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ARUP

## **Table of Contents**

Execu	ıtive Sumı	mary	vii
1.0	Introduction		
2.0	Metho	Methodology	
	2.1 2.2 2.3 2.4	Overview of the Study Area Study Phases Principal Features along the Study Area Soils, Geology and Hydrogeology	3 5 5 21
3.0	Compl	Compliance Requirements	
	3.1 3.2 3.3	Design and Operating Principles Tunnel and Station Design Standards Fire Strategy	35 37 37
4.0	Phase	1: Surveys and Data	39
	4.1 4.2 4.3	Data Collection Topographical Surveys Geological and Geotechnical Surveys	39 41 41
5.0	Phase	Phase 1: Brainstorming to Identify Possible Options	
	5.1 5.2 5.3 5.4 5.5	Settlement Analysis and Damage Classification Compensation Grouting in Glacial Sands and Gravels Launching a large diameter TBM with shallow ground cover Non-Compliant Potential Solutions Summary of Outcome of Brainstorming	45 45 47 47 53
6.0	Phase	Phase 2: Identification and Evaluation of Options	
	6.1 6.2 6.3 6.4 6.5 6.6	Criteria for Evaluation of Possible Options  Metrics for Evaluation  Evaluation of Identified Possible Options  Description of Identified Possible Options  Summary of Evaluation of Identified Possible Options  Summary of Options Advancing to Phase 3  Multi-Criteria Assessment	55 57 57 57 118
			. — .

7.0	Phase 3	3: Methodology for Multi-Criteria Assessment	129
	7.1 7.2 7.3 7.4	Assessment Criteria Criteria Scoped Out Proposed Criteria for Comparative Assessment Comparative Ranking System	129 131 133 133
8.0	Phase 3	3: Construction Planning and Worksites	135
	8.1 8.2 8.3 8.4 8.5 8.6 8.7	Option Twin 1AS Construction Planning Option 3AS Construction Planning Option Twin 2C Construction Planning Option Twin 3C Option Twin 1E Option Mono 2E Option Twin 2F	137 151 159 167 171 172 175
9.0	Phase 3	3: Overview of MCA Criteria	183
	9.1 9.2 9.3 9.4 9.5 9.6 9.7	Capital Cost Interchange Traffic & Transportation Accessibility Landscape & Visual Archaeology, Architectural and Cultural Heritage Settlement	183 183 185 185 185 189 197
10.0	Phase 3: Methodology for Preparing MCA Feasibility Working Cost Estimates		
	10.1 10.2 10.3 10.4 10.5 10.6	Basis of Cost Estimate Quantities derived for the Feasibility Working Cost Estimate Construction Inflation Adjustment to reflect Level of Design Development Feasibility Working Cost Estimates Concept Engineering Design Feasibility Working Cost Estimate	199 200 200 202 203 203
11.0	Phase 3: Multi-Criteria Assessment of Options		205
	11.1 11.2 11.3 11.4 11.5	Economy Integration Accessibility and Social Inclusion Environment Overall Summary of Multi-Criteria Assessment	207 209 213 215 223

12.0	Phase 4	4: Concept Engineering Design of Emerging Preferred Option	225
	12.1	Overview of Concept Design	225
	12.2	Alignment Objectives	232
	12.3	Iarnród Éireann Track Design Standards	232
	12.4	DART System Requirements	233
	12.5	Key Constraints along Route	233
	12.6	Track Design Speeds and Horizontal Geometry Requirements	235
	12.7	Track Cant	237
	12.8	Vertical Track Geometry	241
	12.9	Horizontal and Vertical Geometry at Stations	243
	12.10	Track and Structure Clearances	243
	12.11	Rolling Stock	245
	12.12	Further Alignment Work Required	247
	12.13	Potential Options for Future Development of the Alignment	247
13.0	Phase 4	4: Feasibility Working Cost Estimate of the Emerging	
	Preferre	ed Option	249
	13.1	Running Tunnels	249
	13.2	Cross Passages and Platform Tunnels	251
	13.3	Tunnel Portals and Approach Structures	253
	13.4	Contractor's Overhead, Profit and Bonds	253
	13.5	Feasibility Working Cost Estimate	253
	13.6	Additional Costs due to Disposal	253
14.0	Conclu	sions & Recommendations	255
	14.1	Brief and Objectives	255
	14.2	Options Identification and Assessment	255
	14.3	Concept Engineering and Feasibility Working Cost Estimate	256
	14.4	Recommendations	257



#### References

#### Appendix A

Tunnel and Design Standards

#### Appendix B

Plan Alignment and Profile Drawings for Identified Possible Options

#### Appendix C

Qualitative Assessment of Identified Possible Options

#### Appendix D

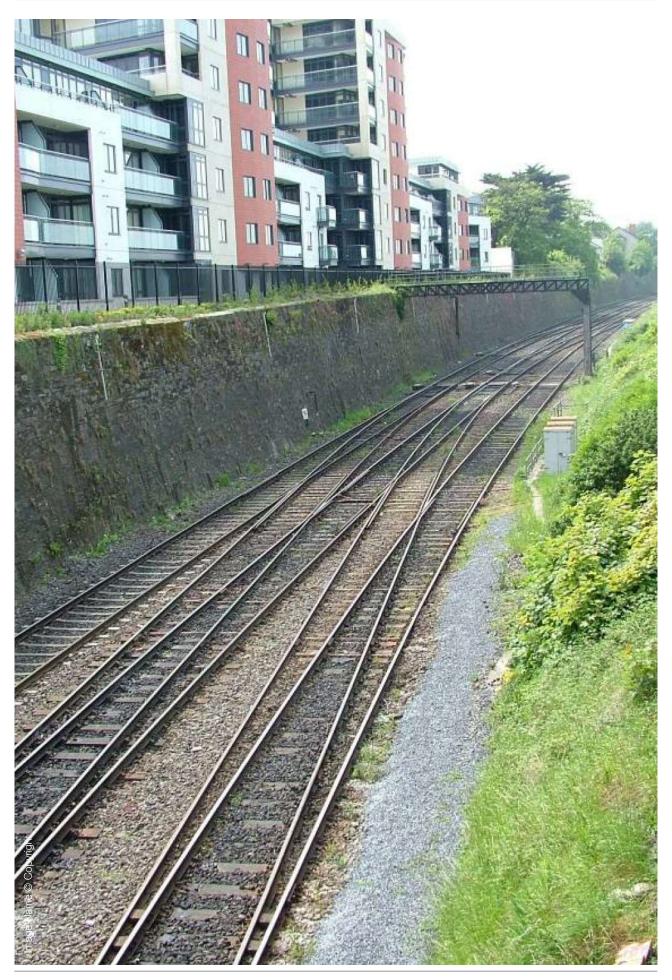
Feasibility Working Cost Estimate of MCA Options

#### Appendix E

Multi-Criteria Assessment of Options

#### Appendix F

Emerging Preferred Option Feasibility Working Cost Estimate



# **Executive Summary**



### **Executive Summary**

The National Transport Authority in collaboration with larnród Éireann has commissioned Arup to evaluate possible connection options to link the proposed DART Underground tunnel project to the existing surface rail line serving Heuston Station, entitled the Heuston Mainline.

This proposed connection is referred to as the "Western Tie-in" and covers an area from Watling Street in the east to Park West / Cherry Orchard Station in the west.

This report outlines the methodology developed to undertake the DART Underground Western Tie-In Study, presents the possible options identified, and describes the Multi-Criteria Assessment undertaken of the feasible and practicable options, which has resulted in the emergence of a "Preferred Option".

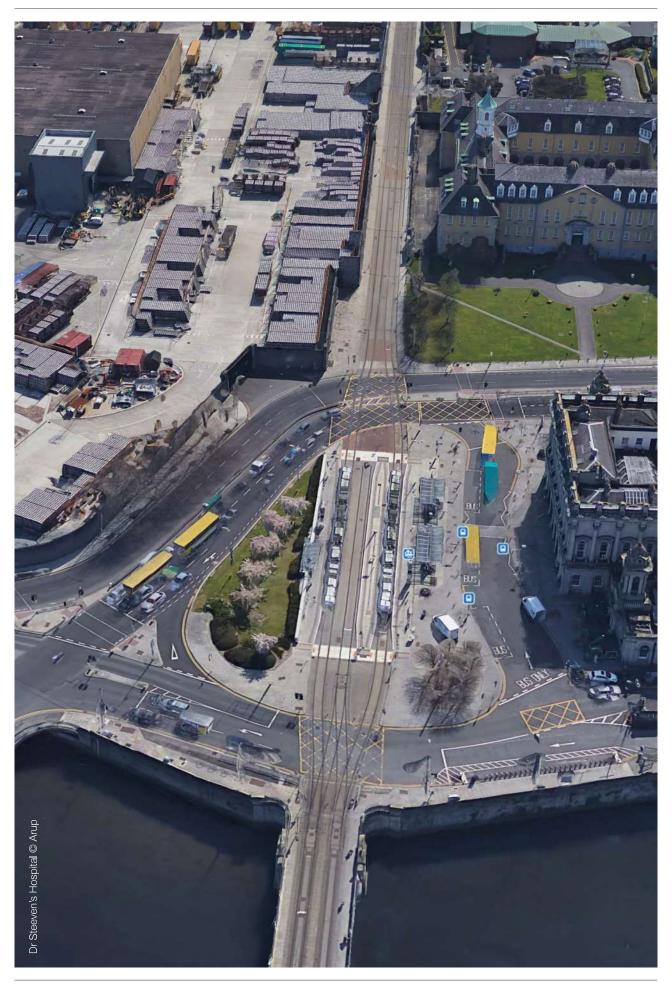
The Study considers various options for a new underground station at Heuston, facilitating either through running connection onto the Heuston Mainline or terminating underground with passenger interchange with the existing Heuston surface station.

The Study has been undertaken in four distinct phases. Phase 1 covers the initial data collection, review of regulatory, technical and operational requirements, brainstorming potential solutions and the sifting of these potential solutions to identify possible options.

Phase 2 of the Study entailed the development and evaluation of a horizontal and vertical rail alignment of each possible option to identify which possible options are both feasible and practicable. In Phase 3 of the Study, a Multi-Criteria Assessment (MCA) was undertaken to comparatively assess the feasible and practicable options against a number of criteria, including Economy, Integration, Accessibility and Social Inclusion, and the Environment. This Multi-Criteria Assessment approach resulted in each feasible and practicable option being ranked under each of the principal criteria and facilitated the emergence of a "Preferred Option".

The Emerging Preferred Option identified from the MCA comparative assessment, proposes a through running connection onto the Heuston Mainline, occurring immediately east of the existing Sarsfield Road Underbridge and four track widening of the existing rail corridor until the end of the previously completed Kildare Route Project Phase 1. A twin bore tunnel configuration is recommended with the tunnel portal sited on the Ballyfermot approach to the junction of the Chapelizod Bypass and the Con Colbert Road. Furthermore, a surface rail station is proposed at Kylemore Road to replace the previously proposed Inchicore Station.

The Emerging Preferred Option was found to offer significant advantages over all other feasible and practicable options, with respect to the criteria of Economy and the Environment. Furthermore, the Emerging Preferred Option also has some advantages over all other options except for the option in which the original DART Underground has been optimised in respect of the principal criterion of Integration.



In Phase 4 of the Study, a Concept Engineering Design has been undertaken of the Emerging Preferred Option together with the Feasibility Working Cost Estimate. The estimated cost of the Emerging Preferred Option in 2017 prices is €801.4 Million, which represents an estimated €228.4 Million saving over the combined, base inflated to 2017, optimised version of the original DART Underground and Kildare Route Project Phase 2 cost estimates.

Following the outcome of these future studies and assuming that the Emerging Preferred Option is re-affirmed as the most appropriate solution for the Western Tie-In, the Study has made a number of recommendations, which will further enable the impacts of the proposed option and landtake requirements to be minimised.

This cost saving from the original DART Underground has only been made possible by a change in the proposed operation of the running tracks from the time of the original DART Underground. By running the track configuration as a Slow, Slow, Fast, Fast configuration from the tunnel portal to the end of the Kildare Route Project, Phase 1, it has been possible to develop alternative solutions which avoid significant impacts to the assets and operations of the CIÉ Inchicore Works. In doing so, it has been possible to develop lower cost technical solutions whilst acknowledging the loss of the opening up of the CIÉ Inchicore Area and Works to the public as a potential integrated transport interchange, which would have resulted from the original DART Underground Scheme.

It is recognised that the selection of the Emerging Preferred Option is made within the confines of the Study Area, scope and constraints of this Study. During the course of the Study, it became evident that a Transport Benefits Study and an overall route alignment options study are required to:

- validate the outcome of this Study,
- identify the optimum alignment east of Watling Street,
- confirm that a through running connection is preferable to an underground terminus arrangement, and
- endorse the recommendation of a twin bore tunnel configuration over a monotube tunnel configuration.



## 1. Introduction



### 1.0 Introduction

The Transport Strategy for the Greater Dublin Area 2016-2035<sup>[1]</sup> includes for the implementation of the DART Expansion Programme as a cornerstone of a suite of infrastructure improvements to provide an integrated, high quality public transport network to the Greater Dublin Area up to 2035 and beyond.

However, following the Revised Business Case for the DART Expansion in 2015 [2] and subsequent review undertaken by the National Transport Authority (NTA), it was recommended to the Department of Transport, Tourism and Sport that the DART Underground project which remains a key element of integrated transport for the Greater Dublin Area, be redesigned to provide a lower cost technical solution, whilst retaining the required rail connectivity.

The NTA in collaboration with lamród Éireann (IÉ) has commissioned Arup to evaluate possible options and recommend a Preferred Option for linking the proposed DART Underground tunnel project to the existing surface rail line serving Heuston Station (the Heuston Mainline). This connection link, which must facilitate a passenger interchange between the DART and the existing surface train network at Heuston, is entitled the "Western Tie-In".

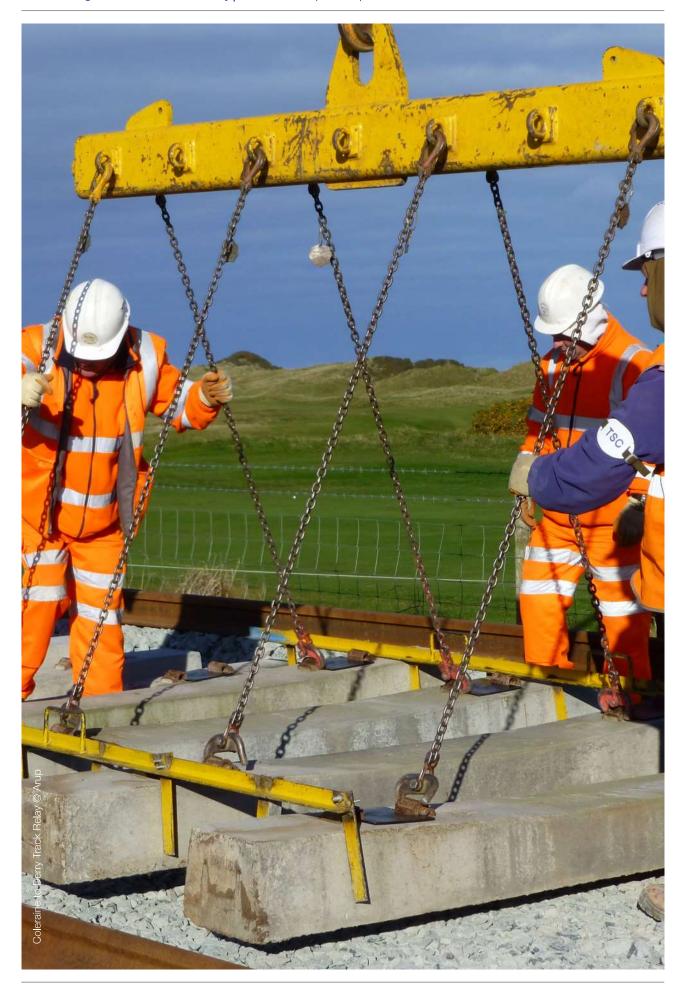
The overriding objectives of the Western Tie-In Study, which covers the area from Park West / Cherry Orchard Station in the west to Watling Street in the east, are:-

- To carry out a comprehensive and robust selection Study, identifying all feasible and practicable options;
- To develop concept designs for key relevant options;

- To carry out data collection, research, studies and appraisals necessary to support a robust and comprehensive options selection process leading to the identification of an optimal design (the Preferred Option);
- To ensure that the design west of the tunnel connection point is capable of supporting four tracks on the surface to connect with the existing four track system at Park West / Cherry Orchard Station;
- To ensure that the design facilitates passenger interchange between DART Underground Heuston Station and the existing surface at Heuston Terminus Station;
- To prepare a concept engineering design for the Preferred Option;
- To prepare a Feasibility Working Cost for the Preferred Option.

This report describes the approach developed to identify possible options, the methodology devised to determine which options are both feasible and practicable, and how the Preferred Option was ascertained through the adoption of a Multi-Criteria Assessment (MCA).

The report then presents the details of the concept engineering design and the Feasibility Working Cost for the Preferred Option over the extent of the Study area.



# 2. Methodology



### 2.0 Methodology

#### 2.1 Overview of the Study Area

The relevant Study Area for this brief extends from the Park West / Cherry Orchard Station in the west to Watling Street in the east, encompassing the areas of Heuston Station, CIÉ Inchicore Works Depot and their environs as shown in **Figure 1**.

For the purposes of this Study, the track alignment of the DART Underground Tunnel is a variable, both horizontally and vertically, between Watling Street and the location of any proposed option to tie-in to the Heuston Mainline.

The scope of the Study considers both "Through Running" rail options in which the DART Underground tunnel ties into the Heuston Mainline and "Terminus Station" options in which the DART Underground Tunnel terminates

below ground level and facilitates an interchange at Heuston Station. In a "Terminus Station" configuration, the underground and surface rail systems are physically disconnected.

The Study examines solutions to widen the existing rail corridor to accommodate four tracks from the location of any proposed tie-in option to the Heuston Mainline, as far as the end of the previously constructed Kildare Route Project Phase 1 Works (KRP Phase 1). The end of the KRP Phase 1 four track widening of the Heuston Mainline is positioned approximately 810 metres (m) to the east of the Park West / Cherry Orchard Station. In the case of "Terminus Station" options, the Study considers the impacts of widening the Heuston Mainline to four tracks from the end of the KRP Phase 1 Works to Heuston Station.

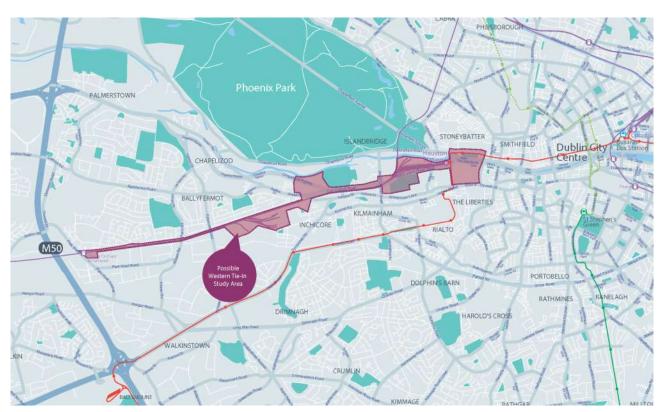
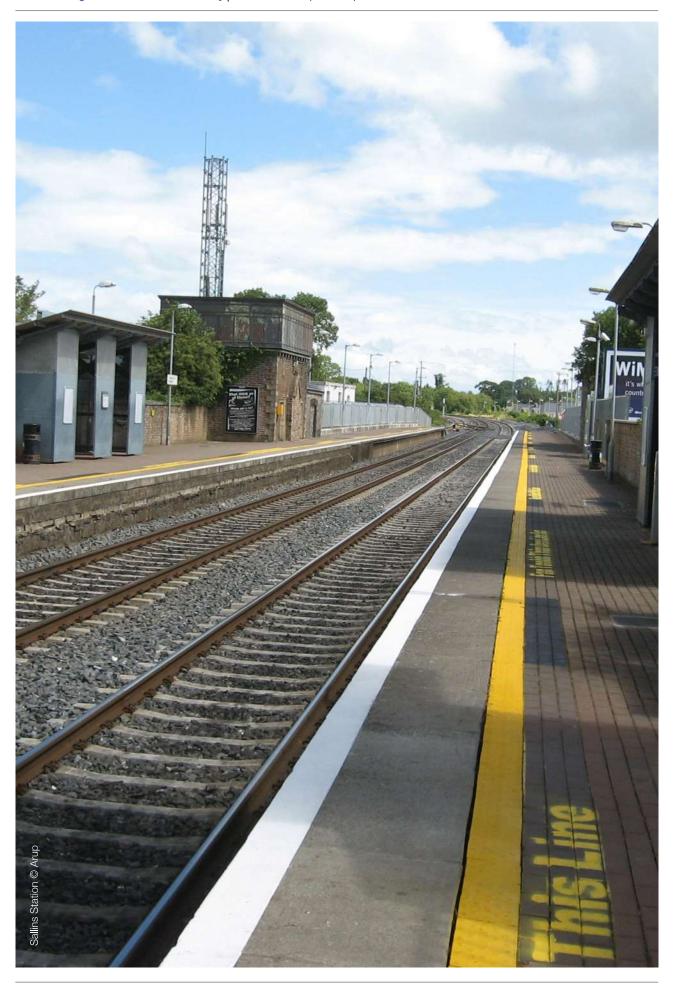


Figure 1: An overview of the Study area for the Western Tie-In



In terms of understanding and addressing impacts to rail systems and operations, consideration of the operational impacts to the rail network was extended to Adamstown Station, approximately six kilometres (km) to the west of Park West / Cherry Orchard Station. There is an existing turnback facility located at Adamstown Station with a capacity of four trains per hour per direction with through running onto the Heuston Mainline. Furthermore, there is an existing turnback facility located at Hazelhatch Station with a capacity of 12 trains per hour per direction with through running onto the Heuston Mainline.

#### 2.2 Study Phases

The methodology developed for the Western Tie-In Study is as illustrated in **Figure 2**. There are four distinct phases of the Study, entitled Review, Options Identification, Assessment of Options and Concept Engineering of Preferred Option. Within each phase of the Study, there are a number of principal tasks as identified in **Figure 2: Study Methodology**.

## 2.3 Principal Features along the Study Area

There are a number of principal features within the extent of the Study Area, which have a significant influence upon the identification of possible options to achieve the objectives of the Western Tie-In Study. The principal features considered in the Study are presented in further detail below.

#### 2.3.1 St. James' Gate Brewery

In 1759, Benjamin Guinness leased land on the south side of James's Street and began to manufacture stout and porter, which were already popular in England. In 1873, Arthur Guinness and Sons began expanding the brewery complex northward, down the hillside towards Victoria Quay.

