain, then land transport to English Channel and cross-Channel ferry or train services to reach mainland.
- Direct Continental Corridor: Various points in Ireland to France, Belgium and Netherlands.

Air services can be divided into Ireland-Britain routes, Ireland-Continent routes and links between Britain and the European mainland serving Ireland-Europe traffic via British hub

airports. Figure 2.1 is a greatly simplified schematic of the access transport network's major components.

The demand for transport can be similarly segmented. Freight divides into a number of different commodities, the exact figure depending on the level of accuracy required in the particular context. Passenger travel can be segmented into business and personal travel; the latter can be further segmented, for instance into holiday, visiting friends and relatives (VFR) and other categories. Alternatively, it can be segmented into car-accompanied, air, and classic (rail and/or coach plus ferry) travel.

Sub-section 3.2.1 in the following chapter describes the characteristics of demand for Irish access transport, passenger and freight, in more detail, and analyses trends over recent years.

2.6 CURRENT DEVELOPMENTS

Current developments likely to affect the long-term development of the Irish access transport system can be divided into three categories: those affecting the demand for transport, those affecting the system itself and those affecting transport technology in general (which do not directly impact on the system but may be expected to in time).

In terms of factors affecting demand, economic and population growth on the island of Ireland are likely to dominate. The Republic of Ireland is entering an economic slowdown after more than five years of record growth. However, it does not seem that the potential for above-average (by EU standards) growth has been exhausted permanently, and the Economic and Social Research Institute [ESRI] (Duffy et al. 2001) predicted that, despite the slowdown, "the Irish economy [would] continu[e] to outperform its neighbours until the end of the decade". There appears to be significant latent potential in the Northern Irish economy, if political stability can be maintained and a progressive economic strategy agreed. Meanwhile, the population of the Republic is projected to grow by at least 16% between 2001 and 2021 and an overall 26% between 1996 and 2031 (CSO 2001a). Northern Ireland's population is also projected to grow by 8% over the period 1998-2020 (Government Actuary's Department 2001).

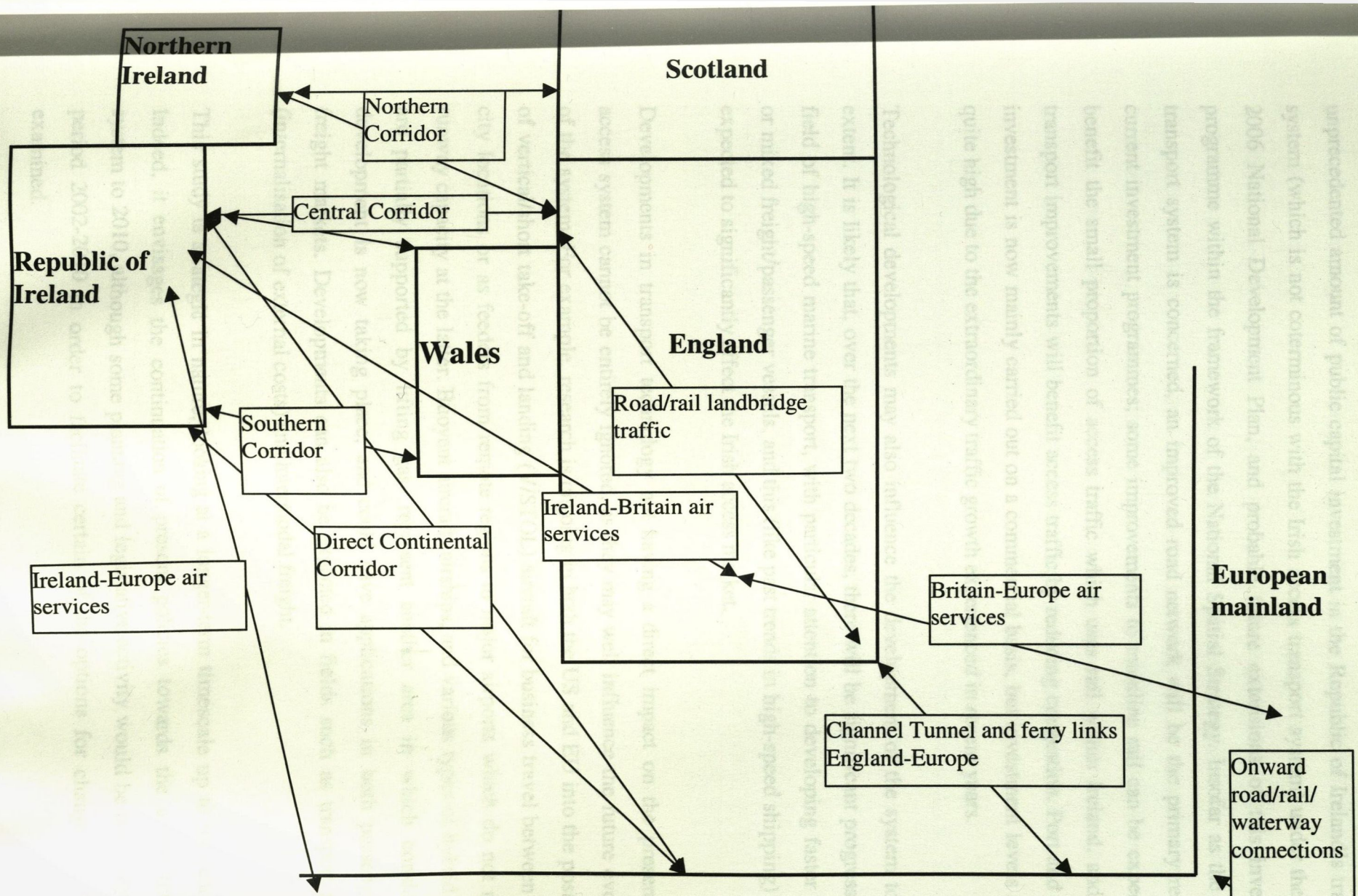


Figure 2.1 Network Schematic

The major influence on the development of the system itself is likely to be the unprecedented amount of public capital investment in the Republic of Ireland's transport system (which is not coterminous with the Irish access transport system) under the 2000-2006 National Development Plan, and probable future extensions of this investment programme within the framework of the National Spatial Strategy. Insofar as the access transport system is concerned, an improved road network will be the primary result of current investment programmes; some improvements to mainline rail can be expected to benefit the small proportion of access traffic which uses rail within Ireland, and urban transport improvements will benefit access traffic by reducing congestion. Port and airport investment is now mainly carried out on a commercial basis, but investment levels remain quite high due to the extraordinary traffic growth experienced in recent years.

Technological developments may also influence the development of the system to some extent. It is likely that, over the next two decades, there will be significant progress in the field of high-speed marine transport, with particular attention to developing faster freight or mixed freight/passenger vessels, and this (like past trends in high-speed shipping) can be expected to significantly affect the Irish access market.

Developments in transport technology not having a direct impact on the present Irish access system cannot be entirely ignored, as they may well influence the future evolution of the system. For example, research is ongoing in both the US and EU into the possibility of vertical/short take-off and landing (V/STOL) aircraft for business travel between inner-city locations or as feeders from remote regions to major airports which do not require runway capacity at the latter. Buoyant aircraft- airships, and various types of hybrid which are partially supported by lifting gas- represent another area in which considerable development is now taking place, and could have applications in both passenger and freight markets. Developments can also be expected in fields such as transport pricing (internalisation of external costs) and intermodal freight.

This study is strategic in nature, looking at a longer-term timescale up to the year 2020. Indeed, it envisages the continuation of present policies towards the access transport system to 2010, although some planning and legislative activity would be necessary in the period 2002-2010 in order to facilitate certain of the options for change that will be examined.

The strategic nature of the research means that little importance is attached to short-term problems and changes in the transport system. This is not to deny their importance. The years 2000 and 2001 have seen a major fuel crisis seriously affecting the road haulage industry, a foot-and-mouth disease outbreak disrupting transport both directly (disinfection at borders and ports) and indirectly (catastrophic effects on agriculture and tourism), serious disruption to train services in Britain due to emergency safety restrictions arising from rail cracking, and disruption and revenue loss for airlines resulting from terrorist attacks in the United States. All these have had significant impacts on the Irish access transport system, but their relevance to the long term at present appears limited.

3 LITERATURE REVIEW

3.1 INTRODUCTION

This chapter summarises the extensive literature review carried out in support of the author's research work. The review covered five main areas:

- Characteristics of the Irish access transport system, including demand patterns, transport supply and traffic characteristics, described in section 3.2 of this chapter.
- Major policy documents relating to Irish access transport (section 3.3).
- Suitable approaches to predicting transport demand (section 3.4).
- Means of appraising alternative transport strategies (section 3.5), including examinations of the roles of accessibility measurement and the economic effects of transport investment.
- Candidate technologies and other measures for the future development of the Irish access transport system (section 3.6)

3.2 THE IRISH ACCESS TRANSPORT SYSTEM

3.2.1 Demand characteristics

It is proposed to summarise here the principal features of the demand for transport in the Irish access market as they emerge from an examination of published quantitative statistics, principally "Tourism and Travel" (CSO 2001b) and "Statistics of Port Traffic" (CSO 2001c).

Total volumes of passengers visiting the Republic of Ireland from abroad have risen more or less linearly for several years (Figure 3.1). The rate of rise has been noticeably higher for air than sea traffic, but the latter nevertheless continued to increase perceptibly, at least until 1998. (Note that, in Figures 3.1 and 3.4, "air cross-channel" and "sea cross-channel" do not sum to total trips, the balance being made up by transatlantic and direct European traffic).

Figure 3.2 presents a more detailed examination of modal split in this sector of the market- it should be noted that the modal split data is only available for traffic to/from Britain. A long-term trend of declining sea market share with a consequent switch to air is visible; this is probably attributable to reduced air fares and increased frequencies resulting from airline deregulation in the late 1980s. However, there appears to have been a stabilisation of mode shares in the 1996-1998 period; this may well be the result of the introduction of high-speed shipping services (although it is uncertain whether this represents a real clawback from air or merely new traffic induced by such services). The sharp decline in sea traffic from 1998 to 2000 probably reflects the abolition of duty-free shopping.

Figure 3.3 shows how the market breaks down by journey purpose. It can be seen that tourist traffic is increasing significantly (air fares again being a likely causative factor) while business traffic and visits to relatives are increasing at a much lower rate; the recent decline in "other" trips probably reflects a change in classifications.

Figure 3.4 presents an overview of visits overseas from Ireland. It will be seen that they are rather fewer in number than those to Ireland, reflecting the island's small population and (until recently) comparative lack of economic development. The same broad trends of increase are apparent in total and air passenger figures as in the case of visits to Ireland, but it will be noted that sea volumes in this case have been declining for longer. The more marked decline of sea traffic amongst Irish trip-makers than those travelling from abroad may be due to the greater preponderance of tourist travel, for which sea services are relatively more attractive, in the latter case.

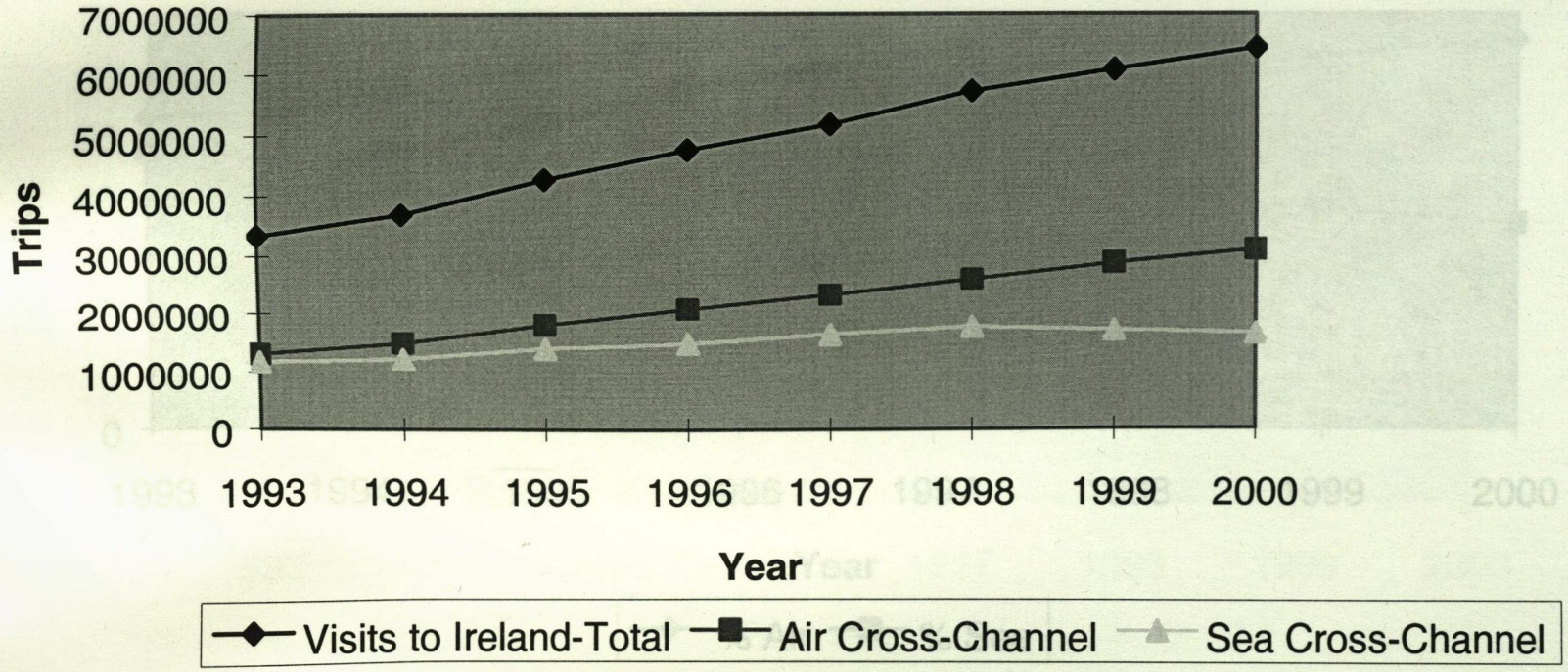


Figure 3.1 Overseas Visits to Ireland

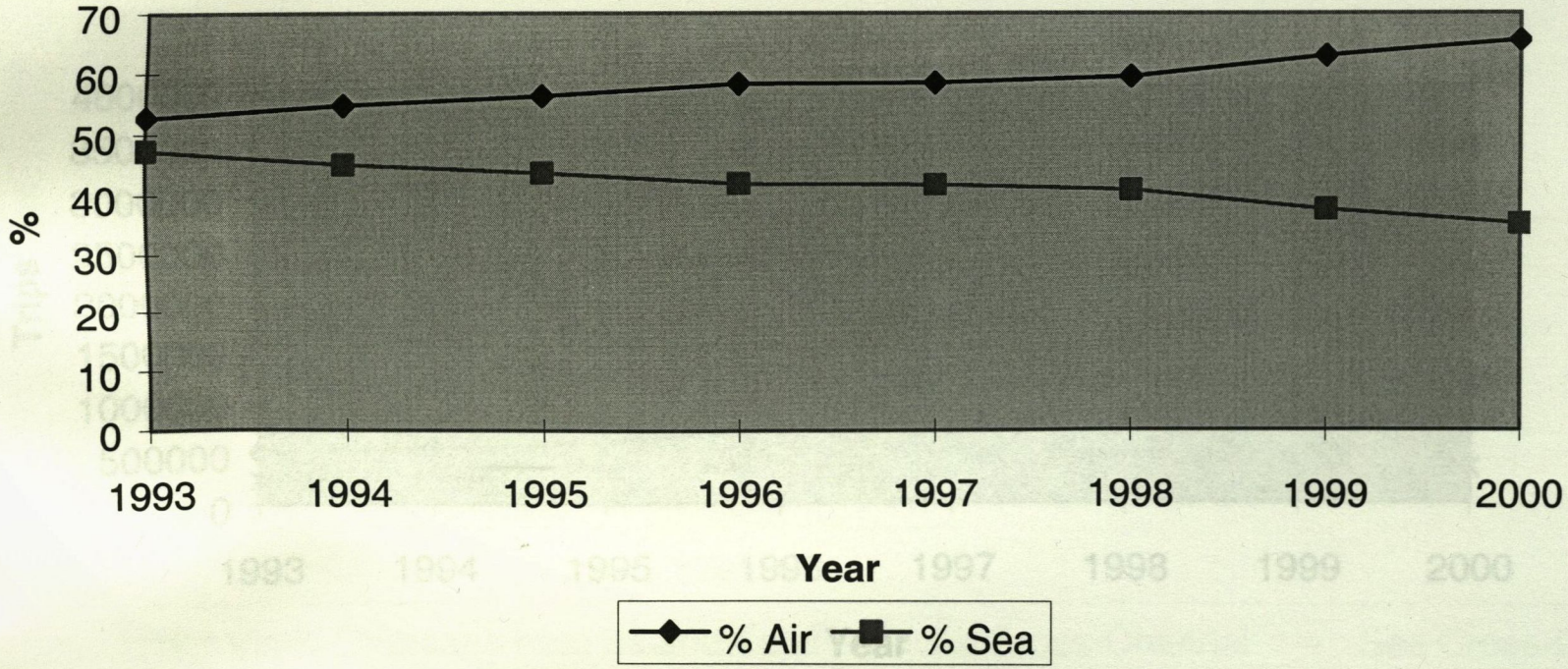


Figure 3.2 Modal Split amongst Visitors to Ireland from Britain

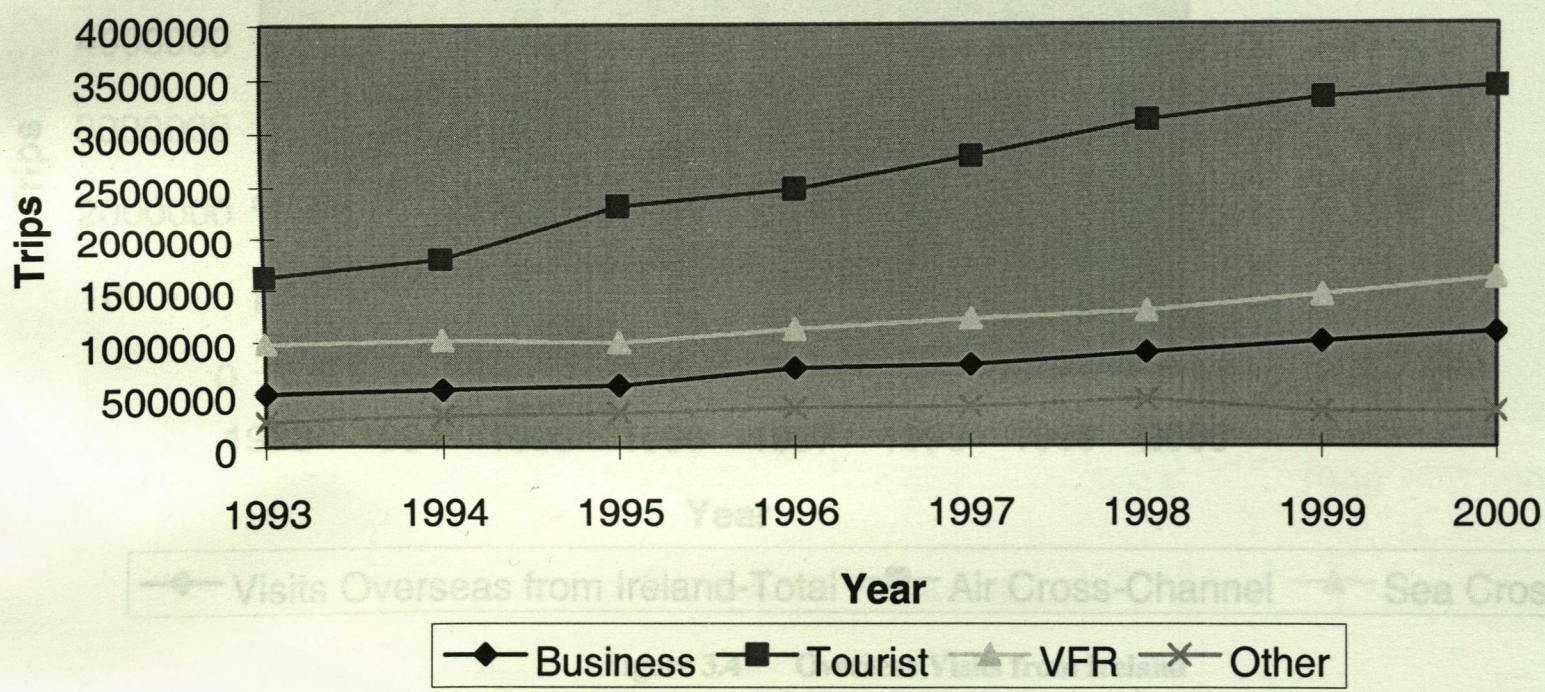


Figure 3.3 Overseas Visits to Ireland by Journey Purpose

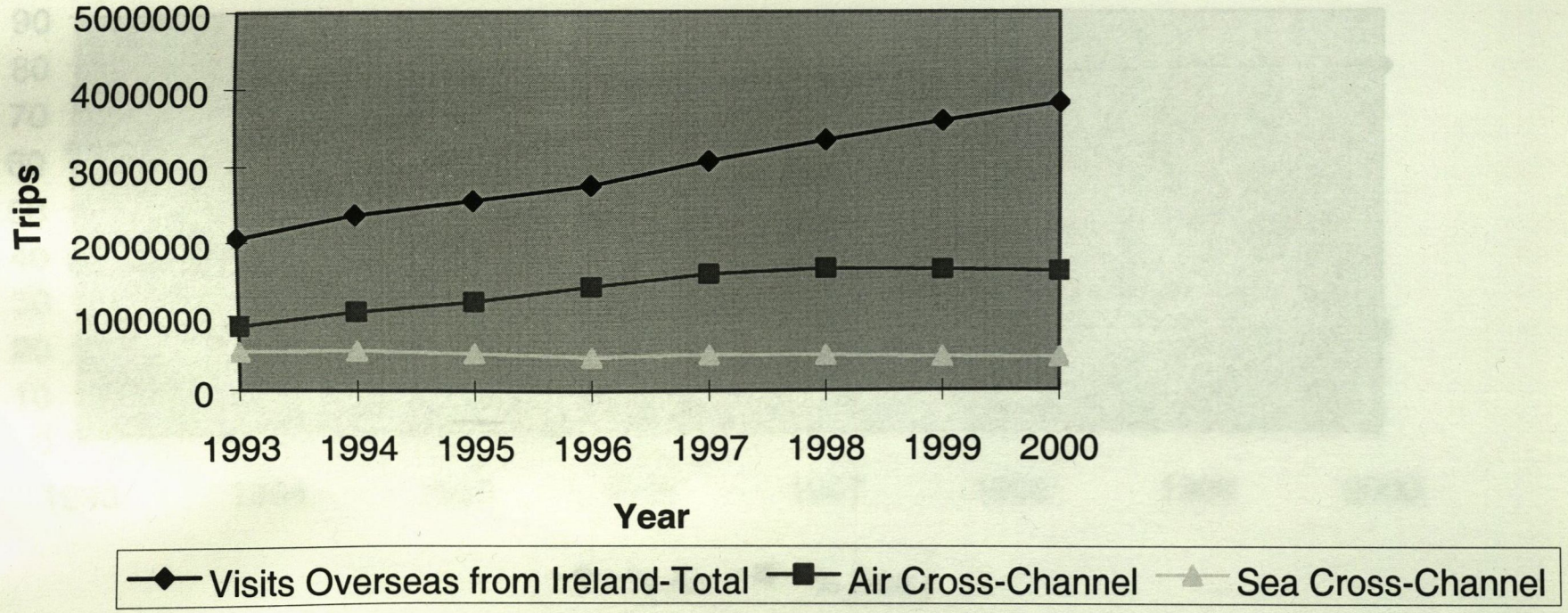


Figure 3.4 Overseas Visits from Ireland

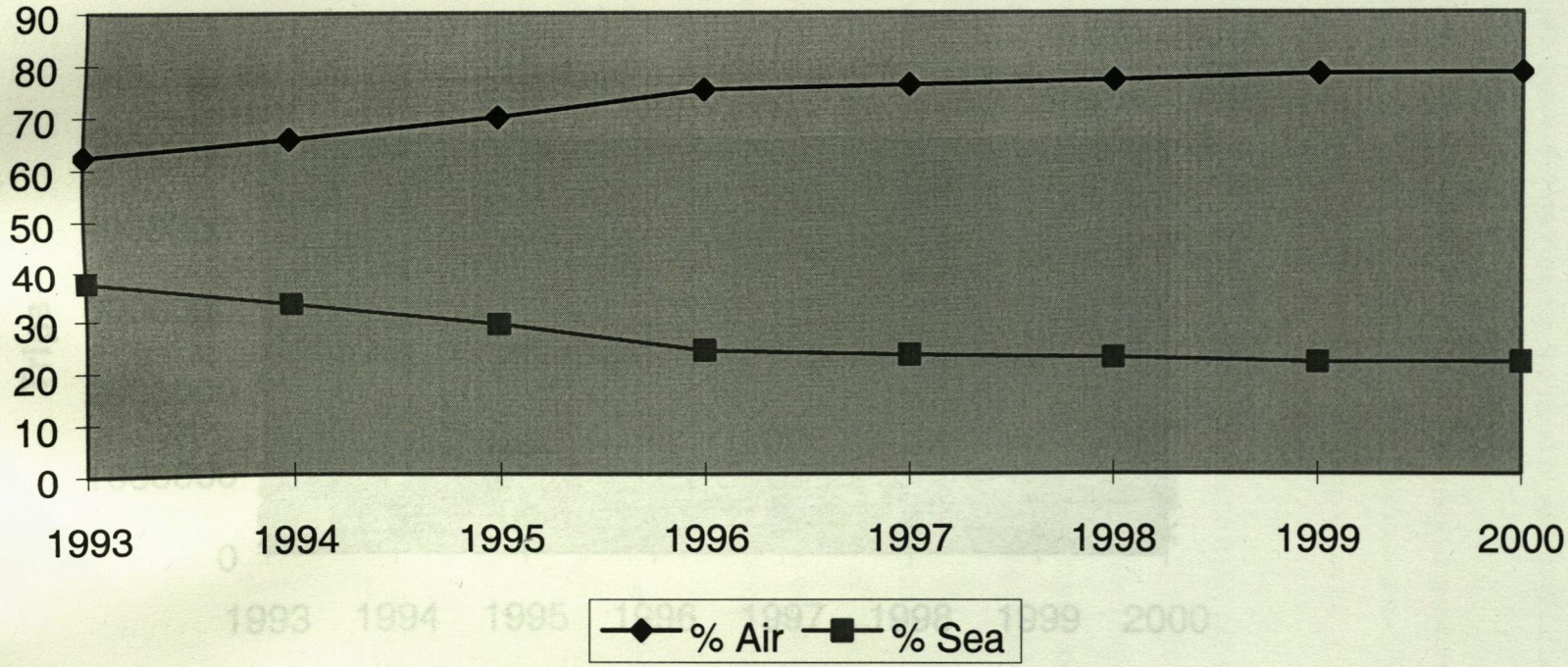


Figure 3.5 Modal Split Amongst Irish Visitors to Britain

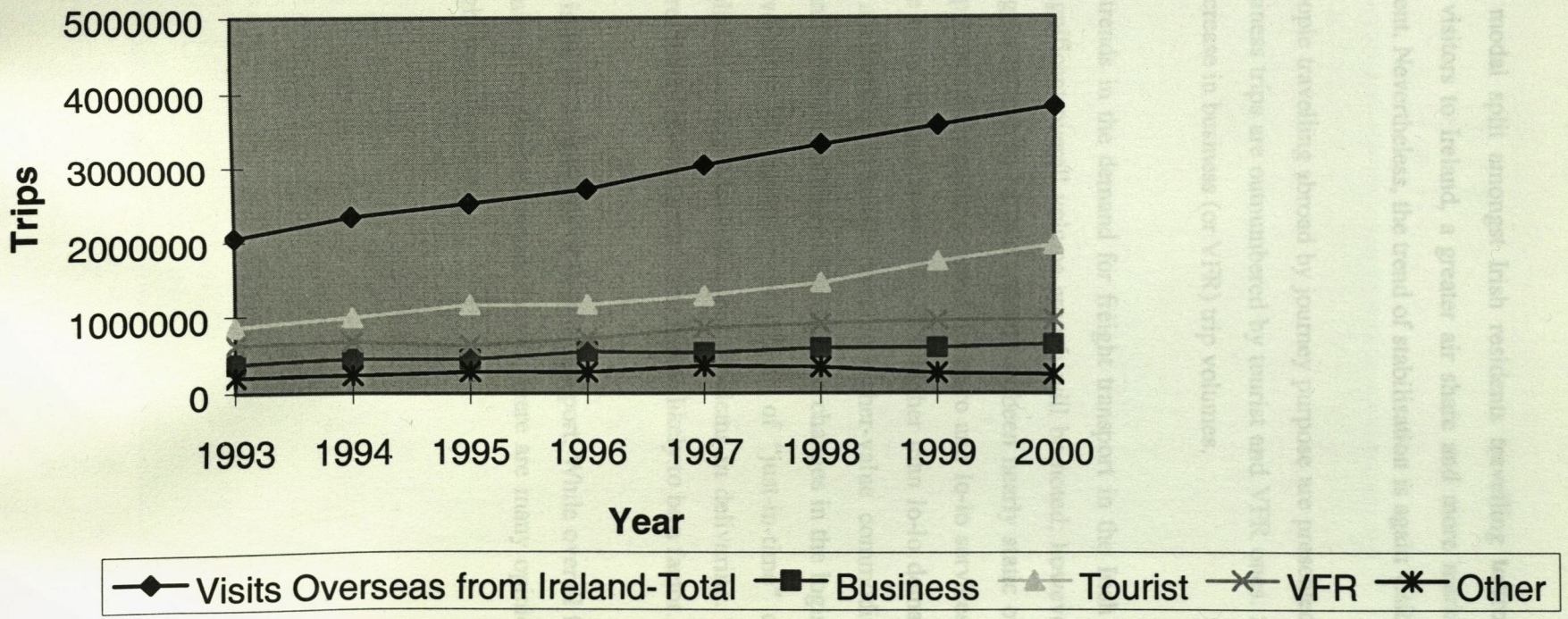


Figure 3.6 Overseas Travel from Ireland by Purpose

Figure 3.5 shows how modal split amongst Irish residents travelling to/from Britain has varied. Compared with visitors to Ireland, a greater air share and more marked modal shift away from sea are apparent. Nevertheless, the trend of stabilisation is again visible.

The numbers of Irish people travelling abroad by journey purpose are presented in Figure 3.6. It will be noted that business trips are outnumbered by tourist and VFR ones. Also, there has been little discernible increase in business (or VFR) trip volumes.

Figure 3.7 summarises trends in the demand for freight transport in the Irish access market over recent years. A significant overall volume growth will be noted; however, lo-lo traffic has grown far more sluggishly than ro-ro, and indeed has been nearly static over part of the period. A situation of approximately equal demand for ro-ro and lo-lo services has gradually given way to one where ro-ro demand is roughly 33% higher than lo-lo demand. It is likely that such changes are attributable to trends towards higher-value commodities (putting a premium on the speed and reliability of ro-ro shipping) and changes in the logistical backdrop for all commodity movements, in particular the growth of "just-in-time" delivery, again necessitating a swift, reliable service which lo-lo has problems in delivering. "Clawback" to Dublin of ro-ro traffic previously diverting via Larne is also likely to be a factor.

Modal split is a crucial issue in the analysis of freight transport. While overall freight demand is predominantly determined by macroeconomic factors, there are many opinions as to what the determinants of freight modal split are.

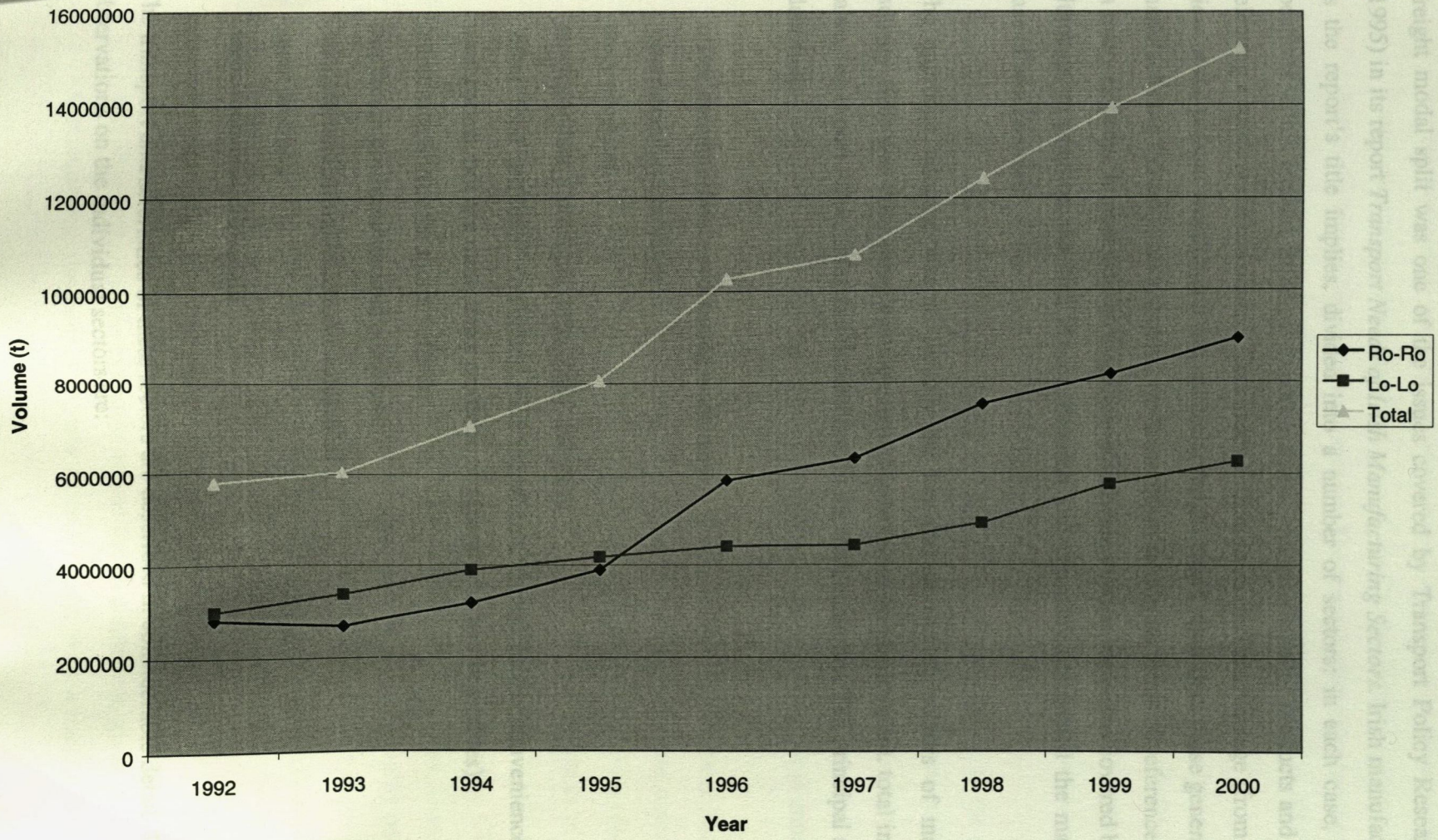


Figure 3.7 Unitised Freight Traffic Through Republic of Ireland Ports

Freight modal split was one of the issues covered by Transport Policy Research Institute (1995) in its report *Transport Needs of Irish Manufacturing Sectors.* Irish manufacturers were, as the report's title implies, divided into a number of sectors; in each case, the sector's locations within Ireland, principal export markets, characteristics of products and priorities in selecting a mode were considered. This study suffers from the disadvantage (from the point of view of the present work) that it did not cover freight flows other than those generated by Irish manufacturing industry; nevertheless, for those flows within its terms of reference, it is of use in many respects. It must also be noted that worldwide exports were also covered by the study, although, in practice, the UK, France, Benelux and Germany dominated the markets in the case of most sectors.

The approach adopted was to identify the key transport-using sectors of manufacturing industry. This was done using a composite indicator based on employment, total import/export value, net export value, sales and expenditure in the Irish economy. Ten principal sectors were identified:

- office computers/data processing machinery
- pharmaceutical products
- dairy products
- service industry products (principally software)
- 'other food products' (including food ingredients, tinned foods, convenience foods and mushrooms, but not meat, dairy products, or general fruit and vegetables)
- parts/accessories for motor vehicles
- healthcare products/medical equipment
- telecommunications/electronic equipment
- meat products
- basic industrial chemicals.

The transport characteristics of these sectors are described in considerable detail. The principal observations on the individual sectors are:

- that 'the key transport issue' for most *computer products* is speed. Quality of service, particularly security and avoidance of damage, is more important than cost. Large shipments travel mainly ro-ro and smaller by express groupage (e.g. TNT, UPS), the latter often using air transport. The main destinations are the UK, France, the Netherlands and Germany; products are often distributed to EU markets via depots in these countries.
- that *pharmaceutical* exports are widely dispersed throughout the world, the EU accounting for only 53.7%; within the EU, the UK/Benelux/French/German markets dominate. Bulk products are shipped lo-lo, in tank containers if in liquid form, while high value, low volume products travel by ro-ro or air express groupage service. Timeliness and speed are the key issues.
- that the characteristics of *dairy product* exports vary according to the perishability of the product in question. Most exports consist of butter, cheese, milk solids etc., which have a long shelf life. These generally travel by lo-lo, sometimes refrigerated. Some perishable products such as yoghurt and fresh cheeses are exported by refrigerated ro-ro, but only on a limited scale. In general, cost is more important than speed.
- that *software* exports are not easily broken down by destination. Fragility is an important factor, but this is complicated by the bulky, low-value manuals shipped with the products. Price is less important than quality of service. There is some limited use of telecommunications for distributing one-off products to users; most exports appear to be by ro-ro.
- that *'other food products'* are not , in general, particularly perishable. Cost therefore dominates over speed, although timeliness is also very important. Most products in this sector travel lo-lo. *Mushrooms* are a special case; they are highly perishable and their export market is effectively confined to the UK. Shipment to Britain was originally by air, but improved surface transport now makes it possible for the products to travel by ro-ro.
- that the *motor parts* industry relies heavily on just-in-time (JIT) logistics, requiring frequent door-to-door deliveries. Although ro-ro would be ideal in terms of speed and reliability, it is too expensive to use for all shipments, given their low density. Consequently, the bulk of exports move by lo-lo, with a backup flow by ro-ro to

maintain frequent, reliable delivery. The influence of freight forwarders appears significant in this sector. The need for frequent shipments is the dominant factor, but timeliness is also of importance.

- that the range of products described as *'healthcare products and medical equipment'* is very wide and thus transport requirements also vary. High volume consignments travel by lo-lo and high value/low volume ones by air. Speed requirements vary, but generally deliveries to end-users are more critical (because holdings of stock are smaller and thus orders tend only to be made when stocks run low) than those to retail/wholesale customers.
- that *telecommunications/electronic equipment and components* require timely delivery and freedom from damage rather than low-cost transport. Their main EU export destinations are the UK, Germany and France; movement is principally by ro-ro (in air suspended trailers) with some air freight for high value/urgent shipments.
- that transport in the fresh meat end of the *meat products* sector is dominated by the effects of perishability, making speed "absolutely critical". Frozen meat products are less speed-critical. Refrigerated ro-ro transport is generally used.
- that cost matters far more than speed to exporters of *basic industrial chemicals*; thus lo-lo (including tank containers for gaseous or liquid products) is generally the mode of choice. Cost can be particularly important for high volume goods such as fertilisers. Where goods are hazardous, this adds to transport costs.

The results of the investigation of particular sectors are summarised by Table 3.1.

Table 3.1: Transport Characteristics of Major Export Sectors (After TPRI (1995), Table 4.1)

Sector	Transport Usage				Importance of transport attributes				
	Ro-Ro	Lo-Lo	Air	Dir/Grp[1]	Cost	Speed	Timing	Vehicle	VAD[2]
Office computers etc.	High	Low	High	D+G	Low	High	High	High	High
Pharma-ceutical	Medium	High	Medium	G	Low	Medium	Medium	High	Low
Dairy	Medium	High	Low	D	High	Low	Low	High	Low
Service industry (software)	High	Low	Low	D	Low	Low	Low	High	High
Other food	Medium	High	Low	D	High	Low	High	Medium	Low
Auto parts	Low	High	Low	D	High	Medium	High	Medium	Medium
Healthcare/ medical	High	Medium	Low	G	Low	Medium	High	Low	Low
Telecom/ electrical	High	Low	Medium	D	Low	Low	High	High	Low
Meat products	High	Low	Low	D	High	High	High	High	Possibly
Basic industrial chemicals	Low	High	Low	D	High	Low	Low	Low	Low

[1] Direct shipment as a single consignment or groupage, i.e. combination of consignments in a single vehicle.
[2] Value Added Distribution, i.e. the carrying out of various packaging, customisation etc. tasks as part of the distribution process.

General observations include:

- that the above sectors are judged to be representative of most exports.
- that transport requirements are significant influences on cost, quality (through damage, perishing, obsolescence etc.) and delivery standards (delays, inventory costs) of goods; the exporter must find the optimum position for the commodity in question on the cost/quality/delivery "triangle".
- that the three principal cost components of a supply chain are transport cost, inventory cost and information cost; inventory cost is clearly related to transport cost (through, for instance, the greater need to hold stocks where the transport element in the chain is less reliable); information cost is also seen by TPRI as related to the other two elements.
- that transport activity is only one part of a chain of activities (referred to as a *supply chain* for materials/components inbound to the manufacturer and a *value adding chain* for final products outbound to consumers) including purchasing, warehousing and distribution activity; increasingly, the elements of the chain are becoming more closely integrated (e.g. "value-added distribution", where distributors take over responsibility for packaging and perhaps some customisation of products).

The study also defined the influences on the cost-quality-delivery characteristics of various stages of a journey; Table 3.2 summarises TPRI's findings in this respect.

Table 3.2: Factors Affecting Cost-Quality-Delivery Performance
(derived from TPRI 1995, 2.11)

Stage	Description	Influences on transport cost-quality-delivery performance
1	Domestic transport by road/rail from local suppliers and between factory location and ports/airports	• Distances • Quality of national network (congestion, average traffic speeds etc.) • Efficiency of available transport services
2	Export port/airport handling activities	• Vehicle queuing and waiting requirements (incl. imposed effect of ship/aircraft service frequency) • Documentation processing • Physical handling
3	Transport from Irish port/airport to destination port/airport (possibly involving landbridge activity or intermediate port/airport transhipments).	• Distances • Vessel/aircraft technologies (scale effects etc.) • Vessel/aircraft speeds (incl. en route delays, port/airport arrival delays) • Transhipment costs • Overland costs
4	Import port/airport handling activities	• Physical handling • Documentation processing times • Vehicle queuing and waiting requirements (incl. imposed effect of ship/aircraft service frequency)
5	Overland transport by road/rail from port/airport to market	• Distances • Quality of international network (congestion/delays, average driving times etc.) • Traffic balance (backhaul availability etc.)

The specific issues relating to the determinants of the quality of access (sea/air) services were also considered; this is of interest in the context of modal split (and the choice between routes within a single mode, which here probably more closely resembles mode choice than conventional assignment). Table 3.3 presents a summary of the characteristics affecting access transport quality and the factors which, in turn, shape them.

Table 3.3: Determinants of Access Transport Quality
(derived from TPRI 1995, 4.3)

Characteristic	Influencing factors
Access route availability	• Location of ports/airports • Configuration of services
Price of sea/air crossings	• Capital cost of vehicles • Utilisation • Route length • Operating costs • Other operational considerations
Speed of transport service	• Vehicle technology • Loading/unloading efficiencies • Terminal throughput times
Service frequency	• Vehicle size • Traffic volume
Access transport reliability	• Technical efficiency • Operational precision • Weather effects • Air traffic control delays • Vulnerability to service interruptions (e.g. strikes) • Market structure effects (e.g. exit from market, monopoly)

KPMG and CHL (1990) investigated influences on modal split in several sectors of the access freight market. Amongst their observations were:

- that the choice between ro-ro and lo-lo surface modes is generally made by the exporter (KPMG and CHL 1990, 7.1)
- that ro-ro predominates on shorter sea routes and lo-lo on longer (because lo-lo's longer handling times are less significant, the longer the route). (KPMG and CHL 1990, 7.1)
- that accompanied ro-ro is chosen mainly for high value or perishable goods, owing to its high security, good time-keeping and shorter port transit times compared with unaccompanied services, but that these advantages were set to decline somewhat with the removal of customs barriers and the stricter enforcement of tachograph regulations.
- that the factors determining choice between direct and "landbridge" (via Britain) ro-ro shipment to Continental Europe are destination (direct route preferred for French, Spanish and Italian destinations), service level (low capacity on direct

routes, and inability to economically expand it due to peaking patterns), cost (landbridge nearly 25% more expensive for French destinations) and time (significantly less, to Belgium and points east, by landbridge) (KPMG and CHL 1990, 7.3).

- that the principal reasons for Larne taking a significant proportion of traffic from Dublin in the 1980s were lower rates, higher shipping capacity, higher frequency, shorter crossing time, better port access and the absence of customs checks at the Northern Corridor (Larne/GB) ports (KPMG and CHL 1990, 7.5).

The report also proposed a structure of mode choice for unitised freight traffic, shown in Figure 3.8 below:

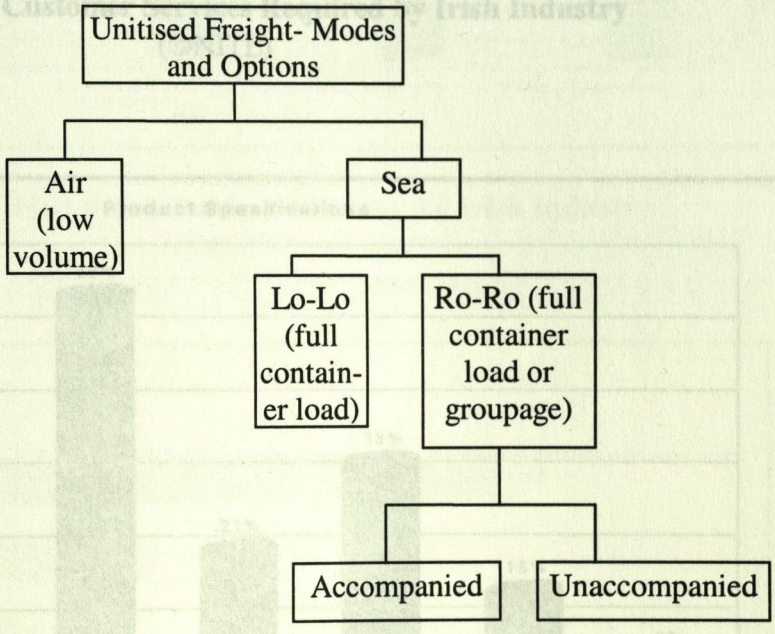


Figure 3.8: Unitised Freight: Modes And Options
(after KPMG and CHL (1990), Figure 4.1)

The National Institute for Transport and Logistics (NITL) (1999) carried out a survey of Irish firms' logistical requirements, based on a sample of 104 companies in business sectors comparable to those identified in the previous TPRI study described above. Figure 3.9 shows the range of customer services (types of delivery) typically required by firms. Figure 3.10 indicates the commonest service requirements by product characteristic and Figure 3.11 the most popular added value services (i.e. those over and above transport itself). Figure 3.12 shows how different attributes are valued in the selection of a carrier, a vitally important aspect of modal split modelling. Finally, Figure 3.13 summarises the principal destinations of exports.

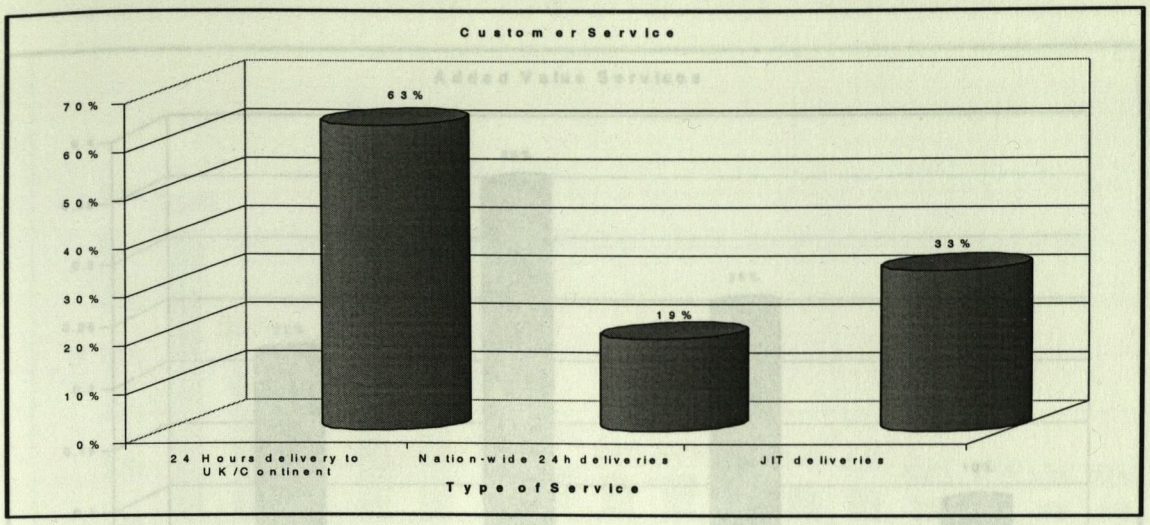


Figure 3.9 Customer Services Required by Irish Industry
(©NITL)

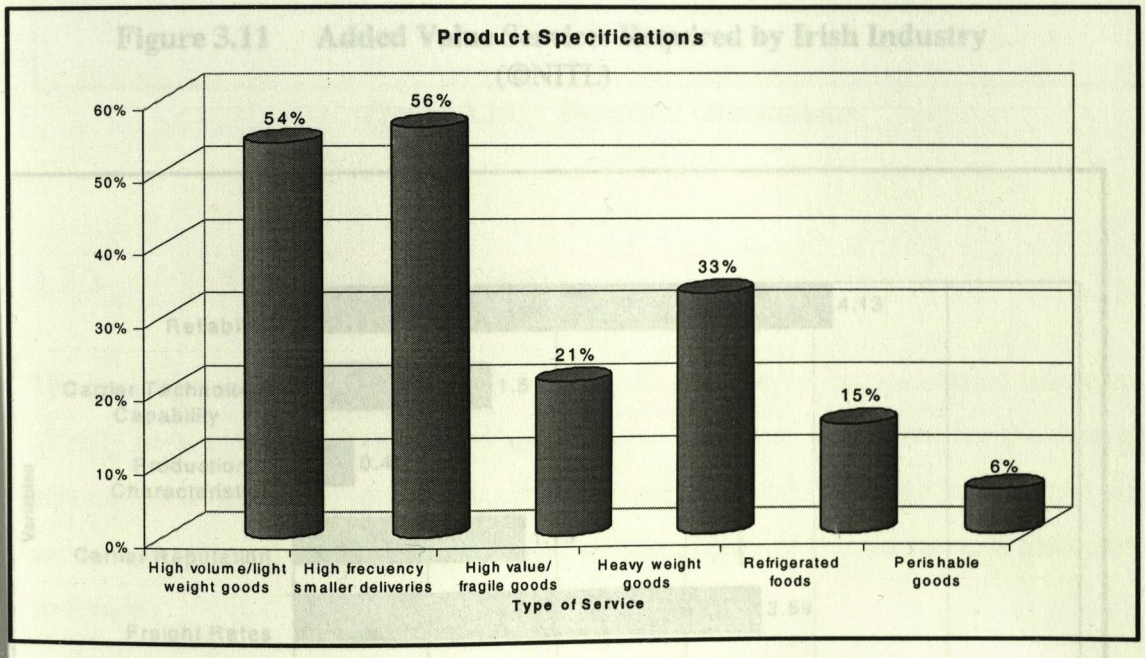


Figure 3.10 Service Types by Product Characteristic
(©NITL)

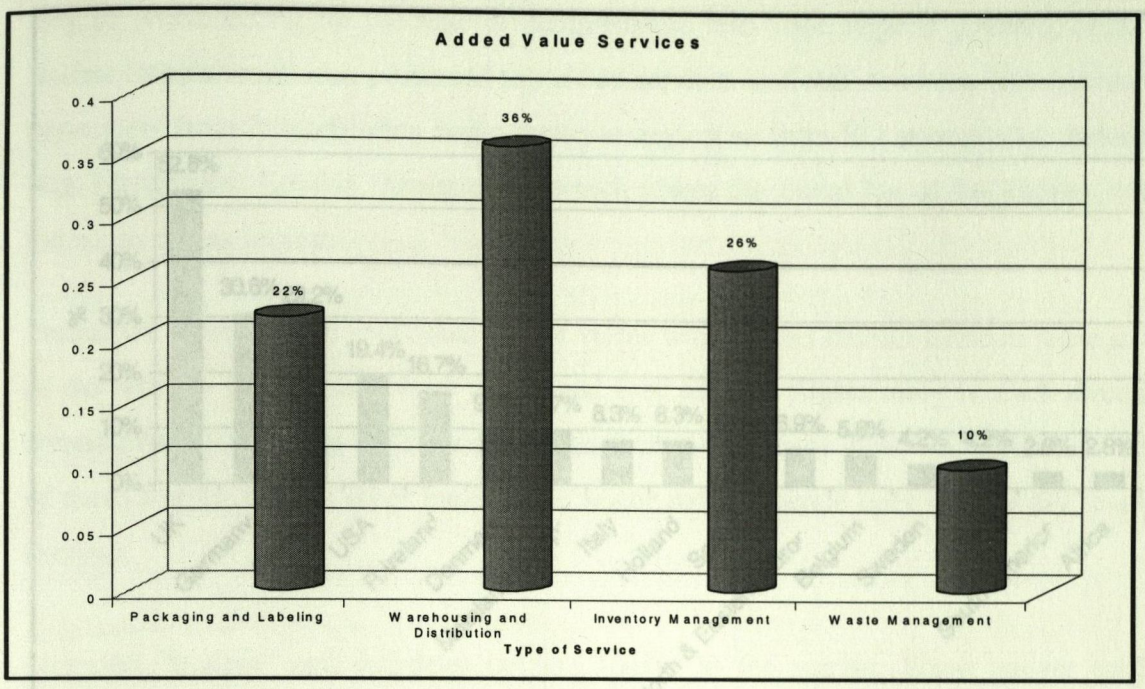


Figure 3.11 Added Value Services Required by Irish Industry
(©NITL)

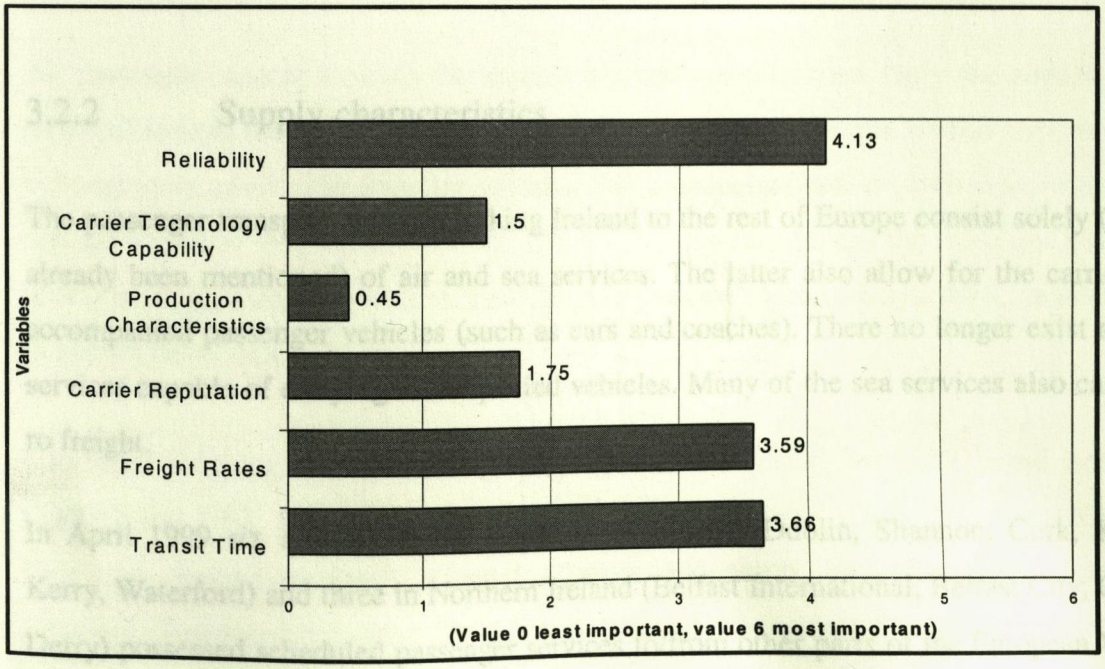


Figure 3.12 Valuation of Attributes
(©NITL)

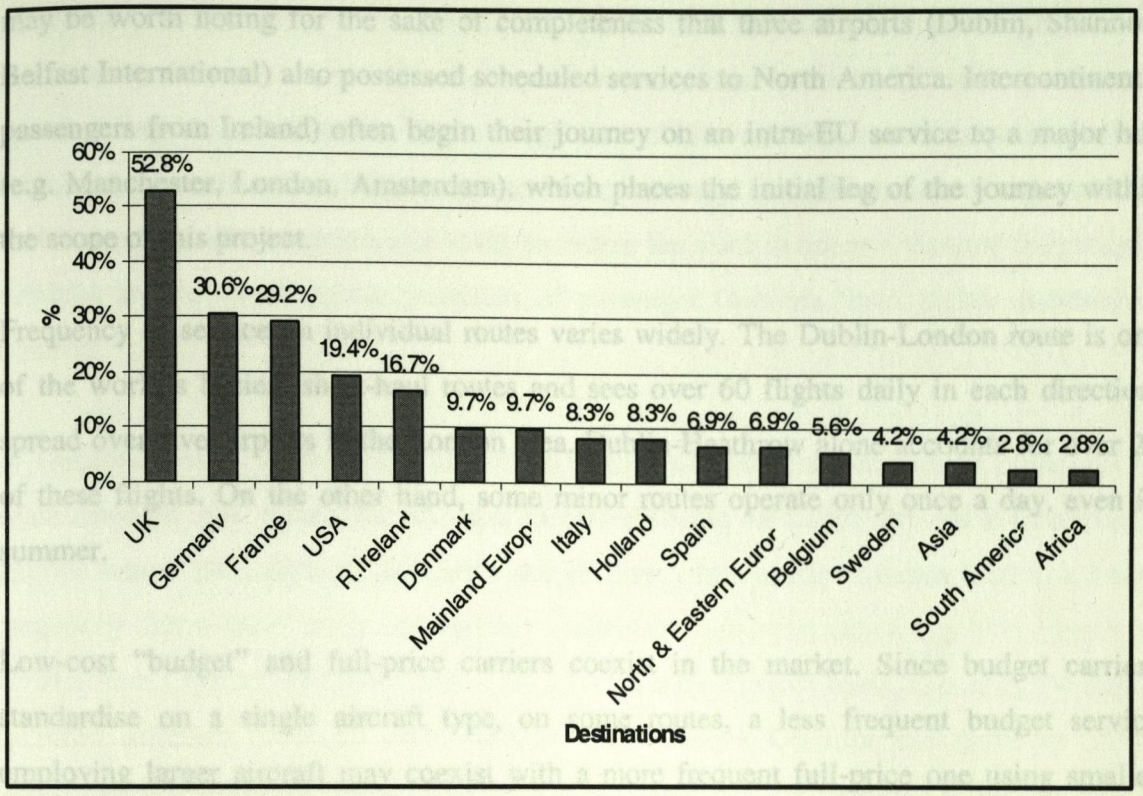


Figure 3.13 Principal Destinations
(©NITL)

3.2.2 Supply characteristics

The passenger transport services linking Ireland to the rest of Europe consist solely (as has already been mentioned) of air and sea services. The latter also allow for the carriage of accompanied passenger vehicles (such as cars and coaches). There no longer exist any air services capable of carrying accompanied vehicles. Many of the sea services also carry ro-ro freight.

In April 1999 six airports in the Republic of Ireland (Dublin, Shannon, Cork, Knock, Kerry, Waterford) and three in Northern Ireland (Belfast International, Belfast City, City of Derry) possessed scheduled passenger services to/from other parts of the European Union. The pattern was not materially different in autumn 2001. Britain was the dominant destination for these services (indeed, the only country served from five of the nine airports), but the northwest of continental Europe (France, Benelux, Germany) was also well served (though predominantly from Dublin). Other European destinations, e.g. the Iberian peninsula, Scandinavia, Switzerland, Austria, Italy, were served to a limited extent,

almost exclusively from Dublin. Other destinations are generally reached by means of connecting services to major hubs outside Ireland. Although outside the study's scope, it may be worth noting for the sake of completeness that three airports (Dublin, Shannon, Belfast International) also possessed scheduled services to North America. Intercontinental passengers from Ireland) often begin their journey on an intra-EU service to a major hub (e.g. Manchester, London, Amsterdam), which places the initial leg of the journey within the scope of this project.

Frequency of service on individual routes varies widely. The Dublin-London route is one of the world's busiest short-haul routes and sees over 60 flights daily in each direction, spread over five airports in the London area. Dublin-Heathrow alone accounts for over 20 of these flights. On the other hand, some minor routes operate only once a day, even in summer.

Low-cost "budget" and full-price carriers coexist in the market. Since budget carriers standardise on a single aircraft type, on some routes, a less frequent budget service employing larger aircraft may coexist with a more frequent full-price one using smaller types. Budget carriers also tend to use lower-cost airports where possible.

Air passengers appear to reach the airports predominantly by road. Only one airport on the island of Ireland (Belfast City) currently possesses a rail link; several British airports do so, although only a few offer intercity services. The principal airports on both sides of the Irish Sea are linked to long-distance coach services, but the car remains the dominant means of access in most cases. The internal systems giving access to ports and airports are dealt with in greater detail below.

Passenger shipping services are (like freight) concentrated into four broad corridors (KPMG and CHL 1990, Transport Policy Research Institute 1995). These are Northern (Northern Ireland-Scotland), Central (Dublin Bay-North Wales/North of England), Southern (Rosslare/Cork-West Wales) and direct to Continental Europe (Rosslare/Cork-France). All conventional ferry services are ro-ro passenger/car operations and are shared with ro-ro freight.

A recent phenomenon has been the emergence of high-speed ferry services (over the past eight years or so) paralleling the conventional multi-purpose services. All the Ireland-

Britain routes possess high-speed services at the time of writing, with the exceptions of Rosslare-Pembroke and Cork-Swansea. In virtually all cases, the high-speed service (carrying predominantly passenger traffic) parallels a slower passenger/freight service operated by the same carrier. The high-speed vessels cruise at about 75 km/h, commercial speeds being around 60 km/h. The average size of conventional vessels appears to have increased somewhat over the past decade or so; this trend towards so-called "superferries" would seem to offer economies of scale, to reduce the need to operate separate freight-only services and to allow greater provision of passenger facilities for a higher standard of comfort.

A frequency of at least once daily- much higher on some of the shorter crossings- is maintained on most routes, the principal exceptions being the direct services to Continental Europe where the length of the routes and relatively low traffic volumes lead to a lower frequency. Some short sea routes may have relatively high frequencies, e.g. 6/day/direction on Northern Corridor fast ferry routes. On a corridor-by-corridor basis, summing the routes between different ports on each corridor, the Northern Corridor has (summer 1999) approximately 30 passenger-carrying sailings/day/direction, the Central 15, the Southern 9 and the direct to Continent corridor 1 to 2.

Domestic air services in Ireland may be of some minor importance in feeding traffic to Dublin from regional airports, though their frequencies are generally low. It is unlikely that many passengers to and from Ireland use connecting air services within Britain, except possibly in the case of remote destinations such as the North of Scotland. There is presumably some use of domestic air services within France and Germany by passengers to or from Ireland, but it is not likely to be very significant. The infrastructure giving access to airports (and ports) consists of a variety of road types, with primary or motorway routes connecting to virtually all the more important nodes in both categories, and a rail network. The latter is subject to considerable variations in technical standards from country to country, particularly clearances, electrification and even track gauge (Ireland 1,600mm, Britain and most of western Europe 1,435mm).

Freight traffic between Ireland and the rest of Europe consists of both unitised (i.e. conveyed in standard units such as containers or trailers) and non-unitised components, the latter principally made up of bulk commodities such as oil products, coal and timber.

The vast majority of unitised freight travels by sea; however, air freight is of significance to several high-value industrial sectors. Air services are, of course, unable to convey the commonest freight-carrying units (ISO containers and ro-ro trailers), which limits their usefulness in many cases.

Sea freight services divide into ro-ro, lo-lo and bulk. Within ro-ro in turn are conventional and high-speed services, as discussed in the case of passenger traffic; however, high-speed ferries are of much less significance in the freight than the passenger market, because the smaller vessels are unable to accommodate trucks and even the larger craft utilised on major routes have only a limited capacity for freight, necessitating the retention of parallel conventional ferry services to cater for the greater part of the freight market.

