Iarnród Éireann

DART Underground

April 2010

Business Case

TRANSPORT
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DEVELOPMENT
PLANNING
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DART Underground

Business Case

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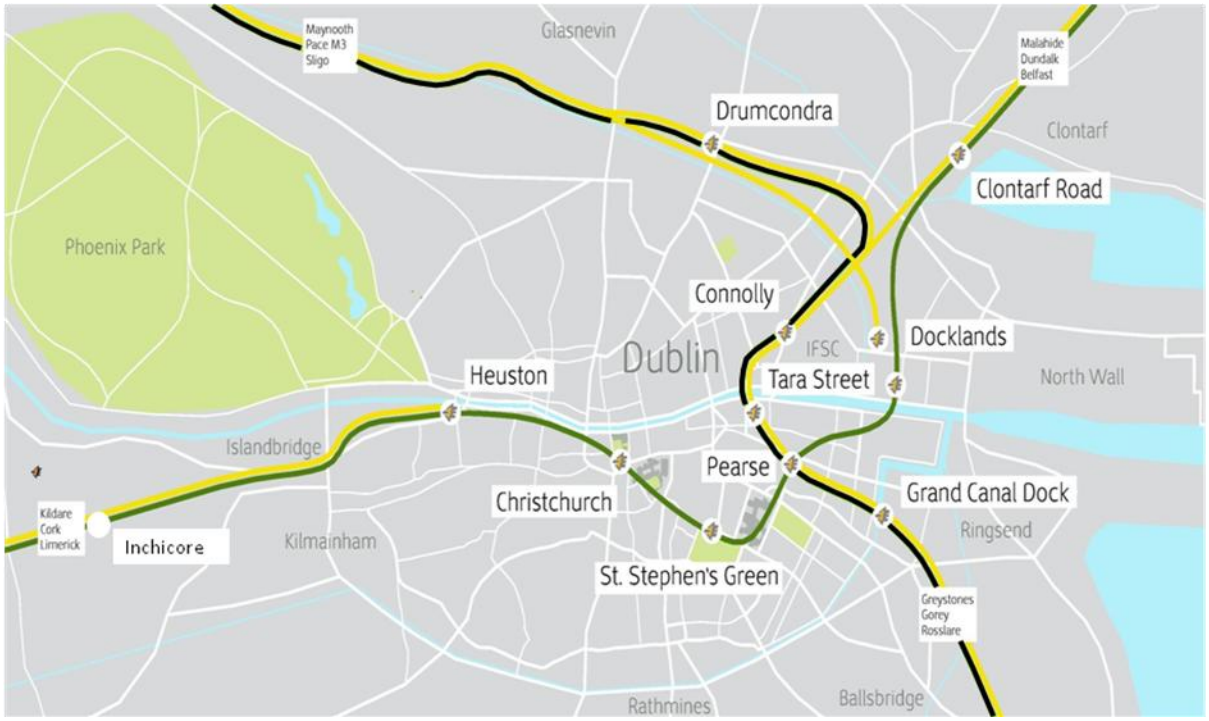
DART Underground Business Case

Executive Summary

The DART Underground project will produce a step change in rail efficiency, accessibility and quality within the Greater Dublin Area (GDA). The project comprises a 7.5km tunnel linking the Northern line to the Heuston mainline with new underground stations at Docklands, Pearse, St Stephens Green, Christchurch and Heuston and a surface station at Inchicore.

The operational and accessibility improvements enabled by the tunnel are maximised not just by through running between the Northern and Kildare lines but also between the Maynooth and South Eastern DART lines via the existing Loop Line Bridge. The tunnel enables a major improvement in accessibility across much of GDA by unlocking the potential of the existing rail infrastructure.



Improved rail access and relief of capacity constraints to the centre of Dublin are crucial to the city's future growth and prosperity. DART Underground (DU) provides an efficient and environmentally sustainable alternative to road transport and the capacity to enable growth within an otherwise constrained city centre.

DART Underground is consistent with local, national and regional plans and strategies. Transport 21 describes it as a vital backbone of the future transport system, Platform for Change as the centre-piece of the suburban rail strategy.

Benefits

The benefits fall into two broad categories: the transport benefits and the Wider Economic Benefits.

Transport Benefits

DART Underground will improve travel in Dublin by:

- Reducing the need to interchange by providing direct routes for many trips whilst at the same time providing new interchange opportunities, linking the disparate rail lines into a network;
- Providing additional capacity, thereby reducing crowding, improving journey quality and enabling new development, especially in the Central Business District (CBD);
- Enabling higher frequencies and improved reliability; and
- Switching trips from car to rail thereby speeding up remaining road traffic.

The transport benefits are derived from NTA (National Transport Authority) modelling of the DART Underground scheme using their multi-modal transport model. The results are based on a cautious planning scenario which takes account of the impact of the current downturn and assumes a permanent fall in central Dublin employment.

The transport benefits have thus been quantified by the NTA model and then valued in line with Department of Transport guidance. The guidance describes values of time for road, rail and bus users and values for accidents, vehicle operating costs and other relevant issues. The benefits are produced for three forecast years 2016, 2020 and 2030. Benefits continue post 2030 but no further growth has been assumed.

Wider Economic Benefits

The economic benefits from railways extend well beyond time savings to users. The approach to valuing Wider Economic Benefits (WEBs) is now established within UK transport appraisal guidance. WEBs are based on the links between density and productivity. Employers like to cluster together, and transport infrastructure can raise overall productivity by enabling increased densities (largely through relief of capacity constraints) and by improving accessibility between existing employment clusters.

DART Underground not only provides additional capacity to central Dublin, it also links the central area together, especially the two major growth poles at Heuston and Docklands. Increasing the effectiveness of the CBD by improving accessibility within it is a key role for DART Underground.

WEBs have been valued in accordance with UK guidance, given that there is no Irish guidance as yet. The analysis suggests that DART Underground would increase GDP by ***[text deleted]*** (as a Present Value) of which ***[text deleted]*** would be compatible with the transport user benefits and could in theory be added to them in an economic appraisal.

Comparing costs and benefits

On a traditional transport appraisal, the scheme has a Net Present Value (NPV) of ***[text deleted]*** with a Benefit/Cost Ratio (BCR) of 2.4 – this indicates a high value for money. If we include WEBs then the case looks even better, with the NPV increasing to ***[text deleted]*** and the BCR becoming 4.0.

Financial issues

This is an economic assessment and has not considered funding of the scheme. The analysis suggests however that DART Underground, would be likely to break even in operating terms (comparing the additional annual operating and maintenance costs associated with DART Underground to the net increase in revenue).

Conclusions

The economic case for DART Underground is strong. The BCR is high, robust to a series of sensitivity tests and even to a combination of downside sensitivity tests. The Wider Economic Benefits of DART Underground are particularly high; this scheme is critical to the future economic growth of Dublin.

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The DART Underground project will produce a step change in rail efficiency, accessibility and quality within the Greater Dublin Area (GDA). The project comprises a 7.5km tunnel linking the Northern line to the Heuston mainline with new underground stations at Docklands, Pearse, St Stephens Green, Christchurch and Heuston and a surface station at Inchicore. It includes a range of other improvements including electrification of surrounding routes and expansion of rolling stock and stabling facilities.

The operational and accessibility improvements enabled by the tunnel are maximised not just by through running between the Northern and Kildare lines but also between the Maynooth and SE DART lines via the existing Loop Line Bridge. The tunnel enables a major improvement in accessibility across much of GDA by unlocking the potential of the existing rail infrastructure.

Improved rail access and relief of capacity constraints to the centre of Dublin are crucial to the city's future growth and prosperity. DART Underground (DU) provides an efficient and environmentally sustainable alternative to road transport and the capacity to enable growth within an otherwise constrained city centre.

DART Underground is consistent with local, national and regional plans and strategies. Transport 21 describes it as a vital backbone of the future transport system, Platform for Change as the centre-piece of the suburban rail strategy.

Costs

Major rail schemes are expensive. The costs of implementing the DART Underground programme are ***[text deleted]*** in current prices, or ***[text deleted]*** as a Present Value (PV). The capital costs cover:

- The stations;
- The tunnel; and
- The signalling, power, rolling stock and other equipment needed to run trains.

In addition there will be the operating, maintenance and renewal costs associated with running the services and maintaining the infrastructure. Those equate to a PV of ***[text deleted]*** over a 60 year appraisal period, in 2009 prices. The costs are summarised in Table S 1. It is intended that the central tunnel element of DART Underground is procured through a PPP arrangement.

Table S 1: Costs of DART Underground

	€bn, 2009 prices
Capital costs	***[Figures Deleted]***
Operating costs	
Maintenance and renewals	
Total	

Benefits

The benefits fall into three broad categories: the transport benefits, the Wider Economic Benefits and the broader policy objectives.

Transport Benefits

DART Underground will improve travel in Dublin by:

- Reducing the need to interchange by providing direct routes for many trips whilst at the same time providing new interchange opportunities, linking the disparate rail lines into a network;

- Providing additional capacity, thereby reducing crowding, improving journey quality and enabling new development, especially in the CBD;
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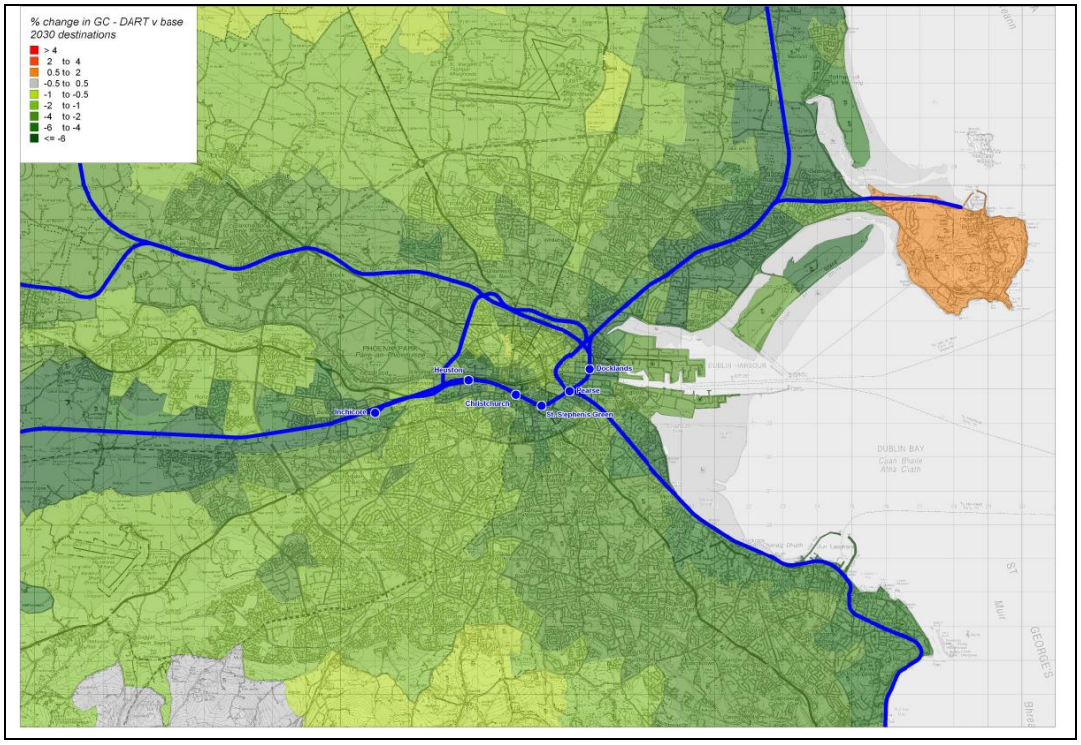
The transport benefits have thus been quantified by the NTA model and then valued in line with Department of Transport guidance. The guidance describes values of time for road, rail and bus users and values for accidents, vehicle operating costs and other relevant issues. The benefits are produced for three forecast years 2016, 2020 and 2030 with the scheme opening in 2019. Benefits continue post 2030 but no further growth has been assumed.

Figure S 1 shows how the generalised costs of travel by public transport in the Dublin area change as a result of DART Underground. There is a benefit to all areas (bar Howth which loses its direct rail service), with a higher impact for areas around the commuter rail lines. Interchange opportunities with both rail and bus services enable much greater spread of the benefits.

Figure S 1: Changes to public transport generalised costs as a result of DART Underground by destination zone, 2030, Dublin area



The values of the user benefits are summarised in Table S 2. These total some ***[text deleted]***, well in excess of scheme costs.

Table S 2: DART Transport benefits

	PV, €bn, 2009 prices
User benefits	
Public transport time savings	***[Figures Deleted***
Public transport congestion relief	
Highway congestion relief	
Vehicle operating costs	
Other benefits	
Accidents & emissions	
TOTAL TRANSPORT BENEFITS	

Wider Economic Benefits

The economic benefits from railways extend well beyond time savings to users. The approach to valuing Wider Economic Benefits (WEBs) is now established within UK transport appraisal guidance. WEBs are based on the links between density and productivity. Employers like to cluster together, and transport infrastructure can raise overall productivity by enabling increased densities (largely through relief of capacity constraints) and by improving accessibility between existing employment clusters.

DART Underground not only provides additional capacity to central Dublin, it also links the central area together, especially the two major growth poles at Heuston and Docklands. Increasing the effectiveness of the CBD by improving accessibility within it is a key role for DART Underground.

WEBs have been valued in accordance with UK guidance, given that there is no Irish guidance as yet. The analysis suggests that DART Underground would increase GDP by ***[text deleted]*** (as a Present Value) of which ***[text deleted]*** would be compatible with the transport user benefits and could in theory be added to them in an economic appraisal. The WEBs are summarised in Table S 3.

Table S 3: Wider Economic Benefits of DART Underground

	PV, €bn, 2009 prices
Pure agglomeration	***[Figures Deleted***
Move to more productive jobs	
Imperfect competition & labour force participation	
Total WEBs	

Broader Policy Objectives

There are other beneficial impacts of the proposal. These include:

- Social Inclusion – DU will bring specific benefits to the mobility impaired, non car owners and low income groups;
- Environment – DU will increase sustainable transport and promote sustainable development patterns. By 2030 the scheme is expected to lead to 38,000 additional boardings on DART and suburban rail during the morning peak period, with a reduction in highway kilometres of 25,000, relative to the without-DU scenario; and
- Integration – DU integrates the transport network, improves the viability of other public transport schemes through better interchange and integrates transport and land use policies.

Comparing costs and benefits

On a traditional transport appraisal, the scheme has a Net Present Value (NPV) of ***[text deleted]*** with a Benefit/Cost Ratio (BCR) of 2.4 – this indicates a high value for money. If we include WEBs then the

case looks even better, with the NPV increasing to ***[text deleted]*** and the BCR becoming 4.0. Those results are shown in Table S 4.

Table S 4: Transport / wider economic benefits and costs of DART Underground

	PV, €bn, 2009 prices	
	Exclude WEBs	Include WEBs
Total transport benefits	***[Figures Deleted***	***[Figures Deleted***
Total Wider Economic Benefits		
TOTAL BENEFITS		
TOTAL COSTS		
NET PRESENT VALUE		
BENEFIT / COST RATIO	**2.4**	**4.0**
INTERNAL RATE OF RETURN	9.5%	13.5%

The results above are for the 'moderate growth' NTA model results based on CSO forecasts, assuming the scheme opens in 2019 and with a 60 year appraisal period. A number of sensitivity tests have also been produced:

- Using 'no growth' and 'high growth' model runs;
- Assuming a two year delay to the scheme, with total construction costs increasing by 25%;
- Using a 30 year appraisal period; and
- A 'most pessimistic' scenario combining the downside sensitivity tests.

The results of those tests are summarised in Table S 5.

Table S 5: Sensitivity test results (excluding WEBs)

Test	Net PV €bn, 2009 prices	Benefit/Cost Ratio
Base (moderate growth)	***[Figures Deleted***	2.4
No growth		1.7
High growth		3.2
Scheme delay		2.2
30 year appraisal		1.7
Most pessimistic		1.1

Table S 5 shows that even in the most pessimistic scenario examined the BCR is 1.1, meaning that the benefits still outweigh the costs. This is very encouraging as it suggests that the case for the scheme is robust.

Financial issues

This is an economic assessment and has not considered funding of the scheme. The analysis suggests, however, that DART Underground would be likely to break even in operating terms (comparing the additional annual operating and maintenance costs associated with DART Underground to the net increase in revenue).

Conclusions

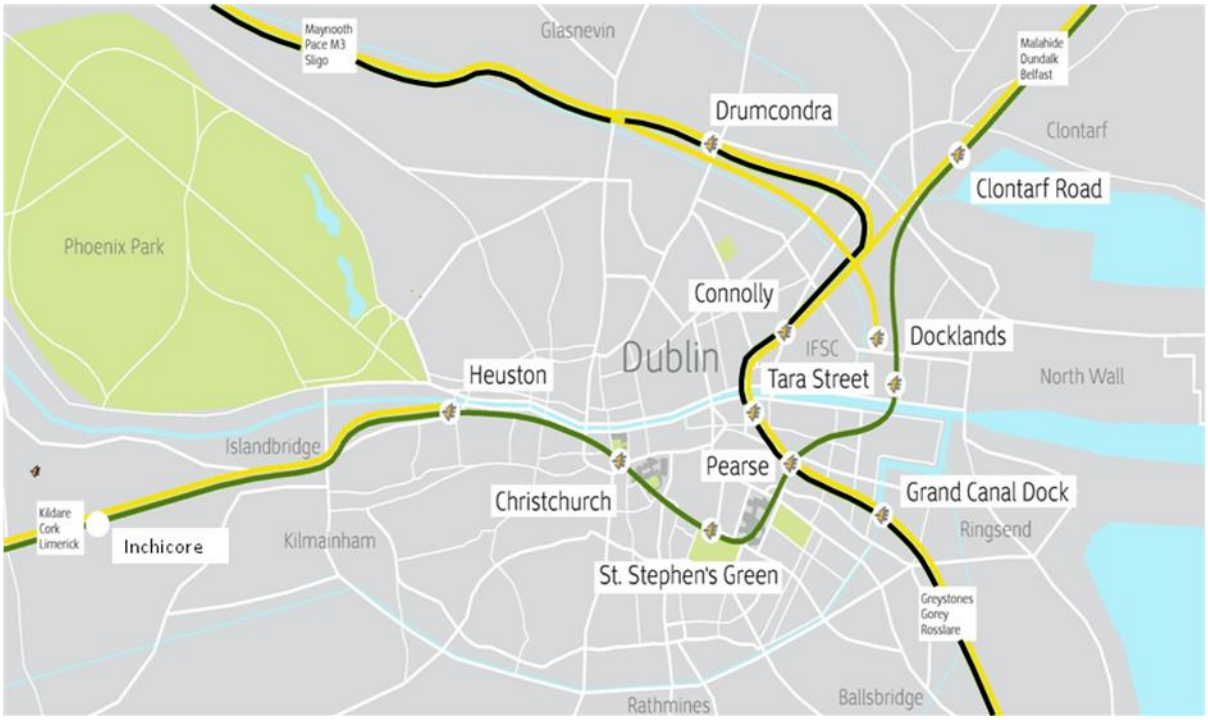
The economic case for DART Underground is strong. The BCR is high, robust to a series of sensitivity tests and even to a combination of downside sensitivity tests. The Wider Economic Benefits of DART Underground are particularly high; this scheme is critical to the future economic growth of Dublin.

1 Introduction

1.1.1 Colin Buchanan (CB) was commissioned by Iarnród Éireann (IE) to produce an updated business case for DART Underground.

1.1.2 DART Underground is a proposed 7.5km twin bore tunnel for electrified heavy rail in Dublin city centre, linking the Northern line to the Heuston Main line. It will serve five new underground stations in the city centre at Docklands, Pearse, St Stephens Green, Christchurch and Heuston, and a new surface station at Inchicore, as shown in Figure 1.1 below. The project also includes a number of other improvements including track electrification and expansion of the rail fleet.