#### **Phase 1 Review**

**Initial Data Collection** 

Review of Regulatory, Technical and Operational Requirements

Brainstorming Potential Solutions and sifting to identify Possible Options

#### **Phase 2 Options Identification**

**Develop Rail Alignment for each Option** 

**Evaluation of Identified Possible Options** 

Identify all Feasible and Practicable Route Options

#### **Phase 3 Assessment of Options**

Identification and Assessment of Key Engineering Issues

**Environmental Assessment** 

**Feasibility Working Cost Estimates** 

Multi-Criteria Assessment (MCA) of Options

#### **Phase 4 Concept Engineering**

Concept Engineering Design

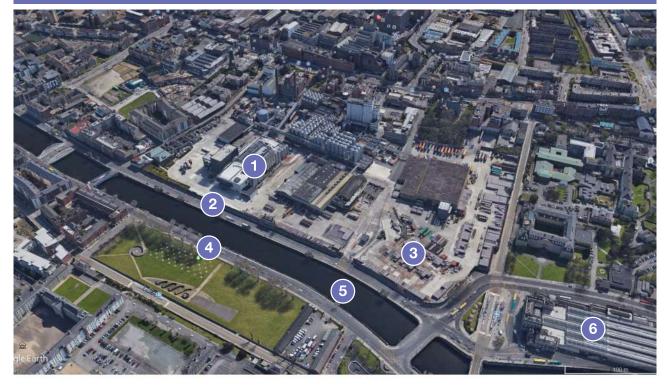
Feasibility Working Cost Estimate for Preferred Option

**Options Report & Drawings** 

Figure 2: Study Methodology

- Brewhouse No. 4
- Victoria Quay
- 3. Kegging Yard

- 4. Wolfe Tone Quay5. River Liffey
- **Heuston Station**



View of the St James' Gate Brewery adjacent to Victoria Quay and the River Liffey, with Heuston Station on the Figure 3: lower right corner of the image

- Brewhouse No. 4
- Victoria Quay
- 3. Kegging Yard

- Croppies' Acre Memorial Park
- Wolfe Tone Quay
- **River Liffey**



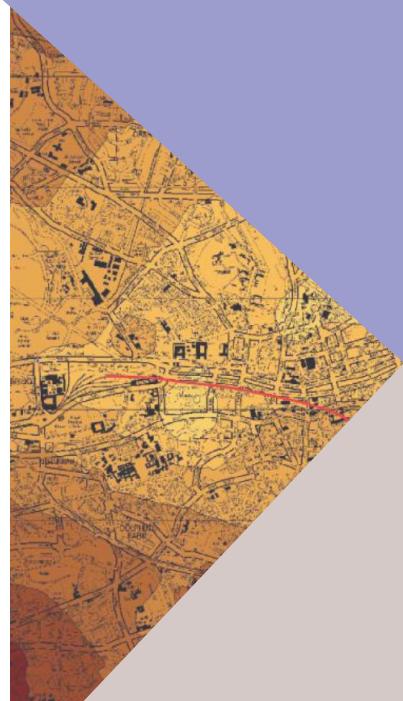
Figure 4: Croppies' Acre on the North Side of the River Liffey

In 1873, the brewery built a jetty onto Victoria Quay as a terminal for the transport of stout in barrels downstream to the Custom House Quay for transfer to seagoing vessels. The quay continued to serve as its river terminus until 1961, when road transport took over and the jetties were removed. Victoria Quay was shortened in 1982 due to the construction of the Frank Sherwin Bridge to the east of Seán Heuston Bridge.

Monitoring of extensive geotechnical investigations took place under archaeological supervision in 2008 for the original DART Underground Project. Boreholes within St. James Gate Brewery were all located close to Victoria Quay and indicated that the lands were reclaimed in the early 19th century when the River Liffey was straightened and new guays built. Up to 1.5 m below the existing ground level, material containing a number of brick walls and surfaces were sourced, below that level from 2 m - 4 m, mixed rubble and sedimentary silts including organic waste with bone and shell were revealed. This suggested that the area was close to the old shoreline as illustrated on the Rocque map of Dublin dating from 1756. Figure 3 shows the extent of the current brewery with a kegging yard located on the north-west corner of the site and the new Brewhouse No. 4 adjacent to Victoria Quay.

#### 2.3.2 Croppies' Acre

The Croppies' Acre memorial park in front of Collins Barracks (now a part of the National Museum of Ireland), is located on the north side of the River Liffey and is adjacent to Wolfe Tone Quay, see **Figure 4**. It is known as Croppies' Acre, as the remains of people executed during and after the 1798 Rising were dumped there for the incoming tide of the tidal Liffey to remove.



"Monitoring of extensive geotechnical investigations took place under archaeological supervision in 2008 for the original DART Underground Project."

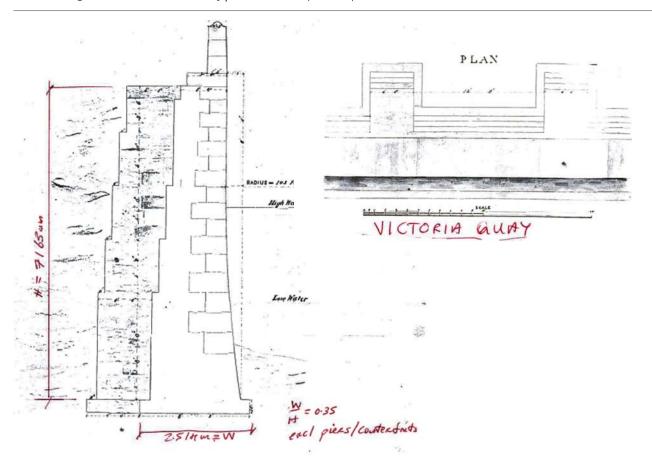


Figure 5: Construction Details Victoria Quay Wall

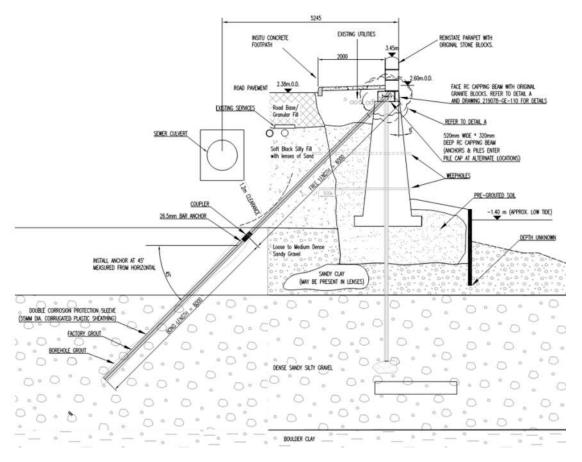


Figure 6: Cross Section of Wolfe Tone Quay strengthening works undertaken in 2012

#### 2.3.3 River Liffey

The River Liffey rises at an elevation of 540 m above sea level near Kippure in the Wicklow Mountains, approximately 20 km south of Dublin. The river forms a large arc as it flows westward, then northward, and finally eastwards through Dublin City to its confluence with the Irish Sea at Dublin Bay. It flows over a range of different geological formations; from granite, to sandstone, to sandstone—limestone and finally pure limestone. The River Liffey has a drainage catchment area of just over 1380 km².

Extensive reclamation of the river floodplain has been undertaken since the seventeenth-century. This reclamation and adaptation of the natural environment was extended to the river as it flowed through the city, the river currently being delineated by a series of eighteenth and nineteenth-century quayside structures. The River Liffey is tidal as far as Islandbridge weir, upstream of Heuston Station.

Victoria Quay was constructed in approximately 1850, see **Figure 5**, whilst Wolfe Tone Quay (formerly Albert Quay) dates from approximately 1800. Wolfe Tone Quay has been strengthened and stabilised in 2001 and 2012, using low permeation grouting, ground anchors, mini-piles and weepholes as illustrated in **Figure 6**.

The river flows have potential to influence flood levels in the vicinity of Heuston Station. The Liffey used to be prone to flooding, but the level of risk has been much reduced since the creation of several water supply reservoirs in its upland catchment. For example, the ESBi report of 1986 into Hurricane Charlie notes that what should have been a 250 year return period event on the Liffey was reduced to a 40 year flow.

The December 1954 flood event produced a flow of 155 m³/s at Celbridge, the highest recorded over a 64 year period, and 3.6 times larger than the mean annual flood. The next highest flow recorded was 89.5 m³/s. While there is considerable distortion of the lower flow record

due to the influence of the reservoirs, since the ratio between the mean annual flood and the 100 year flood is typically around 1.96, it can be reasonably assumed that this event was well in excess of the 100 year return period. While it did cause considerable flooding on the Liffey upstream of Islandbridge, no flooding was noted at Heuston Station.

There are no flood events noted for the Liffey in the vicinity of the Study Area.

The river bed level in the vicinity of Heuston Station is approximately at a level of -1.1 m above Ordnance Datum (mOD), Malin. The footpath level along the Quay Wall is at +5.7 mOD and the top of the parapet is approximately +6.7 mOD.

#### 2.3.4 Heuston Station

Kingsbridge station named after George IV was commissioned in 1846 from Sancton Wood, an English architect following a design competition. In 1966, CIÉ renamed its principal railway stations in honour of the executed leaders of the 1916 Easter Rising. Kingsbridge station was renamed in honour of Seán Heuston, who had worked in the station's office.

During construction of the station, the River Camac was culverted and carried under the new development. Later the shore of the River Liffey was walled to form a private road along the north side of the station, which presently leads to the Station Car Park, IÉ Construction Unit Offices and the through Platform 10, which is situated on the Phoenix Park tunnel line. This wall is reported by IÉ to have previously shown signs of distress with movement having occurred.

The main front of Heuston Station faces eastward towards the River Liffey and has two wings with small towers that were intended to have clocks in them. Following south, a range of offices extend along St. John's Road West, see **Figure 7**. The main passenger entrance has a handsome portecochére with eight columns. Additional office



Figure 7: View of Southern Façade of Heuston Station along St. John's Road West

accommodation, subsequently built on the north side, compliments the original building, which has the advantage of being well set back from the surrounding roadways. The interior of the station initially contained two platforms separated by five carriage sidings, but, in recent years, a two-sided central platform has been added and the sidings have been reduced to one. The overall roof covers 2.5 acres; its original 72 columns of cast iron and connecting spans are still in use, but the roof has been renewed several times.

In 1872, another platform was added on the down side, where military traffic could be handled away from the commercial trains. The goods yard was located to the north of the passenger terminal, occupying the area between the mainline and the river.

The Great Southern and Western Railway (GS and WR) became the third main railway to open in the country in the 1840s and was known as the Premier Line of Ireland. The train shed now contains nine platforms and is one of the largest early station buildings in the country and the retention of its substantial original cast-iron substructure attests to the engineering abilities of its builders.

InterCity rail services from Heuston go to and from Cork, Limerick, Waterford, Galway, Mayo and Kerry. Commuter services stop at all stations to Portlaoise on Mondays to Saturdays and Kildare on Sundays.

There are nine platforms on the station, eight terminal platforms (numbered 1 to 8) and one through platform (platform 10).

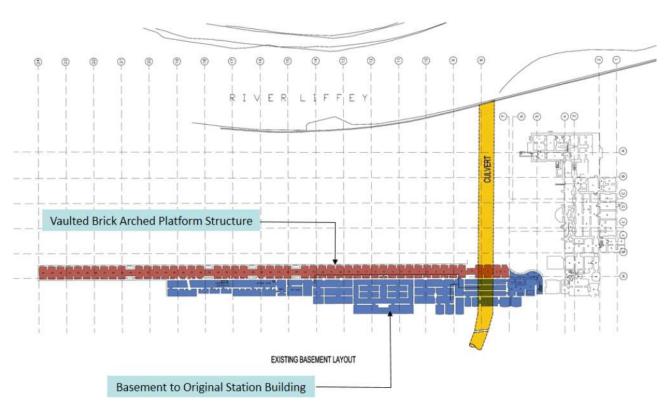


Figure 8: Heuston Station Basement showing the location of the Camac Culvert

#### 2.3.5 River Camac Culvert

The River Camac under Heuston Station is contained within a brick lined culvert, which it enters in the grounds of St Patrick's hospital, just to the South-west of Dr Steevens' Hospital, see **Figure 8**. The culvert discharges to the River Liffey just to the north of Heuston Terminus. The River Camac has flooded regularly at locations upstream of the culvert, including a period of five floods in 15 years.

The Camac River discharges into the River Liffey via an arched and grilled outfall, directly upstream (95 m) of Seán Heuston Bridge.

The culvert beneath the station and the existing River Liffey walls are significant features. Both are of historic construction and strengthening will need to be considered in advance of any tunnelling works beneath. Furthermore, Dublin City Council is obliged by the Eastern Regional Fisheries Board to maintain water quality standards for the Liffey and Camac Rivers due to their salmonid status. Any discharges to the river will have to comply with these water quality standards.

"The culvert beneath the station and the existing River Liffey walls .. strengthening will need to be considered in advance of any tunnelling works beneath"

- St. James' Gate Brewery Kegging Yard
   Dr Steevens' Hospital
   St. John's Road West

- 4. Victoria Quay

- 5. Seán Heuston Bridge
- 6. River Liffey
- 7. Heuston Station



Figure 9: Backdrop of Dr Steevens' Hospital

- 1. Royal Hospital Kilmainham
- 2. Privates and In-Pensioners Graveyard
- Bully's Acre

- 4. OB1
- 5. OB1A
- 6. Heuston Car Park
- 7. Construction Unit Offices
- 8. Heuston Yard
- 9. Platform 10
- 10. River Liffey



Figure 10: Royal Hospital Kilmainham and Bully's Acre

#### 2.3.6 Dr Steevens' Hospital

This hospital was designed by Thomas Burgh in 1718 to house the poor and sick of Dublin. The property was bequeathed by Richard Steevens to his sister Grizel. The design compliments and takes its form from the neighbouring Royal Hospital Kilmainham and nearby St Patrick's Hospital. It was open by the mid 1730s and the design included a clock tower and an internal arched courtyard for patients to walk-in. The building underwent major refurbishment and conservation works including a new entrance on the north front, facing Heuston Station, before reopening as the headquarters of the Eastern Health Board.

The structure is clearly visible to the street as it has no boundary walls and is an important example of a public institutional building in Dublin, see **Figure 9**.

## 2.3.7 Royal Hospital Kilmainham and Bully's Acre

The Royal Hospital (RHK) was constructed in 1680–84 by the Duke of Ormonde, Lord Lieutenant, as a new retirement home for soldiers of the Irish forces. It was occupied by 1684, but work was not finally complete until the tower was added in 1701. The hospital continued in use up to 1927, during most of which time it also provided the residence for the commander of the army in Ireland. The hospital was built on lands previously associated with the medieval priory of the Knights Hospitallers, see **Figure 10**.

The early Christian monastery associated with St Maighnenn, now Bully's Acre, is believed to have been the focus of the cemetery in Kilmainham, see **Figure 11**. The remains of a high cross (9th – 11th century AD) is located in the south-eastern quadrant of the burial ground, while the site of St. John's holy well is recorded to the north. The site is thought to contain burials from circa 1200 AD onwards and is of significant importance in the social history of the area and is traditionally

associated with the burial of Murrugh, son of Brian Boru, who died at the Battle of Clontarf in 1014.

To the north of Bully's Acre is a military cemetery known as the Privates and In-Pensioners graveyard for occupants of the RHK and for soldiers who died during the 1916 Rising. There is a limestone rubble wall that divides the earlier graveyard established in 1880, from the later established in 1905 and in use until 1931. During road widening works in the 1960s, burials were exhumed and re-interred and a new wall erected to the north to replace the original rubble limestone boundary wall.

## 2.3.8 Irish National War Memorial Gardens

The Irish National War Memorial Gardens designed by Sir Edwin Lutyens were laid out between 1933 and 1939 on part of the Longmeadows estate – now Longmeadows Park on the southern banks of the River Liffey. Therefore, the area has an enclosed character and views tend to focus inward providing respite from its urban context, see Figure 12.

In 1987, the construction of the Chapelizod Bypass / Con Colbert Road truncated the southernmost end of the War Memorial Gardens and its outer tree-lined avenue. Nevertheless, the gardens retain their designed intention as a fitting memory of the 49,400 Irish soldiers who gave their lives in the Great War, 1914–1918, and the gardens continue to host formal remembrance events. The gardens and the wider park are zoned for recreational amenity, open space and are identified as being within a Conservation Area.

A small park maintenance compound and two schools, Gaelscoil Inse Chór and St. John of God, lie at the base of an embankment along the Chapelizod Bypass / Con Colbert Road to the east of the Gardens.



Figure 11: View of Bully's Acre



Figure 12: View within the Gardens looking over at the Great Cross of Sacrifice



Figure 13: View of Inchicore Works

#### 2.3.9 CIÉ Inchicore Works

To support the massive undertaking of the construction of the railways, GS and WR Company purchased a 73 acre site in Inchicore for engine workshops and a depot, see **Figure 13**. Before the development of the railway on the 1843 OS map, Inchicore is depicted as two townlands, Inchicore North and Inchicore South, which are subdivided by the main road from Dublin. The townland consisted of open fields; very much part of the countryside with a small number of properties and one large house marked Inchicore House. The development of the depot sparked the industrial development of this part of west County Dublin. The Inchicore rail works are located on the down side of the line.

The Inchicore Railway Works opened in 1846 and became the largest engineering complex of its kind in the country. The original buildings, in a Tudor style of substantial limestone, were also designed by Sancton Wood, and the general contractor was Copthorne. Apart from a small works facility at Limerick, the Inchicore depot represents the sole survivor of a number of independent railway works in Ireland.

When the first workshops were opened, the company had to house the workers in what was an isolated area, they erected several terraces (e.g. St. George's Villas and St Patrick's terraces) of cottage-style houses, see **Figure 14** overleaf. A dining hall, library and recreation centre were also provided, and the company paid part of the cost of a school for the children of the employees.

The original works include a running shed; two erecting shops; a boiler; carriage, paint and wagon shops; a smithy and foundry; and administration and design offices. The roofs of a number of the buildings are supported by iron roof trusses carried on cast-iron columns. These date from the 1840s and were supplied by the Dublin foundry of J. and R. Mallet; they are similar to those found at Heuston Station. The foundry building at the Inchicore depot has an interesting timber-trussed roof from the same period. The façade of the original and existing station building at Inchicore is distinctive and durable with its castellated form and durable blue limestone.



Figure 14: Arrangement of Heritage Buildings in the Inchicore Works and Vicinity

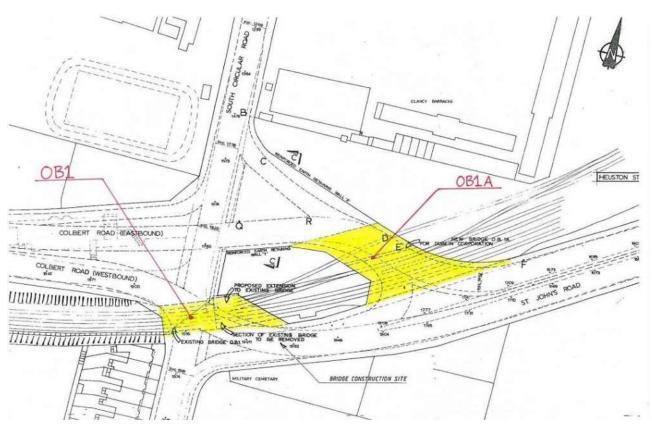


Figure 15: Plan of Rail Overbridges OB1 and OB1A at Islandbridge

#### 2.3.10 Road Junction at Islandbridge

The junction of the R148 Chapelizod Bypass and R111 South Circular Road is one of Dublin's busiest road junctions. A pair of rail overbridges, OB1A and OB1, carries traffic over the Heuston Mainline, approximately 800 m west of Heuston Station. **Figure 15** illustrates a plan arrangement of the junction.

## 2.3.11 OB1A – Eastern Rail Overbridge at Islandbridge

OB1A takes traffic over the railway from the South Circular Road and the Chapelizod Bypass / Con Colbert Road onto St. John's Road West. This is a two-span bridge constructed in the late 1980s / early 1990s. The square clear width available for running lines beneath the southern span, is approximately 17.4 m. Three divergent rail lines currently pass under the southern span as can be seen in **Figure 16**.

The square clear width available for running lines under the northern span is approximately 15.7 m. One rail line currently runs under the northern span. It appears from laser surveys carried out by IÉ that the vertical clearance from the top of the running rails to the underside of the structure are in the range of approximately 4.9 m to 5.2 m. Pre-stressed concrete bridge girders, resting at a skew on bearings, support the reinforced concrete deck slab. The abutments and central pier are constructed from reinforced concrete and are founded on reinforced concrete strip footings. The distance from the underside of the deck at its lowest point to the top of the foundations is shown on the construction drawings as being approximately 6.2 m.

## 2.3.12 OB1 – Western Rail Overbridge at Islandbridge

OB1 carries the South Circular Road over the railway. The original OB1 rail overbridge was widened in the early 1990s. The deck of both the original OB1 Bridge and its widening consist of pre-stressed concrete bridge girders on bearings that support a reinforced concrete deck slab, see **Figure 17**.



Figure 16: Bridge OB1A looking east to Heuston Station

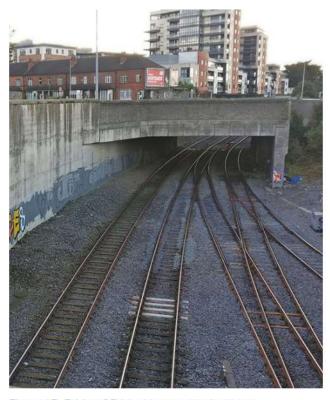


Figure 17: Bridge OB1 looking west to Inchicore



Figure 18: Bridge OB3 looking south-east



Figure 19: Rail Bridge UB4 over Sarsfield Road looking north

The abutments are constructed from reinforced concrete. The southern abutment is faced with stone to match the adjoining retaining wall heading west. The abutments are founded on reinforced concrete strips. The square clear distance between abutments at the narrowest point is approximately 12.0 m. Three railway lines currently run under OB1 with no available space for additional tracks. The current vertical clearance is in the order of 4.5 m.

## 2.3.13 Rail Overbridge OB3 – Longmeadows Bridge

Overbridge OB3 at Inchicore, opposite Memorial Park, carries two lanes of one-way traffic from Memorial Road over the railway and by doing so forms a T-Junction with the Chapelizod Bypass / Con Colbert Road.

Available drawings for Longmeadows Bridge date from 1940 and 1957. They indicate that the deck consists of concrete encased steel I-beams that support a transverse spanning concrete slab. It appears that widening to the original bridge deck was provided on each side for footpaths, post 1940. Two No. 457 mm diameter water mains are indicated within the structural depth of the deck,

The deck sits on closed concrete abutments, clad with stone to the north of the tracks. The span of the bridge is approximately 12.2 m. Three railway lines currently pass underneath with no available space for additional tracks.

The vertical clearance from the underside of the deck to the top of the running rails between 4.4 m and 4.6 m, see **Figure 18**.

## 2.3.14 UB4 – Rail Underbridge at Sarsfield Road

The rail bridge over Sarsfield Road, UB4, consists of a 'silent' steel deck, bearing on reinforced concrete bed stones. The available IÉ drawings indicate that the 'silent' steel deck sits on the existing masonry abutment walls whilst the track

maintenance walkway is a separate standalone structure, which spans between concrete pile abutment walls with stone facing, which were added when the new underbridge was installed. The bridge was upgraded to its current form in 2001 - 2002, see **Figure 19**.

The skewed span of the bridge is approximately 12.1 m. The width of the bridge is approximately 13.1 m measured square to the three railway lines which run over the bridge. The positions of the running rails are fixed by the steel deck units and cannot be modified without replacement of the units themselves.

Sarsfield Road rises significantly to the south and north of underbridge UB4.

## 2.3.15 OB5 – Footbridge at the CIÉ Inchicore Works

Bridge OB5 at Inchicore, also known as the 'Khyber Pass', is a steel footbridge spanning at a skew over the railway at the CIÉ Inchicore Works, see **Figure 20** overleaf. A footbridge has historically been provided at this location to provide access to St. Mary's Terrace.

The walkway is essentially a steel frame tube consisting of a pair of Vierendeel trusses (no diagonal members) made from welded steel box sections. Other box sections laid orthogonally to the trusses tie the top and bottom chords together, and support the steel plate deck. The walkway is supported on latticed column legs at either end. These legs bear on reinforced concrete pad footings.

The clear span measured between the bridge supports, square to the running tracks, is 19.16 m. The vertical clearance from the top of the running rails to the soffit of the bridge deck is approximately 5.15 m.