Conventional ro-ro services subdivide again into those which share ship space with passenger traffic (including accompanied cars and coaches) and those using dedicated vessels. As described previously, the former have grown at the expense of the latter due to the favourable economics of combining passenger and freight traffic on large "superferries". Nevertheless, a significant number of freight-only services remain. In turn, ro-ro freight may be accompanied or unaccompanied; in the former case, the tractor unit and driver travel with the trailer, while in the latter the trailer is loaded without a tractor unit and collected by another driver and tractor unit at the destination port.

The division of the ro-ro (and lo-lo) freight routes into corridors is identical to that of the passenger services, although the actual routes operated may in some instances be different. Frequencies of service again vary; lo-lo services, being generally used for less time-sensitive commodities, are rarely operated more than once per day per direction. Bulk services do not normally operate on a scheduled basis. On Continental European routes, service levels are more typically measured in trips per week rather than per day. Performing a similar exercise to that carried out above for passenger shipping, there are 39-40 ro-ro trips/day/direction on the Northern Corridor, 16-17 on the Central, 4-5 on the Southern and 1- 2 on the direct Continental corridor.

Air freight services are far more limited in capacity than surface shipping, but their destinations cover a greater geographical area. Much air freight is carried as "belly-hold" cargo under the floors of passenger-carrying aircraft on scheduled routes. Of that carried by dedicated freighter aircraft, the majority appears to be transported by "integrators"-

carriers who provide a complete door-to-door logistics service, including road haulage, warehousing, consignment tracking etc. in addition to the flight.

3.2.3 Summary of past studies

In 1990, the European Community and the Irish Government commissioned, in the context of Ireland's access transport problems and the Operational Programme on Peripherality 1989-1994, a study of freight transport needs in the Irish (Republic of Ireland) access market up to the year 2001. This study was carried out by the consultants KPMG and CHL (1990). It initially reviewed the situation with regard to the various elements of the transport system as they existed at that time. Factors affecting choice of sea mode (i.e. lo-lo/accompanied ro-ro/unaccompanied ro-ro) and route were considered along with freight/tourist interactions. Future developments (the Channel Tunnel, growth of Just-In-Time (JIT) logistics, evolution of truck technology) were considered with regard to their impact on the market. Demand predictions were derived principally from econometric models. "Gap analysis" was carried out, identifying the deficiencies in capacity arising from the difference between the projected demand and the do-minimum transport supply.

Principal recommendations were as follows:

- Additional ro-ro capacity on the Central, Southern and Continental European Corridors.
- Additional lo-lo capacity on direct Continental European services.
- New dedicated air freight services to a range of European destinations.
- Improved port infrastructure for both lo-lo and ro-ro services, particularly at Dublin.
- Road and rail infrastructure improvements on both sides of the Irish Sea.

The study was updated two years later by a second report (KPMG and CHL 1992). Demand predictions were re-evaluated in the light of lower than anticipated growth in the British economy. Account was also taken of additional ferry services in the capacity calculations. The capacity gaps were reduced somewhat, but shortfalls remained. Improvements at Holyhead port to increase capacity on the Central Corridor, and both ro-

ro and lo-lo capacity increases on the direct Continental European services, were recommended. Revised demand predictions were extended up to 2006.

The Northern Ireland Economic Council (NIEC 1993) carried out a study which was an overall review of transport in Northern Ireland, not being specific to the access market. It examined trends over recent years and the probable course of events in the immediate future, making recommendations in relation to policy formulation and individual modes. Amongst those of greatest relevance to the matter in hand were:

- that road improvements on a corridor-wide basis, incorporating links within both Northern Ireland and Britain (e.g. Belfast-Carlisle) should be considered.
- that competition between the ports of Belfast and Larne, and between the two Belfast airports, should be preserved by maintaining independence of ownership.
- that port and port access facilities in Britain needed upgrading in order to reduce the impact of peripherality on Northern Ireland.
- that the upgrading of air and sea services should be incorporated into any operational programmes alongside, or in place of, the upgrading of their fixed infrastructure.

(NIEC 1993, chapter 9)

3.2.4 Major issues

Transport, in the general sense, is now one of the most important political issues in both the Republic of Ireland and the UK. Irish access transport represents one aspect of this issue; in turn, the access transport problem is made up of several individual issues. Some impression of what is involved may be gained from the contents of previous studies in the market (see above) and from the near-continuous political and public debate on transport. A more detailed exercise in the determination of objectives for the future development of the access transport system was carried out in the course of this project, and is described in Chapter 7.

The principal issues relating to the access transport system would, on an initial examination, appear to be:

- Ensuring that Ireland as a whole is provided with the transport system that best enables it to compete internationally.
- Facilitating the economic development of peripheral regions within Ireland, particularly the Border, Midlands and West.
- Protecting the natural and human environments from excessive pollution, land take, road accidents and other impacts.
- Alleviating congestion within the system, e.g. traffic congestion caused by port-related HGV movements, landside congestion at airports.
- Minimising both overall expenditure and exposure to financial risks for investors (public or private) in the system.

It is reasonable to assume that any future modifications to the system would address these concerns as far as possible in their design and implementation, preferably offering distinct advantages over the do-minimum option in as many respects as possible. It is not intended to present these factors as a detailed framework for appraisal; that, as referred to above, will be done at a later stage of the project. However, they are of use in this task by virtue of making the connection between the present status of the system and its future possibilities.

3.3 POLICY DOCUMENTS

3.3.1 Republic of Ireland- National Spatial Strategy

In the 2000-2006 National Development Plan (Government of Ireland 1999), the Irish Government committed itself to developing a National Spatial Strategy (NSS) which will "identify broad spatial development patterns for areas and set down indicative [locational] policies...[and] develop...a dynamic conception of the Irish urban system, together with its links to rural areas...". It is to "provide the basis for long-term co-ordination and co-operation in policy formulation and decision-making on major investment in infrastructure, including public and private transport infrastructure" (Government of Ireland 1999, 3.26). The time horizon will be 20 years (Government of Ireland 1999, 3.29).

The NSS is currently expected to be finalised before the end of 2002. By autumn 2001, a consultation paper entitled "Indications for the Way Ahead" had been released. This put forward the following policies with respect to access transport:

- Sea access should be improved "through strategies to reduce the pressure and congestion arising on the central sea crossings...and aligning internal transportation corridors with those strategies."
- Dublin Airport should "[develop] higher levels of service through its role as an international and national hub...supporting this through good land side accessibility by public and private transport".
- Other international airports should "achieve a higher level of service by increasing their population catchments through improved land side access".
- There should be further development of the Dublin-Belfast economic corridor.

(Department of the Environment and Local Government 2001)

3.3.2 Republic of Ireland- National Development Plan

At the time of finalising this text, the general policy framework for access transport in the Republic of Ireland was contained in the 1999-2006 National Development Plan (Government of Ireland 1999). This document sets out the objectives for national policy, with particular reference to the spending of EU Structural and other public funding, over its period of reference. While transport is a central component of the Plan, access transport *per se* is apparently considered somewhat less important than in the case of the previous (1994-1999) Plan. Port and airport investment plans are included, but the sums involved are comparatively moderate and the focus is very much on regional facilities, the primary system of State airports and commercial ports being funded commercially.

The spending programme for intercity road transport is far more significant, and involves the upgrading of the radial routes from Dublin to Dundalk, Galway, Limerick, Cork and Waterford to dual-carriageway or motorway standard throughout their length. Other radial routes and the Rosslare-Sligo circumferential route (important for access to Shannon Airport and the ports of Waterford and Rosslare) would be upgraded to lower standards. The mainline rail spending programme concentrates mainly on improving safety standards and completion of the backlog of improvements from the previous Plan. Several measures

specifically dealing with port and airport access are incorporated in the Plan. The Dublin Port Tunnel, delayed from the 1994-1999 Plan, is amongst them.

The 1994-1999 NDP is not considered in detail here. Appendix D.2 lists policy objectives utilised in the preparation of the Plan.

3.3.3 Northern Ireland- Regional Strategic Framework

Northern Ireland's strategic spatial planning process is known as "Shaping Our Future". This had reached the stage of the formulation of a draft strategy (Department of the Environment for Northern Ireland [DoENI] 1998a) at the time of its examination by the author, and a final strategy has since been adopted. The horizon year is 2025; this long-term outlook and the explicit spatial development provisions of the strategy set it fundamentally apart from the Republic's National Development Plans (but not the National Spatial Strategy).

Central to the strategy are the Strategic Planning Guidelines (SPGs); those relating to access transport are:

SPG1:	To strengthen and extend European and world-wide linkages.
SPG2:	To increase links with neighbouring Regions and capitalise on trans regional development opportunities.
SPG12:	To develop a Regional Strategic Transport Network based on key transport corridors.
SPG16:	To exploit the economic development potential of the key transport corridors.
SPG17:	To promote the regional gateways as economic development opportunities.
SPG19:	To undertake or, where appropriate, facilitate a programme of infrastructure improvements essential to business needs.

In relation to the actual policies proposed to implement the guidelines, the key points of interest include:

- improved air and sea links, particularly to the European mainland;

- upgrading of combined road/sea transport corridors such as Northern Ireland-Britain-Benelux and Northern Ireland-Republic of Ireland-France;
- road and rail improvements in key internal corridors;
- directing major inward investment projects, transport-intensive activities (e.g. distribution) and clusters of high-technology industry to locations close to the strategic corridors;
- developing appropriate economic activities around ports and airports;
- development of a long-term investment strategy for infrastructure to support the region's economy.

The strategy, however, contains comparatively few specific proposals of relevance to access transport.

3.3.4 Northern Ireland- transport policy

At present, Northern Irish transport policy exists mainly in the form of a statement of principles, which makes a commitment to the development of a comprehensive transport plan in the longer term. A ten-year transport plan is now under development and expected to be adopted in mid-2002.

The statement of transport policy (DoENI 1998b) was published some time ago in the wake of the UK Integrated Transport White Paper (see 3.3.7 below). The document states that "efficient and reliable movement of freight is vitally important for the competitiveness of the Northern Ireland economy" and "[m]odern, efficient air and sea ports are vital to Northern Ireland's efforts to reduce its peripherality". It commits government to "work[ing] in partnership with industry to promote sustainable distribution", and to improved access to ports and airports and promotion of efficiency in port and airport management.

3.3.5 UK transport policy

The basis of current transport policy throughout the UK is the "Integrated Transport White Paper" of 1998 (DETR 1998c). As its name implies, this document focuses to a large

extent on the objective of integration in transport policy, which is seen as having several dimensions:

- Integration within and between different types of transport;
- Integration with the environment;
- Integration with land use planning;
- Integration with policies for education, health and wealth creation.

(DETR 1998c, chapter 1).

The document lists a range of measures which make up the "New Deal for transport". Those of greatest relevance in the present context include:

- Better interchanges;
- Tackling the "pinch-points" in transport networks that lead to congestion;
- New airports policy and stronger role for regional airports;
- A new Strategic Rail Authority to promote rail freight and its infrastructure;
- Less damage to roads and the environment through greater use of 6 axle lorries and keeping unsuitable lorries off unsuitable roads;
- Facilitating shipping as an efficient and environmentally friendly [mode];
- Extending freight grants to include coastal and short sea shipping;
- Many decisions on transport issues to be devolved to the Scottish Parliament, the Welsh Assembly and the Assembly for Northern Ireland.

The White Paper was followed by "daughter documents" dealing with specific issues of concern. The two of most interest in the context of this study related to distribution and shipping; however, neither contained proposals of any especial relevance in the Irish access context.

3.3.6 Relevant EU policy

The most recent EU White Paper on Transport Policy (Commission of the European Communities 2001) was released in 2001. It proposes a number of measures which may affect Irish access transport:

- *Revitalising the railways*: Liberalisation of rail freight markets and creation of a dedicated rail network for freight traffic.
- *Improving quality in the road transport sector*: Legal reform and some improvements in safety and employee protection regulations.
- *Promoting transport by sea and inland waterway*: "Sea motorways" involving "better connections between ports and the rail and inland waterway networks together with improvements in the quality of port services" along with safety improvements and technical harmonisation.
- *Striking a balance between growth in air transport and the environment*: Airport improvements and traffic control harmonisation coupled with anti-noise and pollution regulations.
- *Turning intermodality into reality*: improving interoperability and technical harmonisation between different freight modes.
- *Building the trans-European transport network*: with particular emphasis on rail (although a review focusing on sea and air traffic and the needs of peripheral regions is promised).
- *Adopting a policy on effective charging for transport*: encouraging internalisation of external costs and harmonisation of fuel taxation.

The previous policies on the trans-European network (Commission of the European Communities 1995) also affect the development of the Irish access system. Policies in this respect are aimed at promoting integration between countries and modes.

The European Spatial Development Perspective (Commission of the European Communities 1999, para.124) proposes the following policies of relevance to interregional transport:

- Better co-ordination of spatial development policy and land use planning with transport and telecommunications planning.
- Reduction of negative effects in areas subject to high traffic pressure by strengthening environmentally compatible means of transport, levying road tolls and internalising external costs.
- Promoting the interconnection of inter-modal junctions for freight transport, in particular for transport on the European corridors, especially regarding shipping and inland navigation.

- Co-ordinated and integrated infrastructure planning and management for avoiding inefficient investments... and securing the most efficient use of existing transport infrastructure.

3.4 DEMAND MODELLING

3.4.1 Overview

It has been clear from the earliest stages of the study that, in order to facilitate a meaningful appraisal of different future transport strategies, it would be necessary to predict future demand for transport, both passenger and freight. The principal issue emerging from the initial examination of the subject was exactly how demand was best predicted. Different types of demand model and various non-modelling alternatives were all candidate solutions in this field. Passenger and freight traffic were examined separately.

3.4.2 Passenger modelling- general considerations

In the context of an interregional study, there are several important factors which affect any discussion of possible approaches to passenger modelling.

- Most passenger modelling is of short-distance trips for urban/regional studies. This study is interregional in nature, and the different journey lengths and purposes involved are likely to require a rather different approach to modelling.
- There may be issues, particularly behavioural ones, specific to the Irish access market or to long-distance travel in general. For example, changes in transport costs may have a more significant effect on the overall volume of travel than in urban areas.
- Data for calibration and validation of models are extremely scarce in the present context.

These must be fully taken into account in the review of alternative approaches to passenger demand modelling described in this chapter, not to mention the subsequent implementation of a model.

3.4.3 Passenger modelling- four-stage

The archetypal passenger transport demand model consists of four stages (trip generation, trip distribution, modal split and assignment) through which the model progresses sequentially. Although this approach is by no means the only possible one, it is the only one examined in this sub-section. In practice, the literature on interregional modelling provides only information on a number of approaches to individual stages, rather than descriptions of complete models.

Passenger trip generation is covered relatively well in the literature, often in conjunction with the modal split models described below, although significant work has also been carried out on trip generation in single-mode studies.

Beimborn (1969) utilised "a relatively simple procedure...using census data" to generate trips between Washington DC and Philadelphia. Each city was divided into a number of zones, for each of which the total population and proportion of households in three broad income groups were calculated. Trip generation (and distribution) was by means of the equation:

$$TRIPS_{ijk} = \frac{ENDS_{ik}\, ENDS_{jk}}{\sum_j ENDS_{jk}}\, INTEN_k$$

where $ENDS_{jk}$ is number of persons of income group k in zone j and $INTEN_k$ is relative propensity of income group k to travel (based upon nationwide census data).

This equation indicates relative demand, i.e. the distribution of trips among origin and destination zones, rather than actual demand. It is to be noted that the outputs from the model were entirely represented in percentage terms, i.e. as the distribution of trips, within different income groups and overall, amongst modes and (where appropriate) choices of route within a mode. Actual trip numbers were not derived.

Beimborn also analysed mode choice. Access time and cost were considered important to mode choice; a separate model was developed to examine these. The actual modal split model was based on the relative "impedance" of different modes; through subsequent refinements, this "impedance minimisation model" evolved into the utility-based model

outlined below. Sensitivity of results to alternative terminal strategies, such as city-centre check-in points for air or additional stations for rail, was also tested. Conclusions indicated that increases in terminal accessibility were more effective in altering modal split than line-haul service improvements.

Also forming part of the major Northeast Corridor project of the late 1960s and early 1970s was the modal split modelling process described by Shuldiner (1970), which is covered in greater detail at 3.4.4 below, being effectively part of a direct demand model structure.

Leake and Underwood (1976) investigated modal split between rail and air for travel between London, the northwest of England and Glasgow. Data was collected via questionnaire-type surveys of passengers. An "entropy maximisation model" (see below) was applied, with perceived cost and journey time (both weighted for different stages of a journey) being the key variables. Other important factors, such as service level, personal preference and terminal accessibility, were represented by the weights and constants of the equations for cost and time. Alternative models were developed to allow for linear and logarithmic views of increments in generalised cost. Modified versions containing a constant term outside the generalised cost function were also developed; these latter proved more accurate, with the logarithmic model performing better than the linear. While the level of information available from surveys was higher than would be possible in the context of this project, the paper demonstrates one possible modal split modelling technique applied to a generally similar situation.

Theologitis and Powell (1984) examined modal split in the recreational transport market between mainland Greece and a number of island groups, the principal choice being between conventional shipping and air transport in one region, and conventional shipping and hydrofoil in another. There are certain similarities with the Irish access situation in this respect, though the dominance of tourism is probably significantly greater on the Greek routes. The authors reviewed a wide range of available modal split models and their characteristics. Trip-interchange models (post-distribution) are seen as easier than trip-end modal split models to transfer between contexts, and (an important point in the context of the present study) more able to represent the effects of major network changes. Model types considered are outlined as follows:

(W_x = proportion of trips using mode x; W_y = proportion of trips using mode y; GC = generalised cost; b, d are regression coeffs., and A the logit model exponent function.)

1. $W_x = b + d\,[(GC)_y - (GC)_x]$

2. $\ln(W_x / W_y) = b + d\,[(GC)_y - (GC)_x]$ (entropy maximisation, linear)

3. $\ln(W_x / W_y) = b + d\,[\ln(GC)_y - \ln(GC)_x]$ (entropy maximisation, log)

4. $\ln W_y = b + d\,[(GC)_y - (GC)_x]^2$ (utility-based)

5. $W_x = b + d\,[(GC)_x / (GC)_y]$ (relative generalised cost, linear)

6. $\ln W_x = b + d\,[(GC)_x / (GC)_y]$ (relative generalised cost, exponential)

7. $W_y = (1+e^A)^{-1}$ (binary logit)

Application of the models indicated that the logit model was the most satisfactory; this was qualified by the fact that the analysis was highly context-specific. The paper also questions whether recreational trip-makers, at least in the area studied, have any meaningful value of time.

There is relatively little evidence of the existence of, or the need for, any specialised assignment techniques for interregional passenger transport modelling. It is worthy of note that greater weight appears to have been given to modal split than assignment in most cases reviewed, due to the relatively simple networks under consideration.

3.4.4 Passenger modelling- direct demand and quasi-direct

Ortúzar and Willumsen (1994, 6.6) quote examples of an alternative form of model which combines trip generation, trip distribution and modal split, known as the direct demand model. This model form has found particular applications in interregional studies, but suffers from certain limitations. Manheim (1979, 4.3.2), for example, notes in relation to direct demand models that they generally assume a single path per mode between each O-D pair; although this is "often not a bad assumption in the case of intercity passenger travel". Nevertheless, it offers the advantage of avoiding the cumulative error effects of traditional sequential models.

The first example of such a model cited is the SARC model, which takes the form:

$$T_{ijk} = \phi_k (P_i P_j)^{\theta}{}_{k1} (I_i I_j)^{\theta}{}_{k2} \Pi_m [(t_{ij}^m)^{\alpha 1}{}_{km} (c_{ij}^m)^{\alpha 2}{}_{km}]$$

where:

P = population

I = income

t = travel time i-j by mode k

c = travel cost i-j by mode k

m = set of all modes

ϕ, θ, α are model parameters.

In a simplified form:
If:

$$L_{ijm} = (t_{ij}^m)^{\alpha 1}{}_{km} (c_{ij}^m)^{\alpha 2}{}_{km}$$
$$Y_{ik} = P_i^{\theta}{}_{k1} I_i^{\theta}{}_{k2}$$
$$Z_{jk} = P_j^{\theta}{}_{k1} I_j^{\theta}{}_{k2}$$

so that the equation becomes:

$$T_{ijk} = \phi_k Y_{ik} Z_{jk} \Pi_m L_{ijm}$$

Another well-known direct demand model (originating in the Northeast Corridor project, see below) is the McLynn model:

$$T_{ijk} = \phi_k (P_i P_j)^{\theta}{}_1 (I_i I_j)^{\theta}{}_2 \frac{(t_{ij}^k)^{\alpha 1}{}_k (C_{ij}^k)^{\alpha 2}{}_k}{\sum_m (t_{ij}^m)^{\alpha 1}{}_m (C_{ij}^m)^{\alpha 2}{}_m} \{\sum_m [(t_{ij}^m)^{\alpha 1}{}_m (C_{ij}^m)^{\alpha 2}{}_m]\}^{\psi}$$

This can be simplified by letting $\psi = 0$, considering only two modes, dropping indices i and j and defining:

$$Y_{ij} = Y = (P_i P_j)^{\theta}{}_1 (I_i I_j)^{\theta}{}_2$$
$$L_k = \phi_k (t^k)^{\alpha 1}{}_k (C^k)^{\alpha 2}{}_k$$

Then $T_1 = YL_1/(L_1+L_2)$ and $T_2 = YL_2/(L_1+L_2)$ and the modal shares are:

$$P_1 = T_1/T = L_1/(L_1+L_2) = 1/(1+L_2/L_1)$$
$$P_2 = 1 - P_1 = 1/(1+(L_1/L_2))$$

The model is somewhat less complex than the SARC model but "may not have a solid theoretical basis" and only performs satisfactorily for ψ between 0 and 1.

Finally, the "abstract mode" model is outlined. This was originated by Quandt and Baumol (1966) and takes the form:

$$T_{ijm} = \phi_0 \Pi_k(A_{ik}A_{jk})\phi_k\Pi_h C^{\alpha h}_{ijh}\Pi_h(C_{ijhm}/C_{ijhb})^{\beta h}$$

where:

ϕ, α, β are model parameters for calibration

h indicates a cost attribute (e.g. travel time, fare)

A_{ik} are attributes of zone i, e.g. population, income.

C_{ijhm} is value of cost attribute h for mode m between i and j

C_{ijhb} is value of "best" h between i and j (e.g. cheapest fare)- alternatively, the mean value over modes may be used.

Yu (1970) describes the use of the abstract mode model in predicting intercity travel within the state of West Virginia, USA. Improvements to the model are suggested in areas such as the use of dummy variables to represent the effect of unquantifiable factors (particularly personal preference). The final models (separate ones for business and personal trips) make use of a wide range of variables, including employment, bank deposits, property values, population and car ownership. Although the range of variables used would be difficult to replicate in the present context, Yu's work confirms the ability of the abstract mode model to predict demand for nonexisting modes, on the basis of their major service characteristics. Yu's demand models were utilised in a feasibility study into the introduction of Short Take-Off and Landing (STOL) air service in West Virginia (Yu 1971) and appear to have performed satisfactorily.

Shuldiner (1970) describes the Northeast Corridor Transportation Project (NECTP) demand model, one of the best-known applications of direct demand modelling. It is gravity-based, travel volume between any two zones being a function of the traffic generation potential of each area and the travel impedance between them (i.e., trip generation and distribution are again combined), and is expressed as:

$$T_{ij} = \beta_1(P_iP_j)^{\beta 2}\,(\textstyle\sum_k \omega_{ijk})^{\beta 3}$$

where T_{ij} is total number of daily intercity passenger trips between zones i and j; P_i and P_j are populations of zones i and j (originally population above a certain income threshold was used rather than total figures); ω_{ijk} is the level of service of mode k between i and j; and $\beta_{1..3}$ are calibrated coefficients.

The model produced relatively accurate results, though with some overestimation. A particular problem in calibration was the number of different sources which had to be resorted to in order to acquire useful time-series data for all modes; this is also a potential obstacle in the present context.

The modal split model took the form:

$$T_{ijk} = T_{ij}(\omega_{ijk} / \sum_k \omega_{ijk})$$

where T_{ijk} was the average number of daily trips between zones i and j by mode k, T_{ij} the total trip volume i-j and ω_{ijk} a measure of level of service provided by k between i and j. The paper does not draw conclusions as to the effectiveness of the modal split modelling in particular, but makes the general remarks that "Many of the...models are much cruder than they should be" but "On the whole, the model system produces results which correlate with experience" (Shuldiner 1970, p.453).

Crow et al. (1973) compare various direct demand models with respect to a series of reasonableness criteria. These include rising demand with increasing income, no increase in demand for existing modes due to introduction of a new mode, demand for a mode not to decrease if its operating characteristics improve (and vice versa), no increase in total demand by arbitrary subdivision of a single mode (a variation on the "red bus/blue bus" paradox) and zero patronage at zero operating frequency. The analysis is inconclusive other than in rejecting the linear abstract mode model for general use.

A variant of the direct demand model known as the quasi-direct approach involves separating out the modal split stage from the generation of trips. This would obviously allow modal split to be determined using a different methodology and possibly permit multiple paths to be introduced. This approach was used for passenger modelling in the EU's 4th Framework interregional modelling project, STEMM.

The STEMM passenger model (Baxter Eadie et al. 1999, chapter 4) is a quasi-direct model known as MAP-1 (Multicountry Application for Passengers) which covers three journey purposes (business, private and holiday). The starting points for the definition of MAP-1 were two algorithms known as P-2 and L-2.0 (Gaudry et al. 1998).

P-2 was originally developed to estimate the parameters of discrete choice logit models; in the MAP-1 mode choice algorithm, it was combined with further algorithms, P-3 to P-6, representing Dogit and Inverse Power Transformation model families.

L-2.0, the MAP-1 generation/distribution algorithm, was an improvement of an existing trip generation/distribution procedure, enhanced in terms of speed and ability to handle large samples. It was based on an extension of ordinary least-squares regression.

QDF (Quasi-Direct Format) is the name given to the algorithm combining the mode choice and generation/distribution models. This allows modal utilities from the mode choice algorithm to be fed back into the generation/distribution procedure.

Variables incorporated into generation/distribution models included (for business trips) working population, land area and GDP per worker of the origin and destination zones. For personal trips, population of origin and destination, GDP per capita at the origin, travel time, and a number of dummy variables such as need to cross an international frontier, language difference and presence of a coastline at the destination but not the origin were used. For holiday trips, similar variables to those used for personal trips were applied, in addition to a dummy variable for presence of mountains at the destination but not the origin and a variable representing the ratio between average temperatures in the two zones. Mode split was based on cost, travel time, out-of-vehicle time and (for rail transport only) number of transfers.

Calibration was initially based upon databases of domestic interregional flows in Germany and France. Within the STEMM project, an extension of existing Civil Aviation Authority (CAA) and UK Government (International Passenger Survey) surveys was used along with other existing data for the purposes of overall calibration. MAP-1 was applied to two passenger transport case studies in the Scan-Link corridor and Trans-Alpine areas.

Scan-Link calibration was carried out using commercial databases; in the case of Trans-Alpine movements, the model was calibrated simply by fitting the output link flows to observed volumes on road and rail Alpine crossings.

3.4.5 Passenger modelling- other model types

Safwat and Magnanti (1988) describe STEM (Simultaneous Transportation Equilibrium Model). This combines all four stages of the classical model into one, equilibrium being reached by solution of an "equivalent convex program", typically via a variant of the Frank-Wolfe algorithm. It is formulated as follows:

$$G_i = \alpha S_i + E_i \,, \; \forall \; i \in I$$

$$S_i = \max \{0, \ln \sum_{j \in D_i} \exp (-\theta u_{ij} + A_j)\}, \; \forall \; i \in I$$

$$T_{ij} = G_i \exp (-\theta u_{ij} + A_j) / \sum_{k \in D_i} \exp (-\theta u_{ik} + A_k), \; \forall \; ij \in R$$

$$\left.\begin{array}{ll} C_p = u_{ij}, & H_p > 0 \\ C_p \geq u_{ij}, & H_p = 0 \end{array}\right\} \forall \; p \in P$$

$$C_p \equiv \sum \delta_{ap} C_a (F_a)$$

where:

G_i = trips generated at origin i

S_i = accessibility of i

E_i = composite effect of exogenous socio-economic variables on generation at i

I = set of origins

D_i = set of destinations accessible from i

A_j = composite effect of exogenous socio-economic variables on attraction to j

u_{ij} = perceived cost of travel i-j

R = set of O-D pairs

C_p = total perceived travel cost on (possibly multi-modal) path p joining i to j

H_p = flow on path p

P = set of all paths in network

δ_{ap} = 1 if link a on path p, otherwise 0

$C_a(F_a)$ = congestion function on a, relating cost C_a to flow F_a

θ a coefficient.

STEM's first application was in an interregional passenger study. This was carried out in Egypt, focusing on low-income passengers and considering four modes (taxi, bus, local train, express train); it was apparently successful in both computational and behavioural terms. To date, there have been relatively few applications of this model. Nevertheless, it

appears to have been relatively effective, and was retained for further examination in the context of this study.

3.4.6 Freight modelling- general considerations

As in the case of passenger modelling, interregional freight modelling, particularly in the Irish access context, requires that a number of specific issues be taken into consideration. This is particularly true because the modelling of freight demand is still comparatively rare relative to passenger modelling, and many assumptions in the field of transport demand modelling are still rooted in the characteristics of urban passenger demand. In particular:

- Additional difficulties of obtaining calibration information and of dealing with the varying characteristics of different commodities are involved in freight demand prediction.
- There is a particularly acute problem in obtaining detailed calibration information for freight, as for passengers, in the Irish access market.

3.4.7 Freight modelling- four-stage

A four-stage (generation-distribution-modal split-assignment) methodology similar to the classical passenger transport model is sometimes adopted in freight transport demand models, although alternatives to the four-stage model are probably more widely used in freight than passenger modelling.

Ortúzar and Willumsen (1994) outline a variety of methodologies for freight trip generation. These include direct surveys of demand and supply (for homogeneous commodities produced on a large scale, such as coal or cement), macroeconomic models, growth factors, zonal multiple linear regression and (in urban areas) warehouse or retail floor areas in a zone.

In respect of freight trip generation, Friesz et al. (1983) observed that most freight network models in use at that time utilised exogenously determined supplies and demands, typically

generated from macroeconomic models. It was considered that this situation could lead to contradictions arising between the outputs of the econometric model (which assumed a greatly simplified transport network) and the detailed network model. Models with endogenous trip generation, typically based on spatial price equilibrium, were therefore seen as superior.

Trip distribution in interregional freight studies, according to Ortúzar and Willumsen, generally utilises synthetic aggregate models, of which the gravity model and linear programming are the most popular. Direct demand models have apparently been used in some freight studies. This latter point is discussed at greater length below.

Freight modal split is a considerably less well-defined one than its equivalent in passenger transport, as is indeed the case for most areas of freight modelling. The literature does, however, show some examples which could potentially be of use in the context of the present project. Indeed, if the volume of work is less than in the case of passenger transport, the variety of approaches is far wider.

Bayliss (1973) describes the Northeast Corridor Project's "inventory theoretic model"; this is based on the assumption that shippers treat freight in transit similarly to a stationary inventory of stock. The total annual variable cost of freight transport, TVC, is calculated as follows:

$$TVC = cT + utT + a/s + wsT/2$$

where:

T = amount transported per year

c = direct shipping cost/unit

t = mean shipping time

s = interval between shipments (years)

u = carrying cost (deterioration, interest, pilferage) per unit per year.

w = warehouse carrying cost/unit/year.

a = ordering/processing cost per shipment

i = average inventory level.

For optimality, $d(TVC)/ds = 0$

$$\Rightarrow s_{opt} = (2a/wT)^{0.5}$$

$$\Rightarrow \text{TVC}_{\text{opt}} = (2awT)^{0.5}$$

However, the model had to be simplified to take account of shortages of data. The following approximations were made:

$$u \cong 2mV$$

where m a constant, V = unit value of commodity.

$$(2awT)^{0.5} \cong \beta_k(T)^{0.5}$$

where β_k a commodity coefficient.

Then $\text{TVC}_{\text{opt}} = c_m T_k + \alpha_m t_m V_k T_k + \beta_k(T_k)^{0.5}$

for commodity k, O-D ij and mode m

and optimal average variable cost, OAVC

and the modal split is given by:

$$S_{mnk} = 1/(1+ (\text{OAVC}_m/\text{OAVC}_n)^{\gamma} + \phi$$

where S_{mnk} the share (by weight) of mode m (where there are two competing modes m and n) for commodity k on ij

Bayliss further observes that the degree of approximation involved appears to have invalidated the bulk of the inventory-based model's innovations, effectively reducing it to a traditional model based upon costs and times.

Gray (1982) divides freight modal split models as existing at that time into three principal categories. The first is based on so-called "economic positivism", whereby a firm's economic variables (e.g. marginal revenue) determine its choice of mode. The second is "technological positivism"; this relates the physical attributes of the mode to those of the consignment. Finally, the "perceptual approach" is based, as its name implies, on the subjective perceptions of the individual (e.g. a transport manager) making the decision.

Gray proceeds to cite numerous examples of all three approaches, some of which are addressed elsewhere in this section.

Ortúzar and Willumsen (1994) describe freight assignment methods as being generally of a stochastic all-or-nothing nature, some examples making use of multi-class techniques to represent the varying characteristics of vehicle and commodity types. It may be that the situation under study would be amenable to the use of a combined modal split and assignment model- e.g. a hierarchical logit model, with choice of mode for the sea crossing being handled at a higher level than choice of route, and choice of access/egress mode at a lower level again. Indeed, KPMG and CHL's (1990) analysis of the structure of unitised freight transport choices appears to support this contention. Accordingly, the idea was retained for further consideration. Reference should also be made in this respect to the descriptions of STAN and MDST.

3.4.8 Freight modelling- direct demand, STEM and STAN

Ortúzar and Willumsen (1994) refer to the use of direct demand models in freight demand prediction; however, the author has, to date, located relatively few specific examples of these. One notable example is cited by Bayliss (1973). This is the abstract mode freight model from the (already mentioned) Northeast Corridor Project. It takes the form:

$$T_{ijk} = \alpha_0 P_i^{\alpha_1} P_j^{\alpha_2} Y_i^{\alpha_3} Y_j^{\alpha_4} M_i^{\alpha_5} M_j^{\alpha_6} N_{ij}^{\alpha_7} F_1(H) F_2(C)$$

where:

T = freight volume
i, j = origin, destination
k = mode
P = population
Y = gross regional product
M = industrial character index
$F_1(H) = (H_{ij}^{b})^{\beta_0}(H_{ijk}^{r})^{\beta_1}$
$F_2(C) = (C_{ij}^{b})^{\gamma_0}(C_{ijk}^{r})^{\gamma_1}$
H_{ij}^{b} = transit time i-j by fastest mode
H_{ijk}^{r} = *relative* transit time i-j by mode k
C_{ij}^{b} = shipping cost i-j by cheapest mode
C_{ijk}^{r} = *relative* shipping cost i-j by mode k
α, β, γ are coefficients.

It is important to note that (according to Bayliss) this model was found not to be practicable in view of the insufficiency of available data.

Nevertheless, it is obvious that such models would offer certain advantages; these would essentially be similar to those offered in the field of passenger demand prediction, but possibly increased by the greater difficulty in obtaining calibration data for freight. However, there would also be similar disadvantages, notably in respect of the "single corridor" structure.

Although the characteristics of Safwat and Magnanti's (1988) STEM methodology might appear to offer similar advantages in freight demand modelling as in passenger, its use in this field has been even more restricted. Moavenzadeh et al. (1983) describe the use of STEM in the Egyptian Intercity Transportation Planning Model, including both passenger and freight components. Again, the model appears to have performed satisfactorily. Further novel features of the Egyptian methodology included simulation models of link costs (rather than closed-form functions) and the application of fleet capacity constraints in addition to link congestion.

The STAN model (INRO 1997) was used for certain freight transport case studies in the 4th Framework project STEMM, specifically those relating to freight flows to and from Scandinavia across the North Sea and via the Scan-Link (Sweden-Germany) corridor. It was originally developed at the University of Montreal in the late 1980s. Several features are common to both STAN and the urban/regional passenger model EMME/2 (INRO 1997, chapter 1).

STAN owes something to both sequential and simultaneous model forms. Trip generation is exogenous; this can be by means of an econometric model. Trip distribution can be performed according to any rule (e.g. entropy, Fratar) compatible with the model's two-dimensional matrix balancing procedure. An unusual feature is the provision of a three-dimensional balancing procedure for cases where trips are stratified by a further factor other than origin and destination (e.g. screenline crossings, travel impedance intervals). The model then proceeds sequentially to the next stage.

This stage is a simultaneous modal split and assignment process; thus, STAN could be described as a three-stage model with two simultaneous stages within the second stage of a

two-stage sequential process. The theoretical basis of this type of model is outlined by Ortúzar and Willumsen (1994, 7.4.2). Freight flows are assigned to multi-modal paths in such a way as to achieve Wardrop system optimal assignment; solution is by the Frank-Wolfe algorithm. The assignment problem is expressed mathematically as:

Minimise: $F = \sum_{p \in P}(\sum_{a \in A} s_a^p(v) v_a^p + s_t^p(v)\, v_t^p)$

subject to: $h_k = g_{od}^m(p)$

$\}o \in O,\ d \in D,\ m(p) \in M(p),\ p \in P$

$h_k \geq 0,\ k \in K$

where:

F	=	total generalised system cost.
p	=	product (commodity).
P	=	set of products (commodities).
a	=	arc (link).
A	=	set of all arcs.
s	=	cost function.
v^p	=	flow volume of product p on network.
t	=	transfer (i.e. between 2 modes).
T	=	set of all transfers.
m	=	mode.
M	=	set of all modes.
$M(p)$	=	set of all allowable modes for particular product.
$g_{od}^m(p)$	=	total demand for transport of a product.
k	=	path.
K	=	set of all paths.
h_k	=	volume on path k of $k_{od}^m(p)$
$k_{od}^m(p)$	=	set of paths from origin o to destination d.
o	=	origin.
d	=	destination.
O	=	set of all origins.
D	=	set of all destinations.

Specific enhancements to STAN were developed for the STEMM case studies.

In the Scan-Link case study (VTT 1998), a network with 158 zones was developed, representing Norway, Sweden, Finland, Denmark and Ireland at NUTS3 level (in Ireland's case, the planning regions). Benelux, France, Germany and the UK were zoned at NUTS1 (the statistical regions in the case of the UK) and the remainder of Europe at one zone per country, with six "rest of the world" zones. A road, rail and water transport network was developed at varying levels of detail (highest in Scandinavia, lowest on the periphery of Europe). Nine modes (road, rail, fast rail, truck ferry, rail ferry, sea bulk, lo-lo, inland waterway, car/truck ferry) were represented. A new commodity classification was derived for the purposes of the case study, based on SITC, the Standard International Trade Classification (see Appendix F). Three cost functions for each link represented operating cost, logistics performance (risk of damage, reliability) and frequency. Calibration was by comparison of volumes and mode shares with observed results. Trip generation was by a dedicated "STEMM Freight Flow Model".

In constructing the cost functions, weights were derived from Finnish customs statistics and ITS Leeds surveys for six factors (risk of damage, reliability, inventory cost, operating cost, lead time, frequency) in the case of each of the twelve commodity groups in the classification used. While the NITL (1999) cost factors are not entirely identical, the weights used in STEMM do appear to correspond relatively well to Irish conditions.

For the purposes of the Nordic/North Sea case study in STEMM (SINTEF et al. 1998), the same modes and network as in the Scan-Link case study were applied but commodity groups restricted to fertiliser, meat, fish and fruit/vegetables.

3.4.9 Freight modelling- MDST

The MDST model (Baxter Eadie et al. 1999, 5.3) was developed especially for STEMM by the British consultants MDS Transmodal. It is essentially a generalisation- both in spatial and modal terms- of an earlier model of truck traffic across the English Channel. The STEMM project saw MDST applied to multi-modal case studies of both cross-Channel and trans-Alpine freight traffic.

Generation and distribution are not carried out within the transport model but via a separate trade forecasting model. Mode and route choice in the MDST model are handled by a modified multinomial logit model which takes account of the degree of similarity between competing options but (unlike hierarchical models) contains only one level of choice.

3.4.10 Alternatives to modelling

It was intended at the inception of this phase of the project that the possibilities for predicting future demand levels by some means other than modelling would be examined, in view of possible difficulties in the modelling process and the time and resource limitations of the present study. However, in practice it appears that there is no alternative reasonably comparable to modelling for the purposes of this project.

Little of practical use was found in the literature. There has been some application in single-mode studies (typically dealing with the introduction of a new mode into the market or increasing the role of an existing mode) of the principle of identifying "divertable" segments of traffic (in both passenger and freight situations), i.e. segments of the market for other modes which might be induced to shift to the mode under study. Demand predictions could be derived from this. However, this method would appear to be laborious and of limited accuracy in the context of this project, where it is intended to consider several possible strategic options.

It might also prove possible to derive demand levels from an assessment of modal split (and, where appropriate, induced demand) effects of similar measures implemented in other regions. However, this approach is judged not to be worthwhile for two main reasons. Firstly, as with the identification of "divertable traffic", there is no proper spatial context- trip makers are assumed to behave similarly regardless of geographical location. Secondly, the modes to be considered would be limited to those which have been successfully implemented in a region broadly resembling that under study; this may prove an unacceptably tight constraint.

Scenario building is sometimes applied as an alternative to modelling in situations where significant uncertainties exist. However, a preliminary examination of references to the use of scenario-based planning in transport indicates that the construction of a plausible

scenario for each possible option would be difficult and of dubious utility. However, scenarios might find use in sensitivity testing at a later appraisal stage; at present, they appear an attractive alternative to varying a series of possibly inconsistent input assumptions.

Ultimately, there is little to suggest that a viable alternative to modelling could be found for the purposes envisaged in this study.

3.4.11 Modelling in past studies of the Irish access market

The objective of this sub-section is to review the approaches to modelling utilised in previous investigations of Irish access transport. In practice, very little modelling work has actually been carried out in the Irish access transport market. The sub-section is thus confined mainly to a discussion of the freight flow generation model used in the major KPMG/CHL study, with brief asides on passenger flow prediction in this study and a subsequent one by the Northern Ireland Economic Council.

The KPMG/CHL study of 1990 was significant in its attempts at freight traffic prediction; however, it does not appear that modelling, *per se*, of passenger trips was carried out by KPMG. The principal predictions made were updated and extended in time (to 2006) by a subsequent report (KPMG and CHL 1992). Identical modelling methodologies were used.

The KPMG/CHL freight modelling was essentially trip generation work, on a highly aggregate level, representing total freight volumes between the entire island of Ireland and all other British or European destinations. This model (in fact, a series of models, covering total sea freight volumes, total unitised freight volumes and ro-ro freight volumes) did not incorporate assignment or mode split. Instead, the division of traffic between the various corridors was assumed to remain the same as in the 1988 base case- a reasonable assumption where only the existing modes (and, indeed, routes) are to be considered.

Economic performance indicators were considered the main determinants of freight volumes (KPMG and CHL 1990, chapter 9). Specifically, exports from Ireland were determined by GDP in the UK, Germany, France and Benelux; imports were a function of total output in the Irish economy. Prospects for the economies in question up to 2001 were

examined, although (not uniquely) the study failed to predict Ireland's high growth rates in the mid-to-late 1990s.

A series of economic, market and institutional assumptions were made as a basis for the traffic predictions. These included growth rates of Irish GNP and British/French/German/ Benelux GDP, market share of Continental Europe for imports to and exports from Ireland (which was projected to increase), ro-ro and lo-lo freight traffic growth rates where these were exceptional (e.g. ro-ro to the Continent growing faster than the market overall) and increases in average tonnes/unit ratio for ro-ro due to higher load factors resulting from deregulation.

Econometric model "A" was used to generate forecasts of total (unitised and non-unitised) freight traffic by sea on Irish Sea routes to and from the island of Ireland, in tonnes. Model "B" did the same for total unitised traffic (ro-ro + lo-lo) and "C" for ro-ro traffic alone. Lo-lo volumes were derived by subtracting the output of "C" from that of "B". Results were cross-checked against a simple extrapolation of trends, with which they closely agreed. Ro-ro tonnage predictions were converted to units using the tonnes/unit ratio; as previously stated, the assumption was made that this would rise somewhat (as it had been doing since 1983).

A separate set of econometric models was developed to relate ro-ro carryings in units directly to economic factors; these agreed closely with the previous outputs. The previous lo-lo tonnage forecasts were converted to TEU (Twenty foot Equivalent Units) using a TEU/tonne ratio.

Only one model (A) is cited in detail by KPMG and CHL (it is described only in the 1992 report). It takes the form:

$$\log MT = -2.6 + 1.6 \log FD - 0.1 \log (PMT/AAEI) - 0.3 \log CAP$$

where:

MT = total imports to Ireland in constant 1980 money values

FD = Final Demand, i.e. consumer spending + government spending + investment changes in stock + exports.

PMT = index of price of total imports.

AAEI = annual average earnings in industry (current money values)

PMT/AAEI = price index of import value relative to value of labour.

CAP = capital stock of manufacturing industry (an indication of how feasible it is to substitute home production for imports).

Air freight prediction was a further component of the forecasting. It appears that this was based simply on assumptions of annual growth levels.

Predictions were made for sea passenger trips, based apparently on tourism forecasts in conjunction with information received from carriers. The function of this data was essentially to quantify overall demands on mixed-user ro-ro services and their ports. No attempt was made to predict air passenger flows, probably because, unlike their equivalents on ferries, they would not have significantly affected the operation of the freight system whose development was the study's major concern.

The Northern Ireland Economic Council (NIEC)'s study of 1993, "Transport Infrastructure and Policy in Northern Ireland", used a very simple econometric model to predict passenger volumes using Northern Irish airports. It was of the form:

Volume of trips = -3893.5 + 27.1272*(Northern Irish GDP) +37.6459*(World GDP) - 7.3586*(Retail Price Index)

($r^2 = 0.9608$).

This model is typical of many broad-brush approaches used for the prediction of total air traffic volumes. It cannot realistically be applied to detailed transport modelling, but, in such a context, it is of interest from the point of view of the incorporated variables. It should be noted that the Retail Price Index is used as a proxy for fare levels; thus demand is regarded as being sensitive to supply, as has been discussed above in the context of consumer response to airline deregulation.

3.5 APPRAISAL

3.5.1 Overview

As in the case of demand prediction, it is necessary to set out the specific requirements of this project in the area of appraisal. There are many parallels between the factors defining its special needs in both areas. Firstly, the fact that it constitutes an interregional study, rather than an urban or regional one, has an effect. Most transport planning appraisal methodologies (like their demand prediction counterparts) were developed for urban situations. A further problem, not present in demand prediction, is that some of these methodologies have been developed originally for application to fields of planning quite different from transport.

The fact that this study encompasses freight transport as well as passenger might be expected to have an effect on the applicability or otherwise of methods from the general literature. However, it must be noted that freight transport has received at least a modicum of attention in most recent regional studies; the Dublin Transportation Initiative (discussed further as a case study below) is one such. The prime difference between the two situations is the need to give more detailed and explicit attention to the needs of freight traffic in the interregional case.

3.5.2 Cost-benefit analysis

Cost-benefit analysis (CBA) is one of the best-known frameworks for appraising large transport projects. It has also proved to be one of the most contentious. CBA allows a wide variety of impacts to be considered, provided that they are quantifiable in monetary terms. As the name implies, the basis of CBA is the combination of benefits and costs of a project to give some measure of its value to society. Two major problems arise with this approach, however.

The first of these is the difficulty in combining different effects to give an overall index (usually referred to as net present value or NPV). There are two facets to this problem. Firstly, two options with an identical NPV may have very different distributions of impacts

over different social groups; one may well be preferable to the other on these grounds, but CBA will give no indication of this. Baughan (1987) points out that the Pareto criterion on the efficiency of an investment, as modified by Kaldor and Hicks (that "a project is worth while if at least one person would benefit even when the gainers had fully compensated the losers.") is implicit in CBA. However, this criterion does not demand that compensation actually be paid, only that the "gainers" have the potential to compensate the "losers". Furthermore "the interests of a majority of people, each gaining a small benefit, [could] outweigh [those] of a minority, each suffering a severe cost".

The second facet of the impact combination problem is the treatment of time. Costs and benefits occur at specific points in time, but the present value of money falls as time progresses. This is conventionally resolved by discounting future costs and benefits, as follows:

$$V_0 = V_t/(1 + r)^t$$

where:

V_0 = present value of impact occurring in year t

V_t = value at time of occurrence of impact occurring in year t

r = discount rate (expressed as proportion)

The choice of discount rate is one of the most difficult aspects of CBA. Most governments fix standard rates for use in CBA studies of public expenditure; 5% is typical in Ireland. Higher rates (say 10%) are considered closer to private-sector practice, but a strong case can also be made for low rates (say 2%) from a sustainability viewpoint, in order to avoid excessive discounting of future environmental damage. In this context, 5% is probably a good "compromise" rate.

The discounting system means that impacts very far into the future are rendered insignificant, which may be considered as a disadvantage of the method. Indeed, it is usual to restrict CBA to a specified time period (conventionally thirty years) for this reason.

The second major problem of CBA is in the valuation of non-market impacts (such as environmental pollution). This is usually carried out by "willingness-to-pay" methods, i.e. surveying individuals to ascertain what they are willing to pay to avoid a negative impact or guarantee a positive one. Some of the disadvantages Baughan (1987) identified in this method are:

- The non-existence of a perfect market for such effects.
- Estimates derived are usually lower bounds.
- Considerable statistical difficulties exist.
- Willingness to accept compensation may be a better indicator than willingness to pay, but there are no reliable methods for estimating it.
- Those with a greater ability to pay have a greater willingness to pay "so that it tends to give more weight to impacts falling on people with high incomes".
- Short-term individual judgements, as reflected in willingness to pay, may be a poor estimate of long-term impacts on society as a whole.
- There may be philosophical objections to the principle of valuing "things...more fundamental than money" in monetary terms.
- Procedures for estimating willingness to pay are not readily comprehensible to the non-specialist, so that "the money values obtained [may] have to be accepted on faith".
- Impacts which cannot be valued suffer by their exclusion from appraisal.

Willingness to pay is not the sole method of valuing impacts in CBA. Revealed preference methods (as opposed to the stated preference nature of WTP) also exist. Typically, these involve analysis of the impact's effects on some proxy such as house prices.

There are three principal decision rules used in CBA. The first one, and generally the most favoured in the literature, is maximisation of NPV (the sum of discounted benefits and discounted costs). The second is maximisation of the benefit/cost ratio, which indicates benefit per unit of cost. The third rule is the Internal Rate of Return (IRR); this is the discount rate which would give an NPV of 0 for the project. This rule is of most use in comparing the returns of the project with those from alternative, non-project-based, investments.

3.5.3 Multicriteria analysis

The use of multicriteria analysis (MCA), in one form or another, has characterised many recent strategic transport studies in Ireland and elsewhere. Relevant case studies will be

considered in greater depth elsewhere in this section; the objective here is to examine the method itself.

Baughan (1987) describes the synthesis phase of environmental appraisal as involving "a decision on how good a plan is at simultaneously satisfying multiple objectives such as minimising adverse impacts and maximising beneficial ones". "Multiple criteria analysis" therefore consists of "the application of systematic decision making methods to this type of problem".

There appear to be three fundamental approaches to MCA. The first involves scoring the performance of each alternative in respect of each impact and weighting the scores to provide a grand index. This is referred to by Vincke (1992) as "multiple attribute utility theory". The second is based upon pairwise comparisons of alternatives, impact by impact, to establish which plan "dominates" in each pair- the "outranking method". The third (and, apparently, most commonly used in recent Irish examples) uses only ordinal properties of scores and weights (or, more commonly nowadays, qualitative indices). Importance weighting appears to have been abandoned altogether (or rather left to the decision-maker) in recent years; however, the criteria themselves (if not their weights) may be derived from public consultation.

There exist no truly proven methods for determining weights in MCA. Vincke (1992, p.113) states that "it is clearly utopian to hope for any precision: it is preferable to consider several series of weights or to analyse the feasible weight space...". Interactive multicriteria decision-making methods (where the decision-makers' preferences are fed back into the determination of criteria and decision rules) have been developed in recent years (Vincke 1992, chapter 6). However, these are complex and often not well suited to the appraisal of a series of discrete options (as in the classical transport planning situation), being more appropriate to linear-programming-type problems.

Baughan (1987) identifies "where importance weights ought to come from" as one of the defining problems of MCA. The present-day approach to this problem appears to be to choose criteria carefully and either imply that all are equally-weighted or leave weighting to the decision-maker. A further problem is "the danger that important value judgements may be concealed within the method". This does not yet appear to have been resolved other than by ensuring that as many viewpoints as possible are represented in the actual marking process. Baughan also cites "difficulties in making some MCA methods

comprehensible and accessible to the public", although the author is not aware of any recent instances of this.

3.5.4 Planning Balance Sheet and related approaches

The Planning Balance Sheet (PBS), also known, in its current form, as Community Impact Analysis (CIA) (Lichfield 1996), is rooted in cost-benefit analysis. It differs principally in that it gives explicit recognition to the distribution of impacts over various groups and that non-monetary impacts are incorporated into the same summary table as those expressed in monetary terms.

The original development of this approach was focused on the needs of urban and regional planning studies. In such cases, a disparate variety of projects had to be addressed simultaneously (as opposed to the typical CBA application of appraising a single scheme) and the impacts were widely distributed throughout society (Lichfield et al. 1975, pp.60-62).

The PBS procedure is outlined by Lichfield et al. (1975). Firstly, the "producer/operator" groups, those who implement and operate projects, are enumerated. They are then paired in "balance sheet" format with the various incidence groups. Each producer-consumer pair "is considered to be engaged in either a notional or a real 'transaction' whereby the former produces services 'for sale' to the latter". "Transactions" may include non-market items. If the item cannot be costed, a symbolic representation may be inserted in place of a monetary figure. PBS does not produce a grand index; judgement must be exercised in the final choice. The net present value of any option to each of the identified groups can be calculated, assuming that all relevant factors are costed.

While PBS indicates certain implications of a plan more clearly than conventional CBA, it also possesses disadvantages. Although unquantified impacts can be included, Baughan (1987) states that they "may still be at a disadvantage because they are not described in detail in the tabular presentation". Furthermore, where an impact is spread over groups, its significance may be lost (Baughan 1987).

3.5.5 Alternative approaches

Cost Effectiveness Analysis (CEA) compares monetary costs with non-monetary outputs (unlike CBA which assigns a monetary value to outputs). The decision rule in CEA is either the maximisation of some output for a given cost or minimisation of cost for a given output. Baughan (1987) states that it is best suited to cases where only one output is of interest.

The Goals Achievement Matrix (GAM) is "based on the proposition that costs or benefits have meaning only in relation to a defined objective or goal". The axes of the matrix represent goals and incidence groups. Benefits and costs (preferably but not essentially quantified) are defined for each cell in the matrix, reflecting movement towards or away from a goal. Time discounting is applied to quantified impacts. The method incorporates a weighting system and consequent grand index. It has been criticised for the lack of a definite theory on how goals should be selected, the inability of impacts not related to one or other of the previously-determined goals to influence the result (although Baughan (1987) sees this as "really a reason for adding to the list [of goals] rather than for excluding the impact"), the lack of an adequate method for determining the weights, and the inability to take account of unquantified impacts in the grand index.

The Environmental Evaluation System (EES) was developed originally for water projects, but is adaptable to transport plans. Impacts (including unquantified ones) are "converted into ratings on a scale of environmental quality", using "value functions" based on a combination of expert judgement and scientific information. Importance weights (also expert-derived) are applied in order to produce a grand index and attention is deliberately drawn (e.g. with symbols) to serious impacts. It has been criticised for taking insufficient account of the views of the general public and for a relatively complex scoring system.

The Judgmental Impact Matrix (JIM) originated in the assessment of wastewater treatment schemes; it is not known whether it has ever been applied to transport projects, but Baughan (1987) appears to have considered it a possible contender. In this method, the impact of each component of a plan is estimated individually by reference to expert judgement. A grand index can be computed, weightings again being based on expert judgement, but is not essential to the method. Although JIM is "a relatively cheap way of screening a large number of plans", it suffers from several disadvantages related to the use

of experts. These include possible unrepresentativeness, difficulty in aggregating views and incomprehensibility of results to the general public. In addition, there is no provision for time discounting or the assessment of the distribution of impacts over various groups.

Finally there are "suggested" or "idealised" methodologies, those which have been proposed from a purely theoretical point of view, usually on the basis of an assessment of the shortcomings of existing systems. In general, methodologies investigated in this way have not been applied to "real-world" problems. Two examples have been investigated in detail. The first of these was that proposed by Manheim (1979). The methodology is structured as follows:

- Identify *actors* (i.e. groups "essentially similar in their relationship to the issues under study").
- Identify *impacts*.
- Define *goal variables* (indicators) for each impact; these may be qualitative or quantitative.
- Define the *actions* under study, i.e. the alternative options.
- Present the impacts in an *impact tableau*, a matrix relating actions to impacts on the various actors.

This methodology lies within the general scope of multicriteria analysis, although some of its features are reminiscent of the Planning Balance Sheet.

The second example is the so-called "anti-disaster methodology" of Hall (1980), resulting from an examination of previous failures in planning (including the Third London Airport, described further at 3.5.9 below). The essential features of the methodology are:

- A "more conscious effort to forecast the world (or rather the alternative possible worlds) in which the decision may be made".
- The "production of some kind of better balance sheet of costs and benefits". "If possible, these valuations should be expressed in some common measurement, such as money. If impossible, then...in the best measure available- even as an arbitrary scale...". The Planning Balance Sheet is cited as a successful past example of such an approach.
- The final part involves "marry[ing] the forecasting and the valuation elements." Alternative options would be identified and probability-based estimates of cost and

feasibility made, including, where necessary, estimates for different points in time. Impacts on the utilities of various groups would be estimated. Aggregation rules could then be applied but "would be unlikely to yield an unambiguous preferred result...Judgement and debate would still be the basis of selecting the preferred course of action."

Hall summarises the characteristics of the methodology as "it is not neat or tidy. It does not assume that one can feed a whole set of quantities into some mixing machine, homogenise them and get a precise comparison...On the contrary, it assumes that judgement will be needed every step of the way." Hall compares the anti-disaster methodology to the Planning Balance Sheet, although the use of probabilities and the appraisal of alternatives at various points in time are identified as more novel features. There is also some resemblance to certain varieties of multicriteria analysis.

3.5.6 The role of accessibility

Accessibility is a commonly used concept in the appraisal of alternative transport strategies. It can be defined in any of a number of ways, all of which essentially measure the ease of reaching one or more destinations from one or more origins. In the context of this study, accessibility measures might be used to indicate the spatial impacts of a strategy, i.e. the changes in generalised cost for trips to and from specified regions.

There appear to be several fundamental approaches to measuring accessibility. The Standing Advisory Committee on Trunk Road Assessment [SACTRA] (1999) offered four principal alternative ways of defining accessibility, as used in past transport planning practice. They were:

- measurement of ease of access to the transport system itself [e.g. walking distances to bus stops, ease of wheelchair access];
- measurement of ease of access to facilities [sufficient] to meet people's needs within certain minimum travel times, distances or costs;
- measurement of the value which people place on having an option available which they might use only under unusual circumstances... - 'option value' – or... the

existence of an alternative which they have no real intention of using - 'existence value'; and

- measurement of ease of participation in activities (for personal travel) or delivery of goods to their final destination (for goods travel), provided by the interaction of the transport system, the geographical pattern of economic activities, and the pattern of land-use as a whole.

(SACTRA 1999, 9.76).

The first definition of accessibility is more often used in urban/regional contexts, but is not unheard of in interregional transport. For instance, Fitzpatrick Associates (1999a, 1999b) measure accessibility to air transport in the Republic of Ireland by the extent of areas within 90 minutes' drive of an airport. O'Sullivan (1969) defined accessibility in the Irish context as follows:

$$A(i, N) = \sum_{j=1}^{n} d_{ij}$$

where i, j are vertices (zones), N the overall network (the main road network in general, although sensitivity testing on the rail network was also carried out) and d represents distance , time or cost of movement.

The second ("access to facilities") definition was utilised in an interregional context by the Organisation for Economic Co-operation and Development (OECD) in its COST 33 study on intercity passenger transport in Europe (OECD 1977). Three of the five accessibility measures applied in COST 33 were of this general type. They were:

- Regional accessibility by distance: summing the road distances from the centroid of a zone to the centroids of surrounding zones until a total (sum of zones) population of 25 million was reached.
- Regional accessibility by time: as above but replacing road distance with travel time by fastest mode.
- Regional accessibility, hinterland: based on the measurements of regional accessibility by time, the set of adjoining zones containing the most accessible 25 million people for each zone was designated the "hinterland" of that zone. Accessibility of a zone was then measured by how many other zones included it in their hinterland.

The option/existence value definition of accessibility is difficult to implement quantitatively in the absence of extensive stated-preference data (in this, it closely resembles many shadow prices in CBA, of which option and existence values are really a subset). The option/existence value concept is often implicit in debate on issues such as regional airports or passenger rail services, but is seldom explicitly acknowledged. There appears to be too little information available to assess the potential contribution of this type of accessibility measure in the present context.

The final definition is somewhat broad, but encompasses many of the better-known examples of accessibility indices. A small number are listed here.

Daly (1975) proposes the following accessibility measure:

$$A_{ikpt} = -\log_e \Sigma_j \Sigma_m \exp (B_{jpt} - C_{ijkmt})$$

where:

A_{ikpt} is the accessibility for zone I, car ownership category k, trip purpose p in time period t;

B_{jpt} is the benefit derived from destination j for purpose p in time period t;

C_{ijkmt} is the generalised cost of travelling i-j for car ownership category k, by mode m, in time period t.

The values for B_{jpt} are obtained through calibration of a gravity model.

The accessibility indicator used in the Dublin Transportation Initiative (see also 2.6.1 above) was derived as follows:

For origin zones:

$$A_i = \Sigma_j (C_{ij}^{0}/C_{ij}^{1}) T_{ij}$$

$$A_I = \Sigma_{i \in I} A_i / \Sigma_{i \in I} \Sigma_j T_{ij}$$

For destination zones:

$$A_j = \Sigma_i (C_{ij}^{0}/C_{ij}^{1}) T_{ij}$$

$A_J = \Sigma_{j \in J} A_j / \Sigma_{j \in J} \Sigma_i T_{ij}$

where: C_{ij}^0 = travel (generalised) cost in base case

C_{ij}^1 = travel (generalised) cost in strategy under investigation

T_{ij} = volume of trips i-j

A_i = accessibility index at fine (367-zone) level

A_I = accessibility index at strategic (58-zone) level

The accessibility measures were calculated separately for car available and car not available trips. Further area-based accessibility indices were generated by combining the outputs for a group of zones (e.g. Dublin city centre).

Two of the five COST 33 accessibility measures were, broadly speaking, of this type. They were:

- European accessibility by distance: the accessibility of a zone was the population-weighted average of road distances to all other zones.
- European accessibility by time: as above but using travel time by fastest mode rather than road distance.

SACTRA (1999, 9.78) state that "system-wide accessibility benefits/disbenefits are, to a very large extent, subsumed in a *fully-specified* [SACTRA's italics] cost benefit analysis". The accessibility measures utilised in, for instance, the Dublin Transportation Initiative, would probably be superfluous alongside a CBA of the Sugden type (see 3.5.9 and Table 3.6 below). There might be a role for a more comprehensive measure, but the evidence available to the author does not suggest that such a measure could be readily developed.

Overall, it may be concluded that accessibility measures could theoretically make a contribution to the appraisal framework proposed for this project. The most appropriate would probably be those of the third type described above. However, their application would be restricted by the difficulties encountered in developing a format for the presentation of impacts by incidence group. In view of the subsequent adoption of the TEE Table (Sugden) CBA format as the means of presenting impacts in such a way, it does not appear that there is a significant role to be played by accessibility measures.

3.5.7 Transport and the economy

The relationship between the transport system and the economy is complex and much studied. Essentially, economic activity creates demand for freight transport because the production, consumption and sale of goods take place at different locations in space. Economic activity creates demand for passenger transport because people engaged in such activity must travel to and from their workplaces, where these are not also their homes (or, more commonly in the interregional context, travel to other locations in connection with their business). It also creates such demand because increased economic activity leads to greater affluence, which increases the demand for tourism and personal travel. The vast majority of the demand for transport is derived demand, being a consequence of demand for other economic activities rather than a demand for travel *per se*.

Transport activity stimulates the economy because the provision of transport services, the construction of transport infrastructure and the manufacture of vehicles are all economic activities. It also stimulates the economy by minimising the costs incurred by other economic sectors in the movement of their raw materials, products and personnel. Tourism and certain other service industries depend on transport to deliver their customers to them.

Changes in transport lead to changes in the structure of the economy. When a region's accessibility improves, it can be expected to become more competitive in certain ways (because transport costs for its exports are reduced) but less in others (because imports also become cheaper). The precise mechanisms involved are the subject of some debate and will be covered in greater detail at a later stage.