Figure 1.1: DART Underground tunnel



Source: Iarnród Éireann

1.1.3 Since 2000, IE has delivered a number of improvements to the Dublin commuter belt rail network. These include:

- Expansion of the capacity of the DART system to accommodate eight car operations, in line with peak demand, including the doubling of the DART fleet size and the refurbishment of the original fleet which dates back to 1984;
- Expansion of the diesel rail car fleet from 44 to 180 to facilitate the retirement of life expired InterCity carriages from the commuter business and to provide for significant additional service capacity on each of the four lines;
- Acquisition of an ICR fleet, part of which will be used to deliver outer commuter services to Dundalk, Longford, Athlone, Portlaoise, Carlow and Gorey;
- Introduction of a new Clonsilla – Docklands service, which will be extended to Navan on a phased basis in due course. Phase 1 to Pace, including a major park and ride facility, will be operational from late 2010;
- Four tracking of a critical section of the Kildare line between Cherry Orchard and Hazelhatch;
- New commuter stations at Adamstown, Park West, Fonthill and Phoenix Park;

- Improved station facilities including accessibility arrangements all along the DART, the expansion of the real time passenger information system and additional car parking facilities;
- Provision of ticket vending machines, the introduction of a smart card and the roll out of the initial phases of exit validation, at high passenger volume stations, as an effective revenue control measure; and
- The resignalling of the Northern line between Malahide and Grand Canal Dock is currently being delivered on a phased basis and is due for completion by 2012.

1.1.4 The DART Underground scheme being appraised in this report will enable commuter rail services to be run between the Northern and Kildare lines via the tunnel, whilst also allowing the through running of services between the Maynooth and SE DART lines via the existing Loop Line Bridge, using Pearse Station as a major interchange hub between those rail corridors.

1.1.5 In addition, the new stations will provide new interchange opportunities, including:

- Docklands station: connects with the Red Luas line and provides easy interchange with Dunboyne / Navan services operating from the existing surface station at Docklands;
- Pearse station: interchange with the Northern line and Maynooth line commuter services will be facilitated;
- St Stephen's Green station: connects with the Green Luas and Metro to the airport;
- Christ Church station: connects to Luas Line F; and
- Heuston station: links with Red Luas and Iarnród Éireann's Intercity and Commuter services.

1.1.6 This report sets out the costs and benefits of DART Underground. It presents the results of the analysis that has been undertaken and provides an assessment of the business case for the scheme. The business case has been produced in line with the guidance set out in *Guidelines on a Common Appraisal Framework for Transport Projects and Programmes* (Department of Transport, June 2009).

1.1.7 The rest of the report is structured as follows:

- Chapter 2: Background to the scheme and the work that has been undertaken leading to this business case
- Chapter 3: Transport benefits of the scheme
- Chapter 4: Wider benefits of the scheme
- Chapter 5: Costs
- Chapter 6: Overall business case of the scheme
- Chapter 7: Conclusions

1.1.8 The Appendix provides details on the assumptions that have been used in the scheme appraisal, and a history of the scheme.

2 Background

2.1 Definition of scenarios

2.1.1 It is important from the outset to be clear about what is being assessed in the business case. The benefits and costs that are presented in the results in later chapters of this report are those that are associated with the infrastructure included in the 'Do Something' (DS) scenario, incremental to benefits and costs associated with infrastructure in the 'Do Minimum' (DM) scenario.

Do Minimum

2.1.2 The Do Minimum programme contains projects that are already committed, and others that could go ahead to provide additional capacity without DART Underground. These include:

- Phase I of the Kildare route project which will be delivered in early 2010;
- The introduction of commuter services to Dunboyne, which will be achieved by the end of 2010;
- Resignalling of the Northern line through the city centre to Grand Canal Dock (GCD), including turn back facilities in north Dublin and at GCD;
- Resignalling of the Maynooth line, and elimination of level crossings; and
- Provision for additional fleet and depot / stabling facilities. This is necessary in order to deliver the additional services associated with the extra train paths, bearing in mind the limitations that will still exist in the city centre in terms of getting trains from the Northern and Maynooth lines into and through Connolly station.

2.1.3 These projects need to be supported by a new modern CTC facility and the roll out of GSM-R in the Dublin commuter belt. Essentially the Do Minimum programme is aimed at maximising the capacity of the network in advance of the DART Underground and electrification.

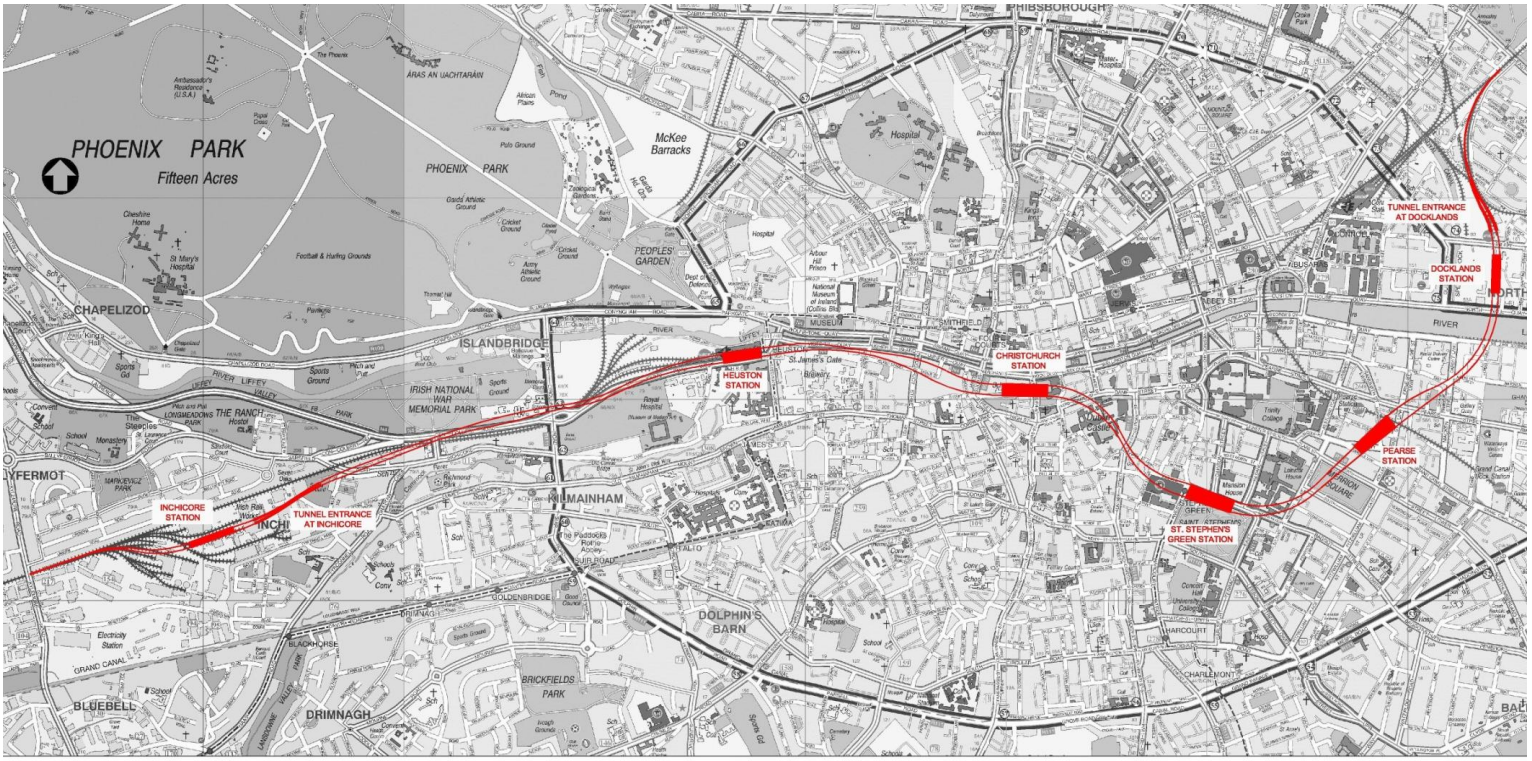
Do Something

2.1.4 The Do Something programme builds on the Do Minimum programme and maximises the capacity of the network by eliminating service conflict in the city centre. Included in the DS are the following elements:

- The DU tunnel between Inchicore and Docklands, as shown in Figure 2.1 below;
- New underground stations at Docklands, Pearse, St Stephens Green, Christchurch and Heuston and surface station at Inchicore;
- Twinning of the Northern line with the South West corridor via the DU;
- Twinning of the Maynooth line with the SE DART line via the existing Loop Line Bridge;
- Completion of four tracking between Inchicore and Cherry Orchard;
- Electrification of the route to Hazelhatch;
- Electrification of the Maynooth line;
- Extension of electrification from Malahide to Drogheda, including immunisation of the signalling system;
- Turn back facilities at Inchicore, Clongriffin and Balbriggan to facilitate short running of services between the Northern and South West corridors in line with demand; and
- Further expansion of the fleet and stabling facilities (phase 2) to cater for the higher level of service.

2.1.5 Throughout this report, unless otherwise stated the term 'DART Underground' is taken to mean the full package of additional infrastructure outlined above.

Figure 2.1: DART Underground tunnel



2.2 Need for the project

2.2.1 The proposed DART Underground programme is the key element of the NTA 'A Platform for Change' strategy and the Government's Transport 21 investment programme in terms of achieving a sustainable balance between the public and private transport modes for the Greater Dublin Area (GDA) and in the context of an increasing population base. The GDA incorporates the four Dublin local authorities and surrounding counties Wicklow, Kildare and Meath. This area has experienced rapid population growth since the mid 1990s.

2.2.2 The need for DART Underground must be looked at from the perspective of:

- Operational improvements;
- Enabling growth; and
- Quality and sustainability.

Operational Improvements

2.2.3 Dublin suffers from a common problem whereby rail lines terminate on the edge of the city centre rather than linking though the centre itself. That imposes operational capacity constraints and forces many rail users to interchange to reach their destination. Currently a wide range of services compete for rail access into and through Connolly Station. These include:

- DART services (from Malahide and Howth);
- Maynooth line suburban services;
- Outer commuter services from the Northern, Maynooth and South Eastern lines; and
- Intercity services from Belfast and Sligo.

2.2.4 DART Underground is the missing link in the system. Without it there are a number of major constraints for InterCity, regional and commuter services since all three service

types compete for limited city centre capacity, particularly during the critical peak periods. DART Underground transforms the Dublin rail network from a series of individual lines into a network.

2.2.5 The DART Underground programme will facilitate the through running of services between two grade separated corridors, thus significantly increasing the central area capacity by bypassing the capacity constraints through Connolly and over the Loop Line Bridge. Access through Connolly Station has been the key bottleneck, particularly over the last decade, as the demand for rail services increased rapidly. DART Underground effectively allows the existing DART infrastructure to be used more intensively making the most of existing assets.

2.2.6 The two grade separated corridors post DART Underground operation will be:-

1. Maynooth – Bray / Greystones via the Loop Line Bridge; and

2. Drogheda – Hazelhatch, via DART Underground, including short running to facilitate a cost effective match of service capacity with passenger demand.

2.2.7 Apart from additional system capacity over a more cohesive network, the other key operational benefits associated with the DART Underground will include:

- More efficient rolling stock allocation / scheduling between the routes;
- Greater ability to deliver even interval 'clockface' timetables for all services; and
- Greater ability to deliver peak hour InterCity service arrivals in Connolly Station from both the Belfast and Sligo lines.

2.2.8 The gains are widespread and many are not captured in the model outputs. Thus for example we know that passengers value the simplicity/predictability of regular clockface timetables, but have not assigned any benefits to that. Similarly the ability to increase peak hour arrivals of long distance services will bring benefits to rail users but has not been quantified within the modelling work.

Enabling Growth

2.2.9 DART Underground is not just about serving the existing needs of Dublin; it is also about enabling future growth in both population and employment. While there may be short term economic difficulties in Ireland, recessions are cyclical and followed by periods of growth. It should be noted that the DART Underground programme will have multi-generational benefits spanning the 21st century. The case for the programme must be viewed in this context.

2.2.10 There are unlikely to be absolute constraints on growth in Dublin, but DART Underground will assist in promoting:

- City centre employment growth with the agglomeration benefits that derive from that as well as the high public transport mode share; and
- Population growth along the rail corridors.

Population and employment growth

2.2.11 Over the period 1996 to 2006, Ireland experienced record population growth and immigration. This resulted in an increased labour force and demand for housing and travel.

2.2.12 As a result the GDA has experienced rapid population growth over the inter-censal period 1996-2006 (+18.2%). The population of the GDA as of 2006 was 1.7m, accounting for approximately 40% of the national population.

2.2.13 The projections of population and employment that have fed into the business case are shown in Table 2.1 and Table 2.2. These are based on a 'moderate' growth scenario from

the NTA so as to not over exaggerate the case for the scheme. The forecasts assume a large fall in central Dublin employment and slow subsequent growth such that the 2007 totals are not reached over the 60 year appraisal period. That seems a highly cautious assumption. Scenarios of 'no growth' and 'high growth' have also been modelled and are included as a sensitivity test in chapter 7.

Table 2.1: Population assumptions used in NTA modelling

	2007	2016	2020	2030
CBD (Central Business District)	123,614	132,753	137,218	147,017
RoCC	391,389	397,984	405,754	422,804
DLRD	249,897	205,002	212,504	228,986
Fingal	198,081	238,480	245,293	260,262
S Dublin	252,357	271,782	286,849	319,934
M East	487,843	585,000	620,207	697,398
Total	1,703,181	1,831,001	1,907,825	2,076,401

Table 2.2: Employment assumptions used in NTA modelling

	2007	2016	2020	2030
CBD	263,871	224,986	231,120	243,023
RoCC	170,730	178,352	183,209	192,649
DLRD	80,454	94,566	97,146	102,143
Fingal	85,736	112,840	115,921	121,889
S Dublin	107,256	128,559	132,060	138,860
Mid East	141,586	176,810	181,628	190,978
Total	849,633	916,113	941,084	989,542

2.2.14 DART Underground is the key to delivering the population and employment growth forecast. It serves the main corridors of population growth and links them to the main city centre areas of employment growth. Without the increase in capacity provided by DART Underground the city centre growth will be constrained and without the accessibility and capacity from DART Underground the population growth will not be achievable.

2.2.15 It should be noted that the latest NTA model scenario assumes a permanent reduction in CBD employment, although employment grows in all other areas. The economic benefits described in subsequent chapters allow for this forecast decline and are lower than they would otherwise be. DART Underground would be expected to deliver more CBD employment growth by increasing both accessibility and capacity.

Wider national policies

2.2.16 The development of the DART Underground programme is compatible with a number of key EU, National and Regional policies including:

- Sustainable Development – A Strategy for Ireland (1997)
- DTO Strategy – A Platform for Change (2001)
- National Spatial Strategy (2002)
- The Strategic Rail Review (2003)
- Draft Regional Planning Guidelines for the GDA, 2010-22
- Transport 21 (2005)
- National Development Plan 2007 – 2013 (2007)
- EU Green Paper: Towards a new culture for urban mobility (2007)
- Ireland National Climate Change Strategy 2007-12 (2007)
- Ireland Energy Policy Framework 2007 - 2020
- Smarter Travel: A Sustainable Transport Future 2009 – 2020

2.2.17 There is strong support for the scheme from a range of organisations, including Dublin City Council. The scheme is critical in supporting future land use and transportation policy across a range of key measures including:

- Core Strategy
- Movement
- Building Height
- Cultural Hubs
- Regional Economic Strategy
- Retail Strategy

2.2.18 The following figures, sourced from the Draft Dublin City Development Plan, help to demonstrate DART Underground's role in supporting those policies.