Figure No.	Title		
20	Bridge OB5 / 'Khyber Pass' looking north-east		
21	Southern Retaining Wall and Northern Embankment looking west from OB1		
22	Southern Retaining Wall and Northern Embankment looking east from OB3		
23	Southern Retaining Wall and Northern Embankment looking west from OB3		
24	Steel fencing along the railway corridor looking west from Bridge OB5		
25	A Freestanding masonry wall separates the railway lines and CIÉ Inchicore Works to the south from the housing to the north. Note the slew in the tracks around the Signal Cabin in the background of the photograph		

## 2.3.16 OB5A – Overbridge at Kylemore Road

Rail overbridge OB5A was constructed during the 1950s and currently carries two lanes of vehicular traffic on the Kylemore Road over the Heuston Mainline. The drawings indicate a clear span of 12.624 m. A full complement of three railway lines currently passes under this bridge. The minimum vertical clearance is approximately 4.45 m.

The deck consists of a reinforced concrete slab supported on in excess of thirty reinforced concrete beams. These beams rest on bearings on top of the concrete abutments. Concrete wingwalls with a decorative treatment, form the sides of the bridge. The wide bases of the abutments and wingwalls bear directly onto the ground.

## 2.3.17 Civil Works - Islandbridge to Murray's Cottages

West of Islandbridge, the railway cutting is formed to the south by a continuous battered masonry retaining wall and to the north by earth embankments sloping up to the Chapelizod Bypass / Con Colbert Road, as can be seen in Figure 21, Figure 22 and Figure 23. This arrangement continues almost as far west as Murray's Cottages, which is just to the east of Sarsfield Road. Here the cutting narrows and a retaining wall to the north is provided.

## 2.3.18 Civil Works - Murray's Cottages to Kylemore Road

The battered masonry retaining wall to the south of the railway cutting terminates shortly after Sarsfield Road in the approach to ClÉ's Inchicore Works. The need for a retaining wall on the south side of the tracks returns as the tracks run alongside an Industrial Estate to the west of the Inchicore Works and continues as far as Rail Overbridge OB5A at Kylemore Road.

Residential developments to the north run parallel to the tracks, west of Sarsfield Road, necessitating the use of freestanding walls to maintain the railway cutting. This arrangement continues until just before Overbridge OB5A where earth embankments are provided.

# 2.4 Soils, Geology and Hydrogeology

The city of Dublin is situated on a low lying coastal plain, and former flood plain of the River Liffey, which is bounded to the south by high granite cored hills up to 540 m above Ordnance Datum (mOD) and to the north-west (north of Finglas) by lower limestone cored hills of up to 230 m in height. To the west the elevation of the land increases gradually merging into the central plain of Ireland, while to the east, ground surface levels generally decrease towards Dublin Bay and the Irish Sea.

The existing ground elevations along the proposed route vary from approximately 56 mOD at Park West / Cherry Orchard Station to 2.4 mOD at Victoria Quay. The topography and landscape is dominated by the presence of the River Liffey, which is a dominant force on the most recent geomorphology of Dublin City and is a prevailing influence on drainage along the proposed route. The Liffey is considered to be estuarine from Islandbridge until it enters the Irish Sea via Dublin Bay. Along with the River Liffey, there are a number of surface water bodies along the proposed route including the River Camac, which as previously discussed, is culverted under Heuston Station to its outfall into the River Liffey.



Figure 26: Quaternary Geology Map - Kylemore Road - Inchicore with alignment of original DART Underground overlaid

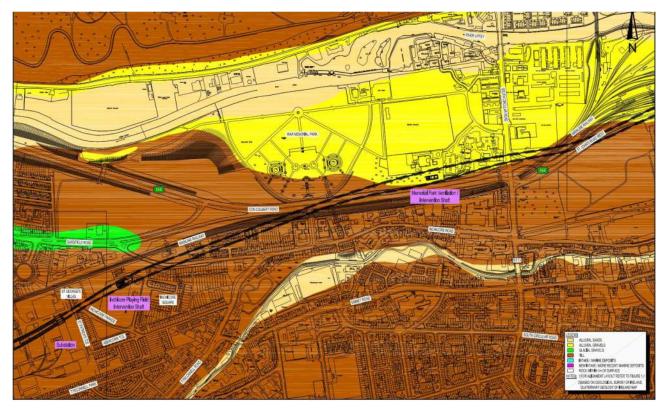


Figure 27: Quaternary Geology Map - Inchicore- Islandbridge with alignment of original DART Underground overlaid

#### 2.4.1 Overview of Soils and Geology

The Quaternary geology of Dublin along the original DART Underground proposed route, from Kylemore Road to just east of Watling Street, and its environs are presented in **Figure 26** to **Figure 28**. These maps were produced from an Environmental Systems Research Institute (ESRI) Geographic Information System (GIS) shape file issued by the Geological Society of Ireland (GSI) in 2006.

During the Pleistocene epoch of the Quaternary (the most recent geological time period) two glaciations covered the Dublin region. The glaciation, which gave rise to the Dublin Boulder Clay, was presumably not continuous. Local withdrawal and re-advance of the ice sheet led to the formation of fluvioglacial sediments (gravel and sand lenses) and glaciomarine sediments (stiff/firm laminated clays, silts, and sands). The glacial deposits can exhibit significant lateral and vertical variations in grain size distributions over short distances.

Upon cessation of the glaciation, rising sea levels, related to the changing climatic conditions, led to the deposition of raised beach deposits and terrace gravel sediments around the Liffey estuary. Recent alluvial sediments were deposited along the rivers and into the river estuaries. Young estuarine sediments were formed along the old shoreline in the vicinity of and within the Liffey river estuary.

In more recent times large parts of tidal areas along the natural shoreline and along the River Liffey were reclaimed. Waste materials of differing kinds including construction/demolition wastes were deposited in these areas.

The general lithological/geological sequence of the overburden within the Dublin area comprises the following units:

- Made ground;
- Estuarine/alluvial clays and silts;
- Estuarine/alluvial gravels and sands;

- Glaciomarine clays and silts and sands;
- Drift (glacial till Dublin Boulder Clay).
- Glacial gravels and sands.

#### 2.4.1.1 Calp Limestone Bedrock

The majority of the Greater Dublin area is contained within the fault bounded Dublin Basin underlain by an argillaceous Limestone, Lower Carboniferous in age, colloquially known as Calp. The GSI, Sheet 13, 1:100,000 scale map, indicates the entire route of the Study Area is underlain by Calp. The Calp bedrock unit is described as a dark grey to black limestone and shale. It is undifferentiated on the geological map but comprises varied dark grey to black basinal limestone and shale in several different formations. The average depth to bedrock along the route of the original DART Underground from Inchicore to just east of Watling Street is illustrated in **Figure 29** to **Figure 31**.

According to the GSI (boreholes and literature), the bedrock topography is dominated by a major buried channel, the pre-glacial Liffey, downstream of Islandbridge. This buried channel turns south of the present River Liffey course to the west of Heuston Station at Islandbridge before turning northwards under Diageo at depths of 20 m to 25 m below ground level (bgl) and on towards Broadstone. The existing River Liffey course, which formed during late and postglacial times flows eastwards towards Dublin Bay. The pre-glacial channel has effectively been filled with sediments related to both marine and transgressional periods.

Based upon local engineering experience of highly stressed and fractured zones at folds in the Calp, it has been determined that conditions during the period immediately before the ice age resulted in erosion and alteration of the rocks at rockhead level. In turn, this led to the formation of buried rock channels and the removal of calcium from argillaceous layers reverting them back to clay. It has also been determined that there are almost no records of solution features in the Dublin Limestone and that the beds generally dip at 5° to 30°, with typical layer thicknesses of 300mm to 500mm.



Figure 28: Quaternary Geology Map - Islandbridge - East of Watling Street with alignment of original DART Underground overlaid

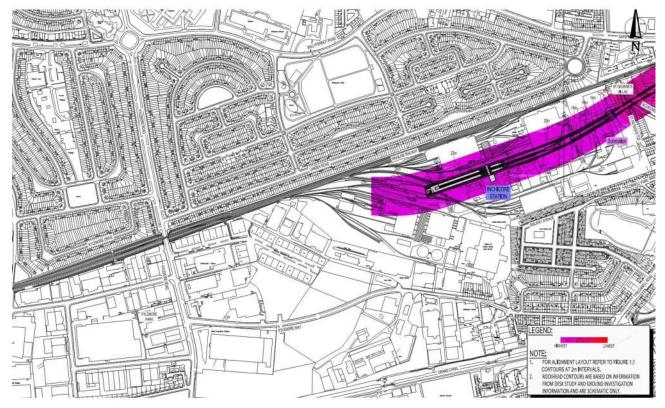


Figure 29: Bedrock Contour Map - Kylemore Road - Inchicore with alignment of original DART Underground overlaid

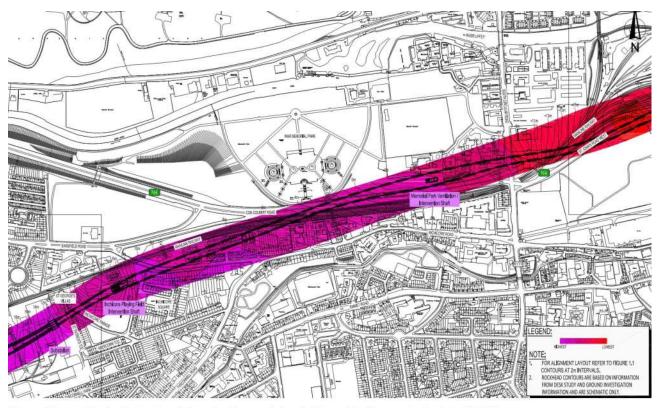


Figure 30: Bedrock Contour Map - Inchicore - Islandbridge with alignment of original DART Underground overlaid

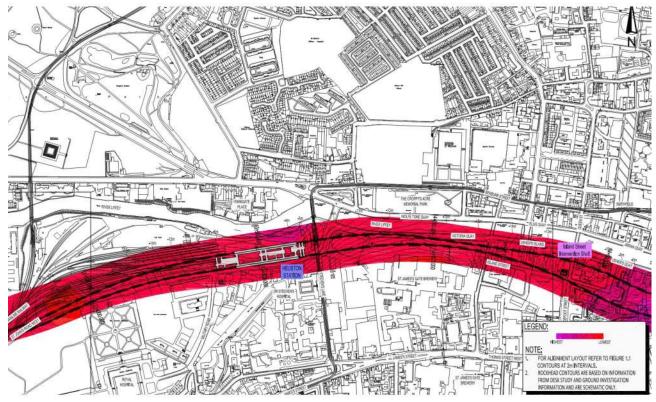


Figure 31: Bedrock Contour Map - Islandbridge - East of Watling Street with alignment of original DART Underground overlaid

#### 2.4.1.2 Made Ground

Previous geotechnical site investigations have determined that the thickness of made ground varies significantly along the route showing depths of 5.0 m to 6.0 m encountered within IÉ Railway Works. Thicknesses of made ground generally increase towards the city centre where there are large expanses of reclaimed land.

The material encountered is very variable across the route ranging from cohesive to granular material comprised of in places, building rubble such as red brick and ash, engineered fill with gravel sized fragments of sandstone and limestone and organic material in the form of peat.

#### 2.4.1.3 Estuarine / alluvial clays and silts

Alluvial clays and silts occur along the profiles of the various streams and rivers, which intersect the Study Area route such as the Rivers Camac and Liffey. They also occur along superficial natural streams or drainage channels, which have been filled with made ground, culverted and/or redirected within recent centuries and may be found as isolated pockets or along infilled channels on top of the boulder clay.

#### 2.4.1.4 Estuarine / alluvial gravels and sands

Alluvial/estuarine sands and gravels dominate the area around Heuston Station and the Diageo St. James' Gate areas. These water-saturated estuarine / alluvial gravels and sands commonly form the uppermost strata along the existing River Liffey channel and the prehistoric/pre-glacial river channel located in the area around Heuston Station and to the north of the existing concourse. The usually dense to very dense, sub-angular to sub-rounded, sandy gravels and gravelly sands are locally overlain by a thin layer of very recent soft estuary clays and silts.

#### 2.4.1.5 Glaciomarine Clays, Silts and Sands

Glaciomarine sediments are more likely to be encountered in the areas around the Docklands and so not of particular interest to this Study. They consist of very stiff (to hard) sandy, clayey silts and medium dense to dense silty sands, locally interstratified with thin laminae of clay.

The clays, silts and sands were deposited under marine interglacial conditions along the coast and within the ancient estuary areas of the River Liffey. The deposit was presumably buried below an advancing glacial ice sheet, leading to the very stiff to hard consistency and slight overconsolidation of the material.

#### 2.4.1.6 Drift (Glacial Till)

Dublin Boulder Clay is a stiff to very stiff glacial till found throughout the Study Area. The till is a well graded soil with numerous cobbles and boulders (the size of the boulders can vary from 0.5 m to 3.0 m). The thickness of these deposits has been found to be very variable across the area and previous geotechnical site investigations noted a depth up to 25 m of till in Inchicore.

The till is predominantly derived from Carboniferous limestone, although the lower units include Old Red Sandstone, schists, quartzites, vein quartz and igneous rocks including a number of granites. The glacial till recovered during previous investigations showed the till to consist of firm to stiff brown sandy gravelly clay with cobbles and boulders in places, underlain by a very stiff dark grey to black sandy gravelly clay with cobbles and boulders in places.

#### 2.4.1.7 Glacial Gravels and Sands

Glacial gravels and sands can occur beneath, within and on top of the glacial till. Previous geotechnical site investigations showed these sediments to be quite prevalent in the area around Heuston Station and the Diageo St. James' Gate areas. These are likely to be associated with the prehistoric Liffey Channel, which is presumed to run to the east and south of its present course in this area.

Glacial gravels within the boulder clay consist typically of very dense, angular to sub-angular sandy, slightly silty gravels or very gravely, slightly silty sands. The deposits occur commonly as water bearing lenses of variable lateral and vertical extent and thickness, ranging from several centimetres to several metres and are commonly not interconnected. They were presumably deposited under fluvio-glacial conditions in glacial ponds or small streams.

### 2.4.2 Hydrogeology

The limestone formation that underlies Dublin City is generally of a low permeability, except in local zones where fissures are encountered. The general low permeability of the limestone bedrock is a major benefit to any proposed tunnelling and deep excavations within the limestone.

Most importantly, the general low permeable character of the bedrock limits the potential for groundwater inflows into the excavations below the water table from the rock itself and from the more permeable sand and gravel horizons found in the overburden deposits, principally in the areas of Heuston Station and Diageo St. James' Gate. Limiting the scale of potential groundwater inflows into the tunnels and excavation also limits the potential for reductions in the water table and ground disturbance.





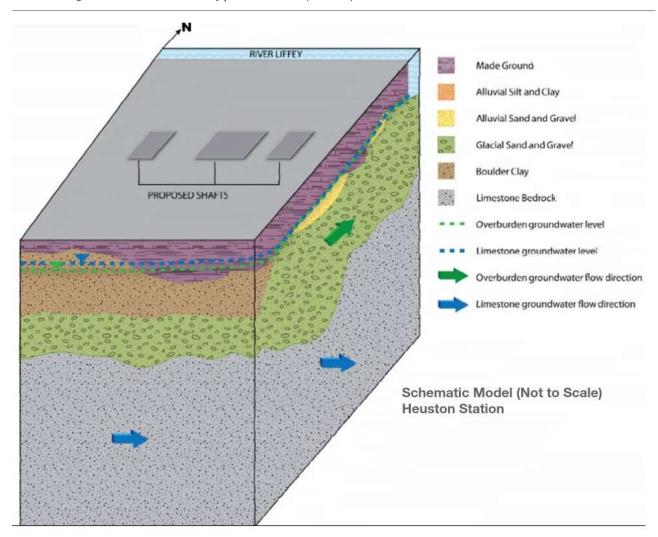


Figure 32: Hydrogeology model in the vicinity of Heuston Station (shaft locations based on the original DART Underground Scheme)

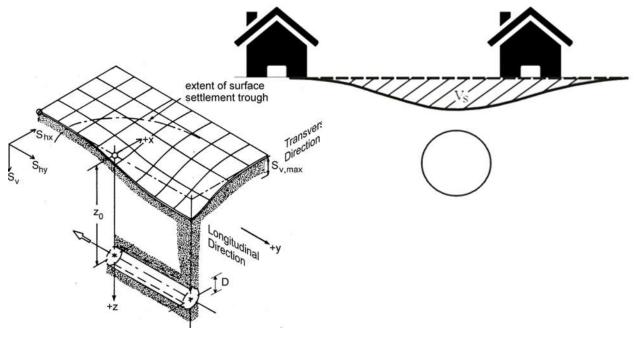


Figure 33: Schematic of settlement trough due to tunnelling

Five broad types of permanent structures are possible for this Study;

- Bored tunnels:
- Cross passages along the bored tunnels;
- Intervention shafts and connecting passages;
- Stations consisting of access and ventilation shafts, connecting passages and overwidened tunnels;
- Cuttings, including cut and cover tunnels constructed in open excavation from the surface.

For the purposes of this Study, the aim of any proposal is to prevent significant lowering of the water table and ground disturbance during construction and in the permanent state by adopting construction methods, which are founded on the principle of minimising the inflow of groundwater into the temporary excavation and permanent structures.

Minimising the dewatering requirement can be achieved in the first case with the use of a tunnel boring machine (TBM) for the tunnel construction. The tunnels will be continually lined during the tunnelling process. If a large amount of water is encountered in the ground, pressure at the tunnel faces can be maintained above natural hydrostatic pressure of the ground, which will minimise groundwater inflows. The continuous lining of the tunnels and the maintenance of the high face pressures will prevent significant groundwater ingress into the tunnel and so will prevent any significant lowering of the water table during construction.

Secondly, for construction of stations and shafts, it is assumed that embedded retaining pile walls, which are effectively watertight will be installed at all excavations. These will be driven down through the overburden strata and footed in the bedrock. The embedded retaining walls will therefore have the effect of cutting off groundwater flow into the excavations from the overburden deposits. The

deepening and widening of the station and shaft openings in bedrock will incorporate grouting of the advancing faces where necessary and the preferential grouting of encountered significant water bearing bedrock fissures to minimise groundwater inflows.

Within the extent of the Study Area, a variety of hydrogeological conditions are present, from low permeability boulder clay to highly permeable sands and gravels. The hydrogeological regime along the route is dependent upon the hydraulic connections between the different overburden deposits, the bedrock and the surface watercourses in the area.

The bedrock in Dublin (Calp Limestone) generally tends to receive its recharge from highland areas outside of the city. This is where the bedrock outcrops at the surface, allowing rainwater to directly infiltrate and recharge the aquifer. Along the route, the bedrock will be separated from the surface recharge by overlying deposits. If low permeability Dublin Boulder Clay is present, then limited or no recharge will be possible. However, if high permeability glacial gravels and sands are present above the bedrock, recharge of the bedrock groundwater system will be possible. The conditions which exist in the vicinity of the area of Heuston Station and Diageo St. James' Gate would permit direct recharge from the River Liffey. This potential risk must be addressed in the development and assessment of the Western Tie-In options.

"The conditions which exist ... would permit direct recharge from the River Liffey. This potential risk must be addressed in the development and assessment of the Western Tie-In"



Structure	Geology	Volume Loss (%)	Trough Width Parameter (k, -)
TBM Tunnels	Glacial Sands & Gravels	1.5	0.3
TBM Tunnels	Boulder Clay	0.75	0.5
TBM Tunnels	Calp Limestone	0.3	0.4
TBM Tunnels	Mixed Face Boulder Clay – Calp Limestone	1.0	0.4
TBM Tunnels	Mixed Face Glacial Gravels and Sands – Calp Limestone	2.0 - 3.0	0.3
Platform Tunnels	Boulder Clay	1.5	0.5
Platform Tunnels	Calp Limestone	0.75	0.4
Cross Passages	Glacial Sands & Gravels	2	0.3
Cross Passages	Boulder Clay	1	0.5
Cross Passages	Calp Limestone	0.5	0.4

Table 1: Volume Loss and Trough Width Parameters for Ground Movement Analysis

#### 2.4.3 Ground Movement Assessments

The extent and magnitude of the ground movement depends on tunnel size, tunnel depth, method of tunnelling and ground conditions.

Figure 33 shows a schematic of the ground movements that occur during tunnelling. The ground movements are calculated using methods proposed by O'Reilly and New [3]. The volume lost around the tunnel as it is excavated is transposed to a settlement trough on a greenfield surface with an equivalent volume. The method of predicting the likelihood of building damage is based on the methodology developed by Burland [4] where the settlements calculated are imposed on a structure to determine the deflection ratio, tensile strain and crack width of any structure. Using this method a category of damage can be assigned. This is an

extremely useful approach for tunnelling where a number of structures need to be assessed, see **Figure 34** and **Figure 35** overleaf.

The Volume Loss parameter,  $V_L$ , and trough width parameters specified for varying forms of tunnelling and underground construction varies depending on the ground conditions encountered. The values proposed for the Western Tie-In Study are presented in **Table 1**.

### Hogging and Sagging Deformations and Definitions of $\Delta$ , L and H (Burland 1995)

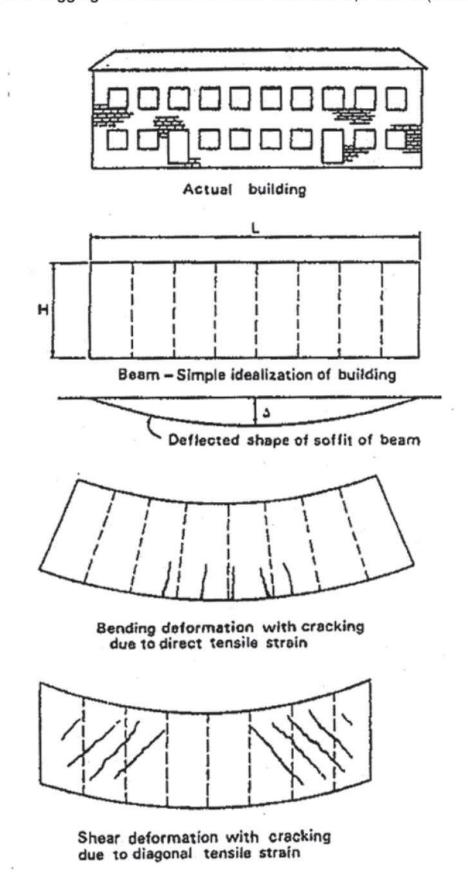


Figure 34: Hogging and Sagging Deformations and Definitions

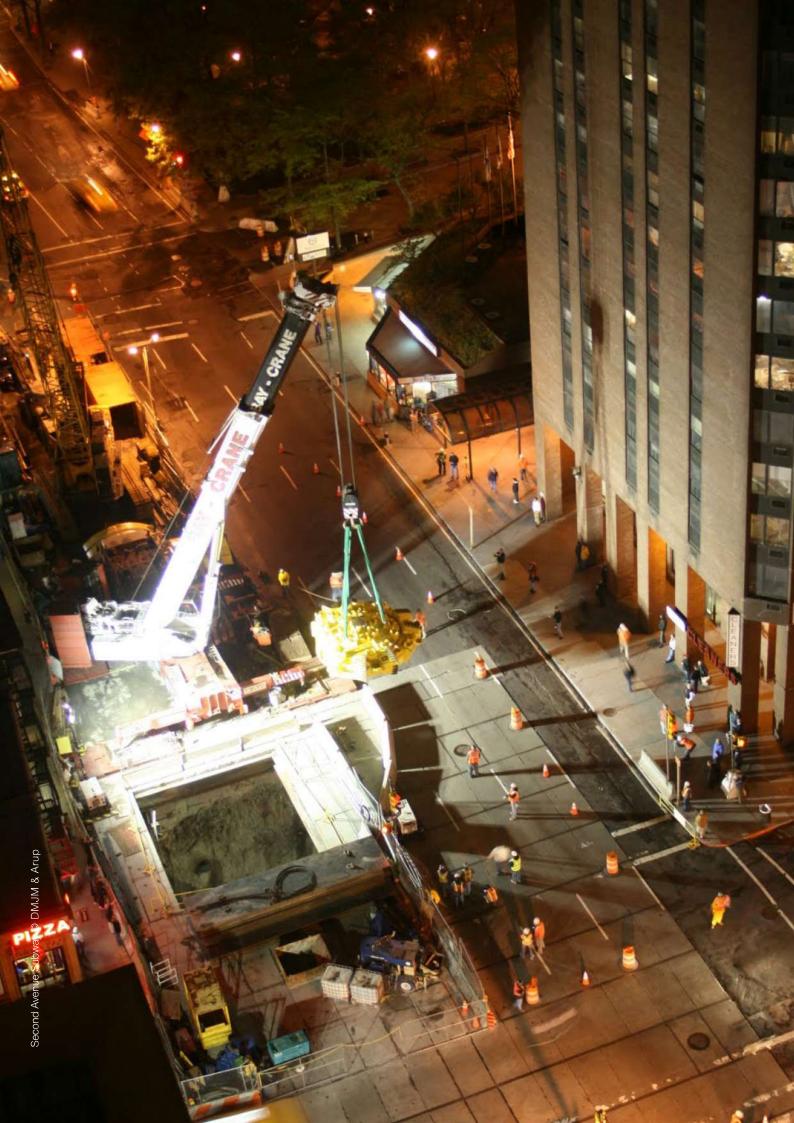
## Building / Structure Damage Risk Classification (Burland (1997))

Damage Category	Category of damage	Description of typical damage <sup>+</sup> (Ease of repair is underlined)	Approx. crack width* (mm)	Limiting tensile strain (%)
0	Negligible	Hairline cracks	< 0.1	< 0.05
1	Very Slight	Fine cracks that can easily be treated during normal decoration.  Perhaps isolated slight fracture in buildings. Cracks in external brickwork visible on inspection.	<1	0.05 - 0.075
2	Slight	Cracks easily filled. Redecorating probably required. Several slight fractures showing inside of building. Cracks are visible externally and some repointing may be required externally to ensure weather tightness. Doors and windows may stick slightly.	< 5	0.075 - 0.15
3	Moderate	The cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable linings. Repointing of external brickwork and possibly a small amount of brickwork to be replaced. Doors and windows sticking. Service pipes may fracture. Weather tightness often impaired.	5 - 15 or a number of cracks > 3	0.15 – 0.3
4	Severe	Extensive repair work involving breaking out and replacing sections of walls, especially over doors and windows. Windows and door frames distorted, floor sloping noticeably. Walls leaning and bulging noticeably, some loss of bearing in beams. Service pipes disrupted.	number of cracks	> 0.3
5	Very Severe	This requires a major repair job involving partial or complete rebuilding. Beams lose bearing, walls lean badly and require shoring. Windows broken due to distortion. Danger of instability.	Usually > 25 but depends on number of cracks.	-

Figure 35: Building / Structure Damage Risk Classification



# 3. Compliance Requirements



## 3.0 Compliance Requirements

The following section comprises a list of the principal regulatory, technical and operational requirements applicable to the design of DART Underground and which have formed the basis of identifying feasible and practicable options for the Western Tie-In.