The relationship between transport and the economy is therefore a two-way one. The exact balance between transport-driven economic change and economy-driven transport change may vary from location to location and is often difficult to determine. An example of this is the correlation between road traffic growth and economic growth: does this reflect increased demand for transport in a growing economy, economic growth through investment in transport, or some combination?

This and many other issues relating to the interaction between transport and the economy were studied in depth by SACTRA, the Standing Advisory Committee on Trunk Road Appraisal (1999). SACTRA's report covered many facets of this interaction (freight transport, business travel, the link between traffic growth and economic growth, the role of

transport infrastructure in regional and national competitiveness, etc.). The observations and conclusions of greatest importance in the present context included:

- "One of the main impacts historically of improvements in transport has been to reduce the costs of long distance trade and thus to make markets better integrated. This is perhaps the aspect which makes transport infrastructure 'special' rather than simply a run of the mill addition to the capital assets of the economy." (SACTRA 1999, 4.02).
- "...conventional CBA will fail to capture all the economic impacts of infrastructure or [traffic] reduction measures" but this is only likely to be important "at the level of assessing big changes (e.g., Britain without its motorway network or the introduction of traffic reduction measures on a very wide scale) rather than of the individual road scheme" (SACTRA 1999, 4.39-4.40)
- In the case of a transport improvement "between a large central region and a smaller more peripheral region", the consequences "typically [start] with a concentration of activity in the central region because of the scale economies" but "There is a theoretical case for an inverse U-shaped relationship between transport costs and regional inequalities such that from a situation of very high transport costs, a reduction can initially lead to increases in inequalities...but further reductions beyond a certain level would lead to the expected reduction in inequality. Very large reductions ... could lead to either increases or reductions in inequality". (SACTRA 1999, 5.93)
- In the case of two peripheral regions and a central region, where transport improvements are made on the links between one peripheral region and the central region, "The effect ...is to shift production towards... that peripheral region at the expense of the other peripheral region. There is little effect on the central region. However, in this case, all regions make a welfare gain, most for the peripheral region whose transport connections are improved, rather less for the central region and less again (but still positive) for the non-connected region which clearly benefits from the overall reduction in transport costs in the network". (SACTRA 1999, 5.95)
- For a similar case where *both* peripheral regions' links to the central region are improved, "both peripheral regions benefit at the expense of the centre region ... Both ... make substantial welfare gains ... The overall improvement in welfare from improving both links is greater than the sum of the improvements associated with each link independently". (SACTRA 1999, 5.96)

- "net benefits may arise from measures to reduce both congestion costs and environmental costs. However, this might also involve adverse effects on GDP" (SACTRA 1999, 7.08).
- "Models for appraising the wider impacts [of transport] on the economy, both in total at a national level and in terms of the distribution of the impacts between localities, involve many difficult questions, the answers to all of which are not obvious or capable of resolution in the foreseeable future". (SACTRA 1999, 8.09)

Preston (2000) provides a comprehensive review of work on the interaction of transport and the economy, up to and including the SACTRA study. He finds considerable disagreement on the core issues, particularly the predominant direction of the "chicken and egg" relationship between the two. Preston concludes that further work is required on various types of transport/economic interaction model and on specific relationships (transport investment/economic growth, transport/housing market, transport/labour market etc.). He also provides a tabular summary (Preston 2000, Table 4) of results from a number of studies on transport infrastructure/economic development linkages. Table 3.4 below is an adaptation of Preston's table, concentrating on interregional examples.

It will be seen that, of the eight studies cited here, none has identified any large-scale economic effects from investment in transport infrastructure. Two found effects on employment distribution, two on logistical operations, one on employment growth and two on economic growth. The only conclusions that can safely be drawn are:

- that no major economic effects are likely from interregional transport investment;
- that, however, there may be some discernible impacts on regional economic growth;
- that logistical reorganisations may also result from such investment.

It must be noted that few of the situations examined in these studies are exactly comparable to the Irish access market, and this limits the applicability of their conclusions.

Table 3.4 Summary of studies examining links between transport infrastructure and local economic development
(adapted from Preston 2000, Table 4)

Author	Year	Geographical scale	Infrastructure	Conclusions
Botham	1980	28 zones (UK)	Changes in national highway stock	Small centralising effect on employment
Briggs	1981	Non-metropolitan counties (US)	Provision of interstate highway	Presence of interstate highway is no guarantee of county development
Cleary & Thomas	1973	Regional level (UK)	New estuarial crossing	Little relocation but changes in firm's operations
Dodgson	1974	Zones in North (UK)	New motorway	Some relationship between transport costs and economic growth
Evers et al.	1987	Northwest Europe (7 zones)	High-speed rail	Some effect on employment growth and distribution
Judge	1983	Regional level (UK)	New motorway	Very limited economic impact
Mackie et al.	1986	Regional level (UK)	New estuarial crossing	Small overall effect- some reorganisation of operations
Wilson et al.	1982	Regional level (Canada)	Highway investment	Some regional economic development identified

In terms of research on transport and the economy in the specific Irish context, a small number of studies do exist.

O'Sullivan (1969) concluded that "investments in transport facilities which reduced the cost of movement, extended potential markets and resource bases, made possible areal and functional specialization [sic] in production...and thus a growth of wealth. Transport investment...could be considered a prime mover and necessary cause in economic development" (O'Sullivan 1969, p.58). Furthermore, "A study of the current structure of

the Irish economy revealed considerable accordance between intensity of activity...and accessibility on the major road network"(O'Sullivan 1969, p.60).

Preston (2000) refers to "public investment...in core infrastructure" as "arguably a factor" in Ireland's late 1990s economic boom. No specific examples are cited. Denny and Guiomard (1997) examine the relationship between the capital stock of road infrastructure in Ireland and the output of the manufacturing sector. Although heavily qualified, the results indicate that road infrastructure investment has a large positive effect on production.

Fitzgerald et al. (1999, pp.18-20) quote a number of studies, mainly dealing with countries other than Ireland, in support of the contention that investment in public infrastructure would positively benefit the Irish economy. They also examine the locational decisions of firms. Their conclusions in this respect are (Fitzgerald et al. 1999, p.24) that the effects of infrastructure in this area are mixed (sometimes benefiting the core and sometimes the periphery- see also the discussion of the SACTRA report above) but that "Industries which face negligible transport costs may prefer to locate in peripheral areas" (as witness the growth of high-value production such as computers and pharmaceuticals in Ireland).

In the Northern Irish context, Northern Ireland Economic Council (1994) studied "the implications of peripherality". Amongst other things, they noted:

- That "none [of the companies interviewed] regarded transport costs as a significant impediment to competitiveness" , but that this could be attributable to "the structure of industry already reflect[ing] the anticipated influence of transport costs" (NIEC 1994, 4.18).
- That low labour and property costs partially compensated for the effect of more costly transport in a remote region such as Northern Ireland.
- That reduced transport reliability was probably the most significant effect of peripherality, but had "at worst a small impact" (NIEC 1994, 5.24).
- That perceptions of peripherality were generally more important than "hard" quantified factors.

On the whole, it may therefore be concluded that transport infrastructure investment has a moderate positive effect on a region's competitiveness, at least in the Irish context.

Whether or not this is significant in terms of benefits over and above those addressed by conventional CBA is a moot point.

In addition, there are various problems with generalising in this manner; as Fitzgerald et al. (1999) stated, the effects of transport investment vary from sector to sector because the importance of transport costs itself varies. It could also be said that these effects may vary between different types of transport infrastructure.

Much recent debate in the Republic of Ireland has focused on the importance of investment in local (particularly public) transport in order to facilitate journeys to work and open up new areas for development, thereby alleviating labour and housing shortages. Debate on interregional infrastructure (such as the national road network) often focuses as much on its "domestic" role in facilitating development by linking various peripheral regions to the core Dublin region as on its importance in the access system. Therefore, there may be difficulties in generalising about the importance of access transport's effects on the economy.

Overall, in the particular circumstances prevailing in this case, it is difficult to justify any explicit quantitative treatment of transport's effects on the economy, assuming that only the access transport system is being considered and that as thorough a CBA as possible is conducted. It is therefore not considered necessary to take the concept further.

3.5.8 Appraisal in past studies of the Irish access market

Comparatively few examples were found in the literature of previous Irish access transport studies in which alternative options had been assessed by a formal process. This section accordingly extends to all studies where defined alternatives were put forward, even where the means of assessment does not fit into the pattern of formal methods outlined in the previous section. The parallels between the subject matter of these studies and the author's work strongly suggested that they should be considered.

The KPMG Access Transport Study (KPMG and CHL 1990, 1992) has been referred to extensively in the context of Tasks 1 and 2. It constitutes the only known study to encompass the whole access transport system, rather than a single mode or piece of

infrastructure. On inspection of the report, there appeared to be two principal areas in which consideration was given to alternative solutions. These were the provision of additional capacity in access services (air and sea) and the location for the development of future port capacity in the Dublin region.

In the first case, no formal assessment criteria were applied. However, it is apparent that the decisions taken were based upon appropriateness of the capacity provided to the needs of the market and also on the principle of minimising capital and operating costs. In this sense, the approach taken resembles cost-effectiveness analysis.

The Dublin port location issue was dealt with by listing advantages and disadvantages of the proposed new north Dublin port compared with concentration on the existing Dublin Bay facilities. The main issues covered by these advantages and disadvantages included:

- Capital costs.
- Environmental factors (particularly land reclamation and road traffic).
- Decongestion effects, including both road traffic and port capacity.
- Institutional factors (including port management and the planning process).
- Timescales for implementation.

The conclusion was unfavourable to the new port proposal, principally because:

- Implementation would be too slow to accommodate traffic growth in the period 1990-2000.
- Other serious institutional difficulties would arise in the relocation of the existing unitised freight terminals.
- The extent to which continued use of the existing Dublin Port facilities would be required had been underestimated.

This appraisal shows some of the features of multicriteria analysis. The underlying objectives of the process appear to include environmental protection, provision of capacity to facilitate traffic growth, minimisation of congestion and minimisation of capital costs.

The second major case study selected was the Dublin Port Access Study (Dublin Transportation Initiative and Steer Davies Gleave 1995) carried out in the early 1990s.

This originated as part of the wider Dublin Transportation Initiative [DTI] (further described at 3.5.10 below) but is worthy of separate consideration because of its independent development of project-specific assessment criteria as well as its obvious relevance to access transport.

The draft transport strategy developed by the DTI had excluded definite provision for port access on the grounds that considerable uncertainty still existed in this area, and it thus merited further study prior to the completion of the final strategy. The principal alternatives in contention were all road schemes. Initially, there were four of these:

- The Eastern Bypass, a north-south motorway link, mainly in tunnel, along the eastern fringe of the Dublin conurbation and forming part of a motorway ring around the city.
- The Northern Port Access Route (NPAR), consisting essentially of the less contentious northern section of the Eastern Bypass.
- The East-West Tunnel, an underground route bypassing the most congested areas of the city centre on a line running broadly from the port to the main western radial roads, but stopping short of both.
- The Royal Canal Route, a surface road, dedicated to trucks and buses, mainly along an existing railway right-of-way.

However, the Eastern Bypass was deleted from the appraisal, for what appear to have been essentially political reasons, at the early stages of analysis.

Two alternatives to road infrastructure were examined. The concept of a rail-based shuttle service carrying containers or "piggyback" road vehicles between the port and an edge-of-city terminal was briefly considered but rejected before entry to the formal analysis. The second option considered was one based on demand management, which was brought forward to the final analysis alongside the NPAR, East-West Tunnel and Royal Canal Route.

Two parallel multicriteria analyses were conducted. The first examined how the different options would affect the environmental impact of HGV traffic in the inner city. The criteria assessed in this case were severance, fear/intimidation, townscape, sensitive land uses (e.g. open spaces, hospitals, residential areas), noise/pollution and an aggregate indicator summing up the overall effect. The second, referring only to the three infrastructure-based

options, examined the impacts of the schemes themselves on severance, fear/intimidation, townscape/amenity, sensitive land uses, noise/vibration/pollution, potential for associated management measures and disruption during construction. An aggregate indicator was again provided.

In parallel with the MCA processes, a conventional CBA, estimating capital and operating costs, time and vehicle operating cost savings and accident cost savings, was conducted for all four options. The NPAR performed best and the management option worst in this regard.

A summary multicriteria appraisal was then carried out, involving the ranking of the three infrastructure schemes on nine criteria (highest HGV volume, least negative NPV against the basic DTI Interim Strategy, least negative NPV against the Interim Strategy with HGV management, IRR and B/C against the same strategy, least number of new car trips, highest benefits to public transport, best environmental performance and highest degree of relief to the inner city in respect of HGV traffic). The NPAR proved the best option on this basis.

3.5.9 Appraisal in other interregional transport and related studies

The classical example of an interregional multi-modal study, in demand modelling and technology assessment aspects as well as in appraisal, is the Northeast Corridor study carried out in the United States in the late 1960s.

This study investigated the potential for new or improved transport systems in the Boston-New York-Washington DC corridor. The systems modelled in the final analysis included various air modes (ranging from conventional airline to vertical take-off and landing), a variety of high-speed guided systems, including air-cushion and steel wheel/steel rail options, and conventional rail and road transport.

The Northeast Corridor study, as described by Rallis (1977, 5.6.5) essentially based its appraisal on conventional financial cost-benefit analysis, with contributions from environmental impact and travel time indicators. In contrast with the demand prediction

aspects of the study, its appraisal process appeared to incorporate relatively few innovations.

STEMM (Strategic European Multi-Modal Modelling) was a 4th Framework project under the auspices of the European Commission, focusing, as its name implies, on the modelling of interregional passenger and freight flows, particularly those where intermodality was an issue. However, the case studies through which the possibilities of modelling were investigated inherently involved at least a basic appraisal of a variety of options. Thus, the appraisal aspects of STEMM are briefly discussed here, having regard to the fact that no comprehensive appraisal framework was developed for the project.

The variety of indicators used in the different case studies within STEMM are probably best summarised in tabular form; this is done in Table 3.5 below.

It can be seen that the indicators used are quite diverse and vary significantly from one case study to another. The list serves primarily as a pointer towards the types of indicator possible (particularly considering that the demand prediction work carried out by the author draws on that done in STEMM) rather than any kind of detailed blueprint for an appraisal framework.

Table 3.5 Appraisal Indicators used in STEMM Case Studies

Indicator → Case study↓	Modal split (trips or tonnes)	Modal split (p-km or t-km)	Transport cost	CO_2 emissions
Scan-Link passenger	•	•		
Trans-Alpine passenger	•	•		
Cross-Channel freight	•	•		
Trans-Alpine freight	•	•		
Scan-Link freight	•	•	•	
Nordic/North Sea freight		•	•	•

An account of a further multi-modal, interregional study is given by Lipinski (1978). This examined freight transport in a 160km×1900km corridor in the southern and midwestern

United States. The analysis was fundamentally multicriteria-based, but weighting was applied to the various criteria. The weights and the functions relating performance of an option to scores on a given criterion were derived from an interactive computer-based process involving representatives of interest groups (such as government, the transport sector, environmentalists, chambers of commerce and banks).

The paper does not give any account of the success or otherwise of the implementation of the proposals emerging from the study, and so it is very difficult to come to a judgement on the merits of the methodology. Weighting, as can be seen from other cases cited in this chapter, is a difficult and risky process. Lipinski does, however, state that the computer database of responses allowed the differing viewpoints of various groups to be examined. Present-day thinking would tend to restrict the role of the evaluator to preparing a summary of the performance of each option- without weighting or derivation of a grand index- and let the decision-makers and other interest groups apply their own weights informally. Lipinski's approach can be seen as a precursor of this in certain ways.

Examination of essentially unimodal studies in the interregional transport field is also of value. One of the best-known interregional fields of application of the various transport appraisal methodologies is in airports policy, and London airports present one of the most frequently cited examples of this.

The development of airport strategy in the London/ South East England region has been long and complex. With a few exceptions where the appraisal process interacts with other aspects such as site selection, it is proposed to ignore the latter aspects in this summary treatment.

Insofar as modern-day appraisal methodologies are involved, the process began in 1966, when plans for a two-runway airport, expanding ultimately to four runways, at the British government's preferred site of Stansted in Essex, were rejected at a public inquiry. Insufficient appraisal of alternative sites was seen as one of the principal objections to the scheme.

An independent commission was set up to select a new site. This "Commission on the Third London Airport" (or "Roskill Commission" after its chairman) did not incorporate in its remit the options of a do-minimum strategy or of alternative strategies for providing

extra capacity (such as a smaller new airport, expanding existing airports or developing more than one new airport). This was one of the many criticisms subsequently made of its methodology.

The Commission relied heavily upon cost-benefit methods for appraisal. Its work has become a landmark in the field, evoking comments as varied as "a pioneer of advanced planning practice" (Lichfield et al. 1975) and "nonsense on stilts" (Self 1975). The methodology was refined in parallel with the refinement of the list of possible airport locations, so that the second-stage list of sites used a finer level of analysis than the first, and so forth. An initial list of 78 sites was ultimately reduced to just four (Flowerdew 1972).

The items costed (see also Appendix C) were airport, road and rail capital costs, airport servicing costs, meteorological services, airspace movements (i.e. aircraft operating costs), passenger and freight user costs (i.e. the generalised cost incurred in accessing the airport), air safety, the relocation of defence facilities, public scientific establishments and private airfields, and impacts on a variety of land uses. These latter included residential, institutional, agricultural, commercial/industrial and recreational uses; for all except agriculture, the costs included both the loss of land to the airport and the devaluing impact of noise nuisance. The Commission conducted its own extensive studies into the valuation of "soft" elements such as time and noise nuisance.

The CBA presentation was unusual for being in terms of the costs or benefits of each site relative to the best site on the respective criterion, rather than absolute figures. For example, noise costs were presented as the excess cost over that of the site causing the least noise nuisance (which was assigned a cost of zero). The final verdict favoured Cublington, an inland site in Buckinghamshire, as the location for the airport. Public opinion and a minority report preferred the worst-performing (in CBA terms) of the four shortlist options, the coastal site of Foulness (also known as Maplin) in Essex. The government's decision ultimately favoured the latter site.

The work of the Commission was extensively criticised as it became apparent that Cublington was the favoured site. The principal objections included:

- The study's terms of reference were too limited. It assumed that a need for airport capacity existed and that this need could only be satisfied by a new four-runway airport.
- Passengers' time was valued too highly. In particular, the attachment of a value to non-British passengers' time was questioned (on the grounds that no benefit to British society accrued from their time savings). The ability of business travellers to make productive use of small time savings was also queried. A high time valuation would tend to favour the inland site of Cublington over the remote coastal Foulness.
- Residential property values were too low. Those who put an infinite value on the loss of their house in the Commission's valuation surveys were arbitrarily assigned a value of twice the market price. This would appear to bear out Baughan's contention (see 3.5.2 above) that willingness-to-pay surveys usually only produce a lower bound figure.
- Inadequate account was taken of intangibles such as historic buildings and wildlife. An attempt was made to cost the former at their fire insurance values, but was much criticised and eventually withdrawn.
- Insufficient attention was given to regional planning considerations.

The Maplin project was abandoned, without construction work beginning, in 1974. The primary reasons for this were the decline in air traffic growth following the 1973 OPEC oil crisis, progress in aircraft technology (reducing noise levels and increasing aircraft size and thus runway capacity utilisation) and the growth in public opposition to Maplin on environmental grounds.

Subsequently, in the late 1970s, the matter was reviewed again in the light of a White Paper on airports policy. An "Advisory Committee on Airports Policy" (ACAP) was appointed to study the implications of not providing a third London airport (now assumed to be restricted to two runways) and the possibility of providing the capacity at some location outside the South East region or through greater use of existing airports in other regions. Meanwhile, a "Study Group on South East Airports" (SGSEA) carried out a detailed technical analysis of potential sites for a new two-runway airport in the South East.

The SGSEA study (SGSEA 1979) began by applying constraints based on built-up areas, topography, defence considerations, surface access, construction timescale, noise,

economic effects, agriculture and the environment to exclude most of the region from consideration. The remaining portion was divided into eight search areas, and 49 possible sites identified. Two search areas were rejected altogether and the best site from each of the remaining six proceeded to the detailed appraisal stage.

Most of the shortlisted sites had (not surprisingly, given the depth of analysis of the previous studies) been considered before. Amongst them were Stansted, Maplin and sites closely corresponding to Cublington and one of the other Roskill shortlist locations. The appraisal explicitly rejected the idea of costing intangible factors, apparently because of the experience of the Roskill Commission.

There appears to have been little or no consideration given to the use of an appraisal methodology not requiring such costings, such as goals achievement analysis or one of the multicriteria family of methods. Instead, a variety of quantitative (numbers of people within 35 and 50NNI[3] contours, number of dwellings requiring demolition, travel time from central London, capital costs of airport, roads and railways, lead time, number of new dwellings required) and qualitative (effect on defence airfields, air traffic control changes, compatibility with spatial plans, quality of agricultural land lost, attractiveness to airlines) indicators were presented, without any attempt to indicate the relevant trade-offs or even provide a summary sheet.

The ACAP report (ACAP 1979) was strongly in favour of the development of a third London airport. Demand management was rejected because of possible negative economic impacts. No feasible site for a two-runway airport was found in areas outside, but readily accessible to, the South East. Existing regional airports were seen as having "some scope for building on the existing structure" but mainly for local demand. No formal appraisal structure was applied by ACAP. ACAP also reviewed SGSEA's report, endorsing the approach to appraisal ("...it would...be unrealistic to seek to attribute a cost to such things as the loss of agricultural land ...the effects of aircraft noise...or to the damage which might be caused to a place of historic or other interest"). However, the importance of some factors was questioned, notably noise and urbanisation impacts (coincidentally the criteria least favourable to Stansted, the site eventually selected).

Stansted was once more selected as the site for a third London airport in the wake of the ACAP and SGSEA reports. The development of Stansted, along with the expansion of terminal capacity at Heathrow, was the subject of a lengthy public inquiry in the early 1980s. The inspector's report (Eyre 1986) was favourable to the initial stage of development at Stansted (i.e. new terminal capacity, with enhanced surface access, based on the existing runway). However, it rejected further development into a two-runway airport (to the extent that the airport authority was required to dispose of land acquired for the purpose). Expansion at Heathrow was also rejected for the time being, but preparatory work for such a project was recommended, in view of longer-term needs and the restricted capacity (without the second runway) at Stansted. Alternative proposals involving greenfield sites (Maplin amongst them) were all rejected. The analysis carried out by Eyre was judicial rather than technical in nature, and therefore did not involve formal methodologies, although the results of previous technical studies were examined. Proposals for a fifth terminal at Heathrow have subsequently (though only very recently) been approved.

Following the development of Stansted, a further study (RUCATSE- Runway Capacity to Serve the South East) was commissioned into future runway capacity requirements in the South East; this reported in 1993 (Working Group on Runway Capacity to Serve the South East, 1993). Options for the development of new runways at the three main London airports of Heathrow, Gatwick and Stansted were examined, along with expansion of capacity on Luton airport's existing single runway and the option of developing two from a list of six regional airports in or near the region to half of maximum capacity each (i.e. collectively providing the equivalent of a single runway). Greenfield sites were deliberately excluded from the analysis, being "most unlikely to be a realistic or acceptable option" (Working Group on Runway Capacity to Serve the South East, 1993, p.11). However, a special examination was made of a proposal for a very large airport on an artificial island in the Thames estuary; an outline analysis of the potential for use of military airfields was also carried out but did not show this to be worthwhile. Neither of these possibilities was investigated to the same level of detail as the options based on existing airports.

[3] NNI = Noise and Number Index, an index of aircraft noise nuisance based upon both the noise output and number of aircraft. NNI has now generally been superseded by other methods. 35NNI is taken to represent significant nuisance, while 50NNI indicates uninhabitability.

Like SGSEA, the RUCATSE report avoided making any recommendation as to which option should be chosen. Again like SGSEA, the appraisal stage consisted of a disparate collection of quantitative indicators and qualitative statements. The former included passenger benefits, capital costs, numbers exposed to noise nuisance, number of properties demolished, land take, volume of earthworks required, additional labour requirements and numbers of new dwellings required for airport employees. Amongst the latter were descriptions of the effect on surface transport congestion, compliance with planning guidance and broader environmental impacts.

The narrowness of RUCATSE's terms of reference may be queried; the underlying assumption that extension of existing airports was inherently "realistic or acceptable", while construction on greenfield sites was not, is open to question. The Heathrow expansion option identified in RUCATSE would have required the demolition of 3,300 dwellings to construct a single runway; by comparison, the *worst* of the sites identified by SGSEA would have involved the loss of 200 dwellings in order to provide *two* runways. The numbers affected by noise nuisance were also an order of magnitude higher than those for the SGSEA sites (despite an improvement in the noise performance of aircraft over the intervening years). While the Gatwick and Stansted options in RUCATSE were considerably less environmentally destructive than the Heathrow one, their impact remained so severe as to be difficult to distinguish from greenfield construction. Indeed, the report itself states (Working Group on Runway Capacity to Serve the South East, 1993, p.14) in relation to Heathrow that "the scale of impact was such that, if we were to base the retention of options...on [environmental impact] alone, no further detailed work should be done on Heathrow...Despite these exceptional reservations, Heathrow was retained for detailed analysis as...the environmental costs and the benefits to UK air transport...needed to be assessed fully".

No action has been taken to date on the provision of additional runway capacity in South East England. Most of the principal options identified by RUCATSE have been ruled out of further consideration by government, but this situation was overtaken by events, as a further study is now in progress.

As a consequence of the British government's 1998 "Integrated Transport White Paper", several regional airport and air service studies were commissioned with a view to developing a long-term (to 2030) airports policy. The London/South East (this time also

including Eastern England) study was later in starting than the other regional studies (commencing only in late 1999/early 2000) and was envisaged as taking considerably longer (two years in total). Thus far, the only documentation publicly available consists of the study's terms of reference and a proposed appraisal framework.

The terms of reference for the South East and East of England Regional Air Service Study (SERAS) (Department of the Environment, Transport and the Regions 2000a) include explicit recognition of the possible roles of demand management and of airports outside the study area. Demand management and infrastructure measures are to be assessed on a common basis, and greenfield sites for new airport capacity not excluded from analysis.

The consultation paper (DETR 2000b) on the appraisal framework for SERAS summarises the requirements for such a framework as:

- "...criteria and associated indicators which allow the elimination of options which would never be preferred, while enabling consistent and effective comparison of options in the later stages..."
- "[consistency] with frameworks...for the appraisal of other transport modes...[while] inclusive of the issues...specific to the aviation sector..."
- "...indicators for which there is a reasonable consensus over the means of arriving at and presenting a consistent assessment of the performance of a scheme..."
- [realism] in its requirement for information..."

(DETR 2000b, 1.8)

The influence of previous studies on this subject can clearly be seen; in particular, the first criterion appears designed to address the failings of SGSEA and RUCATSE and the third those of Roskill.

The proposed approach is rooted in the British "Guidance on Methodologies for Multi-Modal Studies" (GOMMMS) which is in turn derived from the "New Approach to Transport Appraisal" (NATA), described more fully below. The assessments of impacts are verbal but based on indicators which "are a mix of monetary values, physical units, and non-quantified elements...not intended to give prominence to those indicators which can be expressed in terms of monetary values." (DETR 2000b, 6.5). Further details are in

Appendix C.2.6. It is intended to use the framework to reduce a wide range of options arising from constraint analysis of the region (similar to the initial stages of Roskill and SGSEA) to no more than ten for detailed appraisal and ultimately to three or four for public consultation.

The indicators used include population within "areas of risk" near runways, monetary values of benefits to passengers, freight shippers, airlines and government, population within a standard noise "footprint", emission levels and planning impacts. It is intended that the results will be presented in Appraisal Summary Table format (see below).

The principal lessons to be learnt from the experience of London airport planning are that no option (including do-minimum) or family of options should *prima facie* be ruled out of analysis, that the appraisal methodology must treat all options on a comparable basis and that the methodology should be comprehensible and acceptable to the public, but should also provide clear and unambiguous advice to anyone (expert or non-expert) having a part in the final decision.

Like the third London airport (to which it has often been compared) the Channel Tunnel is a major transport project, which has had an extremely long and convoluted history, including numerous re-evaluations. Gwilliam (1983) describes the Tunnel as "a cautionary tale in public decision making" (a description which might also be justifiably applied to the third London airport).

Several methods of appraisal have been applied at varying times to a varying range of alternatives. The use of modern-day appraisal methods in the Channel Tunnel context began in 1963, with the report of a joint working group set up by the British and French governments to examine various proposals for a fixed link (Minister of Transport 1963). Central to this study was a cost-benefit analysis of three alternative solutions to the Channel crossing problem. One was the "do-minimum" (relying upon a combination of sea and air transport similar to the then-prevailing situation), another the tunnel proposal (rail with road vehicle shuttle trains, essentially similar to the scheme implemented thirty years later) and the third a road/rail bridge scheme emanating from a rival study group. The analysis (see also Appendix C) was a financial rather than a social cost-benefit analysis, i.e. it did not take account of externalities accruing to society as a whole rather than to the

transport operators. Capital and operating costs for the three alternatives were examined over a period of fifty years.

A further cost-benefit analysis of the Channel Tunnel (Coopers & Lybrand 1973) was carried out in the early 1970s, by which time a group of companies had been selected to construct and operate the project. This was, unlike the previous study, a social cost-benefit analysis, including time saved by passengers and savings in the inventory costs of freight shippers (see Appendix C). However, quite unlike the near-contemporary Commission on the Third London Airport (see above), no attempt was made to cost environmental factors. The then-recent negative experiences of that study may well have deterred the Channel Tunnel's consultants from taking such an approach.

The second phase of the tunnel project (involving, amongst other things, initial trial borings) proceeded as planned. However, political instability, environmental resistance to the tunnel's terminal facilities and high-speed rail link to London, and the election of a new government in early 1974, committed to "a full and searching reassessment of the project" (Gwilliam 1983, p.89) led to slippage in the timescale and eventually, in early 1975, formal abandonment.

Prior to the abandonment of the project, the aforementioned government had commissioned a Channel Tunnel Advisory Group to study its viability relative to a variety of alternative systems. The group reported shortly after the final decision on abandonment had been taken (Channel Tunnel Advisory Group 1975).

This study defined the four principal options as the Tunnel with or without a dedicated high-speed rail link to London, a "do-minimum" strategy and a variant of the latter with increased usage of hovercraft. The cost-benefit analysis carried out (Appendix C) was essentially similar to the previous Coopers & Lybrand work, except that road capital costs were apparently excluded. The results showed the tunnel project to be viable in both financial and social terms, but the high-speed rail link was "very costly in relation to its return" (Channel Tunnel Advisory Group 1975, chapter 6). No full-scale analysis of impacts excluded from CBA was carried out; it was considered that "the environmental arguments for and against each of the options were fairly evenly balanced" (Channel Tunnel Advisory Group 1975, 2.6.24).

Following the abandonment of the project, attempts were made to revive it in a far more modest form- a single track with no vehicle-carrying shuttle service, carrying only through rail traffic. This would significantly reduce the cost of the tunnel itself and eliminate the costs of the shuttle terminals at both ends, along with their environmental impact and that of their associated road traffic movements. Two tunnel diameter options were contemplated, a full-size option capable of ultimately accommodating vehicle-carrying shuttle trains and a smaller diameter limited to conventional rolling stock. As might be expected, the nationalised railway administrations of Britain and France were the main proponents of this scheme (British Railways Board 1979).

In the light of this project, several further assessments of the viability of a Channel fixed link were carried out. Gwilliam (1983) describes "the most ambitious of the appraisal efforts so far [1983]", carried out on behalf of the then EEC in 1980. Financial and social CBA comparisons were conducted between four alternatives (road bridge, road bridge plus single-track rail tunnel, double rail tunnel, single rail tunnel; in those options incorporating a single rail tunnel, the tunnel diameter would be too small to accept vehicle shuttle trains). Sensitivity to changes in economic growth and discount rate was examined. On NPV and IRR criteria, the double rail tunnel was the best option under all circumstances except for the case of low growth and high discount rate, where the single rail tunnel outperformed it. The traffic and cost assumptions underlying this study were, however, widely questioned (Gwilliam 1983, p.91).

A joint UK/French study group reported in 1982 (Secretary of State for Transport 1982). They carried out a conventional CBA on a series of options, incorporating those examined by the EEC study in addition to a single rail tunnel capable of accommodating shuttle trains (which was tested with and without the shuttle service itself) and a "composite" scheme (road bridge/tunnel plus rail tunnel). The findings once again favoured a double rail tunnel, although phased construction of such a scheme was seen as a possibility.

Another assessment was conducted by the House of Commons Transport Committee (1981), essentially within similar parameters to those immediately preceding it. Again, the double rail tunnel emerged as the preferred option.

In the aftermath of these studies, a definite decision was taken to proceed with the project; however, the choice of technology was left open to groups seeking to finance (the project

would be entirely privately financed) and operate it. The final contenders included a double (bored) rail tunnel, a road bridge plus single (bored) rail tunnel, a road bridge/ (immersed tube) tunnel plus double (bored) rail tunnel and a road tunnel plus double rail tunnel (all bored).

The rationale for the final choice of the double rail tunnel scheme is given by Secretary of State for Transport (1986). A number of criteria (engineering feasibility, capacity, travel time, psychological factors, safety of navigation, environmental impact, economic effects, employment, effect on ferries, sabotage/terrorism, frontier/health matters, financing and public opinion) were assessed in a purely qualitative, verbal manner. The best scheme or schemes on each count was identified. In the vast majority of cases, the Channel Tunnel Group (i.e. double rail tunnel) proposal was best or joint best.

This analysis was supported by a more specialised and detailed document on environmental appraisal (Land Use Consultants 1986). The approach used in this study was quasi-multicriteria in nature; the impacts investigated were (under the heading "social and economic factors") local employment, construction employment, induced development, tourism/recreation, settlements/heritage, planning policies and consultation, (under "health and welfare") hazard/risk and user experience, and (under "physical environment") landscape, terrestrial ecology, marine environment and agriculture. All the impacts were described in a verbal, principally qualitative, form.

Subsequent to the choice of scheme, the project proceeded on a purely commercial basis. While costs proved higher and some categories of traffic (particularly through rail freight) lower than originally forecast, these would seem to be separate issues from the appraisal framework. The development of existing modes, in terms of technology (e.g. high-speed ferries) and levels of competition (ferries, low-cost airlines) has also perhaps been more rapid than was forecast in the appraisal studies.

One further study related to the Channel Tunnel is worthy of comment. Since (at least) the development of the project in the early 1970s, it had been proposed to operate through passenger rail services from locations north of London to Paris and possibly also Brussels. These were latterly referred to as "Regional Eurostar" services. Although rolling stock for them was delivered shortly after the opening of the Tunnel, the services were never introduced. The matter became a subject of considerable political controversy in Britain;

various reviews were carried out, of which only the most recent and comprehensive (Little 2000) is considered here.

While this study was obviously closely related to the Channel fixed link, it differed from those reviewed above in dealing with relatively small incremental capital costs (roughly €37-40million in current prices over 30 years) rather than a very large, multi-billion euro (at current prices) capital investment.

The study is remarkably comprehensive for such a relatively limited field. Consultation with political and business representatives, focus groups and interviews with interest group representatives were all utilised to provide input, and a detailed technical study carried out to determine the optimal pattern of operations. Demand predictions were derived and financial CBA (crucial since the service was required by statute to operate without subsidy) carried out. A multicriteria-type appraisal was also carried out and presented in Appraisal Summary Table format (see below), adapted in accordance with the British government's Guidance on Methodology for Multi-Modal Studies (GOMMMS). The criteria used are listed in Appendix C. It should, however, be noted that some of the criteria (accidents, security, wider economic impact) showed very small impacts indeed. No decision has so far been taken on the results of the study, which found that the service would not be viable until at least 2007.

The lessons to be learned from the forty-year experience of Channel Tunnel appraisal include the need for a sufficiently wide range of options to be analysed, the importance of non-monetary impacts, the need to take account of likely technological and economic improvements in existing transport systems when proposing the introduction of a new system and the importance of a proper in-depth treatment of uncertainties.

The British trunk road appraisal methodology, NATA (New Approach To Appraisal) – also applied in modified form to multi-modal studies- forms the next case study. NATA evolved from the previous COBA system of cost-benefit analysis with pseudo-multicriteria features, which is not dealt with in detail here.

Five criteria (environmental impact, safety, economy, accessibility and integration) are assessed (DETR 1998a). For all except safety and integration, a variety of sub-criteria are considered. A comprehensive list is provided in Appendix C of this report.

Each criterion is assessed (where possible) in three ways; qualitatively, quantitatively and by means of a summary assessment. The latter is in terms of present values of benefits or costs for those items (accidents, journey times/vehicle operating costs, capital cost) included in COBA, and generally expressed on a seven-point textual scale for other items. The NATA results are structured into a single-page summary sheet for each scheme, known as the Appraisal Summary Table (AST). The present values of costs and benefits, NPV and B/C ratio output by COBA are included in the AST, but physically separated from the assessment of compliance with the criteria. Detailed procedures for deriving the AST scores of a road scheme are described by DETR (1998b).

Some work has been done to date on adapting the AST to make it suitable for general application in transport planning, in order to establish "a level playing field" between modes (DETR 1998b, 1.13). Guidance on methodology for multi-modal studies (GOMMMS) has been drafted with a view to utilising an adapted AST in such studies. The final version of this guidance is further described below. A modified form of AST was used in the aforementioned regional Eurostar study, and the draft methodology outlined above for the current London airports study is AST-based. AST was also applied to the appraisal of options for the future of Northern Ireland's rail network (Railways Task Force 2000) and for a ten-year transport plan for Northern Ireland (Department for Regional Development 2002).

As a relatively new methodology, it has proved difficult to assess the performance of NATA. While it improves on previous measures in treating road and public transport investment on a more equal and integrated basis, and in reducing the reliance upon cost-benefit methods, it has not gained universal support. In addition, the treatment of incidence groups appears relatively weak.

Local Transport Today (25/5/2000) describes research carried out at Leeds University's Institute for Transport Studies into the effects of NATA on decision-making. This involved the statistical modelling of the relationship between NATA assessment scores and the outcomes of decisions on road schemes. The results indicated that "Accessibility and Integration...and three of the environmental sub-criteria dropped out as not statistically significant. Noise, Landscape, Heritage, Reliability and Regeneration all performed strongly...Safety benefits appeared to be valued at about 1.25 times their COBA values,

but travel time savings appeared to be significantly downrated...The pattern of decisions...would have been quite different had Ministers considered journey time, safety and scheme costs alone...".

The results of the Leeds study appear to support the author's contention that NATA reduces the degree of concentration on quantitative figures (compared to COBA), but (insofar as they have been reported to date) do not indicate the degree of acceptance which the methodology has gained with the general public or with interest groups, nor the success or otherwise of NATA's somewhat low-key approach to the treatment of incidence groups.

NATA is now in the process of being subsumed into a wider multi-modal methodology, as described below. It appears that, in future, road-only studies will be based on a variant of the multi-modal approach, rather than multi-modal studies utilising variants of NATA, as has tended to happen thus far. The basic structure of NATA is retained, but certain modifications and enhancements are made.

Guidance for this purpose- known as Guidance on the Methodology for Multi-Modal Studies, abbreviated to GOMMMS- was released in its final form in early 2000. However, draft versions had been available since mid-1999, and these influenced the appraisal aspects of the Regional Eurostar study and the development of the South East Airports Appraisal Framework (see above).

Multi-modal studies are generally interurban in nature (since they focus primarily on the trunk road network and those alternative modes which relate to this network); some of those with larger study areas (such as London-South West/SouthWales) would be classified as interregional. It is envisaged that freight movements as well as passenger traffic would be investigated. The content of GOMMMS also supersedes the original NATA approach in the case of roads-based studies; it is thus perhaps best seen as an evolution of NATA rather than a modification.

The guidance (DETR 2000c) sets out five principal objectives of central government in relation to transport, which "should be taken as a 'given' in the study areas" (DETR 2000c, vol.1, 3.3.3). These are identical to the basic objectives of the original NATA (i.e. environmental impact, safety, economy, accessibility and integration). In addition to these, each study team is free to set its own local/regional objectives, which could be derived

from local and regional land use and transport plans, transport providers' plans or interest groups' opinions (DETR 2000c., vol. 1, 3.4.2). It is possible to set an objective in terms of a quantitative target (e.g. noise or pollution levels). Objectives can also be defined through a "problem-oriented approach" whereby consultation, audits and systematic analysis of quantitative data are utilised to identify the scale and spatial location of transport problems, and alternative strategies are assessed according to their success in ameliorating such problems.

The Appraisal Summary Table (AST), as described above, is the basis of the GOMMMS appraisal methodology. The GOMMMS list of AST criteria, which is slightly different from the NATA one, is reproduced in Appendix C of this report. As in the case of NATA, the measures for each criterion fall under three headings: qualitative impact, quantitative measure and a summary indicator which may be quantitative (monetary where possible) or qualitative. In addition to the AST, there are three further strands to appraisal in GOMMMS. These are:

- Assessment of compliance with local/regional objectives.
- Assessment of extent of amelioration of identified problems.
- Supporting analyses of "distribution and equity, affordability and financial sustainability, and practicality and public acceptability" (DETR 2000c, vol. 1, 6.2.5).

The cost-benefit methodology (referred to as the "Sugden approach", after its originator, Professor Robert Sugden) specified by GOMMMS is innovative and, in some respects, resembles the Planning Balance Sheet. The Sugden approach disaggregates costs and benefits by group (users, operators, others), by transport mode and by type of impact (e.g. time, accidents, operating costs). Costs and benefits are valued at market prices rather than factor cost (i.e. exclusive of indirect taxes) as used in most approaches to CBA. This change is required because the rationale for excluding taxes is based on the assumption that transfer payments within society are irrelevant to the assessment of a project from an overall national point of view, which clearly does not hold where separate interest groups are concerned. Benefits are always considered as positive and costs as negative in the Sugden approach.

Table 3.6 reproduces the Sugden summary table, the Transport Economic Efficiency (TEE) table.

Table 3.6 **Transport Economic Efficiency Table** (after DETR 2000c, vol. 2, Worksheet 6.1)

Impact	Total Present Value 1994 prices and values					
User benefits						
Personal travel		*(3)*	Car	Bus and coach	Rail	Other
Travel time						
Vehicle operating costs						
User charges						
NET IMPACT		*(1)*				
Freight			Road freight		Rail freight	Other
Travel time						
Vehicle operating costs						
User charges						
NET IMPACT		*(2)*				

(continued over)

Table 3.6 continued

Private Sector Provider Impacts				Bus and coach	Rail	Other
Revenue						
Operating costs		*(a)*				
Investment costs		*(b)*				
Grant/ subsidy						
NET IMPACTS		*(3)*				
Public Sector Provider Impacts			Road infrastructure			Other
Revenue						
Operating costs		*(c)*				
Investment costs		*(d)*				
NET IMPACTS		*(4)*				
Other Government Impacts			Road infrastructure	Bus and coach	Rail	Other
Grant/subsidy payments		*(e)*				
Indirect tax revenues						
NET IMPACTS		*(5)*				
TOTAL						
Net Present Value, NPV		(6) = (1) + (2) + (3) + (4) + (5)				
Present Value of Costs, PVC		(7) = (a) + (b) + (c) + (d)				
Present Value of Cost to Government		(8) = (4) + (e)				
Benefit/Cost Ratio, BCR		(9) = ((6)-(7))/-(7)				

(continued over)

Table 3.6 continued

Value/Cost to Govt. Ratio, VCGR		(10) = (6)/-(8)

The final case studies arose from the EU's APAS transport research programme, which included two projects aimed at developing appraisal methodologies for use in EU-funded programmes for passenger and freight "nodal centres" such as ports, airports, rail freight terminals and other intermodal interchanges.

The project on freight nodal centre appraisal (Gruppo CLAS/Systema 1996) focused on a single methodology which, in its final form, effectively constitutes a variant of the Planning Balance Sheet. It considered three incidence groups, "owners/operators", "users" and "players in the macro-and-socio-economic context" (which appeared to include government, financial institutions and society as a whole). The costs and benefits considered are listed in Appendix C of this report; however, it must be noted that quantitative but non-monetary indicators were permissible in the case of some of the environmental impacts. The structure was specifically designed to reflect particular issues in freight transport, such as the high degree of private funding for terminal facilities.

The companion project on passenger nodal centres (ISIS et al., 1996) took a slightly different approach. In this case, parallel CBA and MCA methodologies were developed. Again, there was an emphasis on the role of incidence groups. However, the CBA framework in this case was not quite as similar to the Planning Balance Sheet as that in the freight project. The CBA and MCA structures are outlined in Appendix C.

3.5.10 Appraisal in other Irish transport studies

Because Irish interregional transport studies were relatively few in number, it was decided to include in the scope of the review a number of other Irish transport studies in recent years which had involved the application of some form of appraisal methodology.

The first example chosen was the Dublin Transportation Initiative. This project was an attempt to develop a transport strategy for the Dublin conurbation over the period 1991-2011 and put in place an ongoing review and evolutionary process. The DTI has met, thus far, with distinctly mixed success. The reasons for this will not be described in any great detail here (except insofar as they are affected by the adequacy or otherwise of the appraisal procedures). It is sufficient to say that unprecedented levels of economic growth and unexpected delays (due mainly to public opposition) in the implementation of large capital projects have been the principal factors identified by most commentators. It is also possible that the strategy originally recommended may have been (in hindsight) too modest in scale and insufficiently flexible. The first comprehensive review of the DTI strategy was completed in 2000 (DTO 2000).

The main reason, however, for examining the DTI at this point is its appraisal process. In keeping with the ethos of the overall study, the appraisal criteria were intended to be strongly rooted in public consultation. Thus, the basis for appraisal was a so-called "Vision Statement", defining overall objectives for Dublin. This, in turn, drew upon public consultation and the views of the DTI's consultative committees.

Phase 1 of the DTI, completed in 1991, involved various sub-studies aimed at preparing the ground for the main work (which constituted Phase 2). Amongst these was one which proposed terms of reference for Phase 2; within this study, in turn, was a specification for an appraisal structure (Steer Davies Gleave 1991b, Appendix B). The methodology was to "ensure that options consisting of disparate elements are compared on an equal basis"; it was specified as being multi-criteria in nature, and "the use of a formalised weighting system is not envisaged".

The most detailed account of the process from preparation of a Vision Statement to development of a draft recommended strategy is contained in DTI (1993). The initial Vision Statement was designed to address the significance of the Dublin region on an international, national and metropolitan area level, as well as the needs of specific social groups and society's general desire for improved economic and environmental conditions. Objectives were then derived from the Vision Statement, "not...restrict[ed] to those for which quantifiable measures could be deduced directly from the transport model or other statistical devices...[but] derived to relate specifically to items of concern or interest..." (DTI 1993, 3.72).

The objectives were divided into four categories, based on the structure of the Vision Statement, with a fifth category relating to feasibility ("taken as implicit in the Vision Statement"). Criteria relating to each objective were then developed. A complete listing is provided in Appendix C of this report. Minor amendments were made to the Vision Statement and objectives in the review process.

The possible concepts for the development of Dublin's transport system were combined into eight "Themes". These "were seen not as embryonic strategies but as a useful means by which the various policy options could be explored, compared with one another and their strengths and weaknesses identified" (DTI 1993, 4.10). The comparison of Themes "was expected to establish the contribution of individual policy options towards meeting the objectives set". Assessment of Themes was on a multicriteria basis, because this method was considered the most appropriate to assessing policies rather than individual projects. A conventional seven-point scale was used and no attempt made to weight objectives. In addition to the MCA summary sheet, a set of summary quantitative statistics (congestion, energy use, emissions, accessibility, accident levels, modal split) was prepared for each Theme.

The outline recommended strategy was developed from the multicriteria analysis of themes by a methodology known as Strategic Decision Analysis. Primary decision areas (e.g. port access and public transport) and the linkages between them were identified. The actual decisions made use of a variety of methodologies, but CBA (see also Appendix C) played a particularly important role at this stage. The port access issue was so complex that it proved impossible to resolve at this stage and was the subject of a further study, described in detail at 3.5.8 above, completed in time for the formulation of the final recommended strategy.

Although the full methodology of the review process has not so far been published, it appears to have involved a multicriteria comparison of two detailed options. CBA figures for the final strategy have been published (compare the original DTI, in which CBA was only used to compare projects and not conducted on a whole-strategy level). These, unlike earlier CBAs in the DTI process, incorporate environmental (emissions and noise) factors.

It is difficult to come to a final judgement on the effectiveness of the DTI on the basis of its performance so far. The study made extensive use of public consultation; from the

published consultation reports, it can be surmised that the methodology addressed all the points made in relation to appraisal in the preliminary stages (Steer Davies Gleave 1991a) and that the consultative process on the interim strategy did not raise appraisal as an issue. Nevertheless, public acceptance of many DTI proposals has proved to be distinctly lacking.

In part, this is a function of a factor beyond the control of the appraisal process (except in the very important respect that it is vital to investigate a sufficient range of future scenarios), namely unprecedented economic and traffic growth, which has overwhelmed the original DTI proposals to a certain extent. However, there appears to have been unanticipated resistance not deriving from this factor.

It is, as already stated, difficult to identify the exact contributory factors in this respect. Part of the problem may derive from inadequacies in the consultative processes conducted by the relevant implementing agencies subsequent to the completion of the main study.

The MCA process ultimately depends on who decides the scores, and on what basis. Individuals can, in a typical MCA (to which the DTI methodology is no exception) apply their own weights to criteria in coming to a decision. This is one of the most attractive features of MCA as an appraisal method, but it is futile if the *scores* of an option on each criterion are not transparent and defensible. The DTI documentation makes it clear that the scoring was carried out by the Technical Committee, which represented only implementing agencies. Although it is important for technical expertise to be applied to such a task, it could nevertheless be suggested that the committees representing local public representatives and interest groups (since merged into a single committee) should have had a role to play in the scoring process. It is unlikely that this alone would have succeeded in defusing criticism, but it would have represented a small step in the direction of consensus.

Other problems may be identified. Some areas of controversy have related to alternatives that were treated superficially or not at all in the original analysis, such as underground rail operation as an alternative to surface operation in the city centre, or road pricing as a means of demand management. In the latter case, although the theme testing had shown advantages for road pricing, it was replaced by parking control in the final strategy on the grounds of greater acceptability, a decision that has subsequently been subject to review. Both underground rail construction and (in principle) road pricing were adopted as part of the first strategy review.

These latter problems may reflect a failure to choose a wide enough range of options at the theme testing stage, although both the measures referred to above were tested in one form or another (not necessarily the optimal one). However, it is also possible that the Strategic Decision Analysis process as implemented in the original DTI study placed too much emphasis on finding a single solution and not enough on flexibility or the opinions of interest groups and the general public. While the latter were sought through opinion polls, these were restricted to declarations for or against a single concept rather than a package of measures. Full-scale consultation began only when the strategy was fundamentally formulated. The attitude towards the existence of a single best solution inherent in the Strategic Decision Analysis process makes an interesting contrast with the prior MCA which was explicitly designed to avoid "picking winners".

It is not entirely clear as to how the choice might have been better made. The author, as a personal opinion, would suggest an approach closer to that of the Strategic Planning Guidelines described below. This would involve a second round of MCA at a finer level of detail, comparing a smaller number (perhaps, in the DTI case, three to four) of options developed from various combinations of the most promising elements emerging from the first round. The analysis carried out for the first review of the strategy appears- from the limited information available- to bear some resemblance to this approach. It might also be possible to involve public and interest group opinion in this stage of analysis and aim to design options so that they offered a reasonable spread of responses to possible political and economic uncertainties.

The DTI should not be too harshly criticised; it was amongst the first true multi-modal studies to take place in Ireland, and no consultation programme on a comparable scale had ever before been carried out. Undeniably, however, there are lessons to be learnt from it, as from the other case studies. The author believes that these include the need to evaluate the widest possible range of options, the necessity for an appraisal process to be open and transparent, the need to examine the possible impacts of alternative economic scenarios in greater detail, and the importance of flexibility and transparency in the final choice of strategy.

The second example chosen was the preparation of the Strategic Planning Guidelines for the Greater Dublin Area (SPGGDA). In connection with certain of the DTI's

recommendations, a study of future (to 2011) land use strategy for the Dublin region, along with associated transport and other infrastructural provision, was carried out in the late 1990s, reporting in early 1999 (Brady Shipman Martin et al. 1999). It is included in this discussion because of its direct relevance to transport policy and its reflection of changes in opinion and context since the early 1990s.

The appraisal methodology used for the SPGGDA was entirely multicriteria-based. After reviewing the current position, likely level of growth and physical capacity to accommodate it, the study identified broad development principles (sustainable development, the European Spatial Development Perspective, the need for flexibility, the findings of a previous study on housing affordability, guidelines on residential density and conservation factors) which would guide the choice of strategy.

The choice of multicriteria analysis is briefly justified: "the selection of criteria for the assessment of projects has extended beyond...physical feasibility, cost and general impacts on environment and heritage, to more detailed considerations, many of them related to...sustainability...these wider considerations are also being applied to strategies and programmes, though the methods and techniques...are not fully developed." (Brady Shipman Martin et al. 1999, p.50). No formal derivation for the assessment criteria is presented, although a textual justification of each one's relevance is provided. It should be noted that separate incidence groups were not considered.

The criteria themselves are listed in Appendix C of this report. In the first ("strategic models") phase of appraisal, eight broad alternative strategies for development (such as consolidating the Dublin metropolitan area, dispersing development or developing new towns) were identified and assessed against the criteria. Assessment was on a three-point ("accords well", "accords moderately", "does not accord") scale.

The second phase ("strategic options") involved identifying the best-performing aspects of the strategic models and grouping them into three more detailed (including population targets) schemes. These were assessed against the same criteria, but the scale used in this instance was an asymmetric four-point one ("excellent", "good", "fair", poor"). The reason for the change of scale is not explained.

A preferred option was then developed from elements of the strategic options. The overall process bears some resemblance to the DTI, but substituted the "strategic options" stage for the DTI's "strategic decision analysis". In the author's opinion, the result is a more transparent process of choice. However, the general absence of quantitative measures may be a drawback (although this particular case is highly unsuitable for the implementation of a *primarily* quantitative method such as CBA).

It is difficult to comment in depth on the SPGGDA, since insufficient time has elapsed since their completion to assess the full scale of their impact and the degree of acceptance they have gained.

3.6 TECHNOLOGY

3.6.1 Overview of requirements

As has been seen, the Irish access system is very far from perfect- even further so than the average transport system- in terms of travel times, costs, congestion, environmental impacts and so many other areas. Over the years, there have been many attempts at resolving this. Most have centred on the evolutionary development of the existing modes in the system; this approach is well represented in the studies cited in the previous chapter. However, neither radical change in the operation of the existing modes nor the introduction of new transport modes has received much consideration.

There are good reasons for taking such an approach given the uncertainties that will always exist with regard to future technological development, the passive rather than active position of Ireland with respect to most technological change, and the island's relatively small market size. However, in certain circumstances, particularly when the long-term strategic view is under consideration, these factors may favour a fuller analysis of all possible options, including radical ones, as the best way of taking all possible future developments into account.

The first step in such an analysis is to carry out a preliminary appraisal of modes, technologies and "soft" (e.g. fiscal) measures with a view to isolating those which should

proceed to literature review stage. In order to achieve this, a variety of "sieve" criteria were used.

Any change in the access transport system would have to address areas where there exists potential for improvement on the status quo, for instance:

- Reduction of both direct and indirect (e.g. cost of time, freight inventory costs) cost components, through some combination of lower cost, higher operating speed and increased reliability.

- Redressing the balance of development by providing the best possible service to peripheral regions of the island.

- Relief of congested existing links and terminal facilities by either using entirely separate ones, expanding their capacity or otherwise contributing to their more efficient utilisation.

- In the context of Ireland's widely perceived (e.g. Fitzpatrick Associates (1998), Fitzgerald et al. (1999)) "infrastructural deficit", considerable investment will be required in infrastructure for the foreseeable future. However, given finite sources of finance, and competition for funding from urban and other components of the transport system, along with non-transport sectors, investment in access infrastructure should ideally be minimised, subject to maintaining benefits as far as possible. This does not preclude the identification of high-investment options for comparative purposes.

- Environmental factors must also be taken into account. For instance, reduction of pollutant and greenhouse gas emissions from transport activities would be a significant benefit. Land take for existing transport facilities is often considerable. Although a new system would probably not lead to the release of much existing land, it could play a role in minimising future land take. The avoidance of large-scale infrastructure investment, as described above, would also contribute towards this aim. Similarly, the alleviation of congestion would bring about reductions in energy use and emissions. New systems could also potentially contribute towards the reduction of other environmental problems associated with transport, such as noise (road traffic and air) and road accidents.

There are clearly numerous ways in which new modes and technologies could, theoretically at least, contribute to alleviating present transport problems in the Irish access market. There are also, however, a number of constraints which might hinder their doing so. The intention here is to examine those constraints which are products of the environment (in the broadest sense) within which the modes will have to operate, rather than those relating to the technology of specific modes. Issues include:

- The likelihood of competition from existing modes, given the current existence of relatively intense competition in the market, must be taken into account. However, this is difficult to predict entirely accurately. Similarly, political opposition, particularly from groups connected with the existing system, is possible but unpredictable.

- Mention of political factors leads on to the matter of public policy issues; clearly, any new or radically altered modes must- in order to receive public funding and legislative assistance- comply with principles of policy in the Republic of Ireland and the UK (and, where appropriate, other countries) as well as EU policy. This is, of course, subject to the fact that policy was generally formulated with reference to existing modes, and that it can change noticeably over a strategic timeframe.

- The physical surroundings in which the transport system operates also act as constraints. Clearly, any new infrastructure will have to be compatible with the topographical, meteorological, geological and marine conditions, as appropriate, of the area into which it is inserted. It will also need to minimise deleterious impacts on the natural and human environments. This is an important point, particularly with respect to coastal areas. Independently of their infrastructure, sea and air modes must be compatible with the relevant meteorological conditions prevailing around Ireland.

- With regard to the previous section, it is clear that new modes should not contribute to inefficiency and congestion in the use of existing facilities; indeed, they should make a positive contribution, where possible, to relieving these problems. Where new facilities are involved, land availability is also an issue, not only from the point of view of the financial, environmental and human costs of land take, but also in terms of maintaining the availability of land for important non-transport purposes, e.g. high-grade

agricultural or residentially-zoned land. Financial resources must also be available for capital grants and (if necessary) operating subsidy to the system.

It was necessary to develop a series of criteria for the selection of modes and technologies for further consideration. This was done with particular regard to the background opportunities and constraints identified earlier in this chapter.

Logically, those modes currently in service in the market should be selected. Given that none are in such a state of decline as to imply their disappearance within an appropriate strategic timescale, they would, at the very least, form part of a realistic "do-minimum" strategy. Opportunities for development of the modes and their infrastructure also appear to exist (but will have to be considered in greater detail in the full technological review). This would suggest that appropriate development strategies could also be considered as "do-something" options.

It would also be highly appropriate to consider any new modes which have been proposed in the past for introduction into the Irish access system. These have been relatively few and far between, but such proposals have been made on occasion.

By extension, any modes proposed for operation, or actually in operation, in markets generally resembling Irish access transport- i.e. interregional, short/medium-range across water bodies (but with significant overland components to most trips)- are worthy of consideration at this stage. The Britain-Continental Europe market is an outstanding example in this regard; indeed, one currently existing mode in the Irish access market- the high-speed ferry- was introduced largely as a result of experience on English Channel crossings (KPMG and CHL 1990, 7.9.3).

Likewise, modes proposed as part of a Europe-wide system which included Ireland should enter into the analysis, providing that they are not excessively dependent upon the provision of large-scale infrastructure elsewhere in Europe. (However, most such modes will obviously already belong to the preceding category).

In terms of the feasibility of new modes, the essential criterion being imposed at this stage is that the mode should be commercially available in a form suitable for operation in the Irish access market by 2020, and preferably by 2010.

Finally, it is necessary to give some degree of consideration to how passengers and freight reach the terminals of the access services. As outlined earlier in this report, road and, to a lesser extent, rail are the major modes fulfilling this role at present, with a small contribution from air services for passengers and (on the European mainland) inland waterways for freight. It is considered unlikely that a completely new mode will evolve in this part of the market by 2020, but it is appropriate to consider possible developments of the existing modes, especially since variations in their characteristics are considered appropriate for inclusion in the strategic options.

3.6.2 Candidate technologies

There is, without doubt, a wide variety of modes and technologies capable of satisfying one or other of the selection criteria listed above. The first task in relation to this section of the chapter was to identify, in relation to each individual criterion, the modes which enter analysis on that basis.

In terms of existing modes, air and sea systems clearly must be considered. These in turn break down into several modes. Within air transport there are passenger and freight modes, the latter breaking down in its turn into dedicated services and those which share aircraft space with passengers. Within sea transport for passengers are the conventional and high-speed modes (which have different fare levels, speeds and vessel types, so may be considered distinct modes). Each of these in turn breaks down into accompanied car traffic, accompanied coach traffic and "classic" foot passengers. Within freight shipping are ro-ro and lo-lo modes, the former including accompanied and unaccompanied traffic. Account must also be taken of the limited ro-ro freight capacity offered on some high-speed vessels.

The future development of air (defined as heavier-than-air craft only) and sea transport modes encompasses, firstly, evolution of the vehicle types now in use- bigger, more economical on fuel, less weather-sensitive, etc. Secondly, new forms of technology, such as vertical/short take-off and landing (V/STOL) aircraft, may emerge. In the sea mode, high-speed vessels may well evolve into suitable vehicles for both ro-ro and lo-lo freight service. Other forms of high-speed sea transport, such as wing-in-ground-effect craft, may emerge as feasible alternatives to the present technologies.

Most prominent amongst the modes proposed in the past for introduction into the Irish access market has been some form of fixed link. This term would cover all options which proposed the provision of permanent infrastructure- bridge or tunnel- linking Ireland and Britain, on which some land-based mode (most likely rail or road, though more novel guided systems would be an outside possibility) would operate. Since there have been so many proposals in this area (Murray 1995), and at least one such is still current, the option is worthy of further investigation.

The principle of examining modes proposed in analogous markets leads to the introduction to the analysis of buoyant aircraft (airships) for both passenger and freight purposes, since both have been proposed in the English Channel and general European markets over the past thirty years (Mowforth 1974, 1991; Rynish 1971). This principle, along with that of examining Europe-wide network proposals, also validates several of the choices made above, particularly with respect to fixed links and alternative forms of high-speed surface craft.

It is therefore proposed that the modes selected for further analysis will be the following:

- Conventional sea transport systems, defined as those excluded from *Jane's High-speed Marine Transport* (Phillips 1999), i.e. maximum speed below about 45 km/h.
- Conventional air transport systems, defined as all heavier-than-air (i.e. the craft's empty weight is supported exclusively or almost exclusively by wing or rotor lift) vehicles, CTOL and V/STOL, passenger and freight, appropriate to the market.
- High-speed sea transport, including all systems covered by *Jane's High-speed Marine Transport*; conventional displacement vessels of catamaran or monohull form, hovercraft, hydrofoils and wing-in-ground-effect craft.
- Fixed links, including all forms of bridge and tunnel crossing for the use of land-based modes.
- Buoyant air transport systems, both fully buoyant (loaded weight supported almost exclusively by displacement of air, as in the classical airship) and partially buoyant (significant part of weight supported by wing or rotor lift).
- As stated above, the issue of future developments in the modes of "inland" access to terminals will also be considered, though concentrating on the existing road and rail modes.

At this stage, there is nothing to suggest that any of these modes could not fulfil the "commercially available by 2020" criterion set out above, at least in an optimistic scenario. Their ability to exploit opportunities and comply with constraints will be examined at a later stage, firstly in the initial analysis of systems later in this task and subsequently in the analysis of options, which will take place in a subsequent phase.

3.6.3 Summary of characteristics

A wide-ranging review of the characteristics of the transport modes identified above was carried out at an early stage of the research. The primary objectives of this work were to identify which measures might be worthy of further study and to quantify all data required for modelling and appraisal purposes. The review furnished a very considerable volume of data which cannot be reproduced in full within this thesis; the approach therefore has been to summarise concisely the principal results here, while providing more detailed information in Appendix B. Tables 3.7 and 3.8 below summarise key qualitative and quantitative results respectively.