Figure 2.2: Dublin Core Strategy

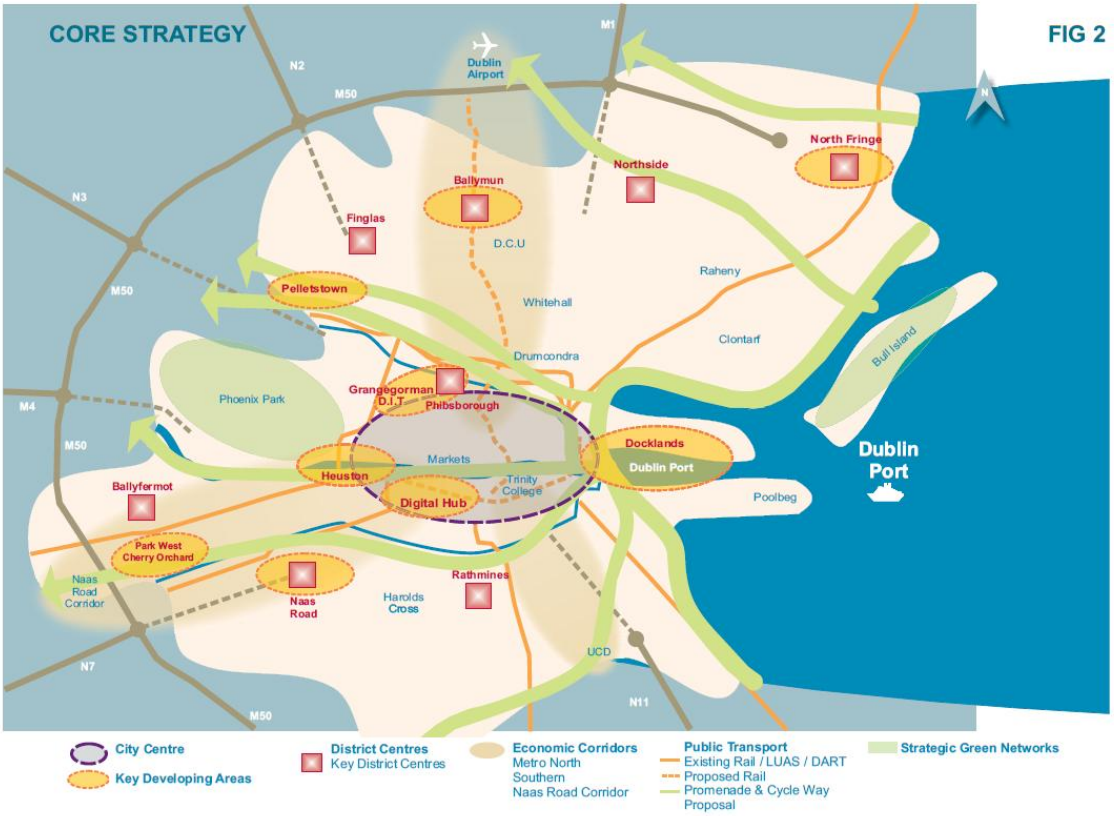


Figure 2.3: Movement – interchange opportunities with DART Underground

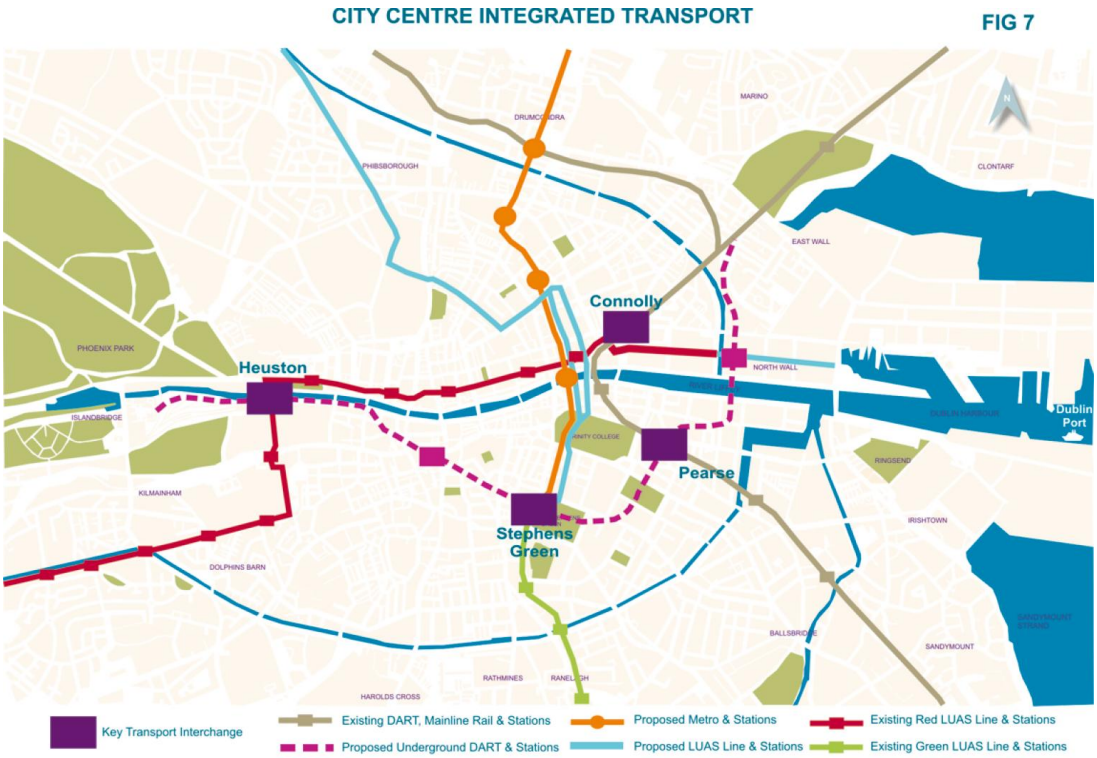


Figure 2.4: Building Height in Dublin

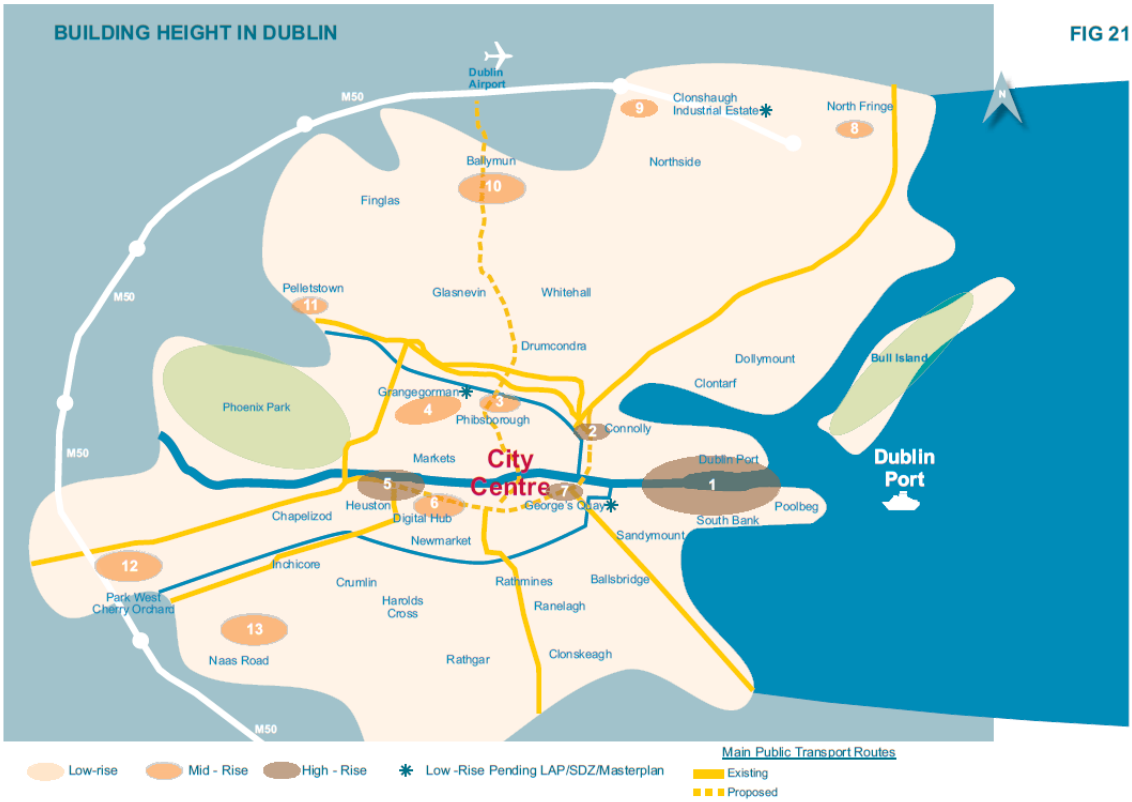


Figure 2.5: Main cultural quarters in Dublin

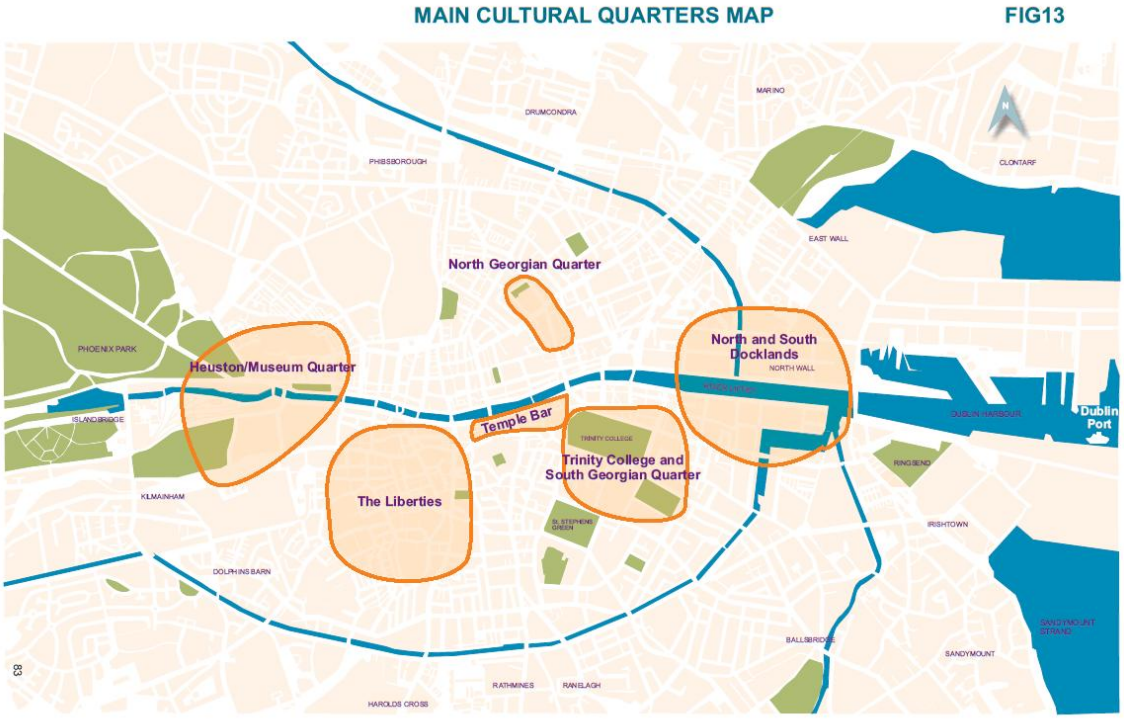


Figure 2.6: Dublin Region Economic Strategy

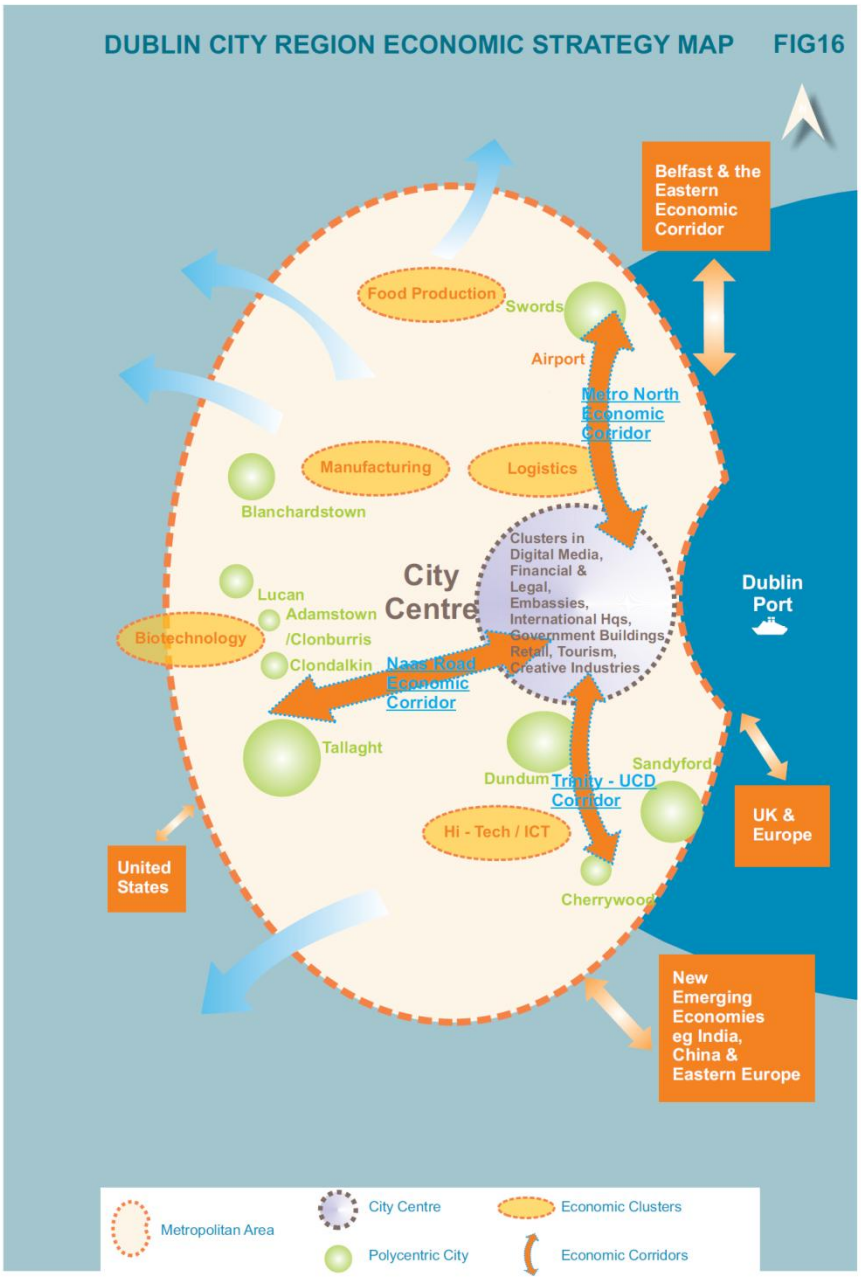


Figure 2.7: Dublin Retail Strategy

Quality and Sustainability

2.2.19 DART Underground is the missing link in the Dublin commuter rail network. In its absence the carrying capacity of the network is severely curtailed and there is relatively poor access to the city centre for many rail users and would-be rail users due to current constraints, including the relative isolation of Heuston Station from the Central Business District and the capacity limitations over the Loop Line Bridge, particularly from the Maynooth Corridor.

2.2.20 While these issues will be partially addressed by the priority resignalling of the Northern and Maynooth lines through the City Centre, the full DART Underground programme is required to deliver the service frequency, capacity and quality required for the 21st century.

2.2.21 In particular from a customer service perspective the DART Underground programme will deliver:

- Increased and more regular service frequencies throughout the day but particularly during the critical peak periods;
- Better integration with other modes and rail lines giving a more cohesive network of public transport services throughout the GDA;
- Better access to the city centre and between suburbs. Nearly all major population centres within a 100km radius of Dublin will have much improved rail access to the capital, and in particular to the Central Business District. DART Underground will promote sustainable development; and
- Greater choice and a real alternative to the private car.

2.2.22 The development of the Dublin commuter rail network of services as proposed, centred on DART Underground, can also be expected to make a major contribution to national, regional and local policies including:

- Facilitating the delivery of more sustainable land use development strategies including higher density, less car dependent developments. There has been a failure in the past to maximise the development potential of key public transport corridors / interchange points. The development of Strategic Development Zone (SDZ) land on rail corridors (eg Adamstown and Hansfield) is a major positive change in this respect.
- A better public transport system will help Ireland to achieve the required 20% reduction in its CO_2 output when compared to 2005, moving towards a return to 1990 levels.
- Reducing dependency on oil, which is a finite energy resource, in favour of renewable energy options through electrification of the high density section of the commuter rail network.
- Facilitating closer integration between the public transport modes, thus improving accessibility, mobility and social inclusion.
- Offering a real alternative to the private car, thus facilitating greater choice and the opportunity to implement much needed demand management measures required to achieve a more sustainable balance between the modes. The most recent Government 'Smarter Travel' policy guideline has a core objective of reducing the modal share of car based commuting from 65% to 45% by 2020. This will require ambitious investment in public transport and particularly rail schemes like the DART Underground programme which will deliver major benefits across the rail network and unlock bottlenecks which currently restrict access to the city centre by providing direct, convenient and high frequency rail services to the key destination areas of the city centre.

2.3 Previous business case

2.3.1 The initial business case[1] for DART Underground was published in March 2008. It provided details on how the preferred alignment was selected from a number of options, the service levels and associated demand projections, costs of the scheme and an economic evaluation.

2.3.2 The business case indicated that the Net Present Value of the scheme is just under ***[text deleted]***, with a BCR of 1.33:1 and Internal Rate of Return (IRR) of 6.4%. A range of sensitivity tests indicated that even under more pessimistic scenarios, the benefits would outweigh the costs.

2.3.3 The business case was subsequently audited[2]. Overall the audit report concluded that the approach to the cost-benefit analysis was sound, but it highlighted a number of issues to address, including:

- The approach to estimating time savings was seen to be weak and contained errors, including a failure to take account of the 'rule of half' for benefits to new passengers;
- Congestion relief benefits were based on data taken from estimates for other schemes rather than modelling of impacts for DART Underground;
- The range of sensitivity tests needed to be expanded to include the effect of lower time savings for rail travellers and congestion relief benefits for road users; and
- An estimate of the wider benefits of the scheme should be prepared, as these could be significant.

2.3.4 Subsequent work has been undertaken to address those issues. This is discussed further in the Appendix. Perhaps most significantly, an estimate has now been made of the

[1] Iarnród Éireann (March 2008), *Dublin DART Interconnector – Business Case*
[2] Goodbody Economic Consultants (July 2008), *Dublin Dart InterConnector – Audit of the Business Case*

WEBs of DART Underground, based on guidance recommended by the UK Department for Transport. This is presented in chapter 4.

2.4 Development of the scheme

2.4.1 In accordance with the Transport (Railway Infrastructure) Act 2001 (as amended), Córas Iompair Éireann (CIE), on behalf of Iarnród Éireann will seek to secure a Railway Order from An Bord Pleanala. The Railway Order is essentially the planning permission required to legally progress the DART Underground process to a stage whereby a PPP Contract for the Design, Building, Finance and Operate of the DART Underground can be tendered.

2.4.2 The Railway Order process is dictated by statutory requirements. Iarnród Éireann undertakes a reference design for the DART Underground. Based on this reference design the following documentation is prepared and lodged with An Bord Pleanala:

1. Book of Reference, comprising a draft of the DART Underground Railway Order and associated schedules that outline the works requirements, the land acquisition requirements and other ancillary requirements;

2. A Plan of the Proposed Works, comprising a set of drawings showing the extent of the works;

3. An Environmental Impact Statement, consisting of an assessment of the impact of the works during construction and operation on the surrounding environment, including impacts on humans; and

4. Ancillary details outlining the extent of notification of statutory and interested bodies and the public.

2.4.3 This information is provided to An Bord Pleanala for assessment. The general public will be provided with a six week timeframe to make submissions or observations on the application. It is the objective of An Bord Pleanala to deal with the application in an expeditious manner, with a target of reaching a decision within a 24 week period following lodgement. During this period an Oral Hearing will be convened to provide a forum for exchange of information between Iarnród Éireann and An Bord Pleanala and the public and An Bord Pleanala.

2.4.4 Assuming approval of the DART Underground Railway Order, the project can progress with its required statutory consent. Any conditions attached to the approval of the Railway Order will be included in the Legal DART Underground Railway Order document, together with all other agreements or understandings reached between Iarnród Éireann and third parties. These will ultimately inform the PPP tender process.

2.4.5 The delivery of many elements of the project has a relatively long lead in time. It is IE's intention to bring many of these to the planning / railway order stage over the next two years. The Railway Order application for the DU will be submitted in 2010 and funding approval will be sought this year for the planning works associated with the next phase of four tracking of the Kildare line, including electrification, and the package of measures required for the Maynooth line including resignalling and electrification, elimination of road crossings and the development of new EMU depot facilities.

2.4.6 A detailed specification has been drawn up for the new EMU fleet, which will be compatible with tunnel operations, to facilitate a Framework Agreement.

2.5 Transport modelling

2.5.1 The transport modelling results that have fed into this study were provided by the NTA. Full details can be provided separately by the NTA, but to summarise:

- The model divides Dublin into 666 zones
- Three years are modelled: 2016[3], 2020 and 2030
- Two main scenarios are modelled – the Do Minimum and Do Something scenarios as described above
- For each scenario and modelled year, three hours in the morning peak period are modelled separately (7-8, 8-9 and 9-10 AM)
- The modes that have been included are public transport, highway and soft modes (walking and cycling)

2.5.2 Matrices of demand, generalised cost and fares by zone were provided by NTA. The generalised costs take into account all aspects of journeys including in-vehicle time, wait time, interchange etc. and adjust for the different values of time between them. Details on the service patterns assumed in the Do Minimum and Do Something are provided in Appendix 1. The underlying population and employment assumptions are as shown in section 2.2.

2.5.3 Table 2.3 summarises the impacts on public transport demand as a result of DART Underground. It shows total boardings for an average morning peak period in the Do Minimum and Do Something.

2.5.4 As would be expected, there is a substantial increase (of around 55%) in DART demand. Most of this is a result of mode shift from suburban rail, Luas and bus. There is also a small amount of public transport trip generation (around 1-1.5%).

2.5.5 In terms of impacts on highway journeys, there are expected to be approximately 25,000 fewer highway kilometres travelled per morning peak period by 2030.

[3] NB the scheme is now assumed to open in 2019, and the economic appraisal takes that into account.