## 3.1 Design and Operating Principles

IÉ identified a series of design and operating principles, which form the basis of the development of any possible option for the Western Tie-In. These principles are as follows:-

- Nominal track gauge shall be 1600 millimetres (mm);
- DART Underground Heuston Mainline shall be designed to accommodate 8-car DART EMUs, operating at 1500V DC and shall incorporate clearance passive provision for transition to 25KV AC in the future, if required;
- DART Underground Heuston Station platform shall be a minimum of 174 m in length and the maximum track gradient at platform level shall not exceed 0.2%;
- Tunnel Boring Machines (TBMs) shall be adopted to construct the future DART Underground running tunnels;
- Capacity of the existing two track Mainline from Park West / Cherry Orchard Station to the existing Heuston Terminus Station shall be 12 trains per hour per direction;
- A signalling design capacity of 20 trains per hour per direction shall be achieved from the DART Underground tunnels to the Park West / Cherry Orchard tie-in which coincides with the eastern end of the KRP Phase 1 Works;

- Pequirement for the provision of a turnback (either underground or at ground level) between Heuston and Park West / Cherry Orchard Station, with a turnback capacity of 8 trains per hour per direction with through running onto the Heuston Mainline.
- Maximum line speed of 75 kilometres per hour (km/h) shall be achieved through the running tunnels, and a line speed of 50 km/h shall be achieved at tie-in junctions between DART Underground and the Heuston Mainline;
- Minimum horizontal radius for new track shall be 400m;
- Maximum cant shall be 100mm; and
- The maximum vertical gradient shall be 3.5% for a maximum length of 1.66km and 3% over longer distances.

An acceptable alternative tumback solution which may be considered is to make use of the existing tumback at Adamstown Station which has a capacity of 4 trains per hour per direction with through running onto the Heuston Mainline, and to provide a tumback of similar capacity at Park West / Cherry Orchard Station, to achieve an overall capacity of 8 trains per hour per direction. It is not viable to provide a tumback at Park West / Cherry Orchard Station with a capacity of 8 trains per hour per direction without acquiring an excessive amount of landtake and rebuilding the existing overbridge at Park West Avenue.

Component	Compliance Document	Commentary
	TSI – SRT – "Safety in Railway Tunnels"	This document is mandatory for DART Underground.
Tunnels	UIC 779-9 – "Safety in Railway Tunnels"	Listed as a parameter within the relevant CRR guidance document for heavy rail projects.
	NFPA 130 – "Standard for Fixed Guideway Transit and Passenger Rail Systems"	Provides guidance for tunnels if required and consistent with standard proposed for stations. Non-mandatory and therefore subject to agreement with the CRR and Dublin Fire Brigade.
01.11	Technical Guidance Document B – "Fire Safety"	Non-mandatory. Applies to stations only. Provides general recommendations relating to compliance with Part B of the Building Regulations.
Stations	NFPA 130 – "Standard for Fixed Guideway Transit and Passenger Rail Systems"	Proposed for the stations due to the lack of appropriate railway guidance within Technical Guidance Document B.
New Vehicles	IS EN 45545 (Railway Applications - Fire Protection on Railway Vehicles).	

Table 2: Principal Technical Fire Compliance Standards







Furthermore, larnród Éireann confirmed that the maximum line speed of DART trains through atgrade sections will be 100 km/h.

## 3.2 Tunnel and Station Design Standards

In **Appendix A** of this report, we have listed the relevant standards applicable to tunnel and underground station design and construction, both nationally and internationally. The Appendix lists the relevant standards in the sequence:-

- Eurocodes, including Irish national annexes;
- European directives;
- Technical references;
- Irish National Standards; and
- International standards relevant to tunnel and station construction.

## 3.3 Fire Strategy

This section provides a summary of the mandatory and proposed guidance in relation to fire and life safety, which has informed the development of options for the Western Tie-In. Further information is contained within Appendix A on current fire and life safety legislation, standards and the approvals process.

The Commission for Railway Regulation (CRR) issue guidance documents which stipulate a list of required design standards that should be followed when designing an underground railway system and these are therefore mandatory (refer to Appendix A). In addition to the guidance documents mandated by the CRR, there are a number of European Regulations, which are direct requirements in member states and are therefore, also mandatory. **Tables A4** and **A5** of Appendix A list the mandatory guidance, which is applicable to DART Underground.

**Table 2** lists the principal technical compliance standards adopted for this Study. Those standards highlighted in red are non-mandatory. It should be noted that European Regulation 402/2013 (as amended by Regulation (EU) N°2015/1136)) requires that a risk assessment is undertaken to assess the level of risk by comparing the developed design of DART Underground as a whole with suitable codes of practice. In instances where the design deviates from the provisions set out in these codes of practice, it may be necessary to undertake performance based design in order to demonstrate that an equivalent level of safety is achieved.

"In addition to the guidance documents required by the CRR, there are a number of European Regulations, which are direct requirements in member states and are therefore, also mandatory"



# 4. Phase 1: Surveys and Data



## 4.0 Phase 1: Surveys and Data

The following section outlines the additional data collected and surveys conducted to inform the development and assessment of options for inclusion in the Western Tie-In Study.

#### 4.1 Data Collection

During the initial phase of this Study, the NTA and IÉ supplied data, reports and records produced as part of the original DART Underground Reference Design and Railway Order Application 2010. A gap identification review ascertained whether additional information needed to be sourced to assist in the development and assessment of options. The findings of the gap identification review are presented below and the additional data collected is contained within Volume 1 of this Study:-

- Development zoning and development proposals;
- Protected structures and recorded/ registered historic monuments. A review was undertaken and it was determined that there were no alterations from the original DART Underground Railway Order over the extent of the Study Area;
- Sites and buildings of Architectural interest. All affected sites and buildings were identified and are discussed in detail within Chapter 9 of this Study under the subheading Archaeology, Architectural and Cultural Heritage;
- Additional architectural and/or archaeological constraints were identified and are also explored in detail within Chapter 9 of this Study;
- Environmental issues which would influence the identification and appraisal of options.
   These have been considered as part of the Preliminary Environmental Appraisal to determine the Preferred Option and are addressed within Chapter 9 of this Study;

- Receptors sensitive to noise, air quality or other environmental emissions. A review of the original DART Underground information identified that there has been no significant changes over the extent of the Study Area;
- Sites of geological interest. There has been no change from the data collected as part of the original DART Underground Reference Design;
- Significant historically contaminated sites and geohazards. No additional sites or geohazards have been identified from the original DART Underground investigations;
- Details of previous flood events and any other relevant flooding issues. No significant new information was identified from the studies undertaken as part of the original DART Underground;
- Any features of significant landscape or visual importance. These features, over the extent of the Study Area, are identified and described within Chapter 9 of this Study;
- Groundwater vulnerability and aquifer classification. There has been no amendments to the classifications from the investigations conducted as part of the original DART Underground.

The Geographic Information System (GIS) database and supporting drawings that were produced as part of the original DART Underground, have been updated to reflect changes which have occurred over the extent of the Western Tie-In Study Area.



These GIS drawings are contained within Volume 1 of this Study and include:

- i. Buildings identified with basements;
- ii. Buildings identified by type of construction;
- iii. Buildings of vintage or protected structures;
- iv. Buildings identified by foundation type;
- v. Buildings identified by number of storeys;
- vi. Buildings sensitive to noise and vibration.
- Details of utilities of relevance to the options assessment were sought from statutory undertakers and providers, and are also provided in Volume 1.

### 4.2 Topographical Surveys

Topographical surveys carried out for the original DART Underground and LiDAR surveys undertaken along the existing Heuston Mainline were provided by the NTA and IÉ. The adequacy of the survey information has been verified for the purposes of the Western Tie-In Study.

Additional height data obtained from LiDAR mapping has been sourced from Ordnance Survey Ireland, to cover those areas in which no height information was available. These additional surveys are included in Volume 1 of this Study.

# 4.3 Geological and Geotechnical Surveys

A desktop Study of the geotechnical and geological surveys undertaken as part of the original DART Underground verified the adequacy and interpretation of the information provided by the NTA and IÉ.

Ground parameters have been derived for inclusion within a greenfield ground movement analysis to determine the anticipated impacts on buildings and infrastructure associated with all feasible and practicable options as discussed earlier in **Section 2.4.3.** 

"Topographical surveys carried out for the original DART Underground ....were provided by the NTA and IÉ. The adequacy of the survey information has been verified for the purposes of the Western Tie-In Study"

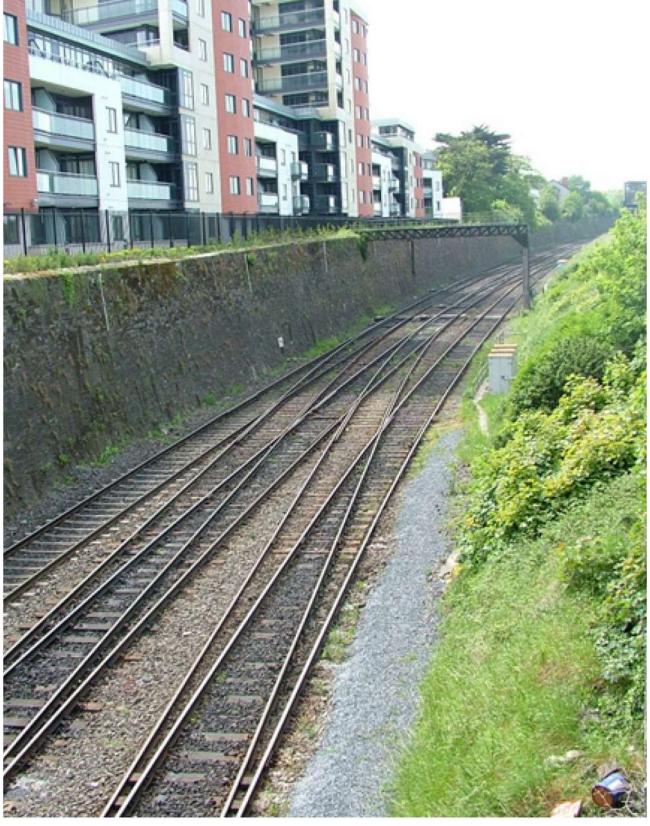


Figure 36: View of existing rail corridor west of rail overbridge OB1 between the masonry retaining wall on the south side and the Chapelizod Bypass / Con Colbert Road

# 5. Phase 1: Brainstorming to Identify Possible Options



# 5.0 Phase 1: Brainstorming to Identify Possible Options

As the first step in identifying possible options for the Western Tie-In, a brainstorming workshop was undertaken with the goal of identifying as many potential solutions, which it hypothetically appeared, could:

- satisfy the design and operating principles listed in **Section 3.1** of the Study;
- ii. complied with the recommendations of the DART Underground Tunnel Configuration Study<sup>[5]</sup> that only a twin bore tunnel or a monotube tunnel configuration be considered for the Project as a whole;
- iii. in recognition of the challenging ground conditions in the vicinity of Heuston Station as discussed in **Section 2.4** of the Study, be constructed in a manner, which would not result in excessive ground induced damage to buildings, infrastructure and utilities in the vicinity of Heuston Station. The objective being that construction of the potential solution would not be likely to result in any worse than a Category 3 'Slight' damage<sup>[3]</sup>.
- iv. recognised that the most westerly desirable point to achieve a tie-in to the Heuston Mainline, with a tunnel portal within the Heuston Yard is at rail overbridge OB1.

A track tie-in occurring west of rail overbridge OB1, would require the DART Underground tracks to be within a retained excavation west of OB1, relative to the mainline, and for there to be sufficient space to accommodate the Mainline and Phoenix Park Tunnel tracks adjacent to the retained excavation during both the construction phase and in the permanent track arrangement.

The rail corridor would need to be wide enough to accommodate three running lines for the Mainline tracks, and two tracks for DART Underground, inclusive of emergency walkways and the width of the retaining walls, equating to a minimum of 25.8 m, but ideally nearer 30 m to minimise disruption and track closures during construction.

It is considered that there is insufficient space available within the rail corridor between the existing masonry retaining wall on the Kilmainham side of the rail corridor and the Chapelizod Bypass / Con Colbert Road on the north side. Therefore achieving a tie-in west of rail overbridge OB1 is highly undesirable, as to do so would result in significant impairment to the operation of trains into the Heuston Yard and Phoenix Park Tunnel, and require extensive reconfiguration of the westbound carriageway of the Chapelizod Bypass / Con Colbert Road.

All potential solutions identified in the brainstorming workshop, were collated and screened for compliance with the requirements listed above. The objective of the screening exercise, which involved developing schematic track alignments, was to identify which options did in fact comply with the requirements and therefore constituted a possible option. Those potential solutions, which did not satisfy the design and operating principles for the project, did not advance to Phase 2 of the Study.

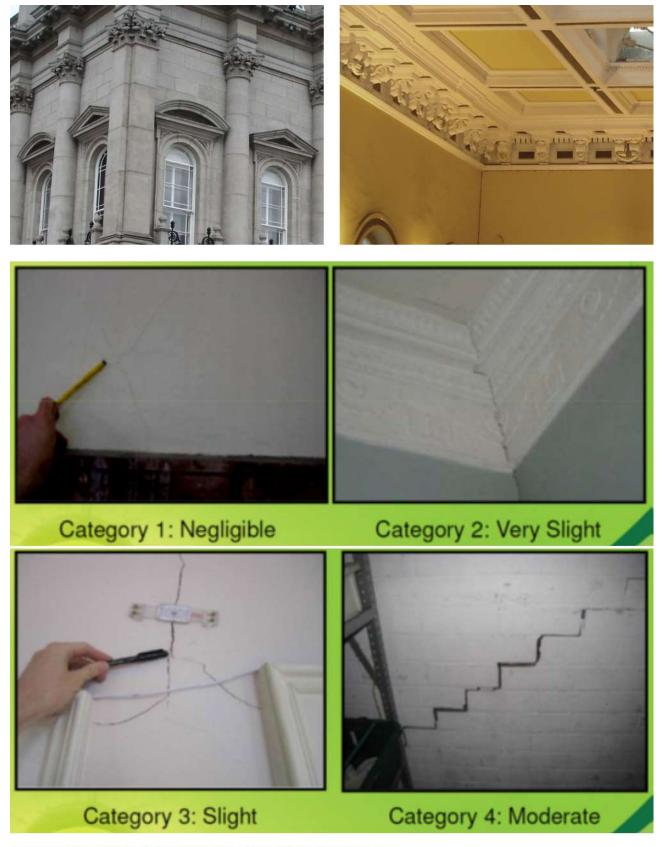


Figure 37: Examples of building damage classification for categories 1-4

In total, 28 potential solutions were proposed during the brainstorming workshop. Through screening for compliance with the requirements, 21 of the 28 potential solutions were found to be compliant and therefore advanced to Phase 2 of the Study, and these identified possible options are presented in **Chapter 6**.

Seven of the potential solutions were found to be non-compliant and therefore did not advance to Phase 2 of the Study. The seven potential solutions and the explanation as to why they were found to be non-compliant are outlined in the following sections.

# 5.1 Settlement Analysis and Damage Classification

A sensitivity Study was undertaken to examine potential ground movements and the resulting ground induced damage arising from driving a twin bore tunnel and a monotube tunnel configuration with differing depths of ground cover above the bored tunnel(s).

The analysis examined the effects of a Volume Loss of both 1.0%, which reflects mixed face boulder clay / Calp limestone conditions and 0.7%, which reflects a potential volume loss in the Dublin boulder clay. The potential volume losses in the mixed face glacial sands and gravels / Calp limestone, which pertain in the vicinity of Heuston are potentially greater as listed in **Table 1**. However, for an initial assessment of the potential ground settlement and potential ground induced damage, values of 1.0% and 0.7% were adopted.

The results of the sensitivity analysis are illustrated in **Figures 38 to 40**. The graphs illustrate that a monotube tunnel configuration can only achieve a slight damage threshold if the depth of soil above the crown of the tunnel is in excess of 15 m, even for a volume loss of 0.7%. In the case of the ground conditions which are present in the vicinity of Heuston, this equates to a requirement that the crown of any monotube tunnel configuration needs to be within the bedrock and with sufficient

rock cover such that mixed face ground conditions (boulder clay / Calp limestone or glacial sands and gravels / Calp limestone) are not encountered.

Only by ensuring that the monotube tunnel is within the bedrock under the existing Heuston Station, in which a volume loss of 0.3% or less realistically can be achieved, is it possible for a monotube tunnel solution to be viable.

In the case of a twin bore tunnel, a ground cover of circa 12 m will typically ensure that the damage category of slight will not be exceeded.

## 5.2 Compensation Grouting in Glacial Sands and Gravels

Compensation grouting is often suggested as a solution to mitigate excessive ground movements. The process involves grout being injected in one position at a time through a selected TAM (tube a manchette). A Manchette tube is a pipe in which rubber sleeves cover holes that are drilled in the pipe at specific intervals.

The tubes are inserted into holes that have been bored into the treatment zone or grout zone. Grout is pumped to a packer and past the flexible rubber sleeve, into the grout zone to help stabilize and/or seal it. The packers are then moved to the next position and the process repeated. In this manner, specific locations can be targeted with each injection.

Compensation grouting has proved to be highly effective in over consolidated stiff clays, such as those encountered in London. However, in glacial sands and gravels, similar to those encountered in the vicinity of Heuston Station, compensation grouting has a varied record, is much less predictable than stiff clays and is not considered to be an effective solution to mitigate against the potential ground movements.

#### Mair et al (1993) and Taylor (1995), displacement on horizontal plane

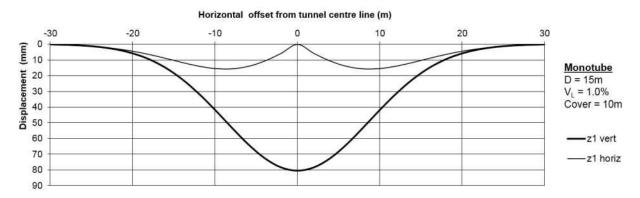


Figure 38: Horizontal and vertical ground movements based on a Monotube tunnel configuration and ground cover of 10 m



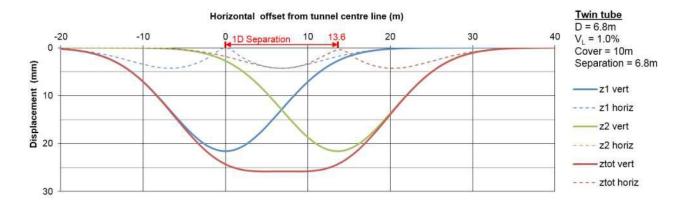


Figure 39: Horizontal and vertical ground movements based on a Twin Bore tunnel configuration and ground cover of 10 m

# 5.3 Launching a large diameter TBM with shallow ground cover

It is feasible to launch a large diameter TBM with relatively shallow ground cover above the crown of the tunnel, as was undertaken on the Washington State Route 99, Alaskan Way tunnel in Seattle. In this case, the 17.52 m diameter TBM was launched with a cover of 5.5 m. However, this was only achievable by confining the soil around the TBM to prevent excessive ground movements occurring. This process necessitated significant ground treatment in front of the TBM, and piling either side of the TBM and constructing a roof slab between the piled walls to confine the soil at the launch point and for a length in front of the portal until the soil was deemed to be stable.

In the case of a portal in Heuston Yard, the TBM would be launched into a face of either glacial sands and gravels or mixed face conditions. It is conceivable that the length of ground treatment and confined piled roof structure to be constructed ahead of the TBM launch portal would equate to the length at which the depth of ground cover equals the diameter of the TBM. Such an extensive length of ground treatment and piled roof structure would have a significant impact on existing rail operations, facilities and the protected structure of the existing Heuston Station. As such, launching a large diameter TBM in the Heuston Yard with relatively shallow cover would be challenging and require substantial mitigation to be feasible.

## 5.4 Non-Compliant Potential Solutions

## 5.4.1 Monotube Tunnel North Terminus Station at Heuston

This potential solution as schematically illustrated in **Figure 43** was for a Terminus Underground Station below the existing Mainline Heuston, constructed with a Monotube tunnel configuration and with the turnback beyond the station platforms. A combined intervention and ventilation shaft would be required at the end of the turnback and it was envisaged that the shaft would be positioned in the vicinity of the existing Guinness sidings.

However, following the brainstorming workshop, it was calculated that the turnback for a monotube tunnel configuration would be 669 m in length. Therefore this shaft would need to be positioned west of the Phoenix Park Tunnel rail tracks, and within the Clancy Barracks, which is currently a series of residential developments. Accordingly, this potential solution with the underground station below the existing Mainline Station was deemed to be non-compliant.

## 5.4.2 Monotube Tunnel Configurations with a Portal in the Heuston Yard

A total of six monotube tunnel configurations were identified as being potential options in which the tunnel portal was positioned in the Heuston Yard. These potential solutions are listed below.