Table 3.7 Key Qualitative Characteristics of Transport Modes

Mode	Technology	Scope	State of development	Possible payload types	General environmental impacts
Conventional air	Medium-range airliner	Narrow-body jet airliners, generally 100-200 seats	Operational	Foot passengers Light freight	High localised land take, high noise
	Regional jet	Narrow-body jet airliners below approx. 100 seats	Operational	Foot passengers Light freight	As medium-range airliner
	V/STOL	Aircraft capable of vertical or short take-offs/landings	In active military service; potential airline variant by 2010	Foot passengers	Lower land take than conventional air services but high noise
	Freight aircraft	All freight-carrying aircraft	Operational	Light freight	As medium-range airliner
Conventional sea	Bulk ship	All vessels carrying non-unitised freight e.g. tankers, bulk carriers, general cargo ships	Operational	Bulk freight	Potential water pollution effects, dredging/ reclamation for ports
	Ro-ro ferry	Vessels designed to carry freight on trucks/trailers; may also carry passengers and cars	Operational	Trailer freight Foot passengers Car-accompanied passengers	
	Container ship	All vessels designed primarily to carry containers	Operational	Containerised freight	

(continued over)

Table 3.7 continued

Mode	Technology	Scope	State of development	Possible payload types	General environmental impacts
High-speed sea	Fast catamaran	Twin-hull vessel with capability for operation above 60km/h	Operational	Trailer freight (large vessels only) Foot passengers Car-accompanied passengers	Disturbance of marine ecology, generation of waves
	Fast monohull	Single-hull vessel similar to above	Operational	Foot passengers Car-accompanied passengers	
	Medium/high-speed freighter	Freight-carrying vessel, faster than conventional freighters, usually slower than fast ro-ro vessels	Likely to be commercially available 2005-2010	Trailer freight Containerised freight	
	Wing-in-ground-effect	Vessel capable of operation just above water surface without pressurised cushion	Some experimental craft operational; initial commercial versions by 2010	Foot passengers Car-accompanied passengers	Noise, visual impact but less wave generation than conventional fast ferries

(continued over)

Table 3.7 continued

Mode	Technology	Scope	State of development	Possible payload types	General environmental impacts
Fixed links	Road link	Road bridge, tunnel or combination	Not extant, but technology has been proven elsewhere (though generally on shorter links)	Foot passengers (via coach) Car-accompanied passengers Trailer freight Containerised freight (on trailers)	Fixed links can have visual, marine ecological, coastline impacts depending on type
	Rail link	Rail bridge, tunnel or combination		Foot passengers Car-accompanied passengers Trailer freight Containerised freight Bulk freight	
Buoyant air	Airship	Aircraft supported primarily by lifting gas	Operational in small sizes; larger versions by 2010	Foot passengers Car-accompanied passengers Trailer freight Containerised freight	High visual impact but low noise/land take
	Dynastat	Aircraft supported by combination of lifting gas and dynamic (wing) lift	Under development	Foot passengers Car-accompanied passengers Trailer freight Containerised freight	Lower visual impact than airship (for comparable payload), higher noise and land requirements

Table 3.8 Key Quantitative Characteristics of Transport Modes

Mode	Technology	Operating speed (km/h)	Vehicle capacity	Capital costs	Operating costs	g CO_2 /p-km	g CO_2 /t-km
Conventional air	Medium-range airliner	700-900	100-200 passengers	€40-50M/aircraft	From €0.07/p-km on low-cost airlines to €0.17/p-km for full-service carriers	100-160	
	Regional jet	600-800	50-100 passengers	€20-30M/aircraft	€0.26/p-km typical	140-180	
	V/STOL	500-700	c.50 passengers	€20-30M/aircraft	€0.16/p-km typical	178 typical	
	Freight aircraft	500-900	50-100t	€20-50M/aircraft	€0.49/t-km typical		800-1,200
Conventional sea	Bulk ship	15-30	1,000t upwards	Extremely varied	€0.01/t-km typical		30 typical
	Ro-ro ferry	30-40	Up to 2,300 passengers plus 850 cars or over 5,000t freight	Up to €100 M/vessel	€0.1-0.15/t-km	35 typical	200 typical
	Container ship	20-30	Up to 8,000t	€25M/vessel typical	€0.01/t-km typical		24 typical

(continued over)

Table 3.8 continued

Mode	Technology	Operating speed (km/h)	Vehicle capacity	Capital costs	Operating costs	g CO_2 /p-km	g CO_2 /t-km
High-speed sea	Fast catamaran	65-75	400-1,500 passengers plus 80-300 cars; over 500t freight on largest craft	Up to €100 M/vessel	€0.3/p-km, €0.15/t-km	100-1,000	200-1,100
	Fast monohull		600-800 passengers plus 150-200 cars		€0.3/p-km typical		
	Medium/high-speed freighter	50-60	1,000-5,000t	€80M/vessel typical	From €0.03/t-km		100-200
	Wing-in-ground-effect	200-500	100-1,000 passengers, possibly also cars	Upwards of €30M/vessel	€0.24/p-km typical	391 typical	

(continued over)

Table 3.8 continued

Mode	Technology	Operating speed (km/h)	Vehicle capacity	Capital costs	Operating costs	g CO_2 /p-km	g CO_2 /t-km
Fixed links	Road link	60-80	Cars 5 passengers, coaches 50; trucks 25t	Potentially multi-billion € for fixed link	Cars typically €0.1-0.2/p-km, coaches €0.05-0.1/p-km, trucks €0.04-0.05/t-km; significant additional costs on fixed links	20 (coach), 100-110 (car)	54-102
	Rail link	100-200	500-1,000 passengers, up to several thousand t freight per train		€0.05-0.1/p-km, €0.01-0.03/t-km; significant additional costs on fixed links	40-70	20-50
Buoyant air	Airship	80-100	Freight 100-1,000t Passenger 50-1,000	€20-200M/craft	€0.05-0.5/t-km, €0.09-0.18/p-km	40-50	70-100
	Dynastat	160-200				71 typical	223 typical

3.6.4 "Soft" components

A transport system is not solely comprised of the "hard" elements of vehicles and infrastructure. "Soft" elements such as charges, taxes, traffic restrictions and logistics also play a very important part; in certain instances the effect of changes in this respect may be greater than that due to introducing a new or radically modified transport mode. Even where such a mode is introduced, its effectiveness might well be enhanced by an appropriate package of "soft" measures.

The primary "soft" measures of relevance in the present context are:

- Vehicle/passenger charges;
- Link-specific charges;
- Fuel/emission taxation;
- Subsidies;
- Management measures;
- Logistics.

Vehicle/passenger charges are monetary charges applied indiscriminately to every vehicle of a certain type or to every passenger using a certain mode, regardless of links used. Examples are road tax, area licences (a form of road pricing involving the display of a licence in order to enter a specific area, use the motorway system etc.) and national (but not location-specific) airport taxes.

Link-specific charges are charges applied according to the link used. The classic example is a road or bridge toll; airport-specific taxes would also be a relevant example in the present context. In particular, charging at the most congested ports and airports might be a worthwhile measure.

"Fuel/emission taxation" covers all taxation applied to fuels (including, where appropriate, that applied to electricity or to the resources used in producing it) used in Irish access transport (including the inland links). It also encompasses charges made on the basis of emissions, which may be implemented through fuel taxation or on some other basis. At present, only road fuel is taxed in Britain and Ireland, though taxation of air transport fuel

is frequently discussed.

The term "subsidies" encompasses all governmental assistance towards the capital or operating costs of transport infrastructure and services. In the past, virtually all forms of transport in Ireland and Britain have received considerable public assistance towards operating costs, but the practice is less widespread now, as a consequence of changing policy and the influence of EU competition legislation. The non-coverage of total social costs, including congestion, pollution, accidents etc., by revenue is not considered a subsidy for the purposes of this sub-section. It is not believed that any Irish access services by air or sea are currently the recipients of public subsidies. However, passenger rail services and some domestic air services are subsidised. Both modes have been granted significant capital sums towards the development of infrastructure (ports and airports) in both the Republic of Ireland and Northern Ireland over recent years, but policy is shifting away from this. Government, however, remains the principal source of capital funds for road and rail projects throughout Europe.

Management measures are non-monetary in nature and include a wide variety of restrictions on transport. These embrace spatial bans (e.g. prohibiting trucks in residential areas), temporal bans (e.g. the bans on weekend truck movements in some continental European countries) and volume restrictions ("capping" traffic levels through ports and airports, cutting road capacity by means of "traffic calming"). Licensing restrictions (where a licence is required to operate a vehicle, e.g. a truck, or a service, e.g. an air route, and quantity restrictions or other constraints are imposed) are a further category of measure. Some management measures are aimed at increasing system capacity; intelligent transport systems (ITS), or transport telematics, are an example of such an approach. This term covers a wide range of technological enhancements based on the application of information technology to the efficient operation of the transport system (traffic control, driver information, vehicle guidance etc.).

Logistics, as defined by Forfás (1996), consists of "the total management of the flow of raw materials, information and goods between suppliers and customers, integrating transport, infrastructure, services and information technology to maximise cost effectiveness, reliability, speed and flexibility for both". The same source identifies infrastructure, transport services and "systems logistics or overall management of the logistics chain" as the principal components of logistics. The third area, that of systems

logistics, is what principally concerns the present discussion. Systems logistics comprises many different elements; not all of these form part of what is understood as constituting the transport system. The contribution which improved logistical systems could make to expediting the numerous intermodal transfers inherent in the Irish access system is perhaps the area of greatest interest to this project. Faster and cheaper road-rail transfers and improved processing of freight through ports are areas where such improvements might find application.

4 COMPONENTS OF THE 2020 ACCESS TRANSPORT SYSTEM

4.1 INTRODUCTION

Task 2 of this project, summarised in section 3.6 of the preceding chapter, attempted to identify a series of individual measures which could potentially be incorporated into one or more strategies for the development of the Irish access transport system in the period to 2020. A preliminary attempt at enumerating and, where possible, quantifying the possible effects of such measures was made in the course of that task. This chapter describes how the aforementioned measures were developed to a level of detail appropriate to their use as inputs to the transport demand models in Task 5.

The initial list of candidate measures, as outlined in the preceding chapter and elaborated in Appendix B, included a number of transport technologies, namely:

- Conventional sea transport systems: measures might include expansion of services, a "decentralised" service pattern to relieve congestion and better serve peripheral regions, and/or the development of new or expanded ports, particularly as alternatives to the port of Dublin.
- Conventional air transport systems (including V/STOL): measures could include similar approaches to those described above for sea transport (i.e. expansion of existing services, decentralisation of services, new airports) and also potentially a V/STOL system, probably based on tiltrotor technology.
- High-speed sea transport: potential measures would be broadly similar to those for conventional sea transport, with the addition of high-speed freight services and potentially ultra-high-speed passenger/car (Seabus) services.
- Fixed links: the potential measure in this case would be the development of a rail tunnel between Dublin and Holyhead, with associated infrastructural and service improvements.
- Buoyant air (airships and "dynastat" hybrid craft): there is potential for the development of passenger and freight networks using this mode. In technological

terms, both roles could be fulfilled by either a fully-buoyant airship or partially-buoyant dynastat. However, only the dynastat would be capable of competing with airlines in the passenger market.

In addition, a number of "soft" measures were identified in the fields of :

- Vehicle/passenger charges;
- Link-specific charges;
- Fuel/emission taxation;
- Subsidies;
- Management measures;
- Logistics.

In these areas, the following individual measures were identified for further investigation:

- Taxation of all (or selected) modes so as to internalise external costs;
- Possible tolling of selected road links;
- Pricing measures to control traffic through the port and airport of Dublin;
- Subsidisation of selected access services;
- Improved logistics, possibly involving public subsidies, for road/rail transfers.

The remainder of this chapter deals with the detailed development of each individual element.

4.2 CONVENTIONAL AIR ELEMENTS

4.2.1 Decentralised service patterns

The technological review described in Appendix B identified the development of a "decentralised" pattern of air services as one possible way in which the present system could be enhanced. Under such a pattern, as developed for the purposes of this project, Irish airports would be classified into four categories.

Class 1 airports (Dublin being the only such) would develop very much along do-minimum lines, with a marginal reduction in service levels.

Class 2 airports (Cork, Shannon, both Belfast airports) would retain their do-minimum services and develop new mainline or low-cost air carrier routes to any of the following places not served under the do-minimum:

- Paris
- Frankfurt
- Amsterdam
- Glasgow
- Brussels

Any new services developed from Belfast would utilise the International airport.

Class 3 airports (Waterford, Galway, Kerry, Knock, Derry, Midlands) would develop new mainline or low-cost air carrier routes (where they did not already exist) to London Stansted. They would also develop regional air carrier routes to:

- Glasgow (Derry only)
- Manchester
- Birmingham
- Paris
- Brussels

Class 4 airports (Donegal, Sligo) would develop regional air carrier services to:

- Glasgow (Donegal only)
- Manchester
- Birmingham
- London Stansted

A net 25 additional regional airliners and one fewer conventional airliner would be required; the capital cost (for 15-year vehicle life and 3% annual traffic growth) would be about €1,803 million over thirty years.

4.2.2 Regional airport upgrades

Clearly, the increased traffic levels at regional (Class 3 and 4 in the terms used above) airports under a decentralised service pattern in Ireland imply a need for enhanced facilities. Most airports would require comparatively little upgrading. For the purposes of this project, Kerry, Knock, Derry, Donegal and Sligo are assumed to require an average of €5 million each (thus a total of €25 million) in capital investment for upgrading. Waterford and Galway would require significantly more, as the existing facilities would be unable to cope with the size of aircraft implied by this service pattern.

At Galway, it is assumed that the proposed replacement airport at Oranmore (supplanting the current Carnmore facility) is constructed at a cost of around €30 million. A runway extension costing €8 million would be required at Waterford.

4.2.3 Midlands regional airport

The only location where an entirely new airport (as opposed to a replacement for an existing facility) appears to be required to support a decentralised service pattern as described above is in the Midlands region of Ireland. This is assumed to be a facility capable of handling aircraft up to the size of the Boeing 737-800 and Airbus A321.

Several criteria enter into selection of a site. These include:

- Proximity to the national road network.
- Proximity to the population centres of the region (principally Athlone but also Mullingar, Portlaoise, Tullamore and Longford).
- Sufficient remoteness from competing airports to avoid either causing significant loss of traffic by other regional airports (e.g. Galway) or a disadvantageous competitive position relative to a major airport (e.g. Dublin).

- Availability of land.
- Minimal environmental impact.

The prime candidates appear to be the existing airfield at Abbeyshrule, the Rochfortbridge area and the recently proposed site at Doon, between Tullamore and Athlone; all three have been advocated at various times as sites for a Midlands airport. Doon appears the most suitable site on grounds of location relative to the national road system and principal population centres; accordingly, it is suggested that it should be chosen.

The Midlands airport would be comparable in scale to the proposed replacement airport at Galway or the present facilities at Kerry and Knock. An investment of roughly €30 million would be required.

4.2.4 Second Dublin airport

The development of new airport (and port) facilities close to existing congested ones (principally in the Dublin area) has also been identified as a possible approach to enhancement of services (see also Appendix B). For the purposes of this project, any second Dublin airport is assumed:

- To be sited within the Greater Dublin Area.
- To have a single runway and a capacity of 15-20 million passengers per annum (mppa).

Given this, the prime candidate would be a development of the existing Baldonnel military airfield. Alternative sites would reduce the noise nuisance compared to Baldonnel, but would be too far from the Dublin metropolitan area to compete effectively with the existing airport and would be likely to be unviably expensive for a single-runway installation.

There is a wider question as to whether significant additional airport capacity should ultimately be developed in Greater Dublin, and, if so, where, when and in what form. The author intends to limit this project to an examination of the possibilities of Baldonnel, although this is not to deny that a more ambitious scheme may deserve examination, nor that it would significantly affect the pattern of Irish access transport.

It is assumed that all low-cost airline services would be transferred to Baldonnel from the existing Dublin airport. No other passenger services would operate from Baldonnel. While this is probably not a perfectly realistic representation of what would happen in reality, it is quite reasonable given the history of the Baldonnel airport proposals (which concentrated on low-cost traffic) and the difficulties of modelling competition between airports. An increase in the frequency of service is assumed on most such routes, compared to the "without Baldonnel" case (see Appendix H). It is assumed that existing freight services would not transfer to Baldonnel, but that a new high-capacity "air bridge" service (see 4.2.6 below) would utilise Baldonnel as its Dublin terminal.

Warburg Dillon Read et al. (2000) quote a cost of £60 million for a 2mppa facility at Baldonnel and £100 million for 5mppa. Hence, £300 million (€380.9 million) for 20mppa would be a reasonable extrapolation. A figure of €400 million is assumed in order to cover certain landside transport infrastructure enhancements.

4.2.5 V/STOL services and infrastructure

Chapter 3 and Appendix B identified a vertical/short take-off and landing (V/STOL) air transport system as a possible strategy element. The V/STOL technology used is assumed to be the tiltrotor and the vehicle is assumed to be identical to the hypothetical CTR2000 design (see Appendix B). The route structure is summarised in Appendix H.

In this case, all current mainline/regional air carrier services between Class 3 and 4 airports and Britain would be withdrawn. The present low-cost services from Derry, Knock and Kerry to London Stansted would, however, be unaffected, as would domestic flights within Ireland.

Approximately 51 vehicles would be required for this pattern of services, along with new city-centre vertiports in Dublin, Glasgow, Manchester, Birmingham and London. Existing VTOL facilities at London Heathrow and Manchester airports would need expansion. No significant investment would be required at the other airports in the system. A total level of investment in the region of €100 million would be involved.

The vehicles (assuming a 15-year lifetime and 3% annual demand growth) would have a 30-year capital cost in the region of €2,518 million.

4.2.6 "Air bridge"

This concept involves the operation of a frequent, high-capacity air freight service between one or more points in Ireland and one or more points in Britain and/or continental Europe. For the purposes of this project, the "air bridge" service is assumed to comprise routes linking Dublin, Cork, Shannon, Knock and Belfast to London and Brussels; further details are given in Appendix H.

The freight charge is assumed to be €0.25/t-km, approximately half of that for conventional air freight, with the difference being made up by public subsidy. Operating speed, transfer costs and times are assumed equal to those for conventional air freight operations.

4.2.7 Likely do-minimum enhancements

A quadrupling of air passenger demand in the period 1995-2020 is assumed for the purposes of developing the do-minimum strategy. Where airport capacity allows, frequency is expanded to meet this demand. In congested areas, expansion of frequency is severely limited (as at London Heathrow)[1]. The modifications to air services resulting are indicated in Appendix H.

[1] There is a distinct possibility that a further runway will be in operation in the London area by 2020, although the possible site cannot be predicted at this stage. Given the level of uncertainty surrounding this, and the poor implementation record of such schemes in the past, only London's existing airport capacity is assumed to be available in 2020.

4.3 CONVENTIONAL SEA ELEMENTS

4.3.1 Decentralised service patterns

If an option involving widespread diversion of traffic away from the Dublin area to remote, uncongested ports were chosen, a different pattern of services would be necessary. Extensive development of new routes from Drogheda and Arklow, in order to relieve Dublin, would be part of this policy (see also 4.3.2 below). Additionally, new routes would be developed from Derry, and there would be greater development of routes from the existing southern and southeastern ports at the expense of Dublin. Modified service patterns are described further in Appendix H.

4.3.2 Drogheda/Arklow port upgrades

One means of alleviating congestion at Dublin Port would be to divert traffic to alternative east-coast ports. The possibility of a new "greenfield" port is covered in the next sub-section, but there is also scope for the use of other, existing ports close to Dublin as "relievers".

The two prime candidates in this field are Drogheda (including possible development on the south shore of the Boyne estuary, which would technically not form part of Drogheda port) and Arklow. Both are existing commercial ports, and in Drogheda's case there is a limited existing container service. Both are either within or on the fringes of the Greater Dublin Area, and dovetail well with the proposed outer ring road scheme for the region (although Arklow would require an extension of the road). Both are well-served by existing main roads, and there is the possibility of a rail link at Drogheda. Both ports have developed plans for significant expansion, including ro-ro facilities, in recent years.

The scheme assumed for the purposes of this project involves the development of a new ro-ro port near Arklow Head, with a road link to the N11. The route from Portlaoise to Arklow via Carlow and Aughrim (N82/R727/R747), linking to the Dublin outer ring via

the N9/M9, would be upgraded. Ro-ro ferry services would operate on the Arklow-Fishguard and Arklow-Holyhead routes.

At Drogheda, a new ro-ro and lo-lo port would be developed on the lower Boyne estuary. Ro-ro services would operate to Liverpool and Holyhead and lo-lo to Liverpool, Le Havre and Rotterdam. A road link between the port and the Drogheda ring road (connecting to the M1 and proposed outer ring) would be provided. €60 million of port investment for ro-ro traffic is assumed at Drogheda, plus €40 million at Arklow. An additional €20 million is assumed for lo-lo facilities (principally upgrading existing facilities) at Drogheda. Road infrastructure at Drogheda is assumed to cost €10 million and at Arklow (including upgrading inland as far as Portlaoise) €70 million. Thus the total infrastructural capital cost of the Drogheda/Arklow package would come to €200 million.

4.3.3 Second Dublin port

An alternative to developing existing ports near Dublin would be the construction of a new port on a "greenfield" site in the region. Topography, built-up areas and the need to locate the facility closer to Dublin than existing (potential competitor) ports such as Drogheda limit the search area to the section of coastline between Malahide and Drogheda. The one-time ESB International proposal for a greenfield port specified a site at Loughshinny, in this area.

Within the search area, there are three potential locations for a port; on the Portrane peninsula, in the Loughshinny area and between Balbriggan and Laytown. However, the last-named site is somewhat close to Drogheda and remote from Dublin; there may also be some doubts about access to deep, sheltered water. This therefore leaves a choice between Loughshinny and Portrane.

Loughshinny appears to be the more favourable location of the two, because of greater remoteness from local population centres and less interference with ecology and heritage. It has therefore been selected.

It is assumed that the second port would handle ro-ro traffic only. Although the ESB proposal for Loughshinny was a general-purpose unitised port handling both lo-lo and ro-

ro traffic, it was conceived as a replacement for the existing unitised facilities at Dublin Port. The focus of attention appears now to have shifted towards a competitor/reliever port (rather than a full replacement). The ro-ro market is clearly the area on which any efforts in this field should concentrate, because of the more severe constraints on ro-ro operation at Dublin arising from the high volume of traffic compared to lo-lo, the absence of a rail option for ro-ro traffic and the greater manoeuvring space requirements of trailer traffic.

The ESB proposal was costed at £160 million in 1989 prices; KPMG and CHL (1990) considered that certain aspects had been underestimated, but did not offer an alternative capital cost figure.

It is assumed that the facility is limited to ro-ro traffic and that it has the capacity to handle roughly half of the total Dublin Bay market for such traffic. The ESB proposal assumed a capacity of 10 million tonnes per annum, lo-lo and ro-ro combined. In 1999, Dublin Port handled approximately 6 million tonnes of ro-ro and 4 million tonnes of lo-lo traffic; the total volume of unitised freight through all ports in the country was about 75% higher in 1999 than in 1995 (the base year for this study).

An overall Dublin area market of about 12-15 million tonnes per annum of ro-ro traffic would be a reasonable assumption for 2020; this suggests that a second port would require a capacity of 6-8 million tonnes per annum, or 60-80% of the ESB scheme's. Because this capacity would be entirely ro-ro (and thus would not require container stacking space or cranes) the reduction in capital cost arising from the omission of lo-lo facilities would be higher than the proportionate reduction in traffic volume. Accordingly, a capital cost of £100 million at 1989 prices, equating to €150 million in 1999 prices, is assumed for the port itself. A further €50 million is allocated for road access provisions. Thus a capital cost of approximately €200 million is involved in this development.

4.3.4 Likely do-minimum enhancements

It has been assumed that shipping demand (passenger and freight) will increase by a factor of three in the period 1995-2020, and that capacity will expand to meet it. The forecasts of Davies (1998) have again been used as a basis. Capacity expansion can take the form either

of increased frequency or the use of larger vessels; in practice, it is likely that some combination will be applied. Appendix H summarises the likely impact on service patterns.

The evidence of trends in ro-ro shipping to date suggests that the average vessel size in this market will have approximately doubled, to roughly 60,000 gross tons, by 2020. Therefore, a 50% increase in frequency (and thus fleet numbers) will be required to meet the target of three times 1995 capacity. However, allowance must be made for an increased fast ferry market share, which will reduce the requirement for conventional ferries somewhat. Fast ferry sizes are assumed to follow a similar trend to those of conventional vessels, i.e. approximately doubling (though of course from a lower base).

In the lo-lo market, a similar trebling of demand is assumed. There seems no compelling reason, however, to assume any significant increase in average vessel size. Again, a portion of the demand increase is assumed to be met by high-speed vessels, in this case 30-knot lo-lo ships.

4.4 HIGH-SPEED SEA ELEMENTS

4.4.1 Expanded/decentralised service patterns

For the case of expanded service (reflecting high investment) the high-speed sea routes added to the system (aside from Seabus routes) would be:

- Dublin-Bristol (fast lo-lo).
- Cork-Bristol (fast lo-lo).
- Dublin-Le Havre (fast lo-lo).
- Belfast-Rotterdam (fast lo-lo).
- Belfast-Liverpool (fast lo-lo).
- Cork-Rotterdam (fast lo-lo).
- Waterford-Rotterdam (fast lo-lo).
- Rosslare-Roscoff (fast passenger/freight ferry).

The following routes would be withdrawn:

- Rosslare-Roscoff (conventional passenger/freight ferry; replaced by fast ferry).
- Dublin-Liverpool (fast ferry; replaced by Seabus and fast ferry from new Dublin port; existing lo-lo and conventional ferry services unaffected).
- Rosslare-Fishguard (fast ferry; partially replaced by Seabus to Bristol).
- Belfast-Troon (fast ferry; replaced by Seabus to Glasgow).

In a decentralised service pattern, the following new routes would be added:

- Drogheda-Holyhead (fast passenger/freight ferry).
- Drogheda-Liverpool (conventional passenger/freight ferry).
- Arklow-Holyhead (fast passenger/freight ferry).
- Arklow-Fishguard (fast passenger/freight ferry).
- Rosslare-Roscoff (fast passenger/freight ferry).
- Waterford-Le Havre (fast lo-lo).
- Waterford-Rotterdam (fast lo-lo).
- Cork-Le Havre (fast lo-lo).
- Cork-Rotterdam (fast lo-lo).
- Cork-Bristol (fast passenger/freight ferry).
- Derry-Troon (fast passenger/freight ferry).
- Belfast-Le Havre (fast lo-lo).
- Belfast-Rotterdam (fast lo-lo).
- Belfast-Liverpool (fast passenger/freight ferry).

Only the Rosslare-Roscoff conventional ferry would be withdrawn. The Rosslare-Fishguard fast ferry is assumed to be reintroduced as a passenger/freight service.

Further details of service changes are given in Appendix H.

4.4.2 High-speed freight services

High-speed freight-only vessels are assumed to be similar to the Blohm+Voss Fast Trailer Carrier (see Appendix B.5). A basic network linking Dublin and Belfast to Rotterdam was

assumed in the 2020 do-minimum case, with enhancements in the high investment and managed demand strategies. Further details are in Appendix H.

4.4.3 Seabus services

Chapter 3 and Appendix B found that the Seabus wing-in-ground-effect ultra-high-speed ferry was a potential contributor to an enhanced future access transport system. The notional network for this mode would be:

- Dún Laoghaire-Liverpool.
- Rosslare-Bristol.
- Cork-Bristol.
- Belfast-Glasgow.
- Belfast-Liverpool.

More information on the service pattern is available in Appendix H.

Connections with rail services would be provided at the terminals. It is envisaged that Seabuses would operate in a passenger/car configuration, carrying car-accompanied, coach and "classic" passengers. They would not convey freight.

A total of eight Seabus vessels is likely to be necessary. Over a 30-year period (assuming a 15-year vehicle life and 3% annual demand growth) the capital cost would come to about €612 million.

4.4.4 Likely do-minimum enhancements

Those enhancements to the high-speed sea transport system which are likely to occur in any case are summarised in Appendix H. The principal qualitative differences between the 1995 and do-minimum 2020 situations relate to the transport of freight on high-speed ro-ro ferry routes (which was impossible in 1995 but is assumed possible on all routes in 2020;

in 2001, a limited number of such routes carry freight) and to the introduction of a small number of fast container freighter services.

4.5 FIXED LINK ELEMENTS

4.5.1 Choice of corridor and technology

Any notional fixed link between Britain and Ireland could take a variety of routes. These would broadly correspond to the Northern, Central and Southern Corridors identified in sub-section 2.5.2 of this thesis; however, a choice of routes exists within some of the corridors. The author has identified six possible options, based on Nolan (1990), Murray (1995) and Davies (1998); further details are given in Appendix B. Figure 4.1 below shows the six routes.

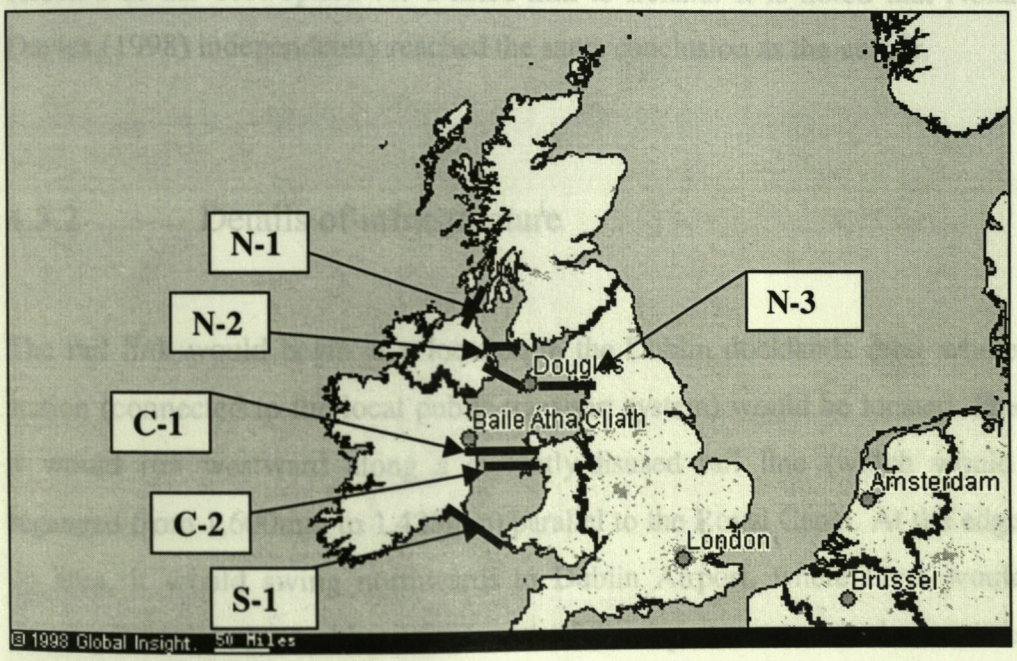


Figure 4.1 Possible Irish Sea fixed link corridors

The link could also be a bridge, bridge/tunnel combination, bored tunnel, immersed tube tunnel or submerged floating tunnel and could carry a railway, road or both modes. The decisions on link type and mode interact insofar as tunnels are more suitable for rail than road, particularly at this length (due to diameter and ventilation requirements), while a bridge-tunnel would probably involve gradients too extreme for rail. Bored tunnels and submerged floating tunnels were ultimately ruled out on technical grounds.

The author identified options N-2 and C-1 as the only ones of the six not to involve prohibitive expense in constructing road and rail links to the tunnel portals. N-2 could be either a road bridge, road/rail bridge, immersed tube road tunnel or immersed tube rail tunnel; C-1 would be an immersed tube rail tunnel.

The N-2 option would offer a shorter, and thus theoretically cheaper, tunnel. However, this is balanced by increased inland access costs. The seabed conditions in the area might pose greater difficulties than those on the C-1 corridor. The alignment is close to the busy Northern Ireland-Scotland (Northern Corridor) shipping route but poorly situated for the principal desire lines. The C-1 option would be longer and more expensive in tunnelling terms; however, access costs would be much lower, undersea conditions simpler, and the route apparently more favourably placed to attract traffic (particularly passenger). Therefore, a rail immersed tube tunnel between the Dublin area and Holyhead has been selected as the best option for a fixed link to Ireland. It is noted that Nolan (1990) and Davies (1998) independently reached the same conclusion as the author.

4.5.2 Details of infrastructure

The rail link would begin at a location in the Dublin docklands area, where a passenger station (connected to the local public transport system) would be located. From this point, it would run westward along a currently-disused rail line (which would need to be regauged from 1,600mm to 1,435mm) parallel to the Royal Canal. At the edge of the built-up area, it would swing northwards to Dublin Airport, where there would be another passenger station. It would continue north of the airport to a terminal site north of Swords.

At the latter location would be facilities for loading and unloading vehicle shuttle trains, through piggyback trains and through container trains. There would also be provision for gauge-changing on freight wagons and a spur connecting the terminal to the Dublin-Belfast line for exchange of freight traffic. A maintenance depot for shuttle and through passenger trains would be located adjacent to the terminal.

The line would then turn eastwards, entering the tunnel to the south of Portrane and continuing along the bed of the Irish Sea. The tunnel would generally run to the north of, but parallel to, the main Dublin Bay-Holyhead shipping lanes. It would make landfall at

Penrhos (on the eastern tip of Holy Island, just east of Holyhead), the Welsh terminal being situated at Valley on Anglesey.

Supporting measures for the tunnel scheme include road improvements between Holyhead and the British motorway system and locally around the terminals, plus the upgrading and electrification of the Crewe-Holyhead railway (North Wales Coast Line).

A cost of €22,000 million is assumed for the tunnel infrastructure (including upgrades to the North Wales Coast Line and a rail link to Dublin). Supporting road infrastructure- including a Dublin- North West Ireland upgrade- would come to about €1,666 million, based on road construction/upgrading costs quoted by O'Sullivan and Scetauroute (1998) and the analysis of required measures conducted in Task 2.

4.5.3 Service patterns

Shuttle services for vehicles and accompanying personnel would operate between the two terminals.

Through passenger services would operate on the following basis:

- Dublin-London direct: hourly.
- Dublin-London via Birmingham: hourly.
- Dublin-Manchester: hourly.
- Dublin-Liverpool: 8/day.
- Dublin-Paris: 4/day.
- Dublin-Brussels: 4/day.

No overnight through passenger services are assumed.

It is not necessary to make any specific provision for a pattern of through freight operations. The link is assumed to connect with existing freight-carrying railways at either end, though of course a break of gauge is involved at the Irish terminal. A rail/road transhipment facility is also assumed at the latter point. The piggyback rail network (apart

from shuttle trains between the terminals) would comprise services from Dublin to London and Lille.

Shuttle rolling stock is assumed to be included in the capital cost of the tunnel, as per the author's communications with Gareth Davies. Through passenger services would require approximately 30 trains, the unit cost of which is likely to be around €40 million (allowing for safety modifications), thus giving a total spend of around €1,200 million over 30 years.

Fifteen locomotives, probably costing about €4 million each (thus €60 million in total) are assumed necessary for through freight operations (permitting approximately one freight train per hour in each direction between Dublin and the London area). This does not include locomotives required for shuttle trains (included in the tunnel's capital costs) or for longer-distance piggyback services (dealt with below).

The piggyback service pattern would comprise 15 trains per day in each direction between Dublin and Lille plus 9 between Dublin and London. A total of 23 trains would be required. If each consisted of two locomotives and twenty wagons, €650 million would be a reasonable estimate of the total capital cost.

4.6 BUOYANT AIR ELEMENTS

4.6.1 The choice between airship and dynastat

Appendix B describes in more detail the two major concepts of relevance to this study in the field of buoyant aircraft, the fully-buoyant airship and the partially-buoyant (with the remaining weight being supported dynamically, i.e. by wing lift) dynastat or hybrid airship. A preliminary analysis pointed towards dynastats as being the only buoyant air technology likely to be competitive in the passenger transport market, at least in the Irish access context. Analysis of speeds and door-to-door times suggested that a conventional airship could not realistically compete with airlines on the vast majority of Ireland-Britain routes, and preliminary economic analysis suggested that fares would be too high for the airship to compete with coaches and ferries. However, the dynastat promised broadly airline-competitive door-to-door times and fares (though the latter would be higher than those for a conventional airship and thus less competitive with surface transport).

Technological investigations into the feasibility of a craft of this type concentrated on the SkyCat series (see Appendix B) and on the modified version of the mid-1970s Goodyear Aerospace project, also described in Appendix B. The larger versions of the SkyCat were considered too large for the Ireland-Britain passenger market, and the smaller ones both too small for certain routes and insufficiently fast to be generally competitive with airlines. (The range of craft sizes from 200 to 500 passengers would appear best suited to a compromise between serving the maximum number of routes and efficient handling of the passenger volumes on the busiest services.) Analysis for passenger transport purposes therefore concentrated on the modified Goodyear concept. Some thought was given to the potential for a heavily modified version of the SkyCat, or even a craft developed in outline form from first principles, but detailed investigation of these possibilities would have been too time-consuming and presented numerous practical difficulties.

The dynastat was chosen for freight transport primarily because the SkyCat project, in unmodified form, appeared highly suitable for the freight segment of the Irish access market (minimal ground infrastructure needs, ro-ro capability, etc.). There was no overriding requirement for high speed; obviously, however, within reasonable cost and environmental impact limits, a faster buoyant aircraft would be better able to compete with surface systems. Economic analysis was based around the SkyCat 1000 (i.e. 1,000t payload) and used information from a number of sources on freight airship operating costs.

4.6.2 Passenger services

Initial analysis has concentrated on Ireland-Britain services, on the grounds that buoyant aircraft probably could not deliver airline-competitive travel times on routes between Ireland and mainland Europe. A second-round option incorporating Ireland-mainland Europe routes was later modelled.

Levels of service have been based on an assumption that the buoyant aircraft captures approximately 40% of the market. In the vast majority of cases, city-centre terminals are assumed. Further details of the network are given at Appendix H.

A variant network was also developed for second-round testing. This included the following modifications:

- Introduction of services from Dublin to Paris, Brussels and Amsterdam;
- Introduction of a second terminal point in London, at Heathrow airport;
- Transfer of part of the Dublin-London and Belfast-London services to Heathrow;
- Transfer of all services from smaller airports (those with no existing Heathrow service by conventional airline) to Heathrow;
- Introduction of services between Heathrow and additional smaller airports (.g. Waterford);
- Introduction of services between Baldonnel and central London.

It is also described in Appendix H.

4.6.3 Freight services

Buoyant air freight services are based on broadly similar routing to the "air bridge" described at 4.2.6 above. As described above, the use of SkyCat 1000 or a similar vehicle is assumed. Further details are in Appendix H.

4.7 TERMINAL ACCESS ELEMENTS

4.7.1 The do-minimum road network

This network assumes the completion of all currently-programmed improvements, specifically:

- The 2000-2006 National Development Plan projects for motorway/dual-carriageway roads from Dublin to Dundalk, Waterford, Cork, Limerick and Galway.
- Completion of the Dublin motorway ring (including the Port Tunnel, Eastern Bypass and South East Motorway).

- An outer Dublin ring road from Drogheda to Naas, constructed to dual-carriageway or motorway standard.

Improvements to British or mainland European road networks are not considered in detail.

4.7.2 The do-minimum rail network

Few major improvements in the rail system are assumed. Where the frequency of passenger trains is represented in the model (i.e. within Ireland only) it is assumed to increase somewhat. The do-minimum strategy also assumes a rail link to Dublin Airport. The Central Railway scheme, involving the provision of a rail link suitable for piggyback (road trailer on rail vehicle) freight traffic between Liverpool and the Channel Tunnel, is assumed to be complete by 2020. In the case of a fixed link option, a high-speed (300km/h) railway is assumed to be constructed between the London area and the West Midlands by 2020.

4.7.3 Dublin port rail link improvements

There have been numerous proposals over the last ten to fifteen years for an enhancement of the existing rail facilities in the port of Dublin. Indeed, a short extension, reconnecting lo-lo berths to the rail network, opened in recent years. Further improvements are believed to be under consideration at the time of writing.

The basic element of the improved rail link to Dublin Port is a rail extension connecting the berths on the south bank of the Liffey to the existing network. This was costed at IR£7 million by KPMG and CHL (1990), which is assumed to correspond to €11 million at 1999 prices. An additional €5 million is allocated for improvements to the existing rail network on the north bank of the Liffey.

An inland terminal facility was proposed in the past for a site in the west Dublin area and costed at around IR£100 million, apparently inclusive of warehousing and other supporting facilities, in the mid-1990s. For the purposes of this project, €80 million is assumed to

cover all the infrastructure directly associated with the road-rail transfer function and any storage of containers. €40 million is allocated to improvements in rolling stock. No subsidy increases are assumed.

The total capital cost of this package is therefore €136 million in its basic form. A more extreme version was also developed; this would involve subsidisation of road-rail transfers in Ireland (subsidisation of the entire road-rail transfer cost incurred at the terminal is assumed, although shippers would still have to meet any additional inventory costs, and the rail line-haul costs, themselves), investment in six additional terminals (assumed to cost €40 million each) plus €100 million of additional rolling stock investment. Thus, the cost of this extended variant would be in the region of €476 million.

4.7.4 Piggyback rail freight services

Apart from piggyback services associated with a fixed link (which are considered in more detail at 4.5 above), the only additional (to do-minimum) services considered are routes linking Holyhead to London and Lille via the proposed Central Railway (which itself forms part of the do-minimum situation).

In order for these services to operate, it would be necessary to upgrade the Crewe-Holyhead railway line (plus a connecting section between the Crewe area and Central Railway) to provide the required clearances for piggyback traffic. A cost of perhaps €30 million would be involved in upgrading infrastructure and providing terminal facilities, assuming continued diesel operation (which would necessitate a change of locomotive on joining the electrically-worked Central Railway system). If the service level were similar to that proposed for the fixed link, around 21 trains (versus 23 in the fixed-link case; the reduced requirement is due to trains not running through to Dublin) would be required. €595 million would be a reasonable estimate of the capital cost. Thus, a total investment in the region of €625 million would be involved in providing piggyback services from Holyhead.

4.7.5 Shannon airport rail link

This element assumes the provision of rail services from Limerick and Galway to Shannon airport, involving realignment of the Limerick-Ennis railway and completion of the Western Corridor passenger rail upgrade (see 4.7.9 below). The capital costs directly related to the Limerick-Galway corridor (including service to the airport) are estimated at €200 million. Additional costs associated with the Limerick-Rosslare section of the western rail corridor are not included under this heading and are estimated at 4.7.9 below.

4.7.6 Belfast International Airport rail link

This scheme would involve diversion of the Belfast-Derry rail route to serve Belfast International (Aldergrove) airport. The link would be serviced by through trains to Derry, commuter services and a dedicated airport service. A cost of around €20 million would be involved.

4.7.7 Dublin- North West road upgrade

Improvement of the Dublin-North West road network would involve a new Dublin-Sligo dual carriageway link, connecting with the Northern Irish road system and with the improved Western Corridor (see below). The capital cost would depend on the route chosen, but, for what is probably the cheapest option (largely following the existing N4), €866 million would be an indicative figure. However, an option providing links to a greater range of destinations (in particular, to both Derry and Sligo) would have a cost nearer €1,250 million.

4.7.8 Western Corridor road upgrade

This project would involve providing dual carriageway on any of those portions of the Western Corridor (Rosslare-Waterford-Limerick-Galway-Sligo), plus its extension to Letterkenny and continuation within Northern Ireland to Derry, Larne and Belfast, not

attaining this level of service under the do-minimum. A cost of about €2,600 million would be involved in this upgrade.

4.7.9 Western Corridor rail upgrade

This scheme assumes the completion of the Limerick-Shannon-Galway upgrade described at 4.7.5 above but would also include upgrading of the Limerick-Rosslare line for both passenger and freight traffic. An additional cost of €100 million is assumed.

4.8 "SOFT" ELEMENTS

4.8.1 Dublin area road tolling

The tolling of national roads at the fringes of the Greater Dublin Area (in order to divert traffic away from Dublin's port and airport) was considered as an option in earlier stages of the project. However, on investigating it further, it appeared that there would be significant problems in choosing an appropriate cordon location and in terms of impacts on other sectors of the transport system. Direct taxation of traffic passing through the port and airport appeared to be a superior option, and hence was chosen in preference.

4.8.2 Logistical elements

The key logistical element investigated in this project- ignoring for the present time the fact that most of the "soft" elements described here could be argued to be logistical in nature- is that of providing a number of inland "logistics centres". These could complement ports by allowing warehousing and road freight terminal activities to take place on the more spacious inland site, with shuttle trains linking the logistics centre with the port. Aspects of this concept are covered in greater detail at 4.7.3 above and 4.8.3 below.

4.8.3 Subsidies

Two key areas for subsidy to the access transport system were considered. The first is the subsidisation of air freight services to provide a high-capacity, relatively low-cost "air bridge" connecting Ireland to principal markets. This measure has been considered on several occasions since the late 1980s. It is referred to, in various forms, by KPMG and CHL (1990), Transport Policy Research Institute (1995) and a number of others.

The second is somewhat more radical and has not thus far been proposed for Ireland in the exact form suggested by the author. It would involve subsidisation of transfers between road and rail freight transport at selected locations, as a complement to an inland terminal/ "logistics centre" network of the type briefly outlined at 4.8.2 above. See also sub-section 4.7.3 above.

Apart from these two key areas, the issue of subsidisation of airline or ferry services on certain "thin" routes may arise. However, this has not been addressed explicitly in the context of the present research.

It should be noted that "subsidy" is here defined solely in terms of assistance towards operating costs. Public assistance towards the capital costs of access transport vehicles would be difficult to implement within EU law. However, public funding for certain infrastructure capital costs is assumed.

4.8.4 Taxation

The key taxation measures considered in the context of this project are:

- Taxes per passenger-or-tonne-kilometre, designed to internalise the external costs of the relevant transport mode.
- Taxes per passenger or tonne passing through congested ports and airports.

In the first case, the tax rates are set exactly equal to the external costs, the calculation of which is described in chapter 7 and Appendix B of this document. A variant was also

developed for the combined strategy; this involved concentration on those transport modes where the overall external cost (taking account of both number of passenger-or-tonne-kilometres produced and unit external cost) was highest and the savings from the use of alternative modes greatest. Furthermore, the level of charges was reduced to one sufficient only to cover the difference between the external costs of the mode and its alternative, rather than full external costs (though, of course, the *difference* in user costs between the modes would not be reduced, since the alternative modes would not be subject to charging). In its final form, this variant involved the following:

- Charging car users €0.014/p-km, the difference between car and rail external costs.
- Charging air passengers by all airline types (coincidentally) €0.014/p-km, the difference between mainline or low-cost airline external costs and buoyant air external costs. Regional airlines incur higher external costs, but the charge was held constant to avoid penalising peripheral regions heavily reliant on such carriers.

In the second case, the following assumptions are made:

- Taxes are only levied on passenger traffic through Dublin airport and on freight traffic through Dublin and Dún Laoghaire ports.
- The level of taxation is €10 per passenger (in each direction) at Dublin airport and €1 per tonne at Dublin and Dún Laoghaire ports.
- Rail freight traffic through Dublin port is exempt from the tax.

4.8.5 Do-minimum position

The decision was made to assume no material change in transport taxation and subsidy policies up to 2020. This was primarily due to the extreme difficulty of "second-guessing" changes in public policy and background (e.g. oil availability) over the period in question. Therefore, the do-minimum situation in these respects is assumed identical to the base year situation. While it is possible to foresee changes in certain other "soft" aspects of transport policy (for instance, greater promotion of competition), it is difficult to quantify the exact impact of such policies.

5 SCENARIOS AND STRATEGIES FOR THE FUTURE

5.1 PURPOSE OF SCENARIOS AND STRATEGIES

The concepts of scenarios and strategies are of considerable importance to this project. They represent two distinct but interacting fields. Scenarios are alternative sets of values for "background" variables (those which are important to the system, but outside its scope) such as population and economic performance. Strategies represent alternative solutions for the development of the transport system itself, each being built up from a series of the strategy elements described in chapter 4. The scenario concept is described in section 5.2 below and the scenarios themselves in section 5.3. General issues relating to strategies are discussed in section 5.4 and the strategies described in section 5.5.

Each strategy may theoretically be tested under one or more scenarios. In practice, there was insufficient time to permit the use of alternatives to the "central" scenario in testing, but alternative scenarios have been developed in outline.

A number of strategies have been developed, including a do-minimum strategy and four do-something strategies in the first round of modelling, and two additional do-something strategies in the second round. An outline description of the strategies is given in section 5.5 of this chapter. The strategy elements are described in greater detail by chapter 4 and the results of model testing on the strategies by chapter 8.

5.2 SCENARIOS-AN OVERVIEW

5.2.1 The scenario concept

The fundamental idea underlying the use of scenarios is the representation of a number of alternative futures, in order to reflect the considerable uncertainty which must always exist

in respect of future trends in areas such as economic growth, population, employment and so forth.

Porter (1998, pp.446-447) writes that:

"By constructing multiple scenarios, a firm can systematically explore the possible consequences of uncertainty for its choice of strategies".

"Scenarios are a powerful device for taking account of uncertainty in making strategic choices. They allow a firm to move away from dangerous, single-point forecasts of the future in instances where the future cannot be predicted".

Porter continues with a more specific description of industry scenarios (i.e. scenarios of an industry's future structure developed for the purposes of a firm's forward planning). However, many of his comments are of more general interest (Porter 1998, p.448):

"An industry scenario is an internally consistent view of an industry's future structure. It is based on a set of plausible assumptions about the important uncertainties that might influence industry structure, carried through to the implications for creating and sustaining competitive advantage. An industry scenario is *not a forecast* [Porter's italics] but one possible future structure. A set of industry scenarios is carefully chosen to reflect the range of possible (and credible) future industry structures with important implications for competition".

Fahey and Randall (1998b, pp.6-7) state, *inter alia*, that:

"scenarios are descriptive narratives of plausible alternative projections of the future...methodically researched and developed in sets of three, four or more to study how an organization [sic] or one of its decisions, might fare in each future in the set."

"Scenario sets provide vividly contrasting narrative descriptions of how several uncertain aspects of the future might evolve."

"...scenarios are projections of a potential future...a combination of estimations of what might happen and assumptions about what could happen, but they are not forecasts of what

will happen. Thus, projections should not be confused with predictions: A projection should be interpreted as one view of the future that is based upon specific information and a set of logical assumptions."

Transport and Logistics Panel (n.d.) proposed three scenarios for the Irish transport system in 2015, as part of the major multi-sectoral Forfás "Technology Foresight" programme. They may be summarised as:

Steering the Tiger: a lasting constitutional settlement in Northern Ireland, successful European monetary union, high investment in research and development, increased application of automation and telecommunications, an expanded labour force, general conversion to "clean" propulsion technologies, extensive transport infrastructure investment, enhanced air and sea services.

Riding the Downturn: limited success in EU expansion and monetary union, some investment in "clean" technologies, high unemployment and increased social tensions, increased transport taxes and enhanced enforcement, some increased application of information technology.

80s Action Replay: serious internal divisions within EU, unsuccessful monetary union, war in the Middle East followed by a major oil crisis, violence in Northern Ireland, high inflation, taxation and public expenditure, declining employment, high emigration, absence of necessary transport investment, increased transport costs, inadequate air and sea services.

It will be noted that some of the items included in the scenarios cannot directly form inputs into transport demand models, while others may be more appropriate in the present context as components of alternative strategies rather than as scenario elements.

Since these scenarios were prepared (believed to be circa 1998) development has been broadly along the lines of the "Steering the Tiger" scenario (employment and immigration remain high, and indeed have increased since 1998, there has been significant commitment to additional transport infrastructure investment), with elements of "Riding the Downturn" (European monetary union has been somewhat troubled, the economy has entered a slowdown- albeit not as severe as that predicted). However, some high-profile elements of

"80s Action Replay" have come to pass (an oil crisis, albeit short-lived, the Irish electorate's rejection of a major European treaty, inflationary problems, some withdrawal from Ireland by multinationals) but without, thus far, anything like the catastrophic socio-economic consequences predicted in that scenario.

Very tentatively, therefore, "Riding the Downturn" might be considered a "central" scenario, with "Steering the Tiger" representing "high" conditions and "80s Action Replay" "low" conditions. The Foresight scenarios thus reflect closely the approach adopted in this project, even if there are differences of detail.

To summarise, therefore:

- The purpose of scenario building is to address uncertainty.
- A scenario describes a feasible and plausible, internally consistent, set of outcomes for several prime areas of uncertainty.
- Scenarios are developed in sets of three, four or more contrasting variants.
- The risk involved in the use of a number of scenarios is considerably lower than that involved with a single-point forecast.

5.2.2 Variables included in scenarios

As scenarios were required to furnish data for input to the transport demand models, it was necessary that they include all desired variables not relating to the transport system itself. Essentially, these comprise gross domestic product, broken into agricultural, industrial and service sectors, for each zone, along with the population of each zone.

Zones correspond to countries outside the Ireland-UK-Benelux-France-Germany area, with a few minor exceptions. The Republic of Ireland is represented by eight zones, Northern Ireland, Scotland and Wales by one each, England by eight, France by eight, Germany by sixteen, Belgium and Luxembourg by three and the Netherlands by four. Hence, it has in some cases been necessary to disaggregate national-level projections to zone-level data.

5.2.3 Sources for scenario data

For the purposes of calculating future population numbers in the Republic of Ireland, the Central Statistics Office's latest set of projections (CSO 2001a) was used as a base. This document offers population projections for five-yearly intervals from 2001 to 2031. Labour force projections were available from the same source, but were not required for the purposes of this work.

The Economic and Social Research Institute (ESRI)'s Medium-Term Reviews provide economic projections (the most recent one extending to 2015), disaggregated by principal sectors, for the Republic of Ireland (Duffy et al. 1999). They also contain certain information on the assumptions on Irish population, labour force participation, world economic performance etc. used in producing the forecasts. The economic forecasts for the Republic of Ireland used in this project are closely based on those in the current Medium-Term Review.

Population projections for Northern Ireland (and the rest of the UK) were based on those published by the UK Government Actuary (Government Actuary's Department 2001). The derivation of population data is described in greater detail below. Economic projections utilise the current Northern Irish economic strategy (Northern Ireland Economic Development Strategy Review Steering Group, 1999) as a basis, along with British economic projections (see below).

Population projections for Britain are based on Government Actuary's Department (2001). Other population projections are those published by the United States Bureau of the Census (2001a, 2001b). Economic projections for Europe outside Ireland are the author's own. These are simply based upon assumed growth rates. These in turn arise from the assumptions that the EU generally will grow somewhat more slowly than Ireland, and the accession countries faster (at rates comparable to Ireland's performance in the 1990s) The EU rates broadly resemble the projections for major European economies (such as the UK and Germany) in the ESRI Medium-Term Review. Lower levels of growth are assumed in Europe outside the EU and accession countries. See also Table 5.7 below.

5.3 THE SCENARIOS DESCRIBED

5.3.1 Basic concepts

The initial concept called for three scenarios, representing central, low and high conditions for population and economic growth. The possibility of investigating the effects of environmental taxation was considered; after examining the potential for incorporating this into one or other of the three basic scenarios, it was decided to test it via a variant of the central scenario, thus effectively giving four scenarios.

At a much later stage in the project, the structure of the scenarios was reviewed. The decision was made to eliminate the "environmental taxation" scenario and transfer appropriate measures into the other scenarios or the strategies. It was also decided that initial testing would use only the central scenario; the other two would be applied as sensitivity tests to a smaller range of strategies in a later stage of analysis.

The final definition thus called for three scenarios in all, but with heavy concentration on the central scenario. Unfortunately, eventual modelling work was confined entirely to the central scenario. Some information on the development of alternative scenarios has nevertheless been provided in this chapter (see 5.3.3 below), though it is important to bear in mind that these have not been developed to the same level as the central scenario.

It appeared relatively obvious that scenarios should primarily represent "low, central and high" conditions for economic and population growth, and there did not appear to be any requirement for more than three scenarios to represent the possible range of these variables. However, consideration was given to representing a number of additional variables, possibly by means of further scenarios.

The main priority in this latter area was the possibility of representing taxation reforms aimed at internalising the external costs of transport through the medium of a "variant" scenario. Ultimately, however, it was decided not to test such a scenario, but to incorporate certain features into the "managed demand" strategy.

Thus, the scenarios developed in detail represent simple "low, central and high" projections with respect to Irish population and economic development. For simplicity, all three are identical with regard to population and incomes outside the island of Ireland.

5.3.2 Central scenario

The Central scenario represents what the author considers the most likely economic and demographic position for the year 2020. It is based on CSO population projections (although the population distribution is based on the author's own assumptions rather than the CSO regional projections, which were unavailable when most of the work on this task was being done, and which anyway do not represent the most likely future situation) and on ESRI economic projections. Outside Ireland, the population projections are from the US Bureau of the Census (excepting the UK, where they are based on those of the Government Actuary) and economic projections are the author's own, informed by the ESRI's work.

The population projections for the Republic of Ireland in the central case are based on the M1F2 combination of migration and fertility assumptions in CSO (1999a), interpolating between 2016 and 2021. M1F2 is generally accepted as giving "central" values. The CSO's M1F2 values from its first ever set of regional population projections (CSO 2001a) are included in Table 5.1 for comparison, along with 1996 census figures. However, it must be remembered that the CSO projections were only released after the completion of the author's own projections, and that they do not represent a "most likely" situation but rather a "do-minimum" (i.e. no regional development policy).

Distribution of population in the central case has been based on a broad continuation of the trends prevailing from the 1970s to the 1990s. The Greater Dublin Area is treated as one region and the population subsequently assigned to its two zones (Dublin and Mid-East) on the basis of the Strategic Planning Guidelines' (Brady Shipman Martin et al., 1999) projected distribution for 2011. No account is taken of the fact that the distribution between these two zones in 2020 could be different from that in 2011, or the possibility of variation in this distribution between different population scenarios. However, because the regions are so closely linked, any error from this source, on the scale of access transport, is

likely to be small. Northern Irish population is derived from the UK Government Actuary's current projections (Government Actuary's Department 2001).

Table 5.1 Population Projections for Irish Zones, Central Scenario

Zone Number	Zone Name	1996	2020 Central	2020 CSO M1F2
5301	Border	406,444	467,955	435,300
5302+5303	Greater Dublin	1,403,335	1,782,466	1,985,400
5302	Dublin	1,058,000	1,283,376	1,504,720
5303	Mid-East	345,335	499,090	480,680
5304	Midlands	205,252	237,763	201,500
5305	Mid West	316,875	376,828	369,460
5306	South East	391,046	463,746	411,000
5307	South West	546,209	659,860	592,400
5308	West	351,874	424,961	417,740
5611	Northern Ireland	1,649,000	1,818,000	n/a

For individual countries represented at one zone per country (i.e. everywhere except the UK, France, Germany and Benelux), the 2020 population forecast is taken from US Bureau of the Census (2001a), with the exception of Turkey, which is taken from US Bureau of the Census (2001b). Additionally, Wales and Scotland are represented by single zones, and specific projections for these are available from Government Actuary's Department (2001).

In the case of zones in England, France, Germany and Benelux, the existing regional population distribution is assumed to remain constant; the factor of change for each zonal population is assumed to be identical to that for the overall population of the country (or, in the case of Belgium and Luxembourg, two countries together). Nominal 1995 populations (not every country, obviously, conducted a census in 1995) have been derived from a variety of sources. The 2020 populations are derived from US Bureau of the Census (2001a) for France, Germany and Benelux and from Government Actuary's Department (2001) for England. Table 5.2 shows the results.

Table 5.2 Population Projections for Zones outside Ireland

Zone number	Zone name	1995 population (000)	2020 population (000)
1001	Sweden	8,700	8,928
2003	Norway	4,331	4,862
3003	Finland	5,050	5,235
4001	Denmark	5,189	5,570
5101	Schleswig-H	2,687	2,830
5102	Hamburg	1,699	1,790
5103	Bremen	761	802
5104	Niedersachsen	684	721
5105	Nordrhein-W	17,722	18,668
5106	Hessen	5,945	6,262
5107	Rheinland-P	3,903	4,111
5108	Thuringen	2,538	2,674
5109	Sachsen-A	2,788	2,936
5110	Saar	1,085	1,143
5111	Bayern	11,817	12,448
5112	Mecklenburg-V	1,852	1,951
5113	Brandenburg	2,546	2,682
5114	Berlin	3,471	3,656
5115	Baden-W	10,196	10,740
5116	Sachsen	4,624	4,871
5201	Ile de France	10,937	11,892
5202	Paris Basin	10,397	11,305
5203	Nord-Pas de Calais	3,986	4,334
5204	Est	5,060	5,502
5205	Ouest	7,575	8,236
5206	Sud-Ouest	6,045	6,573
5207	Centre-Est	6,045	6,573
5208	Mediterranee	6,836	7,433
5401	Noord-Nederland	1,611	1,800
5402	Oost-Nederland	3,136	3,505
5403	West-Nederland	7,167	8,009
5404	Zuid-Nederland	3,374	3,771
5501	Brussels	950	922
5502	Flanders	5,836	5,665
5503	Wallonia/Lux	4,397	4,268
5601	North	3,100	3,425
5602	Yorks	5,010	5,536
5603	E Mid	4,080	4,508
5604	E Ang	2,090	2,309
5605	SE England	17,720	19,580
5606	SW England	4,760	5,260
5607	W Mid	5,290	5,845
5608	NW England	6,410	7,083
5609	Wales	2,900	3,043

(continued over)

Table 5.2 continued

Zone number	Zone name	1995 population (000)	2020 population (000)
5610	Scotland	5,120	5,063
5700	Spain	39,083	39,233
5710	Portugal	9,870	10,101
5720	Greece	10,380	10,636
5730	Bulgaria	8,769	6,326
5740	Slovakia	5,432	5,475
5750	Romania	22,836	21,267
5760	Czech Rep.	10,433	9,891
5770	Ex-Yugoslavia	10,211	23,401
5780	Albania	3,290	4,127
5790	Turkey	61,945	79,679
5800	Belarus	10,437	10,274
5810	Lithuania	3,876	3,556
5820	Latvia	2,763	2,151
5830	Russia	150,000	138,978
5831	Estonia	1,487	1,332
5840	Poland	38,620	38,455
5850	Iceland	266	297
5860	Switzerland	7,085	7,395
5870	Austria	7,991	8,339
5880	Italy	57,138	55,540
5890	Malta	349	442
5900	Ukraine	51,867	44,362
5910	Hungary	10,471	9,484
5920	Moldova	4,490	4,737
5930	Faeroes	44	51

The author has chosen the ESRI Central Forecast from the most recent Medium-Term Review available at the time of preparing the scenarios (Duffy et al. 1999) as the basis for the central economic forecast. This assumes the following growth rates for total GDP at factor cost:

Table 5.3 ESRI Growth Rates for GDP, 1990-2015

Period	1990-95	1995-00	2000-05	2005-10	2010-15
Annual average % growth	4.2	7.7	5.0	4.3	3.2

The growth rates actually assumed, combining the ESRI Central Forecast with the author's assumptions for growth in the period 2015-2020 (which are extrapolations of the ESRI data) are given in Table 5.4 below.

Table 5.4 Central Scenario Economic Growth

	Annual average % growth						GDP: 2020 as % 1990
	1990-95	1995-00	2000-05	2005-10	2010-15	2015-20	
Agri-culture	-0.5	-0.4	0.3	1.6	1.6	1.6	123.12
Industry	7.3	11.4	5.3	4.2	3.1	2.5	511.47
Market services	3.3	6.3	5.8	5.1	3.4	2.9	370.07
Non-market services	2.5	2.5	2.6	2.5	2.5	2.5	210.78

Table 5.5 shows the distribution of output in agriculture, industry and services over the planning regions of the Republic of Ireland (corresponding to the zones of the demand model) in 1997 (CSO 1999b). Table 5.6 is a central-case estimate for 2020, informed by the relevant population projections.

Table 5.5 1997 Regional Distribution of Output (% of national total)

Region	Agriculture	Industry	Services
Border	17.0	8.7	19.0
Midlands	6.8	2.9	4.0
West	12.4	5.7	7.2
Dublin	2.8	33.0	47.9
Mid East	7.5	11.8	6.1
Mid West	12.4	8.9	6.7
South East	17.2	10.6	7.1
South West	23.9	18.5	13.3

Table 5.6 2020 Central Case Regional Distribution of Output (% of national total)

Region	Agriculture	Industry	Services
Border	20.0	10.0	20.5
Midlands	10.0	5.0	4.5
West	15.0	6.5	8.0
Dublin	2.5	24.0	35.0
Mid East	5.0	15.0	8.5
Mid West	12.5	9.0	7.0
South East	15.0	11.5	6.0
South West	20.0	19.0	10.5

For the central case, it is assumed that Northern Ireland's per capita GDP rises to 100% of the UK average in 2020. For comparison, it was at roughly 80% in the late 1990s and the current Northern Irish economic development strategy (Northern Ireland Economic Development Strategy Review Steering Group, 1999) aims to increase it to 90% by 2010.

The Northern Irish GDP figures are then derived from the UK projections (see below) and the population assumptions (see above). The ratio of the split of Northern Irish GDP between sectors to that in Britain is assumed to remain constant over the period 1995-2020. In 1995, Northern Irish GDP split 4% to agriculture, 29% industry and 67% services, compared with 2% agriculture, 31% industry and 67% services in Britain. The rest of world GDP evaluation for 2020 (see below) indicated 1% agriculture, 28% industry and 71% services in Britain; therefore, 2% agriculture, 27% industry and 71% services were assumed for Northern Ireland.

The assumed economic growth rates for zones outside Ireland are shown in Table 5.7. Their derivation is discussed at 5.2.3 above.