Table 2.3: Average public transport boardings per morning peak period

		2007	2016	2020	2030
DART	Base	30,415			
	Do Minimum		74,052	79,739	94,321
	Do Something		118,718	126,919	146,286
	DS - DM		44,666	47,180	51,966
Suburban rail	Base	55,737			
	Do Minimum		95,211	102,598	117,592
	Do Something		84,750	91,092	103,665
	DS - DM		-10,462	-11,506	-13,927
Luas	Base	25,018			
	Do Minimum		111,470	120,291	142,276
	Do Something		99,365	106,790	125,217
	DS - DM		-12,104	-13,501	-17,059
Dublin bus	Base	202,450			
	Do Minimum		171,963	177,356	192,378
	Do Something		155,144	159,591	172,937
	DS - DM		-16,819	-17,765	-19,441
Bus Eireann	Base	27,439			
	Do Minimum		23,656	24,196	25,492
	Do Something		22,441	24,090	25,218
	DS - DM		-1,215	-106	-273
Total	Base	341,058			
	Do Minimum		476,352	504,180	572,058
	Do Something		480,418	508,480	573,323
	DS - DM		4,066	4,301	1,266

2.5.6 The model results are used to estimate the transport and wider benefits; this is outlined in chapters 3 and 4.

3 Transport benefits

3.1 Introduction

3.1.1 DART Underground will bring about a number of transport-related benefits – both to transport users and society more generally. The impacts that have been included in the quantitative analysis for this study are as follows:

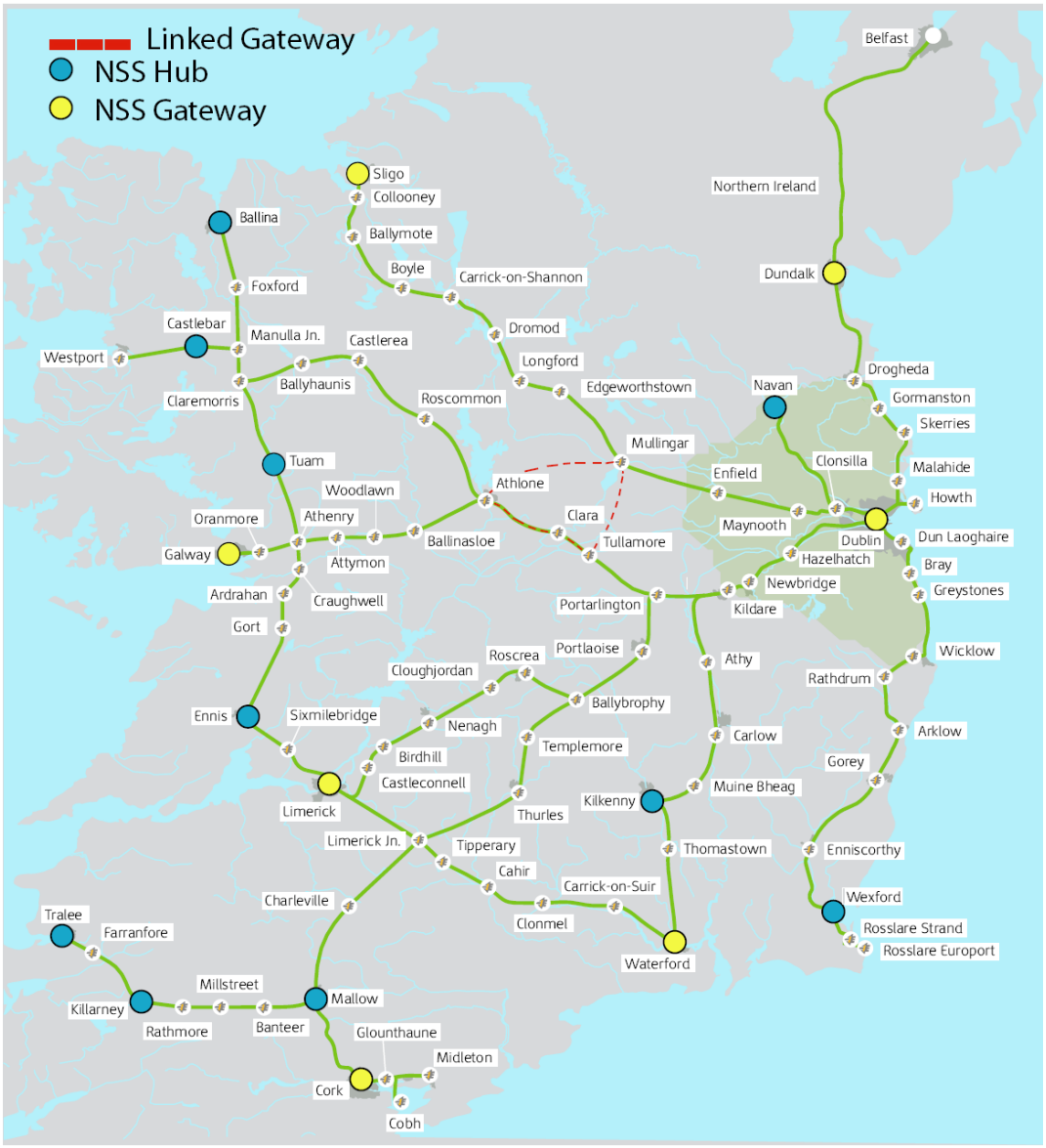
- Time savings – by improving accessibility on the rail network in Dublin, DART Underground will bring about improvements to journey times for public transport users;
- Highway congestion relief – the improvements to the public transport system will lead to a mode shift from highway to public transport. That will lead to an improvement in journey times for the remaining highway users due to the resulting congestion relief;
- Vehicle operating costs – changes to highway usage mean that there is a change to the total amount spent on fuel, oil, vehicle maintenance etc;
- Accidents – typically a reduction in highway usage leads to a reduction in road accidents, and this impact has been quantified and valued; and
- Emissions – a mode shift away from highway leads to a reduction in the emission of pollutants.

3.1.2 Section 3.2 outlines the method that has been used for quantifying and valuing those benefits. Section 3.3 presents the results. Details on the main assumptions underpinning the analysis are provided in the Appendix.

Wider Irish Rail Network Benefits

3.1.3 This business case focuses on the benefits of the DART Underground Programme within the Dublin commuter belt. It should be noted however that, given the radial nature of the InterCity network with the capital as its major focus, there will be significant network wide benefits associated with the much improved rail access to / from and through Dublin associated with the investment. In particular it is clear from Figure 3.1 that the wider rail network links all of the main Gateways and Hubs, identified in the National Spatial Strategy for concentrated growth over the coming decades, with the capital.

Figure 3.1: Wider Rail Network



3.1.4 Heuston and Connolly Stations will continue to be the main InterCity focal points in Dublin. The reconfigured DART network, associated with the DART Underground programme, will facilitate onward connections for InterCity travellers at these locations. In addition, if a decision is taken at a future date to develop a DART spur to Dublin Airport off the Northern line, there would be attractive nationwide, regional and local rail access to prime international gateways.

3.1.5 It should also be noted that Iarnród Éireann's 2030 vision for the wider rail network includes the expansion of the Dublin electrified DART rail system to a 50 km radius and the delivery of less than two hour InterCity journey times between Dublin, the four provincial cities and Belfast. These network developments will contribute significantly towards sustainable development both at regional and national levels.

3.2 Methodology

Time savings

3.2.2 The time savings are estimated by using the matrices of demand and generalised time provided by NTA. For each modelled year (2016, 2020 and 2030), demand is multiplied by generalised time in order to obtain the total generalised time between each modelled zone. The difference between the Do Minimum and Do Something scenarios is then taken – a reduction in the total generalised time in the Do Something relative to the Do Minimum indicates a benefit. Account has been taken of the 'rule of half', whereby the full time saving is applied to existing passengers but only half that value applied to new passengers.

3.2.3 Generalised time is not the same as clock time but includes additional weights placed on certain types of time. Those include waiting for trains and buses, walking whilst accessing rail or bus services and standing on crowded trains. Those weights are well established in transport planning and appraisal and represent changes to the average values of time for being in particular circumstances.

3.2.4 Once the benefit for the morning peak period has been calculated, a factor needs to be applied to convert it to a full annual total. Generalised costs for public transport have therefore been split between 'crowded' and 'uncrowded' time (ie journey time spent in crowded and uncrowded conditions), since different annualisation factors need to be applied. This is because passengers generally tend to experience crowded time during the peak periods only, so applying the same annualisation factor as that used for uncrowded time would overestimate the benefit by assuming that crowded conditions also exist during the off peak. The annualisation factor for public transport in uncrowded conditions is 1,061 (taken from the NTA modelling report). The annualisation factor for public transport crowded time is assumed to be 506 – ie the equivalent of two peak periods a day on the 253 weekdays in a year. It is (very conservatively) assumed that the annualisation factor for highway congestion relief is also 506.

3.2.5 Once the change in total minutes has been annualised, it needs to be converted into a monetary value. This has been done by applying the values suggested in Department of Transport guidance[4]. A weighted average of the 'in work time', commute and leisure values of time is obtained and the DoT recommended growth rate applied over time (see Appendix for details of growth rates).

3.2.6 The benefits between 2016 and 2020, and between 2020 and 2030, are interpolated ie straight-line growth is assumed. After 2030, demand is assumed to remain constant, thus any growth in benefits is solely a result of value of time growth.

Highway congestion relief

3.2.7 The highway congestion relief benefit is estimated in the same way as the time savings for public transport described above, with the same value of time and future growth rate applied.

Vehicle operating costs

3.2.8 There are two elements to estimating the vehicle operating cost (VOC) benefit:

- Estimate change in vehicle kilometres between Do Minimum and Do Something
- Estimate fuel and non-fuel operating costs per vehicle kilometre

3.2.9 The change in vehicle kilometres is provided as one of the outputs of the NTA model. Fuel and non-fuel operating costs per kilometre can be estimated using formulae from the

[4] Department of Transport (June 2009), *Guidelines on a Common Appraisal Framework for Transport Projects and Programmes*

DoT guidance. In those formulae the operating costs are affected by vehicle speed, so speeds from the NTA model are also required.

3.2.10 The total vehicle kilometres are then multiplied by the vehicle operating cost per kilometre. The benefit is taken as the difference between the Do Minimum and Do Something scenarios.

Accidents

3.2.11 To estimate this benefit, information is required on average accident rates (and numbers of casualties per accident). This was derived using a report[5] by the Road Safety Authority.

3.2.12 The accident / casualty rates per vehicle kilometre are then applied to the change in highway kilometres from the model to estimate changes to total accidents and casualties as a result of DART Underground. This is then valued using the Department of Transport's recommended values.

Emissions

3.2.13 Costs of emissions (split between CO_2 and non-CO_2) are provided in the DoT guidance. The change in emissions as a result of mode shift due to DART Underground can therefore be valued by applying those costs to the change in total distance travelled by highway.

3.3 Results

3.3.1 The benefits are estimated over a 60-year appraisal period (2019-78) and discounted to a Present Value. In the main text of the report we have used 2009 as the base year for prices and discounting, but Appendix 3 shows results discounted to 2002, in line with DoT guidance.

3.3.2 The DoT guidance recommends using an appraisal period of 30 years, although it allows for a longer appraisal period depending on the length of the asset life. In the case of DART that has been assumed to be 60 years, although even this is likely to be conservative. The results are presented in Table 3.1.

Table 3.1: DART Transport benefits

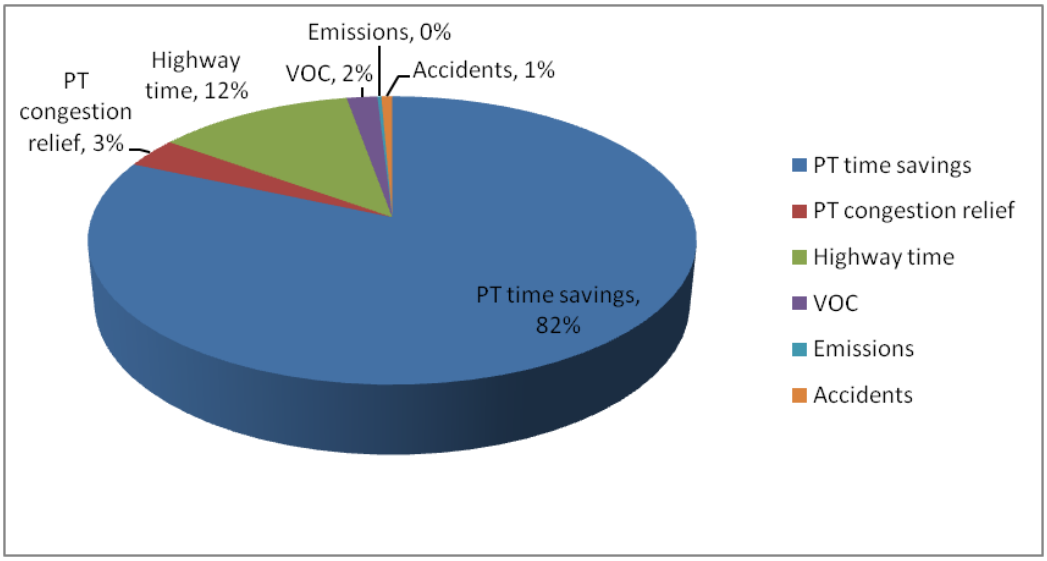
	PV, €m, 2009 prices
User benefits	
PT uncrowded time savings	***[Figures Deleted***
PT congestion relief	
Highway congestion relief	
Vehicle operating costs	
Other benefits	
Accidents	
Emissions	
TOTAL TRANSPORT BENEFITS	

NB figures may not add due to rounding.

[5] Road Safety Authority (2007), *Road Collision Facts – Ireland 2007*

3.3.3 The transport benefits are estimated as ***[text deleted]*** as a Present Value over 60 years (***[text deleted]*** if a 30 year appraisal is used). The vast majority of the benefits are comprised of time savings to public transport users (82%), as shown in Figure 3.2.

Figure 3.2: Share of benefits by category over full appraisal period



3.3.4 Figure 3.3 shows how the public transport and highway time savings accumulate over time. The benefits are assumed to build up gradually over four years. Demand growth then continues until 2030 and is assumed to be constant thereafter. The benefits continue to increase year-on-year after 2030 due to value of time growth.

Figure 3.3: Annual time savings during the appraisal period

[Table Deleted

3.3.5 Figure 3.4 shows changes to total public transport generalised costs by destination within the NTA model in 2030. Zones shaded green indicate a reduction in generalised costs as a result of DART Underground (the darker the shade, the larger the reduction).

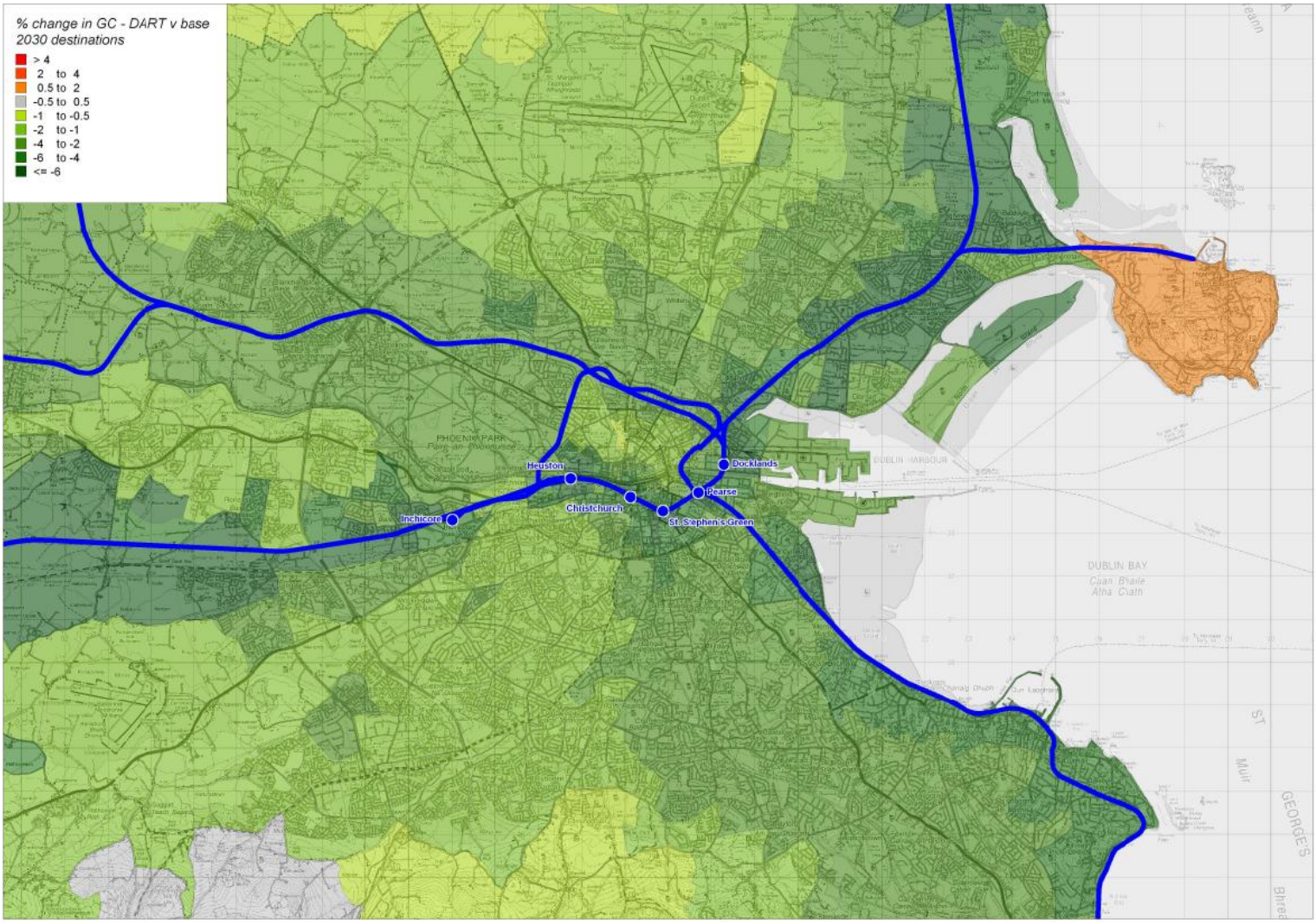
3.3.6 The largest benefits will accrue to those passengers that avoid having to interchange as a result of DART Underground. People who previously alighted at Connolly and Heuston stations to catch a bus or walk can now travel directly to one of the new stations without having to change. Time savings are also brought about by the increase in frequency /

higher train capacity resulting from DART Underground, as well as increases in speed associated with electrification.

3.3.7 It can be seen that there is a disbenefit to passengers travelling to Howth. This is because the direct service changes into a shuttle with an interchange at Howth junction.

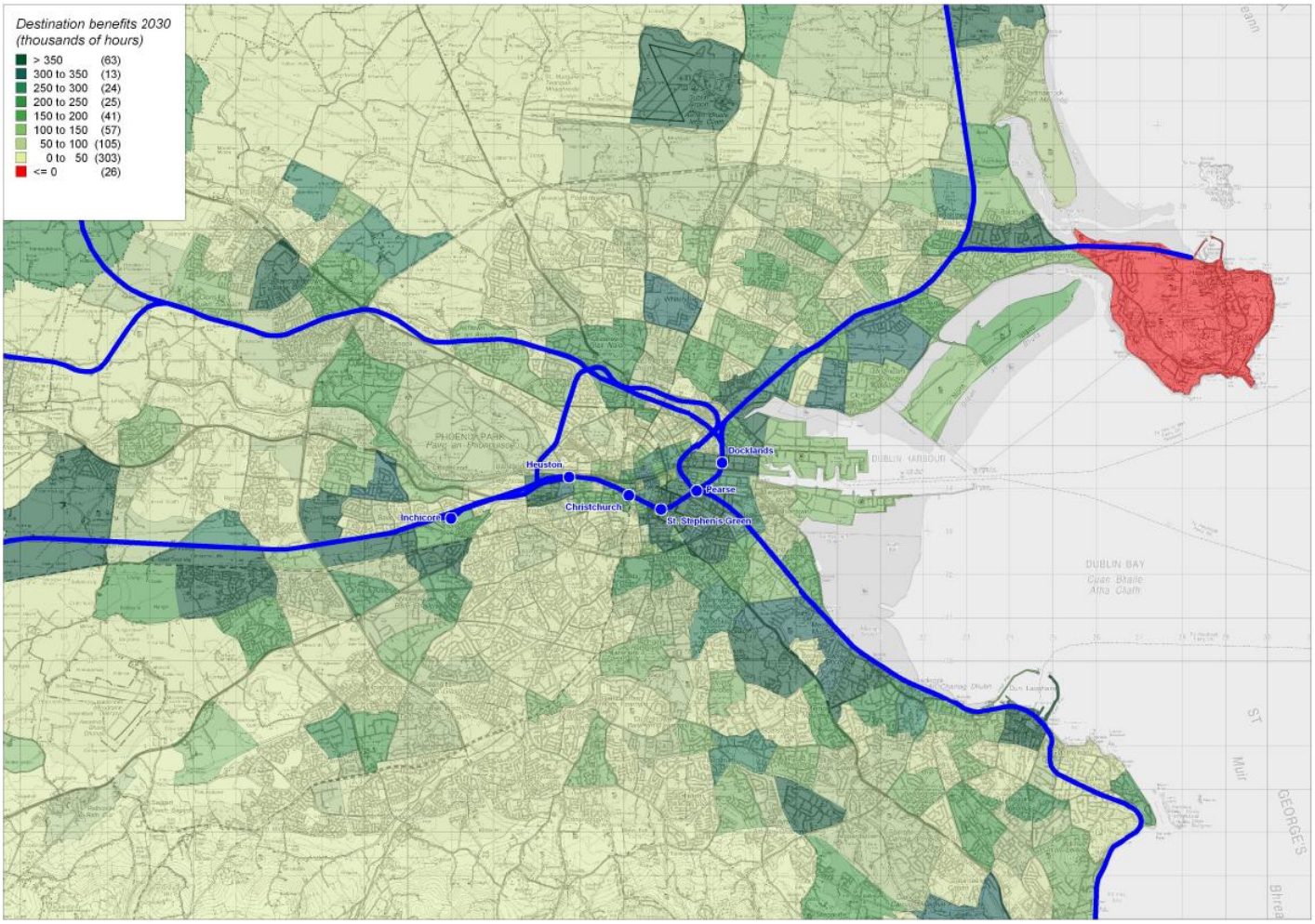
3.3.8 Figure 3.4 shows that DART Underground will reduce the costs of travel for the vast majority of public transport journeys in the Dublin area. As would be expected, the impacts are more pronounced for trips in areas around the rail lines that lead into the centre of Dublin, as passengers travelling to the city centre will be able to benefit from quicker journeys as a result of the new underground tunnel.

Figure 3.4: Changes to public transport generalised costs as a result of DART Underground by destination zone, 2030, Dublin area



3.3.9 Figure 3.5 replicates the map above, but using the absolute change in journey time benefit rather than the percentage change. This helps to emphasise that the city centre shows a high level of benefit by destination as commuters travelling to the central business district benefit from the time savings brought about by DART Underground.