- Monotube configuration, Tie-In to Heuston Mainline at Overbridge OB1, southerly alignment with station on the south side of the existing station, under the footprint of the existing Mainline Station;
- 2. Monotube configuration, Tie-In to Heuston Mainline at Overbridge OB1A, southerly alignment with station on the south side of the existing station, under the footprint of the existing Mainline Station;

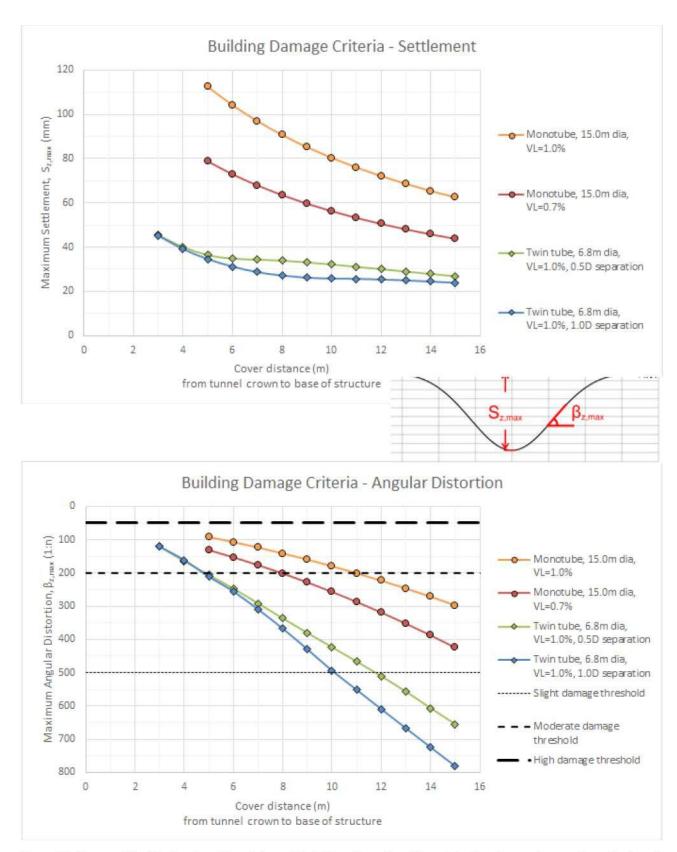


Figure 40: Damage Classification for a Monotube and Twin Bore Tunnel for different depths of ground cover above the bored tunnel(s)



Figure 41: Example of Compensation Grouting and the use of TAMs to control ground movements

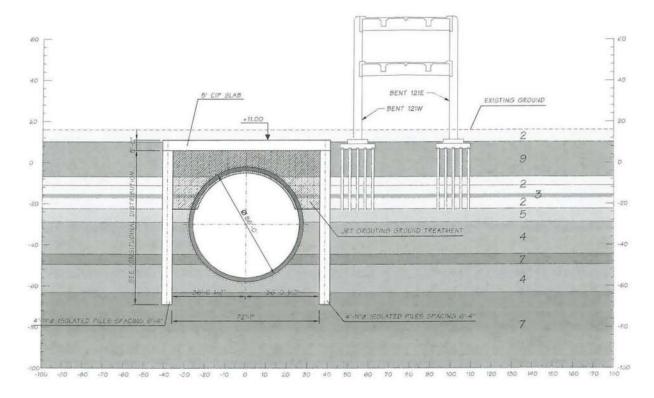


Figure 42: Example of Launching a large diameter TBM with shallow cover on the Washington State Route 99 in Seattle, United States of America

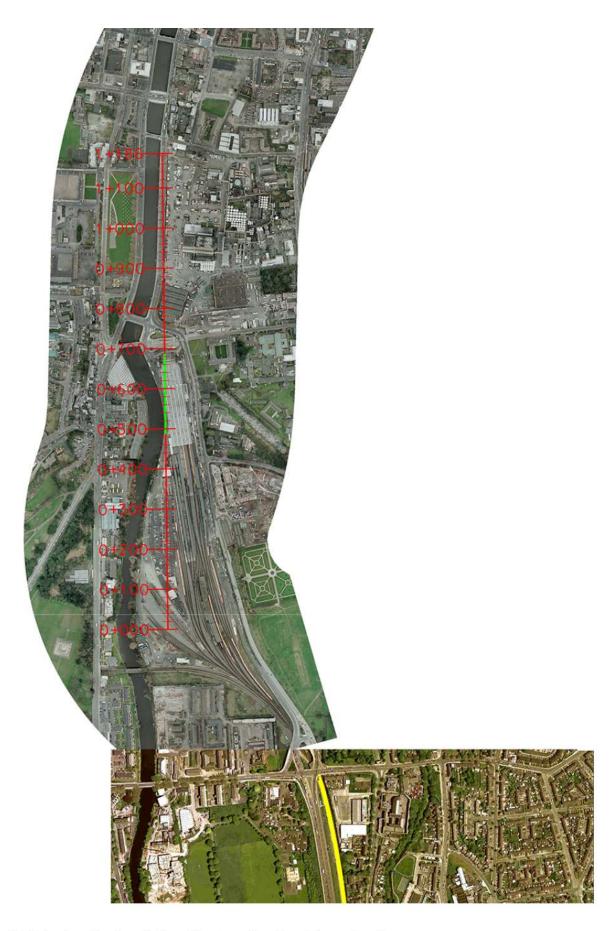


Figure 43: Option for a Terminus Station at Heuston with a Monotube configuration

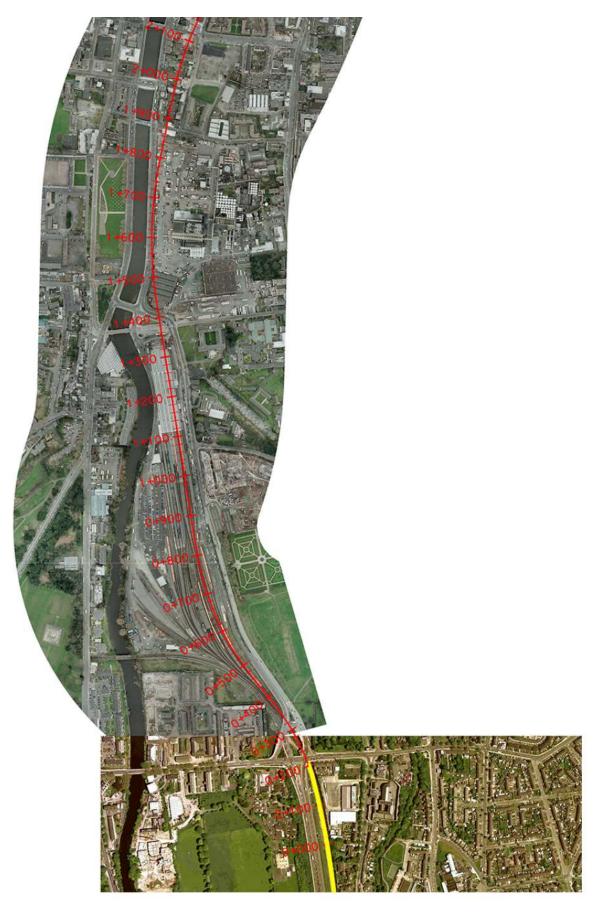


Figure 44: Monotube configuration, Tie-In to Heuston Mainline at Overbridge OB1, southerly alignment with station on the south side of the existing station, under the footprint of the existing Mainline Station

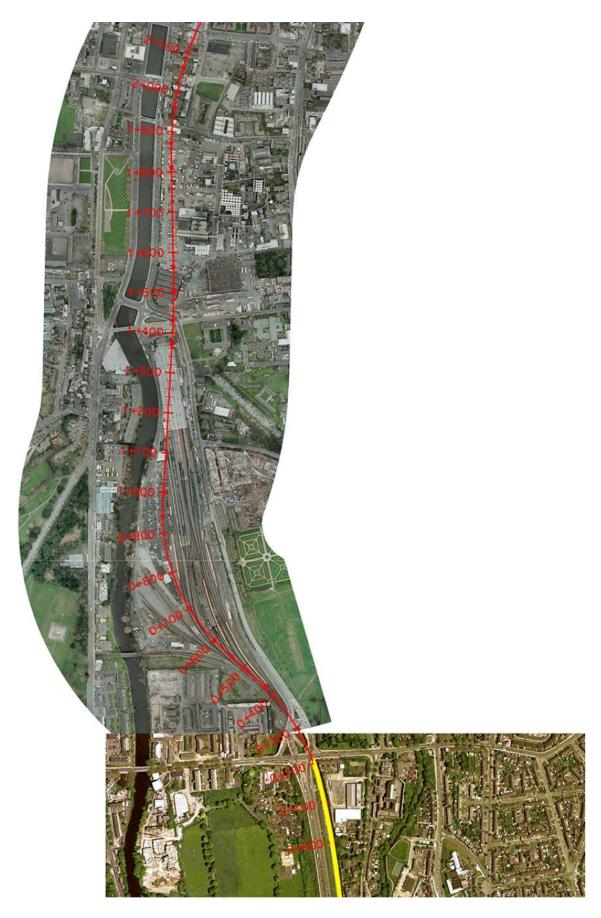


Figure 45: Monotube configuration, Tie-In to Heuston Mainline at Overbridge OB1, northerly alignment with station on the north side of the existing station, under the footprint of the existing Mainline Station

- 3. Monotube configuration, Tie-In to Heuston Mainline East of Overbridge OB1A, southerly alignment with station on the south side of the existing station, under the footprint of the existing Mainline Station;
- 4. Monotube configuration, Tie-In to Heuston Mainline at Overbridge OB1, northerly alignment with station on the north side of the existing station, under the footprint of the existing Mainline Station;
- Monotube configuration, Tie-In to Heuston Mainline at Overbridge OB1A, northerly alignment with station on the north side of the existing station, under the footprint of the existing Mainline Station;
- 6. Monotube configuration, Tie-In to Heuston Mainline East of Overbridge OB1A, northerly alignment with station on the north side of the existing station, under the footprint of the existing Mainline Station.

To achieve a viable underground station solution directly below the footprint of the existing Heuston Station for a monotube tunnel configuration with a portal in the Heuston Yard, the required minimum ground cover above the crown of the monotube tunnel was determined to be 21.0 m.

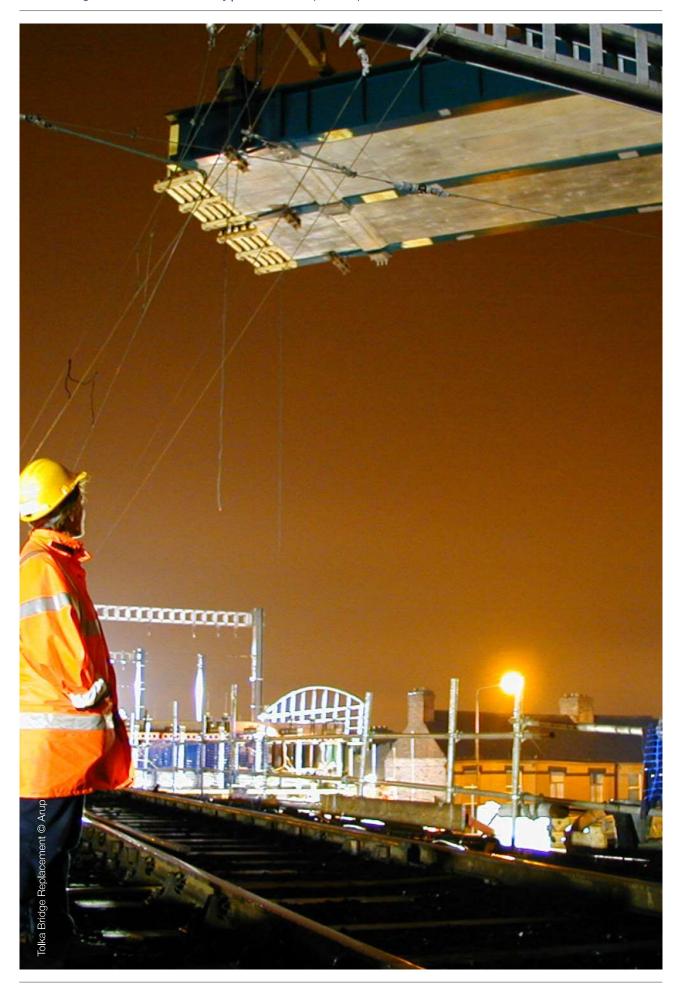
In the case of potential solution (1) as illustrated in **Figure 44**, the actual cover which could be achieved is 13.2 m, which is less than the 21.0 m identified as being required for a viable monotube solution with an underground station beneath the existing station footprint. By implications, the potential solutions (2) and (3) are not viable.

In the case of potential solution (4) as illustrated in **Figure 45**, the actual cover which could be achieved is 14.7 m, which is less than the 21.0 m identified as being required for a viable monotube solution with an underground station beneath the existing station footprint. By implications, the potential solutions (5) and (6) are not viable.

Therefore, it was demonstrated that for a monotube tunnel configuration with a TBM portal located in the Heuston Yard and track tie-in at rail overbridge OB1, the station platforms would have to be located east of the existing Heuston Station in order to be viable. Accordingly, all six of the potential solutions listed above did not advance to Phase 2 of the Study.

### 5.5 Summary of Outcome of Brainstorming

Following the brainstorming exercise and subsequent screening to identify which potential solutions are in fact possible options, a total of 21 possible options were identified and these options advanced to Phase 2 of the Study as presented in **Chapter 6**.



# 6. Phase 2: Identification and Evaluation of Options



## 6.0 Phase 2: Identification and Evaluation of Options

This section presents the methodology developed to evaluate all identified possible options within the extent of the Study Area, which achieve the primary objective of linking the proposed DART Underground tunnel to the Heuston Mainline and facilitate an interchange at Heuston Station.

In total, 21 possible options, each of which satisfies the primary objective of the Study have been identified.

To demonstrate compliance with the rail technical requirements for the Study, a track alignment design has been undertaken for each possible option. The design also includes identifying the plan location and depth of a potential underground station in the Heuston vicinity capable of providing an interchange to the Mainline Services, the location of the bored tunnel portal and the extent of the approach retaining structures from the Heuston Mainline tie-in location to the bored tunnel portal. The proposed plan arrangement and vertical profile for each respective option is contained within Appendix B of this Study.

To evaluate which of the 21 identified possible options are both feasible and practicable, an options sifting and appraisal process was employed, using qualitative engineering, constructability and rail operations criteria. The methodology devised to undertake this objective-based assessment, founded on professional judgement, is set out below.

## 6.1 Criteria for Evaluation of Possible Options

The qualitative engineering, constructability and rail operations assessment facilitates a structured approach to determine performance across a number of objectives (or criteria), which are considered fundamental to DART Underground.

The criteria applied to the evaluation is as follows:-

- Potential ground movement and the potential for ground induced damage to buildings, infrastructure and material assets within the Heuston vicinity given the prevailing challenging ground conditions;
- Rail operational impacts;
- Existing Heuston Mainline Station operational impacts during and post construction of the DART Underground;
- Underground Station location and configuration in the vicinity of Heuston, and potential impacts on third party properties and commercial undertakings;
- Practicality of constructing the identified possible option and required landtake for the associated worksites:
- Safety of constructing, inspecting, maintaining and operating the identified possible option.

Evaluation Criteria	Metric
Potential ground movement and the potential for ground induced damage to buildings, infrastructure and material assets within the Heuston vicinity given the prevailing challenging ground conditions.	Qualitative appraisal of the likelihood that ground induced damage resulting from the construction of this possible option, will not result in any worse than a Category 3 - 'Slight' damage threshold [3] to the existing buildings, infrastructure and utilities in the vicinity of the existing Heuston Station, without the need to undertake substantial and costly ground movement mitigation measures.
Rail operational impacts	Qualitative appraisal of the operational impacts of the possible option on existing Mainline services during and post construction of DART Underground, including degraded scenarios.
Existing Heuston Mainline Station operational impacts during and post construction of the DART Underground	Qualitative appraisal of the operational impacts of the possible option on the ability of the existing Heuston Station to cater for the forecast passenger demand during and post construction of DART Underground.
Underground Station location and configuration in the vicinity of Heuston, and potential impacts on third party properties and commercial undertakings	Qualitative appraisal as to the feasibility of constructing the proposed DART Underground station in the Heuston vicinity in a location and manner, which minimises the impact on third party properties and commercial undertakings, minimises the potential for land acquisition and relocation of commercial facilities and operations.
	Qualitative appraisal of the location, footprint, configuration and suitability of the construction worksites for the particular works required to be undertaken in relation to each possible option.
Practicality of constructing the identified	Qualitative assessment of the construction methodology, sequencing and programme, including anticipated enabling works and any mitigation measures.
possible option and required landtake for the associated worksites	Qualitative assessment of the means of access and egress from the site in relation to likely construction traffic volumes.
	Qualitative assessment of the geology, hydrogeology, tunnelling methodologies, and permanent and temporary ground support systems associated with each possible option.
Safety of constructing, inspecting, maintaining and operating the identified possible option	Qualitative appraisal of the hazards and risk associated with constructing each possible option. This shall include ensuring the safety of the general public, passengers, staff and construction site personnel; hazards associated with working adjacent to a live railway, buildings, highways and utilities.
	Qualitative appraisal of the safety for inspecting, maintaining and operating DART Underground within the Study Area and interfaces with the Mainline railway. The appraisal shall consider the safety of the general public, rail passengers, larnród Éireann staff, Contractor and Sub-Contractor personnel.

Table 3: Metrics for the Evaluation Criteria

Category	Description
Α	Underground Station in the vicinity of the Existing Heuston Station Twin Bore Tunnel configuration with Portal located in the Heuston Yard
В	Underground Station located beyond the immediate vicinity of the Existing Heuston Station, Twin Bore Tunnel configuration with Portal located in the Heuston Yard
С	Options proposing either a Twin Bore Tunnel or a Monotube Tunnel configuration with the Portal positioned West of Heuston / Islandbridge
D	Monotube Tunnel configuration Options with the Portal located in the Heuston Yard
E	Terminus Underground Station Options at Heuston with either a Twin Bore Tunnel or a Monotube Tunnel configuration
F	Options with a Twin Bore Tunnel configuration and a Portal located within the IÉ Railway Works at Inchicore

Table 4: Categorisation of Identified Possible Options

#### 6.2 Metrics for Evaluation

The criteria adopted for the evaluation of possible options and the metric by which the qualitative assessment is performed against each of the individual criterion are described in **Table 3**.

## 6.3 Evaluation of Identified Possible Options

In assessing the performance of each identified possible option against any individual criterion, a 'Pass / Fail' approach is adopted.

Each possible option is qualitatively assessed against each specific criterion. If a possible option is considered to be both feasible and practicable when measured against an individual criterion, it is recorded as a 'Pass'. If the qualitative assessment records that a possible option when measured against an individual criterion is either not feasible and/or not practicable, then a 'Fail' is recorded against that criterion.

For an option to be considered as both feasible and practicable and to advance to the Phase 3 Multi-Criteria Assessment of Options, a 'Pass' must be recorded against each individual criterion for that possible option. Any option, which records a 'Fail' measured against any particular criterion, does not advance to the Phase 3 Multi-Criteria Assessment.

## 6.4 Description of Identified Possible Options

Of the twenty-one possible options identified, many of the options shared similarities in respect of the tunnel configuration, the relative location of the tunnel portal and the location of the proposed Underground Station relative to the existing Heuston Station. Therefore, the possible options were categorised as presented in **Table 4** (above) to aid the nomenclature and presentation of the options evaluation, and the interpretation of the outcome of the qualitative assessment.

In some instances, a further sub-division of the categories presented in **Table 4** is adopted to indicate where the proposed Underground Station will be located relative to the existing Heuston Station. Thus, a sub-division with the nomenclature 'S' indicates a proposed Underground Station positioned along the southern end of the existing Heuston Station location. A sub-division with the nomenclature 'N' indicates a proposed Underground Station positioned along the northern end of the existing Heuston Station.

A description of the 21 identified possible options is provided below and the results of the evaluation, together with a narrative of the principal findings, are presented in **Section 6.5**. The detailed evaluation and the track alignment drawings developed for each option is contained within **Appendix B** and the approximate geological lithology is contained in Volume 2.

Figure 46: Option Twin 1AS Station and Tunnel Portal Layout

#### 6.4.1 Option Twin 1AS

Tunnel Configuration	Single Track Twin Bore Tunnel Configuration
Overview Description	Tunnel Portal in Heuston Yard, Station on South Side under the footprint of the existing station  Rail level at western end of Platform is circa -19.4 mOD  Track Tie-In occurs under Rail Overbridge OB1
Proposed Underground Station Location	Proposed Station is located on the south side of the existing Heuston Station. The bored tunnels will be enlarged to create the platform tunnels. Three cut and cover shafts are proposed; one on the east providing emergency intervention / escape and ventilation; a central escalator shaft, and a western emergency intervention / escape and ventilation shaft.  The eastern and central cut and cover shafts are separated by the Camac Culvert which will be strengthened / underpinned ahead of tunnelling and station excavation.
Proposed Location of Bored Tunnel Portal	Tunnel portal is located within the Heuston Yard at Chainage +720 m and tie-in to the existing Mainline occurs under Overbridge OB1. This solution will require new rail overbridges at the location of the existing overbridges OB1 and OB1A to facilitate four tracking of the existing rail corridor.
Commentary	The platform rail level has been selected such that it is high enough to achieve a tie-in at Overbridge OB1 while ensuring that the footprint remains under the existing station. This option achieves a short tie-in length from the Underground Station platform level to the existing Mainline. The rockhead cover above the mined enlarged platform tunnels is approximately 2 m at the western end of the platform. Thus, it is considered that some alternative form of temporary ground support and additional settlement mitigation measures will be required.

Figure 47: Option Twin 2AS Station and Tunnel Portal Layout

#### 6.4.2 Option Twin 2AS

Tunnel Configuration	Single Track Twin Bore Tunnel Configuration
Overview Description	Tunnel Portal in Heuston Yard, Station on South Side, under footprint of existing station and straddling under the Luas Stop and Traction Sub-Station  Rail level at western end of Platform is circa -19.4 mOD  Track Tie-In occurs under Rail Overbridge OB1A
Proposed Underground Station Location	Proposed Station is located on the south side of the existing Heuston Station. The bored tunnels will be enlarged to create the platform tunnels. Three cut and cover shafts are proposed; one on the east providing emergency intervention / escape and ventilation; a central escalator shaft, and a western emergency intervention / escape and ventilation shaft.  The proposed station straddles under the existing mainline station footprint, under the station forecourt and under the Luas Heuston Stop and the below ground Luas Traction Sub-station. The eastern cut and cover shaft would be located adjacent to the existing station façade. The Camac Culvert underpinning/strengthening would have to be incorporated into the structure of the central cut and cover shaft.
Proposed Location of Bored Tunnel Portal	Tunnel portal is located within the Heuston Yard at Chainage +770 m, 50 m west of Option Twin 1AS and thus creates more space at the tie-in to accommodate the temporary diversion of the existing Mainline. The proposed DART vertical alignment would tie-in under Overbridge OB1A. This solution will require new rail overbridges at the location of the existing overbridges OB1 and OB1A to facilitate four tracking of the existing rail corridor.
Commentary	The platform rail level has been selected such that it is high enough to achieve a tie-in at Overbridge OB1A while ensuring that the footprint remains under the existing station. This option achieves a short tie-in length from the Underground Station platform level to the existing Mainline.