Table 5.7 Economic growth in study area outside Ireland 1995-2020

Zones	Growth rates 1995-2020		
	Agriculture	Industry	Services
EU + Faeroes, Iceland, Norway, Switzerland	1%	2.5%	3%
EU Accession Countries (Bulgaria, Czech Rep., Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia[1])	1.05%	5%	6%
Albania, Belarus, Moldova, Russia, Ukraine, ex-Yugoslavia	1%	1%	1%

5.3.3 Alternative scenarios

Although only the central scenario was eventually utilised for modelling purposes, it is important to note that "high" and "low" alternative scenarios were, in fact, developed in outline form. This sub-section gives a brief overview of these latter scenarios.

[1] Cyprus and Slovenia are also accession countries, but Cyprus is not represented in the network and Slovenia is considered part of the "ex-Yugoslavia" zone.

In terms of the Republic of Ireland's population, the "low" projection has been based on the M2F3 migration/fertility combination. The "high" projection is based on M1F1 but with an additional 33,000 immigrants per annum in the period 2000-2010 (based on the "high growth" scenario of the ESRI Medium Term review, whose authors considered the M1F1 scenario somewhat conservative for an upper bound). Distribution in the "low" scenario assumes replication of the patterns experienced during the 1980s (when economic performance was particularly poor) with particular attention to Dublin's share. The "high" scenario is based on the population distribution (rather more evenly dispersed than today's) prevailing at the time of the 1979 census, on the assumption that high population levels will require a policy of regional balance. The best that this can realistically achieve is assumed to be the reversal over approximately two decades (2000-2020) of the tendencies of the preceding two decades (1979-1999). Table 5.8 shows the results of this analysis.

Table 5.8 Population Projections for Irish Zones, Alternative Scenarios

Zone Number	Zone Name	2020 Low	2020 High
5301	Border	426,127	569,652
5302+5303	Greater Dublin	1,635,112	1,756,426
5302	Dublin	1,177,280	1,264,627
5303	Mid-East	457,831	491,799
5304	Midlands	216,237	284,826
5305	Mid West	344,954	427,239
5306	South East	429,551	522,181
5307	South West	601,425	712,065
5308	West	385,733	474,710
5611	Northern Ireland	1,636,200	1,999,800

Northern Irish population is assumed to be 10% higher than central in the high scenario and 10% lower in the low scenario. No changes in population are assumed for zones outside Ireland.

Tables 5.9 and 5.10 show the assumed Republic of Ireland economic growth rates for the low and high scenarios respectively. The low and high cases are broadly based on those proposed by the ESRI; specifically, the high scenario is derived from the ESRI's "more rapid growth through immigration" scenario. The low value for Northern Irish GDP is 90% of the UK average, and the high 110%, with the same sectoral distribution as the central case. Again, no change is assumed outside Ireland.

Tables 5.11 and 5.12 indicate the distributions of economic activity within the Republic of Ireland as assumed for the low and high scenarios respectively. As in the case of the central scenario (Table 5.6), they are estimates informed by the respective population projections.

Table 5.9 Low Scenario Economic Growth

	Annual average % growth						GDP: 2020 as % 1990
	1990-95	1995-00	2000-05	2005-10	2010-15	2015-20	
Agriculture	-0.5	-0.4	0.1	1.3	1.4	1.4	95.92
Industry	7.3	11.4	4.9	3.8	2.7	1.5	452.06
Market services	3.3	6.3	5.4	4.2	3.2	2.7	341.16
Non-market services	2.5	2.5	2.6	2.5	2.5	2.5	186.30

Table 5.10 High Scenario Economic Growth

	Annual average % growth						GDP: 2020 as % 1990
	1990-95	1995-00	2000-05	2005-10	2010-15	2015-20	
Agriculture	-0.5	-0.4	0.4	1.6	1.6	1.6	123.73
Industry	7.3	11.4	6.3	5.2	4.1	2.5	590.26
Market services	3.3	6.3	7.0	6.1	3.4	2.9	410.53
Non-market services	2.5	2.5	3.0	2.5	2.5	2.5	210.78

Table 5.11 2020 Low Case Regional Distribution of Output

Region	Agriculture	Industry	Services
Border	20.0	9.0	20.0
Midlands	10.0	4.0	4.0
West	15.0	6.0	7.5
Dublin	2.5	25.0	35.5
Mid East	5.0	16.0	9.0
Mid West	12.5	9.0	7.0
South East	15.0	11.5	6.0
South West	20.0	19.5	11.0

Table 5.12 2020 High Case Regional Distribution of Output

Region	Agriculture	Industry	Services
Border	20.0	10.0	20.5
Midlands	10.0	5.0	4.5
West	15.0	6.5	8.0
Dublin	2.5	24.0	35.0
Mid East	5.0	15.0	8.5
Mid West	12.5	9.0	7.0
South East	15.0	11.5	6.0
South West	20.0	19.0	10.5

5.4 STRATEGIES-AN OVERVIEW

5.4.1 Candidate strategy elements

The strategies chosen for further analysis should, as far as reasonably possible, be coherent in nature. This implies that the elements constituting each strategy should be compatible with one another and with any general principle underlying the strategy in question.

The question of compatibility between individual strategy elements is considered in greater depth at 5.4.3 below. In relation to general principles forming the basis of alternative strategies, a number of possible candidates were identified at an early stage of the analysis. These included:

- Do-minimum.
- High investment.

- Management of demand, with lower capital investment.
- Strategies based primarily on the implementation of a single major project, such as an Irish Sea tunnel or an airship system.

These principles were identified on the basis of the findings of Task 2 and of experience in other transport studies. They were borne in mind in the development of the final strategies and proved to have considerable influence in this context.

5.4.2 Development of the elements

The elements utilised as a basis for the strategies are described in detail by chapter 4 of this thesis. Supplementary information on the development process is provided in Appendix B.

An analysis of vehicle (air and sea transport, including existing and new modes, but excluding bulk shipping) requirements for the various strategies was carried out on the basis of cost information derived from Appendix B and service patterns from Appendix H. The results were used to estimate changes in vehicle capital costs from strategy to strategy. For the second-round strategies, a different approach was used, as described in chapter 8; capital costs were estimated using changes in actual demand rather than patterns of transport supply.

5.4.3 Compatibility analysis

An analysis of the degree of compatibility between various possible strategy elements was carried out in order to assist in their successful "packaging" into a small number of coherent alternative strategies. An attempt was made to apply a formalised methodology to the problem. This required the construction of a "compatibility matrix" which rated the interactions between each pair of elements as either positive, neutral or negative, strategies then being derived by grouping together sub-matrices containing as many positive interactions and as few negative as possible. Unfortunately, this analysis (carried out for a set of strategy elements slightly different from the current one) failed to produce any robust conclusions, although it validated some of the choices made in the draft strategies.

The principal problems encountered were the unwieldiness of any matrix incorporating all possible strategy elements and the amount of effort required to determine whether every possible interaction (the total number of such interactions being proportional to the square of the number of strategy elements) was positive, negative, or neutral.

In practice, the approach actually taken has been less formal but nonetheless rigorous. From the pre-planning of the project up to the production of this report, a series of sets of alternative strategies were constructed and examined in outline. In several cases, the author discussed the various alternatives with other individuals involved in the project, and took account of their views. If the attempt to consult with stakeholders (see chapter 7) had produced useful results (which, unfortunately, it did not), these too would have been fed into the process of strategy definition.

Strategies considered since the inception of the project have included:

- Do-minimum;
- High air investment;
- High air/sea investment;
- High sea investment;
- Decentralisation of port/airport facilities;
- Managed air/sea demand (including decentralisation, internalisation of external costs)
- Buoyant air transport system;
- Irish Sea fixed link.

The discussion of "areas of choice" in sub-section 5.4.4 below builds, in part, on the initial strategy possibilities identified here. Section 5.5 further develops these choices into a number of definite strategies, some of which closely reflect those listed above.

5.4.4 Areas of choice

Having identified the possible strategy elements and outlined some possible strategy approaches into which they could be incorporated, the possible areas of choice between alternatives were examined. These included:

- V/STOL; whether or not to implement a vertical/short take-off/landing air system.
- Air network; what form the air transport network should take, with particular reference to the balance between links to/from main hubs and those serving minor regional airports. In this context it was realised that development of conventional air services from peripheral locations might present a partial alternative to the V/STOL system described above.
- Airport provision; possibilities for new airports, with specific reference to a Midlands regional airport and a second Dublin airport at Baldonnel.
- Shipping network; a similar choice to the air network as to whether main hubs or peripheral ports are emphasised.
- High-speed freight shipping; as this was considered likely to exist on at least a modest scale by 2020, the issue in this case was the scale of network to be provided under different options.
- Seabus; whether or not to implement an ultra-high-speed ferry system for passenger and car traffic, based upon the Seabus-Hydaer hybrid hydrofoil/wing-in-ground-effect technology described more fully in Appendix B.
- Port provision; whether or not to develop alternatives to Dublin Port and, if so, whether development should concentrate on upgrading existing ports (Drogheda and Arklow) or on the development of an entirely new facility.
- Additional road provision; specifically, possible improvement of northwesterly links from Dublin (e.g. to Derry and Sligo) and of the Western Corridor from Belfast to Rosslare via Derry, Sligo, Galway and Limerick.
- Additional rail provision; the possibility of freight shuttle services linking Dublin Port to inland terminals, passenger links to Shannon and Belfast International airports, and an upgrade (for both passengers and freight) of the Western Corridor line from Galway to Rosslare via Shannon, Limerick and Waterford.
- New mode; whether an entirely new mode introduced into the system should be based on a rail fixed link across the Irish Sea, on a buoyant aircraft system, or, indeed, whether broadly-conventional rail and sea services would suffice.
- Subsidy/taxation policy; including taxation measures to internalise external costs and possible subsidies to (for instance) road/rail transfer costs.

The various strategies were then developed on the basis of decisions on these areas of choice. The strategies themselves are outlined at 5.5 below. In the comparison of net

capital cost figures, it must be remembered that the costs are *net*, i.e. that they take account of assumed savings on investment in existing transport systems as well as the costs of new systems. This is of particular importance in respect of the fixed link strategies, where a very high *gross* capital cost for new infrastructure is partially offset by such savings.

5.5 THE STRATEGIES DESCRIBED

5.5.1 Strategy 01: Do-Minimum

This strategy simply assumes that the Irish access transport system continues to follow a logical development path, within the constraints of existing technology, and taking account of the likely trends in the demand for such transport.

It incorporates road and rail improvements already planned or otherwise likely, along with evolutionary development of the air and sea networks. The strategy is assigned a *net* capital cost of zero, as the baseline to which other strategies refer. Naturally, there will be capital costs associated with upgrading and fleet renewal, if the present situation is taken as the baseline.

5.5.2 Strategy 02: Air/Sea, High Investment

This strategy is based on the assumption that the current dominance of sea and conventional air transport in the Irish access market reflects an optimal state of affairs. The best means of dealing with congestion and other problems in the existing system is therefore to invest in additional ports and airports, supplemented by an intensification of services. Some use is made of new technology (ultra-high-speed ferries and vertical take-off/landing aircraft) within the overall framework of air and sea transport.

Elements of this strategy are:

- A second Dublin airport, located at Baldonnel. Capital cost of approximately €400 million involved.

- Enhanced low-cost airline services, involving approximately €1,496 million of expenditure on additional aircraft over thirty years.
- A network of vertical take-off/landing air services linking regional Irish airports to main British hubs, secondary Irish airports to major British city centres and Irish city centres to British city centres. Vehicle capital cost approximately €2,518 million.
- Development of terminal facilities to service this network, including new inner-city facilities (vertiports) in Dublin, London, Birmingham, Manchester and Glasgow and dedicated vertical take-off/landing facilities at London (Heathrow) and Manchester airports. Capital investment approximately €100 million.
- A new high-capacity subsidised air freight service ("air bridge") providing links from Irish airports to London and Brussels, involving €5,000 million in aircraft capital costs (over thirty years).
- A new ro-ro port at Loughshinny, cost €200 million.
- Enhanced high-speed sea freight services. Net additional vessel capital cost of €4,072 million.
- Introduction of ultra-high-speed ferries, at a capital cost of roughly €600 million (including provision for terminal improvements).
- Upgraded Dublin-North West road link, cost €1,250 million.
- Rail links to Shannon and Belfast International airports. Capital cost approximately €220 million.
- Rail freight improvements in Ireland, capital cost €136 million.
- Piggyback rail services from Holyhead to London and Lille. Capital investment of about €625 million involved.

The net undiscounted capital cost of this strategy is approximately €16,617 million.

5.5.3 Strategy 03: Air/Sea, Managed Demand

This strategy is based on the assumption that the current dominance of sea and conventional air transport in the Irish access market is optimal, but that the spatial balance of traffic on the relevant networks and their inland feeder systems (particularly the national road network), and the pricing and management of the system, are not. It therefore proposes extensive development of a decentralised access transport network, with a large

number of routes from peripheral areas relieving pressure in Dublin and elsewhere. Pricing reform is used to support the aim of decentralisation and also to maximise the sustainability of the system through the internalisation of external costs. Capital investment is minimised as far as possible.

Elements of this strategy are:

- Imposition of taxes on all modes such that external costs are internalised.
- Surcharges on passengers passing through Dublin Airport and freight through Dublin Port.
- Significant improvements to the Irish regional airport system, including a new airport at Doon near Athlone, relocation of Galway airport, expansion of Waterford airport and minor improvements to other regional airports. Total capital cost €93 million.
- Extension of air services from regional airports, with cutbacks in services from other airports (especially Dublin). Net capital cost of additional aircraft €1,803 million.
- Development of Drogheda and Arklow ports, at total capital cost of €200 million.
- A less centralised pattern of shipping services; net capital cost of additional vessels €1,665 million.
- Upgraded Dublin-North West road link, cost €1,250 million.
- Upgraded Belfast-Derry-Sligo-Galway-Shannon-Limerick-Waterford-Rosslare road link, cost €2,600 million.
- Rail links to Shannon and Belfast International airports, capital cost €220 million.
- Upgraded Galway-Shannon-Limerick-Waterford-Rosslare rail link, cost €100 million (upgrade between Limerick and Galway already included in cost of Shannon rail link).
- Extensive upgrading of rail links from Dublin Port; capital cost €476 million.

The net undiscounted capital cost of this strategy is approximately €8,407 million.

5.5.4 Strategy 04: Fixed Link

This strategy is based on the assumption that only the construction of a fixed rail link between Dublin and Holyhead, with supporting works to the road and rail systems, will provide an efficient, sustainable access transport system in the long term.

Elements of this strategy are:

- A rail immersed tube tunnel between the Dublin and Holyhead areas; capital cost €22,000 million (note that this is an unmodified- except for inflation and currency conversion- version of the promoters' estimate; the author was unable to make an independent estimate in the time available).
- Electrification and upgrading of the North Wales Coast main line; costs included in above.
- Upgrading of roads around the terminals and of the Dublin-North West Ireland and Holyhead-North West England links; capital cost €1,666 million.
- Shuttle train services conveying vehicles through the tunnel. Capital costs included in tunnel costs.
- High-speed train services (assuming a new high-speed railway between London and the West Midlands) linking Dublin to Liverpool, Manchester, Birmingham, London, Paris and Brussels. Capital cost of rolling stock approx. €1,200 million.
- Piggyback rail services from Dublin to London and Lille. Capital investment of about €650 million involved.
- Through freight trains from Ireland to the south of England and mainland Europe; capital cost €60 million for additional locomotives.
- A scaled-down air and sea network, capital cost saving €1,130 million on ships and €2,730 million on airliners.

The net undiscounted capital cost of this strategy is approximately €21,332 million. In comparing it with other strategies, it must be noted again this is a *net* cost and takes account of savings in vehicle costs for existing modes. While this caveat applies to the net costs of all strategies, the cost of this particular strategy makes it especially important in this case.

5.5.5 Strategy 05: Buoyant Air

This strategy is founded on a similar assumption to strategy 04 (that an entirely new transport network is an essential component of an effective future Irish access transport

system). It differs in considering the use of buoyant aircraft (airships or hybrid craft) to be the most cost-effective and flexible means of providing such a network.

Elements of this strategy are:

- Passenger-carrying dynastat (hybrid airship) system linking major cities in Britain and Ireland; vehicle capital cost €7,140 million.
- Terminal facilities to serve the above; capital cost €440 million.
- Freight dynastat system linking selected points in Ireland to London and Brussels; vehicle capital cost €6,460 million.
- Terminal and servicing facilities for above freight system; capital cost €750 million.
- A scaled-down air and sea network, capital cost saving €795 million on ships and €2,880 million on airliners.

The net undiscounted capital cost of this strategy is approximately €11,115 million.

5.5.6 Second-round strategies (06,07)

Two strategies (more properly considered as two variants of a single strategy) were developed for the second round of modelling. The background to their development is more fully described by chapter 8 of this thesis. In essence, both reflect combinations of the elements making up the first-round strategies, informed by the relative performance of these strategies.

Both strategies included the following common elements:

- Dublin-North West and Western Corridor road improvements from managed demand strategy, plus road improvements necessary for Drogheda port upgrade (see below), total capital cost €3,860 million.
- Drogheda port improvements (and associated shipping services) from managed demand strategy. Capital cost €60 million.
- Limited charging policy, excluding port and airport charges and restricting en-route charges to car and airline travel, at a relatively low level of charging (see chapter 4).

- Rail improvements for passengers and freight as per managed demand strategy; capital cost €776 million in total.

Additional elements incorporated in the "combined buoyant air" variant (06) are:

- Enhanced version of the strategy 05 buoyant air transport network: capital cost €8,925 million for passenger craft, €6,460 million for freight craft and €500 million for supporting infrastructure, giving a total cost of €15,885 million.
- Savings of €7,702 million on airliners, but a net increase of €725 million in the capital costs of surface ships, owing to changed demand patterns.
- Road/rail (freight) transfer subsidies within Ireland (omitted from the fixed link variant because the problem of short freight hauls in Ireland is overcome in the latter case by connecting it to the European rail network).

The net undiscounted capital cost of this strategy is approximately €13,604 million.

Additional elements incorporated in the "combined fixed link" variant (07) are:

- The fixed link project from strategy 04, with supporting road and rail measures. Capital cost approximately €24,326 million.
- Savings of €7,506 million on airliners, and €1,300 million on surface ships, owing to changed demand patterns.

The net undiscounted capital cost of this strategy is approximately €20,216 million.

6 DEMAND MODELLING

6.1 INTRODUCTION

As is clear from the objectives listed in chapter 1, the development of an approach to demand modelling (or an alternative means of predicting future demand) is of considerable importance to this project. The literature review described in chapter 3 of this thesis covered an extensive range of possible approaches to the modelling of passenger and freight transport demand. This chapter continues the process by taking the literature review results as a starting point and describing the refinement of options and the development of final definitive methodologies.

Section 6.2 of this chapter describes the shortlisting process used to produce a manageable number of alternative approaches from the numerous examples investigated in chapter 3. Section 6.3 deals with the development of a workable, calibrated and validated, passenger demand model from the starting point of this shortlist. Section 6.4 treats freight modelling in a similar manner.

6.2 SHORTLISTING OF MODEL TYPES

6.2.1 Overview

At this stage, it is obvious that there exist a wide range of alternative methodologies for the prediction of the demand for passenger and freight transport in interregional situations analogous to the Irish access market. A number of broad-brush options emerge from the initial review (see section 3.4 of chapter 3), e.g. the choice between four-stage, direct demand and STEM models. It is clear that the availability of calibration information is an important determinant of the final choice.

The following key points emerge from the consideration so far given to both the literature in interregional transport modelling and the 'real world' evidence from the current Irish access transport situation:

- The situation to be modelled is relatively complex. It cannot be simplified into a single-corridor network, since there is too high a degree of interaction between, for instance, different routes across the Irish Sea. However, there is scope for simplification of the network on the basis of representing in full detail only those links connecting Ireland to Great Britain and the European mainland, with the "inland" links being reduced to as low a level of detail as possible.
- Several types of model emerge as candidates for predicting both passenger and freight demand in this market. Classical four-stage, STEM and direct demand (including quasi-direct) appear to be the most suitable.
- The advantages and disadvantages of the different methodologies can be briefly summarised as follows:

Table 6.1 Comparative Advantages/Disadvantages of Methodologies

Methodology	Advantages	Disadvantages
Four-stage	• Full multi-path representation • Very well proven in urban and interregional applications	• High calibration requirements • Not originally developed for interregional applications • Difficulties in making demand responsive to supply
STEM	• Full multi-path representation • Lower calibration requirements • Ability to make demand responsive to supply	• Relatively unproven
Direct demand	• Proven history of use in interregional studies • Lower calibration requirements • Ability to make demand responsive to supply	• Hard to adequately represent multiple paths on an O-D pair

- No clear favourite emerges from the initial assessment of modelling methodologies; examination in greater detail is thus considered necessary.

- The review of previous studies in the Irish access market yielded valuable information on the factors affecting freight demand patterns, though not so much on passenger demand; however, this information was of comparatively little use in determining the optimal model form.
- Viable alternatives to modelling for the purpose in hand proved relatively difficult to find; it was not considered that there existed any such methodologies worthy of further consideration, assuming the scope of the overall project to remain similar.
- Most methodologies examined are suitable for both passenger and freight demand prediction, though, of course, this does not imply that the methodologies finally chosen for both purposes need be identical.
- Calibration difficulties on existing information would be considerable. It was thus likely that the ability of a model to minimise calibration requirements could be an important factor in the choice; however, an alternative would be to obtain present-day data from an alternative source, e.g. a European research project, if such a source existed. Therefore, further attention will be given to this area.

6.2.2 The shortlist

It was decided, on the basis of the evidence assembled in the initial review, that the best way of choosing a model would be to initially draw up a shortlist of methodologies drawn from the review which appeared promising in the context of the study, then to make a choice from amongst these. It was further decided that, as a rule, these methodologies would be applicable (with modification) to either passenger or freight traffic (though, as previously stated, not constraining the study to choose a similar methodology for both). The models had to be relatively well covered in the literature, with a background- however limited- of application to problems broadly resembling those of the present study. An outline of the level of zoning/network detail applicable, where relevant, was to be associated with each methodology.

The methodologies chosen were:

1. Classical four-stage model, with consideration being given to simplified assignment methods, possibly even combining assignment with modal split. The zoning system for this model would have to incorporate several zones per country- an outline

system of four zones for the island of Ireland (3 Republic of Ireland, 1 Northern Ireland), four for Great Britain and three for northwest Europe was developed, though it should only be regarded as indicative. It might be preferable to use regionally-based (NUTS 2) zones, and the OD-ESTIM- based estimation work was carried out on this basis (apart from continental Europe, where the 3-zone system was retained). Serious problems were anticipated in calibration, unless OD-ESTIM could be successfully applied.

2. Direct demand model. This could possibly be applied to a country-by-country zoning system, in which case it was anticipated that the transport level of service functions would be calculated as the sums, weighted by regional populations, of the levels of service between pairs of regions within the countries. A precedent for this approach exists in the form of Beimborn's (1969) methodology- described in greater detail in sub-section 3.4.3- which involved generating trips between zones within two cities but calibrating modal split at the city-to-city level. The main advantage would be that (apart from Northern Ireland) all data for calibration would be on the better-documented national level rather than the regional level. The general advantages of direct demand (see also 3.4.4 above) would, of course, apply. However, a problem might possibly arise with the fact that direct demand models assume only one path per mode between a given origin and destination.

3. Quasi-direct model, using regional-scale zoning. Calibration problems (and possible solutions) would be likely to present themselves as in the case of approach 1 above. However, the "one path per OD pair" problem would be effectively overcome. MAP-1 would be an obvious choice in this area.

4. STEM, probably with similar zoning system to the four-stage model outlined above, but with fewer calibration problems anticipated. However, construction of a model or the acquisition of suitable pre-programmed software (if such indeed exists) could be problematic.

6.2.3 Approaches to calibration

Because of the problems in obtaining adequate calibration information which have already been referred to in chapter 3, particular attention was paid to possible methods of producing accurate synthetic origin-destination data using only minimal "real-world" information. Attention quickly came to focus on the 4th Framework project OD-ESTIM (NEA 1997). This aimed to develop simplified means of estimating matrices for both passenger and freight traffic.

The approach followed involved developing simplified models capable of handling trip generation, trip distribution and modal split, which were then calibrated against national models in France and the Netherlands and validated on information from other countries. Results were mixed; there was insufficient information for complete validation, but it appears that estimation of the distribution of trips by region was more accurate than that of total trips.

The actual form of the passenger model was as follows:

Trip generation- business:

$N_trips = 16.05*N_hh*f(area)$

where: N_trips = number of trips generated in region

N_hh = number of households in a class in the region

$$f(area) = \frac{\sum_j \sum_i \{(1/(distance(ij))^2)*(GDP(j)^{0.7})\}}{\sum_{j \in NL} \sum_{i \in NL} \{(1/(distance(ij))^2)*(GDP(j)^{0.7})\}}$$

where NL denotes that a zone is located in the Netherlands (i.e. a trip to that zone constitutes a national as opposed to international journey)

Trip generation- "holiday" (i.e. all non-business):

$N_trips = 33.61*N_hh*f(area)$

all definitions as for business trips.

Trip distribution (both journey purposes):

Trips (region i to region j) = a(ij)*N_trips(i)

where:

$a(ij) = \{(1/(distance(ij))^2)*(GDP(j)^{0.7})\} / \Sigma_j\{(1/(distance(ij))^2)*(GDP(j)^{0.7})\}$

Modal split (both journey purposes):

Binary logit with cost functions:

cost_road = 0.60*distance(ij) + 10*traveltime(ij)

cost_rail&air = 0.22*distance(ij) + 10*traveltime(ij)

Note that rail and air were considered as a single mode "because this approach guaranteed the best estimation results" (NEA 1997, 5.4.3.3)

In general terms, there is nothing to suggest that the OD-ESTIM approach would be unsuitable for matrix estimation in this project. Since the results with respect to distribution of trips were significantly better than those for total numbers, it was considered possible that, if initial results for the totals proved unsatisfactory, coefficients could be modified to control them to the readily-available figures. The cost functions for modal split are not especially applicable to the present study, but the need is primarily for a matrix of total trips; modal split modelling was handled separately.

A C++ program (Appendix E.1) was written to carry out estimation based on OD-ESTIM. Two 23×23 trip matrices (business and non-business trips) were then derived for 1996 conditions. Comparisons with published data, where available, were carried out in order to assess their accuracy or otherwise.

The first such comparison involved comparing the total volumes of Republic of Ireland-Britain and Britain- Republic of Ireland passenger travel produced by OD-ESTIM with the corresponding real-world data from the "Tourism and Travel" statistics (CSO 2001b). This

showed that OD-ESTIM overestimated volumes by a factor of roughly 10. Such a result was not unexpected given the presence of a water barrier in the area of study, a factor not generally present in the locations where the model was calibrated. It was considered that it could be relatively easily overcome by calibrating the constant in the trip generation equation to fit the actual volumes, as outlined above.

A more serious problem was observed in the distribution of trips. The percentage distribution by British region of the total trips to and from Northern Ireland (chosen because comparatively few passengers from the Republic use Northern airports, and thus the region's access traffic volumes could be expected to correspond closely to its origins and destinations) was calculated from the OD-ESTIM output and compared with that of air passenger traffic as recorded by CAA (1996b). Table 6.2 outlines the result.

Table 6.2 Performance of OD-ESTIM Passenger Model

Region	% CAA	% OD-ESTIM
Scotland	9.4	38
NW England	11.9	17.6
NE England	2.1	6.8
Yorkshire/Humber	7.6	7.9
East Midlands	2.8	4.3
London + SE England	54.4	8.6
SW England	1.5	4.4
West Midlands	9.7	6.3
Wales	0.5	6

The value of r^2 achieved was an extremely poor 0.003. Allowance must be made for the exclusion of sea trips from this analysis; these would be expected to have a somewhat different distribution (favouring shorter journeys in particular) to air trips. The principal errors visible above are the apparent overestimation of Scottish and Welsh trips and the underestimation of London traffic. Since the Scottish error, at least, could possibly be attributed to the exclusion of sea travel (which is a particularly convenient mode between Northern Ireland and Scotland), the figures were re-analysed with Scotland excluded; r^2 increased to 0.06- still very far from acceptable. Excluding London brought it to a reasonable 0.55, but clearly this exclusion was far from satisfactory.

The error in the case of London, and probably also in several other instances, may well be attributable to the inability of OD-ESTIM's distance-based trip distribution to take account of higher frequencies and lower fares on major routes, particularly to and from London, which attract larger numbers of passengers to them than might be the case if generalised

cost were purely a function of distance. There may also be effects resulting from the exclusion from this preliminary analysis of "interlining" traffic changing aircraft in London to continue to Continental Europe or elsewhere, but these are hardly likely to explain the full magnitude of the error. A similar exercise using Dublin passenger figures but combining OD-ESTIM totals for several regions to allow for Dublin airport's wide catchment area produced remarkably similar results. These initial exercises suggested that OD-ESTIM in its present form was likely to be rather less than optimal for passenger calibration purposes. Indeed, this reflects the aforementioned mixed results noted by NEA (1997, 7.5 and 8.2) for the passenger model. Unlike one form of its freight counterpart, the OD-ESTIM passenger methodology does not allow for the inclusion of cost as a substitute for distance.

In addition to passenger demand matrix estimation, the OD-ESTIM project incorporated a similar procedure for freight traffic. Four basic approaches were developed, calibrated on Netherlands and French data and validated on Italian, Spanish and Polish examples in order to assess their relative performance. They were broadly divided into entropy-maximising and econometric approaches; within each of these categories were two alternative methods. In the case of the entropy approach, these were a model with separate generation, distribution and modal split stages and a two-stage model combining distribution with modal split. For the econometric approach, a two-stage model with combined generation and distribution as well as a combined single-stage (similar to direct demand) method were compared (NEA 1997, Table 5.2).

The form of the models (excluding modal split stages, where they are separate, because they are not considered of direct relevance to the matter under discussion at this stage and in any case were of entirely conventional logit form) was as follows:

Entropy 1:

Trip generation:

$T_i = \alpha_1 + \alpha_2 P_i$

$T_j = \beta_1 + \beta_2 A_j$

where T_i tonnage generated from i ,T_j tonnage attracted to j, P,A are production and attraction indices respectively (typically GDP in sectors producing and consuming the commodity group) and α,β parameters.

Distribution:

$$T_{ij} = \alpha_i P_i \beta_j A_j \exp(-\lambda d_{ij})$$

subject to:

$$\sum_i (Tij) = P_i$$

$$\sum_i (Tij) = A_j$$

where P_i = total tonnage produced at i, A_j = total tonnage attracted to j, d_{ij} = distance between zones, α,β,λ are parameters.

Entropy 2:

Trip generation:

$$T_{im} = \alpha_1 + \alpha_2 P_i$$

$$T_{jm} = \beta_1 + \beta_2 A_j$$

(as Entropy 1 but mode-specific)

Distribution/modal split:

$$T_{ijm} = \alpha_{im} P_{im} \beta_{jm} A_{jm} \exp(-\lambda c_{ijm})$$

(again a mode-specific variation on the previous model, with the further modification that generalised cost by mode m on i-j, c_{ijm} ,is substituted for distance.)

Econometric 1:

Trip generation/distribution:

$$T_{ij} = \alpha_1 P_i^{\alpha 2} A_j^{\alpha 3} d_{ij}^{\alpha 4}$$

where P_i the sectoral production variable (usually GDP) in zone i, A_j the sectoral attraction variable in zone j, the αs are parameters and all other variables defined as previously.

Econometric 2:

Trip generation/distribution/modal split:

$$T_{ijm} = \alpha_1 P_i^{\alpha 2} A_j^{\alpha 3} c_{ijm}^{\alpha 4}$$

definitions as previously.

The conclusions of the study favoured the entropy models in general, although the overall differences were small. For the purposes of this project, models incorporating mode split were considered inappropriate at the present stage of work owing to the difficulty in estimating cost functions and the fact that only an indication of total demand was desired initially. Further investigation of OD-ESTIM's entropy model 1 was carried out (a program was completed to the stage of generating trip ends and is reproduced at Appendix E.2), but its applicability was limited by the choice of the STEMM commodity classifications, rather than the NSTR ones on which OD-ESTIM was calibrated, for modelling. However, the approach ultimately chosen (see 6.4.3 below) closely resembles that used in OD-ESTIM as far as generation is concerned, although distribution is simplified.

The final conclusion was therefore that OD-ESTIM, in itself, was not adequate for providing passenger or freight calibration information. Some features have, however, been incorporated into the freight calibration process.

6.3 COMMENTS ON SHORTLISTED APPROACHES

It is now intended to examine the approaches shortlisted above in greater detail, with a view to establishing whether any of them should be rejected at this stage.

The four-stage model is very well proven in practice, such that it would be necessary to demonstrate very serious drawbacks before rejecting it out of hand. However, it remains true that the level of transport demand in the classical four-stage model is completely unrelated to transport supply. On the evidence available, this does not appear to be a particularly accurate description of the Irish access market. Furthermore, the calibration process could be quite complex.

Direct demand models appear considerably more attractive- and, on the face of it, seem to have at least as respectable a pedigree in interregional applications (for passengers) as the four-stage model. The strategy suggested above, involving calibration at national level of a model generating trips at regional level, may not be as appropriate a method as the use of OD-ESTIM for calibration (although the latter could be argued to be merely a more sophisticated form of the former).

Quasi-direct models were attractive in combining the demand responsiveness of direct demand models with the network representation potential of the classical four-stage structure. Indeed, they would seem- assuming no undue calibration difficulties- to possess distinct advantages over all other methodologies. Their main disadvantage is the very small number of implementations so far; MAP-1, successfully proven in international European applications, is the principal exception, as described below.

STEM offers most of the same attractions as quasi-direct models but appears to be even less extensively used and also more complex in structure. Despite this, it was considered important to retain it for further examination.

Particular regard was had to the outcome of the STEMM project. The MAP-1 passenger model utilised in STEMM (described elsewhere in this report) was the outstanding example of a quasi-direct model in the literature; it was thus logical to investigate it

further. The STAN freight model represents a simultaneous model which appears to be better proven and more accessible than STEM, though requiring a separate trip generation module. STAN was also of interest because of the simplified calibration strategy (STEMM Freight Flow Model) developed in the STEMM Scandinavian case studies.

The MDST model, the second STEMM freight model, reflects some of the approaches explored by the author on a preliminary level in the early stages of the project, notably the development of a logit mode/path choice methodology. It was also originally developed for the English Channel crossing, which possesses obvious similarities with the Irish situation. However, calibration needs appear considerably more extensive than in the case of STAN.

In view of the factors listed above, it was decided to add MAP-1, STAN and MDST to the shortlist for further consideration. At this stage, the shortlist was divided into separate passenger and freight lists. All the original approaches were retained on the passenger list, with the original option of a generic quasi-direct model being narrowed down to one specific option, MAP-1. In the case of freight, it was decided to remove STEM from the list because simultaneous models were better represented by STAN, and to remove direct demand and quasi-direct models because no truly successful freight examples of either could be found in the literature.

The final shortlists (in no particular order) thus became:

Passenger:

- Classical four-stage
- Direct demand
- MAP-1
- STEM

Freight:

- MDST
- STAN

The following two sections of this chapter present the final choice of model for passenger and freight applications respectively; they also describe how each model was brought up to the calibration and validation stages.

6.4 THE PASSENGER MODEL

6.4.1 Choice of model

The final shortlist of possible modelling options for passenger purposes generated in the previous section was:

- Classical four-stage
- Direct demand
- MAP-1
- STEM

Detailed descriptions of the different model types will be found in chapter 3 of this report. Section 6.2 contains preliminary assessments of their advantages and disadvantages.

It will be seen from the evidence presented thus far in this report that:

- Direct demand and four-stage models both suffer significant disadvantages from the point of view of the work carried out in this project.
- Quasi-direct (e.g. MAP-1) and STEM models offer advantages by comparison.
- However, neither of these latter model types has been very widely applied to date.

In view of the significant similarities between the advantages and disadvantages (though not the basic methodologies) of the MAP-1 and STEM models, it was considered a priority in the choice process to determine whether one or other of them could be eliminated at this stage.

The principal area where differences might exist in the relative performance of the two methodologies was in terms of successful previous implementation. STEM's only known interregional application to date was in the Egyptian national model (where, it must be said, it performed well). STEM is a generic format which can be applied to either urban or interregional modelling (although urban applications have also been relatively few).

MAP-1, on the other hand, was developed explicitly for European interregional conditions. The model and its antecedents had been applied without major problems to several domestic interregional passenger transport networks. It was successfully calibrated in the STEMM project, giving a virtually Europe-wide passenger model. Applications to case studies in STEMM were generally successful. There seemed to be a distinct advantage for MAP-1 in calibration terms because of the aforementioned work.

It was therefore decided that MAP-1 dominated STEM on all relevant criteria and that the latter could thus be excluded from further consideration. Hence, the choice was narrowed down to MAP-1 versus direct demand versus sequential four-stage.

The latter two model formats both suffer significant problems in the context of the present project which have been extensively covered in this thesis. There was no reason to believe that MAP-1 would be inferior to them on any criterion other than number of past applications. In this last respect, the STEMM work was a powerful argument in MAP-1's favour. Conversely, there were several reasons to believe that direct demand and sequential four-stage were inferior to MAP-1. However, if the MAP-1 format could not be implemented, direct demand was considerably superior to sequential four-stage as an alternative approach.

The final choice thus pointed towards MAP-1 and, to a lesser degree, direct demand models in general. Enquiries were made as to the availability of the IWW passenger transport model in a readily transferable form, but these ultimately showed that no commercial quality implementation of the model existed to date. The focus of the work therefore changed to the development of a modelling framework embodying as many of the advantages of MAP-1 as possible while remaining tractable.

Preliminary work on developing the generation-distribution side of this framework concentrated on direct demand methodologies, as these appeared most suitable to the characteristics of the market.

An evaluation of possible software platforms for the passenger model's network representation was carried out. The prime candidates were EMME/2, SATURN and STAN; for a variety of reasons, including affordability, familiarity and ease of implementation, STAN was chosen.

6.4.2 Detailed specification

After some consideration, it was decided to represent two categories of passenger trip, business and non-business, in the generation/distribution model. Initially, the division of non-business travel into tourist and other personal travel was considered, but indications were that this course of action would lead to excessive complexity, particularly with regard to determining (and projecting credibly into the future) relevant variables for generation of tourist trips. Consideration was also given to the possibility of dividing trip categories into Irish-based and non-Irish-based travel, but available data were again insufficient to support this. Calibration was carried out using Microsoft Excel spreadsheets.

The original IWW passenger model, based around the MAP-1 suite of algorithms, used a NUTS 3 zonification, the finest level permitted by the NUTS system. NUTS 3 corresponds to the planning regions in the Republic of Ireland and to counties in Great Britain. Since the passenger model was being constructed from scratch, NUTS 3 was considered an unacceptably high level of detail having regard to constraints of time, financial and human resources and computing capacity. As the freight model utilised an essentially NUTS 1 zonification (except in Ireland, where NUTS 3 was substituted because NUTS 1 would have resulted in only one zone for the entire Republic, and the Nordic countries, which the author simplified from NUTS 3 to NUTS 0, i.e. national level), this was adopted.

The proposed zonification thus became:

- Ireland (Republic): NUTS 3

- UK: NUTS 1
- France/Benelux/Germany: NUTS 1
- Rest of Europe: NUTS 0

The following modes were included in the 1995 base network (the letters corresponding to the modes being those used by the author within the STAN model):

- Private car (mode "l")
- Coach (mode "C")
- Conventional airline (mode "A")
- Low-cost airline (mode "L")
- Regional airline (mode "R")
- Rail (mode "r")
- Ferry (mode "f")
- Fast ferry (mode "s")
- Airport dummy links (mode "D")

Modes incorporated in alternative future networks included:

- Wing-in-ground-effect passenger/car ferry (mode "w")
- Tiltrotor V/STOL (mode "t")
- Buoyant aircraft (airship) (mode "B")
- Piggyback rail services on fixed link (mode "p")
- Through high-speed rail services on fixed link (mode "H")

For calibration and general trip generation/distribution purposes, trips on the existing network were divided into four generalised modes or "meta-modes", each corresponding to a sub-network. These were:

- Air: all airlines (conventional, low-cost and regional), airport dummy links plus car and train.
- Car accompanied: car, ferry and fast ferry.
- Classic: coach, train, ferry and fast ferry.

- New mode: only applying to fixed link and buoyant air strategies, consisting of high-speed rail or buoyant air, plus car and train.

Meta-modal split is handled at the generation-distribution stage, while sharing between the modes within each meta-mode takes place at the assignment stage, using STAN's combined modal split/assignment algorithm.

The passenger networks were modelled in STAN, and used the STEMM freight networks as a basis. Consideration was given at various times to using EMME/2 or SATURN as the basis for the passenger network model, but the ultimate decision favoured STAN, in large part because it was already in use within the project for freight modelling purposes and could be readily adapted for passenger modelling at the desired level of detail.

The networks incorporated the modifications to zonification and road/rail networks made for the freight model (see 6.4.2 and 6.4.3 below). They also included an air network, which was built from scratch on the following principles:

- Timetabling data were based on the June 1995 ABC World Airways Guide (ABC 1995).
- Virtually all direct links from Irish airports were included, excepting a few which operated at a very low frequency (less than 3 flights/week/direction) in 1995 or did not operate for the majority of that year.
- Almost every zone had at least one airport; in general, additional airports were only provided in Irish and British zones.
- Where an airport had no direct links from Irish airports, one was added from a non-Irish location in the order Manchester-London Heathrow-London Gatwick-mainland European airports (i.e. the link would be from Manchester if such a service existed in 1995, else from Heathrow etc.).
- Routes were defined as regional if the predominant aircraft types (specified by ABC) were turboprops or small (below 150 seats) jets. Otherwise, they were defined as mainline operations, except for certain carriers, which were designated as low-cost.
- Fare data were based on financial statistics published by CAA (1996b).

Some additions to the sea network were made, particularly on fast ferry routes (which were not of relevance for freight in 1995). The bulk and lo-lo networks were, of course, deleted from the passenger network model.

The derivation of cost data for air transport has been described above. Data for other modes were obtained from the information gathered in the course of Task 2, and is further described in appendix B. See also Appendices G and H.

6.4.3 Calibration

No observed origin-destination data were directly available in a suitable format to calibrate the model. Thus, a number of compromises were inevitable.

The primary objective was to locate datasets which were readily available and could be transformed into a format suitable for calibration of the passenger model without making an excessive number of assumptions. The principal sources used were:

- Bord Fáilte (Irish Tourist Board) "Perspectives on Irish Tourism" statistics (Bord Fáilte 1999).
- Northern Ireland Tourist Board (1996) statistics.
- Civil Aviation Authority (CAA) origin-destination surveys (CAA 1993a, 1993b).
- Aer Rianta statistics on passenger origins (Lynch 2000).

Matrices were derived from these wherever possible, although these were inevitably partial, i.e. only including trips originating from one end (for instance, Bord Fáilte statistics only provide data on trips originating outside Ireland). Microsoft Excel was used to calibrate direct demand generation-distribution models (via the well-known method of linearisation by taking logarithms) for business and non-business trips.

The independent variables for the originally-chosen business model were Gross Value Added (GVA) in origin and destination zones, along with the average cost (a weighted sum equal to 0.9 times the air cost plus 0.1 times the car accompanied cost) of travel between the two. The weightings were determined empirically, starting from the principle that air cost was considered significantly more important than car accompanied cost in this market.

However, had stated or revealed preference data been available, it would have been preferable to use them for this purpose. The calibration process showed somewhat disappointing t-statistics for cost, but it was retained in the model as a matter of principle. However, attempts to project 2020 demand showed an unduly large growth in business traffic over the period 1995-2020, out of line with growth in non-business traffic. As a consequence, the model was reconsidered. The only alternative giving satisfactory performance utilised the populations of the two zones and GVA per capita in the origin zone as independent variables. While the omission of cost from this model is regrettable, no way of incorporating it without incurring considerable inaccuracy could be found.

In the non-business model, population in origin and destination zones, GVA per capita in the origin zone, services GVA in the destination zone (as a proxy for the size of its tourist sector) and average cost of travel (this time equal to 0.6 times the air cost plus 0.3 times the car available cost plus 0.1 times the classic cost) were the independent variables. Weightings were determined by a parallel process to that described above for business costs. Services GVA of the destination zone proved insignificant on t-statistics; as there was no good theoretical reason for retaining it, the variable was dropped.

Experiments with various multiplicative and linear modal split models were conducted, but the results were disappointing. The decision was taken to apply a nested logit model. Calibration was carried out principally on modal-split data extracted from Bord Fáilte statistics; as this was at country level, it was necessary to utilise population-weighted sums of the individual regional costs in the calibration process. The upper level of the model deals with air/surface modal split (with "new mode" trips, where relevant, being considered alongside air at this level). The lower level deals with the split between car-accompanied and classic travel- for non-business traffic only, all surface business traffic being assumed to be car-accompanied- and, where relevant, between air and "new mode". It should be noted that the available sample was limited in geographical extent to inward travel to Ireland from Britain, France, Germany, Italy and Switzerland. Furthermore, it only applied to non-business travel (although a 95:5 air: surface split was assumed for business travel, based on statistics from English Channel traffic (DETR 1999b), and this was incorporated into the calibration). Figure 6.1 summarises the pattern of modal split modelling.

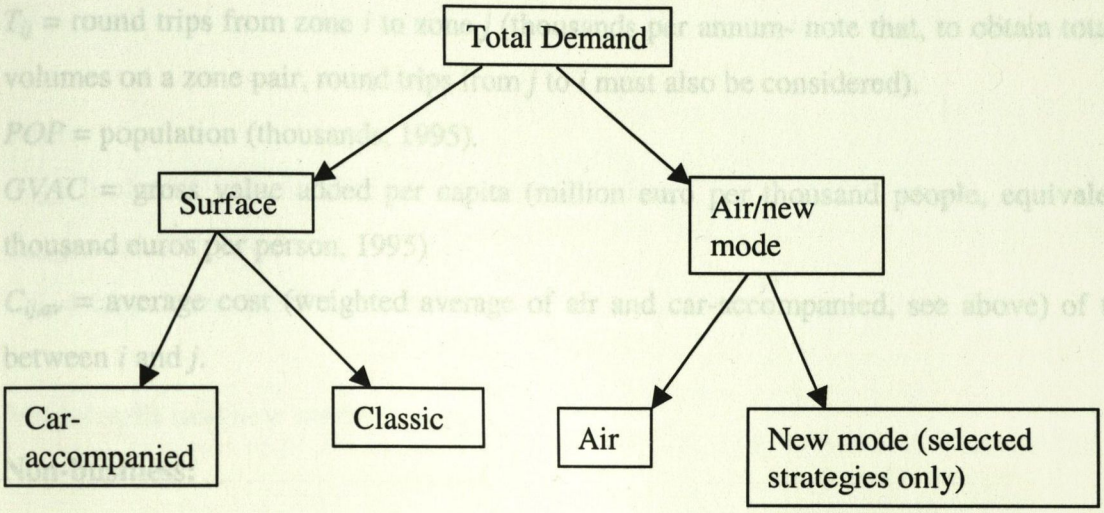


Figure 6.1 Passenger Modal Split

In their eventual form, the modal split models can split demand between air, car-accompanied, classic and "new mode" travel. Air trips are then assigned to a network consisting of all three (mainline, low-cost, regional) airline types plus road and rail. Car-accompanied trips are assigned to a road/ferry network and classic ones to a coach/rail/ferry network. "New mode" trips are only considered in those strategies incorporating fixed link or buoyant air networks, and are assigned to a network consisting of the new mode (buoyant air or high-speed rail) plus road and rail. As described in chapter 8, the second round of modelling incorporated the experimental assignment of air as well as new mode demand to the new mode networks; the results (and merits) of this measure are further discussed in chapter 9. All signs and magnitudes of coefficients, in both generation and modal split models, appear to accord with what might be intuitively expected.

The models resulting from this process were:

Business:

$$T_{ij} = 0.00000000123456 \left(POP_i^{0.933573} \right)\left(GVAC_i^{1.317533} \right)\left(POPj^{1.245637} \right)$$

$(r^2 = 0.67)$

where:

T_{ij} = round trips from zone i to zone j (thousands per annum- note that, to obtain total trip volumes on a zone pair, round trips from j to i must also be considered).

POP = population (thousands, 1995).

$GVAC$ = gross value added per capita (million euro per thousand people, equivalent to thousand euros per person, 1995)

$C_{ij,av}$ = average cost (weighted average of air and car-accompanied, see above) of travel between i and j.

Non-business:

$$T_{ij} = 17.767(POP_i^{0.97487})(GVAC_i^{0.272038})(POPj^{0.756245})(C_{ij,av}^{-2.59667})$$

$(r^2 = 0.60)$

definitions as above.

Note that $C_{ij,av}$ in this case takes account of classic travel as well as air and car-accompanied- see above.

Modal split (air/surface)

$$P_{air} = 1/(1 + \exp\{-0.016188(C_{surface} - 1.77432 - C_{air})\}$$

$(r^2 = 0.87)$

where:

P_{air} = probability of choosing air mode.

$C_{surface}$ = surface mode cost (= 0.8 car-accompanied cost + 0.2 classic cost)

C_{air} = air mode cost.

Modal split (car-accompanied/classic)

$$P_{c/a} = 1/(1 + \exp\{-0.013225(C_{classic} + 1.812258 - C_{c/a})\}$$

$(r^2 = 0.40)$

where:

$P_{c/a}$ = probability of choosing car-accompanied travel.

$C_{classic}$ = classic travel cost.

$C_{c/a}$ = car-accompanied travel cost.

Modal split (air/new mode)

Regrettably, it was not possible to independently calibrate a model for this purpose. Given that the model would have to deal with modes not currently operational in the market, the only possible approach would have involved the use of stated or revealed preference data, which were not readily available. Therefore, the decision was taken to use the previously-developed air/surface modal split model. The car-accompanied/classic model was not used because it appeared to be less readily transferable, reflecting the specific circumstances of that choice, and less robust.

$$P_{air} = 1/(1 + \exp\{-0.016188(C_{new} - 1.77432 - C_{air})\}$$

where:

P_{air} = probability of choosing air mode.

C_{new} = new mode cost.

C_{air} = air mode cost.

The models' performance may be regarded as satisfactory in the context of the limited time available for development and the poor quality of demand data. However, it is important to observe that their performance is not in the same league as that of the STEMM (MAP-1) passenger model (see 3.4.4 above). This latter model exhibited r^2 values in excess of 0.95

(Gaudry et al. 1998, Appendices 1-3). However, it utilised a large sample of formal origin-destination data (though Ireland was not included) for calibration. It is furthermore important to remember that, as discussed in chapter 3, it was not possible to apply this model directly in the present context and that replication of its approach was not feasible owing to the lack of readily available data for some of the variables used.

6.4.4 Validation

It was considered that the relative dearth of suitable data made a validation of true statistical worth extremely difficult. Therefore, it was decided that validation would consist of assessments of overall numbers to and from the Republic of Ireland, passenger volumes through Dublin airport and volumes on selected air routes.

The assessment of overall numbers was unable to produce any realistic value for r^2, given the small sample size; however, it appeared that the general level of demand had been broadly replicated. A comparison of modelled and actual (CAA 1996a, 1996b) volumes on air services was also attempted but (using the final form of the trip generation model) did not give an acceptable value for r^2. It was noted that the model had an apparent tendency to overestimate volumes on routes serving heavily-populated zones and underestimate volumes on thinner routes, but there were several exceptions to this rule.

Experiments were carried out with aggregation of the air routes into regions or airport groups in order to confirm or refute a further apparent tendency to produce significantly more reliable results on a corridor level than a link-by-link one. Two different grouping systems were used: one (Table 6.3) based on NUTS 2 regions for the island of Ireland (Border, Midlands & West, Southern & Eastern, Northern Ireland) and a division of Britain into three (Scotland/Wales/South West England, East/South East England, rest of England), the other (Table 6.4) on four groups (Dublin, Ulster, South West/South East, rest of Republic) in Ireland and six (Scotland, Wales/South West England, North/Yorkshire, North West, Midlands, East/South/East England) in Britain. Both showed broadly acceptable values (0.53 to 0.72) of r^2. It is therefore likely that the model is indeed considerably more effective on a corridor than a route-by-route basis; this level of accuracy is entirely appropriate for the uses intended in the context of the present project. Airport-specific cost penalties were used in a small number of instances in order to optimise the model results; these did not affect user costs in later stages of analysis.

Table 6.3 Passenger Validation Results by Airport Groups 1

From	To	Modelled	Actual
Dublin	Scotland	43	378
Dublin	North/Yorks	50	123
Dublin	North West	560	664
Dublin	Midlands	523	488
Dublin	East/SE	5,013	3,074
Dublin	Wales/West	34	95
South	North West	0	48
South	Midlands	8	48
South	East/SE	148	498
West	North West	0	31
West	East/SE	1,314	442
Ulster	Scotland	449	224
Ulster	North/Yorks	38	124
Ulster	North West	414	331
Ulster	Midlands	26	281
Ulster	East/SE	3,737	1,529
Ulster	Wales/West	0	14

Table 6.4 Passenger Validation Results by Airport Groups 2

From	To	Modelled	Actual
S&E	Scot/Wales/SW	74	473
S&E	NW/North/Yorks/Mid	1,141	1,384
S&E	E/SE	6,475	3,912
BMW	Scot/Wales/SW	0	6
BMW	NW/North/Yorks/Mid	0	20
BMW	E/SE	0	103
NI	Scot/Wales/SW	249	232
NI	NW/North/Yorks/Mid	478	735
NI	E/SE	3,737	1,529

Finally, comparison of Dublin airport passenger flows showed 7,448,000 passengers per annum in the model versus 7,189,000 in the actual 1995 situation (excluding transatlantic passengers). This was considered to be well within the bounds of acceptability in the circumstances.

The model may again be compared to the STEMM/MAP-1 model in this respect. The latter produced a value of $r^2 = 0.93$ on road and rail Alpine crossings (calculated by the author from IWW 1998, Table 15). Again, this model outperforms the author's, but the factors referred to at 6.4.3 above must again be taken into account.

6.5 THE FREIGHT MODEL

6.5.1 Choice of model

The evaluation of model forms in Chapter 4 led to a final shortlist of just two models, MDST and STAN. Both were used in the STEMM 4th Framework project; MDST was a development of a limited pre-existing model, whereas STAN was an essentially "off the shelf" package using existing software with some minor enhancements requested by the relevant STEMM partners. Detailed descriptions of MDST and STAN are given in sub-sections 3.4.9 and 3.4.8 respectively, of this thesis.

Both MDST and STAN had proven successful in their STEMM applications; furthermore, STAN had been successfully applied in several previous studies in a variety of countries principally located in Scandinavia and North and South America. They were therefore both judged to be well proven in practice, but with STAN possessing distinct advantages by virtue of its pre-STEMM history.

A feature of the MDST model was that it was developed from a cross-Channel model and generalised to apply to any "crossing" situation- the example in STEMM being the Alpine crossing. This would imply suitability for Irish applications; however, it is not clear whether it necessarily implies greater suitability than STAN. The latter was employed in STEMM case studies of freight traffic across the North Sea and on the Scan-Link corridor (Germany-Sweden); both of these involve crossings of a significant water barrier and thus resemble the Irish Sea situation. There was no reason to suppose from the results of the various case studies that STAN experienced any problems in representing and analysing such a situation.

In terms of compliance with the basic technical requirements which have emerged from the review, both models appear to perform well. Both can represent complex multi-modal networks. The MDST model was to have incorporated an allowance for the longer term effects of new infrastructure on freight flow patterns, but it was not possible to develop this within the STEMM project. As they stand, therefore, both models rely on exogenous trip generation. Unlike the passenger situation, there is no evidence to believe that transport changes have a significant immediate effect on the overall volumes of freight movements

in the Irish access market. Therefore, the sacrifice involved in accepting a trip generation format that did not respond to changes in transport supply would not be unacceptably large.

Calibration has been an area of concern throughout this phase of the project. Chapter 3 makes it clear that calibration requirements were considered important to the choice of model format; however, different model types were not always found to have significantly differing requirements. The situation with regard to the choice between MDST and STAN was somewhat different. In this case, the STEMM project had shown that STAN could be successfully implemented with a simplified calibration methodology (STEMM Freight Flow Model), as used in the Scan-Link case study. The position with regard to MDST was less clear; in the cross-Channel case study at least, the model had been calibrated on data from surveys. Such resources would not be available to the present project, and the surveys carried out for STEMM had anyway proved less adequate than might have been desired in some respects.

On the basis of the formats of the two models as they were employed in STEMM (making no allowance for any possible future enhancements), STAN is distinctly superior on grounds of ease of calibration and a more extensive record of successful applications. There did not appear to be much to choose between the two models on other matters. The overall judgement was that the acquisition of STAN for the purposes of this project should proceed.

6.5.2 Detailed specification

The model chosen for modal split and assignment purposes is the STAN model. The structure of STAN is described in greater depth in chapter 3. Although matrices from the Scan-Link STEMM case study were made available to the author, these include only trade flows to or from the Nordic countries of Iceland, Denmark, Sweden, Norway and Finland. Therefore, the majority of flows would have to be derived from some other source.

A decision in principle was taken to use OD-ESTIM to predict freight flows in future years, since (without a trade forecasting model) the STEMM Freight Flow Model is

insufficient for this purpose. This was subsequently modified to the development of a very simple regression model from Irish commodity flow data (the "external trade by ports" statistics published until 1993; CSO 1993). OD-ESTIM itself was of limited use because it had been calibrated on a different commodity classification. Development of this model was carried out in Microsoft Excel.

The zonification used in the Scan-Link case study was considered adequate for the requirements of the present work. The key areas-Ireland, UK, France, Benelux, Germany- are covered at a good level of regional detail in this system, and the coverage of the rest of Europe is more than adequate. The one alteration desired was to aggregate the Scandinavian countries to one zone per country (comparable to the rest of Europe outside Ireland/UK/France/Benelux/Germany) because there was no obvious benefit in representing them at a higher level of detail for the purposes of an Irish-based study. In addition, aggregation of the very complex Scandinavian network in the original data bank was necessary in order to reduce the system to a size manageable for the version of STAN used by the author. It was also a corollary to the drastic simplification of the zone structure in those countries.

The modal classification utilised in the Scan-Link study was considered appropriate for the Irish access market, with certain exceptions. "Piggyback rail" (mode "p") was not part of the Scan-Link base year network, although coded in the data bank. It was retained for possible use in a design-year scenario. "Rail ferry" and "inland waterway" (mode "i") networks were considerably reduced in size from the STEMM originals, and the rail ferry network eventually removed, but residual inland waterway links allowed to remain where they were of relevance. Two modes- air freight and fast car/truck ferry- were considered for addition to the list in order to better represent the characteristics of the Irish access transport system. It was decided to incorporate air freight (mode "A") into the 1995 base system, but not fast ferries, as no fast ferry services capable of conveying freight existed on Irish routes until 1996.

The modes in the 1995 network were therefore:

- Truck (mode "l")
- Rail (mode "r")
- Lo-lo (mode "a")

- Bulk ship (mode "b")
- Inland waterway (mode "i")
- Ferry (mode "f")
- Air freight (mode "A")

The following new modes were added in one or more of the 2020 strategies:

- Fast ferry (mode "s")
- High-speed (lo-lo) freight vessel (mode "H")
- Truck on piggyback rail or fixed-link rail shuttle (mode "p").
- Buoyant aircraft (mode "B").

The STEMM network was utilised as the basis for the 1995 base-year network. However, several changes were made:

- The networks in the Nordic countries (Norway/Denmark/Sweden/Finland) were entirely deleted and replaced by a greatly simplified version. This was done in order to keep the network tractable within the restrictions of the version of STAN available to the author, and because a high level of detail in this region was unnecessary for the purposes of this study. It must be noted that the original Nordic STEMM networks originated from national-level models, which is perhaps indicative of the very high level of detail.
- In the same vein, the number of centroids in the Nordic countries was reduced to one per country.
- Some general "thinning out" of the road, bulk shipping and rail networks in peripheral regions was conducted.
- A slightly denser road and rail network was provided in Ireland.
- The original cost functions were not available to the author. They were therefore replaced with new ones based on the data collected for the STAN North Sea case study. The opportunity was taken to update the price levels from 1995 to 1999.

6.5.3 Calibration

A calibration process was carried out by those responsible for constructing the STAN network used for the STEMM Scan-Link case study. According to VTT (1998, 3.9), "assignment results were compared with observed traffic volumes in Finnish ports and the rail and road network [leading to the imposition of port capacity restrictions]...the assigned mode share was compared with the share predicted in older studies. They were quite close to each other and no calibration had to be done except for checking bridge tolls".

It was considered that a more specific examination of the Irish situation needed to be made. Furthermore, it would be necessary to calibrate the freight flow generation model developed by the author for this specific context.

The calibration of the generation model was undertaken first. Table 6.5 shows how the NSTR classifications utilised by the original statistics were transformed to STEMM classifications. The STEMM classifications run down the table and the NSTR across; reading across from any STEMM classification, the coefficients in the cells of the table indicate what proportion of each NSTR category was assigned to that STEMM category. (The columns each sum to 1). Although this approach may seem somewhat crude, it was preferable in terms of resources available to the considerably lengthier and costlier alternative of examining trade data (which would have to be purchased) in detail so as to make up the flows in STEMM format.

Table 6.5 **NSTR-STEMM Commodity Transformation**

Commodity number	Commodity name	Ag. Prod./ live animals	Food-stuffs/ fodder	Solid mineral fuels	Petroleum products	Ores/ metal waste	Metal products	Crude/ manuf. minerals	Fertilisers	Chemicals	Machinery etc.
1	Food/live animals	0.75	0.5								
2	Beverages/ tobacco		0.25								
3	Crude inedibles	0.25				1		0.5			
4	Mineral fuels			1	1						
5	Animal/ Veg. oils		0.25								
6	Chemicals								1	1	
7	Paper/ Paper-board										
	Metal products						1				
9	Manuf. goods							0.5			0.25
10	Machine-ry										0.25
11	Misc. manuf. articles										0.25
12	Valuable machinery etc.										0.25

Once Ireland's total imports and exports in STEMM format for the years 1986-1992 inclusive had been generated by the above method, the next step was to calibrate a regression model on these data. A simple linear regression was used, based on GDP (at 1993 prices) by sector (agricultural/industrial/services), with the best approximation to the commodity's producing sector being used to generate exports and a similar approximation to the consuming sector to generate imports. Table 6.6 indicates the GDP sectors utilised for the various commodities. Table 6.7 provides a concise summary of the calibration process.

Table 6.6 Production/Attraction Variables for Freight Traffic

Commodity number	Commodity name	Production variable	Attraction variable
1	Food/live animals	Agricultural GDP	Services GDP
2	Beverages/tobacco	Industrial GDP	Services GDP
3	Crude inedibles	Agricultural GDP	Industrial GDP
4	Mineral fuels	Industrial GDP	Industrial GDP
5	Animal/veg. oils	Agricultural GDP	Industrial GDP
6	Chemicals	Industrial GDP	Industrial GDP
7	Paper/paperboard	Industrial GDP	Services GDP
8	Metal products	Industrial GDP	Industrial GDP
9	Manuf. goods	Industrial GDP	Services GDP
10	Machinery	Industrial GDP	Industrial GDP
11	Misc. manuf. articles	Industrial GDP	Services GDP
12	Valuable machinery/ manuf. articles	Industrial GDP	Services GDP

Table 6.7 Freight Calibration Results

Commodity number	Commodity name	Exports			Imports		
		Intercept	Slope	r^2	Intercept	Slope	r^2
1	Food/live animals	1225	0.2	0.21	94	0.11	0.77
2	Beverages/tobacco	90	0.03	0.74	-548	0.06	0.88
3	Crude inedibles	727	0.18	0.58	123	0.06	0.77
4	Mineral fuels	170	0.05	0.54	7066	0.08	0.24
5	Animal/veg. oils	-20	0.15	0.73	173	0.03	0.93
6	Chemicals	-247	0.11	0.84	1368	0.16	0.89
7	Paper/paperboard	22	0.01	0.81	-388	0.03	0.86
8	Metal products	-25	0.02	0.67	155	0.02	0.69
9	Manuf. goods	221	0.04	0.57	-1998	0.16	0.9
10	Machinery	3	0.01	0.9	-575	0.05	0.97
11	Misc. manuf. articles	3	0.01	0.9	-575	0.05	0.92
12	Valuable machinery/ manuf. articles	3	0.01	0.9	-575	0.05	0.92

It will be seen that the r^2 values obtained are generally quite satisfactory, though their importance should not be exaggerated in view of the approximate nature of the transformation between commodity classifications.

Following this, the total Irish imports and exports for 1995 (this time including Northern Ireland) were generated. They were then disaggregated two-dimensionally by the share of Irish GDP in the relevant sector produced by each region of the island (8 planning regions of the Republic, plus Northern Ireland) and the share of "rest of Europe" GDP in that sector produced by each zone in the remainder of the continent. This led ultimately to the generation of a matrix for each commodity. These matrices were then assigned to the modified Scan-Link network using STAN.

6.5.4 Validation

As in the case of the passenger demand model (described in chapter 5), there was insufficient information available to attempt a validation of true statistical worth. Furthermore, the absence of usable link volume counts, such as the airline passenger statistics used to validate the passenger model, made the task even more difficult.