Figure 3.5: Changes to public transport journey time benefits as a result of DART Underground by destination zone, 2030, Dublin area



4 Wider Economic Benefits

4.1 Introduction

4.1.1 The traditional transport economic appraisal concentrates on the user benefits derived from particular transport improvements. It says that there is a value associated with saving travel time and places a value on that saving according to journey purpose, with trips In Work Time (IWT) valued much higher than leisure trips.

4.1.2 It has long been clear that urban railways in particular have other very important economic impacts, but transport economists lacked a framework within which to value them. That framework for valuing what have become known as the WEBs of transport projects was developed by CB for Crossrail in the early 2000s and subsequently formalised within UK DfT guidance.

4.1.3 That initial work built on economic geography analysis which showed that towns and cities with higher densities of employment had higher levels of productivity. That relationship was found to apply across all sizes of urban area and is the essence of the "pure agglomeration" measurement described below.

4.1.4 The (UK) DfT guidance applies the concept of "effective density" (ED) rather than absolute employment density. ED is in essence a gravity model style calculation of accessibility, combining the number of jobs and the generalised cost of reaching them. Thus a transport improvement can increase effective density without changing the distribution of employment.

4.1.5 The WEB values derive from unpicking the "perfect market" assumptions that underlie the standard user benefits approach to transport economics. There are four distinct elements of WEBs within the DfT guidance, which are summarised in Table 4.1.

Table 4.1: Summary of WEBs Elements

WEBs	Description	Rationale
Pure Agglomeration	External productivity gains from increases in effective density	Increasing accessibility between businesses raises productivity of all those businesses, according to defined agglomeration elasticities
Move to More Productive jobs	Overcoming capacity constraints on central area employment growth	Relieving transport capacity restraints on employment distribution can enable significant changes in productivity
Labour Force Participation	Increasing LFP by reducing commuting costs	Marginal increases in LFP generate higher returns because they reduce public sector subsidies as well as increasing output
Imperfect Competition	Increasing output by reducing business transport costs	Imperfectly competitive markets artificially restrain output and raise prices. Boosting output by reducing transport costs has additional economic benefits.

4.2 Applying WEBs in practice

4.2.1 The different elements of WEBs have different issues and problems associated with their application. In addition this is the first application of WEBs to a transport project in Ireland and a number of data issues have emerged during the course of the study. This section discusses those issues.

Productivity data

4.2.2 The main issue we have faced in valuing WEBs has been to do with the lack of detailed productivity and earnings data. Of these two, productivity data is never available at a detailed geographic level; it is synthetic and produced at regional level. However in order to apply that productivity data to agglomeration analysis we have in the past always used more geographically detailed earnings data to derive variations in productivity at smaller area scales.

4.2.3 In this instance we have been unable to secure any local earnings data to be able to compare earnings and productivity in different geographical areas of Dublin. The analysis is therefore based on a number of key assumptions which are described later. In essence we have assumed that productivity varies in accordance with variations in effective density factored by an agglomeration elasticity. That is slightly circular, but if you accept the existence of agglomeration benefits then it makes sense.

Employment changes

4.2.4 Our base case excludes the Move to More Productive Jobs value, but we have run a sensitivity test where we have added 10,000 jobs to central Dublin. The impact of that, and the issues associated with it, are discussed in section 4.7 of this chapter.

4.3 Understanding the base situation

4.3.1 Output data for Dublin is only available at the county level, with no disaggregation into the various administrative areas of Dublin City Centre, Fingal, Dun Laoghaire Rathdown and South Dublin. Similarly average earnings data is produced at the national level with no further spatial breakdown below this. This makes it difficult to derive average earnings or productivity data for different areas of the city region from official statistics sources.

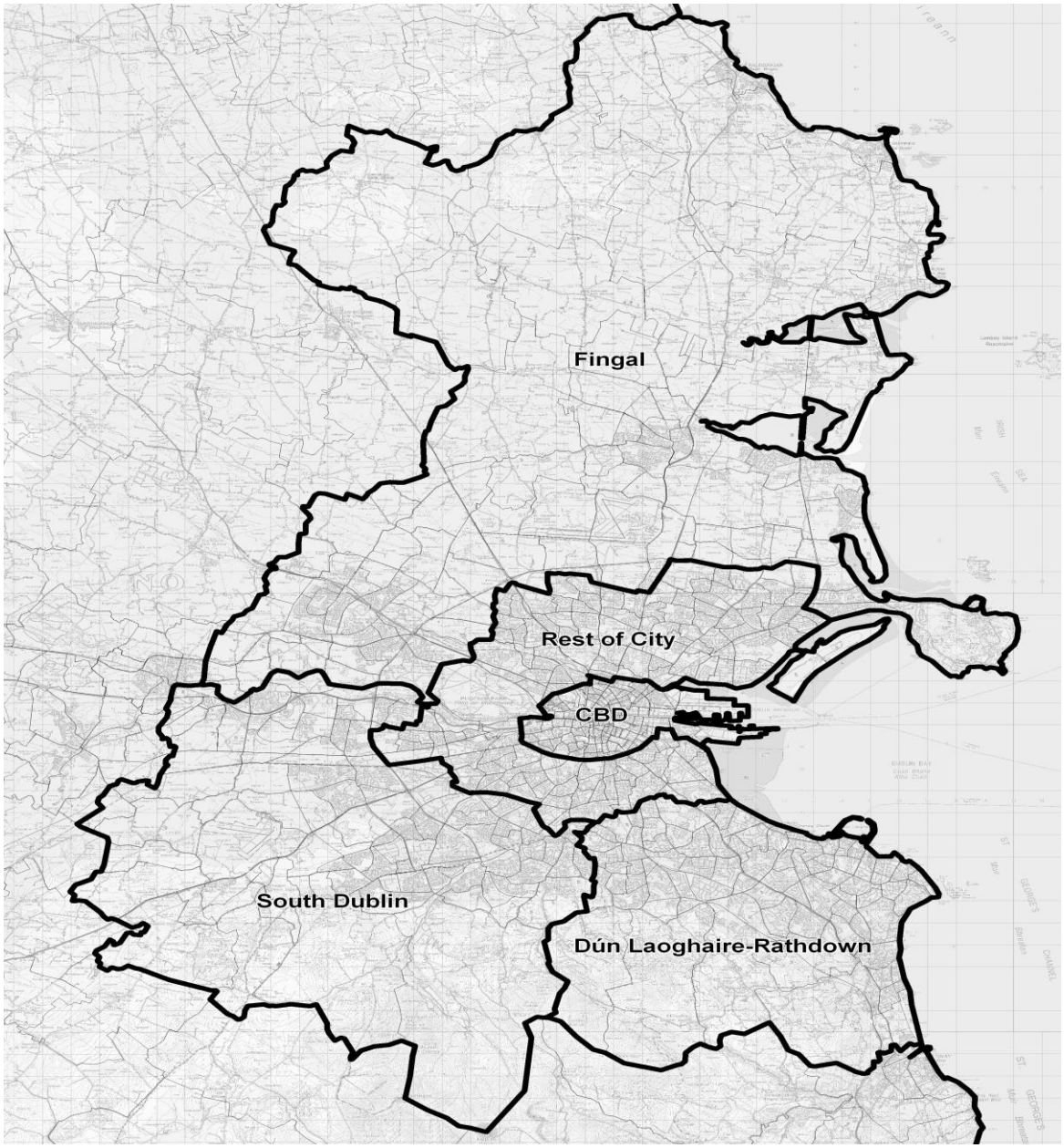
4.3.2 For that reason, in order to extract productivity data we have taken average earnings data by broad industrial sector from the National Employment Survey 2006 and applied it to the sectoral breakdown of workplace employment for the four areas of Dublin, as is available at 2006 Census Enumeration Area (EA) level[6]. Using the NTA model zones we have identified an additional geographical area to represent the Central Business District (CBD). This covers an area approximately equal to that part of central Dublin which lies inside the Canals and Docklands.

4.3.3 An outline map of the CBD and administrative boundaries of County Dublin used in this analysis is shown in Figure 4.1.

4.3.4 Using data from the Regional Accounts the average earnings figure for each of the areas is then scaled up for each sector by the ratio of earnings to output at the State level, to produce an estimate of Gross Value Added (GVA) per worker.

[6] Taken from the Working Population of Large Towns Census data 2006. Please note that the sectoral employment breakdown for Fingal, Dun Laoghaire-Rathdown and South Dublin only partially covers those areas.

Figure 4.1: Map of County Dublin Areas and Administrative Boundaries



Spatial Distribution of Employment Activities

4.3.5 The spatial balance of different employment activities in County Dublin shows a familiar pattern of manufacturing and industry being concentrated in the outer areas of the city region, and service industries being proportionately more dominant in the inner and central areas. Furthermore the split between lower-value consumer services and higher, 'value added' producer services such as finance, legal and business services typically shows that the latter are concentrated in the CBD.

4.3.6 As a result of these spatial patterns of employment activities the average GVA per worker across all sectors is higher in the CBD than elsewhere in County Dublin. The results of these calculations are summarised in Table 4.2. This distribution clearly undervalues the productivity differential of the city centre. It fails to differentiate between bank tellers in the

suburbs and foreign exchange dealers in the CBD, or between local accountants and management consultants.

Table 4.2: Average GVA per worker by Dublin County Area based on composition of employment activities

Admin area	GVA per worker (€, 2009 prices)
CBD	90,410
Rest of City Centre	84,348
Fingal	85,420
Dun Laoghaire Rathdown	80,592
S Dublin	79,706

Introducing the Pure Agglomeration effect

4.3.7 The variations in GVA per worker by area so far take into account only the sectoral split of activities in each area. To accurately represent productivity the approach needs to take into account the density of employment and accessibility to jobs, ie the agglomeration effect. From wide-ranging case studies undertaken in the UK and elsewhere a relationship between effective density and labour productivity can be observed. Moreover, it can be observed that transport schemes influence this relationship by improving the accessibility to jobs from a given location.

4.3.8 Our estimate of effective density for the base takes jobs by NTA model zone and calculates the distance to jobs from each zone to all other zones. By taking the mean average effective density for all zones we can work out the percentage difference from the mean for each zone. Applying a uniform agglomeration elasticity to this figure gives the percentage difference in average GVA per worker by zone for each of the five areas.

4.3.9 This is then worked into an absolute money difference and is added to the average GVA per worker from Table 4.2 to produce a revised productivity figure by area, which is now adjusted for pure agglomeration. This is shown in Table 4.3.

Table 4.3: GVA per worker based on effective density and agglomeration elasticity

Admin area	GVA per worker (€, 2009 prices)	Difference relative to CBD (€)
CBD	99,154	
Rest of City Centre	84,947	-14,207
Fingal	77,528	-21,626
Dun Laoghaire Rathdown	83,575	-15,579
South Dublin	77,754	-21,400

4.3.10 Adding in the agglomeration effect increases the differential in GVA per worker between the CBD and the rest of Dublin County, compared to an estimate purely based on the sectoral breakdown of employment. We believe that this still produces a cautious estimate, but with the absence of definitive data it is best to take a cautious approach. In London, productivity in the central area is typically 50% higher than in the rest of London compared to a differential of roughly 21% in Table 4.3.

4.4 Understanding the future

4.4.1 There are a number of forecast changes which are important to the estimation of the productivity impact of DART Underground.

Employment

4.4.2 The NTA forecasts steady increases in employment for the County with a total increase of approximately 90,000 jobs by 2030. However part of this is offset by a decline of around 40,000 jobs in the CBD by 2016 to take account of the economic downturn. Employment in the CBD rises again after 2016 but is projected to remain lower in 2030 than in 2007.

4.4.3 Employment in the areas outside the CBD is expected to rise over the whole forecast period. Overall total employment in Dublin County is expected to increase by approximately 13% between 2007 and 2030. Table 4.4 summarises the projected level of employment and percentage change for base year and each model year for each area.

Table 4.4: Employment by Dublin County Area and Mid East; base and model year and percentage change

	2007	2016	2020	2030	2007-2016	2016-2020	2020-2030
CBD	263,871	224,986	231,120	243,023	-15%	-12%	-8%
RoCC	170,730	178,352	183,209	192,649	4%	7%	13%
DLRD	80,454	94,566	97,146	102,143	18%	21%	27%
Fingal	85,736	112,840	115,921	121,889	32%	35%	42%
S Dublin	107,256	128,559	132,060	138,860	20%	23%	29%
Total	***708,047***	***739,303***	***759,456***	***798,564***	***4%***	***7%***	***13%***

Accessibility

4.4.4 The estimate of pure agglomeration does not assume any changes in the spatial distribution of employment resulting from the change in accessibility that DART will bring. This means that the impact on productivity is purely accessibility related.

Productivity growth

4.4.5 Over the long term, total economic output grows in real terms due to changes in productivity and this needs to be factored into any assessment of the output impacts of DART. We have used the real growth in the value of time as specified in the DoT guidance to increase productivity each year. A table of value of time growth for the base case is provided in the Appendix.

4.5 Valuing the impact of DART Underground

4.5.1 Figure 4.2 maps the changes in effective density from DART Underground[7]. The increases in effective density are dispersed around the city region due to the various changes planned. The CBD will see significant increases in effective density, and being the densest and most productive area of the Dublin economy will produce the largest increase in output of the Dublin region.

[7] NB the scheme has been modelled as if it opens in 2016, but the final results included in the appraisal are adjusted to account for 2019 being the opening year.

4.5.2 Table 4.5 summarises the percentage change in effective density for the County Dublin areas for each model year, with the City Centre split into the CBD and Rest of City Centre.

Table 4.5: Percentage change in Effective Density by Area and Model year relative to base year 2007

	2016	2020	2030
CBD	2.5%	3.5%	2.7%
Rest of CC	1.7%	2.5%	1.4%
Fingal	1.6%	2.3%	1.4%
Dun Laoghaire/RD	1.6%	2.6%	1.2%
South Dublin	2.3%	3.7%	1.5%

4.5.3 As highlighted earlier, the pure agglomeration scenario assumes that the impact of DART on productivity is purely an accessibility change, without an effect on the distribution of employment around Dublin. Hence the projected change in employment in 2016, 2020 and 2030 occurs independently of whether DART Underground goes ahead or not.

4.5.4 This means that the estimated change in output is based on the difference in productivity of projected employment between the do-something (ie with the scheme) and the do-minimum (without the scheme) in each of the model years, caused by a change in effective density.

Estimating the output change

4.5.5 The next step is to apply the changes in effective density to the agglomeration elasticity to derive the change in productivity for each area. We have assumed a simple elasticity for all jobs in the city economy of 0.08. This figure is taken from the UK Department of Transport's most recent guidance on Wider Economic Benefits and is applied to all areas of Dublin[8].

4.5.6 The methodology for estimating the output change can be summarised as follows:

% Δ effective density x agglomeration elasticity (0.08) = % Δ productivity

then:

% Δ productivity x GVA per worker x employment = Δ total output

4.5.7 This is applied to each of the five areas of County Dublin. The change in output using the above equation, for each of the model years is shown in Table 4.6.

[8] Please refer to the UK Department of Transport's Appraisal Guidance webpage. These are their latest agglomeration elasticities to date which are currently being put out to consultation. More details can be viewed at http://www.dft.gov.uk/webtag/documents/expert/unit3.5.14c.php

Figure 4.2: Changes in Effective Density as a result of DART Underground – County Dublin 2016

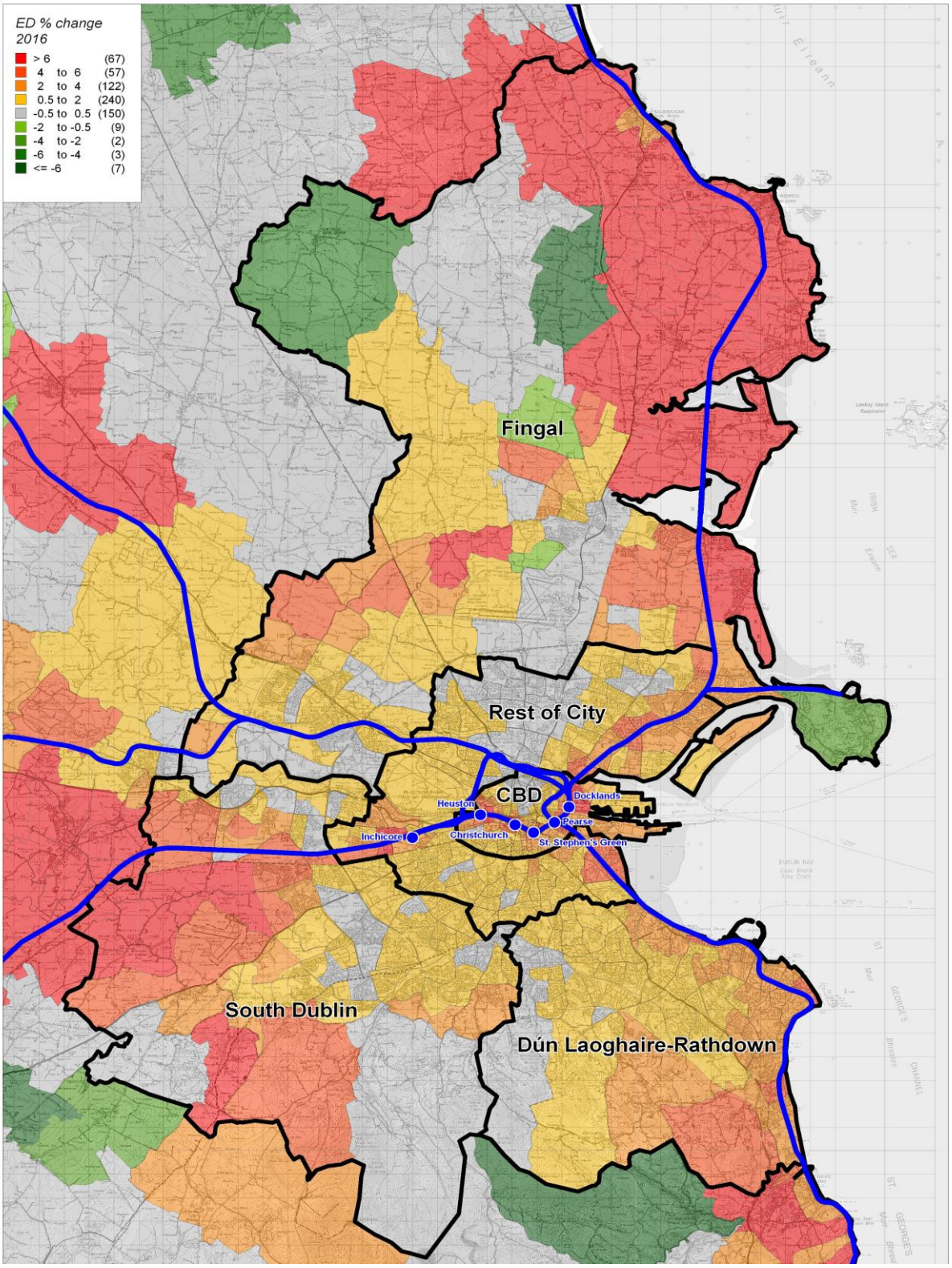


Table 4.6: Change in Total Output (GVA) by Area of Dublin and Year (€m), 2009 prices

Area	2016	2020	2030
CBD	[Figures Deleted	[Figures Deleted	[Figures Deleted
Rest of CC			
Fingal			
Dun Laoghaire/RD			
South Dublin			
Total			
Estimated % share of Dublin GVA			

NB Figures may not add due to rounding

4.5.8 The results indicate that the CBD generates the largest increase in output of all of the areas and for each of the model years. This is not surprising as the central area (within the Canals) contains the largest share of jobs and has the highest level of average productivity, as well as being the area that the DART Underground will primarily serve.

4.5.9 The additional output in 2016 would equate to approximately 0.3% of total annual output for County Dublin.

4.5.10 The WEBs are appraised over a 60-year lifetime of the scheme in line with the full business case methodology. The changes in output are repeated every subsequent year to 2078 with appropriate growth in productivity, in line with growth in the value of time as highlighted earlier.

4.5.11 Appraising the benefits over 60 years and discounting to Present Values using a discount rate of 4% per annum would give a total increase in output of approximately ***[text deleted]*** in 2009 prices. This is broken down by Dublin County area as shown in Table 4.7.