Figure 48: Option Twin 3AS Station and Portal Layout

Station Platform Location

Extents of retained structure and cut and cover Tunnel

Station escalator, ventilation and intervention shafts, cross passages and ventilation adits

Extents of four tracking the existing mainline

#### 6.4.3 Option Twin 3AS

Tunnel Configuration	Single Track Twin Bore Tunnel Configuration
Overview Description	Tunnel Portal in Heuston Yard, Station on South Side straddling the St. James' Gate Brewery and below the footprint of the existing Station  Rail level at western end of Platform is circa -21.1 mOD  Track Tie-In occurs east of Rail Overbridge OB1A
Proposed Underground Station Location	Proposed Station is located on the south side of the existing Heuston Station. The bored tunnels will be enlarged to create the platform tunnels. Three cut and cover shafts are proposed; one on the east providing emergency intervention / escape and ventilation; a central escalator shaft, and a western emergency intervention / escape and ventilation shaft.  The proposed station straddles under the existing mainline station footprint, under St. John's Road West and into the St. James' Gate Brewery. The eastern cut and cover shaft will be constructed in an area currently designated as the Kegging Yard of the Brewery whilst the central escalator cut and cover shaft will be constructed within the existing station.  There is then a need to construct a mined escalator tunnel to the track level and construct a mined passenger access tunnel and adits leading onto the platforms, and leading to the eastern cut and cover shaft.
Proposed Location of Bored Tunnel Portal	Tunnel portal is located within the Heuston Yard at Chainage +805 m, 85 m west of Option Twin 1AS and thus creates more space at the tie-in to accommodate the temporary diversion of the existing Mainline. The proposed DART vertical alignment would tie-in approximately 40m to the east of overbridge OB1A. This solution will require a new rail overbridge at the location of the existing overbridge OB1 to facilitate four tracking of the existing rail corridor.
Commentary	The platform rail level has been selected such that it is low enough to enable the mined passenger and escalator tunnels to be constructed between the St. James' Gate Brewery and Heuston Station with generally sufficient rockhead cover with the exception of the eastern end where the rockhead cover reduces and alternative construction methodologies and settlement mitigation will be required.  The rockhead level dips significantly beneath St. James' Gate Brewery reflecting the location of the pre-glacial River Liffey as discussed in <b>Section 2.4</b> of this report.  The central and western cut and cover shafts straddle the Camac Culvert which will be strengthened / underpinned ahead of tunnelling and station excavation.

Table 7: Overview of Option Twin 3AS

Figure 49: Option Twin 1AN Station and Portal Layout

#### 6.4.4 Option Twin 1AN

Tunnel Configuration	Single Track Twin Bore Tunnel Configuration
Overview Description	Tunnel Portal in Heuston Yard, just north of the Valeting Depot and south of the former Guinness sidings. Station on North Side below the footprint of the existing Station.  Rail level at western end of Platform is circa -19.5 mOD  Track Tie-In occurs just west of Rail Overbridge OB1.
Proposed Underground Station Location	Proposed Station is located on the north side of the existing Heuston Station and runs skewed to the Mainline platform arrangement.  The bored tunnels will be enlarged to create the platform tunnels. The alignment is such that the tunnel enlargement does not occur under the River Liffey, which is considered too great a construction risk due to the low rockhead cover and the risk of groundwater recharge if glacial sands and gravels are encountered. Three cut and cover shafts are proposed; one on the east providing emergency intervention / escape and ventilation; a central escalator shaft, and a western emergency intervention / escape and ventilation shaft.  The Camac Culvert underpinning/strengthening would have to be incorporated into the structure of the eastern cut and cover shaft.
Proposed Location of Bored Tunnel Portal	Tunnel portal is located within the Heuston Yard at Chainage +740 m and the tie- in to the existing Mainline occurs just west of Overbridge OB1. This solution will require new rail overbridges at the location of the existing overbridges OB1 and OB1A to facilitate four tracking of the existing rail corridor.
Commentary	The platform rail level has been selected such that it is high enough to achieve a tie-in at Overbridge OB1 while ensuring that the footprint remains under the existing station. This option achieves a short tie-in length from the Underground Station platform level to the existing Mainline.  It should be noted that it is not possible to achieve a platform configuration which is parallel to the existing Mainline Station platforms by adopting minimum permissible horizontal radii in the alignment design, and that a skewed arrangement is unavoidable.  The rockhead cover above the mined enlarged platform tunnels is approximately 1 m to 2 m at the western end of the platform. Thus, it is considered that some alternative form of temporary ground support and additional settlement mitigation measures will be essential.

Station Platform Location

Extents of bored tunnel

Extents of retained structure and cut and cover Tunnel

Station escalator, ventilation and intervention shafts, cross passages and ventilation adits

Extents of four tracking the existing mainline

Figure 50: Option Twin 2AN Station and Portal Layout

#### 6.4.5 Option Twin 2AN

Tunnel Configuration	Single Track Twin Bore Tunnel Configuration
Overview Description	Tunnel Portal in Heuston Yard, just north of the Valeting Depot and south of the former Guinness sidings. Station on North Side below the footprint of the existing Station and straddling under the forecourt at the main entrance to the existing Station.  Rail level at western end of Platform is circa -19.5 mOD.  Track Tie-In occurs just west of Rail Overbridge OB1A.
Proposed Underground Station Location	Proposed Station is located on the north side of the existing Heuston Station and runs skewed to the Mainline platform arrangement.  The bored tunnels will be enlarged to create the platform tunnels. The alignment is such that the tunnel enlargement does not occur under the River Liffey, which is considered too great a construction risk due to the low rockhead cover and the risk of groundwater recharge if glacial sands and gravels are encountered.  Three cut and cover shafts are proposed; one on the east providing emergency intervention / escape and ventilation; a central escalator shaft, and a western emergency intervention / escape and ventilation shaft.  The proposed station straddles under the existing mainline station footprint and under the forecourt at the front of the existing station. The eastern cut and cover shaft would be located in what is currently the south-east corner of the existing station. The Camac Culvert underpinning/ strengthening would have to be incorporated into the structure of the central cut and cover shaft.
Proposed Location of Bored Tunnel Portal	Tunnel portal is located within the Heuston Yard at Chainage +793 m and the tie-in to the existing Mainline occurs just west of Overbridge OB1A. This solution will require new rail overbridges at the location of the existing overbridges OB1 and OB1A to facilitate four tracking of the existing rail corridor.
Commentary	The platform rail level has been selected such that it is high enough to achieve a tie-in at Overbridge OB1A. This option achieves a short tie-in length from the Underground Station platform level to the existing Mainline.  It should be noted that it is not possible to achieve a platform configuration which is parallel to the existing Mainline Station platforms by adopting minimum permissible horizontal radii in the alignment design, and that a skewed arrangement is unavoidable.  The rockhead cover above the mined enlarged platform tunnels is approximately 1 m to 2 m at the western end of the platform. Thus, it is considered that some alternative form of temporary ground support and additional settlement mitigation measures will be essential.

Table 9: Overview of Option Twin 2AN

Figure 51: Option Twin 3AN Station and Portal Layout

#### 6.4.6 Option Twin 3AN

Tunnel Configuration	Single Track Twin Bore Tunnel Configuration
Overview Description	Tunnel Portal in Heuston Car Park and adjacent to the existing Platform 8. Station on North Side straddling into the St. James' Gate Brewery and below the footprint of the existing Station.  Rail level at western end of Platform is circa -19.4 mOD  Track Tie-In occurs approximately 80 m east of Rail Overbridge OB1A.
Proposed Underground Station Location	Proposed Station is located on the north side of the existing Heuston Station and runs skewed to the Mainline platform arrangement.  The bored tunnels will be enlarged to create the platform tunnels. Three cut and cover shafts are proposed; one on the east providing emergency intervention / escape and ventilation; a central escalator shaft, and a western emergency intervention / escape and ventilation shaft.  The proposed station straddles under the existing mainline station footprint, under St. John's Road West and into the St. James' Gate Brewery. The eastern cut and cover shaft will be constructed in an area currently designated as the Kegging Yard of the Brewery whilst the central escalator cut and cover shaft will be constructed within the existing station and forecourt area.  There is then a need to construct a mined escalator tunnel to the track level and construct a mined passenger access tunnel and adits leading onto the platforms.
Proposed Location of Bored Tunnel Portal	Tunnel portal is located within the Heuston Yard at Chainage +888 m and the tie- in to the existing Mainline occurs approximately 80 m east of Overbridge OB1A to create more space for the arrangement of a temporary track diversion during construction. This solution will require a new rail overbridge at the location of the existing overbridge OB1 to facilitate four tracking of the existing rail corridor.
Commentary	The platform rail level has been selected such that it is high enough to achieve a tie-in east of Overbridge OB1A. This option achieves a short tie-in length from the Underground Station platform level to the existing Mainline.  It should be noted that it is not possible to achieve a platform configuration which is parallel to the existing Mainline Station platforms by adopting minimum permissible horizontal radii in the alignment design, and that a skewed arrangement is unavoidable.  The rockhead cover above the mined enlarged platform tunnels is approximately 0 m to 1 m at the eastern end of the platform. Thus, it is considered that substantial temporary works will be required to provide temporary ground support during construction and to provide settlement mitigation.

Table 10: Overview of Option Twin 3AN

Figure 52: Option Twin 1BS Station and Portal Layout

#### 6.4.7 Option Twin 1BS

Tunnel Configuration	Single Track Twin Bore Tunnel Configuration
Overview Description	Tunnel Portal in Heuston Yard, encroaching into the citybound carriageway of St. John's Road West. Station located fully within the St. James' Gate Brewery. Rail level at western end of Platform is circa -28.6 mOD. The reason for the increased depth compared with previous options such as 1AS to 3AS inclusive, is that the pre-glacial River Liffey cuts through the site of the Brewery and the rockhead level drops very rapidly from -10.5 mOD under St. John's Road West to -20 mOD in the Brewery. To provide sufficient rockhead cover to enable the running tunnels to be enlarged to create the platform tunnels, the rail level must be at least -28.6 mOD.  A cut and cover station would enable the rail level to be raised but this would mean demolishing the Brewhouse and numerous other facilities within the Brewery.  Track Tie-In occurs east of Rail Overbridge OB1.
Proposed Underground Station Location	Proposed Station is located within the St. James' Gate Brewery. The bored tunnels will be enlarged to create the platform tunnels.
Proposed Location of Bored Tunnel Portal	Tunnel portal is located within the Heuston Yard at Chainage +870 m and tie-in to the existing Mainline occurs just east of Overbridge OB1a. This solution will require a new rail overbridge at the location of the existing overbridge OB1 to facilitate four tracking of the existing rail corridor.
Commentary	The platform rail level has been selected such that it is high enough to achieve a tie-in just to the east of Overbridge OB1A while ensuring that the construction of the enlarged platform tunnels within the St. James' Gate Brewery is feasible, albeit challenging. This mined construction for the platforms, passageways and ventilation adits would require significant temporary works in an area of shallow rockhead cover and substantial settlement mitigation measures would be required.

Figure 53: Option Twin 1BN Station and Portal Layout

#### 6.4.8 Option Twin 1BN

Tunnel Configuration	Single Track Twin Bore Tunnel Configuration
Overview Description	Tunnel Portal in Heuston Yard Car Park. Station located fully within the St. James' Gate Brewery.  Rail level at western end of Platform is circa -29.0 mOD. The reason for the increased depth compared with previous options such as 1AN to 3AN inclusive, is that the pre-glacial River Liffey cuts through the site of the Brewery and the rockhead level drops very rapidly from -10.5 mOD under St. John's Road West to -20 mOD in the Brewery. To provide sufficient rockhead cover to enable the running tunnels to be enlarged to create the platform tunnels, the rail level of -29.0 mOD was adopted.  A cut and cover station would enable the rail level to be raised but this would mean demolishing the Brewhouse and numerous other facilities within the Brewery.  Track Tie-In occurs east of Rail Overbridge OB1
Proposed Underground Station Location	Proposed Station is located within the St. James' Gate Brewery. The bored tunnels will be enlarged to create the platform tunnels.
Proposed Location of Bored Tunnel Portal	Tunnel portal is located within the Heuston Car Park at Chainage +950 m and tie-in to the existing Mainline occurs just west of Overbridge OB1a. This solution will require a new rail overbridge at the location of the existing overbridge OB1 to facilitate four tracking of the existing rail corridor.
Commentary	The platform rail level has been selected such that it is high enough to achieve a tie-in just before Overbridge OB1A while ensuring that the construction of the enlarged platform tunnels within the St. James' Gate Brewery is feasible, albeit challenging. This mined construction for the platforms, passageways and ventilation adits would require significant temporary works in an area of shallow rockhead cover and substantial settlement mitigation measures.

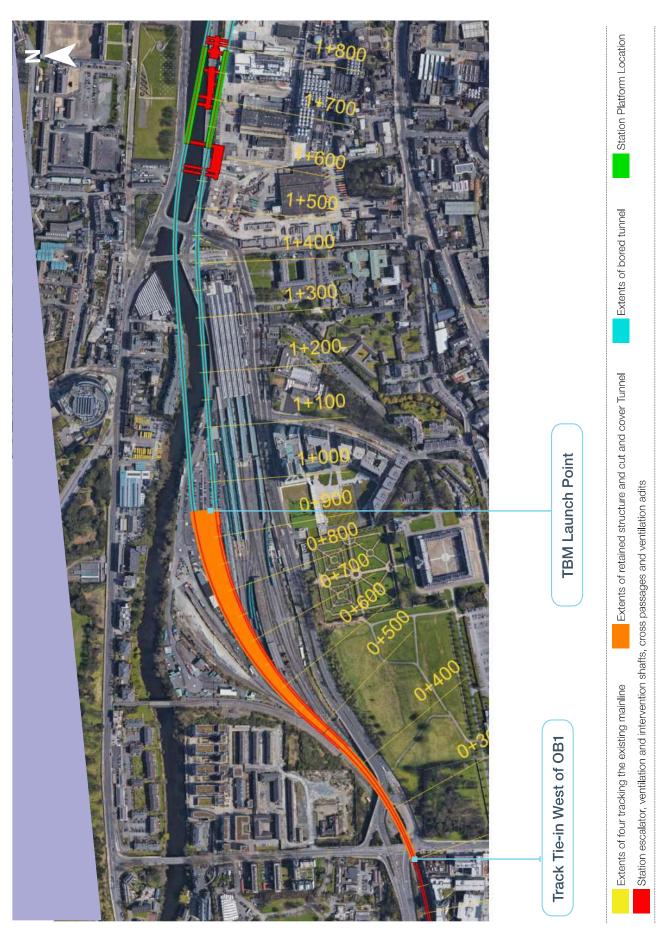


Figure 54: Option Twin 2B Station and Portal Layout

#### 6.4.9 Option Twin 2B

Single Track Twin Bore Tunnel Configuration
Tunnel Portal in Heuston Station Car Park. Station located principally under Victoria Quay, the St. James' Gate Brewery and eastbound (down line) platform under the River Liffey.
Rail level at western end of Platform is circa -29.0 mOD. The reason for the increased depth compared with previous options such as 1AN to 3AN inclusive, is that the pre-glacial River Liffey cuts through the site of the Brewery and the rockhead level drops very rapidly from -10.5 mOD under St. John's Road West to -20 mOD under Victoria Quay. To provide sufficient rockhead cover to enable the running tunnels to be enlarged to create the platform tunnels, the rail level must be at least -29.0 mOD with further site investigation required to confirm the exact rockhead profile and potential for groundwater recharge.
Track Tie-In occurs at Rail Overbridge OB1, the reason being that the river bed level is -1.1 mOD and foundation of the Quay Wall is circa -3.5 mOD, to achieve sufficient clearance to tunnel beneath the Quay Walls, the track level at the river / car park interface must be circa -16.0 mOD.
Proposed Station is located under Victoria Quay and the River Liffey. Cut and cover shafts would need to be constructed on Victoria Quay and within the St. James' Gate Brewery with tunnel enlargement, passageways and ventilation adits mined from the cut and cover shafts. Victoria Quay would be closed for the duration of the station construction.
Tunnel portal is located within the Heuston Yard at Chainage +950 m and tie-in to the existing Mainline occurs just west of Overbridge OB1. This solution will require new rail overbridges at the location of the existing overbridges OB1 and OB1A to facilitate four tracking of the existing rail corridor.
The platform rail level is driven by the need to have sufficient rockhead cover to be able to construct the enlarged platform tunnels, passageways and ventilation adits, whilst the vertical alignment is dictated by the need for the running tunnels to have sufficient cover beneath the Quay Wall adjacent to the existing Heuston car park. As a result, the tie-in to the Heuston Mainline is located at Overbridge OB1.

Figure 55: Option Twin 3B Station and Portal Layout

#### 6.4.10 Option Twin 3B

Tunnel Configuration	Single Track Twin Bore Tunnel Configuration
Overview Description	Tunnel Portal in Heuston Station Car Park. Station located under Croppies' Acre Memorial Park, north of the River Liffey.  Rail level at western end of Platform is circa -20.5 mOD.  Track Tie-In occurs just west of Rail Overbridge OB1, the reason being that the river bed level is -1.1 mOD and foundation of the Quay Wall is circa -3.5 mOD, to achieve sufficient clearance to tunnel beneath the Quay Walls, the track level at the river / car park interface must be circa -16.0 mOD.  This solution involves tunnelling under the River Liffey three times between Heuston and just east of Watling Street.
Proposed Underground Station Location	Proposed Station is located under Croppies' Acre Memorial Park. This proposed station could be constructed as a Cut and Cover Station as opposed to a mined tunnel configuration.
Proposed Location of Bored Tunnel Portal	Tunnel portal is located within the Heuston Yard at Chainage +910 m and tie-in to the existing Mainline occurs just west of Overbridge OB1. This solution will require new rail overbridges at the location of the existing overbridges OB1 and OB1A to facilitate four tracking of the existing rail corridor.
Commentary	The vertical alignment is dictated by the need for the running tunnels to have sufficient cover beneath the Quay Wall and river bed adjacent to the existing Heuston car park and under the river bridges. As a result, the tie-in to the Heuston Mainline is located just west of Overbridge OB1.

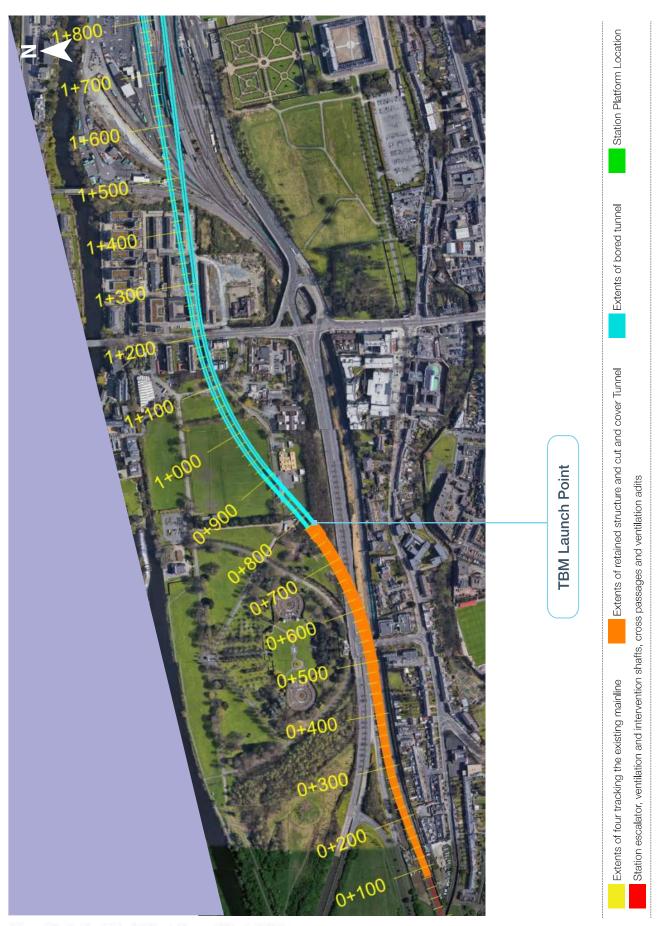
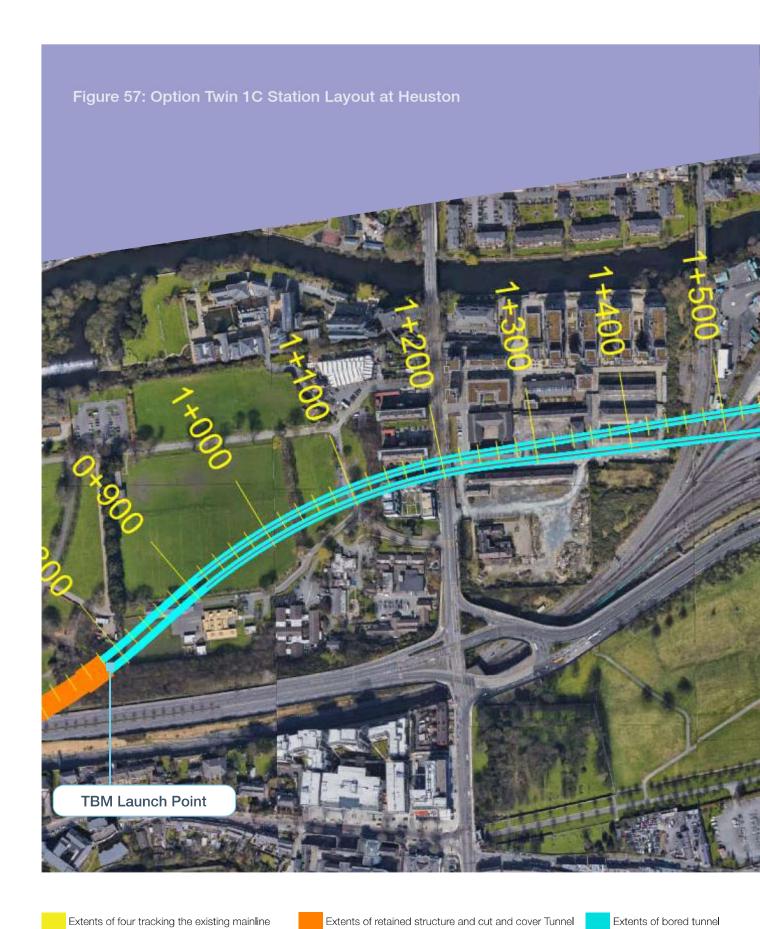
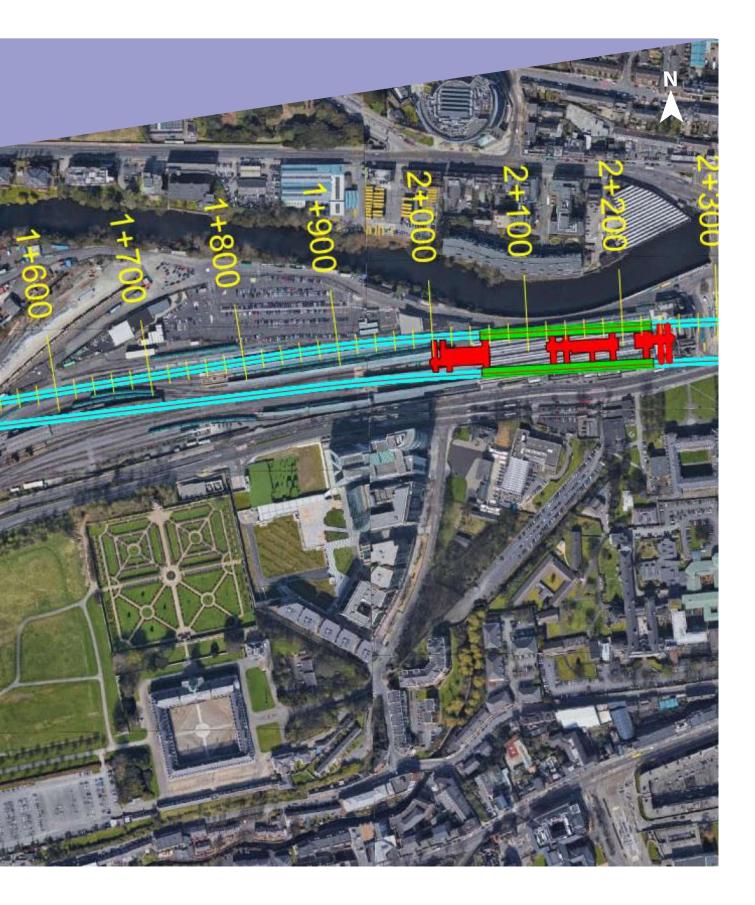


Figure 56: Option Twin 1C Portal Layout West of OB1

#### 6.4.11 Option Twin 1C

Tunnel Configuration	Single Track Twin Bore Tunnel Configuration
Overview Description	Tunnel Portal is located west of Islandbridge, positioned in the eastern end of the Irish National War Memorial Park, adjacent to Gaelscoil Inse Chór.  Rail level at western end of Platform is circa -20.4 mOD.  In this arrangement, the DART Underground tracks will tie into a widened Heuston Mainline rail corridor and the Chapelizod Bypass / Con Colbert Road will need to be supported on a viaduct to carry the road over the DART Underground tracks.
Proposed Underground Station Location	Proposed Station is located on the south side of the existing Heuston Station, similar to Option Twin 1AS. The bored tunnels will be enlarged to create the platform tunnels. Three cut and cover shafts are proposed; one on the east providing emergency intervention / escape and ventilation; a central escalator shaft, and a western emergency intervention / escape and ventilation shaft.  The eastern and central cut and cover shafts are separated by the Camac Culvert which will be strengthened / underpinned ahead of tunnelling and station excavation.
Proposed Location of Bored Tunnel Portal	Tunnel portal is located within the Memorial Park at Chainage +780 m.  The proposed alignment follows beneath the Hurling Grounds, under Clancy Barracks and into the Heuston Yard. There needs to be sufficient cover above the crown of the TBM at the launch point, taken as approximately 6.8 m for the twin bore tunnel configuration. This dictates the rail level at the launch point and in turn the geometry of the tie-in to the Heuston Mainline.
Commentary	Tie-in occurs at Chainage +80 m. It will be essential for the Chapelizod Bypass / Con Colbert Road to be supported on a deck structure to enable construction to proceed below and for the existing rail corridor to be widened from Longmeadows Bridge to the Sarsfield Road Underbridge.  A retaining structure will be required between the existing Mainline tracks, and the DART Underground tracks due to the difference in vertical level to the west of Longmeadows Bridge.