In the end, validation was confined to comparing actual and modelled volumes for freight traffic through a number of ports. Dublin/Dún Laoghaire (considered as one unit), Rosslare, Waterford and Cork were chosen; in each case, ro-ro, lo-lo and bulk traffic were considered, except for Rosslare (ro-ro only) and Waterford (no ro-ro). Thus, a total of eighteen traffic figures (i.e. split into import and export) could be compared. Initial experiments showed a disappointing r^2 value of 0.16, with a distinct tendency to overestimate lo-lo traffic at the expense of ro-ro. Modification was therefore indicated; this took the form of manipulation of the generic unit cost values for the various modes and addition of port-specific penalties where appropriate. After fifteen iterations, an acceptable value of 0.58 for r^2 was achieved. Table 6.8 below shows the results in detail.

Table 6.8 Quantitative Freight Validation Results

Port	Mode	Import/Export	Modelled	Actual
Rosslare	ro-ro	export	1,028	562
Rosslare	ro-ro	import	1,656	569
Waterford	lo-lo	export	28	631
Waterford	lo-lo	import	44	635
Waterford	bulk	export	697	116
Waterford	bulk	import	1,552	394
Cork	lo-lo	export	232	316
Cork	lo-lo	import	455	215
Cork	ro-ro	export	0	40
Cork	ro-ro	import	0	82
Cork	bulk	export	1,285	2,309
Cork	bulk	import	3,068	4,141
Dublin Bay	lo-lo	export	383	1,053
Dublin Bay	lo-lo	import	1,001	1,325
Dublin Bay	ro-ro	export	1,088	1,155
Dublin Bay	ro-ro	import	3,439	1,487
Dublin Bay	bulk	export	502	558
Dublin Bay	bulk	import	3,288	3,324

Additionally, a qualitative comparison was conducted between the findings of TPRI (1995) and those emerging from the freight demand model. The results are indicated in Table 6.9 below.

Table 6.9 Qualitative Freight Validation Results

TPRI commodity	STAN commodity	TPRI ro-ro use	STAN ro-ro use	TPRI lo-lo use	STAN lo-lo use
Office computers etc.	Valuable machinery/ manuf. articles	High	High	Low	Medium
Pharmaceutical	Chemicals	Medium	Medium	High	Low
Dairy	Food/live animals	Medium	High	High	Low
Service industry (software)	Misc. manuf. articles	High	High	Low	Medium
Other food	Food/live animals	Medium	High	High	Low
Auto parts	Manuf. goods	Low	Medium	High	Low
Healthcare/ medical	Valuable machinery/ manuf. articles	High	High	Medium	Medium
Telecom/ electrical	Valuable machinery/ manuf. articles	High	High	Low	Medium
Meat products	Food/live animals	High	High	Low	Low
Basic industrial chemicals	Chemicals	Low	Medium	High	Low

The results achieved are generally acceptable; however, a loss of accuracy is apparent in some areas where the TPRI commodities obviously account for only a very small portion of the STAN ones, particularly where several TPRI categories with conflicting requirements make up a STAN commodity. Problems of this nature are inevitable in freight modelling, where the classification of commodities is critical to the replication of real-world behaviour. This issue is further discussed in chapter 9.

Unfortunately, insufficient information was available on the accuracy of the STAN freight modelling processes to permit their comparison with the author's work (along the lines of the comparison conducted above for passenger modelling).

7 APPRAISAL FRAMEWORK

7.1 INTRODUCTION

One of the primary objectives of this project is the development of a framework to facilitate the appraisal of alternative strategies for the future development of the transport system. The relevant literature has been reviewed in chapter 3 (section 3.5 in respect of appraisal methodologies, and section 3.3 in respect of the objectives of current policy, which form another important input to the development of the appraisal framework). This chapter aims to build on the work already carried out, selecting an appropriate approach or combination of approaches for further use.

Section 7.2 of this chapter gives a general overview of the principal methodologies available and the main choices to be made. Section 7.3 examines the most appropriate objectives and criteria for use in multicriteria analysis (MCA). Section 7.4 addresses issues arising from the representation of various incidence groups within the framework, while section 7.5 deals with technical issues affecting MCA. Finally, section 7.6 covers issues relating to cost-benefit analysis (CBA).

7.2 PRINCIPAL OPTIONS

7.2.1 General classification of methodologies

By this stage, it is apparent that the spectrum of possible analysis methods can be divided into two major categories. The first of these comprises those based upon some form of quantification of the outputs of a scheme, set against its monetary costs. Cost-benefit analysis, cost-effectiveness analysis and the Planning Balance Sheet are examples of this approach.

The second approach involves assessment of how well a scheme satisfies certain objectives. Multicriteria analysis is the most commonly used form of this approach, but

goals achievement analysis, the Judgmental Impact Matrix and the Environmental Evaluation System are others (albeit rarely seen in contemporary transport applications).

It was considered probable that the methodology finally chosen for this project would incorporate elements of both these categories. The specific methods on which it will draw, and the way in which they might be combined, are the subject of the remainder of this chapter.

Of the various methodologies investigated in the previous chapter, there is little doubt that cost-benefit analysis and multicriteria analysis are the best proven in practice. The Planning Balance Sheet (really a special case of cost-benefit analysis) has had various successful applications, but is not well established in applications analogous to this one. Therefore, it is proposed that any further investigation should be confined to cost-benefit analysis and multicriteria analysis.

Although CBA and MCA have been selected as the probable bases of the appraisal framework, this does not imply any preference as to where on the scale from pure CBA to pure MCA this methodology should lie, nor as to how exactly the two should be combined. Such issues are addressed in the remainder of this chapter.

7.2.2 Further analysis

The possible solutions have, by this stage, been narrowed down to CBA and MCA. However, within these constraints, there are many forms which the analysis framework could take. The following are examples of the major options:

- Entirely multicriteria-based analysis.
- Multicriteria analysis with cost-benefit data used as an indicator in the determination of the scores. This would resemble the British trunk road appraisal system, except that the final summary sheet would contain only multicriteria marks and not indicators.
- Parallel, independent CBA and MCA processes.
- CBA with multicriteria-type presentation of those impacts which are difficult to cost.

- Purely cost-benefit-based analysis. Every possible impact would be costed, and no account taken of uncosted effects.

The last of the options listed above can immediately be seen to be of dubious viability. A "pure" CBA would require non-contentious methods for the costing of all relevant impacts; otherwise, the choice would lie between making costings with insufficient supporting evidence and omitting the effects from the analysis altogether, neither of which approaches is likely to lead to a credible result.

On a superficial level, the all-MCA concept (that is, the first one on the list of options) appears considerably more attractive. There would be little problem in converting all effects (via the intermediary stage of indicators where possible) into a multicriteria format.

However, there are considerable difficulties inherent in the pure MCA approach, resulting mainly from the lack of any quantitative consideration of cost. This is particularly true in the present circumstances, where capital costs can easily be measured in tens of billions of euro.

It may be argued that other studies- the Dublin Transportation Initiative being the prime example- made decisions on extremely costly projects using MCA alone. This is not, however, entirely true. The various Themes were assessed on a pure MCA basis, but the most costly elements were also subjected to CBA, by virtue of the fact that they generally fell into the categories of public transport or port access measures (which areas were the subjects of more detailed analysis).

The methodologies remaining in serious consideration at this stage are thus the three CBA/MCA combinations. The first of these- the use of the CBA outputs as indicators in determining multicriteria scores- is attractive in terms of achieving a seamless integration of methodologies. It does not attempt to overstretch CBA's capabilities, but equally does not deny the utility of CBA in those roles to which it is most appropriate. This approach makes clear the fact that the aspects considered in CBA represent only one facet of a complex appraisal. It would, however, require careful design to avoid the tendency towards either CBA or MCA dominance, but this is not believed to be a significant problem.

The second- the parallel, entirely independent approach- has the attraction of a diversity of methodologies, so that the outcome of the appraisal is less likely to be influenced by the choice of method. Unfortunately, it is also likely to lead to contradictory and contentious results, and it may not be entirely appropriate to put CBA on an equal footing with MCA.

Finally, the approach involving mixed MCA and CBA treatment of the appropriate impacts within a single table must be considered. This has some attractions as a framework, but also distinct disadvantages. One of the methods may distract from the other in the presentation of results, and, although a clash between CBA and MCA outcomes would be less of a problem in this case, it would nevertheless still affect the credibility of the appraisal.

Ultimately, the author believes that the appropriate choice is the first of the three combined approaches listed above.

7.3 OBJECTIVES AND CRITERIA

7.3.1 Previous work

The choice of appraisal criteria for this project has drawn on a number of sources. Initial work suggested that four broad areas- competitiveness, equity, sustainability and feasibility- could be identified in much of the literature described in chapter 3 (see also Appendix D). Further analysis of this material provided considerable assistance in relation to refinement of the list of criteria for each objective. Unfortunately, the consultation work (see below) proved of comparatively little value in this context. However, discussions with others involved in the project were of considerable assistance in the refinement process.

Appendix C provides a comprehensive listing of criteria utilised in reviewed appraisal frameworks. Table 7.1 below lists the broad areas covered by the appraisal criteria of some of the more important past multicriteria studies.

Table 7.1 Criteria in past multicriteria studies

	DTI	SPG	NATA	SEAAF	Eurostar
Economic development	•	•	•		•
Tourism	•				
Reliability/comfort			•		•
Safety	•		•	•	•
Security	•				•
Environmental impacts (general)	•	•			
Noise			•	•	•
Air pollution			•	•	
Climate change			•	•	
Consistency with other plans/policies	•		•	•	
Spatial balance	•	•			
Access to markets	•				
Access to region	•				
Financial efficiency	•	•	•	•	•
Best use of existing resources	•	•			
Timescale	•				
Legislative requirements	•				
Disruption	•				

(DTI = Dublin Transportation Initiative; SPG = Strategic Planning Guidelines for the Greater Dublin Area; NATA = New Approach to Transport Appraisal; SEAAF = South East Airports Appraisal Framework; Eurostar = Review of Regional Eurostar Services. See chapter 3 and Appendix C for further details of the studies/frameworks)

7.3.2 Consultation

It was always intended that consultation with relevant interest groups would have a vital role to play in this research project. The author saw this process as being important to relating the outcome of the research to real-world Irish access transport issues as perceived by those directly involved. It was furthermore hoped that consultation would contribute to raising awareness of alternatives to the do-minimum, particularly if the final analysis found such courses of action to be worthwhile.

The initial concept of the consultative process was as an input to the development of an appraisal methodology. As the idea was progressed, it became apparent that there were potential advantages in involving interest groups in the appraisal process itself. However,

this would be futile if the appraisal framework proved unacceptable to the majority of such organisations. Accordingly, it was felt that consultation on a suitable methodology was an essential first step.

The fundamental framework has already been laid down in the preceding chapters of this report. The objectives of competitiveness, equity, sustainability and efficiency will be used as the basis of the framework. The author drew up a preliminary list of criteria, based on those incorporated into previous studies and on an analysis of the project's objectives. These were then used as a basis for development, in parallel with the input from consultation.

The actual list of organisations to be included in the consultative process was loosely based on a number of principles. These included:

- Organisations which had made contributions to the access transport debate, in the form of opinions published in the general and specialist press, or of submissions or interviews in the context of previous studies.
- Organisations which had contributed in a similar vein to the more general transport debate (but not specifically on access transport matters), provided that their scope of activity was not so narrow as to exclude access transport.
- Any other organisations representing business, regional interests or the environmental lobby, provided again that access transport fell within their scope of activity.

Organisations consulted included: Chambers of Commerce of Ireland, Confederation of British Industry (Northern Ireland), Council for the West, Earthwatch, Friends of the Earth (Northern Ireland), Friends of the Irish Environment, Irish Business and Employers' Confederation, Irish Congress of Trades Unions, Irish Exporters' Association, Irish Hotels Federation, Irish Road Haulage Association, Irish Tourist Industry Confederation, An Taisce and Western Development Commission. Most but not all replied to enquiries; however, not all of the respondents had specific views on access transport.

It was readily apparent that a number of alternative methodologies existed for the conduct of the consultation process. A review of literature in the area (Oppenheim 1966, Hoinville

et al. 1975, Moser and Kalton 1975, Taylor and Bogdan 1998) was carried out. In addition, discussions were held with others involved in the project.

The primary options emerging from this process appeared to be:

- Face-to-face interviewing; impractical because of travel costs (the interest groups to be considered being based at various locations throughout the island of Ireland) and the time implications for interviewees.
- Telephone interviewing; this would be a lower-cost approach than either face-to-face interviewing or a postal questionnaire, but more costly and somewhat more complex than the use of e-mail. It was considered worthy of attention in cases where e-mail was not available.
- Questionnaire survey; costs would be modest compared to face-to-face interviewing, although it would not be the cheapest option. Extreme care would have to be taken in the design of the questionnaires in order to encourage the recipients to reply. Even then, the literature (e.g. Oppenheim 1966) suggested that the reply rate could be expected to be relatively disappointing. This was a particular cause for concern in the context of the limited overall number of possible respondents for this study.
- E-mail interviewing; this would be an extremely low-cost and flexible (allowing the combination of elements of interviewing and questionnaire surveys, facilitating "reminder" messages, etc.) approach. It suffers from two principal disadvantages; it is relatively unproven and not always feasible (because access to e-mail is not universal, even amongst major interest groups). Nevertheless, a modest amount of literature on the subject (e.g. Coomber 1997, Selwyn and Robson 1998) now exists, and it was felt that, provided telephone communication was available as a back-up, no significant problems would arise.

The decision was therefore made to use a combination of e-mail and telephone communication in the survey. It must be pointed out that initial draft questionnaires were, in fact, produced for a possible postal survey, but the concept was abandoned as excessively time-consuming and presenting too many difficulties of questionnaire design; it was subsequently decided to investigate the possibilities offered by the use of e-mail.

The early draft questionnaires formed an input to the process of drafting guidelines for the e-mail survey, but it was decided to limit the scope of these guidelines to simple outline

guidance on the content of correspondence and not to draft a full e-mail questionnaire. This is in accordance with general practice in the field of qualitative interviewing; for example, Taylor and Bogdan (1998) describe such a process as being inherently "nondirective, unstructured, nonstandardized, and open-ended".

The responses received were in two principal forms: specific replies to the queries raised and copies of more general policy documents relating to the field. Although extreme caution should be exercised in generalising about the response, given the very small sample involved, the following points are of note:

- Very few organisations have specific views on access transport (as opposed to transport in general). This has limited the utility of the consultation process somewhat.
- At least one respondent stated that they were not concerned with issues of access transport policy.
- Environmental issues emerged principally in terms of favouring public transport over roads for inland transport purposes (including improved rail links to ports and airports). There was no mention of environmental issues associated with aviation, seaports or any other aspect of access transport proper.
- Peripheral development issues were also considered important, although principally by lobby groups or other organisations dedicated specifically to that aim. A "front-loading" of spending (within the current National Development Plan period) towards the Border, Midlands and West region of the Republic was favoured by one respondent. Specific proposals for this region (including some not included in the current NDP) were made by two respondents.
- Competitive passenger fares, particularly for inward tourist traffic, were favoured by one respondent.

The results appear to, broadly speaking, validate the author's approach to development of the appraisal framework. It is not envisaged that any modifications to this framework will be necessary as a direct result of the consultation process.

It has been mentioned that consideration was given to involving interest groups in the appraisal process itself, such that the ultimate results would reflect their views as well as the author's. Some theoretical investigation was carried out in this field. The initial approach considered was that of bringing the parties together in a face-to-face meeting and

proposing a result based upon a synthesis of views as described above, which would then be discussed by those present and modified until the maximum degree of consensus was achieved. This was rejected principally on grounds of cost and time limitations.

Attention therefore turned to the possibility of a participation method that would be effective in building consensus but not necessarily require a face-to-face meeting. In particular, the author investigated the potential of the Delphi method.

Delphi was developed by the Rand Corporation in the US during the 1950s, initially for use in strategic studies of national defence, although its subsequent applications have been many and varied. Linstone and Turoff (1975b) define Delphi as "a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem". In its conventional form, Delphi is "a combination of a polling procedure and a conference procedure" whereby an initial questionnaire is sent to a respondent group, the results summarised and an opportunity offered to the respondents to change their views in the light of the group response. This can go on for any number of rounds, but Brockhoff (1975) found no statistically discernible benefit in extending the process beyond three rounds. He also found that "a general positive relationship between group size and group performance cannot be recognised".

Many Delphi applications have been in the area of forecasting technological, commercial or societal trends. Typically, the process is used to determine a "target" year by which time a change in market share, demography etc. will take place. Another application is in identifying issues of concern for examination in a subsequent, more detailed, study; this could be regarded as similar to the process of identifying objectives and criteria in this report, although it was not intended to use Delphi for the latter purpose.

In the context of this project, the author investigated the use of a quasi-Delphi methodology for the marking of multicriteria evaluation matrices, based on a mixture of qualitative indicators and quantitative descriptions of the relevant effects. It was proposed that the first round of questioning should consist of a table showing criteria, indicators and descriptions for each alternative strategy, with a column being provided for marking (on the project's standard seven-point scale- see also Table 7.6 below). The marks awarded by the individual participants would then be combined, along with the author's own views, into a "consensus" marking. This would be circulated to participants in the second round;

they would have the opportunity to question these marks and state their reasons for doing so. The process would be repeated in a third round before drawing up the final assessment.

Unfortunately, the relatively poor response to consultation on objectives and criteria suggested that this approach was unlikely to prove feasible, and it did not come to fruition.

7.3.3 Selected objectives and criteria

The final list of criteria is given below. These criteria were developed using previous studies and current policy objectives (see also chapter 3 and Appendix C) as a basis, along with the author's judgement as to the particular needs of this study. They were then gradually refined over a period of more than six months. It is hoped that a robust and transparent framework has resulted.

Competitiveness

Reduce logistical costs
Reduce passenger fares
Reduce passenger travel times
(the above two criteria later combined into "reduce passenger generalised cost")
Minimise capital expenditure

Equity

Balance between regions
Equitable treatment of user groups

Sustainability

Reduce climate change effects
Reduce air pollution
Reduce noise impact
Minimise land take
Preserve marine/coastal environment

Minimise visual intrusion

Minimal impact on ecology/heritage/community

Improve road safety

Efficiency

Economic efficiency

Minimise risk

Best possible use of existing infrastructure

Lead time

Need for legislative measures

Flexibility in implementation

7.3.4 Indicators

Indicators- quantitative measures whose changing values are used to assess compliance with criteria- are of considerable importance in most contemporary appraisal frameworks. The concept may be extended to take in concise, clearly-defined qualitative descriptions which aid the assessment of compliance in areas where quantitative indicators clearly do not suffice. This chapter deals with the definition of indicators- in the broadest sense of the word, including both quantitative and qualitative measures serving the common purpose of translating the "raw" output of the transport demand models into meaningful inputs to the process of assessing the various strategies.

The majority of the criteria selected for inclusion in this appraisal framework relate to the ability of a strategy to improve the situation relative to the base case. "Base case" is interpreted as meaning the base year (1995) for a do-minimum strategy and the do-minimum strategy itself for any "do-something" strategy. In these cases, the degree of compliance with the criteria is measured by the degree of reduction or increase (depending on which change is desirable) in the relevant indicator(s) compared to the base position.

Table 7.2 below presents the indicators provisionally identified as suitable for the relevant criteria. In the table, (-) in brackets following the description of an indicator signifies that the value of the indicator should decrease relative its value under the do-minimum strategy,

(+) that it should increase, (min) that it should be minimised and (max) that it should be maximised. In certain cases, other special conditions are set, and these are also described in the table.

The question of whether or not it is possible to quantify the selected indicators interacts to a certain degree with the selection process itself. Obviously, any quantitative indicator identified in respect of a chosen criterion must be supported by a clear method of deriving the necessary value(s) from available information such as demand model outputs. It does not, however, necessarily follow that all indicators must be quantifiable, as such an approach would be overly restrictive and could potentially lead to problems similar to those sometimes experienced in cost-benefit analysis.

The first stage in the process of investigating the feasibility of quantification was to examine the outputs available from the demand models selected in Task 1. This led to the conclusion that overall volumes by mode (in tonnes, t-km, passengers and passenger-km) along with transport costs for passengers and freight and the breakdown of such costs into their various components (e.g. out-of-pocket versus time costs) could generally be readily calculated, though problems experienced in some of these areas at a later stage required amendments to the methodology. Other indicators such as emissions and accident levels could be based on these. Considerable effort was devoted to the investigation of accessibility as a possible indicator (see chapter 3) but its use was ultimately rejected in favour of the Sugden (TEE table) cost-benefit analysis framework also described in chapter 3.

Table 7.2 Indicators and Criteria

Objective/criterion	Quantitative value	Qualitative description
Competitiveness		
Reduce logistical costs	Total logistical costs (-)	None
Reduce passenger fares	Average fare/p-km (-)	None
Reduce passenger travel times	Total passenger time costs (-)	None
Minimise capital expenditure	Total undiscounted capital expenditure (-)	None
Equity		
Balance between regions	NPV by region (+)	None
Equitable treatment of user groups	NPV by group (+ and balance between groups)	None
Sustainability		
Reduce climate change effects	Greenhouse gas emissions (-)	None
Reduce air pollution	Pollutant emissions (-)	None
Minimise visual intrusion	None	Description of impacts of new transport facilities and vehicles on visual environment (min)
Reduce noise impact	Numbers of people affected by high noise levels (e.g. around airports) (-)	Description of likely impact of strategy on overall noise levels (-)
Minimise land take	Area of land required for new transport facilities	Description of any special characteristics (agricultural quality, residential zoning) (min)
Preserve marine/coastal environment	Length of coastline affected by construction (min)	Description of likely effects on marine environment (min)

(continued over)

Table 7.2 continued

Objective/criterion	Quantitative value	Qualitative description
Sustainability (continued)		
Minimal impact on ecology/heritage/ community	Number of sites of scientific interest, heritage sites, affected by proposals, number of houses demolished (min)	Description of likely community severance effects (min)
Improve road safety	Number of road accidents (-)	None
Efficiency		
Economic efficiency	NPV (+)	None
Minimise risk	None	Assessment of degree of technological and physical (e.g. geological) risks involved (min)
Best possible use of existing infrastructure	Flows on key links as proportion of capacity (minimise both overloading and underuse)	Extent of new infrastructure required (min)
Lead time	Estimated years of commencement and completion (earliest possible)	Assessment of ability to implement by 2020 and of possibilities for limited implementation before 2010 (max)
Need for legislative measures	None	Assessment of possible legislative measures required (min)
Flexibility in implementation	Variation in NPV and other output measures under different scenarios (minimise variation)	Assessment of ease of incremental implementation (max)

The next step was to produce a tentative listing of all quantified indicators and their derivation, as shown in Table 7.3 below.

Table 7.3 Derivation of Quantitative Indicators

Indicator	Derivation
Logistical cost	Directly from transport models (broken down by zone where necessary)
Passenger fares	Directly from transport models (broken down by zone where necessary)
Passenger travel times	Directly from transport models (broken down by zone where necessary)
Capital expenditure	Author's estimates
NPV	CBA table
Greenhouse gas emissions	Passenger/tonne-km data from models + emission factors
Pollutant emissions	Passenger/tonne-km data from models + emission factors
Population affected by airport noise	SEAAF standard "footprints" + census data
Land take	Author's estimates
Length of coastline affected	Author's estimates
Number of scientific/heritage/residential sites affected	Author's estimates
Road accident levels	Passenger/tonne-km data from models + accident factors
Flows on key links as proportion of capacity	Flows from models + author's estimates of capacity
Timescale to commencement/completion	Author's estimates

Following this, a brief assessment was made of the availability of the required outputs and modifying factors described in the right-hand column of Table 5.2. This indicated that there seemed at this stage to be no significant problems in derivation of the chosen indicators, although the matter would have to be kept under review as the modelling and appraisal process continued.

Actual modelling work, as described in chapter 8, has brought some shortcomings to light. Fares and travel times had to be merged into passenger generalised cost, because this was the easiest way of deriving the information from the demand model. Quantitative indicators for noise, land take, coastal and scientific/heritage effects did not survive into the final appraisal, primarily because they were too complex to be realistically appraised within the time available. Flows on key links are considered without direct reference to capacity because definite long-term capacity projections were not available for all such links. The use of CBA outputs within the MCA had in practice to be rather more limited

than originally proposed, due to technical problems with the CBA which are covered in greater detail by chapters 8 and 9.

In some cases, it has proved necessary to adopt an approach of minimising further impacts (where these are undesirable) rather than reducing them relative to the base case. This is done because of the need to ensure a balanced assessment of all possible strategies, including do-minimum; some impacts (such as land take) may inevitably involve some increase relative to do-minimum for any do-something strategy, and the approach taken here would be to minimise this increase.

7.4 INCIDENCE GROUPS

Many applications of multicriteria analysis make use of one or more classifications of society into incidence groups in order to investigate the distributional implications of the impacts under study. The precise classifications used will depend very much on the purpose of the application.

The most comprehensive classification of this type known to the author was that carried out for the Dublin Transportation Initiative (1993). This recognised three separate sets of incidence groups: user, spatial and social.

The five user groups represented the users of four passenger modes (public transport, car, walking, cycling) and freight users. The six spatial groups represented residents of Dublin's major sub-regions (the Western Towns, city centre, northern and southern suburbs, free standing towns and outlying areas). Five social groups (the unemployed, the elderly, children, the mobility impaired and women) were examined. Therefore, there were a total of sixteen impact groups. Not every criterion was examined in the case of every group. The "quality of life" criteria (reliability, safety, security, pollution etc.) were examined for all sixteen, but, at the other extreme, the criterion "improve access to and from the sub-region" was only related to three groups (public transport, motorists and freight).

No summary of the overall impact of each alternative on an individual group (i.e. combining all the criteria under the group's heading) was carried out, although summary assessments of their impact across all groups (i.e. combining the impacts of each criterion on all the groups) were provided.

The author would suggest making the DTI classification the basis for the development of a group structure for this project. However, several modifications must be made in order to reflect more accurately the interregional situation.

The first amendment to the methodology suggested by the author would be to do away with social groups entirely. This does not mean that different social groups do not have different needs in terms of interregional transport, but rather that these are adequately covered by the user groups, insofar as they reflect differing patterns of journey purpose (e.g. some social groups may be more likely to travel on business than others). Furthermore, the importance of social groups to a regional transport study often lies in the importance of short distance transport to daily life (access to jobs, shopping, education etc.); interregional transport does not generally play such a role.

The user group structure applied by the DTI is too tied to modes to be readily transferable to a situation where most journeys are multimodal; it is suggested by the author that journey purpose would be a more appropriate basis for a classification by user group in the present context. This would also complement the observations on social groups made above.

As to the number of user groups examined, the logical division of passenger system users is into business and non-business. The latter could be divided further into tourist and personal users, and personal users into those travelling to visit friends and relatives and all others, but not all statistics or models support this level of detail. Freight system users could be treated separately or assumed to form part of the business user group.

The author would also propose including non-users of the system in the list of "user" groups. Essentially, this is because a larger proportion of the population will be non-users of the access transport system at any given time than will be non-users of a local system. This fact has been at the root of previous controversies over interregional transport infrastructure such as the Channel Tunnel and the Third London Airport. Additionally, the

absence of obviously "vulnerable" groups such as pedestrians and cyclists from the classification proposed in this study might otherwise lead to under-rating of negative impacts such as emissions and noise.

Spatial groups are an important part of any examination of the Irish access transport market. This arises principally from the fact that there are significant spatial inequalities in the existing network (such as the concentration of ports and airports along the eastern and southern coasts), as described in chapter 2. A future plan should redress rather than accentuate these inequalities; accordingly, spatial appraisal of options is necessary.

Several levels of spatial detail could potentially be applied. Obviously, a meaningful spatial appraisal must use (in the Republic of Ireland) units smaller than the country itself, which implies NUTS 2 or NUTS 3 zones, to use the EU terminology, or sub-NUTS 3 units such as counties. However, it does not appear likely that demand models allowing zonification at a level below NUTS 3 will be available for the purposes of this project. The choice therefore lies between NUTS 2 and NUTS 3.

At NUTS 2 level, the country is divided into two units, each of which is an agglomeration of NUTS 3 regions. The NUTS 2 regions are the Border, Midlands and West (which is peripheral and relatively poor) and the East and South (closer to the rest of Europe and comparatively prosperous). This regional division was, indeed, originally developed with a view to identifying the most disadvantaged regions for EU funding purposes.

There are three NUTS 3 regions in the Border, Midlands and West and five in the South and East. However, it does not appear that the fundamental differences in the characteristics of NUTS 3 regions within a NUTS 2 region are anywhere near as significant (at least for access transport purposes) as those between the two NUTS 2 regions. It is therefore proposed to use the NUTS 2 regions as the units for assessing spatial impacts in the Republic of Ireland (this must not be confused with the zoning structure for demand prediction, which, in Ireland, is at NUTS 3 level).

Northern Ireland cannot be meaningfully subdivided on the basis of readily available data. It is necessary to treat it separately from the remainder of the UK on the grounds that the project deals with the specific problems of the island of Ireland (including Northern

Ireland). Therefore, it should be considered as one of the units for assessing the distribution of impacts.

Outside the island of Ireland, all spatial groups can be aggregated without much loss of accuracy in the present context.

Therefore, the initial list of incidence groups was proposed to be:

User Groups:

- Business
- Tourist Industry
- Personal Travel
- Non-Users

Spatial Groups:

- Border, Midlands and West (BMW)
- South and East (S&E)
- Northern Ireland (NI)
- Rest of world

These were later modified, subsequent to extensive discussion others involved in the project, to take account of suggestions made. The modified group structure was:

Interest Groups:

- Business
- Tourist Industry
- Personal Travel
- Society at large
- Government

Spatial Groups:

- Border, Midlands and West (BMW)
- South and East (S&E)
- Northern Ireland (NI)
- Rest of world

An MCA appraisal table utilising these groups was developed and is shown in its final form in Table 7.4 below. The bullet points indicate the locations where scores would be entered, and the shaded cells in the table are impacts which were not considered of relevance (e.g. the aim of "minimise capital expenditure" is relevant to those who fund it- business, government and society at large- but not to spatial groups, which are assumed to favour maximum benefits to their regions regardless of cost).

The eventual decision, however, was not favourable to the explicit inclusion of incidence groups in the multicriteria analysis. This was primarily because the structure of the appraisal matrix became too complex once the incidence group concept was introduced. This would render the results less comprehensible (although it was always intended to provide a summary matrix showing the *overall* impact, aggregated across all groups, of each alternative on each criterion). It would also exacerbate the difficulties involved in having representatives of interest groups (who would be unfamiliar with the format) mark the appraisal.

Table 7.4 Multicriteria Appraisal Matrix with Incidence Groups

		Impact on groups								
	Strategy: **(name)**	Interest groups					Spatial groups			
	Criteria	Business	Tourist industry	Personal travel	Society at large	Government	BMW	S&E	NI	Rest of world
Competitiveness	Reduce logistical costs	•					•	•	•	
	Reduce passenger fares	•	•	•			•	•	•	
	Reduce passenger travel times	•	•	•						
	Minimise capital expenditure	•			•	•				
Equity	Balance between regions				•		•	•	•	•
	Equitable treatment of user groups	•	•	•						
Sustainability	Reduce climate change effects				•	•				
	Reduce air pollution				•					
	Reduce noise impact				•		•	•	•	•
	Minimise land take				•		•	•	•	•
	Preserve marine environment				•		•	•	•	•
	Minimise visual intrusion				•		•	•	•	•
	Minimal impact on ecology/heritage/community				•		•	•	•	•
	Improve road safety				•		•	•	•	•
Feasibility	Economic efficiency				•					
	Minimise risk	•			•	•				
	Best possible use of existing infrastructure				•	•	•	•	•	•
	Lead time	•	•	•	•	•				
	Need for legislative measures					•				
	Flexibility in implementation	•	•	•	•	•				

Some thought was given to the possibilities for incorporation of incidence groups into the CBA rather than the MCA. The Sugden approach to CBA (described in greater detail at 3.5.9 above) would be the obvious candidate methodology for such a measure. An adaptation of the TEE table was developed in outline for use in the context of this project. Table 7.5 below indicates how such an adapted table might appear. The principal modifications consist of:

- The replacement of modal user groups with spatially-based ones.
- Purpose-based user groups are defined on a finer level than in the original TEE table; business and non-business passenger travel are considered separately, and each is divided into Irish-based and non-Irish-based categories (later merged).
- The division between private and public sector providers is replaced by that between service and infrastructure providers, on the grounds that it is the more appropriate one for the Irish access market.
- Externalities are included (as a separate category).

The approach outlined in Table 7.5 was adopted in principle during the development of the appraisal framework. However, when the modelling and appraisal process began, it became clear that modifications were necessary in order to maintain the tractability of the approach. In particular, it was not possible to calculate monetary costs for individual regions in isolation, but only for passenger or freight traffic in aggregate. This in turn meant that cost-benefit analysis could not be carried out on a regionally disaggregated basis, so that modification of the CBA presentation was inevitable. Furthermore, the distinction between Irish-based and non-Irish-based travel was removed, due to difficulties in separating these categories in the demand models. However, the disaggregation by interest/user group was retained, and supporting analyses of generalised cost changes were able to provide some indication of how alternative strategies affected different regions. The revised table is reproduced as Table 7.11 in sub-section 7.6.6 of this chapter.

Table 7.5 Modified Transport Economic Efficiency Table

Impact	Total Present Value 1995 prices					
User Impacts						
Irish-based business travel			BMW	S&E	NI	Other
Travel time						
Vehicle operating costs						
Charges/ fares						
NET IMPACT		*(1)*				
Non-Irish-based business travel			BMW	S&E	NI	Other
Travel time						
Vehicle operating costs						
Charges/ fares						
NET IMPACT		*(2)*				
Irish-based tourist/ personal travel			BMW	S&E	NI	Other
Travel time						
Vehicle operating costs						
Charges/ fares						
NET IMPACT		*(3)*				

(continued over)

Table 7.5 continued

Non-Irish-based tourist/ personal travel			BMW	S&E	NI	Other
Travel time						
Vehicle operating costs						
Charges/ fares						
NET IMPACT		*(4)*				
Freight			BMW	S&E	NI	Other
Operating cost						
Inventory						
Frequency/ delay						
NET IMPACT		*(5)*				
Transport Infra-structure Provider Impacts			BMW	S&E	NI	Other
Revenue						
Operating costs		*(a)*				
Investment costs		*(b)*				
Grant/subsidy						
NET IMPACTS		*(6)*				
Transport Service Provider Impacts			BMW	S&E	NI	Other
Revenue						
Operating costs		*(c)*				
Investment costs		*(d)*				
NET IMPACTS		*(7)*				

(continued over)

Table 7.5 continued

Other Government Impacts			BMW	S&E	NI	Other
Grant/ subsidy payments		*(e)*				
Indirect tax revenues						
NET IMPACTS		*(8)*				
Externalities						
Emissions						
Accidents						
Pavement damage						
NET IMPACTS		*(9)*				
TOTAL						
Net Present Value, NPV		(10) = (1) + (2) + (3) + (4) + (5) + (6) + (7) +(8) +(9)				
Present Value of Costs, PVC		(11) = (a) + (b) + (c) + (d)				
Present Value of Cost to Government		(12) = (4) + (e)				
Benefit/Cost Ratio, BCR		(13) = ((10)-(11))/-(11)				
Value/Cost to Govt. Ratio, VCGR		(14) = (10)/-(12)				

7.5 MULTICRITERIA ANALYSIS

7.5.1 Overview

Multicriteria analysis (MCA) forms the core of the appraisal framework. Broad objectives have been set, along with a series of more specific criteria for each objective. The aim is, as is normal in MCA, to assess strategies' compliance with the objectives, and thus their overall merits, by assigning them scores in respect of the criteria. The derivation of these scores is informed by a range of qualitative and quantitative indicators.

At this point, the overall form of the MCA has already been determined, primarily through the analysis of objectives and criteria in section 7.3 above. The aim here is to address certain other issues, primarily relating to a marking system, decision rules and the presentation of the MCA results.

7.5.2 Marking system

It is proposed to use a simple symmetrical seven-point scale for the rating of impacts. The scale is summarised in Table 6.1 below.

Table 7.6 Symmetrical Seven-Point Scale for Multicriteria Analysis

Impact	Major negative	Negative	Minor negative	Neutral	Minor positive	Positive	Major positive
Symbol	---	--	-	0	+	++	+++

There are relatively few alternatives in this area; the principal ones would seem to be asymmetric scales (i.e. differing numbers of points either side of zero), for which there appears to be no convincing argument in this case, and the use of a scale with a smaller number of points. In the latter case, it is difficult to see how the scale could go below five points without an unacceptable loss of accuracy. A seven-point scale is, in the opinion of the author, more desirable than a five-point one because of the possibilities for finer rating of impacts. It would also be in accordance with those used in several other transport

studies, such as the Dublin Transportation Initiative. Scales with more than seven points would be likely to become excessively complicated in marking.

7.5.3 Presentation of results

The MCA results for individual strategies are presented in a similar form to that used in the UK NATA method, i.e. rows of a matrix representing the relevant criteria, with each row divided into columns for criterion name, measure (indicator) and score. Table 7.7 below presents an example.

MCA results for a number of strategies together (i.e. allowing comparison of strategies) are presented in the manner shown in Table 7.8, dispensing with the details of indicators. It should be noted that results from the first round of modelling were only provided in this summary form, because there was insufficient time to present a full derivation of the scores (as in Table 7.7) for every strategy. A full derivation was provided for the second-round strategies.

Although it was originally intended to present an assessment of the impact on interest groups as part of the MCA (see Table 7.4 above), this was ultimately rejected because it proved too difficult to develop a tractable, comprehensible presentation of the results (see also section 7.4 above). Further investigation of such issues has taken place within the cost-benefit analysis.

Table 7.7 Multicriteria Appraisal Table

	Criterion	Measure	Description	Assess-ment
Competitive-ness	Reduce logistical costs			
	Reduce passenger generalised cost			
	Minimise capital expenditure			
Equity	Balance between regions			
	Equitable treatment of user groups			
Sustainability	Reduce climate change effects			
	Preserve air quality			
	Reduce noise impact			
	Minimise land take			
	Preserve marine/coastal environment			
	Minimise visual intrusion			
	Minimal impact on ecology/heritage/community			
	Improve road safety			
Feasibility	Economic efficiency			
	Minimise risk			
	Best possible use of existing infrastructure			
	Lead time			
	Need for legislative measures			
	Flexibility in implementation			

Table 7.8 Multicriteria Comparative Table

	Option / Criterion	01	02	03	04	05
Competitiveness	Reduce logistical costs					
	Reduce passenger generalised cost					
	Minimise capital expenditure					
Equity	Balance between regions					
	Equitable treatment of user groups					
Sustainability	Reduce climate change effects					
	Reduce air pollution					
	Reduce noise impact					
	Minimise land take					
	Preserve marine/coastal environment					
	Minimise visual intrusion					
	Minimal impact on ecology/heritage/community					
	Improve road safety					
Feasibility	Economic efficiency					
	Minimise risk					
	Best possible use of existing infrastructure					
	Lead time					
	Need for legislative measures					
	Flexibility in implementation					

7.5.4 Decision rules

The author does not envisage use of a formal decision rule for the multicriteria aspects of the appraisal process. Examination of the case studies of MCA reviewed for the purposes of this report shows that the outranking method would be of limited use in a complex transport planning analysis such as this one. The use of formal weights is- to say the least- fraught with problems. The most popular form of MCA in contemporary practice appears to be that in which the weighting is left to the decision-maker. It is suggested that (particularly as this study does not involve making a "real-world" decision) it should be limited to deriving robust, non-contentious estimates for the multicriteria scores of the alternatives. Interested individuals and groups would theoretically be able to apply their own weightings in determining their preference.

7.6 COST-BENEFIT ANALYSIS

7.6.1 Overview

Cost-benefit analysis (CBA) plays a role in the appraisal framework which is secondary to the MCA but nevertheless of considerable importance. It provides a monetary estimate of the socio-economic benefits corresponding to the (possibly very considerable) monetary costs of a strategy, and attempts to set one against the other in order to determine some measure of the "value for money" offered by the strategy.

In the present context, it has already been determined that the CBA methodology to be used will be based on that utilised in the UK's Guidance on the Methodology for Multi-Modal Studies (GOMMMS), i.e. the "Sugden" or "TEE" (Transport Economic Efficiency) approach. This was chosen primarily for its ability to indicate the distribution of costs and benefits over different groups.

This section of the chapter addresses subsidiary (to the choice of methodology) issues in CBA, which are nevertheless of considerable importance. They include exactly which items should be costed, what levels of "shadow prices" should be used to represent non-

monetary factors in a monetary form, the discount rate and analysis period to be used, how results are presented and which decision rules should be applied.

7.6.2 Possible items for costing

One of the most contentious aspects of CBA is the question of which effects can realistically be costed. Opinions on this matter have varied over time. Different studies in different areas of transport have come up with different lists of costed items. Table 7.9 is a summary of those reviewed by the author. These include past studies of specific issues (on which greater detail is given in Appendix C) and three studies concentrating on the issue of valuing transport externalities (Maddison et al. 1996, ECMT 1998, Centre for Economic Studies et al. 2000).

Table 7.9 Summary of costed items in selected CBA cases

Study	Channel Tunnel 1 (Minister of Transport 1963)	Roskill (Flower-dew 1972)	COBA	Channel Tunnel 2 (Coopers & Lybrand 1973)	DTI-original	DTO 2000 Strategy Review	Maddison et al. (1996)	Efficient Transport for Europe (ECMT 1998)	TRENEN II STRAN (Centre for Economic Studies et al., 2000)
Capital cost	•	•	•	•	•	•	implicit	implicit	implicit
Operating cost	•	•	•	•	•	•	implicit	implicit	•
Time		•	•	•	•	•			•
Noise effects		• (air only)				•	• (road only)	•	Not inter-regional
Other non-market property effects		•							
Non-market agricultural effects		•							
Road accidents			•		•	•	•	•	•
Accidents on other modes		•							•
Pavement damage							•	•	•
Pollutant emissions						•	•	•	•

7.6.3 Shadow prices

Inherent in social (though not in purely financial) CBA is the issue of "shadow prices", i.e. prices of commodities for which a conventional market does not exist (time, emissions etc.). The determination of the appropriate shadow prices to use is an important- and contentious- step in the analysis.

The resources and timescale of this study do not permit the carrying out of primary research into shadow prices. Indeed, several major studies, such as the Dublin Transportation Initiative, have utilised standard sets of prices rather than conduct their own research. It is therefore proposed that the relevant data be extracted from the literature.

It is proposed that benefits to travellers and shippers of all nationalities should be included in the analysis. While CBA carried out on a national level generally excludes non-nationals' costs and benefits, the nature of this study (involving two different jurisdictions on the island of Ireland) suggests that it would prove difficult to draw a meaningful boundary. The difficulty in subdividing modelled demand according to nationality is a further factor.

There remains the matter of choosing the most appropriate shadow prices from the literature. It was decided to begin by identifying the commonest items costed in CBA and, if possible, corresponding monetary values on which a broad consensus existed.

Time costs were the logical starting point in this respect. Most time costs used in transport CBA in Britain and Ireland are derived from estimates made at various stages by the (UK) Department of the Environment, Transport and the Regions (DETR) or its predecessors. Those used in this case were the values applied in the Regional Eurostar study (Little 1999). These are £stg4.7/hour for non-business traffic and £stg19/hour for business traffic (both 1999 prices). At 1999 exchange rates, these would correspond to €6.94/hour and €28.07/hour respectively.

Pollutant emissions to air were considered next. The values given by ECMT (1998) are widely accepted in Europe and have been applied to the Irish situation by Department of Public Enterprise (n.d.). However, alternative values, derived from another research

project, were utilised by the Trenen II STRAN 4th Framework project (Centre for Economic Studies et al., 2000). Table 6.3 compares the values.

Table 7.10 Shadow Prices of Emissions

Pollutant	ECMT value (10^{-3} €/g)	Trenen interregional value (10^{-3} €/g)
PM	0 (rural areas)	169.8
NO_x	5	9.4
SO_2	4	9.4
CO	None	0.002
HC/VOC[1]	5	0.78
CO_2	0.05	0.0252

The Trenen values have the clear advantage of covering a greater range of pollutants (although, insofar as can be ascertained, the overall external cost estimates by mode emerging from the two studies are similar). It is therefore considered that the Trenen values should be the ones used for further appraisal work, subject to ability to determine the various emission factors for the relevant vehicle types.

Noise costs were considered for inclusion, but no reliable methodology was found to exist for taking the effects of new transport modes or technical development in existing modes into account. It was therefore decided to exclude noise from the CBA, while retaining a (largely qualitative) treatment of the issue in the overall appraisal framework.

The only other costs for which any significant amount of valuation literature appeared to exist were accident costs. The determination of such costs in new modes would come up against similar problems to those for noise; in fact, because so many variables (such as the type of regulatory regime applied to the mode) are involved, it could even be a more complex process. However, the literature suggests that uncovered accident costs for non-road modes, passenger and freight, are comparatively insignificant relative to those for road transport. As none of the possible new transport modes would operate on roads, the loss of accuracy arising from their exclusion (and that of existing non-road modes, for consistency) is considered to be acceptably small.

Valuation of road accident costs utilised Trenen data. The Trenen external accident costs for interregional transport are €45.70 × 10^{-3} / vehicle-km for cars, €62.64 × 10^{-3} / vehicle-

[1] VOCs are a subset of HCs. The ECMT values relate to VOCs only and the Trenen ones to all HCs

km for coaches and €47.63 × 10^{-3} / vehicle-km for trucks. Making the same assumptions as above, these can be expressed per passenger-or-tonne-kilometre as:

Car €22.85 × 10^{-3} / p-km

Coach €1.90 × 10^{-3} / p-km

Truck €1.91 × 10^{-3} / t-km

The work of Bacon (1999), specific to the Republic of Ireland, was investigated as an alternative, but appeared less reliable in the present context.

Finally, external costs related to pavement damage must be identified. It is suggested that the Trenen values be used for this purpose. Trenen estimated the external pavement damage costs of a typical five-axle articulated truck at €1.411× 10^{-3} / vehicle-km.

7.6.4 Discount rate

5% per annum is, as previously described, the standard Irish CBA discount rate. There is little evidence to suggest that an alternative rate would be superior.

The use of alternative rates could be considered as a sensitivity test. However, the author has previously decided that scenarios are preferable to sensitivity testing as a means of addressing uncertainty, though the time available ultimately did not permit modelling of alternatives to the central scenario.

7.6.5 Time period

The period of time used in CBA is generally thirty years. Fifty-year timescales are found in some isolated cases. The basis for the time horizon is usually the period beyond which discounted values become insignificant.

The period of analysis should start in 2010. This assumes that a decision on the broad direction of access transport strategy will be taken in 2008-2009 (when the mid-term

review of the next National Development Plan and the first five-yearly review of the National Spatial Strategy are likely to be taking place). Furthermore, it is assumed that the necessary technology for the implementation of the options envisaged in this study is likely to become available by that time. The horizon year for demand modelling purposes is assumed to be 2020. In some cases (particularly the fixed link option) it would be necessary for investment to begin in 2010 or shortly thereafter in order that the project's full capacity would be available in 2020.

The analysis period should therefore consist of the years 2010-2039 inclusive. Costs and benefits are discounted to 2010, but price levels based on the mid-1999 ones used in Task 2.

7.6.6 Presentation of results

It has been decided that the CBA results will be presented using a modified version of the TEE table. An initial version was developed in section 7.4 above and is represented by Table 7.5. However, problems became apparent in subsequent modelling work, which necessitated that the presentation be simplified considerably. A second version was then developed, retaining most of the features of the original, but eliminating the separate columns for spatial groups. This is shown in Table 7.11 below. The final version of the table was developed during the process of appraisal itself, and hence may not be theoretically optimal. It is, however, probably the best that could be achieved with the data available while remaining workable.

Table 7.11 Modified Cost-Benefit Analysis Presentation

	Benefits (positive benefit, negative disbenefit)	
Business travel	Travel time	
	Costs/fares	
	Net impact	
Non-business travel	Travel time	
	Costs/fares	
	Net impact	
Freight	Inventory/delay costs	
	Direct costs	
	Net impact	
Transport providers	Revenue	
	Operating costs	
	Investment costs	
	Grant/subsidy	
	Net impact	
Government	Grant/subsidy	
	Tax	
	Net impact	
Externalities	Net impact	
	Net present value	

7.6.7 Decision rules

There are three principal decision indicators in CBA; these are Net Present Value (NPV), Benefit/Cost Ratio (B/C) and Internal Rate of Return (IRR). It is relatively common for them to be used together (although, if the final decision is genuinely based on CBA alone, conflicts between the indicators may pose a problem).

In the circumstances of this project, where CBA is used primarily to provide indicators for input to an overall non-CBA decision-making process, the choice of decision indicator is less critical. NPV should be retained as the principal indicator, given its very wide acceptance. B/C ratio and the Value/Cost to Government Ratio (VCGR) as used in Sugden-type CBA should also be incorporated. Further consideration was believed necessary regarding the use of IRR.

However, it must be borne in mind that the cost-benefit analysis actually conducted, as described in chapter 8, raised a number of problems. The reliability of the outputs was limited and no realistic calculation of indicators other than NPV could be made. The values for NPV itself were, unfortunately, not entirely reliable, but could at least be utilised to provide a general indication of the relative merits of strategies. These problems account for the omission of indicators other than NPV from Table 7.11. The possible causes of the problems experienced are further addressed in chapter 9.

8 RESULTS

8.1 INTRODUCTION

8.1.1 The modelling process

In its final form, the modelling process consisted of two rounds. In the first round, the initial set of strategic options were tested against the 2020 do-minimum situation (or, in the case of the do-minimum itself, against the 1995 base situation). Analysis at this stage was on a broader, less detailed scale than in the second round.

The second round involved developing two variants of a strategic option based on elements of the first-round strategies and differing in whether a fixed link or buoyant air transport system was introduced. These were then tested against the 2020 do-minimum and analysed in rather greater detail, including a full cost-benefit analysis.

The possibility of further sensitivity testing on the second-round strategies was also investigated.

Section 8.2 of this chapter summarises the first-round testing process. Section 8.3 gives a preliminary analysis of the results from the first round. Section 8.4 describes the second-round testing, and sections 8.5, 8.6 and 8.7 analyse the relevant results. Section 8.8 deals with the possibilities for sensitivity testing.

8.1.2 Options examined

A do-minimum and four do-something strategies for 2020 were developed in earlier stages of the research (see Chapters 4 and 5). These comprised the strategies tested in the first round.

The strategies were:

- Strategy 1: Do-Minimum (Do-Min).
- Strategy 2: Air/Sea High Investment (ASHI).
- Strategy 3: Air/Sea Managed Demand (ASMD).
- Strategy 4: Fixed Link (FL).
- Strategy 5: Buoyant Air (BA).

Further details of strategies are contained in chapter 5. Each strategy comprised both passenger and freight transport networks.

8.2 FIRST ROUND TESTING

The strategies tested in this round are described at 8.1.2 above. The fact that passenger and freight networks are modelled separately (see also Chapter 6) required that two model runs be carried out for each strategy. In addition, the direct-demand trip generation approach used for passenger modelling meant that an initial run using "dummy" matrices had to be made for each passenger option, in order to allow the STAN model to make the cost calculations necessary for input to the direct demand functions.

No attempt to optimise the various strategies was made at this stage, as this would have been too time-consuming in the context of the direct demand trip generation, which required recalculation of the demand matrices after every network change.

Demand information and modal splits were directly output by STAN. Cost calculations were made by generating matrices of zone-to-zone costs (which, in the case of passenger traffic, also formed inputs to the trip generation models as described above) in STAN and making further calculations (weighting costs for modal split, allowing for generated traffic etc.) in a spreadsheet. Emissions and external costs were derived from a spreadsheet analysis of the demand data.

8.3 INITIAL COMPARATIVE ANALYSIS

8.3.1 Demand levels and modal splits

Tables 8.1 and 8.2 below illustrate the results of the first-round testing in terms of freight and passenger demand respectively. The tables provide the following information:

- Total demand for (passenger or freight, as appropriate) transport in passenger-or-tonne-kilometres, and as a percentage of the 1995 base demand and 2020 do-minimum demand.
- Demand for transport by mode (again expressed in passenger-or-tonne-kilometres).
- Modal split (percentage of passenger-or-tonne-kilometres represented by the relevant mode).

In relation to freight transport (Table 8.1), it can be observed that:

- Total demand measured in t-km will approximately double over the period 1995-2020.
- Total demand remains fairly constant across the range of strategies; this is to be expected, given that transport costs do not feed into the generation of freight flows.
- In the do-minimum case, the principal mode split trend is a movement away from traditional shipping modes towards rail (due to development of the Channel Tunnel) and fast ferries.
- A high investment strategy would produce very little in the way of freight mode shifts. Note also that the enhanced and subsidised air freight system incorporated in this strategy is not successful in attracting traffic.
- Under the managed demand strategy, the primary shifts are away from fast ferries (because of their high external costs) and rail (because bulk shipping has lower external costs) and towards lo-lo and bulk shipping (due to low external costs) and road haulage (which is probably a reflection of longer road hauls resulting from policies designed to encourage the use of peripheral ports in Ireland). This last result may be considered counter-productive.
- Predictably, a strategy incorporating a (rail) fixed link leads to a shift towards rail at the expense of road and the various sea modes.

- Introducing a buoyant air system leads predictably to a shift towards that mode; less predictably, there is a large (perhaps unrealistically so) movement away from rail, greater than can be attributed to the buoyant air system alone. It is possible that this results from the assumed reductions in surface shipping, and particularly lo-lo.
- The managed demand strategy gives the lowest road and (jointly with the high investment strategy) highest rail modal share, the buoyant air strategy the highest road and lowest rail.

The passenger transport results (Table 8.2) show that:

- Total demand in p-km will again approximately double.
- The variation in total passenger demand from strategy to strategy is greater than that for freight demand, presumably due to the direct demand modelling approach adopted.
- In the do-minimum, the primary mode shift (relative to 1995) is away from mainline air carriers and towards low-cost carriers.
- The high investment case shows a slight shift away from air transport, some of which may be taken up by the Seabus and V/STOL systems.
- A "managed demand" strategy produces a very small shift away from air transport, but also increased car use (probably due to the attempt to "decentralise" air and ferry demand to peripheral ports and airports, and possibly also to shifts from air to road travel) and reduced rail use (which may be due, at least in part, to the use of longer ferry routes).
- Predictably, a fixed link strategy leads to a significant shift away from air, sea and road transport towards rail modes.
- A buoyant air strategy results in a shift away from (primarily) rail and airline travel towards buoyant air. The reduction in airlines' mode share is not as pronounced as for a fixed link.
- The do-minimum and fixed link strategies jointly achieve the lowest mode share for car travel. The latter strategy also shows the highest rail (including high-speed rail) share. The highest car share occurs in the "managed demand" strategy.
- The lowest conventional air (airline and V/STOL) share occurs under the fixed link strategy and the highest in the do-minimum.

Table 8.3 presents a number of additional indicators derived from STAN output data. These are:

- Annual passenger traffic through Dublin Airport (excluding domestic and transatlantic traffic).
- Annual freight traffic through Dublin Bay (Dublin and Dún Laoghaire ports).
- Annual road traffic in vehicle-kilometres, i.e. summing truck, car and coach traffic (on the assumption of 25 t-km/veh-km for road freight, 2 p-km/veh-km for car travel and 33 p-km/veh-km coach traffic).

From the results in Table 8.3, it will be observed that:

- Dublin airport traffic will nearly quadruple over the period 1995-2020 in the do-minimum case.
- Buoyant air and fixed link strategies both cut this traffic by approximately 30% relative to do-minimum.
- A managed demand strategy leads to a smaller reduction of about 8%.
- A high investment strategy cuts Dublin airport traffic by as much as two-thirds, but this is partly achieved through the provision of a second airport at Baldonnel which itself would be operating at capacity before 2020.
- Dublin Bay port traffic will grow to nearly five times the 1995 level in a 2020 do-minimum situation.
- All do-something strategies (except high investment, which shows a marginal rise) lead to massive- possibly unrealistic- reductions in Dublin port traffic.
- Road traffic will almost double in the do-minimum. No other strategy achieves a reduction relative to do-minimum, and the managed demand strategy more than doubles traffic again.

Table 8.1 Freight Demand and Modal Split, First Round

Strategy		1995 Base	01Do-Min	02 ASHI	03 ASMD	04 FL	05 BA
Total freight transport (t-km)		93,599,976,000	191,158,786,000	189,045,629,000	191,847,716,000	189,353,134,000	183,198,443,000
Total as % 1995		100%	204%	202%	205	202	196
Total as % 2020 do-min		49%	100%	99%	100%	99%	96%
Freight transport by mode:							
Road	Total	19,571,078,000	35,444,324,000	32,995,918,000	53,789,536,000	38,185,920,000	68,412,056,000
	Share	21%	19%	17%	28%	20%	37%
Rail	Total	22,265,862,000	94,110,048,000	93,303,928,000	15,535,162,000	79,884,912,000	4,149,805,000
	Share	24%	49%	49%	8%	42%	2%
Piggyback	Total	0	1,450,147,000	1,495,109,000	102,111,000	1,040,995,000	0
	Share	0%	1%	1%	<1%	1%	0%
Ferry	Total	1,753,047,000	74,654,000	66,019,000	66,669,000	58,070,000	58,070,000
	Share	2%	<1%	<1%	<1%	<1%	<1%
Lo-lo	Total	1,225,909,000	998,282,000	15,490,000	27,443,116,000	3,992,279,000	3,316,024,000
	Share	1%	1%	<1%	14%	2%	2%
Bulk shipping/ inland waterway	Total	48,784,076,000	53,755,184,000	51,514,480,000	94,868,712,000	69,775,136,000	68,061,352,000
	Share	52%	28%	27%	49%	37%	37%
Fast ferry	Total	0	5,326,147,000	4,771,025,000	42,410,000	0	0
	Share	0%	3%	3%	<1%	0%	0%
Fast freighter	Total	0	0	4,883,660,000	0	0	0
	Share	0%	0%	3%	0%	0%	0%
Air freight	Total	0	0	0	0	0	0
	Share	0%	0%	0%	0%	0%	0%
Buoyant air	Total	0	0	0	0	0	39,201,136,000
	Share	0%	0%	0%	0%	0%	21%

Table 8.2 Passenger Demand and Modal Split, First Round

Strategy		1995 Base	01 Do-Min	02 ASHI	03 ASMD	04 FL	05 BA
Total passenger transport (p-km)		24,735,664,000	53,028,116,000	61,235,316,000	55,714,932,000	67,798,120,000	53,361,984.000
Total as % 1995		100%	214%	248%	225%	274%	216%
Total as % 2020 do-min		47%	100%	115%	105%	128%	101%
Passenger transport by mode:							
Car	Total	2,524,559,000	4,327,841,000	6,175,572,000	13,019,934,000	5,962,893,000	4,501,361,000
	Share	10%	8%	10%	23%	9%	8%
Rail	Total	6,814,219,000	16,544,308,000	18,724,736,000	12,916,160,000	25,269,182,000	16,659,424,000
	Share	28%	31%	31%	23%	37%	31%
High-speed rail	Total	0	0	0	0	10,304,042,000	0
	Share	0%	0%	0%	0%	15%	0%
Coach	Total	996,641,000	901,979,000	26,238,000	758,904,000	66,561,000	880,342,000
	Share	4%	2%	<1%	1%	<1%	2%
Piggyback	Total	0	0	0	0	4,173,000	0
	Share	0%	0%	0%	0%	<1%	0%
Ferry	Total	145,162,000	177,632,000	52,651,000	389,463,000	138,059,000	123,560,000
	Share	1%	<1%	<1%	1%	<1%	<1%
Fast ferry	Total	33,849,000	42,949,000	0	330,123,000	954,000	39,734,000
	Share	<1%	<1%	0%	1%	<1%	<1%
Ultra-high-speed ferry (Seabus)	Total	0	0	2,294,077,000	0	0	0
	Share	0%	0%	4%	0%	0%	0%
Air (mainline carriers)	Total	11,253,660,000	18,542,436,000	18,638,530,000	16,079,840,000	16,600,014,000	16,013,666,000
	Share	45%	35%	30%	29%	24%	30%
Regional airline	Total	415,071,000	323,496,000	463,980,000	197,602,000	359,991,000	210,937,000
	Share	2 %	1%	1%	<1%	1%	<1%
Low-cost airline	Total	2,552,503,000	12,167,476,000	14,336,942,000	12,022,910,000	9,092,252,000	10,017,088,000
	Share	10%	23%	23%	22%	13%	19%
V/STOL	Total	0	0	501,578,000	0	0	0
	Share	0%	0	1%	0%	0%	0%
Buoyant air	Total	0	0	0	0	0	4,915,871,000
	Share	0%	0%	0%	0%	0%	9%

Table 8.3 Additional Demand Indicators, First Round

Strategy	1995 Base	01 Do-Min	02 ASHI	03 ASMD	04 FL	05 BA
Dublin Airport traffic (passengers/ annum)	7,448,000	26,744,000	8,978,000 (+ 23,871,000 at Baldonnel)	24,649,000	18,334,000	19,506,000
% base	100	359	121	331	246	262
% 2020 do-min	28	100	34	92	69	73
Dublin Bay freight traffic (tonnes/annum)	9,701,000	46,926,000	47,603,000	441,000	864,000	2,148,000
% base	100	484	491	5	9	22
% 2020 do-min	21	100	101	1	2	5
Road vehicle-km/annum	2,075,323,862	3,609,026,157	4,408,417,811	8,684,545,531	4,510,900,300	5,013,839,770
% base	100	174	212	418	217	242
% 2020 do-min	58	100	122	241	125	139

8.3.2 General observations

This sub-section deals with tendencies which have observed through the graphical output functions of STAN, but which may be obscured in the aggregate demand and modal split results listed above. In particular, it aims to provide a spatial context for the results by drawing attention to divergences between different parts of the study area, which the modal split model could not do without extensive and complex modification to accommodate separate link classes for each sub-area.

A sample of STAN's graphical output capabilities is presented in Figure 8.1. This shows part of the (passenger) road network (covering Ireland, Britain and the northwestern extremity of the European mainland), with the figures adjacent to the links indicating the percentage change in traffic between the 1995 base and 2020 do-minimum cases. (Right-hand traffic is assumed, i.e. the figure relating to a given direction of travel will be to the right of the link when proceeding in that direction).

The 2020 do-minimum exhibits the following changes from the 1995 base:

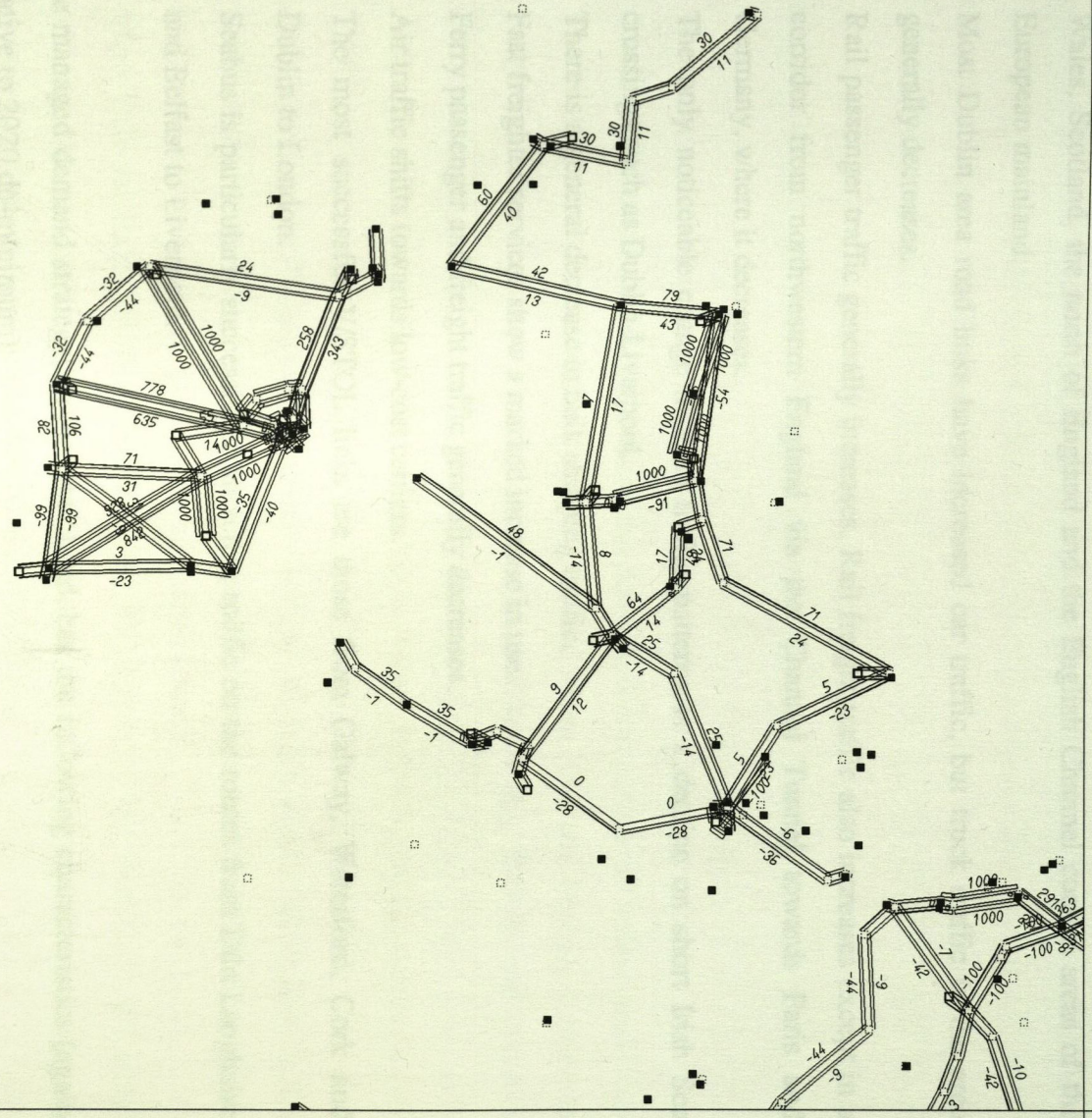
- Car traffic increases on main Irish radial routes, but decreases on peripheral routes and in the English Channel area.
- Truck traffic rises on the main Irish radial routes, across most of Britain and on the northwest edge of the European mainland, but falls elsewhere.
- There is a general decrease in car traffic passing through central Dublin. However, most of the relevant links see an increase in truck traffic.
- Rail passenger and freight traffic generally increases.
- There is a moderate general decrease in lo-lo freight traffic.
- Ferry traffic rises on most routes, but with a shift from conventional towards fast ferries.
- Air passengers make increased use of direct services from Ireland, and interlining through hubs such as Heathrow declines.