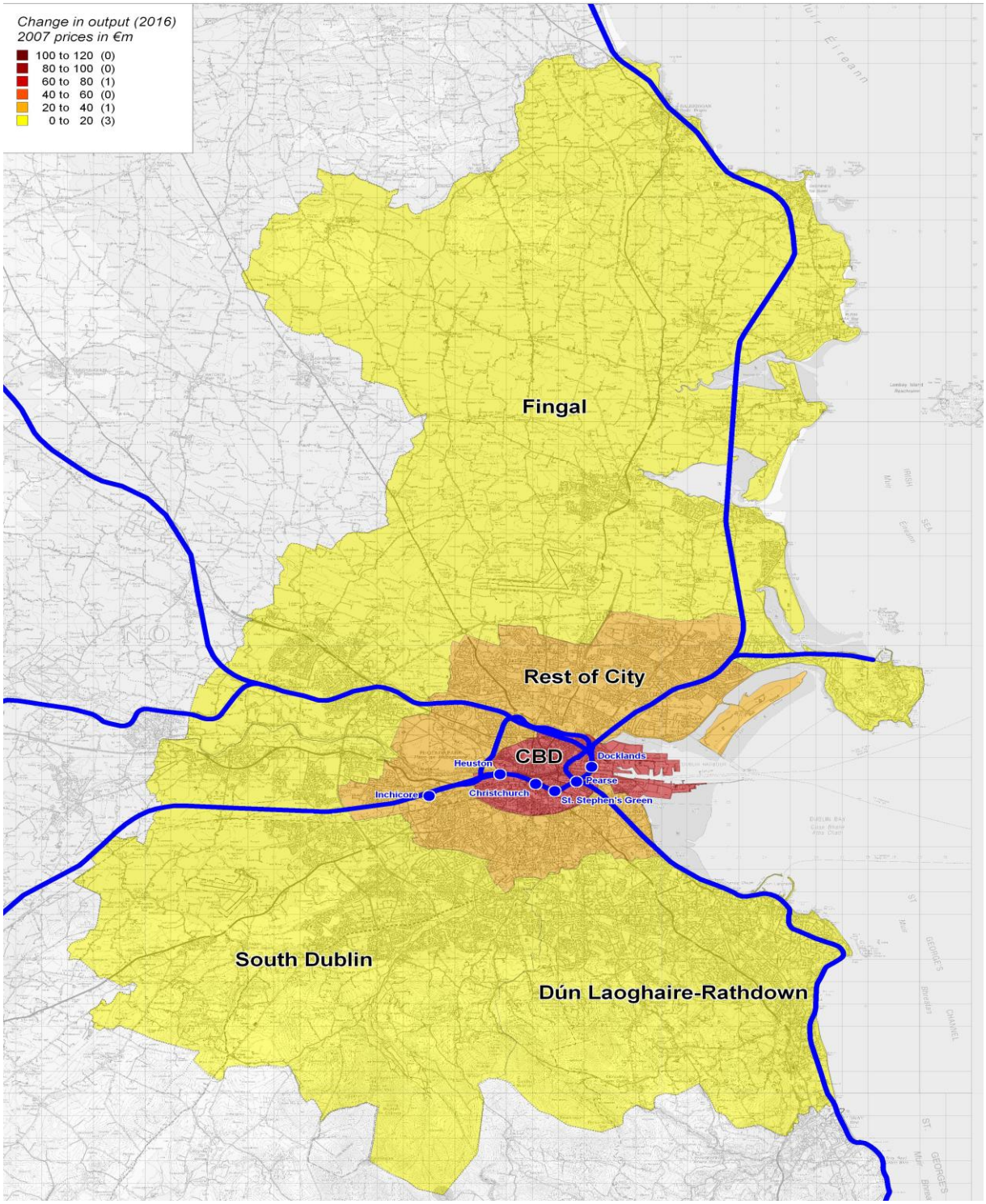
Table 4.7: Present Value Output by Area €m, 2009 prices

	PV, €m
CBD	[Figures Deleted
Rest of CC	
Fingal	
DLRD	
South Dublin	
Total	

4.5.12 The results show that the CBD accounts for 70% of the additional output generated by improved accessibility, with the City Centre as a whole accounting for more than 80%. The three administrative areas outside the City Centre account for a relatively small share of the output gain, although there will be considerable benefits from improved accessibility to the City Centre from these three areas.

4.5.13 Figure 4.3 maps the change in output for each of the areas for 2016.

Figure 4.3: Output Change by Area, County Dublin 2016



4.6 Sensitivity tests

4.6.1 We have applied several sensitivity tests to the results to assist in understanding which assumptions and parameters have the greatest influence on the WEBs. The tests proposed at this stage are summarised as the following:

1. Alternative agglomeration elasticities of 0.05 and 0.11
2. Fixed employment beyond 2016

4.6.2 The results of the tests are summarised in Table 4.8.

Table 4.8: Summary of Sensitivity Tests and Difference in benefits from the Base Case

€m / % change	2016	2020	2030	PV €m
Agglom Elasticity of 0.05	[Figures Deleted	[Figures Deleted	[Figures Deleted	[Figures Deleted
difference from base case				
Agglom Elasticity of 0.11				
difference from base case				
Fixed Employment post 2016				
difference from base case				

4.6.3 The pure agglomeration element of the WEBs is clearly dependent on the assumption used for the agglomeration elasticity. A lower elasticity of 0.05 leads to a reduction of almost 40% in the WEBs, while the higher elasticity of 0.11 boosts the benefits by 36%.

4.6.4 With fixed employment beyond 2016, the results show little overall impact on the base scenario except for a small increase up to 2020 due to the assumed declines in employment in the base case. There is no change in 2030 as much of the additional employment occurring after 2020 is outside the City Centre where the impact of DART underground on effective density is lower.

4.7 Move to more productive jobs

4.7.1 The move to more productive jobs (M2MPJ) element of the WEBs estimates the effect of redistributing employment activities into the CBD as a result of DART Underground. Those increases in employment tend to be more concerned with increases in transport capacity which overcome existing capacity constraints to city centres than with changes in accessibility. The recent history of Dublin with employment growth taking place more in the outer suburbs than the city centre is indicative of a city with constraints on city centre access or development.

4.7.2 DART will provide additional capacity at key employment and development locations and corridors in and around Dublin City. This will increase the attractiveness of such locations for development, with an associated knock-on impact on land use patterns over time around stations and areas that benefit most from the improved accessibility.

4.7.3 For this analysis we have considered the potential impacts around Heuston, Christchurch, St Stephen's Green, Pearse and Docklands stations. There are three possible scenarios that need to be taken into account in estimating the redistribution of employment to locations around the stations:

- NTA employment projections;
- Effect of improved transport accessibility based on the accessibility-density relationship; and
- Site assessment of probable development impact.

4.7.4 Current and projected employment levels for NTA zones around the stations are summarised in Table 4.9 for 2007 and 2016.

Table 4.9: Jobs around DART Underground Stations and Change: NTA Planning Projections 2007-2016

Station	2007	2016	Change
Heuston	5,527	1,202	-4,325
Christchurch	5,913	4,712	-1,201
St Stephen's Green	9,667	12,278	+2,611
Pearse	5,383	4,821	- 562
Docklands	5,208	19,966	+14,758
Total	**31,698**	**42,979**	**+11,281**

Assessment of Development Potential

4.7.5 A planning assessment of the development potential of existing sites around the stations above has been undertaken by CB. For the purposes of assessing the M2MPJ impact we have assumed that the introduction of DART Underground leads to an additional 2,000 jobs being located around each of the five stations, giving a total increase of 10,000 jobs. These jobs are assumed to be redistributed to the CBD from elsewhere within County Dublin; they do not represent an increase in total employment.

4.7.6 This economic benefit of this redistribution relates to the increase in productivity that the jobs will experience from relocating to the central area, with a higher GVA per worker resulting in a net increase in output.

4.7.7 The planning report highlights that policy is fully supportive of DART Underground as it will facilitate more intensive development and functioning of the Dublin Metropolitan Area through the densification of sites at or in close proximity to the stations.

4.7.8 While there are constraints on new development at particularly sensitive locations such as Christchurch and St Stephens Green, this does not exclude opportunities for more intensive use of existing sites. Moreover the potential for employment based development is likely to be much greater for the other stations, particularly in the Docklands.

4.7.9 Our assumption for an increase of 10,000 jobs over the appraisal period is a relatively conservative assumption for employment growth which adheres to the planning context and is supported by CB's planning assessment of capacity around each station.

Estimating the productivity effect

4.7.10 The valuation of the economic benefits from M2MPJ is based on the productivity premium that will be captured by employment relocating to the CBD. For example, if the difference in output between an accountant working in the CBD and one working in the suburbs is €10 per head, then the relocation of 1,000 accountants to the CBD from the suburbs would result in a total boost to output of €10,000.

4.7.11 In Dublin, the productivity premium is calculated as the difference in average GVA per worker between the CBD and a weighted average in the rest of Dublin, which we have estimated at approximately €17,500 in 2009 prices.

4.7.12 Applying this premium to our estimate of 10,000 redistributed jobs gives approximately €176m in additional output per annum for County Dublin as a whole.

4.7.13 However, the productivity boost will accumulate gradually as jobs relocate over time to new developments around the stations, rather than happening all at once. Building in this assumption that the M2MPJ occurs over a period of 10 years from the introduction of the scheme, and repeating the benefits over a 60-year appraisal period gives a total output increase of approximately ***[text deleted]*** in Present Value terms (2009 prices).

4.8 Imperfect competition / labour force participation

4.8.1 The theory behind these two remaining WEBs is as follows:

- Imperfect competition: in imperfectly competitive markets, firms keep output below its optimal level. An improved transport system leads to lower transport costs for firms, thus inducing them to increase output.
- Labour force participation: an increase in accessibility leads to effective wages increasing. As a result, some additional workers are incentivised to enter the labour market, leading to an increase in output if they become employed.

4.8.2 The valuation of these impacts is more straightforward than the process for pure agglomeration and M2MPJ; the UK DfT recommends that the benefit is assumed to be equivalent to a proportion of journey time savings. For labour force participation, 21% of the value of commuter time savings is used; for imperfect competition 10% of business time savings are used. The resulting values of the increase in output are ***[text deleted]*** and ***[text deleted]*** respectively, as Present Values over 60 years in 2009 prices.

4.9 Conclusions

4.9.1 Table 4.10 provides a summary of the WEBs for both the pure agglomeration and M2MPJ elements. All values are discounted to Present Values in 2009 prices.

Table 4.10: Estimate of Total Wider Economic Benefits

WEBS Element	€m, 2009 prices, PV
Pure Agglomeration	***[Figures Deleted***
M2MPJ	
Labour Force Participation	
Imperfect Competition	
Total PV	

4.9.2 In total the combined increase in output from the four WEBs is estimated at approximately ***[text deleted]*** as a 60-year Present Value.

4.9.3 There are differences between valuing increases in output and socio-economic benefits. For the pure agglomeration, UK DfT advice is that it requires no change in behaviour so the full increase counts as a benefit. In the case of M2MPJ and labour force participation, however, the advice is that only the “tax wedge” element of the increase in GDP should count as a net benefit. We take that as 30% and 40% of the increase in output for M2MPJ and LFP respectively. When the WEBs are added to the transport benefits in Chapter 6, those are the assumptions that we have used.

5 Costs

5.1 Capital costs

5.1.1 Capital costs for DART Underground have been estimated by Iarnród Éireann. The costs include:

- The DART Underground tunnel
- Ancillary works including:
  - Electrification to Drogheda, Maynooth and Hazelhatch
  - Additional depot / stabling facilities
  - Other ancillary track works
- A rolling stock requirement of 282 cars

5.1.2 The assumed phasing of costs is shown in Table 5.1. Sunk costs are excluded. The costs are shown in 2009 prices and are expressed in market prices (ie they include VAT) as recommended in DoT guidance. The costs in Table 5.1 are shown as undiscounted values, whereas the tables in chapter 6 use Present Values.

Table 5.1: Capital costs of DART Underground (€m, 2009 market prices, undiscounted, excluding cost escalation)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
DU tunnel	4	16	17												
Other works	0	0	3												
Rolling stock	0	0	0												
Total	4	16	20												

[Figures Deleted]

5.1.3 The capital costs are ***[text deleted]*** in total; the DART Underground tunnel accounts for approximately ***[text deleted]*** of this.

5.2 Ongoing costs

5.2.1 The ongoing costs included relate not only to the tunnel, but also to the other new infrastructure and rolling stock that is incremental to the Do Minimum scenario. The ongoing costs of the scheme are based on a combination of estimates produced by AHJV, IE and Mott MacDonald and include:

- Operating costs (utilities, taxes, staffing etc);
- Maintenance costs; and
- Renewals costs.

5.2.2 The operating costs amount to ***[text deleted]*** a year in 2009 prices; the maintenance costs are ***[text deleted]*** a year ***[text deleted]*** every nine years to include plant maintenance).

5.2.3 The renewal costs vary year-on-year and amount to ***[text deleted]*** in total over the appraisal period. As well as costs related to the DART tunnel, the renewals include the cost of replacing the fleet of rolling stock.

5.3 Costs in economic appraisal

5.3.1 Some adjustments are made to the costs described above when including them in the overall business case. These are as follows:

- For costs incurred in future years a real cost escalation has been applied. In line with the previous business case, a 2% real inflation rate per annum has been applied for the infrastructure and ongoing costs.
- The costs are discounted to a Present Value.

5.3.2 Further information on the treatment of costs is provided in the Appendix.

6 Business case

6.1 Introduction

6.1.1 This chapter brings together the costs and benefits described earlier in the report to make an overall assessment of the strength of the business case for the scheme, based on the incremental impacts of the DU programme over and above what is included in the Do Minimum. This is done in several stages:

- Financial appraisal: an assessment of the costs and revenues of the scheme
- Transport appraisal: this compares the transport benefits with the costs
- Transport appraisal + WEBs: this includes the agglomeration benefits outlined in chapter 4
- Transport appraisal + WEBs + other objectives: this also includes qualitative assessments of other appraisal objectives such as social inclusion

6.2 Financial appraisal

Net financial effect

6.2.2 This section describes the financial implications of DART Underground in a manner consistent with the economic appraisal, using the moderate growth scenario. It ignores financing costs and structures and who bears those costs. DART Underground themselves are preparing a project financing strategy with more appropriate financial numbers. The financial appraisal here shows the changes in costs and revenues from DART Underground discounted in the same way as the economic benefits. As it shows the impact on the Exchequer, the values are presented net of VAT (as opposed to the economic appraisal which values everything at market prices). As a result the value of the costs shown in Table 6.1 differs from the values shown in the tables in sections 6.3 and 6.4.

6.2.3 Essentially the financial appraisal for DART Underground therefore includes:

- Capital costs;
- Changes to operating, maintenance and renewal costs; and
- Changes to revenue.

6.2.4 To estimate changes to rail revenue, the change in total passenger kilometres on DART and suburban rail from the transport model has been used, with a value of revenue per passenger kilometre applied. Revenue per passenger kilometre is assumed to be €0.17, based on data provided by IE. The assumption regarding real fares growth can be altered, but in Table 6.1 below it is assumed to be 2% a year.

6.2.5 Table 6.1 summarises the financial impacts of DART Underground, with the values expressed in 2009 prices and discounted to the base year 2009.

Table 6.1: Financial impacts of DART Underground

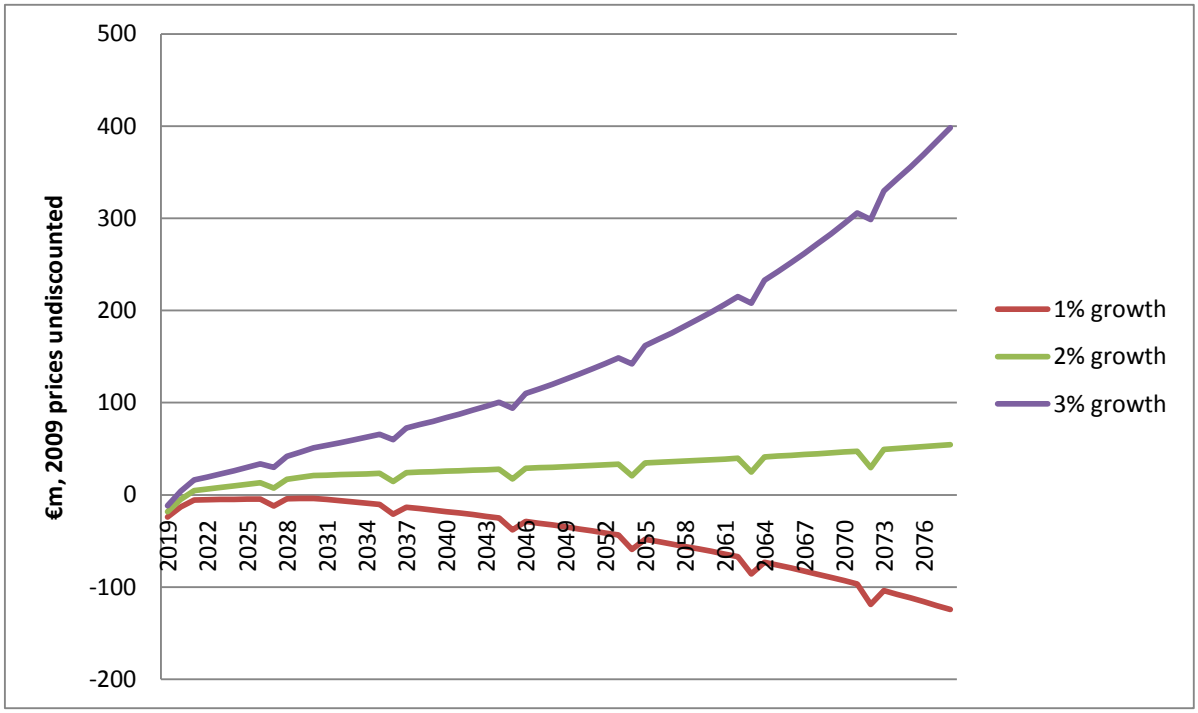
	€m, 2009 prices, PV
Capital costs	*[Figures Deleted*
Operating costs	
Maintenance	
Renewals	
Revenue	2,197
NET FINANCIAL IMPACT	

6.2.6 Under the assumptions used, the scheme is expected to lead to a net cost to the Exchequer of ***[text deleted]*** over the 60 years of the appraisal period, in Present Value terms.

Operating surplus

6.2.7 The impact of the scheme on operating subsidies can be shown, by taking the difference between year-on-year revenues and ongoing (operating and maintenance) costs. Figure 6.1 below shows the change to the operating surplus for DART and suburban rail at different assumed levels of real fare growth (1%, 2% and 3%). The approach is to consider that, at present (based on 2008 data), DART runs at an operating loss of €15m a year. If the change to the operating surplus is compared relative to that €15m loss, the results are as shown in Figure 6.1.

Figure 6.1: Change to DART & suburban rail operating surplus relative to Do Nothing loss



6.2.8 Figure 6.1 shows that, relative to the loss of €15m a year in the Do Nothing scenario, the operating surplus for DART Underground would be positive under 2% or 3% real fare growth. The costs of the scheme are assumed to rise by 2% a year in real terms, and it

seems reasonable to assume that the same may be the case for revenues in the base case.

Summary

6.2.9 Taking all changes to costs and revenues into account, the DART Underground Programme will be a net cost to the Exchequer. In Present Value terms the net cost may be approximately ***[text deleted]*** over 60 years.

6.2.10 Under the most likely scenario, in operating terms the scheme is expected to break even or make a slight surplus. However, there would be a relatively large operating loss if fares were to only increase by 1% a year in real terms.

6.2.11 Clearly the financial impact of DART is important, but in terms of the overall evaluation of the scheme it is necessary to take the economic impacts into account too. That is addressed in the following sections.

6.3 Transport appraisal

6.3.1 Table 6.2 combines the transport appraisal results from chapter 3 with the costs to produce a NPV and BCR for the scheme.

Table 6.2: Transport benefits and costs of DART Underground

	€m, 2009 prices, PV
User benefits	
PT uncrowded time savings	***[Figures Deleted***
PT congestion relief	
Highway congestion relief	
Vehicle operating costs	
Other benefits	
Accidents	
Emissions	
TOTAL TRANSPORT BENEFITS	
Capital costs	
Operating costs	
Maintenance and renewals	
TOTAL COSTS	
NET PRESENT VALUE	
BENEFIT / COST RATIO	2.39
INTERNAL RATE OF RETURN	9.54%

6.3.2 Table 6.2 shows that the transport benefits far outweigh the costs of the scheme, with a BCR of 2.39 and IRR of 9.54%.