Station Platform Location

Station escalator, ventilation and intervention shafts, cross passages and ventilation adits



Figure 58: Option Mono 1C Portal Layout West of OB1

## 6.4.12 Option Mono 1C

Tunnel Configuration	Monotube Tunnel Configuration
Overview Description	Tunnel Portal is located west of Islandbridge, positioned in the eastern end of the Irish National War Memorial Park, adjacent to Gaelscoil Inse Chór.
	Rail level at western end of Platform is circa -31.4 mOD for the lower track in the vertical stacked arrangement of the monotube. The upper rail track level at the western end of the platform is circa -25.6 mOD.
	In this arrangement, the DART Underground tracks will tie into a widened Heuston Mainline rail corridor and the Chapelizod Bypass / Con Colbert Road will need to be supported on a viaduct to carry the road over the DART Underground tracks.
	Proposed monotube tunnel incorporating the platform tunnels is located under the footprint of the existing station.
Proposed Underground Station Location	The main entrance cut and cover shaft, incorporating ventilation, intervention and emergency escape, is positioned below the entrance forecourt to Dr Steevens' Hospital. This avoids the need for any significant construction works at the concourse level within the footprint of the existing station.
	A subway beneath St. John's Road West will directly link the concourse of the existing station to the Ticket Hall level of the proposed underground station entrance. At platform level, passageways and ventilation adits will run from the monotube to the cut and cover shaft.
	An intervention, emergency escape and ventilation shaft is also required at the western end of the platform. A smaller cut and cover shaft is proposed at the location of the current bike storage and ancillary building on the north side of the station, adjacent to Platform 8. Mined passageways and ventilation adits will link the end of the monotube platform and running tunnel to this northern shaft. There will be some intervention within the footprint of the existing station for access and strengthening / underpinning of the existing Camac Culvert will be necessary.
Proposed Location of Bored Tunnel Portal	Tunnel portal is located within the Memorial Park at Chainage +1170 m. The proposed alignment follows beneath the Hurling Grounds, under Clancy Barracks and into the Heuston Yard. There needs to be sufficient cover above the crown of the TBM at the launch point, taken as approximately 13.6 m for the Monotube tunnel configuration. This dictates the rail level at the launch point and in turn the geometry of the tie-in to the Heuston Mainline.
Commentary	Tie-in occurs 350 m to the west of the existing Sarsfield Road Underbridge. This solution necessitates the closure of Sarsfield Road to traffic. It will be essential for the Chapelizod Bypass / Con Colbert Road to be supported on a deck structure to enable construction to proceed below and for the existing rail corridor to be widened from Longmeadows Bridge to the Sarsfield Road Underbridge.  A significant retaining structure will be required between the existing Mainline tracks, and the DART Underground tracks due to the difference in vertical level to the west of Longmeadows Bridge.

Table 16: Overview of Option Mono 1C



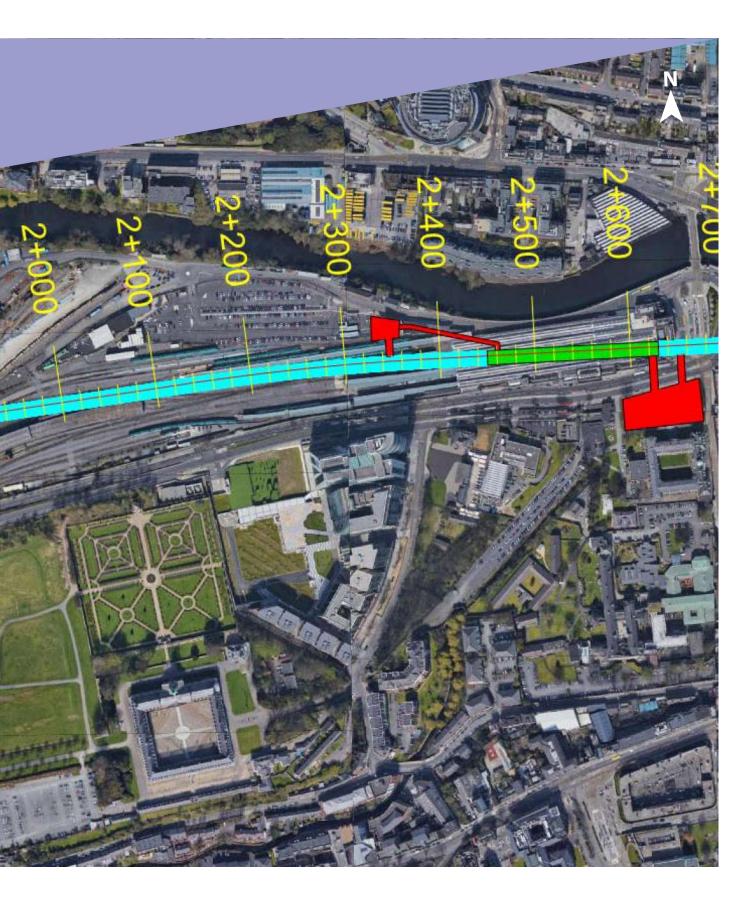
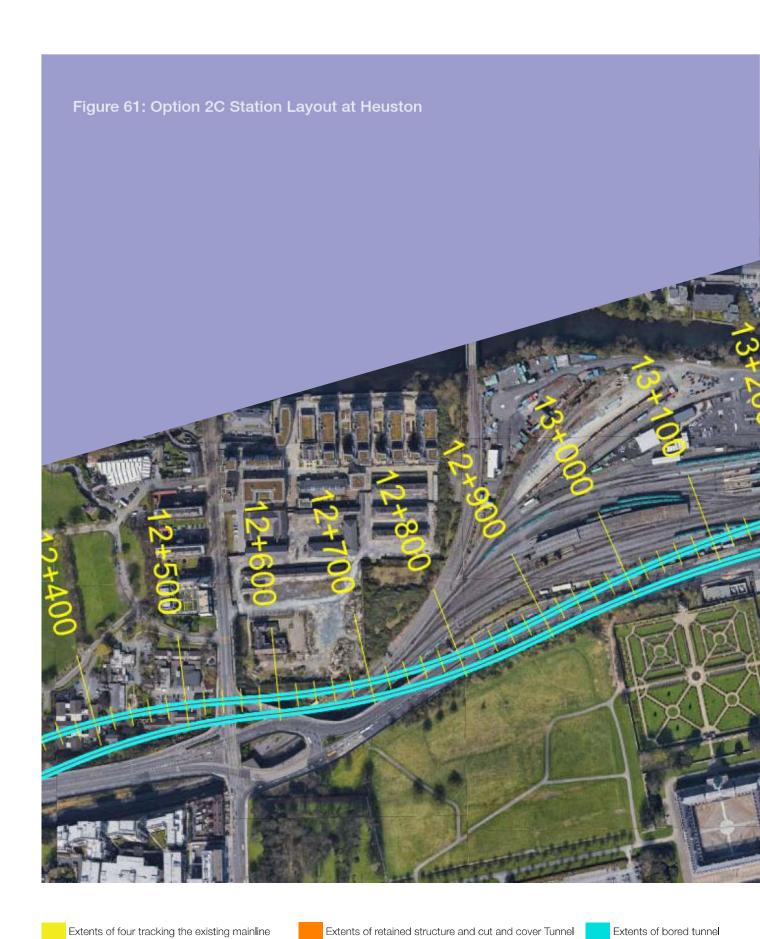




Figure 60: Option 2C Portal Layout West of OB1

## 6.4.13 Option Twin 2C

Tunnel Configuration	Single Track Twin Bore Tunnel Configuration
	Tunnel Portal is located west of Islandbridge, positioned on what is currently the westbound carriageway of the Con Colbert Road which acts as a slip lane off the Chapelizod Bypass, leading into Ballyfermot.
	Rail level at western end of Platform is circa -20.4 mOD.
Overview Description	Rail level at Portal is approximately 14.25 m OD
	In this arrangement, the DART Underground tracks will tie into the Heuston Mainline just east of the existing Sarsfield Road Underbridge. The existing Mainline tracks will need to be slewed south over a new underbridge at Sarsfield Road and then tie back into the existing Heuston Mainline.
Proposed Underground Station Location	Proposed Station is located on the south side of the existing Heuston Station, similar to Option Twin 1AS. The bored tunnels will be enlarged to create the platform tunnels. Three cut and cover shafts are proposed; one on the east providing emergency intervention / escape and ventilation; a central escalator shaft, and a western emergency intervention / escape and ventilation shaft. The eastern and central cut and cover shafts are separated by the Camac Culvert which will be strengthened / underpinned ahead of tunnelling and station excavation.
	Tunnel portal is located under the Con Colbert Road western carriageway.
Proposed Location of Bored Tunnel Portal	The proposed alignment runs directly beneath the Chapelizod Bypass / Con Colbert Road before moving north under the St. John of God School, passing under the South Circular Road and skirting just south of the Heuston Yard.
Commentary	This proposal requires the existing Mainline to be slewed south at Sarsfield Road and tie back into the existing Mainline just north of Murray's Cottages. The portal structure and approaches are positioned north of the existing Mainline tracks, under the westbound carriageway of the Con Colbert Road and the area referred to locally as the "Horses Field", which separates the Con Colbert Road from the Heuston Mainline.  The DART Underground tracks would follow a similar plan alignment as the
	existing Sarsfield Road Underbridge but the vertical alignment would differ, requiring a new bridge deck structure at this location.



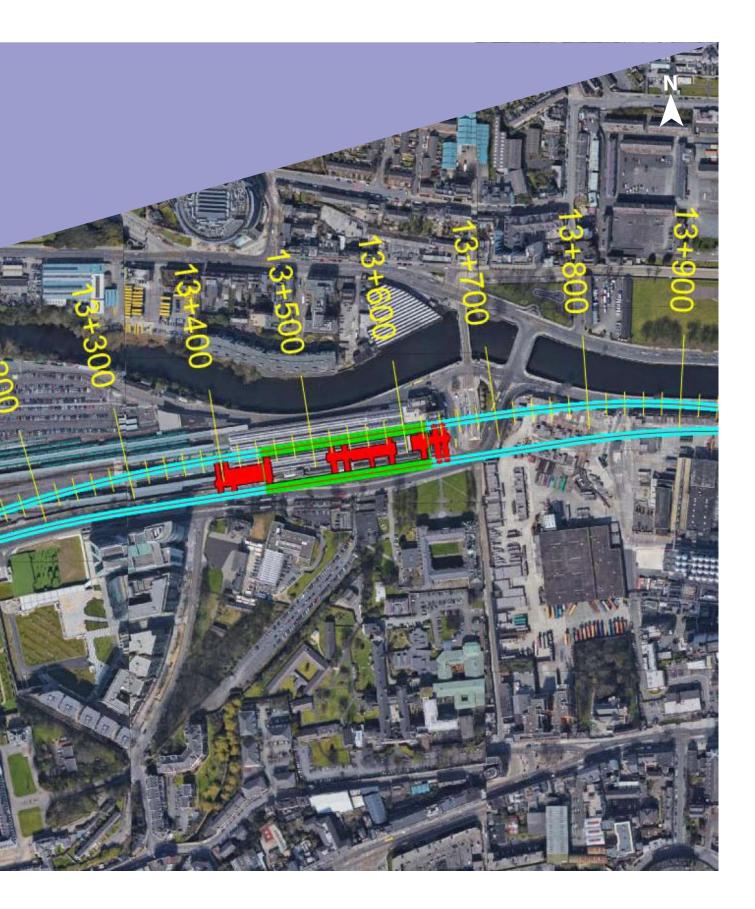




Figure 62: Option Twin 3C Portal Layout West of OB1

## 6.4.14 Option Twin 3C

Tunnel Configuration	Single Track Twin Bore Tunnel Configuration
	Tunnel Portal is located west of Islandbridge, positioned on what is currently the westbound carriageway of the Con Colbert Road which acts as a slip lane off the Chapelizod Bypass, leading into Ballyfermot.
	Rail level at western end of Platform is circa -20.4 mOD.
Overview Description	Rail level at Portal is approximately 12.7 m OD.
	In this arrangement, the DART Underground tracks will tie into the Heuston Mainline to the west of Sarsfield Road Underbridge. The existing Mainline tracks will need to be slewed south over a new underbridge at Sarsfield Road and then tie back into the existing Heuston Mainline.
Proposed Underground Station Location	Proposed Station is located on the south side of the existing Heuston Station, similar to Option Twin 1AS. The bored tunnels will be enlarged to create the platform tunnels. Three cut and cover shafts are proposed; one on the east providing emergency intervention / escape and ventilation; a central escalator shaft, and a western emergency intervention / escape and ventilation shaft.
	The eastern and central cut and cover shafts are separated by the Camac Culvert which will be strengthened / underpinned ahead of tunnelling and station excavation.
Proposed Location of Bored Tunnel Portal	Tunnel portal is located under the Con Colbert Road western carriageway. The tunnel is deeper than Option Twin 2C at the portal and therefore the tie-in occurs west of Sarsfield Road Underbridge.
	The proposed alignment runs directly beneath the Chapelizod Bypass / Con Colbert Road.
Commentary	The tie-in occurs approximately 130 m west of Sarsfield Road Underbridge due to the greater depth of tunnel at the portal, therefore Sarsfield Road will need to permanently be closed to vehicular traffic. The vertical alignment of the DART Underground is rising at the location of the underbridge and it is not possible to provide an acceptable headroom for vehicles. An underpass could be provided for cyclists and pedestrians.
	This proposal requires the existing Mainline to be slewed south at Sarsfield Road and tie back into the existing Mainline just north of Murray's Cottages. The portal structure and approaches are positioned north of the existing Mainline tracks, under the westbound carriageway of the Con Colbert Road and the area referred to locally as the "Horses Field", which separate the Con Colbert Road from the Heuston Mainline.

Table 18: Overview of Option Twin 3C

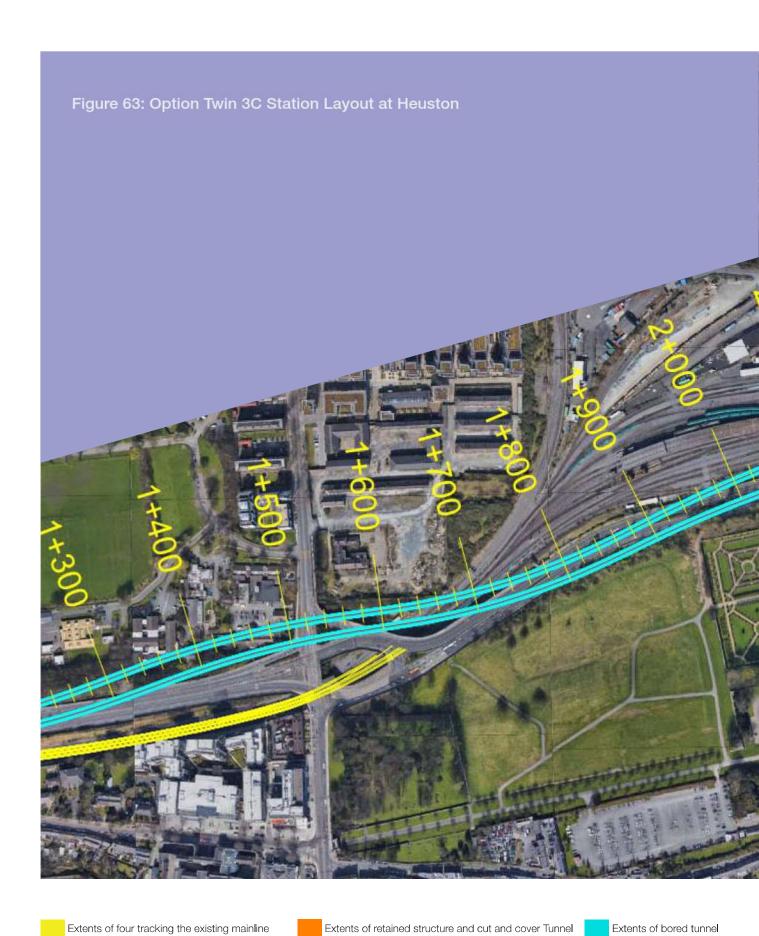




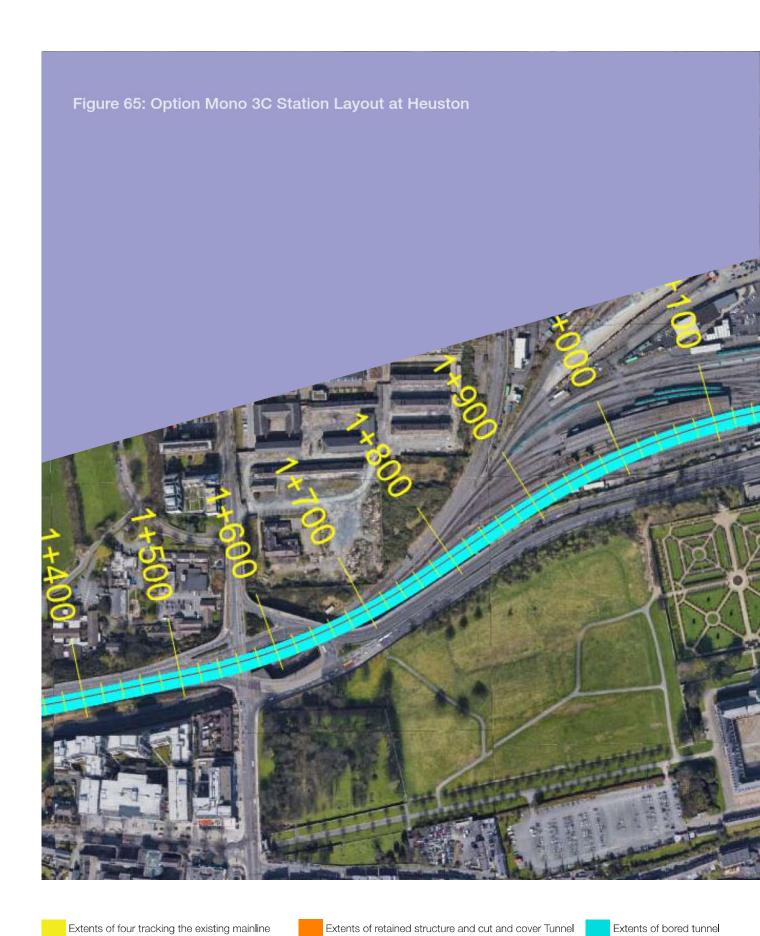


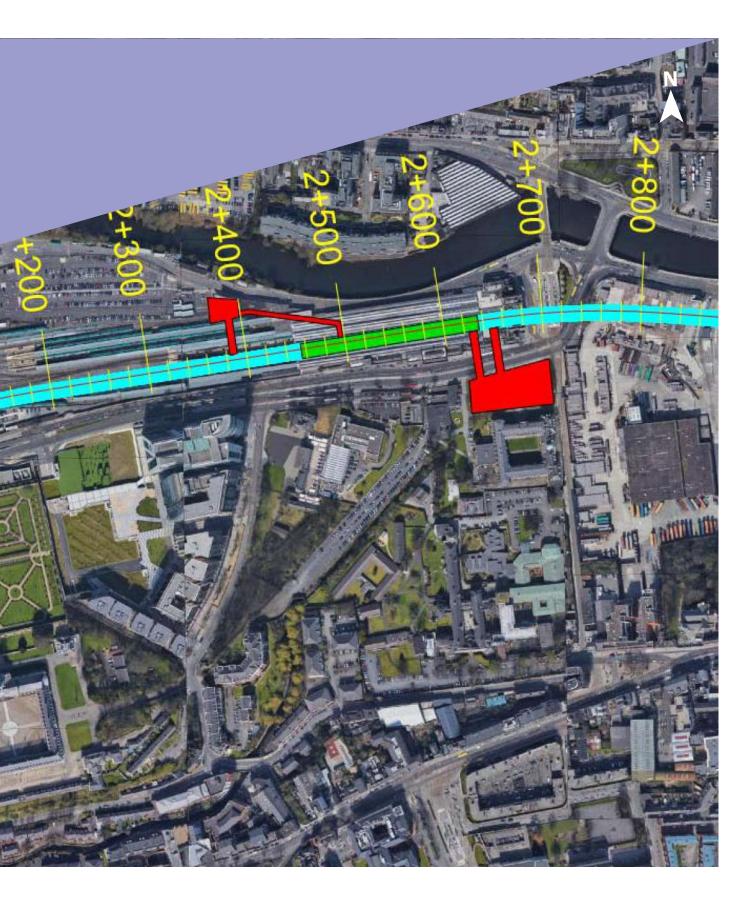
Figure 64: Option Mono 3C Portal Layout West of OB1

## 6.4.15 Option Mono 3C

Tunnel Configuration	Monotube Tunnel Configuration
Overview Description	Tunnel Portal is located west of Islandbridge, positioned on what is currently the westbound carriageway of the Con Colbert Road which acts as a slip lane off the Chapelizod Bypass, leading into Ballyfermot.  Rail level at western end of Platform is circa -31.4 mOD for the lower track in the vertical stacked arrangement of the monotube. The upper rail track level at the western end of the platform is circa -25.6 mOD.  In this arrangement, the DART Underground tracks will tie into the Heuston Mainline 360 m to the west of Sarsfield Road Underbridge. The existing Mainline tracks will need to be slewed south over a new underbridge at Sarsfield Road and then tie back into the existing Heuston Mainline
Proposed Underground Station Location	Proposed monotube tunnel incorporating the platform tunnels is located under the footprint of the existing station.  The main entrance cut and cover shaft, incorporating ventilation, intervention and emergency escape, is positioned below the entrance forecourt to Dr Steevens' Hospital. This avoids the need for any significant construction works at the concourse level within the footprint of the existing station.  A subway beneath St. John's Road West will directly link the concourse of the existing station to the Ticket Hall level of the proposed underground station entrance. At platform level, passageways and ventilation adits will run from the monotube to the cut and cover shaft.  An intervention, emergency escape and ventilation shaft is also required at the western end of the platform. A smaller cut and cover shaft is proposed at the location of the current bike storage and ancillary building on the north side of the station, adjacent to Platform 8. Mined passageways and ventilation adits will link the end of the monotube platform and running tunnel to this northern shaft.
Proposed Location of Bored Tunnel Portal	Tunnel portal is located under the Con Colbert Road western carriageway. The crown of the tunnel has to be approximately 13.6m below existing ground level and this pushes the tie-in to approximately 400 m west of Sarsfield Road Underbridge.  The proposed alignment runs directly beneath the Chapelizod Bypass / Con Colbert Road.
Commentary	Tie-in occurs 360 m to the west of the existing Sarsfield Road Underbridge. This solution necessitates the permanent closure of Sarsfield Road to vehicular traffic due to the depth of the track at the portal and substantial retaining structures will be required over the length from the tie-in to the portal. A combined pedestrian and cycle bridge could be provided which would span over the slewed Heuston Mainline and over the DART Underground tracks. This proposal requires the existing Mainline to be slewed south at Sarsfield Road and tie back into the existing Mainline just north of Murray's Cottages. The portal structure and approaches are positioned north of the existing Mainline tracks, under the westbound carriageway of the Con Colbert Road and the area referred to locally as the "Horses Field", which separates the Con Colbert Road from the Heuston Mainline.