Relative to the do-minimum, the high investment strategy differs as follows:

VOLUME COMPARISON ON BASE NETWORK

RELATIVE DIFFERENCE SCENARIO 4 - SCENARIO 2 IN %

STAN



REL.TO: 2
MAXDIFF: 1000%
MODES:
l ——
LINKS:
all
SCENARIO 4
PRODUCTS:
all
SCENARIO 2
PRODUCTS:
all

SCALE: 467.04

1000
-2000
3000
-4000
5000

WINDOW:
-514.5/5585.26
688.6/6487.56

STAN PROJECT: Access 2020
SCENARIO 4: 2020 Do-Min Pax
SCENARIO 2: 1995 Base Pax

Figure 8.1 STAN Graphical Output

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MODULE: 6.23
omahony....WJW

- Car traffic increases in most areas; however, it decreases in peripheral areas of Ireland and close to principal Irish Sea ports.
- Truck traffic increases in the north and west of Ireland, southeastern England and a corridor from the English Channel towards Germany. It decreases in the rest of Ireland, Wales, Scotland, the north of England and the English Channel coastal areas of the European mainland.
- Most Dublin area road links have increased car traffic, but truck traffic in the area generally decreases.
- Rail passenger traffic generally increases. Rail freight traffic also increases except in a corridor from northwestern England via the Channel Tunnel towards Paris and Germany, where it decreases.
- The only noticeable change in lo-lo traffic patterns is a decline on short Irish Sea crossings such as Dublin-Liverpool.
- There is a general decrease in bulk shipping traffic.
- Fast freighter services show a marked increase in use.
- Ferry passenger and freight traffic generally decreases.
- Air traffic shifts towards low-cost carriers.
- The most successful V/STOL links are those from Galway, Waterford, Cork and Dublin to London.
- Seabus is particularly successful in attracting traffic on the routes from Dún Laoghaire and Belfast to Liverpool.

The managed demand strategy, on the other hand, has the following characteristics (again relative to 2020 do-minimum):

- Truck traffic declines on radial Irish routes, across most of Britain and in the northwest of mainland Europe.
- However, it rises on Irish circumferential routes and in more remote parts of Europe.
- Car traffic exhibits a contrasting pattern, rising on Irish radial routes and declining on circumferential ones. It generally increases outside Ireland.
- Truck traffic declines, but car traffic increases, in inner Dublin.
- Rail traffic, both passenger and freight, rises in Ireland. Outside Ireland, it is generally reduced, though freight traffic rises in most of Britain.

- Lo-lo freight traffic increases except on short Irish Sea crossings such as Dublin-Liverpool.
- Bulk sea freight rises except along the west coast of Ireland and the east coast of Britain.
- Ferry freight traffic generally declines but passenger traffic rises. There is a shift from Dublin towards Drogheda and Arklow.
- Fast ferry passenger traffic rises slightly.
- Air traffic decreases.

In the fixed link strategy, the following are observed:

- Car traffic reduces generally, except on the principal radial routes in Ireland.
- Truck traffic increases on links along the south and east coasts of Ireland and from Dublin to the west and northwest, declining elsewhere. Outside Ireland, it rises in peripheral areas of Europe but falls in more central areas (e.g. Britain and northern France).
- There is a slight increase in car traffic, but a decline in truck traffic, within central Dublin.
- Rail passenger traffic generally increases across the study area. Rail freight traffic increases in Ireland and most of Britain, but individual links in the rest of Europe show both increased and reduced traffic, in no apparent pattern.
- Many bulk sea links- primarily those serving minor ports on the west coast of Ireland and the east and west coasts of Britain- show a slight decrease in demand, though demand on the remainder of the network is unchanged.
- Lo-lo freight traffic rises on longer routes and falls on shorter ones.
- Ferry passenger and freight traffic generally declines.
- Air traffic declines across almost all routes.
- The fixed link and its associated rail services are used quite heavily, particularly the truck-carrying shuttle trains, through rail freight services and the Dublin-London and Dublin-Manchester high-speed rail services.

The buoyant air strategy has the following effects:

- Truck traffic decreases in most of Britain, and in coastal regions of the European mainland, but increases elsewhere.
- Car traffic generally declines. However, it increases on main radial routes from Dublin.
- Truck traffic through inner Dublin is reduced. Car traffic increases on some of the relevant links and decreases on others.
- Rail freight traffic increases in Ireland but reduces elsewhere. There is a general slight rise in rail passenger traffic.
- Airline traffic declines on shorter routes.
- Lo-lo traffic increases, but bulk shipping traffic is reduced.
- Ferry passenger and freight traffic generally declines.
- Buoyant air services (passenger and freight) are generally successful in attracting demand.

8.3.3 Emissions

Table 8.4 presents the results of the emissions analysis (utilising data from Appendix B) of the first-round strategies. Calculations are made for six individual substances: carbon dioxide (CO_2), oxides of nitrogen (NO_x), sulphur dioxide (SO_2), volatile organic compounds (VOC), carbon monoxide (CO) and particulate matter (PM). A figure for total air pollutants (i.e. sum of the above excluding CO_2) is also provided. It can be observed that:

- CO_2 and SO_2 emissions roughly double in the do-minimum relative to 1995; however, other emissions (and total air pollutants) rise by only between 4% and 50%, significantly less than the growth in transport demand.
- A high investment strategy increases all emissions by between 10% and 50% relative to the do-minimum. Total air pollutants rise by 25% and CO_2 by 20%.
- A managed demand strategy cuts all emissions (except NO_x and CO) by between 2% and 34%. Total air pollutants are reduced by 5% and CO_2 by 2%.
- A fixed link strategy cuts all emissions (except NO_x and CO_2) by between 9% and 28%. Total air pollutants are reduced by 9%, but CO_2 rises by 4%.
- A buoyant air strategy cuts all emissions, without exception, by anything from 3% to 44%. Total air pollutants are reduced by 14% and CO_2 by 9%.

- Overall, the buoyant air strategy achieves the lowest overall pollution levels, the lowest CO_2 emissions, and the lowest levels of every individual pollutant aside from CO and SO_2 (where the fixed link strategy is superior).

Table 8.4 Emissions, First Round

Pollutant	1995 Base	01 Do-Min		02 ASHI		03 ASMD		04 FL		05 BA	
	t	t	% 1995	t	% 01	t	% 01	t	% 01	t	% 01
CO_2	7,318,181	15,419,011	211	18,531,837	120	15,142,589	98	16,079,679	104	14,094,543	91
NO_x	102,073	106,569	104	124,000	116	111,522	105	109,638	103	88,956	83
SO_2	35,591	59,431	167	88,172	148	50,996	86	42,801	72	57,716	97
VOC	6,292	9,012	143	9,886	110	5,983	66	8,585	95	4,903	54
CO	14,328	14,924	104	17,145	115	16,563	111	12,115	81	14,343	96
PM	9,933	14,826	149	16,381	110	10,152	68	13,248	89	9,293	63
Total air pollutants	168,217	204,672	122	255,584	125	195,216	95	186,387	91	175,211	86

8.3.4 Economic factors

It was not considered feasible to carry out a full cost-benefit analysis of the initial round of tests. Instead, the impacts of the various strategies in terms of generalised cost, external cost and taxation have been examined and compared with their capital costs. Table 8.5 summarises the results of this analysis.

The items included in the table are:

- Passenger benefits: reduction (positive) or increase (negative) in passenger generalised cost (inclusive of taxes), as output by STAN, between do-minimum and strategy in question.
- Freight benefits estimate 1: change in freight generalised costs, calculated similarly to above.
- Freight benefits estimate 2: change in freight generalised costs for an "average" product (metal products), factored up to total freight volumes. This alternative approach was taken in an attempt to shed light on the reasons for large freight disbenefits accruing to most of the do-something options in estimate 1; however, the position was not fundamentally changed by the alternative approach to estimation. The issues arising are further discussed in chapter 9.
- External benefits: changes in external costs calculated from demand and modal split data in accordance with the rules given in Appendix B.
- Taxation/charging benefits: changes in net cash flow to government (tax increases positive, subsidy increases negative).
- Net benefit stream: sum of passenger, freight, external and taxation/charging benefits. Three calculations are made: one using estimate 1 for freight benefits, one for estimate 2, one ignoring freight entirely.
- Net capital cost: as calculated in chapter 5. Note once again that this is *net* cost, taking account of cost savings (e.g. reduced ship and aircraft costs due to construction of a fixed link), which are set against the additional capital costs due to a strategy. This is particularly relevant for the high-cost fixed link options.
- Net benefit stream/capital cost: an indicator of cost-effectiveness. Again calculated three times to reflect the alternative benefit estimates.

Note that none of these figures is discounted, that (apart from capital cost) they represent a single year in each case, and it must be repeated that this analysis does not constitute a full cost-benefit analysis.

It will be noted that:

- Passenger and freight benefits are generally negative (increased generalised cost), as are the resulting net benefit streams.
- External benefits are generally positive.
- Only the managed demand strategy produces any change in the tax/subsidy field, and this is positive (i.e. tax income exceeds subsidy expenditure).
- Although the picture varies depending on how benefits are calculated, generally the high investment strategy appears most cost-effective, followed by buoyant air. However, the managed demand strategy shows up well on one calculation. It must be noted that (by the rules utilised here) no strategy produces positive benefit flows across all alternative calculations.

A calculation was also made of how benefits were distributed over three travel purposes (freight, business passenger, non-business passenger) and three regions of Ireland (Border/Midlands/West [BMW], South/East [S&E], Northern Ireland [NI]). Table 8.6 expresses this in terms of benefits per unit of do-minimum user cost for each of the nine combinations of region and travel purpose.

From Table 8.6, it may be observed that:

- In terms of freight costs, S&E benefits more than BMW under all strategies, while S&E benefits more than NI under all but the high investment strategy.
- BMW benefits more than S&E in terms of business costs under high investment and managed demand strategies, less under the other two; NI benefits less than S&E under all but the managed demand strategy.
- Non-business benefits to BMW are greater than to S&E under all except the fixed link strategy, while benefits to NI are less than those to S&E under all but the high investment strategy.

- Business benefits generally exceed non-business under the managed demand and buoyant air strategies, the reverse being true in the other two cases.
- Freight benefits are generally somewhat less than those to passengers in the high investment case and much less in the other cases.
- The best balance between benefits to different user groups appears to be given by the high investment strategy. This strategy also gives the best balance between regions, although the managed demand strategy is broadly comparable in the latter respect.

Table 8.5 Preliminary Costs and Benefits of First-Round Options (€)

	02	03	04	05
Passenger benefits	156,809,000	-1,499,523,000	117,260,000	-308,039,000
Freight benefits estimate 1	109,102,000	-32,000,000,000	-18,000,000,000	-8,974,909,000
Freight benefits estimate 2	-26,731,500	-14,000,000,000	-8,096,680,000	-1,711,154,000
External benefits	-813,579,432	606,379,861	361,186,245	1,083,608,846
Taxation/charging benefits	0	3,668,198,340	0	0
Net benefit stream estimate 1	-547,668,432	-29,224,944,800	-17,521,553,760	-8,199,339,154
Net benefit stream estimate 2	-683,501,932	-8,225,898,799	-7,618,233,755	-935,584,154
Net benefit stream excl. freight	-656,770,432	2,775,055,201	478,446,245	775,569,846
Net capital cost	16,617,000,000	8,407,000,000	21,730,000,000	11,115,000,000
Net benefit stream estimate 1/ capital cost	-0.033	-3.476	-0.806	-0.738
Net benefit stream estimate 2/ capital cost	-0.041	-0.978	-0.351	-0.084
Net benefit stream excl. freight/ capital cost	-0.039	+0.330	+0.022	+0.070

Table 8.6 Benefits/Unit Cost by Region and Travel Purpose

Strategy	02 ASHI	03 ASMD	04 FL	05 BA
BMW freight	+0.00093	-1.73141	-1.05273	-0.48002
S&E freight	+0.006865	-1.72028	-0.97864	-0.46422
NI freight	+0.008109	-1.97284	-1.13073	-0.60581
BMW business	+0.013322	+0.010262	+0.000496	+0.000467
S&E business	+0.008107	+0.004196	-0.00595	-0.00579
NI business	+0.003074	-0.00054	-0.00576	-0.00763
BMW non-business	+0.045747	-0.09509	+0.046267	-0.02143
S&E non-business	+0.007302	-0.10803	+0.033304	-0.04248
NI non-business	+0.017828	-0.12635	-0.01332	-0.06166

8.3.5 Other effects

Table 8.7 lists important (mainly environmental) effects which are not captured by the preceding analyses. These lie principally in environmental fields other than emissions (e.g. noise, land take) and in areas relating to the feasibility of the various strategies (e.g. lead time and legislative requirements). All are described verbally.

Table 8.7 Miscellaneous Effects

Effect / Strategy	01 Do-Min	02 ASHI	03 ASMD	04 FL	05 BA
Noise	Increased air and road traffic noise	Severe noise impacts around Baldonnel; some reduction in noise at Dublin Airport, but number of people affected insufficient to compensate for Baldonnel effects. Moderate localised noise impacts at V/STOL terminals. Some increase in road traffic noise.	Significantly increased road traffic noise. Some minor impacts around regional airports.	Moderate noise impacts along railway corridors; some increases in road traffic noise; reduced noise around airports.	Moderate localised noise impacts around terminals; some increases in road traffic noise; reduced noise around airports.
Land take	Some additional requirements relative to 1995 (e.g. road improvements, Dublin airport)	Extensive land take for new port at Loughshinny. Moderate land take to expand Baldonnel airfield.	Moderate land take at new Midlands airport and around Drogheda/Arklow ports.	Extensive land take for tunnel passenger terminals at Dublin and Holyhead	Moderate land take at several locations for terminal facilities.
Marine/coastal impact	Minor impacts around ports; some pollution risk from increased shipping traffic	Severe effects on coastline at Loughshinny.	Moderate to serious coastline impacts at Drogheda and Arklow.	Severe maritime impacts from tunnel construction; some positive impacts from reduced shipping traffic.	No significant impacts likely.
Visual intrusion	Some minor increases in intrusion due to road and airport development	Severe visual intrusion at Loughshinny; moderate localised intrusion in V/STOL terminal areas and around Baldonnel.	Moderate visual intrusion at Drogheda, Arklow; minor impacts at regional airports.	Moderate to severe impacts in terminal areas; reduced visual effects around airports (fewer conventional airliners).	Moderate visual intrusion from buoyant aircraft in flight; moderate localised intrusion in terminal areas; reduced visual effects around airports (fewer conventional airliners).

(continued over)

Table 8.7 continued

Effect Strategy	01 Do-Min	02 ASHI	03 ASMD	04 FL	05 BA
Ecology/heritage/ community	Minor negative effects in existing port/airport areas	Severe effects at Loughshinny	Moderate effects at new port facilities; minor impacts at some other locations (e.g. regional airports).	Moderate impacts around terminals.	Minor effects in terminal areas
Risks	Low risk- continuation of current technological policies	Moderate risks in use of V/STOL and Seabus (unproven modes)	Considerable political risks related to taxation/charging policy, but also risk reduction due to less concentration on few major projects	Severe risks associated with unknown seabed conditions in tunnel construction.	Moderate to severe technological risks from using unproven mode
Lead time	No major problems with implementing necessary measures by 2020; most in place by 2010	Major infrastructure schemes would require approximately 10-year lead time, could be in place by 2015	Lead time 5-10 years depending on measures; infrastructure schemes relatively modest in scale; could be largely complete by 2010	Lead time >12 years from initial feasibility study to tunnel opening; high risk of overrun	Technology not likely to be fully available pre-2010; all measures probably in place by 2015 but significant overrun risk
Legislative needs	Minimal	Possible legislation for certain infrastructure schemes; also need to regulate V/STOL and Seabus	Legislation required for pricing reform	Extensive legislative process required before tunnel construction	Minor legislative reform necessary to accommodate new technologies
Flexibility in implementation	Very high- can implement incrementally, equipment has alternative uses in many markets.	Large infrastructure schemes are "lumpy", i.e. must be implemented in one unit. Specialised V/STOL and Seabus equipment may have limited alternative uses.	Infrastructure schemes relatively small, no use of new technologies.	Very low due to extensive infrastructure content.	Moderate to high- some equipment likely to have limited alternative uses, but comparatively little investment in fixed infrastructure.

8.3.6 Preliminary multicriteria analysis

Table 8.8 presents a summary multicriteria analysis of the first-round alternatives, in accordance with the methodology described in chapter 7. The table should be read in conjunction with the supporting data presented in the preceding tables of this chapter, on which the scores are based.

The following will be noted:

- The do-minimum strategy performs well in terms of feasibility (not surprisingly, since it involves minimal alterations to the present-day system) but not on other criteria.
- A high investment strategy performs well on competitiveness (lower transport costs) and equity (favouring peripheral regions) but poorly on other criteria and particularly poorly on sustainability.
- A managed demand strategy performs poorly except on some sustainability and feasibility criteria.
- A fixed link strategy also performs relatively poorly.
- A buoyant air strategy dominates the fixed link strategy except on passenger benefits, and is particularly strong on certain sustainability criteria.

At this stage, therefore, it appears that no single strategy is dominant. However, elements of the managed demand and buoyant air strategies are promising, and the performance of the high investment strategy may indicate that options retaining existing service levels as far as possible, particularly for freight, are likely to perform better than those which involve significant cuts in existing services. The do-minimum option performs relatively well against the do-something alternatives.

Table 8.8 Preliminary Multicriteria Analysis, First Round

Criterion	Option	01 Do-Min	02 ASHI	03 ASMD	04 FL	05 BA
Competitiveness	Reduce logistical costs	-	+	---	--	-
	Reduce passenger generalised cost	-	+	0	+	-
	Minimise capital expenditure	+++	--	---	---	--
Equity	Balance between regions	--	+	-	--	--
	Equitable treatment of user groups	-	+	--	--	--
Sustainability	Reduce climate change effects	---	---	+	-	+++
	Reduce air pollution	---	---	+	++	+++
	Reduce noise impact	--	---	--	+	+
	Minimise land take	-	---	--	--	--
	Preserve marine/coastal environment	-	--	-	--	0
	Minimise visual intrusion	0	---	--	-	-
	Minimal impact on ecology/heritage/community	-	---	--	--	-
	Improve road safety	---	-	---	-	-
Feasibility	Economic efficiency	++	-	++	+	+
	Minimise risk	+++	-	0	---	---
	Best possible use of existing infrastructure	0	+	++	+	+
	Lead time	+++	-	++	---	--
	Need for legislative measures	+++	--	-	---	--
	Flexibility in implementation	0	-	+	---	-

8.4 SECOND ROUND TESTING

No single "favourite" emerged from the first-round testing. On balance, it appeared that a promising option would be one combining features of the buoyant air and managed demand strategies. However, there was insufficient evidence at this point to conclusively rule out the fixed link strategy, so this was examined as a variant. The basic approach was therefore to develop a "core" consisting of the do-minimum strategy with the addition of certain managed demand elements, onto which a buoyant air network or a fixed link could be alternatively superimposed.

The core included the surface shipping pattern from the do-minimum strategy, and a more modest reduction in airline services than the first-round fixed link and buoyant air strategies. While this approach has some shortcomings in terms of realism- it would not be expected that the shipping network would remain 100% unchanged on the introduction of a new freight transport mode- it was necessary in order to avoid the large increases in generalised cost which such policies produced in the first round. It was not possible, in the time available, to investigate whether modifications to the treatment of service frequency in the model would have made a difference in this field, but the matter is discussed further in chapter 9.

The core also included the following items:

- Dublin-North West and Western Corridor road improvements from managed demand strategy.
- Drogheda port improvements (and associated shipping services) from managed demand strategy. The Arklow improvements were excluded because they attracted less traffic in the first round, and the Loughshinny project from the high investment strategy was not considered further because of its environmental impacts and failure to attract traffic.
- Limited charging policy, excluding port and airport charges (which were found to have too many counterproductive effects in reducing utilisation of existing assets and generating extra road traffic) and restricting en-route charges to car and airline travel, at a relatively low level of charging (see chapter 4).

- Rail improvements for passengers and freight as per managed demand strategy, including road/rail transfer subsidies within Ireland but only for the buoyant air case (they are omitted from the fixed link variant because the problem of short freight hauls in Ireland is overcome by connecting it to the European rail network).

The buoyant air version of this strategy contained the buoyant air freight network from the first round and a modified passenger network as described in chapter 4. The fixed link version contained the freight and passenger networks from the first-round fixed link strategy. The strategies were termed "combined buoyant air" (CMBA) and "combined fixed link" (CMFL) respectively.

A further modification was made in the demand modelling field, namely allowing air passengers to use the new mode (buoyant air or high-speed rail) as well as the airline modes and airport access modes (car and conventional rail). This was done in order to investigate the degree to which intermodal trips (partly air, partly new mode) could be promoted by the provision of such a new system (particularly with respect to the variant buoyant air network, described in chapter 4, incorporating feeder connections to London Heathrow airport). However, the accuracy of this approach is limited by the fact that trips nominally in the "air" category are not constrained to utilise airline services at any point. In practice, study of the results for the combined strategies has shown that the error due to this is small in the buoyant air strategy but perhaps larger in the fixed link one. A separate "intermodal" trip category was considered but found to be impossible (too many matrices involved) within the constraints of the version of STAN in use. Matters arising in this area are further discussed in chapter 9.

8.5 COMPARATIVE ANALYSIS

8.5.1 Demand levels and modal splits

Tables 8.9 and 8.10 indicate overall demand and its division between modes for freight and passengers respectively in the second-round tests, in much the same way as tables 8.1 and 8.2 do for the first round.

Key observations on these data are:

- There is little variation between the strategies in the total volume of either freight or passenger traffic.
- Both do-something strategies shift freight away from road transport (and to a lesser extent some sea modes) and towards rail and buoyant air or piggyback.
- The combined buoyant air strategy is the more successful in terms of minimising road freight use; if piggyback and rail freight shares are combined, however, the combined fixed link strategy is the more successful in maximising rail use.
- Both do-something strategies shift passenger traffic away from airlines and towards the new passenger mode (buoyant air or high-speed rail); there is little to choose between them in this area.
- Overall, across both passenger and freight traffic, the effects of the two do-something strategies are very similar.

Table 8.9 Freight Demand and Modal Split, Second Round

Strategy		1995 Base	01	06	07
Total freight transport (t-km)		93,599,976,000	191,158,786,000	189,134,896,000	185,369,597,000
Total as % 1995		100%	204%	202%	198%
Total as % 2020 do-min		49%	100%	99%	97%
Freight transport by mode:					
Road	Total	19,571,078,000	35,444,324,000	22,715,176,000	29,924,250,000
	Share	21%	19%	12%	16%
Rail	Total	22,265,862,000	94,110,048,000	104,598,437,000	81,498,616,000
	Share	24%	49%	55%	44%
Piggyback	Total	0	1,450,147,000	807,196,000	26,312,832,000
	Share	0%	1%	<1%	14%
Ferry	Total	1,753,047,000	74,654,000	74,587,000	114,605,000
	Share	2%	<1%	<1%	<1%
Lo-lo	Total	1,225,909,000	998,282,000	1,121,237,000	742,743,000
	Share	1%	1%	1%	<1%
Bulk shipping/ inland waterway	Total	48,784,076,000	53,755,184,000	50,917,916,000	46,732,632,000
	Share	52%	28%	27%	25%
Fast ferry	Total	0	5,326,147,000	4,845,355,000	43,919,000
	Share	0%	3%	3%	<1%
Fast freighter	Total	0	0	0	0
	Share	0%	0%	0%	0%
Air freight	Total	0	0	0	0
	Share	0%	0%	0%	0%
Buoyant air	Total	0	0	4,054,992,000	0
	Share	0%	0%	2%	0%

Table 8.10 Passenger Demand and Modal Split, Second Round

Strategy		1995 Base	01	06 CMBA	07 CMFL
Total passenger transport (p-km)		24,735,664,000	53,028,116,000	51,355,032,000	52,774,376,000
Total as % 1995		100%	214%	208%	213%
Total as % 2020 do-min		47%	100%	97%	100%
Passenger transport by mode:					
Car	Total	2,524,559,000	4,327,841,000	3,831,843,000	4,241,099,000
	Share	10%	8%	7%	8%
Rail	Total	6,814,219,000	16,544,308,000	17,359,488,000	18,180,388,000
	Share	28%	31%	34%	34%
High-speed rail	Total	0	0	0	8,251,792,000
	Share	0%	0%	0%	16%
Coach	Total	996,641,000	901,979,000	1,104,634,000	900,551,000
	Share	4%	2%	2%	2%
Piggyback	Total	0	0	0	0
	Share	0%	0%	0%	0%
Ferry	Total	145,162,000	177,632,000	209,845,000	174,203,000
	Share	1%	<1%	<1%	<1%
Fast ferry	Total	33,849,000	42,949,000	44,726,000	37,628,000
	Share	<1%	<1%	<1%	<1%
Ultra-high-speed ferry (Seabus)	Total	0	0	0	0
	Share	0%	0%	0%	0%
Air (mainline carriers)	Total	11,253,660,000	18,542,436,000	14,393,812,000	15,946,026,000
	Share	45%	35%	28%	30%
Regional airline	Total	415,071,000	323,496,000	159,923,000	171,293,000
	Share	2 %	1%	<1%	<1%
Low-cost airline	Total	2,552,503,000	12,167,476,000	6,760,112,000	4,870,749,000
	Share	10%	23%	13%	9%
V/STOL	Total	0	0	0	0
	Share	0%	0	0%	0%
Buoyant air	Total	0	0	7,490,402,000	0
	Share	0%	0%	15%	0%

Table 8.11 presents the same additional indicators as were provided in table 8.3 for the first round. In this case it will be noted:

- Both do-something strategies bring very substantial reductions (40%-60%) in traffic through Dublin airport, the combined fixed link strategy performing better in this respect.
- The combined buoyant air strategy causes a small but significant reduction (c.7%) in freight throughput at Dublin Bay ports. The combined fixed link strategy reduces throughput below the 1995 base figure, although the reduction is not as extreme as that for the equivalent strategy in the first round.
- Both do-something strategies cut total road traffic, but the combined buoyant air strategy is more effective in this regard (21% cut versus 7%).

Table 8.11 Additional Demand Indicators, Second Round

Strategy	1995 Base	01 Do-Min	06 CMBA	07 CMFL
Dublin Airport traffic (passengers/ annum)	7,448,000	26,744,000	15,537,000	10,772,000
% base	100	359	209	145
% 2020 do-min	28	100	58	40
Dublin Bay freight traffic (tonnes/annum)	9,701,000	46,926,000	43,575,000	6,965,000
% base	100	484	449	72
% 2020 do-min	21	100	93	15
Road vehicle-km/annum	2,075,323,862	3,609,026,157	2,858,002,298	3,344,808,924
% base	100	174	138	161
% 2020 do-min	58	100	79	93

8.5.2 General observations

This sub-section performs the same role for the second round as sub-section 8.3.2 above did for the first round, and remarks made with reference to that analysis continue to apply. In this case, both strategies are being compared to the 2020 do-minimum.

The combined buoyant air strategy had the following results:

- There is a general decline in truck traffic, the main exceptions to this rule being (in Ireland) links from Dublin to the west, northwest and Northern Ireland and (elsewhere) routes from France into Spain and Italy.
- Car traffic exhibits a similar pattern to truck traffic in Ireland, rises in Britain and falls in mainland Europe.
- Truck traffic through inner Dublin declines, but there are moderate increases in car traffic.
- Rail freight traffic increases except on certain links in peripheral parts of the study area. There is a general increase in rail passenger traffic.
- Bulk sea freight declines on minor routes, but core links maintain traffic levels.
- There is a decline in lo-lo traffic on the Dublin-Liverpool route and an increase on Belfast-Liverpool, with the rest of the network unaffected.
- Ferry freight traffic generally declines, though there are exceptions. However, ferry passenger traffic increases moderately.
- Virtually all direct air links from Ireland show decreased traffic, though there is some increase in utilisation of hubs such as Heathrow.
- The buoyant air links are generally well-utilised.

In the combined fixed link strategy:

- Truck traffic rises on main Irish radial routes and across most of mainland Europe, but declines elsewhere in Ireland, on most British routes and near mainland Europe's English Channel coast.
- There is a general decline in car traffic, though some Irish radial routes (north and west from Dublin) experience an increase.

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- There is a general decline in car traffic, though some Irish radial routes (north and west from Dublin) experience an increase.

- Truck traffic in central Dublin rises on some links but falls on others. Car traffic exhibits a similar pattern.
- Rail freight traffic increases in Ireland and most of Britain. On the European mainland, it falls on many routes, though there are increases on some trans-Alpine corridors.
- There is a general increase in rail passenger traffic.
- There is a moderate decrease in bulk sea traffic, concentrated on peripheral links.
- Impacts on lo-lo freight are similar to those of the CMBA strategy.
- Ferry freight traffic generally declines, as does passenger traffic.
- Almost all airline links see a decrease in traffic.
- As in the FL strategy, the rail services operating on the fixed link attract significant traffic, though in this case piggyback services are more successful than conventional rail freight.

8.5.3 Emissions

The emissions data for the second-round options is presented in Table 8.12 below (corresponding to Table 8.4 for the first round). Here it can be seen that:

- Both do-something strategies cut all categories of emission relative to do-minimum.
- The combined fixed link strategy performs better in terms of total air pollutants and on every individual air pollutant except NO_x.
- However, the combined buoyant air strategy performs better on CO_2 emissions (as well as NO_x), though the margin is quite small.

Table 8.12 Emissions, Second Round

Pollutant	1995 Base	01 Do-Min		06 CMBA		07 CMFL	
	t	t	% 1995	t	% do-min	t	% do-min
CO_2	7,318,181	15,419,011	211	15,004,036	97	15,291,937	99
NO_x	102,073	106,569	104	101,619	95	102,276	96
SO_2	35,591	59,431	167	48,288	81	36,415	61
VOC	6,292	9,012	143	8,929	99	8,868	98
CO	14,328	14,924	104	12,867	86	9,503	64
PM	9,933	14,826	149	14,143	95	13,439	91
Total air pollutants	168,217	204,672	122	185,846	91	170,501	83

8.5.4 Preliminary economic results

Table 8.13 below performs the same function for the second round options as table 8.5 did in the first round. The quantities included are the same, except that only one estimate (estimate 1 as previously defined) for freight benefits is used in this case.

Here, it can be seen that:

- Both strategies have positive benefits in all areas except passenger costs.
- The combined fixed link strategy has the greater benefits of the two on each criterion.
- Both strategies give a positive return in terms of overall benefits per unit of cost. However, the combined fixed link strategy performs better than the combined buoyant air one.

Table 8.13 Preliminary Costs and Benefits of Second-Round Options (€)

	06 CMBA	07 CMFL
Passenger benefits	-736,254,000	-454,496,000
Freight benefits	640,784,300	3,802,473,000
External benefits	338,749,883	522,363,979
Taxation/charging benefits	334,951,120	353,208,338
Net benefit stream	578,231,303	4,223,549,317
Net capital cost	13,154,000,000	20,506,000,000
Net benefit stream/capital cost	+0.044	+0.206

Table 8.14 shows benefits per unit cost for various regional and user groups, in a similar way to table 8.6 in the first-round analysis. Notable conclusions in this case include:

- Both strategies are significantly more beneficial to freight than passenger traffic, with the difference being more pronounced for the combined fixed link strategy.
- Both are more beneficial to the S&E region than the BMW region in terms of freight costs, but the position is reversed for passenger traffic.
- Northern Ireland consistently benefits least of the three regions across both strategies and all journey purposes.
- The combined buoyant air strategy gives higher benefits per unit cost for business than non-business passenger traffic across all regions. The combined fixed link strategy repeats this pattern in the case of Northern Ireland, but the position is reversed for other regions.

Table 8.14 Benefits/Unit Cost by Region and Travel Purpose, Second Round

Strategy	06 CMBA	07 CMFL
BMW freight	+0.030214	+0.200558
S&E freight	+0.044096	+0.227151
NI freight	+0.020483	+0.187036
BMW business	-0.03135	-0.03788
S&E business	-0.03481	-0.04629
NI business	-0.05353	-0.04793
BMW non-business	-0.06115	-0.0042
S&E non-business	-0.08125	-0.02267
NI non-business	-0.08876	-0.05822

8.6 COST-BENEFIT ANALYSIS

The cost-benefit analysis carried out on the second-round strategies was based on the principles developed in chapter 7. The following quantities were necessary as inputs to the analysis:

- Changes in time costs for freight, business passenger and non-business passenger transport. These were calculated as the difference between the changes in generalised cost and the changes in monetary cost (see below). They increase in line with demand (assuming linear growth from zero benefit in 2010, or 2016 for the fixed link option, to 2020, then 3% p.a. thereafter). A reduction in time costs is treated as positive.
- Changes in monetary costs for the three transport categories. Although monetary cost is one of the three cost components used in the STAN model, it is impossible to calculate monetary cost as an output unless an assignment includes *only* that cost (and therefore fails to take account of other components). Hence, it was decided to calculate monetary costs using the demand outputs from STAN and the link/transfer costs taken directly from the cost functions. This unfortunately made it impossible to calculate monetary cost on a regional basis, so that the original intention to present the user benefit figures region by region had to be reversed. There is also a small error arising from the fact that the generalised cost figures are adjusted downwards for generated traffic (i.e. generated trips receive half the average benefit of other trips) while the monetary cost could not be so adjusted in the time available. Again, a reduction is treated as positive, and the same profile is used for growth in benefits over time.
- Changes in revenue for transport providers. Equal to changes in monetary cost, but opposite in sign (i.e. increased transport costs, a disbenefit for users, are a benefit for providers and vice versa).
- Changes in operating costs. For this purpose, operating costs were assumed to be equal to 95% of revenues, net of depreciation (a detailed operating cost model would have been more accurate, but too complex to construct within a project such as this). Reductions in operating costs are positive.
- Changes in investment costs. These were calculated in chapters 4 and 5, but their timing had to be determined for the purposes of the cost-benefit analysis. It was assumed that vehicle costs were incurred evenly over the period 2010-2019, then again for replacement of vehicles having a 15-year lifetime (but at 1.55 times the initial level of provision, to reflect increased demand) over 2025-2034. Vehicles having a 20-year lifetime (conventional ships) were assumed to be initially provided in 2010-2019, then replaced and augmented to 1.55 times initial provision in 2030-2039. It was originally intended that vehicle capital cost savings from reduced demand for a mode would be calculated from the service frequencies for that mode; however, given the decision to represent most frequencies as unchanged from do-minimum (because of modelling problems) in the second round, the was a risk that benefits would be underestimated.

The revised approach involved calculating the altered vehicle requirements from the actual levels of p-km or t-km for each mode. Infrastructure capital costs were assumed to be spread over the 2010-2014 period apart from the Irish Sea tunnel (2010-2016). Increased investment costs are treated as a disbenefit (negative).

- Changes in grant/subsidy. It was assumed that public capital investment grants are available for 100% of infrastructural costs (including railway rolling stock, apart from that intended for service on a fixed link) and 25% of the costs of a fixed link (including shuttle trains but not other rolling stock). No other items are assumed to be eligible. Subsidies are only paid in respect of road-rail (freight) transfers within Ireland; the costs involved were calculated from STAN outputs (based on the assumption that the subsidy per tonne is equal to the entire amount of the average transfer cost). Subsidies grow in line with traffic. Note that grants and subsidies are counted twice with different signs as income for transport operators and expenditure by government.
- Changes in tax receipts. The charging regime eventually tested consists simply of fixed charges per passenger-km on car and conventional air travel; these are again assumed to grow in line with traffic (the assumption of starting from zero charge and gradually ramping up to the 2020 level could here be interpreted as reflecting a phased introduction of the charge). Allowance is also made for 15% indirect tax on all investment costs.
- Changes in external costs. These were calculated from demand and modal split data. They again grow in line with traffic. Reductions in external costs are positive.

Table 8.15 below shows the results of the CBA in broadly the format adopted in chapter 7 of this thesis.

Table 8.15 Cost-Benefit Analysis Results (€ million)

	Benefits (positive benefit, negative disbenefit)	CMBA	CMFL
Business travel	Travel time	-675.5	+5,861.4
	Costs/fares	-2,361.6	-8,787.2
	Net impact	-3,037.1	-2925.8
Non-business travel	Travel time	-1,298.6	+151,938.4
	Costs/fares	-5,309.6	-153,925
	Net impact	-6,608.2	-1,986.6
Freight	Inventory/delay costs	+13,994	+21,344.6
	Direct costs	-5,605.5	+19,703.5
	Net impact	+8,388.5	+41,048.1
Transport providers	Revenue	+13,276.6	+143,008.6
	Operating costs	+4,546.5	+136,734.7
	Investment costs	-9,866.1	-18,109.7
	Grant/subsidy	+5,059.1	+6,783.8
	Net impact	+13,016.1	+268,417.4
Government	Grant/subsidy	-5,059.1	-6,783.8
	Tax	+6,087.9	+6,527.6
	Net impact	+1,028.8	-256.2
Externalities	Net impact	+4,433.8	+5,640
	Net present value	+17,221.9	+309,336.9

The cost-benefit analysis shows significant variation, perhaps more than would be realistic, in user cost levels between strategies. It will furthermore be noted that the net present value for the combined fixed link strategy is high, almost certainly unrealistically so. This latter factor means that calculation of supporting data such as benefit/cost ratios could be misleading, so NPV is left to stand alone as an indicator. Even the NPV results must be interpreted with caution; the author considers that the only conclusions that can realistically be made are that both strategies are likely to have positive overall NPV and that the fixed link strategy will probably perform the better of the two.

A sensitivity analysis was carried out by investigating the effects of reducing user cost changes to 50% and then 10% of their original values. The results of this measure are indicated in Table 8.16. They appear to endorse the conclusions reached above, except insofar as the combined buoyant air strategy may have negative NPV at very low levels of user cost. Note also that the NPV of the combined fixed link strategy is unusually high (if "usual" is understood to imply lying in the same order of magnitude as the investment costs) except at the same low level of user cost. Again, the results cannot be interpreted as implying anything more than that both strategies are likely to have positive NPV and that the combined fixed link strategy would perform better than the combined buoyant air one. It must also be borne in mind that sensitivity tests at this stage can compensate for any excessive weight given to user costs relative to other costs, or to one user cost relative to another, in earlier stages of the project, but not for any excessive sensitivity to differences between strategies, which relates primarily to the design of demand models. This area is further discussed in chapter 9.

Table 8.16 Cost-Benefit Analysis: NPV Sensitivity (€ million)

Costs varied	Variation	CMBA	CMFL
All user costs	-50%	+8,938.8	+151,997.4
	-10%	-2,121.6	+25,645.8
Time costs	-50%	+11,212	+220,364.7
	-10%	+6,404	+148,706.9

In terms of the sectoral impact of the different strategies, as indicated by Table 8.15 (and having regard to the reservations expressed above), both strategies are shown to have generally negative economic effects on passengers and positive effects on freight users and external costs. The combined buoyant air strategy achieves a positive impact on government finances, but its fixed link equivalent has a negative one. Impacts are not perfectly balanced between the two passenger journey purposes, being more negative for non-business travel in the buoyant air case and business travel in the fixed link case. It may also be noted that the impact of the two strategies on business travel is very similar, the difference lying almost entirely in non-business travel. The bulk of the difference between the two strategies is accounted for by the very large impacts of the fixed link strategy on freight and non-business passenger travel. The CBA structure adopted, although rather more complex than a basic tabulation of costs and benefits, is thus shown to be of use in indicating more clearly the distribution of impacts.

8.7 MULTICRITERIA ANALYSIS

Table 8.17 (a) and (b) show the inputs to the multicriteria analysis and the scores which have been calculated on the basis of these inputs, using the methodology developed for this purpose in earlier stages of the research (see also chapter 7).

Table 8.18 summarises the results from this process, and permits side-by-side comparison of the scores for the two do-something options and the do-minimum (the latter being assumed to perform identically in the first and second rounds).

Table 8.17 (a) Multicriteria Analysis, Combined Buoyant Air Strategy

	Criterion	Measure	Description	Assessment
Competitiveness	Reduce logistical costs	Total logistical costs fall by €641 million p.a.	None	++
	Reduce passenger generalised cost	Passenger generalised cost rises by €736 million p.a.	None	--
	Minimise capital expenditure	€13,154,000 million in additional (undiscounted) capital expenditure	None	--
Equity	Balance between regions	None	S&E benefits more than BMW for freight traffic, BMW more for passenger; NI performs worst	-
	Equitable treatment of user groups	None	Significantly higher freight than passenger benefits; moderately higher business than non-business benefits	---
Sustainability	Reduce climate change effects	CO_2 emissions fall by 3%	None	+
	Preserve air quality	Air pollutant emissions fall by 9%	None	++
	Reduce noise impact	None	Moderate localised noise impacts around terminals; some increases in road traffic noise; reduced noise around airports.	+
	Minimise land take	None	Moderate land take at several locations for terminal facilities.	--
	Preserve marine/coastal environment	None	No significant impacts likely.	0
	Minimise visual intrusion	None	Moderate visual intrusion from buoyant aircraft in flight; moderate localised intrusion in terminal areas; reduced visual effects around airports (fewer conventional airliners).	-
	Minimal impact on ecology/heritage/community	None	Minor effects in terminal areas	-
	Improve road safety	Road traffic falls by 21%	Increased proportion of dual carriageway within Ireland	+++
Feasibility	Economic efficiency	NPV €17,222 million	None	++
	Minimise risk	None	Moderate to severe technological risks from using unproven mode	---
	Best possible use of existing infrastructure	Dublin Airport traffic reduced by 42%; Dublin Bay port traffic by 7%	Modest requirements for new infrastructure	+++
	Lead time	Minimum 5 years from 2010	Significant overrun risk	--
	Need for legislative measures	None	Minor legislative reform necessary to accommodate new technologies	--
	Flexibility in implementation	None	Moderate to high- some equipment likely to have limited alternative uses, but comparatively little investment in fixed infrastructure.	-

Table 8.17 (b) Multicriteria Analysis, Combined Fixed Link Strategy

	Criterion	Measure	Description	Assessment
Competitiveness	Reduce logistical costs	Total logistical costs fall by €3,802 million p.a.	None	+++
	Reduce passenger generalised cost	Passenger generalised cost rises by €454 million p.a.	None	-
	Minimise capital expenditure	€20,506,000 million in additional (undiscounted) capital expenditure	None	---
Equity	Balance between regions	None	S&E benefits more than BMW for freight traffic, BMW more for passenger; NI performs worst	-
	Equitable treatment of user groups	None	Significantly higher freight than passenger benefits; moderately higher non-business than business benefits	--
Sustainability	Reduce climate change effects	CO_2 emissions fall by 1%	None	+
	Preserve air quality	Air pollutant emissions fall by 17%	None	+++
	Reduce noise impact	None	Moderate noise impacts along railway corridors; some increases in road traffic noise; reduced noise around airports.	+
	Minimise land take	None	Extensive land take for tunnel passenger terminals at Dublin and Holyhead	--
	Preserve marine/coastal environment	None	Severe maritime impacts from tunnel construction; some positive impacts from reduced shipping traffic.	--
	Minimise visual intrusion	None	Moderate to severe impacts in terminal areas; reduced visual effects around airports (fewer conventional airliners).	-
	Minimal impact on ecology/heritage/community	None	Moderate impacts around terminals.	--
	Improve road safety	Road traffic falls by 7%	Increased proportion of dual carriageway within Ireland	++
Feasibility	Economic efficiency	NPV €309,337 million	None	+++
	Minimise risk	None	Severe risks associated with unknown seabed conditions in tunnel construction.	---
	Best possible use of existing infrastructure	Dublin Airport traffic reduced by 60%; Dublin Bay port traffic by 85%	Very considerable requirements for new infrastructure.	++
	Lead time	Upwards of 12 years from first feasibility study	High overrun risk	---
	Need for legislative measures	None	Extensive legislative process required before tunnel construction	---
	Flexibility in implementation	None	Moderate to high- some equipment likely to have limited alternative uses, but comparatively little investment in fixed infrastructure.	---

Table 8.18 Summary of Second-Round Multicriteria Results

	Option / Criterion	01 Do-Min	06 CMBA	07 CMFL
Competitiveness	Reduce logistical costs	-	++	+++
	Reduce passenger generalised cost	-	--	-
	Minimise capital expenditure	+++	--	---
Equity	Balance between regions	--	-	-
	Equitable treatment of user groups	-	---	--
Sustainability	Reduce climate change effects	---	+	+
	Reduce air pollution	---	++	+++
	Reduce noise impact	--	+	+
	Minimise land take	-	--	--
	Preserve marine/coastal environment	-	0	--
	Minimise visual intrusion	0	-	-
	Minimal impact on ecology/heritage/community	-	-	--
	Improve road safety	---	+++	++
Feasibility	Economic efficiency	++	++	+++
	Minimise risk	+++	---	---
	Best possible use of existing infrastructure	0	+++	++
	Lead time	+++	--	---
	Need for legislative measures	+++	--	---
	Flexibility in implementation	0	-	---

From the multicriteria results, it will be seen that:

- The performances of the two do-something strategies are generally very similar.
- The combined fixed link strategy appears to have a very small advantage on equity. The combined buoyant air strategy has similar small advantages on sustainability and feasibility. It is not realistically possible to choose between the two on competitiveness.
- Overall, the combined buoyant air strategy is the better-performing (in MCA) of the two, although the margins are extremely small.
- Both do-something strategies are broadly worthwhile relative to do-minimum, on the basis of the MCA.

8.8 FURTHER TESTING

Several options for additional strategy tests were considered. However, the second-round testing was somewhat more complex than originally anticipated (because it was necessary to test two combined strategies instead of the expected one) and the additional testing was in any case predicated on finding a single dominant do-something strategy which could be tested against do-minimum under alternative scenarios. Hence, no additional tests have been carried out.

Two alternative "low" and "high" scenarios for Irish population and economic development were constructed in outline, as described in chapter 5. However, they were not actually used for testing, owing to the factors outlined above. It had been intended to test at least one combined do-something strategy against the do-minimum under each of the variant scenarios.

Some consideration was also given to investigating the effects of (most likely upward) changes in the capital cost of the Irish Sea tunnel on the combined fixed link strategy (it should be noted that the author has used only the project promoters' original cost estimates thus far). Charges for traffic using the tunnel would be adjusted to take account of the increased capital cost, which would affect modal split and, to some extent, total demand. The revised costs could also be utilised alongside the new demand data in a variant cost-benefit analysis.

However, some of the problems experienced in modelling suggested that the capital cost of the tunnel would be a comparatively minor factor relative to more fundamental issues such as the treatment of frequency (see also chapter 9). Hence, addressing these latter would be a greater priority, if the time were available, and the idea of a model sensitivity test on capital costs was dropped. A cost-benefit analysis sensitivity test (assuming same modal split, but adjusting costs) was also considered but dropped as the tunnel costs would be relatively small compared to changes in overall user cost.

Thus, model testing has ended with the examination of the second-round options under the central scenario. The question of which areas would be the most appropriate for investigation if there were to be any further testing will be addressed in the discussion in chapter 9.

9 DISCUSSION

9.1 INTRODUCTION

This chapter discusses the findings described in chapter 8. They are considered from a number of points of view: since a primary aim of the project is the development of an appraisal and modelling framework, much of the discussion relates to issues in these fields. However, attention is also given to findings in respect of the various alternative strategies for the transport system's future development and the individual measures which make up these strategies. Although the project does not aim to select a single "best" course of action, it has nevertheless produced a sufficient volume and variety of results to enable some general comments to be made about the characteristics of various transport solutions.

Section 9.2 of this chapter deals with those issues specifically affecting the modelling of passenger transport demand, while section 9.3 does likewise for freight modelling. Section 9.4 covers issues which relate to modelling in general and are not specific to either passengers or freight. Section 9.5 addresses issues relating to the appraisal framework (including cost-benefit and multicriteria analysis). Finally, section 9.6 discusses the relative performance of different strategies and strategy elements.

9.2 PASSENGER MODELLING

9.2.1 General considerations

There is no reason to believe that a non-modelling approach could achieve the same level of detail and accuracy as the modelling approach taken in this research project. In this respect, the decision to take an approach based on modelling (see sub-section 3.4.10) has been validated. It is possible that an acceptable simplified non-modelling approach could be developed for coarse-level analysis using basic data from models, but this is clearly not the same as developing such a methodology from scratch without model assistance.

The model itself has proved satisfactory in many ways, within the substantial constraints imposed by the practical limitations of the software and the time and other resources available for this project.

9.2.2 Representation of frequency

One of the most notable areas of deficiency in the passenger model (though perhaps not quite as severe as the corresponding problem in the freight model) relates to how the frequency of an airline, ferry or other scheduled service is treated.

The approach taken in both passenger and freight models, as described in chapter 6, has been to represent frequency in terms of number of departures per week; average waiting time is then considered to be half the average interval between departures, assuming the latter to be evenly distributed over the week. This approach was chosen because of its simplicity, and appears to have been a reasonable choice at the time of selection, but possesses a number of drawbacks.

In particular, it may overestimate the waiting time penalty on low-frequency links, and therefore underestimate demand. A definite tendency in this direction was noted in the modelling process. Reductions in frequency (associated with a shift of emphasis between modes in some strategies) are likely to impose disproportionate penalties.

Conversely, the benefit of increased frequencies may be overestimated; it is unlikely that, for instance, a reduction in nominal "waiting" time shorter than the check-in time (which latter is represented separately in the model) is perceived by airline passengers. Furthermore, demand on high-frequency links is likely to be overestimated even in the base situation as the corollary to the underestimation of demand on lower-frequency routes described above.

An apparently excessive sensitivity of transport costs to network changes was noted at several points in the first round of strategy testing. On closer examination, this appeared to be due primarily to frequency alterations. Since the approach to frequency could not be reformulated from first principles at this comparatively late stage of the analysis, the problem was addressed primarily by reducing the scale of frequency alteration in second-round strategies. It must also be noted at this point that the problem in question appeared to

affect freight modelling more severely than passenger modelling, and freight-related issues arising from it are described in greater detail elsewhere (sub-section 9.3.2) in this chapter.

It is necessary at this point to consider whether a more effective and permanent solution could ultimately be found. One obvious option is to ignore frequency entirely, but experimentation with the 1995 base network in the early stages of the modelling process suggested that this would give an unrealistic assignment pattern. Intuitively, it may be argued that low-frequency services impose additional costs, and that passengers are not realistically indifferent between, say, hourly and weekly frequencies. Therefore, ideally some means of representing frequency would have to be retained within the model.

One possible alternative would be to represent "waiting time" penalties at some level which is lower than the simple "half interval" approach described above but remains (at least roughly) proportional to actual frequency on the link in question. This might involve dividing links into frequency "classes" with a penalty corresponding to each one. Table 9.1 illustrates a notional classification and possible corresponding penalties. The classifications are chosen to represent "less than daily", "approximately daily", "several times daily" and "high frequency" (i.e. numerous times daily) service categories.

Table 9.1 Alternative Approaches to Frequency Representation

Classification	Departures/week/ direction	Time penalty (half interval, as modelled)	Possible fixed time penalty
Less than daily	<5	2-3 days	1 day
Approximately daily	5-10	c.1 day	½ day
Several times daily	11-40	5-15 hours	1 hour
High frequency	>40	<5 hours	Zero

In the absence of a model test of the alternative method, it is difficult to definitively judge its merits. However, the likely reduction in the sensitivity of generalised cost to frequency changes would be a significant advantage. If implemented, it is likely that some optimisation of the values through iterative modelling would be necessary. Although this

modification is of considerable potential value and would simplify the strategy modelling process considerably (because there would be less need to modify frequencies between strategies, and the modification procedure itself could be simplified), it would require significant effort. All waiting time functions would require alteration, as would the links using them. The modelling process would have to be repeated, starting with the 1995 base; although the effort involved would be less than in the initial runs because less network development and modification would be needed. Ultimately, it was not considered feasible to carry out such a task at an advanced stage of the research, although this does not diminish the theoretical value of the modification.

It is also possible that the weights attached to frequency may vary from mode to mode (which it would not be realistically possible to replicate without considerable effort and very probably the assistance of survey data) or between the different types of demand (air, car-accompanied, classic). However, the only definite conclusion which emerged from the calibration and validation process in the latter respect was that waiting time was apparently valued lower (across modes and journey purposes) than travel time. This was contrary to what was initially expected (although it is not necessarily counter-intuitive), but it may simply reflect the suspected over-sensitivity of costs to frequency described above.

Ideally, the treatment of frequency would be rooted in stated or revealed preference data on passengers' actual perceptions, but nothing of this nature was realistically possible as part of this project, nor were data of this type readily available in a form applicable to the Irish access market. These issues are further discussed at 9.4.1 below.

9.2.3 Direct demand versus four-stage

Chapters 3 and 6 addressed the choice between four-stage and direct demand approaches to passenger modelling. The decision eventually reached was firmly in favour of a quasi-direct (i.e. trip generation and distribution are by direct demand methods, but modal split and assignment are handled separately) approach. A four-stage model was rejected primarily because total demand in such a model is not responsive to transport supply. There is past evidence from the Irish access market to the effect that supply improvements can generate additional demand, and this would tend to favour some variety of direct demand or quasi-direct approach.

However, the evidence from the model tests is rather mixed in this respect. Demand in terms of passenger-kilometres varied from 100% to 128% of do-minimum across the first round do-something strategies, compared with a variation in freight tonne-kilometres (which are only influenced by route changes, because overall freight demand is kept fixed) between 96% and 100% of do-minimum. On balance, this would suggest that transport supply does cause measurable changes in demand and that the direct demand approach is indeed justified. The second round, however, showed freight and passenger demand (in t-km or p-km) varying within the same range of 97%-100% of do-minimum. This evidence would suggest, at the very least, that fixed matrices would not have caused an unacceptable level of inaccuracy in the second round. It may also be inferred that four-stage models deserved closer attention overall, but the author does not feel (particularly in view of the first-round results) that a definite case can be made for the four-stage model in this context.

The most that can be confidently concluded in this respect (in the author's opinion) is that there might be some merit in examining an outline four-stage model as an alternative to the various direct demand formulations which were tried (and the ones eventually chosen), particularly in the context of any attempt to utilise time-series data (as discussed below). However, there seems no reason at this point to reject the direct demand approach.

9.2.4 Time series data

It is possible that some of the problems relating to insufficient calibration data could have been at least partly overcome by using base data from more than one year, which would give a greater range of information with which to work. This was rejected in the modelling stages of the research because even producing data for one year required considerable effort. It must also be borne in mind that base networks for additional years would have to be developed if the chosen modelling methodology required transport supply data, and this would also involve very considerable effort.

In this context, four-stage models (see above) might possess advantages, because they do not require transport supply data for their trip generation stage. Nevertheless, the author is not convinced that this model type's benefits outweigh its disadvantages with respect to response to changes in transport supply.

If data for two successive years or a similar short period over which the transport network can be assumed to remain broadly similar but the economic background changes, it might be possible to carry out time-series calibration of a direct demand model without too much loss of accuracy. It must, however, be recalled that the manipulations necessary to produce origin-destination data from the available figures are complex and of limited accuracy, so that the benefits of having two years' data would be limited. Furthermore, several data sources used are updated less than annually.

On balance, the use of time-series data on an origin-destination scale is not a particularly attractive concept. If ways could be found of utilising the more reliable time-series information on overall demand levels to enhance the accuracy of the passenger model, this might be explored, but is likely to require supplementation by other measures in order to achieve a significant improvement.

9.2.5 Cost functions

The question of whether there are any clearly detectable anomalies or errors in the cost functions for each mode (referring in this case specifically to the passenger networks, and particularly to the monetary cost functions; there is less of a problem determining travel time costs, and waiting time costs are treated separately) must be addressed. It does not, on a first examination, appear that there are any obvious inaccuracies in the passenger model outputs which might indicate an underlying problem of this nature. However, account must be taken of the fact that the information available for the determination of cost functions, both for existing and new modes, was rather limited.

In general, samples used were relatively small, and some data (e.g. airline fare levels) is based on average incomes of operators (revenue per p-km) rather than actual quoted fares, but may actually be more accurate than the latter because of the very considerable variation in rates depending on time of year, advance booking etc. Ferry (including fast ferry) and coach fares are similarly derived from small samples, while rail fares were generalised from Irish data. There probably exist a number of inaccuracies in this information, but the author has seen no evidence from the modelling results to suggest that they have any serious effects.

Of greater concern is the information on fare levels for new modes. The buoyant air fares have been built up using a detailed operating cost model, and reasonable confidence can be attached to them. V/STOL data came from the report of the Civil Tiltrotor Development Advisory Committee (1995) and is also based on operating cost models; even higher confidence can be attached to this information.

The fixed link modes, high-speed rail and piggyback, are more problematic. The Irish Sea tunnel "toll" on these modes came from the average revenue projected by Davies (1998); it is likely to be broadly accurate as long as the same source's capital costs for the tunnel may be assumed to be so. The rate per p-km for high-speed rail was set at a level that reflected French high-speed train fares and was somewhat higher than the average (Irish-based) fare used for the main rail mode. This may be an underestimate, although it is difficult to tell in the absence of more widely-based data for high-speed rail costs. Piggyback fares were extrapolated from those for freight piggyback services, which in turn were extrapolated from rail freight costs. These figures are thus probably the most doubtful.

No massively disproportionate effects were noted in the modal split analysis of the fixed link options. However, the high-speed rail share is high and may be unduly so if there are inaccuracies in the underlying data.

Ideally, operating cost modelling would be used to provide a base (preferably through the medium of a common multi-modal cost model) for fare levels. This would, needless to say, involve a considerable effort in obtaining data and building it into a model, whose results would then need to be validated. The effort involved was not considered worthwhile in the context of this project, although such a model might be of use if Irish access transport were to be examined on a more detailed level at some future stage.

9.2.6 Intermodal travel

The initial approach to passenger modelling involved dividing demand into three categories, based largely upon the mode chosen for the Irish access link. These were: air (assigned to a sub-network consisting of airlines, road and rail), car-accompanied (assigned

to road, ferry and piggyback rail) and classic (assigned to rail, coach and ferry). For the fixed link and buoyant air strategies, a fourth category was added to cover "new mode" trips, which were assigned to the new mode (high-speed rail or buoyant air) along with rail and road. All categories were examined for both business and non-business journey purposes, apart from classic, where business travel volumes appeared negligible.

However, there is at least one obvious drawback to this approach, in that new mode trips cannot use the established access modes (air and ferry) at any point in their journeys. This implies that intermodal trips using, say, high-speed rail via the Irish Sea tunnel or buoyant air services to reach a British airport from Ireland, then continuing onwards by airline, are impossible.

It was unclear to precisely what degree this distorted results. Because there was cause to believe that a modest restructuring of the buoyant air network to incorporate better connections with conventional air transport might increase its utility, intermodal trips of this kind were explicitly considered in the analysis of the second-round "combined buoyant air" option. Similar assumptions were made for the testing of the variant "combined fixed link" strategy, although no network changes specifically aimed at accommodating intermodal trips were made in the latter case.

More than one approach to the modelling of these intermodal trips was considered. A specific separate category of intermodal trips, assigned to a sub-network consisting of air, new mode, road and rail, was the preferred option for a time. However, this would have required more matrices than the available modelling software could readily handle, and could also possibly have caused complications in modal split modelling.

The approach eventually chosen, which has already been alluded to in the preceding chapter, involved permitting air trips to use the relevant new mode (in addition to air, road and rail). It was recognised that this might give rise to inaccuracies, as the shortest-cost path between two zones by "air" (to which all the air demand would be assigned) might not include any conventional air links and might indeed be the same as the shortest-cost path by "new mode". This raised obvious issues of possible overestimation of new mode demand and interdependence of "air" and "new mode" in the modal split model (which had assumed a choice between independent alternatives). On balance, it was considered most

appropriate to proceed with the approach described here, while recognising that it might have drawbacks.

The results described in the preceding chapter showed that the shift from the first-round fixed link and buoyant air to the relevant second-round combined strategies (which involves more modifications than simply taking account of intermodal trips) led to increases in market share (and, in the case of buoyant air, in absolute demand) for the relevant new modes. These increases were not so large as to be intuitively unrealistic, and of course are partly attributable to other factors (e.g. the imposition of additional charges on air and car travel).

However, there was some loss of realism as a result of the change in assumptions. Examination of the zone-to-zone costs utilised as inputs to the demand modelling process showed that, for many zone pairs, the air cost was equal to the fixed link cost, indicating that the shortest path for nominal "air" travel was in fact one which did not involve airline use. This problem did not appear to any extent in the modelling of the combined buoyant air strategy.

It can be concluded (as was already said in chapter 8) that this method of dealing with intermodal trips probably leads to an overestimate of demand for high-speed rail services in the fixed link case. There is insufficient evidence to decide whether it overestimates buoyant air demand. However, this must be balanced against the likelihood that the alternative of ignoring intermodal travel underestimates demand for the new modes.

Theoretically, airline links from Ireland to Britain, and Britain onwards to other locations, could be considered as two separate modes for assignment purposes (separate link types within a mode would not suffice, as STAN demands that sub-networks for assignment be specified only in terms of modes). Assignment of intermodal trips would then be to a sub-network consisting of the new mode, rail and road, and the Britain-Europe air links. However, this possibility was not anticipated at the inception of modelling work, and it would have been excessively complex to add retrospectively at a late stage of the project. Additionally, to work effectively it would require that intermodal trips were treated as a separate category, which would raise various problems already described.

Thus, it appears that the simplified approach taken to representing intermodal travel is the best that can be achieved with the model in its present form.

9.3 FREIGHT MODELLING

9.3.1 General considerations

As in the case of passenger modelling, the experience gained strongly suggests that a satisfactory model can be developed for the purpose of examining the Irish access market, and that the model is capable of achieving more than could be done by a nominal non-modelling alternative.

Again, constraints of various kinds have meant that the model falls somewhat short of ideal status, but they have not been severe enough to justify favouring an alternative approach over modelling.

9.3.2 Representation of frequency

This aspect of modelling affects both passenger and freight models in broadly similar ways (see also sub-section 9.2.2 above). However, its impacts appeared more pronounced in the case of freight.

The approach taken to the representation of frequency on freight links is exactly the same as that described previously for passenger links. The drawbacks relating to this approach are also likely to be similar.

Freight links generally have a significantly lower frequency than passenger links, however. Thus, the "waiting time" costs will be higher in relative terms (not necessarily in absolute terms, as not every commodity has a time value comparable to passenger traffic). Any alteration in frequency will have a larger relative impact on costs, and this may be magnified by the fact that it is more difficult to make small adjustments to frequency

where the number of departures per week is already low, so that changes between strategies are rather larger than those made to high-frequency services.

Thus, if changes in frequency give rise to disproportionate changes in cost for passenger travel, they are likely to lead to even more disproportionate changes for freight. This explains the observed tendencies in freight costs from strategy to strategy.

A possible remedy for this problem is again likely to take a similar form to the solution of the passenger link frequency problem described at 9.2.2 above. The approach tentatively suggested in Table 9.1 appears (on the very preliminary analysis which it has been possible to carry out) equally applicable to freight. Once again, similar considerations apply in respect of the difficulty in implementing such a revised approach (involving practically a complete reconstruction of the model) at an advanced stage of work. These considerations tend to suggest that further investigation of the concept is not worthwhile at this point.

9.3.3 Cost functions

Although a complete European freight network in STAN format was provided to the author by VTT, the cost functions were not included for copyright reasons. Wherever possible, the functions used in this project have been taken from other STEMM deliverables (e.g. SINTEF et al. 1998, Nautical Enterprise Centre 1998). The latter primarily relate to another STEMM case study which was also conducted using the STAN model and the above network, but covering a different area and fewer commodities.