6.4 Transport appraisal and WEBs

6.4.1 Table 6.3 replicates Table 6.2, this time including the Wider Economic Benefits of the scheme as well as the transport benefits.

Table 6.3: Transport / Wider Economic Benefits and costs of DART Underground

	€m, 2009 prices, PV
User benefits	
PT uncrowded time savings	***[Figures Deleted***
PT congestion relief	
Highway congestion relief	
Vehicle operating costs	
Other benefits	
Accidents	
Emissions	
Total transport benefits	
Pure agglomeration	
Move to more productive jobs	
Imperfect competition	
Labour force participation	
Total Wider Economic Benefits	
TOTAL BENEFITS	
Capital costs	
Operating costs	
Maintenance and renewals	
TOTAL COSTS	
NET PRESENT VALUE	
BENEFIT / COST RATIO	4.04
INTERNAL RATE OF RETURN	13.54%

6.4.2 The WEBs add over ***[text deleted]*** to the total benefits. This increases the BCR from 2.39 to 4.04.

6.5 Transport appraisal, WEBs and wider objectives

6.5.1 Table 6.4 shows an assessment of the scheme against government objectives.

Table 6.4: Appraisal Summary Table

Objective	Qualitative assessment	Quantitative assessment
ECONOMY		
Transport Efficiency	DU delivers substantial transport benefits to public transport and road users as described in the main report.	PT uncrowded time savings + highway congestion relief + vehicle operating cost savings = ***[text deleted]*** PV
Transport Reliability & Quality	Congestion relief to rail users from DU has been valued from the NTA model. DU will significantly improve the reliability of DART operations through more double tracking and improved signalling.	PT congestion relief valued at ***[text deleted]*** PV
Other Economic Impacts	DU will deliver substantial Wider Economic Benefits, focused on central Dublin.	***[text deleted]*** PV
	DU will encourage residential development along the various DART branches.	
SAFETY	By 2030 DU will switch over 25m car kms from road to rail thereby saving approximately 170 accidents a year (over 80% of which would be 'damage only') and 50 casualties.	***[text deleted]*** PV
ENVIRONMENT		
Air Quality	Reduction in emissions due to mode shift from road to rail.	***[text deleted]***
Noise & Vibration	Temporary impact during short term construction. No significant impact during construction.	
Landscape and visual quality	New surface structures integrated into existing streetscape.	
Biodiversity	Neutral.	
Cultural and architectural heritage	As with all urban construction, archaeological material may be encountered. All material will be recorded. No significant impact on Architectural Heritage.	
Land use	Predominantly underground, therefore no significant impact on land use. Insertion of new transport mode into historical Dublin environment.	
Water Resources	Neutral	
ACCESSIBILITY & SOCIAL INCLUSION		
Vulnerable Groups	Non-car owners – DU will be of particular benefit to non-car owners.	
	People with disabilities – DU will provide accessible transport for the mobility impaired.	
Deprived geographic areas	Serves a number of deprived areas	
INTEGRATION		
Transport Integration	DU creates new interchanges with Luas at Docklands, St Stephen's Green and Heuston stations and to Metro North at St Stephen's Green. It opens up new journey opportunities between the Northern and Kildare lines and improves links between the Maynooth and SE DART lines.	These are reflected in the scale of the PT user benefits

	DU brings together the Dublin rail network and is key to maximising the potential of that network. It is a vital backbone of an integrated public transport system for Dublin and key to optimising the benefits to be delivered through other elements of Transport 21. DU will eliminate many of the existing city centre capacity constraints that are largely attributed to the existing loop line connecting Pearse and Connolly stations.	
Land Use Integration	DU supports national and local land use strategies. It promotes employment growth in central Dublin and commuting by rail and enables increase density of development. It also supports redevelopment of several city centre sites especially around Docklands and Heuston stations.	
Geographic Integration	DU will unlock key capacity bottlenecks on the rail network in the GDA improving rail access to the Capital from the rest of the country. Enhanced inter-regional accessibility is a key objective of the National Spatial Strategy.	
Other Government Policy Integration	DU is consistent with Government policy at all levels including Transport 21, Regional Planning Guidelines, the National Spatial Strategy and the National Development Plan. It is highly consistent with Government policy 'Smarter Travel – A Sustainable Transport Future 2009 – 2020' which seeks to reduce car based commuting from 65% to 45% by 2020.	

7 Risks and sensitivities

7.1 Sensitivity tests

7.1.1 A number of sensitivity tests have been undertaken to assess the robustness of the main results. These are all produced on the basis of the transport benefits only, ie they exclude the WEBs.

Future growth

7.1.2 Model outputs were produced for a 'no growth' scenario (which assumes no increase in population and employment after 2007) and a 'high growth' scenario, which includes the most optimistic forecasts for population and employment growth up to 2030. The base results use a 'moderate' growth scenario. Table 7.1 shows the results if the other scenarios are used.

Table 7.1: Results of alternative growth sensitivity tests

€m, 2009 prices, PV	Base case (moderate growth)	No growth scenario	High growth scenario
Total transport benefits	*[Figures Deleted*		
Total costs			
Net Present Value			
Benefit/Cost Ratio	2.39	1.71	3.20
Internal Rate of Return	9.54%	7.46%	11.83%

7.1.3 Table 7.1 shows that even if there is assumed to be no growth after 2007, the benefits still outweigh the costs with a BCR of 1.71 and IRR of 7.46%.

Scheme delay

7.1.4 Table 7.2 shows the results if it is assumed that the scheme does not open until 2021, incurring an additional 25% of capital costs in 2019 and 2020.

Table 7.2: Results of scheme delay sensitivity test

€m, 2009 prices, PV	Base case (scheme opens in 2019)	Scheme delay (opens in 2021)
Total transport benefits	*[Figures Deleted*	
Total costs		
Net Present Value		
Benefit/Cost Ratio	2.39	2.23
Internal Rate of Return	9.54%	8.51%

7.1.5 The case for the scheme would only worsen very slightly due to the type of scheme delay assumed for this test, with the BCR decreasing from 2.39 to 2.23 compared to the base case.

Shorter appraisal period

7.1.6 Table 7.3 shows the impact of using a 30-year appraisal period instead of 60 years (no residual value is included).

Table 7.3: Results of shorter appraisal period sensitivity test

€m, 2009 prices, PV	Base case (60-year appraisal)	30-year appraisal
Total transport benefits	[Figures Deleted	
Total costs		
Net Present Value		
Benefit/Cost Ratio	2.39	1.73
Internal Rate of Return	9.54%	8.58%

7.1.7 The shorter appraisal period means that 30 years of benefits and ongoing costs are excluded. The net impact of this is to reduce the BCR from 2.39 to 1.73.

Most pessimistic scenario

7.1.8 A scenario has also been tested using the following combination of assumptions:

- 30 year appraisal
- Two year delay to the scheme as per the scenario above
- No growth scenario is used

7.1.9 Table 7.4 shows the results of this test relative to the base case.

Table 7.4: Results of most pessimistic sensitivity test

€m, 2009 prices, PV	Base case (scheme opens in 2019)	Most pessimistic test
Total transport benefits	[Figures Deleted	
Total costs		
Net Present Value		
Benefit/Cost Ratio	2.39	1.12
Internal Rate of Return	9.54%	4.92%

7.1.10 The results shown in Table 7.4 are encouraging as they show that, even in the most pessimistic scenario, the benefits outweigh the costs with a BCR of 1.12.

8 Conclusions

8.1.1 DART Underground will produce a step change in rail efficiency, accessibility and quality in the wider Dublin commuter rail belt. Specifically, the scheme will:

- Deliver a large improvement in rail accessibility to the city centre from a wide catchment area (there will be benefits for each of the four rail corridors radiating from the city centre);
- Facilitate close integration between all of the public transport modes in the city centre (commuter rail / DART, bus, Luas, Metro North) and other key locations outside the immediate city centre (eg Inchicore and Drumcondra);
- Deliver a significant increase in peak hour capacity of the commuter rail network (up to a three fold increase which can be cost effectively phased in, in line with demand);
- Support the local authorities, and particularly Dublin City Council, in their objectives for more sustainable development patterns including higher densities. In particular, the competitive position of the city centre will be reinforced; and
- Afford real choice for commuters (higher frequencies, better central area access, more competitive journey times, easier modal interchange) and hence deliver a modal shift from the private car and reduction in greenhouse gas emissions.

8.1.2 The scheme is crucial to the future economic development of Dublin; it brings together the central area into a functioning economic core, links the two main growth areas in Docklands and Heuston and effectively integrates the different IE and Luas lines into a network by enabling interchange between them. The economic case for DART Underground is therefore very strong, with a Benefit/Cost Ratio in the base case of 2.4. The assessment is robust to downside sensitivity tests, both individually and in combination, including large increases in costs and assuming no growth in population and employment.

8.1.3 The Wider Economic Benefits of the scheme are also strong, as would be expected. DART Underground links the key parts of Dublin's central business district and provides integration with the rest of the rail network. Adding WEBs to the transport benefits increases the BCR to 4.0.

8.1.4 This is a long term project with an expected life in excess of 100 years. It is an investment in Dublin's future, facilitating over 40% of the population of Ireland, and should not be overly affected by short term economic problems.

Appendix 1 – Assumptions Register

Table A 1: Assumptions register

Assumption	Value	Source
Opening year of scheme	2019	
Transport schemes included in Do Minimum scenario	**Luas / Metro Network** - Extension of Luas Line A from Belgard to Saggart (Line A1) - Extension of Luas Line C from Connolly to The Point (Line C1) - Extension of Luas Line B from Sandyford to Cherrywood (Line B1) - Extension of Luas Line B from Cherrywood to Bray (Line B2) - Luas Line D between City Centre, Broadstone and Liffey Junction - Luas Line BX, Cross City Centre connection of LUAS Line A and Line B which also connects Line B to Line D, enabling trips from Liffey Junction to Bray - Luas Line between Lucan and Trinity (Line F) - Line between Swords and Stephen's Green (Metro North) - Line between Tallaght and Clondalkin (Metro West Phase 1) - Line between Clondalkin and Lucan (Metro West Phase 2) - Line between Lucan and Blanchardstown (Metro West Phase 3) - Line between Blanchardstown and Ballymun and Dublin Airport (Metro West Phase 4) **Bus Network** – services included as described below: - A Platform for Change, DTO, 2001 – Quality Bus Network - Ten Year Plan 2016 Network, DTO, 2005 – Addition of new buses and services to service Transport 21 proposed rail, Luas and Metro - Dublin Bus Network Review, MVA, 2006 –	NTA

	Reconfiguration of services and addition of new bus routes and services **Road Network** – the following additional infrastructure is included as part of the Transport 21 Proposals: - Outer Ring Road (N7 to N4 and extension to Fingal) - M50 Upgrade (Phase 2) - N2 Upgrade M50 to North of Ashbourne - N4 Widening Leixlip to M50 - M3 Motorway to North of Kells - N81 Tallaght to Citywest **City Centre Car Parking Restraint** It was assumed that the 2008 level of city centre parking availability was maintained in the future, as it was deemed that very little scope exists to significantly increase the number of car parking spaces available in future.	
Service patterns	See additional text below	IE
Appraisal period	60 years (2019-78)	
Price / discounting base year	2009 (main report) 2002 (Appendix 3)	DoT guidance
Discount rate	4% a year	DoT guidance
Journey purpose splits	In Work Time: 5% Commute: 30% Leisure: 65%	Previous DART business case
Value of time per hour (market prices, 2002)	In Work Time: €26.50 Commute: €8.10 Leisure: €7.30 Weighted average: €8.50	DoT guidance, using journey purpose splits to obtain weighted average.
Value of time growth rate (% a year)	2002 – 2010: 2.70% 2011 – 2015: 2.37% 2016 onwards: 2.29%	DoT guidance
Annualisation factor	Public Transport (uncongested time): 1,061 Public Transport (congested time): 531 Highway: 1,246	Previous DART business case (assume that the PT congested annualisation factor is 50% of the uncongested one)
Vehicle operating costs (cents per kilometre)	Use the formula $C = a+bV+cV^2$ for fuel, and $C = a^1+b^1/V$ for non-fuel. Values of the parameters taken from DoT guidance.	DoT guidance
Value of accidents / casualties (€, 2002 prices)	*Per casualty* / *Per accident* Fatal: 2,018,126 / 15,882 Serious Injury: 226,757 / 6,769 Slight injury: 17,486 / 3,896 Damage only: n/a / 2,403	DoT guidance
Cost of emissions per vehicle mile (€)	*CO2* / *Non CO2* Total Passenger Cars: 0.012 / 0.013 Total Light Duty Vehicles: 0.012 / 0.012 Total Heavy Duty Vehicles: 0.022 / 0.028 Urban Bus: 0.223 / 0.345	DoT guidance – values for urban roads are used

Ramp-up of benefits	Year 1: 35% Year 2: 70% Year 3: 90% Year 4 onwards: 100%	Based on UK approach to transport appraisal
Rebasing factors (from 2009 to 2002 prices)	Rolling stock: 0.969 (price index = 104.3 in 2002, 107.6 in 2009) Other capital costs: 0.775 (price index = 109.0 in 2002, 140.7 in 2009) Ongoing costs: 0.812 (price index = 1.00 in 2002, 1.23 in 2009)	Central Statistics Office: Wholesale Price Index for commercial vehicles (Jan 2003 is taken as a proxy for 2002, as the 2002 values available from the CSO website do not use a consistent base index year) Wholesale Price Index for building and construction (Jan 2003 is taken as a proxy for 2002, as the 2002 values available from the CSO website do not use a consistent base index year) CB created an index with 2002 = 1, based on CPI inflation rate
Real cost escalation	2% a year	Previous DART business case

Service patterns

Do Minimum

Table A 2: Northern Line service frequency – Do Minimum

Route	Trains Per Peak Hour	Peak Frequency
Dundalk – Connolly	3	20 minutes
Drogheda – Grand Canal Dock	3	20 minutes
Balbriggan – Bray	4	15 minutes
Howth - Greystones	4	15 minutes

Table A 3: Maynooth Line service frequency – Do Minimum

Route	Trains Per Peak Hour	Peak Frequency
Maynooth - Connolly	3	20 minutes
Maynooth – Grand Canal Dock	3	20 minutes
Pace - Docklands	3	20 minutes
Longford - Docklands	1	60 minutes
Longford – Grand Canal Dock	2	30 minutes

Table A 4: Kildare Line service frequency – Do Minimum

Route	Trains Per Peak Hour	Peak Frequency
Hazelhatch - Heuston	4	15 minutes
Portlaoise - Heuston	2	30 minutes
Carlow - Heuston	1	60 minutes
Athlone - Heuston	1	60 minutes

Table A 5: South East Line service frequency – Do Minimum

Route	Trains Per Peak Hour	Peak Frequency
Greystones - Howth	4	15 minutes
Bray – Balbriggan	4	15 minutes
Arklow – Connolly	2	30 minutes

Do Something

Table A 6: Maynooth – Bray / Greystones Line service frequency – Do Something

Route	Trains Per Peak Hour	Peak Frequency
Maynooth / Bray*	8	7.5 minutes
Bray/Connolly**	2	30 minutes
Navan / Docklands	4	15 minutes
Pace /Docklands***	2	30 minutes
Longford/Grand Canal Dock****	3	20 minutes

**Frequency between Bray and Greystones is 4 trains per peak hour*
*** Frequency between Connolly and Bray will be 10 trains per peak hour, giving a frequency of 6 minutes.*
**** Frequency between Pace and Docklands will be 6 trains per peak hour, giving a frequency of 10 minutes (diesel operated services)*
***** Total peak service / diesel operated services*

Table A 7: Drogheda - Hazelhatch Line service frequency – Do Something

Route	Trains Per Peak Hour	Peak Frequency
Drogheda/Inchicore	8	7.5 minutes
Balbriggan/Hazelhatch*	4	15 minutes
Grange Rd/Hazelhatch*	4	15 minutes
Dundalk/Connolly**	3	20 minutes
Howth/Howth Junction	6	10 minutes

** Frequency between Drogheda and Inchicore will be 8 trains per hour giving a frequency of 7.5mins. This will be supplemented by 4 trains per hour in the peak between Balbriggan – Hazelhatch and Clongriffin – Hazelhatch. This will provide a total service through the DART Underground tunnel of 16 trains in the peak hour (3.75 minutes frequency).*
*** Diesel operated services*

Appendix 2 – Changes in response to the business case audit

The initial business case produced by IE was audited by Goodbody Economic Consultants in July 2008. Overall the audit report concluded that the approach to the cost-benefit analysis was sound, but it highlighted a number of issues to address. Table A 8 summarises the issues and how they have been dealt with in this updated business case.

Table A 8: Issues arising from business case audit and action taken

Issue	Comment in business case audit	Action taken for updated business case
Public transport time savings	"The method of assessing time savings to existing and new passengers is weak and contains a number of calculation errors"; "Time savings are largely based on guesstimates rather than the outputs of the demand modelling process"	The time savings benefits are now fully based on modelling by the NTA.
	"Different values for walking, waiting and in-vehicle time are not employed"	The modelling includes weighted generalised costs for public transport users, taking into account the different journey elements such as walk, wait and in-vehicle time, boarding penalties, transfer penalties and crowding.
	"There is a logical problem with the estimate of benefits arising to new passengers, as these are assumed to be in excess of those for existing passengers, as the rule of one-half is not applied to benefits to new passengers"	The rule of half is now applied for benefits to new passengers.
Highway congestion relief	"Decongestion benefits are not based on a modelling of network impacts for the InterConnector, but on data gathered for decongestion estimates applying to other networks"	This has now been addressed by the NTA, with the modelling including generalised costs for highway; this is used to estimate the highway congestion relief benefit.
Demand and service levels	"There is an apparent mismatch between the demand which the InterConnector will cater for and the service levels assumed. There is a need to ensure that service levels sufficient to cater for demand are proposed and that operating costs are calculated accordingly"	Analysis of appropriate service levels has been undertaken; see Appendix 1 for details.
Sensitivity tests	"The sensitivity test should be expanded to include the effect of lower than expected time savings for rail travellers and decongestion benefits for road users"	Several sensitivity tests have been undertaken and the results are shown in chapter 7. This includes an assessment of the business case if no population and employment growth is assumed after 2007, leading to the transport benefits being approximately 30% lower than in the base case. The BCR for that test is 1.71.
Wider impacts	"In view of the scale of the project the "other" economic effects could be significant and some estimate of the scale of these should be prepared"	Substantial work has now been undertaken to estimate the Wider Economic Benefits of DART Underground. This is summarised in chapter 4.

Patronage forecasts	"The review of patronage forecasting has raised a number of points that should be addressed. In particular: - Confirmation of why only one InterConnector forecast year was adopted; - Explanation of a seeming discrepancy in Figure 21 of the Business Case with regard to the Do Minimum and InterConnector patronage levels; - Derivation of the pre-2016 per annum growth trends; and - Analysis underpinning the selection of the post 2016 Do Minimum and InterConnector growth trends"	The latest modelling by the NTA provides results for three years – 2016, 2020 and 2030 – in addition to the 2007 base year. There is no longer a discrepancy in the opening year – patronage is higher in the Do Something than the Do Minimum from the opening year onwards. Growth trends are discussed in chapter 2. There is assumed to be no growth beyond 2030.

Appendix 3 – Tables in 2002 prices

The figures presented in the main body of the report are in 2009 prices and, where applicable, are discounted to 2009 when estimated as a Present Value.

The DoT guidance recommends that 2002 is used as the base year for pricing and discounting. In this Appendix the key tables from the report are replicated, using 2002 as the base year.