Most of the cost data were generalised from those provided for food products and fertiliser by SINTEF et al. (1998). The "generalisation" was conducted using the commodity operating cost weights described by VTT (1998, figures 5-9). There may have been some unavoidable loss of accuracy here because the commodities in the first source did not exactly correspond to those in the second, but observation of the relative cost weights in both cases suggests it was probably small. However, it would have been preferable, had it been possible, to work from primary operating cost sources for each individual commodity.

The do-minimum assignment results suggested a small number of possible problems with the cost functions. Amongst these were:

- No traffic was assigned to the air freight network. This may be due to unrealistically high costs for this mode, but it may be noted that the halving of costs in a later strategy test failed to attract traffic, so that the problem perhaps lies with an excessively "coarse" classification of commodities. It may indeed be the case that air freight is such a specialised service that it cannot be treated adequately within a general-purpose freight model.
- A realistic assignment of traffic to Irish ports was achieved, but required the attachment of empirical cost penalties to the various ports. While there will always be local variations in cost structures, the author would have preferred a more analytical approach, specifically through use of a capacity/congestion restraint in assignment. It was observed that penalties tended to be higher at busier ports, which would suggest that they reflect some form of congestion function. Unfortunately, insufficient information was available to derive such a function.
- It is possible that rail volumes may be overestimated. However, the utilisation of rail within Britain and Ireland was in line with what might be expected (i.e. relatively low owing to the short distances) and any problem is likely to lie in the mainland European network. The absence of specific penalties for cross-border traffic (which is known to be an area of difficulty in the present European rail freight network) may be the problem, although it might be easier to resolve it by increasing assumed costs or delays for the mode as a whole. Nevertheless, it must be remembered that there is no definite evidence of inaccuracy in this area.

The cost functions for those transport modes not existing in 1995 were compiled from a variety of sources. As in the case of passenger cost functions (see sub-section 9.2.5 above), their reliability varies from mode to mode. Buoyant air cost functions have been based on an average from a number of sources, as described in Appendix B. However, high-speed ferry costs had to be extrapolated from passenger fares and piggyback rail costs from those for rail freight. Furthermore, the costs for high-speed lo-lo ships are based on a single source only. Transfer costs for new modes were based on assumptions about their relationship to those for existing ones. In spite of these possible drawbacks, no clear instances of errors resulting from them can be identified.

It would also have been desirable to incorporate costs for reliability and risk of damage into the model. Although this was done in the STEMM Scan-Link case study (using what is substantially the same network), the relevant data were unavailable to the author.

As in the case of passenger transport, a comprehensive operating-cost model covering all modes would be the ideal solution. Consideration was given to this approach, but the problems of effort required and poor data availability ultimately frustrated it.

9.3.4 Commodity classifications and weights

Ideally, the freight commodity classification would be considerably "finer" than the twelve-commodity (STEMM) approach used in the modelling work. There is, however, no clear indication of precisely how many commodities would be appropriate, or what they should be.

One possible approach- one considered in detail in earlier stages of the research- would involve concentrating first on the sectors identified by Transport Policy Research Institute (1995) as important to Irish exporters, the remaining commodities then being classified broadly along the lines of the STEMM classification. Table 9.2 indicates how this approach might work. It also shows that it would lead to an increase from twelve commodities to at least twenty, which would probably rule it out within the constraints of the present model. The generation of flows would also be more complex, involving a variety of industry-specific data which ideally would have to be available on a Europe-wide level and preferably disaggregated to sub-national units. Thus, it cannot be favoured over the coarser but more tractable approach taken in the modelling work.

The latter approach could itself be enhanced in a number of ways. The distribution of freight flows was based purely on the proportion of Irish or "rest of study area" GDP in the relevant sector (on a three-sector basis) represented by each zone. A number of alternative measures to GDP, such as population, agricultural land area and industry-specific statistics of the proportion of production or sales accounted for by each zone, were utilised by SINTEF at al. (1998), but some of these required special requests for data, which would have been very time-consuming and costly for the number of commodities involved in the

author's research. The use of GDP by sector allowed all commodities to be treated on a broadly consistent basis without incurring excessive data requirements.

Table 9.2 Possible Alternative Commodity Classifications

STEMM (as used)	Nominal alternative
Food/live animals	Dairy products
	Meat products
	Other food products
	Live animals
Beverages/tobacco	Beverages/tobacco
Crude inedibles	Crude inedibles
Mineral fuels	Mineral fuels
Animal/veg. oils	Animal/veg. Oils
Chemicals	Pharmaceutical products
	Basic industrial chemicals
	Other chemical products
Paper/paperboard	Paper/paperboard
Metal products	Metal products
Manuf. goods	Auto parts
	Other manuf. goods
Machinery	Machinery
Misc. manuf. articles	Misc. manuf. articles
Valuable machinery etc.	Computers/ data processing equipment
	Telecommunications/electrical equipment
	Medical/healthcare products

There may be scope for improvement in relation to the weights applied to different cost components for each commodity. Although the commodity groups used remain the same as those used in STEMM, it is possible that the cost components in this study do not correspond exactly to those in STEMM. For instance, the delay cost in STEMM included factors other than waiting time, while the present research covered only waiting time under this heading. Similarly, STEMM made use of damage and reliability costs, which were not covered by this project owing to insufficiency of data. The absence of these components may affect the weightings applied to other cost components, although it is difficult to tell exactly how.

It may also be the case that the weightings do not reflect the Irish position, being derived mainly from Finnish data. However, it would be difficult to come to a definite conclusion of this without a detailed survey of average freight costs, which does not exist in the Irish access market (the position is further discussed in sub-section 9.4.1 below).

9.4 COMMON MODELLING ISSUES

9.4.1 Quality of calibration data

The absence of reliable origin-destination data on which to calibrate the models has been one of the most severe drawbacks affecting the work, and it is not one which is easily rectified.

Serious consideration was given in the initial stages of the author's research to carrying out a survey utilising questionnaires and/or interviews to furnish suitable data for both passenger and freight transport. This idea was ultimately rejected, because the available resources would be insufficient to support a survey which would inevitably have to be carried out on a large scale. A smaller-scale survey would not provide sufficient accuracy, and would only be of value as a "pilot" for a larger subsequent effort, or possibly an *ex post* check on modelling work, rather than as a primary source of information.

The concept of a full-scale origin-destination survey remains valid, if sufficient resources were available to carry it out. In the author's view, a survey on this scale is regrettably well beyond the capability of a student research project. It may furthermore be noted that most of the STEMM case studies (in an EU-funded 4th Framework project) could not justify the expense of a new dedicated origin-destination survey, though some were able to draw on modified versions of established survey processes. On the other hand, any larger-scale study of Irish access transport might consider the potential for a dedicated survey, preferably on a recurring basis and possibly drawing in part on modifications of current trade and tourism surveys.

Data on transport costs represent a further area where existing information sources remain quite weak. This is particularly the case in relation to freight movement. The STEMM project used data from a wide range of sources to derive freight transport cost information, but little of this is directly applicable to Irish access transport. It would be preferable to have available the results of a specific and detailed survey on Irish access costs, but no such work has been carried out. Efforts were made in this direction as part of the Technical

Assistance Programme of the 1994-1999 National Development Plan's Operational Programme for Transport (Government of Ireland 1994). However, the author has been informed that these efforts did not meet with success, and were abandoned at a comparatively early stage. The concept remains valid, in the author's opinion, if its problems can be overcome, but does not appear a realistic possibility for implementation as part of a research project on the moderate scale of the present one.

There is scope for the use of stated and/or revealed preference data, at least in the passenger model, to inform modal choice modelling work. In the absence of such data, the author has (as described in chapter 6) had to utilise modal split models based purely on generalised cost, with no allowance for "intangible" factors. This has given rise to a certain loss of accuracy, although it is doubtful whether it is as significant as that due to inadequate calibration data on origin-destination patterns by mode. Without the latter information, the contribution of stated/revealed preference data would be somewhat restricted, although it could nevertheless be of value in certain situations (e.g. new modes).

Overall, the quality and quantity of data available are generally quite poor. This has not prevented the construction of a model to an acceptable degree of accuracy, but any attempt to increase this level of accuracy would inevitably demand considerable effort in the acquisition of additional data. Since the work involved would be very considerable and certainly beyond the capabilities of a research project such as the present one, it is not worthwhile in the context of this project. Any further improvement of modelling accuracy, if it were indeed possible, would have to concentrate on the more minor issues discussed elsewhere in this chapter.

9.4.2 Network resolution

Owing to the constraints of model size, the network modelled could not be extremely dense. It could not, for instance, equal that utilised for the MAP-1/STEMM passenger model (see chapter 3). However, the level of detail on the freight network is comparable to that on the STEMM Scan-Link network from which it was derived. In this case, the necessary reduction in size was achieved primarily through radical simplification of the very detailed Norwegian, Swedish and Finnish networks embodied in the original.

The passenger network was derived from the freight network (see also chapter 6) by altering cost functions, removing freight-only sea links and adding an air sub-network. This latter was, of course, constrained by the need to avoid exceeding the maximum network size (which was a distinct possibility even with the freight-only links removed) and by the time available for development, and hence could not be as detailed as might ideally be desired.

The principles followed in the addition of air links have been described in chapter 6. To recap briefly, the primary ones are:

- All Irish airports are included.
- All British airports with services to Ireland (above a minimum frequency of approximately three per week) in 1995 are included.
- Elsewhere, only one airport per zone is represented.
- All air services to and from Ireland operating above the aforementioned minimum frequency in 1995 are represented.
- Other links are only modelled extremely sparingly.
- All 2020 strategies are assumed to be identical to the 1995 base in terms of air links not serving Ireland directly.

The zoning resolution and route choice (shortest path) approach used by the model do not, however, appear to generate non-zero flows on all links, particularly where there is more than one airport in a zone. Much of the air network is therefore essentially superfluous, except for purposes of calculating overall fleet needs.

Clearly, an improved network could incorporate a degree of simplification in this respect. It is difficult to separate this issue reliably from that of the treatment of frequency (examined separately above); a different approach to frequency could possibly assign more traffic to lower-frequency routes. However, there would be other benefits, principally resulting from greater network flexibility by freeing more spare capacity in the model, accruing to any network simplification.

The most basic way of simplifying the air network would be by reducing it to one airport per zone throughout the study area. This approach would have the most dramatic benefits in reduction of network size, but would risk an unacceptable diminution of accuracy in

those areas where conventional and low-cost airlines used different airports at significantly varying distances from the zonal centroid location.

An alternative approach would be to limit zones to one airport each as a rule, and always concentrate conventional airline links on a single airport, but allow an additional airport for low-cost airlines where the situation described above prevailed (e.g. in the south-east of England, conventional airlines would be concentrated on London Heathrow and low-cost airlines on Stansted). In some cases, where an airport restricted to regional airline links existed "closer in" even than the location used by conventional carriers (London City is the obvious example), it might be possible to model it separately. However, regional air links would generally be concentrated on the same location as conventional airlines.

There may be scope for a similar process, reducing networks to a "one port per zone" level, in (passenger and freight) ferry networks. However, the benefits here are likely to be more limited.

The road and rail networks were modified from the STEMM originals by selective reduction of their resolution outside Ireland, and increased resolution within Ireland. Apart from the previously-mentioned alterations in Norway, Sweden and Finland, these did not represent drastic changes. There would appear to be further potential for a general "thinning out" of the rail and road networks (outside Britain and Ireland), but this would require great care and could be extremely time-consuming. There is also a (to some extent contrary) case for increasing the level of differentiation between different link types (e.g. single-carriageway, dual-carriageway and urban roads, high-speed versus conventional passenger rail) across the entire network, but this could easily outstrip the capacity of the model. On balance, the extent of the road and rail networks (passenger and freight) is probably the optimum that could be attained without excessive effort.

The possibility of configuring the model to permit demand and modal split outputs to be disaggregated by area was considered. This would imply designation of different link types for each area, within each mode. The original network utilised in STEMM incorporated such a feature (though the level of disaggregation, as with the detail level of the network itself, may not have been the most appropriate one in the present context), but the links added by the author do not. The author instead chose (as described in chapter 8) to address the spatial context through information derived from the visual output functions of STAN.

It appears that the designation of link types would probably involve a moderate amount of additional work on network development, but that the additional analysis involved at the appraisal stage could be more considerable. Because all network variants would have to be altered, it was not considered feasible to incorporate this feature retrospectively within the time available, but it could be further considered in any future enhancement of the model.

9.5 THE APPRAISAL FRAMEWORK

9.5.1 Cost-benefit analysis

As an appraisal methodology, cost-benefit analysis (CBA) is sometimes controversial and not always an entirely accurate reflection of the relative performance of alternatives (at least as perceived by society in general). However, there were a number of reasons, set out in chapter 7, for making use of this methodology within the project's appraisal framework- not as the core element, but as an important supporting feature. The modelling work incorporated a cost-benefit analysis of two possible strategies (see chapter 8) and the results have been used to inform this discussion.

The most notable feature of the CBA results was the unusually high change in user costs between strategies. This was discussed briefly in chapter 8; the apparent cause of this anomaly was undue sensitivity of the costs to changes in service frequency. The latter issue has been discussed in some detail in preceding sections of the present chapter. It is sufficient to note here that any errors due to this factor do not reflect negatively upon CBA itself or the particular form of CBA chosen, but rather on the cost results from the models. Hence, it is not intended to draw inferences about the performance of CBA from this problem. While it indicates that CBA is quite sensitive to user costs, this is a trivial observation and not specific to any particular type of CBA.

It may be regretted that it has not been possible to calculate time and monetary costs entirely independently of one another. The method adopted involved calculating monetary costs from the demand and modal split data, and deducting them from the STAN costs (which include both time and monetary elements) to give time costs. This is a consequence of the way in which costs are handled by STAN. The cost data used for analysis come from

the zone-to-zone cost outputs of STAN, which in turn reflect the costs applying to a particular assignment. STAN recognises three cost categories for assignment purposes- monetary cost and two types of "time" cost, broadly corresponding to travel and waiting/delay time respectively. Because the weightings for each category are decided in the assignment process, it is possible to carry out an assignment including, say, only monetary or only time costs, and calculate the resulting zone-to-zone costs. However, the latter will be calculated on shortest paths which only take account of the cost components included in the assignment. For example, calculation of zone-to-zone monetary cost will be based on shortest paths which ignore non-monetary cost, and a separate calculation of zone-to-zone time costs would use a different network of shortest paths and thus not be directly comparable.

There does not appear to be a simple solution to this, but it must be questioned whether it is genuinely likely to be a major source of inaccuracy. If the overall cost calculations are correct, then the results of a calculation carried out by deducting the monetary costs (which are calculated identically to the monetary component of overall costs) from these figures should also be accurate. It appears that the greater problem in cost calculations is, in fact, the oversensitivity of costs to frequency changes rather than any error resulting from the process used to separate the different cost components.

The treatment of environmental factors is frequently a cause for concern in CBA. In the case of the present research work, there appear to be no reasons to question the overall validity of the figures for environmental costs. However, it is possible that some minor enhancements could be made.

The values used for costing pollutant emissions are described in chapter 7. They are not the only ones available, but they have been chosen following investigation of alternatives, and they come from a respected source (the TRENEN II STRAN 4th Framework research project). Furthermore, the difference in modal external costs between this set of values and its major alternative are small. There appears no reason to revisit the choice of approach in this case.

There might, however, be a case for weighting of pollution costs according to where the emission actually takes place. Local air pollution is more important in urban than rural areas, more important on land than at sea or in the air (although sea and air transport can,

of course, contribute significantly to pollution on land around ports and airports). Some emissions have greater impacts on climate change or other atmospheric factors (e.g. ozone depletion) at aircraft cruising altitudes than at ground level. Weighting might provide a means of better reflecting these factors in the CBA outputs. Against this, it must be noted that the author has found no replicable examples of such weighting in the literature relating to valuation of external costs, and that considerable modification to the network might be necessary to enable emissions to be suitably disaggregated.

There also exists the theoretical possibility of incorporating other environmental effects into the CBA. This is hindered by the lack of data on appropriate valuations and, indeed, the fact that the literature and case studies (see the example of London airport planning in chapter 3) suggest that attempts to value every single impact are frequently unwise. There may be an argument for the inclusion of noise impacts in the CBA, primarily on the grounds that DTO (2000), in a relevant recent Irish example of a transport planning CBA, included them. On the other hand, there is insufficient information available to permit calculation of noise values, and the process could become extremely complex when the special factors relating to air and sea transport and the need to accommodate new technologies in the analysis are taken into consideration. On current evidence, therefore, it appears that incorporation of noise, or any further effects, into the CBA would not be worthwhile.

A possible weakness in the CBA as implemented is the inability to calculate net present value (NPV) by region. While the "Sugden" Transport Efficiency Table (TEE) methodology adopted- an adaptation of the standard British transport CBA- can provide estimates of NPV to different groups, it is not primarily intended to show the regional distribution of benefits. An outline approach to incorporating regional estimates of NPV into the methodology was proposed in earlier stages of the project (see chapter 7) but difficulties arose with its practical implementation. In particular, it proved difficult to disaggregate by region costs and benefits other than those incurred directly by users. Furthermore, although the total changes in user cost could be disaggregated by region (and this information was, in fact, utilised in chapter 8), the method used for calculating monetary costs did not permit such disaggregation. Modification would have overtaxed the capacity of STAN in terms of the total number of matrices required.

The "Sugden"/TEE methodology is somewhat more complicated than a conventional CBA. However, this is normally understood to be compensated for by the advantages it gives in disaggregating impacts on different groups (e.g. operators, users, government). The author (although it is a personal opinion) considers the disaggregation of results to be sufficiently useful in this case to justify the additional effort involved. In addition, the availability of CBA results (again in the author's personal opinion) is sufficiently beneficial to the overall analysis to justify the use of CBA alongside MCA. Therefore, the choice of this approach rather than a simpler one is considered appropriate.

Overall, therefore, the CBA approach taken is supported in retrospect by the evidence, even if its utility is reduced by the demand model's problems in treatment of frequency (addressed elsewhere in this chapter). There do not appear to be major flaws in the CBA methodology, and few of the possible minor enhancements investigated appear worthwhile. Some improvement in the method used to derive monetary costs may be desirable, but this appears less important than improvements to the demand models themselves, and the possible difficulties involved are considerable. In retrospect, the principal decisions taken in developing the CBA methodology appear correct.

9.5.2 Multicriteria analysis

The core of the appraisal framework is the multicriteria analysis (MCA) methodology, whose development was described in chapter 7. The MCA has been used as the central tool in the presentation of results from the various strategies examined in chapter 8.

Observation of the results in chapter 8 has shown that MCA has the particular advantage in this case of reduced sensitivity (compared with CBA) to large changes in user cost. This comes about partly as a consequence of the fact that there is no predetermined numerical relationship between inputs and outputs in MCA, and partly because MCA can take account of a wider range of impacts than CBA. In this case, it serves to illustrate that MCA can be a more robust approach than CBA where demand models are subject to limitations of accuracy or detail. However, the discussion of CBA above does suggest that the use of CBA alongside (and, to some extent, integrated with) MCA brought certain additional benefits (allowing for the fact that CBA was only applied in the second round of modelling).

The objectives and criteria used in the MCA process (see also chapter 7) have not been called into question by the results of the modelling work. They appear to cover all major effects of changes in the access transport system and provide a practicable means of differentiating between strategies. However, the applicability of such a conclusion is limited by the fact that it proved impossible to gain access to the views of relevant interest groups on what constituted appropriate objectives. As described in chapter 7, few of those groups which responded to enquiries had any particular interest in access transport, and, even then, objectives had usually to be inferred from statements of general policy. Nevertheless, the overall validity of the objectives and criteria does not (in the context of this research) rest solely on their approval by interest groups. It can thus be concluded that they are satisfactory for the present purpose.

It was also noted that some of the criteria, as originally conceived, required an excessively detailed supporting analysis relative to the strategic level of modelling. For instance, it was originally hoped that estimates of numbers of people severely affected by noise could be provided in support of the "reduce noise impact" criterion. This proved too high a level of detail to be tractable, and only verbal estimates could be used. It is possible that more explicit attention should have been given to the problems of producing appropriate strategic-level indicators, although it must be noted that virtually all the literature, even where it deals with the appraisal of interregional transport systems, focuses on more localised levels of analysis.

There are also unresolved issues in relation to the balance between criteria seeking to reduce the level of impacts (versus do-minimum) and those seeking to minimise the additional (over and above do-minimum) impacts. An excessive concentration on reduction of impacts could disadvantage any do-something strategy involving, say, additional infrastructure (which would increase negative impacts on the environment and on public funds) even though it might reduce negative impacts in other areas (e.g. climate change). On the other hand, concentrating on minimisation of additional impacts could give undue advantage to strategies which, though they had minimal additional negative impacts, gave little actual advantage relative to the do-minimum. The approach taken in this project has broadly been to set "minimise additional impacts" objectives where reduction is not (on the strategic level) realistically feasible, and otherwise to use "reduce impacts" objectives. On balance, this approach appears to have performed satisfactorily.

Some problems (though not especially severe ones) were experienced in translation of qualitative or quantitative results into multicriteria scores. There is always a certain degree of reliance on judgement in MCA, but this may be reduced somewhat if detailed guidance on how to derive scores, explicitly specifying what range of results corresponds to a particular score, is available. Guidance of this nature is provided for the UK NATA/GOMMMS appraisal framework, but this cannot be applied directly to the MCA structure used here, because the set of objectives and criteria is significantly different. (Furthermore, scoring in NATA/GOMMMS is verbal, while a symbolic approach is used in this project; however, the scales used are compatible). The development of such guidance was considered, but rejected on the grounds of the effort involved. It does not seem that detailed guidance of this type is a practicable option unless the appraisal framework is being developed as a standard one for general use, rather than a "one-off" project. Thus, and taking account of the absence of noticeably severe problems in this area, it would not seem worthwhile to develop detailed MCA scoring guidance.

In summary, the performance of the MCA component of the appraisal framework has been satisfactory, and has justified the choice of approach. Some minor issues remain in areas such as the precise expression of criteria, but these do not appear to constitute significant defects in the methodology.

9.6 STRATEGIES, MODES AND TECHNOLOGIES

9.6.1 Performance of strategies

The results from the modelling process are presented, within the appraisal framework developed specifically for the purpose, in chapter 8 of this thesis. The intention of this section of chapter 9 is primarily to discuss the performance of the transport strategies examined in the preceding chapter, and of their individual components. Performance of the demand models and appraisal framework is dealt with elsewhere in this chapter.

In the first round of modelling, the following strategies were tested:

- Strategy 1: Do-Minimum (Do-Min).
- Strategy 2: Air/Sea High Investment (ASHI).
- Strategy 3: Air/Sea Managed Demand (ASMD).
- Strategy 4: Fixed Link (FL).
- Strategy 5: Buoyant Air (BA).

The do-minimum was compared to the 1995 base situation and the do-something strategies to the do-minimum. Full details of the results are contained in chapter 8.

The results showed that the do-minimum strategy had distinct advantages in terms of feasibility (because no major change from present policies and networks was envisaged) but did not perform well against the other objectives. However, it performed better than certain do-something strategies on a number of criteria, and was overall far from the worst-performing strategy. It therefore seems that, for all the problems of the present system, the do-minimum case may not necessarily be as disadvantageous as it might theoretically seem. However, it must be observed that it does not appear, at first sight, to be the optimum solution.

One important conclusion emerging from the first round was that a "high investment" strategy would be the most favourable in terms of user costs and the balance of these costs between geographical areas and user groups, but would fail to deliver benefits in most other areas. The strategy would have high capital costs, would deliver only limited relief from congestion on existing transport networks, and would have severely negative environmental impacts. It performed very poorly in multicriteria analysis.

The results are of particular interest because the "high investment" strategy has been developed to reflect maximum development of the existing air and sea modes, with some introduction of new technologies (addressed in greater detail at 9.6.2 below) and no attempt to restrain demand. As such, it is probably the most likely do-something outcome if access transport policy continues to follow its present course. While it provides important benefits in the field of user costs (whose importance should not be underestimated), its disadvantages are sufficient to suggest that future policy should look beyond unconstrained development of the existing modes as a solution. Indeed, the do-minimum situation may be superior to such a "high investment" approach.

The "managed demand" strategy is again conservative in seeking to develop existing transport modes rather than introduce an entirely new system; indeed, it omits the more radical developments (V/STOL and Seabus) contained in the "high investment" strategy. It also differs from this latter strategy in imposing a range of charges intended to optimise use of the transport system by internalising external costs and penalising the use of congested facilities, and in a refocusing of route structures and capital investment away from the most congested areas.

Results indicate that this strategy is perhaps not quite the optimum it might seem. Although it achieves environmental benefits, it is generally outperformed in terms of pollutant emissions by the "fixed link" and "buoyant air" strategies. Predictably, it has significant disbenefits in user cost terms. It is relatively low in capital cost, and performs slightly better than the "high investment" strategy in MCA, although it appears inferior to the do-minimum. The strategy is not an ideal solution, but appears a better way to build on the strengths of existing modes than the "high investment" approach. It is possible that optimisation of the charging element could render this strategy more attractive.

The "fixed link" strategy is predictably characterised by high capital costs. It achieves significant modal shifts and accompanying emissions reductions (though these must be set against negative impacts on the marine environment). The strategy does not perform particularly well in MCA; as has already been noted in chapter 8, the "buoyant air" strategy tends to dominate it in this respect.

The "buoyant air" strategy itself achieves broadly similar modal split (at least for passenger traffic) and emission results to the "fixed link" one. However, it does so at lower capital cost and with a rather less negative environmental impact. The strategy performs quite well in MCA.

The fixed link/buoyant air results collectively appear to indicate that a strategy incorporating a major "new" transport mode can achieve benefits not attainable through modification of the existing system. However, the MCA shows that both strategies are problematic in terms of feasibility, and the "managed demand" strategy may be superior in this field, but at the cost of reduced benefits in other areas.

As previously outlined in chapter 8, combination of features from the "managed demand" strategy and one or other of the "new mode" (fixed link/buoyant air) strategies appeared a promising course of action, and this approach formed the basis of the do-something strategies in the second round.

The second round of modelling examined two do-something strategies. These were:

- Strategy 6: Combined Buoyant Air (CMBA).
- Strategy 7: Combined Fixed Link (CMFL).

The derivation of both these strategies is covered in greater depth by chapter 8. Essentially, they combine elements of the "managed demand" strategy- a heavily modified charging regime and certain better-performing infrastructure elements- with the respective "new mode" networks from the first round (modified significantly in the case of the buoyant air network). Certain assumptions in relation to demand modelling were also modified in an attempt to better reflect the potential roles of the new modes.

A more detailed analysis of the second-round strategies was carried out than was the case in the first round. Cost-benefit analysis (CBA) was applied, although its utility was limited somewhat by an apparent oversensitivity of user costs to certain network changes, which has already been addressed at length elsewhere in this chapter. The MCA was conducted on a more detailed and formalised basis in the second round.

The results indicated that both do-something strategies would have broadly similar results. While one or the other may be superior on certain individual measures, it is extremely difficult to judge between them overall. The lower capital cost is a significant advantage for the "combined buoyant air" strategy, and MCA also indicated a slight advantage for this strategy. CBA showed that both strategies were likely to have positive benefits but that the "combined fixed link" strategy would probably be superior.

Overall, the "combined buoyant air" strategy appears the best, but only by a small margin. Both do-something strategies involve significant risks due to the use of relatively untried technology. (In the case of the fixed link, although the rail technology used and the basic system of immersed tube tunnel construction are established, considerable technological

development would be necessary to allow construction at such lengths and depths). Both appear broadly preferable to the do-minimum on MCA, but the margin again seems small.

In general terms, the appraisal of alternative strategies has indicated that an "ideal" strategy would probably incorporate some degree of demand restraint (though much more would have to be done to optimise the nature and level of this restraint). This would be combined with a "new mode" network- which could comprise buoyant air transport services or a fixed link- and selected improvements to road, rail, port and airport infrastructure. In practice, a "second best" strategy concentrating on existing modes, which should again make use of demand restraint and be selective in its provision for infrastructure (unconstrained investment in high-demand areas may not be optimal) is required as an alternative to high-risk "new mode" strategies. In the context of the testing, the two second-round do-something options are closest to the "ideal" strategy and the first-round "managed demand" strategy to the "second best".

9.6.2 Individual elements: modifications to the existing system

After considering the results of the modelling and appraisal work on the strategy-by-strategy level, the performance of the principal individual measures making up such strategies must be examined. Here, it must be warned that analysis on the element-by-element level is more susceptible to errors in modelling than strategy-level comparisons, particularly if the elements examined consist of individual links or nodes rather than sub-networks.

The category of "modifications to the existing system" is interpreted to encompass all individual strategy elements aside from those relating to the buoyant air and fixed link networks. The vertical/short take-off and landing (V/STOL) and Seabus networks are included under the present heading, as they relate closely to the airline and fast ferry networks, respectively, rather than forming entirely new modes.

In the do-minimum situation, enhancements to air and sea transport relative to the 1995 base include the development of additional air routes providing direct service from Dublin (and to a lesser extent other Irish airports) to an increased number of mainland European

destinations. Low-cost air services are expanded. Fast ferry services are also greatly expanded and vessels capable of carrying freight introduced.

These improvements generally appear to attract significant demand, and thus can be considered worthwhile from the operators' viewpoint. Therefore, they are indeed likely to be implemented under a do-minimum situation. In retrospect, it is possible that an even more pronounced increase in low-cost airline provision should have been modelled (see 9.6.4 below); however, the modal split changes in chapter 8 suggest that even the increase actually modelled has very significant effects on choice of airline type. The effect of the do-minimum improvements on wider social objectives is mixed; they generally assist in reducing user costs, but there may be some negative environmental impacts, e.g. through modal shift from conventional to fast ferries.

Enhancements to road and rail networks in the do-minimum include the implementation of the 2000-2006 National Development Plan (NDP) road network in the Republic of Ireland, provision of new motorway links (Dublin Port Tunnel/Eastern Bypass) to the port of Dublin and a rail link to Dublin airport. The Channel Tunnel is another important addition to the network; although it is already operational at the time of writing (unlike most other improvements listed here), it only became fully operational during 1995 and does not form part of the base network.

All these enhancements attract significant traffic in the 2020 do-minimum situation. Again, from the point of view of Irish access transport, they all appear to be worthwhile and beneficial projects, although they have not been analysed in the same detail as those elements actually forming part of alternative strategies.

In the first of these strategies ("high investment"), the centrepiece of the enhancements to air passenger transport is the transfer of low-cost services operating from Dublin to a new second airport at Baldonnel, accompanied by increased frequency and the creation of new routes. This is very successful initially in relieving pressure on Dublin airport, but does comparatively little to attract traffic from other airlines to low-cost carriers. Furthermore, Baldonnel would be operating over capacity in 2020, so that some traffic would have to be transferred back to the existing Dublin airport. In the light of these results and the very considerable noise-related disadvantages of Baldonnel, the scheme does not appear

worthwhile. Likewise, the expanded and subsidised air freight network in this strategy is unsuccessful in attracting traffic.

The sea transport equivalent of the Baldonnel project is the development of a new ro-ro port at Loughshinny. Like Baldonnel, this project has significant negative environmental impacts. Again, it does little to relieve existing facilities and indeed attracts little or no demand, though this is partly attributable to the lower frequency of service from this port compared to Dublin. Nevertheless, it must be questionable whether a scheme with such high capital and environmental costs is worthwhile, particularly when the alternative of developing ports such as Drogheda is available.

The V/STOL and Seabus networks are also included in the "high investment" strategy. Both are passenger-only (including car-accompanied travel in the case of Seabus). Both networks appear to have similar impacts, i.e. attracting a small share of traffic (<5% of total passenger-km) but making comparatively little difference to overall costs or congestion levels. Overall, neither appears to be justified as a primary objective of public policy, but both would seem to be viable as stand-alone projects for their operators. Infrastructure provision, particularly for V/STOL, might however require governmental support.

The "high investment" strategy includes a number of other elements. These principally comprise improvements in road and rail access to ports and airports. The improved rail access to Dublin port results in a significant increase in rail freight usage within Ireland, but the improved airport links are less successful in terms of passenger traffic. Road improvements appear to have only a moderate effect on overall traffic patterns.

The "managed demand" strategy contrasts in many ways with the "high investment" one. The concentration of airport investment on one specific project is replaced by investment on a dispersed basis across a series of regional airports. Unfortunately, this investment, and its accompanying air network enhancements, are not generally successful in attracting traffic. While this is partly a reflection of the very low frequencies on most such air routes and the fact that the model may be oversensitive to frequency changes, the results do cast some degree of doubt on the likely success of such a policy.

Instead of the Loughshinny project, the "managed demand" strategy incorporates development of the two existing ports at Arklow and Drogheda. This is considerably more successful than Loughshinny in attracting traffic, although it must be borne in mind that additional charges are levied on traffic through Dublin port in this strategy, which contribute significantly to the pattern of demand. Of the two ports, Drogheda is significantly more attractive to traffic and this, coupled with the greater environmental impacts of road access provisions at Arklow, suggest that a strategy using Drogheda alone may be preferable. However, Arklow performs relatively well in terms of passenger ferry traffic.

The "decentralised" sea transport network applied in this strategy had rather less of an impact on patterns of movement than might be expected. In general, no major change in route choice was observed.

Other elements of this strategy include port/airport access improvements, subsidisation of road/rail transfers and extensive taxation measures (involving internalisation of external costs and additional charges on use of ports and airports in the Dublin area). The pattern of road freight movement in Ireland shows a shift away from the main radial routes and towards circumferential ones such as Galway-Cork and Cork-Rosslare; this probably reflects a combination of improvements to the western road corridor and taxation of Dublin port traffic. The impact on car traffic is far less pronounced. Some Irish rail freight links are more heavily used in this strategy than the "high investment" one, reflecting the impact of subsidy, but conversely some see less use, possibly because of a reduction in service levels at Dublin port (though railborne traffic is exempt from the additional port charges). The impact on rail passenger traffic of the infrastructural improvements proposed is small.

It appears that the taxation measures modelled are too extreme. In general terms, they increased user costs significantly without producing commensurate benefits in terms of environmental impact. The charges at Dublin port, in particular, produce a distorted demand pattern, with under-use of existing port facilities and excessive truck mileage resulting from haulage to alternative ports. This does not, of course, preclude the possibility of an optimised charging regime having more beneficial effects.

Modifications to existing systems in the two "new mode" ("fixed link" and "buoyant air") strategies were generally a subset of those implemented in other strategies. Their impact on

the transport system appears to have been small by comparison with that of the "new mode" networks themselves.

The enhancements and modifications to existing systems in the second round were essentially drawn from first-round strategies, particularly "managed demand". The charging regime used was minimal compared with that included in the latter strategy; all port/airport charges were abandoned, along with all freight charges, and only car and airline travel were taxed (at a reduced rate) in the case of passenger traffic. Improvements to Drogheda port and some of the better-performing road and rail measures were also included.

The second-round results show that the modified charging scheme has a more positive impact, but still significantly increases user costs and thus might not be politically feasible. The Drogheda port improvements are not particularly successful in traffic terms, though this may relate to problems with the representation of frequency, i.e. underestimating traffic on lower-frequency links compared with higher-frequency alternatives. The rail improvements and subsidies achieve a significant increase in rail freight use within Ireland. The Dublin-North West and Western Corridor road improvements appeared to attract significant traffic, but there is a moderate reduction in traffic (passenger and freight) on most Irish road links. This is most probably attributable to a combination of rail freight subsidies and charges on car use.

9.6.3 Individual elements: new transport systems

The category of "new transport systems" is here understood to include the fixed link and buoyant air networks, for both passengers and freight, developed in the final two first-round strategies and also modelled in the second round. In the case of the fixed link network, the high-speed train network plus rail freight and piggyback services using the link are understood as forming the "new system". The equivalent system in the "buoyant air" and "combined buoyant air" strategies consists simply of the passenger and freight buoyant air links. Changes to other modes are included in these strategies but not addressed by this sub-section.

The "fixed link" strategy in the first round shows very heavy usage of the Dublin-London and Dublin-Manchester passenger services and moderate numbers on other routes. There is also heavy usage of car-carrying shuttle trains through the tunnel by passenger traffic. The link sees similarly heavy use for through rail freight, but piggyback shuttle services for freight are only moderately used, and longer-distance piggyback routes very little used. General rail freight use in Ireland is much heavier as a result of the provision of the fixed link, but the impact on road traffic is mixed. The fixed link and its ancillary measures make up the majority of the strategy, and so it is more appropriate to judge the overall strategy (see 9.6.1 above) rather than these elements alone, but the project appears broadly viable, from the limited observations that can be made.

The first-round buoyant air network is similarly relatively successful in attracting traffic. The freight services only account for a small proportion of demand, but seem to bring about a worthwhile cost reduction for higher-value commodities. Both passenger and freight networks typically show low or zero demand on the lowest-frequency links, which may not be entirely realistic and has been addressed at length elsewhere. In general terms, the network again appears to be viable and to contribute towards the overall objectives set for the transport system.

The modified buoyant air network in the second round shows increased demand on the vast majority of passenger links, likely to be partly attributable to expansion and modification of service and partly to the effects of taxation on airline travel. However, freight links have reduced demand levels, which may be attributable to the higher level of service assumed on surface shipping links in this strategy.

The fixed link network examined in the second round was virtually identical to that in the first round. However, compared to the first round, there is significantly reduced demand for through rail freight services, coupled with an increase in demand for road freight and piggyback transport. The precise reason for this could not be identified, though it may relate to the increased shipping services referred to above (which are the same for both strategies in this round).

9.6.4 Other issues

Consideration has also been given to the issue of whether there are measures which have not been incorporated into the modelled networks but might nevertheless have merit. The emphasis in this field is on "modellable" measures rather than those which might be desirable but are not susceptible to appraisal by such methods. It is not denied that the latter type of measure may be worthwhile, but the focus of this project has been primarily on more strategic measures which are better suited to modelling, and it is intended to maintain such a focus in this discussion.

As previously mentioned, an expansion in low-cost airline services was assumed as part of the do-minimum. Prior reference has also been made to the fact that this assumed expansion may not have been as large in scale as might actually be the case. In particular, a strengthening of low-cost carriers' position *vis-à-vis* conventional airlines appears to have occurred as a result of the airline industry crises of late 2001. If such trends continue, low-cost carriers may account for the majority of future airline expansion in Europe, and other airlines' networks contract significantly. However, the situation is too fluid at the present time to judge the long-term outcome, and there are technical issues limiting the overall size of the modelled networks which might make it more difficult to simulate such developments.

It is also possible that a more "drastic" approach could be taken to the allocation of traffic (primarily freight) between different ports. For example, ro-ro traffic could be withdrawn entirely from the port of Dublin (coupled with a new port at Loughshinny or the development of Drogheda and/or Arklow for such traffic). A more extreme variant involving the withdrawal of all unitised services, ro-ro and lo-lo, from Dublin- as proposed in the past- is theoretically possible but would risk making poor use of the improved road access planned for the port. Similar policies could be applied outside the Dublin area, but the justification for them would be more dubious. The limiting factors are probably political feasibility and the risk of under-utilisation of capacity. While it would be technically feasible to model such an approach, considerable development work would be required. Additionally, possible shortcomings in the demand models affecting the modelling of route choice may need to be addressed beforehand, and it would also be desirable to incorporate some measure of congestion into the assignment process (see also 9.2.2, 9.3.2 and 9.3.3 above).

It would be theoretically possible to model more than one fixed link option in terms of routing (e.g. Dublin-Holyhead versus Larne-Stranraer) or mode (road versus rail). However, the justification for this course of action in a strategic study such as this one is weak. The author considers that the choice between modes and routes has been adequately addressed for the purposes of this project by the analysis described in chapter 4 and Appendix B. It is conceivable that a more detailed study of fixed links would require modelling of the candidate options, but the author considers the overall "fixed link" concept to represent a single strategic option in the present context, so that lower-level choices should be addressed outside the strategic modelling/appraisal process.

Overall, the concepts described above for an enhanced low-cost airline network and possible alternative approaches to ports policy are of interest but remain in need of considerable development. Given this, and the fact that they depend in large part on observations made during the modelling process itself and wider market developments taking shape only near the end of that process, they are not considered for further work at this point. The concepts remain valid in spite of this. The idea of modelling multiple fixed link options, on the other hand, is not considered to be of relevance to the aims of this project.

9.7 WIDER ISSUES

9.7.1 Comparison with other studies

It may be useful to compare the findings of this study with the outcomes of other similar efforts in the past. A problem in this respect- as in terms of modelling or appraisal- is that the number of directly comparable studies in the literature is rather limited.

A prime candidate, however, must be the 4th Framework project STEMM, which has already been referred to extensively in chapters 3, 6 and 7 of this thesis. STEMM investigated both infrastructural and charging measures for both passenger and freight transport in a number of case studies in different regions of Europe. STEMM's principal findings included:

- Infrastructure/charging combinations achieve better mode shift than infrastructure measures alone in the Trans-Alpine passenger case, but their performance is similar in the Scan-Link case.
- Strong pro-rail policies are superior to purely anti-road ones in the English Channel freight case. The trans-Alpine freight case study shows generally similar results: improved rail services and increased road charges are considered to be of equal importance.
- Rail improvements had significant positive impacts on the Scan-Link freight situation, but anti-road measures decreased the overall level of service and were considered less desirable. Findings in the Nordic/North Sea freight case study were similar, insofar as targeted "positive" measures (such as rail subsidies) were effective, whereas "negative" ones (such as taxes) could have unexpected effects.

The author's work generally bears out the conclusions of STEMM. An infrastructure/charging combination has been shown to be more effective than infrastructure alone (compare the second-round strategies to their first-round equivalents). However, charging is not a panacea, and can have serious negative effects, some expected (cost increases), some unexpected (e.g. the increased road haulage distances in the managed demand strategy). Charging measures must be carefully developed and should not be implemented in isolation from infrastructural investment.

Previous studies of Irish access transport may also be of interest in this context, but they are generally shorter-term and more limited in scope than the author's work. For instance, the KPMG and CHL (1990,1992) studies focus to a very high degree on immediate port and shipping needs. Some individual findings may be echoed in this project: the Northern Ireland Economic Council's (1993) belief that "soft" measures may be as important as infrastructure is one example.

It is difficult to draw direct comparisons with other studies apart from the above. A possible exception may be the Europe-wide COST 33 passenger transport study (OECD 1977), which suggested that infrastructure investment alone was not necessarily the wisest solution, but that charging measures might not necessarily give the desired effects, conclusions broadly in agreement with the author's own. However, even this study is not entirely comparable with the author's because it was Europe-wide, excluded freight

transport, was carried out over 25 years ago and did not address certain issues (such as user cost).

9.7.2 International applicability

It may also be beneficial to consider whether the findings of this project have wider applicability beyond the Irish access context. In particular, the methodological approach, appraisal framework, and findings on various possible strategies and measures might find application elsewhere.

In the EU context, similar situations exist in the Mediterranean area (connections between the mainland and islands, as well as cross-water links between two parts of the European mainland, as for instance between Greece and Italy) and the Baltic/Scandinavian region (particularly between Finland and western Europe). Areas such as these could benefit from studies along the lines of what the author has attempted for the Irish access market. There could also be advantages in examining new transport technologies across a number of such markets, as the combined potential of several such applications might render research and development less costly and risky than if it were directed purely towards the needs of one region.

Similar considerations apply to other island or cross-water situations worldwide, although in this case the author feels that greater variability in geography, political and socio-economic situations make it considerably more difficult to generalise from the Irish case. Nevertheless, island and archipelago regions such as New Zealand or the Caribbean could potentially apply lessons learnt from Ireland.

9.7.3 Public policy implications

Since public policy creates the overall framework for the development of the access transport system (and aspects of public policy, for instance in the field of statistics, affect the level of detail in which it is possible to examine the system), it is of value to examine the implications of the author's work for policy decisions. This is of particular importance

in the context of the National Spatial Strategy and concomitant development of longer-term policies for various areas of the transport sector.

In terms of possible general strategies, the author would reiterate his conclusions at 9.6.1 above. The essence of these findings is that a conceptual "ideal" strategy would incorporate a new transport system (fixed link or buoyant air), a means of demand restraint and selected improvements to existing modes. However, it has not been proven conclusively that such a strategy, with its considerable risks, would be entirely superior to a conceptual "second best" strategy relying on the existing modes but again making use of demand restraint alongside carefully-selected infrastructure investment projects.

In a general sense, therefore, public policy should not rule out the possibility of developing new access transport systems. In this respect, further investigation of the current fixed link proposals within the next 5-10 years would probably be worthwhile. However, an important condition for this is that equal effort is devoted to a parallel investigation of buoyant aircraft or another alternative system. Significant enhancements to the existing modes should also be addressed by any such study.

There is considerable potential for enhancement and optimisation of the existing access transport system, and this will be the only realistic solution for the next decade at least. Public policy should be more pro-active in this field. National (and, if possible, island-wide) long-term port and airport policies should be developed in the light of the National Spatial Strategy and reviewed regularly (taking account if appropriate of any studies on fixed links or other new transport modes). Road and rail policies should be developed on a similar basis and should take explicit account of access transport needs.

In relation to particular projects involving the existing transport modes, the author's work indicates that Dublin port will continue to be vitally important to the overall access transport system, though he has been unable to ascertain exactly to what degree its capacity can be practically expanded over the next two decades. Additional port capacity would probably be better provided at existing locations such as Drogheda rather than on a greenfield site, but this should be further investigated within the context of a national ports policy. The author's findings suggest that, even with an expansion to cater for 40 million passengers per annum (not yet approved), Dublin airport will come under severe pressure shortly after 2020, and (the author's findings against the Baldonnel scheme

notwithstanding) detailed study of future airport provision, again within a national policy framework, will again become necessary.

The findings of this project are generally supportive of improvements to the Irish road network, though these should ideally be coupled with pricing measures. However, rail freight would appear to have an important part to play in future access transport development. Thus, positive policies for developing the freight service are necessary, along with a long-term commitment to its continued operation. Public policy in the Republic of Ireland has been lacking in these areas, at least in recent years.

Examination of significant alterations to the access transport system would benefit from the application of transport modelling techniques. While the author's work in this field could be extended somewhat, the use of some of the existing Europe-wide models described in earlier chapters of this thesis could also be considered.

In support of such modelling efforts, and in the interest of a better overall understanding of the access transport situation, there is a need for greatly improved statistical information on transport. This might include regularly-updated (and published) origin-destination surveys of both passengers and freight traffic, possibly in collaboration with other countries or the EU as a whole. Improved statistics are also necessary for domestic transport, and access transport would benefit from better information in this area too. The development of structured national transport policies, as described above, would be greatly eased by enhanced statistical information on both domestic and access transport.

Finally, more use should be made of standardised appraisal frameworks. At the very least, projects affecting access transport, whatever the mode, should all be assessed within a common framework. Serious consideration could also be given to extending this framework to cover all transport schemes within the Republic (including urban/regional projects) on a similar basis to the UK's Appraisal Summary Table. The author's appraisal framework is one possible base for such a methodology.

10 CONCLUSIONS

10.1 INTRODUCTION TO THE CONCLUSIONS

This chapter describes the conclusions reached on the basis of the results presented in chapter 8 and the discussion of these results contained in chapter 9. Conclusions are drawn in three major areas. The demand models themselves are dealt with in section 10.2 below, while section 10.3 draws conclusions in relation to the appraisal framework. Section 10.4 addresses the strategies and strategy elements themselves. Finally, section 10.5 summarises the conclusions. The structure of this chapter broadly reflects that of the discussion in the preceding chapter.

10.2 CONCLUSIONS ON DEMAND MODELLING

10.2.1 Basic model structures

A very extensive review of the possible approaches to modelling both passenger and freight demand was carried out in earlier stages of the research (see chapters 3 and 6). The results of this review informed the eventual choice of approach (chapter 6). However, final conclusions could only be reached in the light of the results of the modelling process (described in chapter 8 and discussed further in chapter 9).

The principal conclusions in this area are:

- In both freight and passenger cases, the approaches chosen appear to have led to models which are generally satisfactory and capable of replicating conditions in the market, notwithstanding any difficulties identified here.
- In neither case can the use of alternative, non-modelling-based, methodologies (which were seriously considered in earlier stages of the work) be justified as a serious alternative to modelling for the work involved.

- While there might be some merit in examining in outline the four-stage approach to passenger modelling as an alternative to the quasi-direct demand model actually used, there is no evidence to suggest that it would perform any better.
- The methodology used for generation of freight flows appears to be the best consistent with the limited data available (see also 10.2.2 below).
- The approach taken to the representation of intermodal passenger travel has limitations, but appears to be the best achievable with the passenger model in its present form.

10.2.2 Data sources

Experience with the models has also been able to shed some light on the strengths and weaknesses of the sources used to obtain data for calibration and validation purposes. A number of possible alternative approaches have been investigated in the light of the results emerging from the initially-chosen methodology; however, these have proved to have disadvantages of their own.

A variety of issues relating to this important aspect of modelling have been discussed at various stages in chapter 9. The conclusions drawn from this work now follow:

- There does not appear to be any potential for new (passenger or freight) origin-destination surveys in the context of a project such as this one. Although they would be of use, the effort required to produce an accurate result would require greater resources than realistically likely to be available to such a project.
- More reliable data on transport costs are desirable, but not apparently available at present. Again, a comprehensive survey would be beyond the scope of this project.
- There may be a role to be played by stated or revealed preference data in passenger modal choice modelling, but this would appear to require better origin-destination calibration data.
- Time-series data have been investigated as an alternative to calibration on a single-year basis, but would require radical modification to the model structure and appear to be of limited utility.

- In summary, the quality and quantity of the data available are generally quite poor, but a model with an acceptable degree of accuracy has been constructed using only what is readily available.

10.2.3 Networks

The structure of the transport networks used in the passenger and freight models has been examined in the light of the results emerging from the modelling process, with a view to determining the extent to which it met the project's requirements and whether or not potential existed for enhancements. This examination has led to the following conclusions:

- Network density is necessarily limited by model capabilities and available development time, but there is no reason to believe it is anything other than satisfactory.
- In fact, some simplification of the network would appear to be possible. This applies particularly to the airline network, where there seems to be potential for a reduction in the number of airports in certain zones.
- In the road and rail networks, there is potential both for increased differentiation of link types and for simplification of the network structure itself, but neither course of action can be unequivocally recommended. The modelled network for these modes is probably the optimum that could be attained without excessive effort.
- The network in general is broadly satisfactory, but could be improved, particularly with regard to the aforementioned potential for simplification. The use of discrete link type designations for various geographical areas, in order to permit greater spatial disaggregation of demand levels and modal splits, may also be an area of potential.

10.2.4 Cost functions

Like the network structure, the cost functions forming part of the modelled passenger and freight networks have been examined in the context of the modelling results. Again, the approach taken has been generally proved satisfactory by this analysis. Although certain areas of concern have been identified, the relative dearth of source data in this field makes it difficult to fully address them.

The following are the principal conclusions reached:

- The results do not definitively indicate any general tendency towards inaccuracy which might be attributed to the cost functions used, although there are problems with a small number of specific modes.
- There do appear to be certain unresolved issues surrounding the treatment of frequency (on scheduled services) in the "waiting time" functions. These are addressed separately at 10.2.5 below.
- More data are needed on some modal costs, particularly for new modes.
- Air freight may require analysis at a finer level (e.g. in terms of commodity definitions) than applied in this project.
- Port time costs should preferably be derived from congestion functions, but there was insufficient information available to permit such a course of action in the present context.
- Ideally, a common multi-modal operating cost model would form the basis of monetary cost functions for passenger and freight traffic. The possibility was investigated, but its time and data requirements made it unattractive in this context.

10.2.5 Frequency issues

As referred to above, there have been some problems apparently attributable to the treatment of service frequency in certain cost functions, both for passengers and freight. The nature of the problem became apparent only at an advanced stage of the research, so that it was not possible to fully resolve the issue within the modelling process. However, it has been investigated in the light of the modelling results, and the following conclusions have been reached:

- The option of ignoring service frequency entirely in the cost functions has been considered and, indeed, was experimentally tested in early stages of modelling. It does not appear to be a satisfactory solution.
- An alternative solution using time penalties corresponding to frequency ranges, imposing a lower penalty than the "half interval" approach actually utilised, has been

investigated. This appears to have merit, but would require extensive restructuring of the models and cannot be examined further at this stage.

- Whatever the chosen approach to modelling the effects of frequency, it appears that an empirical derivation is unavoidable in the absence of stated or revealed preference data (see also 10.2.2 above).
- In summary, the "half interval" approach appears to have been a reasonable choice at the time of selection, but with hindsight can be viewed as problematic.

10.2.6 Commodity definition issues

The number, scope and characteristics of the various commodities into which freight traffic is divided have been outlined elsewhere in this thesis. In view of the modelling results, an examination has been made of this classification in order to determine whether it might be improved upon in any way. The relevant conclusions are:

- A more detailed approach was developed in outline for purposes of discussion, but proved to pose excessive difficulties. These resulted primarily from the increases model and calibration requirements associated with a transition from twelve to at least twenty commodities. It was therefore not favoured.
- Consideration was also given to amendment of the weights attached to the various cost components in respect of each commodity, to improve accuracy and better reflect the position in the Irish access market. This was ultimately considered impossible in view of limited information on actual costs in the market.
- Overall, the commodity classification adopted for the research appears the most appropriate under the circumstances.

10.3 CONCLUSIONS ON THE APPRAISAL FRAMEWORK

10.3.1 Cost-benefit analysis

Cost-benefit analysis (CBA) forms an important part of the appraisal framework developed for this project, as described in chapter 7. Although it must be noted that CBA is not the central element, it nevertheless remains true that its performance is of concern, given the importance of its results.

The conclusions reached in relation to the performance of CBA are:

- The difficulties experienced in relation to user cost changes are not attributable to the CBA methodology, but rather to the way in which frequency is treated.
- There is no viable alternative to the method chosen for calculating monetary costs, but this method is unlikely to constitute a major source of inaccuracy.
- There is no reason to question the overall validity of the figures for environmental costs. Certain minor enhancements were investigated, but generally appear to pose excessive difficulties in comparison to their benefits.
- Overall, the presence of CBA alongside MCA appears to have been beneficial to the performance of the appraisal framework. It also appears that the chosen CBA format is preferable to simpler approaches because of its disaggregation of results, even though this involves additional work.

10.3.2 Multicriteria analysis

The core of the appraisal framework is the multicriteria analysis (MCA) process. This is also described in detail by chapter 7, and involves assessing compliance with a set of objectives and criteria, using both qualitative and quantitative measures, and producing a formalised series of output "scores". Given its importance in the framework, examination of MCA's performance is obviously a necessity. The discussion of this issue contained in sub-section 9.5.2 of the preceding chapter points to the following conclusions:

- The objectives and criteria utilised in MCA have generally performed well. Although it would have been preferable to secure a greater degree of participation from interest groups, the efforts made in this direction met with limited success.
- The balance between criteria aimed at reducing (negative) impacts and those aimed at minimising additional impacts needs to be carefully considered. However, the mixture of criteria used appears to represent a satisfactory compromise between the two.
- Some of the criteria proved to require too high a level of detail in their inputs, considering the strategic level of analysis.
- The idea of detailed guidance on the translation of qualitative or quantitative results into multicriteria scores was considered. However, the difficulties encountered in this respect were insufficient to justify the considerable effort required to develop such guidance.

10.4 CONCLUSIONS ON ALTERNATIVE STRATEGIES AND STRATEGY ELEMENTS

10.4.1 Strategies

In total, over two rounds of modelling (see chapter 8), six do-something future strategies were compared against a do-minimum case (in addition to comparison of the do-minimum against the base situation). The conclusions on the performance of these strategies are obviously important to the project as a whole, although it must be stressed that examining alternative strategies is not the sole objective of the research.

The discussion of the strategies' performance is contained in sub-section 9.6.1 of the preceding chapter. Conclusions in this area are:

- The do-minimum strategy has advantages in terms of feasibility but does not perform well on other criteria, though it is not the worst-performing strategy overall.
- The "high investment" strategy is successful in reducing user costs and achieving an equitable balance of costs between regions and user groups, but has few other benefits. It is costly and has major negative environmental impacts.

- The "managed demand" strategy has significant environmental benefits, but is generally not the best strategy in this area. Although its capital costs are low, it significantly increases user costs. It is not an ideal solution, but appears to represent a better way to build on the strengths of existing modes than the "high investment" approach.
- The "fixed link" strategy is very costly, is dominated by the "buoyant air" strategy in MCA, and has negative impacts on the marine environment, but reduces emissions significantly.
- The "buoyant air" strategy achieves broadly similar emission results to the "fixed link" strategy but at lower capital cost and with a less negative impact on other aspects of the environment.
- It appears that the "new mode" ("fixed link" and "buoyant air") strategies achieve advantages over those involving purely modification of the existing air and sea system. This is, however, balanced by problems of feasibility.
- The second-round strategies were designed on the basis that the most advantageous course of action would involve combination of a "new mode" network with selected elements from the "managed demand" strategy.
- Both the do-something strategies investigated in the second round- "combined buoyant air" and "combined fixed link"- proved to have similar overall results. The "combined buoyant air" strategy was marginally favoured in MCA.
- CBA results suggested that both alternatives would have positive benefits, but the "combined fixed link" strategy would perform better.
- Overall, the "combined buoyant air" strategy is favoured by a small margin.
- In more generic terms, the results indicate that an "ideal" strategy would combine some form of demand restraint with a "new mode" network and selected infrastructural improvements in other modes.
- However, such a strategy would involve considerable risks, and thus a "second-best" strategy, which would be similar except in omitting the "new mode" network, is required as an alternative.
- The second-round do-something strategies are the closest of those tested to the hypothetical "ideal" strategy, while the first-round "managed demand" strategy is closest to "second-best".

10.4.2 Principal strategy elements

In addition to examining the performance of each strategy, a similar investigation has been carried out (see sub-sections 9.6.2 and 9.6.3) into the performance of the individual elements which make up the strategies. The elements themselves were described in chapter 4.

The principal conclusions are:

- The enhancements to existing transport modes assumed in the do-minimum situation appear worthwhile in attracting traffic, though there may be some disadvantages (e.g. environmental impact of increased use of fast ferries) in overall social terms.
- The Baldonnel airport scheme (in the "high investment" strategy) is judged not to be worthwhile because of its environmental disadvantages and limited long-term impact on airport congestion.
- The expansion and subsidisation of air freight services, as proposed in the same strategy, does not appear successful in attracting traffic.
- The Loughshinny port scheme, also contained in the "high investment" strategy, does not appear successful enough to justify its cost and environmental impact. This must be seen in relation to the problems in the demand model's division of traffic between alternative routes (see 10.2.5 above), the absence of a capacity constraint on assignment to existing ports (see 10.2.4 above) and possible alternative approaches to ports policy (see 10.4.3 below).
- The V/STOL and Seabus networks attract a small but significant proportion of traffic, but do not appear to contribute much to the furtherance of wider objectives.
- Other elements of the "high investment" strategy, principally road and rail, have mixed effects.
- The "managed demand" strategy's modified air network, placing greater emphasis on regional airports, does not greatly alter traffic patterns.
- Development of Arklow and Drogheda ports is more successful than the Loughshinny scheme, though this may be attributable to the presence of additional port charges at Dublin in this strategy, as well as the factors outlined above in relation to Loughshinny.
- The "decentralised" sea transport network does not produce a significant reassignment of traffic.

- Other elements of the "managed demand" strategy produce various effects. The subsidisation of road/rail transfers appears the most worthwhile of these.
- Taxation measures in this strategy appear too extreme, significantly raising user costs without commensurate benefits and sometimes with perverse effects (e.g. increased truck mileage due to higher charges at Dublin port).
- The fixed link (Dublin-Holyhead rail tunnel) modelled in the strategy of the same name attracts considerable passenger (through rail and car-accompanied) and through rail freight traffic.
- The buoyant air network also succeeds in attracting demand, both passenger and freight; in the case of freight transport, its share of the market is small, but higher-value commodities are attracted to the mode.
- In the second round of modelling, the modified buoyant air network exhibited increased passenger demand levels and reduced freight demand (the latter probably due to changes in the levels of service of other modes).
- The fixed link network in the second round showed a transfer of freight traffic from rail to piggyback and road transport compared with the first round, though the precise cause of this is unclear.

10.4.3 Measures not modelled

Some potential strategy elements have only come to prominence through the modelling process itself or as a result of external events occurring at an advanced stage of the modelling work. Consequently, it has not been possible to model all of them in the time available. However, they have been briefly examined in chapter 9 (see sub-section 9.6.3) and the following principal conclusions reached:

- It was considered quite possible that low-cost airlines would develop to an even higher degree than modelled in the period to 2020. Uncertainty and technical difficulties, along with time factors, precluded full-scale modelling of this, but the concept remains valid.
- The possibility of more radical developments in ports policy was considered, particularly in the light of the relatively poor performance, when not accompanied by punitive charging levels, of schemes to provide an alternative port to Dublin. Potential

- measures might include the complete withdrawal of ro-ro, or of all unitised, traffic from Dublin and transfer to a new or expanded port nearby. This concept also posed technical and time problems, so was not modelled, but again remains valid.
- Modelling of an alternative fixed link option was considered, but the idea was rejected as inappropriate to a strategic-level multi-modal study. There appears to be no reason to revisit this decision.

10.5 POLICY RECOMMENDATIONS

As discussed in section 9.7 of the preceding chapter, the work carried out in this project may also have implications for the development of public policy. It has been possible to make some tentative recommendations in this area. These include:

- Public policy should not rule out the possibility of developing new (e.g. fixed link, buoyant air) access transport systems.
- Further investigation of the current fixed link proposals within the next 5-10 years would probably be worthwhile, but only if buoyant aircraft (or another alternative system) and significant enhancements to the existing modes are examined in parallel.
- Enhancement and optimisation of the existing access transport system will be the only realistic solution for the next decade at least; public policy should be more pro-active in this field.
- National long-term port and airport policies should be developed in the light of the National Spatial Strategy and reviewed regularly; road and rail policies should be developed on a similar basis.
- Further detailed investigation, within a national context, of long-term port and airport provision in the Dublin area is necessary.
- Improvements to the Irish road network will benefit access transport- particularly if coupled with appropriate pricing measures- but parallel development of the rail freight service is also important. Positive policies for developing the freight service are necessary, along with a long-term commitment to its continued operation.
- Appropriate transport modelling techniques should be considered for the examination of significant alterations to the access transport system.
- There is a need for greatly improved statistical information on Irish transport, particularly regular origin-destination surveys.

- More use should be made of standardised appraisal frameworks. In particular, a standardised framework for all transport schemes in the Republic of Ireland (similar to the Appraisal Summary Table in the UK) should be considered.

10.6 SUMMARY OF CONCLUSIONS

This research project was undertaken with a number of aims in mind. The examination of possible alternative strategies for the transport system, and the development of modelling methodologies and an appraisal framework to support this, were the most important of these.

As far as the examination of alternative strategies is concerned, while the aim was not to produce a single unequivocal "best solution", the modelling and appraisal work have produced definite indications as to which courses of action would be most productive.

An "ideal" strategy would apparently incorporate the development of a "new mode" system, comprising either buoyant air services for passengers and freight or a rail fixed link with associated services. The buoyant air network is marginally preferred to fixed link. The strategy would also include some form of demand restraint and limited enhancements to the infrastructure of the existing transport modes.

Such a strategy would involve considerable risks. Clearly, the development of a fixed link- concentrating a considerable volume of access traffic onto a single route, committing a large amount of investment to creating this link, incurring technological and site-specific (e.g. geological) risks- is not to be undertaken lightly. Neither is a strategy which would commit policy and resources on a large scale to the buoyant air mode, still very much unproven in practical transport applications. Therefore, it is possible that a more moderate approach, broadly resembling the "ideal" strategy except in omitting the new mode, should be considered as a "second-best" alternative.

In relation to the modelling methodology, the project has succeeded in developing an approach to modelling the passenger and freight aspects of the Irish access market, something apparently not hitherto attempted on any significant scale. This approach has

proved capable of replicating, on a broad strategic level, the base-case position and has produced usable results for future strategies. It is of course necessary to observe that the models are only as good as the available calibration data, and this latter is far from perfect. Nevertheless, the author is satisfied that the results are superior to those which might emerge from any alternative, non-modelling-based, approach.

This is not to deny that there are some areas in which the capabilities of the models could be enhanced, even in the absence of comprehensive demand data. Some potential areas for such enhancement have been identified, but not all could be fully tested within the time available (particularly where an issue only came to prominence in the course of the modelling process itself). These issues are summarised in the preceding sections of this chapter.

An appraisal framework appropriate to the needs of the research was also successfully developed. This framework embraces aspects of both multicriteria analysis (MCA) and cost-benefit analysis (CBA). It has generally performed satisfactorily. As in the case of the demand models, certain enhancements have been investigated, but few have ultimately been judged worthwhile.

Overall, therefore, the project has achieved its original aims to a great extent. Some setbacks have been encountered, but the author considers these relatively few in number in view of the difficulties presented by the comparatively little-explored and under-documented nature of the subject matter.