Table A 9: Financial impacts of DART Underground (compares with Table 6.1)

	€m, 2002 prices
Capital costs	[Figures Deleted
Operating costs	
Maintenance	
Renewals	
Revenue	1,356
NET FINANCIAL IMPACT	

Table A 10: Transport benefits and costs of DART Underground (compares with Table 6.2)

	€m, 2002 prices
User benefits	
PT uncrowded time savings	[Figures Deleted
PT congestion relief	
Highway congestion relief	
Vehicle operating costs	
Other benefits	
Accidents	
Emissions	
TOTAL TRANSPORT BENEFITS	
Capital costs	
Operating costs	
Maintenance and renewals	
TOTAL COSTS	
NET PRESENT VALUE	
BENEFIT / COST RATIO	2.39
INTERNAL RATE OF RETURN	9.54%

Table A 11: Transport / Wider Economic Benefits and costs of DART Underground (compares with Table 6.3)

	€m, 2002 prices
User benefits	
PT uncrowded time savings	[Figures Deleted
PT congestion relief	
Highway congestion relief	
Vehicle operating costs	
Other benefits	
Accidents	
Emissions	
Total transport benefits	
Pure agglomeration	
Move to more productive jobs	
Imperfect competition	
Labour force participation	
Total Wider Economic Benefits	
TOTAL BENEFITS	
Capital costs	
Operating costs	
Maintenance and renewals	
TOTAL COSTS	
NET PRESENT VALUE	
BENEFIT / COST RATIO	4.04
INTERNAL RATE OF RETURN	13.54%

Table A 12: Sensitivity test results (compares with Table S 5)

Test	Net Present Value (€bn, PV)	Benefit/Cost Ratio
Base (moderate growth)	[Figures Deleted	2.4
No growth		1.7
High growth		3.2
Scheme delay		2.2
30 year appraisal		1.7
Most pessimistic		1.1

Appendix 4 – Scheme history

History of the scheme

Córas Iompair Éireann (CIÉ) has been considering an underground system in Dublin since the early 1970s when they undertook some extensive land use and transport planning studies following the publication by An Foras Forbartha Teoranta of the Dublin Transportation Study in 1972 (AFFT, 1972).

This report proposed the creation of four new towns in the Greater Dublin Area ie Lucan, Clondalkin, Tallaght and Blanchardstown and recommended that CIÉ review transportation options to facilitate such growth. Following the publication of this report, CIÉ prepared the 1975 Dublin Rapid Rail Transit Study (DRRTS) (CIÉ, 1975).

The DRRTS set out a four phase approach to expanding the city rail network to the suburbs, as follows:

- Phase 1 comprised the upgrade and electrification of the Northern Line and Southeastern Line from Howth to Bray (DART).
- Phase 2 comprised the development of a tunnel from Connolly to Heuston. From Heuston the lines would extend to Fox and Geese with a spur extending to Tallaght. This stage would also include the construction of rapid transit tracks alongside the main railway from Heuston to Clondalkin.
- Phase 3 comprised the development of a spur off the Maynooth (Northwestern) Line to serve Blanchardstown Shopping Centre and connecting to the city via the old railway alignment to Broadstone Station. This phase also included the development of a branch off the new Blanchardstown line to serve the Finglas/Ballymun area and provide an opportunity for extension to the airport at a later stage.
- Phase 4 comprised the development of services to the south-east central area with a tunnelled railway from Broadstone to Sandymount serving underground stations at Grafton Street, Baggot Street and Ballsbridge. An extension of the Phase 2 line from Fox and Geese to Ronanstown was to be constructed concurrently.

Phase 1 was completed in 1984.

Phase 2 was partially advanced in the early 1980s in that property was acquired along the proposed route. However, the onset of an economic decline adversely affected the progression of CIÉ's plans and the four phase approach was not developed beyond this point. Some of the lands acquired at that time were eventually used for the Luas Red line.

Following this period, the Department of Transport published the Dublin Transport Initiative (DoT, 1995). This government policy was an integrated transportation strategy for the Greater Dublin Area for the period up to 2011.

The strategy proposed maximising use of the existing network and focusing future investment on the development of a light rail network instead of on heavy rail. The constructions of the Luas Green and Red lines were outcomes of this strategy.

In 1999, during a period of unprecedented economic growth in the Greater Dublin Area, CIÉ commissioned Ove Arup and Partners to assess a number of rail transport options for Dublin City and identify which schemes should be considered as part of a plan for developing the network up to 2020. This included several key tasks:

- Review of existing suburban rail network and operations.

- Assess the impact of committed schemes and firm proposals already identified for the period up to the year 2006.
- Identify the range of realistic rail improvements that could form the 2020 vision.
- Assess in broad terms the engineering feasibility of the identified rail schemes including outline capital costs.
- Produce preliminary patronage and revenue forecasts for the identified rail schemes for input into an outline financial and economic evaluation.
- Rank the schemes according to criteria agreed with CIÉ and recommend an implementation programme.
- Review the options for funding these schemes.

The assessment of these key tasks resulted in the publication of the Dublin Suburban Rail Strategic Review (Arup, 2000) which proposed and developed the idea of an east–west DART Underground route (originally known as the Interconnector). This assessment concluded that there were severe capacity constraints on three of the four suburban rail corridors into the city, the Northern Line, the Kildare Line and the Northwestern (Maynooth) Line. Six options were considered for improving capacity and passenger service:

- Phoenix Park Line – divert Kildare Line trains to Connolly Station.
- North-South Suburban Line Upgrade – maximise capacity on the existing north-south network.
- Loop Line Quadrupling – Widen the Connolly to Barrow Street section and other measures.
- Broadstone Tunnel Loop – Maynooth (Northwestern) Line trains in a tunnelled loop from Broadstone to Connolly and back with stops at Spencer Dock and Pearse.
- Heuston Tunnel Loop – Kildare line extended in a tunnelled loop from Heuston to Connolly and back with stops at Spencer Dock and Pearse.
- East to West Tunnel – Tunnel link between the Kildare line and the Northwestern and/or Northern Line.

An evaluation of the options was carried out by assigning a ranking to each option under fourteen different criteria which included, amongst others, environmental factors, catchment, development opportunities and cost.

The results showed significantly higher scores for the three tunnelled options with the East–West tunnel emerging with the highest ranking.

The report concluded that more city centre capacity was required in order to facilitate the expansion of the network, through the development of high quality, rail-based public transportation links between the development centres and the metropolitan area, in accordance with the Strategic Planning Guidelines for the Greater Dublin Area (Dublin Corporation, 1999).

The preferred option for achieving this increased capacity was through the provision of an East–West Tunnel linking the Northern and/or Northwestern Suburban Lines with the Kildare Lines.

Other recommendations included upgrades to the existing network, construction of new rail links, removal of existing constraints and electrification of lines from Maynooth and Sallins/Kildare.

The Interconnector concept (DART Underground) was endorsed in 2001 with the publication of the Dublin Transportation Office Policy Document entitled A Platform for Change (DTO, 2001). Within this document there were a number of transport strategies considered in the evaluation and development of a final adopted integrated transport plan for the Greater Dublin Area.

The starting point for the evaluation was the development of a baseline Do Minimum model scenario. This scenario included for the following elements:

- Luas line from Tallaght to Connolly Station.
- Luas line from Sandyford to St. Stephen's Green.

- The completed M50 motorway.
- The Dublin Port Tunnel.
- Eleven Quality Bus Corridors.
- DART extension to Malahide and Greystones.
- Upgrade of Maynooth line from Clonsilla to Connolly.
- Lengthening of platforms and additional DART and diesel rail-cars.

The results of the Do Minimum scenario testing indicated that, because of a huge increase in overall trip demand, there would be a demand for an additional 135,000 trips by car which would lead to severe congestion on the highway network. The report concluded the following:

"It is clear, therefore, that a major transportation deficit will exist in 2016 unless further transportation infrastructure is provided and measures to reduce car travel are introduced. The severe congestion on the transport networks in the Do-minimum scenario causes a diversion of trips from routes that are normally shortest and quickest to routes that involve significant detours avoiding congested areas."

A further scenario was then tested based on the Strategic Planning Guidelines, called the Do-Strategic Planning Guidelines Scenario. This scenario included for the following additional transport infrastructure projects:

- Luas lines D and E (Ballymun to Broadstone and Broadstone to St Stephen's Green).
- M50 enhancements.
- Dualling the N2 and N3.
- Macken Street bridge.
- Phoenix Park rail tunnel.
- Rail line to Navan.
- Additional QBCs and extensions of existing QBCs.

The findings of the Do-Strategic Planning Guidelines Scenario test run were considered beneficial in terms of significant increases in trips by rail (37,000 trips) and a small reduction in trips by car (4,000 trips) by 2016.

The guiding concept for the strategy development included for the following concepts;

- The provision of a quality public transport system that is within walking distance of the origins and destinations of the majority of trips in the urban area (ie a walk and ride network).
- The development of a comprehensive cycle network designed to encourage greater use of bicycles.
- The improvement of pedestrian facilities to create a safer walking environment for short journeys to work, school or shops and for access to public transport.

Three different approaches to strategy development were then evaluated: Bottom Up, Middle Road and Top Down. These are described as follows:

- Bottom Up: Public transport lines were incrementally added to the existing networks (light rail, heavy rail and bus). Several transport networks were constructed by systematically adding light rail and heavy rail lines to the Do Minimum network, and these networks were tested using the DTO Model. However, none of these tests represented a transportation solution and this methodology proved unsatisfactory as a development tool for arriving at the final recommended strategy.
- Middle Road: Given the difficulties encountered with the Bottom Up approach, the next method tried was to take the Do Minimum road and rail networks and to test whether a major enhancement of the bus system could deal with the anticipated demand. This comprehensive bus option assumed a dense network of bus routes that would satisfy the walk and ride criterion. The network contained four orbital and fifteen radial Quality Bus Corridors with a comprehensive range of frequent

bus services on each route allowing most trips to be made with, at most, one interchange. The DTO Transportation Model was used to analyse the performance of this scenario. The report concludes:

"In summary, the analysis of the 'Comprehensive Bus' scenario established that buses alone could not address the problem because in many of the main transportation corridors the bus mode cannot provide the necessary capacity to cope with the forecast demand. However, the assessment showed that if the bus network were more comprehensive than currently and if it offered extensive coverage over the Greater Dublin Area, it would be well used and it would attract significant transfers from car"

- Top Down: The starting point, again, for this third method was that an extensive public transport network was required to meet the walk and ride criterion. For the purposes of this Top Down approach the entire higher mode network as modelled was assumed to have the characteristics of a heavy rail or Metro type system. In practice, the levels of passenger demand output by the model would not justify building such a tight mesh of heavy rail or Metro lines involving hundreds of kilometres of rail. In reality, a mix of public transport modes, including quality bus and light rail, would represent a more realistic network. It was concluded that the higher mode network tested in the Top Down approach satisfied the walk & ride criterion. Such a high quality, high capacity public transport network would provide a viable alternative to the car for most trips and hence would attract large volumes of car users onto more sustainable modes.

The DTO Transportation Model was used to assign the travel demand to the theoretical public transport network. The range of trip levels on each transportation corridor immediately indicated a need to consider a full hierarchy of public transport modes from conventional bus at the lower end to heavy rail at the upper end. The following public transport modes were considered in developing the public transport network:

- DART/heavy rail.
- Luas (surface running light rail).
- Metro (ie light rail that is completely segregated along its alignment).
- Bus and Quality Bus Corridors.

Using these general conclusions, three separate themes (Metro, heavy rail and on-street light rail) were developed to deliver the required rail network using different combinations of rail modes. Each theme included the same highway improvements and greatly enhanced QBC and bus networks.

The heavy rail theme included the underground interconnector in the city centre linking Heuston Station, Pearse Station and East Wall, which was taken from the Dublin Suburban Rail Strategic Review (Arup, 2000).

Emerging from the above was a preferred strategy, known as Strategy 4, which incorporated into the assessment information from the Dublin Suburban Rail Strategic Review (Arup, 2000) and the Bus Network Strategy Appraisal for the Greater Dublin Area (CIÉ, 2000). Strategy conclusions at this stage included in particular that:

- The east-west heavy rail underground interconnector (as proposed in the Dublin Suburban Rail Strategic Review (Arup, 2000)) was the best way to satisfy the strong east-west passenger demand in the city centre and to provide a link between the Maynooth and Kildare lines. This inter-connector also interchanges with the north-south suburban rail line at Pearse and again north of Connolly station and hence provides a high degree of flexibility for the provision of services and route variants on the entire heavy rail system.
- Though the Phoenix Park Tunnel does bring Kildare line passengers somewhat closer to the city centre than Heuston, it bypasses the important south-east inner city business area. In addition, it reduces the capacity on the Maynooth line for

services from Maynooth and Navan, does not resolve the capacity problems of the Loop Line and brings Kildare trains on a circuitous route to the city centre (taking in excess of fifteen minutes from Heuston to Connolly). For these reasons, the Phoenix Park Tunnel was excluded.

Strategy 4 was further refined as Strategy 5 (renamed Strategy A), while a second strategy, Strategy B (an option based on Strategy A that did not contain the Metro and instead incorporated the rail extensions developed by the Dublin Suburban Rail Strategic Review (Arup, 2000) as an alternative) was also evaluated as a comparator. Strategy A was considered to be:

"more compatible with the development of a sustainable economy, provides higher levels of accessibility for non-car users, caters better for long term transport needs, and is more in keeping with land use planning aspirations"

Strategy A was subjected to further sensitivity tests, in terms of higher and lower economic growth scenarios.

The overall conclusion of A Platform for Change (DTO, 2001) was the need for an integrated public transport network comprising public bus services, DART (heavy rail) existing and proposed underground, Luas (light rail) and Metro (City Centre to Airport).

Within the specific DART/suburban rail strategy it is noted that:

> *"The centrepiece of the DART/suburban rail strategy is an underground interconnector linking Heuston Station with East Wall junction north of Connolly Station, via the south inner city, Pearse Station and Docklands. This interconnector allows for through running from the Kildare line to the Maynooth line and/or the Dundalk line. It provides a bypass of the existing severe bottleneck approaching Connolly Station; it serves areas of high demand, especially the south-east inner city and Docklands; and it allows for the maximum use of the Maynooth and Kildare lines. The tunnel will be too long and will have too many underground stations to allow diesel trains. Therefore, both the Maynooth and Kildare lines will be electrified so that these services can run via the tunnel. This, in effect, will be a major extension of the present DART system. The interconnector will transform the DART/suburban rail system from one with severe constraints in terms of capacity and accessibility to a system that has a well balanced high capacity, that is operationally very efficient and that penetrates all the major areas of demand in the city centre"*

After publication of A Platform for Change (DTO, 2001), the Interconnector became a project (DART Underground Project). At this stage, station locations were considered in greater detail and route alignment options were developed.

DART Underground was confirmed in November 2005 as part of Transport 21. Transport 21 sets out a ten-year transport investment framework costing just over €34 billion and covering Exchequer and PPP capital investment in national roads, public transport and regional airports from 2006 to 2015.

The need for DART Underground, as the crucial missing link in the wider public transport network, is well established on a number of fronts and recognised in a number of key land-use and transportation policies. DART Underground is a major driver of sustainable development, better customer service, and more efficient rail operations. In addition DART Underground will unlock many legacy bottlenecks on the rail network in the Greater Dublin Area providing significant regional and inter-regional benefits.

The objectives of the scheme are presented below. There are two levels of objectives, primary and secondary.

- Primary Objectives:

- Assist in the delivery of the national transportation strategy by increasing the passenger carrying capacity on the Northern and Heuston (Kildare) main lines.
- Improve the economy, integration and efficiency of transportation, by increasing the use of public transport.

- Secondary Objectives:
  - Support the national spatial objectives by encouraging economic growth and improving quality of life and the environment.
  - Support the Dublin City Council sustainable development and regeneration objectives including a better balance of development in the city centre by improving accessibility and transport integration.
  - Provide for the integration of the National and Greater Dublin Area Rail Networks (including Intercity, Commuter, DART, Luas and Metro).
  - Provide a rail route that penetrates all the major areas of demand in the city centre, facilitate CIÉ's capacity enhancement work programme established to respond to anticipated passenger demands and the national transportation strategy, by linking the Northern and Heuston (Kildare) main lines. This programme of works includes, in addition to DART Underground:

i. The extension of the Kildare Route 4 tracking.

ii. Signalling improvements.

iii. The extension of the electrified network.

iv. Additional fleet and associated maintenance facilities.

v. The provision of a Train Control System.

Scheme design

The history of the development and design of DART Underground thus far can be categorised into three distinct phases as follows:

- Phase 1: In 2002, Parsons Brinckerhoff Ireland Ltd. (PB) was commissioned by CIÉ to examine various permutations of the east-west alignment recommended in the Dublin Suburban Rail Strategic Review (Arup, 2000) and to look at optimum station locations.

  The Phase 1 assessment comprised three stages between 2002 and 2003:

  Stage 1 comprised the collation of data, the establishment of standards and constraints, the generation of feasible alignments and the identification of three alignments for further development and comparison. Stage 2 developed, compared and contrasted the three DART Underground route options generated in Stage 1 to determine an identified alignment for detailed development. Finally, the Stage 3 process further developed, refined and costed the identified alignment.

- Phase 2 (Preliminary Design): In 2006, Mott MacDonald Pettit Ireland (MPI) was commissioned by CIÉ to undertake the feasibility (or preliminary) design for DART Underground. They also identified issues to be addressed in more detail in the next project phase, the Reference Design.

  As part of the preliminary design, alternatives for various aspects of the scheme were reviewed. The route alignment and station options identified in the Phase 1 reports were reviewed and in conjunction with CIÉ and stakeholders the preferred route and station options were identified. The Phase 2 assessment also included a review of constraints, tunnel type (single bore versus twin bore) and construction

methodologies considered. Finally alternatives were also reviewed for the East Wall Tie-in.

- Phase 3 (Reference Design): In September 2008, Arup Halcrow Joint Venture (AHJV) was commissioned by CIÉ to undertake the reference design for the DART Underground project which culminated in the preparation of the Railway Order Application.

  During this phase the DART Underground team revisited some of the fundamental decisions made during the earlier phases including:

  Mono Bore v Twin Bore

  The team verified the decision to progress the design on the basis of twin bore (two tunnels) based on cost, risk and safety criteria.

  The Use of the Phoenix Park Tunnel

  The team re-assessed the Phoenix Park option and concluded that the use of the tunnel does not satisfy the objectives of the project in that:

  1. The Maynooth line does not have the capacity to facilitate the additional traffic.

  2. The capacity constraints to the Northern and Kildare lines are not relieved:

  3. The proposal takes commuters away from the target destinations, namely Docklands and South Inner City.

  4. The proposal does not provide for integration with the Luas and Metro railway networks.

  Location of the Tie-in on the Kildare line

  Following design development works, the impact on the railway operations and city traffic was re-evaluated and it was concluded that there were environmental benefits in moving the tie-in to the Kildare Line west to Inchicore.

  Pearse Station

  Following a review of the potential impacts of residents in the area of Pearse Station it was concluded that the station concourse should be relocated east of the Phase 2 proposed position.

Appendix 5 - Glossary

Table A 13: Glossary of key non-financial terms used in the Business Case

Term	Definition
Rule of a Half	An accepted economic principle whereby the full time saving benefit from a new transport scheme is applied to existing passengers but only half is applied to new passengers.
Decongestion	A highway congestion relief benefit attributed to the impact of a new transport scheme eg DART Underground resulting from a transfer from road to rail.
Generalised Cost	The sum of monetary and non-monetary costs of a journey. Monetary costs are 'out of pocket' costs for example fares whereas non-monetary costs refer to the time spent undertaking the journey including a weighting applied to walk and wait times and an allowance for overcrowding.
Value of Time (VoT)	The value of time is the opportunity cost of the time that a traveller spends on a journey. In essence this makes it the amount that a traveller would accept as compensation for lost time. Values of time are used to calculate the non-monetary costs incurred as part of a journey and have different values depending on whether the trip is for leisure, commuting or in the course of business.
Annualisation	Factoring of periodic data to represent a yearly estimate.
Wider Economic Benefits (WEBs)	Indirect impacts transport can have on transport in markets that are not perfectly competitive. Traditionally these were excluded from the appraisal of transport schemes but are now included in the latest CAF guidelines. In particular they recognise links between employment density and productivity.
Pure Agglomeration	A component of WEBs referring to the external productivity gains arising from increased accessibility between existing businesses / employees as a result of new transport schemes.
Move to More Productive Jobs	A component of WEBs valuing the impact of new transport schemes overcoming existing capacity constraints on central areas thereby enabling employment growth.
Labour Force Participation	A component of WEBs which reflects the impact of reduced commuting costs arising on labour force participation rates.
Imperfect Competition	A component of WEBs reflecting that in imperfect markets output is artificially restrained and reducing transport costs has additional economic benefits.