Table 19: Overview of Option Mono 3C





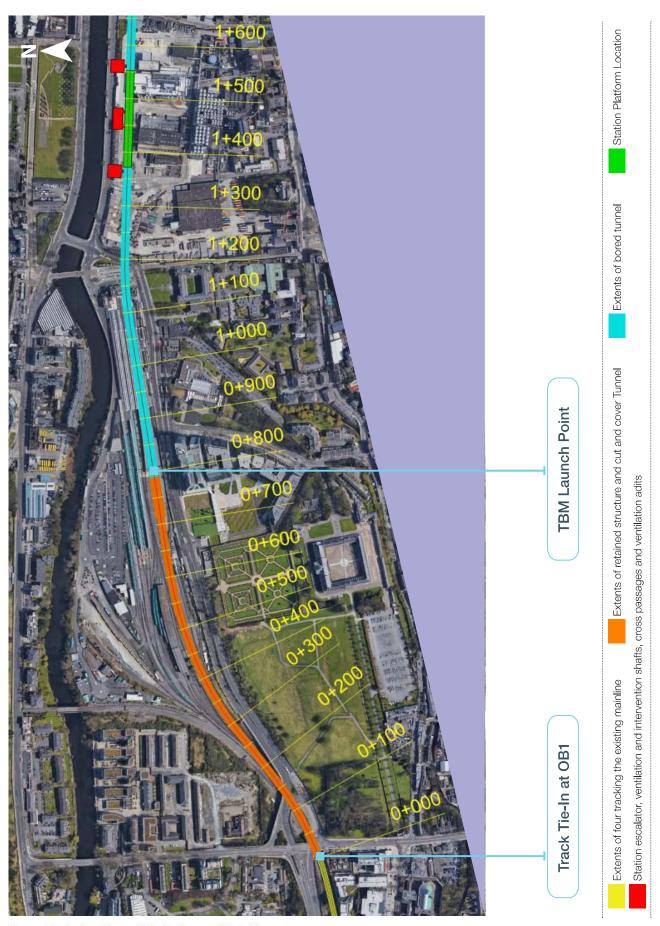


Figure 66: Option Mono 1DS Station and Portal Layout

## 6.4.16 Option Mono 1DS

Tunnel Configuration	Monotube Tunnel Configuration
Overview Description	Tunnel Portal is located in the Heuston Yard at Chainage +790 m, whilst the tie-in to the Heuston Mainline is positioned just west of rail overbridge OB1. The alignment follows a southerly direction within the Heuston Yard and along St. John's Road West.  The location of the portal is dictated by the need to have sufficient ground cover above the crown of the tunnel and to achieve a tie-in close to overbridge OB1.  The underground station platforms are located under the St. James' Gate Brewery and the associated cut and cover shafts straddle both Victoria Quay and the Brewery. It is envisaged that the above ground structures would sit along the northern edge of the Brewery with direct access onto Victoria Quay.  Rail level at western end of Platform is circa -32.1 mOD for the lower track in the vertical stacked arrangement of the monotube. The upper rail track level at the western end of the platform is circa -26.3 mOD.
Proposed Underground Station Location	Proposed monotube tunnel incorporating the platform tunnels is located under St. James' Gate Brewery. Three cut and cover shafts are required, a central entrance leading directly onto Victoria Quay, and a combined ventilation, intervention and emergency evacuation shafts at each end of the platform, also with direct access onto Victoria Quay.  Below ground level, these cut and cover shafts would straddle beneath Victoria Quay and the northern perimeter access road within the existing Brewery. Thus, it is envisaged that the manufacturing facilities within Brewhouse No. 4 could largely continue unaffected during the construction period. Passageways and ventilation adits would be mined to link the monotube tunnel with the cut and cover shafts.
Proposed Location of Bored Tunnel Portal	Tunnel portal is located along the southern end of the Heuston Yard at Chainage +790 m, with a ground cover of approximately 11 m in depth, which is less challenging and will increase the risk of ground movements occurring. However the portal cannot move further east and remain feasible to construct unless the existing platforms and station building are adversely impacted to an unacceptable extent.  The tie-in is located just west of rail overbridge OB1.
Commentary	The tie-in location cannot feasibly be located west of rail overbridge OB1 and permit an adequate level of train service into the existing Heuston station during construction of DART Underground.

Table 20: Overview of Option Mono 1DS



Figure 67: Option Mono 1DN Station and Portal Layout

## 6.4.17 Option Mono 1DN

Tunnel Configuration	Monotube Tunnel Configuration
Overview Description	Tunnel Portal is located in the Heuston Car Park at Chainage +790 m, whilst the tie-in to the Heuston Mainline is positioned just west of rail overbridge OB1. The alignment follows a northerly direction within the Heuston Yard and Car Park, then running skewed beneath the footprint of the existing Heuston Station.  The location of the portal is dictated by the need to have sufficient ground cover above the crown of the tunnel and to achieve a tie-in close to overbridge OB1.  The underground station platforms are located under the St. James' Gate Brewery and the associated cut and cover shafts straddle both Victoria Quay and the Brewery. It is envisaged that the above ground structures would sit along the northern edge of the Brewery with direct access onto Victoria Quay.  Rail level at western end of Platform is circa -32.1 mOD for the lower track in the vertical stacked arrangement of the monotube. The upper rail track level at the western end of the platform is circa -26.3 mOD.
Proposed Underground Station Location	Proposed monotube tunnel incorporating the platform tunnels is located under St. James' Gate Brewery. Three cut and cover shafts are required, a central entrance leading directly onto Victoria Quay, and a combined ventilation, intervention and emergency evacuation shafts at each end of the platform, also with direct access onto Victoria Quay.  Below ground level, these cut and cover shafts would straddle beneath Victoria Quay and the northern perimeter access road within the existing Brewery. Thus, it is envisaged that the manufacturing facilities within Brewhouse No. 4 could largely continue unaffected during the construction period. Passageways and ventilation adits would be mined to link the monotube tunnel with the cut and cover shafts.
Proposed Location of Bored Tunnel Portal	Tunnel portal is located in the existing Heuston Car Park at Chainage +790 m, north of Platform 8, with a ground cover of approximately 11 m in depth which is challenging and will increase the risk of ground movements occurring. However the portal cannot move further east and remain feasible to construct unless the existing platforms and station building are adversely impacted to an unacceptable extent.  The tie-in is located just west of rail overbridge OB1.
Commentary	The tie-in location cannot feasibly be located west of rail overbridge OB1 and permit an adequate level of train service into the existing Heuston station during construction of DART Underground.

Table 21: Overview of Option Mono 1DN

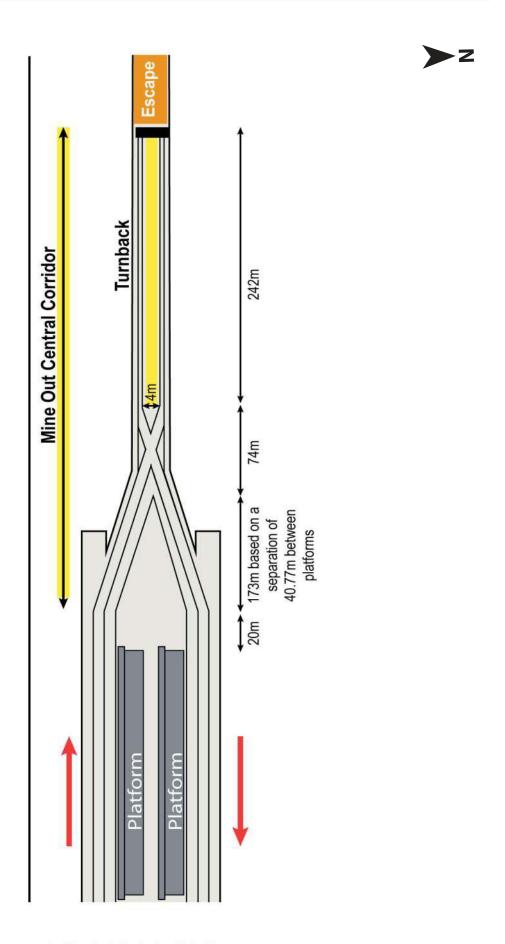


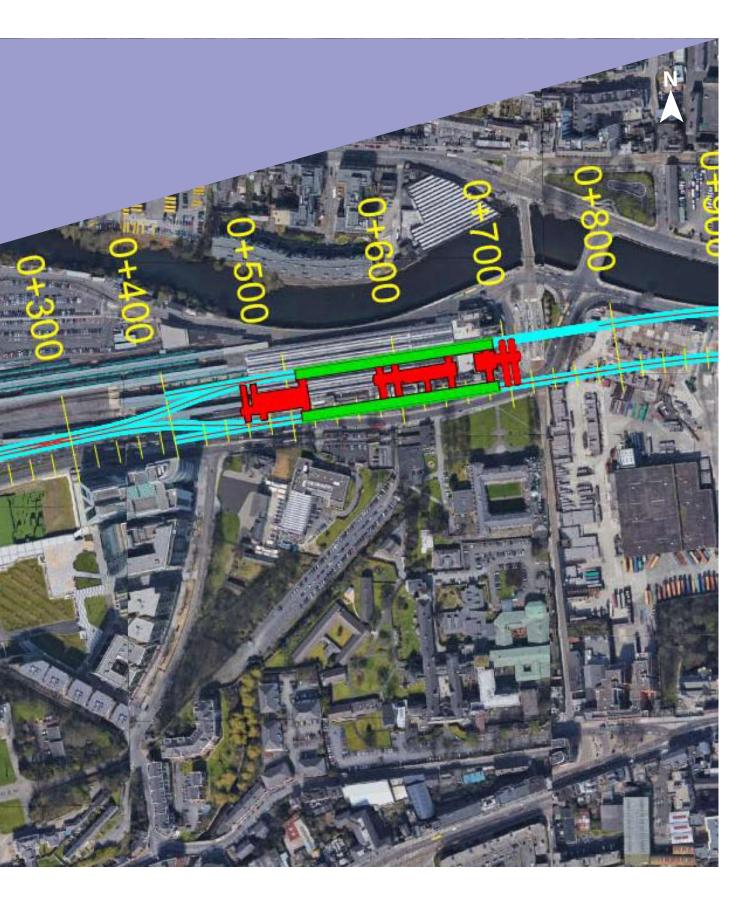
Figure 68: Plan Schematic Arrangement of Turnback for Option Twin 1E

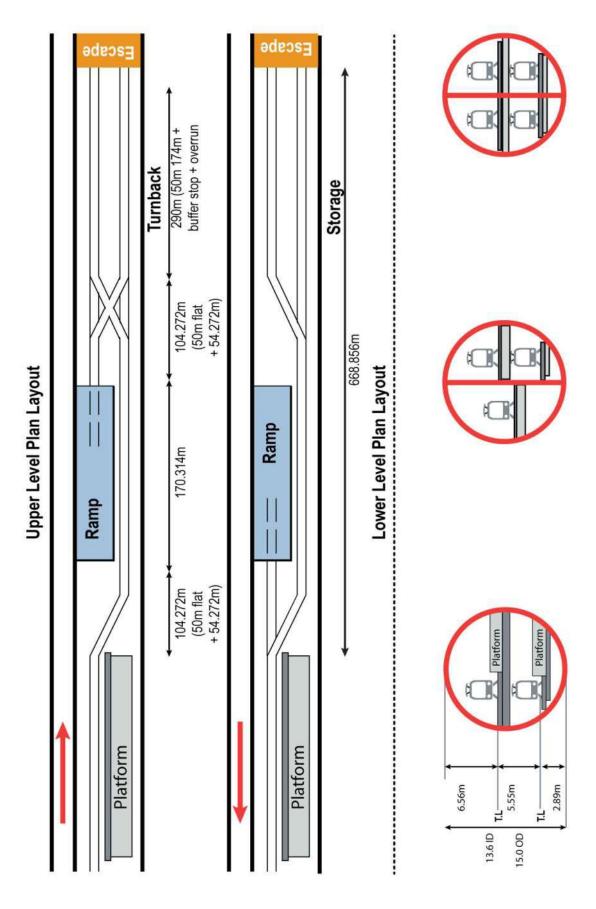
## 6.4.18 Option Twin 1E

Tunnel Configuration	Single Track Twin Bore Tunnel Configuration
Overview Description	This proposal is for an underground terminus turnback arrangement at Heuston Station with a capacity of up to 12 trains per hour per direction based on a twin bore tunnel configuration.  The twin bored tunnels would terminate approximately 20m beyond the end of the platforms. The central turnback arrangement and connecting link tunnels to the running tunnels are constructed as mined tunnels. A ventilation, intervention and evacuation shaft is provided at the end of the central turnback, which also acts as a means of access for the train drivers and maintenance personnel. Rail level at western end of Platform is circa -30.0 mOD.  The rail level is dictated by the need to mine an enlarged 460 m length of tunnel where the rockhead dips to the west of the existing Heuston Station. To provide a sufficient level of rock cover above the mined excavation, it is necessary for the track level at the platforms to be circa -30.0 mOD.
Proposed Underground Station Location	Proposed Station is located on the south side of the existing Heuston Station. The bored tunnels will be enlarged to create the platform tunnels. Three cut and cover shafts are proposed; one on the east providing emergency intervention / escape and ventilation; a central escalator shaft, and a western emergency intervention / escape and ventilation shaft.  The eastern and central cut and cover shafts are separated by the Camac Culvert which will be strengthened / underpinned ahead of tunnelling and station excavation.
Proposed Location of Bored Tunnel Portal	It is assumed that the bored tunnels will be driven from the east and the TBMs will be buried in the rock just beyond the end of the platform tunnels.  The arrangement of the turnback is shown schematically in <b>Figure 68</b> and the actual arrangement is then shown in <b>Figure 69</b> . The turnback is 509 m in length from the end of the platform tunnel to the ventilation, intervention and evacuation shaft.
Commentary	The ventilation, intervention and evacuation shaft at the end of the mined turnback is proposed to be located just north of the eastbound carriageway of St. John's Road West. Thus, access can be gained from the public highway for emergency services and there is sufficient space at ground level for any personnel evacuating the system.  As the proposed shaft is also sited at the location of some existing lÉ signalling huts, access for authorised personnel can be gained from within the existing lÉ lands of Heuston Station.

Table 22: Overview of Option Twin 1E







Note: The 50m lengths above are to allow for the vertical curves in the ramp section. The smallest vertical curve acceptable is 90m, thus a

requirement for a 45m length on the flat plus an additional 5m tolerance to give a length of 50m.

Figure 70: Schematic Layout of the Monotube Turnback Arrangement

## 6.4.19 Option Mono 2E

Tunnel Configuration	Monotube Tunnel Configuration
	This proposal is for an underground terminus turnback arrangement at Heuston Station with a capacity of up to 12 trains per hour per direction based on a monotube tunnel configuration.
	The arrangement of a tumback within a monotube is illustrated schematically in <b>Figure 70</b> . The turnback is a total length of approximately 669 m including the buffers.
	A ventilation, intervention and evacuation shaft is provided at the end of the turnback, which also acts as a means of access for the train drivers and maintenance personnel.
Overview Description	Rail level at western end of Platform is circa -31.5 mOD for the upper rail level and -37.3 mOD for the lower rail level.
	The rail level is dictated by diameter of the bored tunnel, approximately 15.0 m outer diameter. The rockhead dips to the west of the existing Heuston Station and to provide a sufficient level of rock cover above the large diameter TBM tunnel, it is necessary for the crown of the tunnel to be at circa -23.7 mOD at the end of the turnback and -25 mOD at the western end of the platform. This will ensure that the tunnel is constructed with adequate rock cover to ensure that the potential for ground movement is substantially reduced and that potential ground induced damage is within acceptable limits.
	Proposed monotube tunnel incorporating the platform tunnels is located under the footprint of the existing station.
Proposed Underground Station Location	The main entrance cut and cover shaft, incorporating ventilation, intervention and emergency escape, is positioned below the entrance forecourt to Dr Steevens' Hospital. This avoids the need for any significant construction works at the concourse level within the footprint of the existing station.
	A subway beneath St. John's Road West will directly link the concourse of the existing station to the Ticket Hall level of the proposed underground station entrance. At platform level, passageways and ventilation adits will run from the monotube to the cut and cover shaft.
	An intervention, emergency escape and ventilation shaft is also required at the western end of the platform. A smaller cut and cover shaft is proposed at the location of the current bike storage and ancillary building on the north side of the station, adjacent to Platform 8. Mined passageways and ventilation adits will link the end of the monotube platform and running tunnel to this northern shaft. There will be some intervention within the footprint of the existing station for access and strengthening / underpinning of the existing Camac Culvert will be necessary.

Table 23: Overview of Option Mono 2E

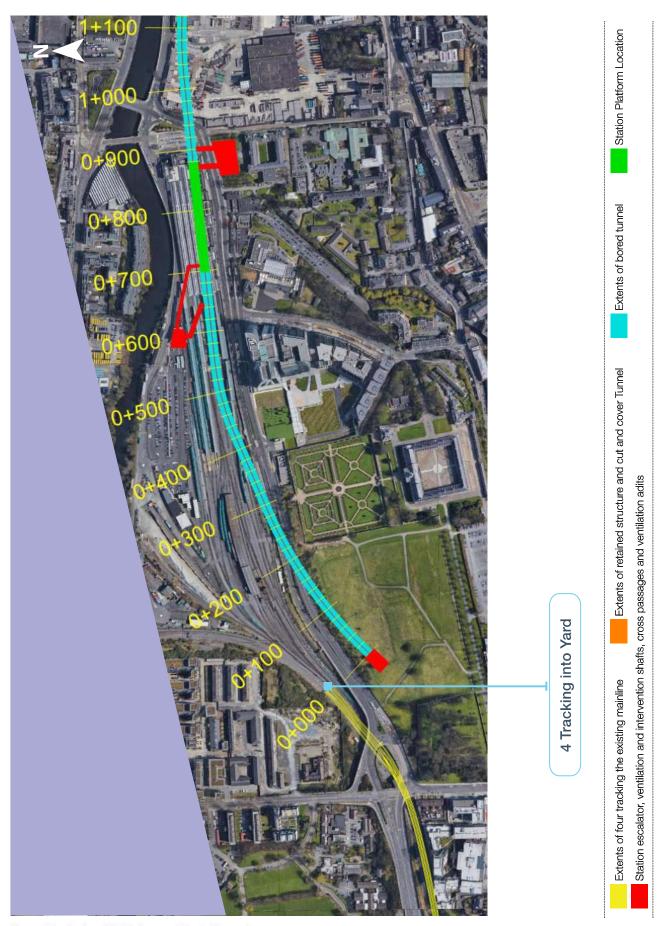


Figure 71: Option 2E Station and Portal Layout

# 6.4.19 Option Mono 2E (continued)

Tunnel Configuration	Monotube Tunnel Configuration
Proposed Location of Bored Tunnel Portal	It is assumed that the bored tunnel will be driven from the east of the final proposed route alignment.  The arrangement of the turnback is shown schematically in <b>Figure 70</b> and the actual arrangement is then shown in <b>Figure 71</b> . The turnback is 669 m in length from the end of the platform tunnel to the end of the buffers.
Commentary	The ventilation, intervention and evacuation shaft at the end of the mined turnback is proposed to be located in the fields of the Royal Hospital Kilmainham (RHK), between the formal gardens and Bully's Acre.  Given the length of the turnback, it is considered that the shaft could be constructed within this field and the above ground elements of the shaft could be positioned with an entrance directly onto the westbound carriageway of St. John's Road West. Thus, the fire brigade would have ease of access to the shaft from the public highway and there is sufficient space at ground level for any personnel evacuating the system. Equally the visual impact of such a proposal within the RHK lands could be lessened.  It may be necessary to have a secondary shaft positioned within IÉ lands such that drivers and maintenance personnel could directly gain access to the trains from within the existing IÉ lands of Heuston Station.

Table 23: Overview of Option Mono 2E

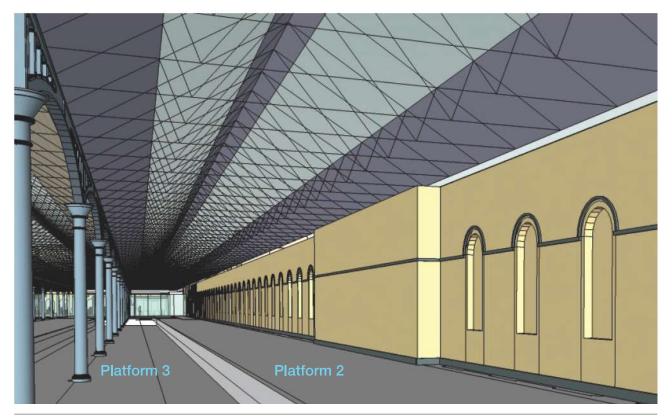




Figure 72: Option 1F Portal Layout at Inchicore

## 6.4.20 Option Twin 1F

Tunnel Configuration	Single Track Twin Bore Tunnel Configuration
Overview Description	This option is identical to the original DART Underground Reference Design undertaken between 2008 and 2010 and which received an approved Railway Order on 9th December 2011 from An Bord Pleanála.  A reception portal is located within the Inchicore Works and a below ground station is proposed within the Inchicore Works. Connection to the Heuston Mainline is facilitated via a grade-separated junction east of Kylemore Road Bridge to facilitate a Fast, Slow, Slow, Fast track configuration.  An intermediate ventilation, intervention and emergency escape shaft is provided in the eastern end of the Irish National War Memorial Park, south of Gaelscoil Inse Chór. A further intermediate intervention shaft with passive provision for future ventilation is provided just north of the Inchicore Sports Ground football pitch.
Proposed Underground Station Location	Proposed Station is located on the south side of the existing Heuston Station. The bored tunnels will be enlarged to create the platform tunnels. Three cut and cover shafts are proposed; one on the east providing emergency intervention / escape and ventilation; a central escalator shaft, and a western emergency intervention / escape and ventilation shaft.  The eastern and central cut and cover shafts are separated by the Camac Culvert which will be strengthened / underpinned ahead of tunnelling and station excavation.
Proposed Location of Bored Tunnel Portal	A reception tunnel portal is located within the Inchicore Works at Chainage 1+340 m based on <b>Figure 72</b> . Thereafter a length of cut and cover tunnel of approximately 160 m is constructed to the proposed below ground but open to air station at Inchicore. This station also facilitates a twin turnback arrangement.
Commentary	This proposal matches that of the approved DART Underground Railway Order with no variation. This option was studied and developed in detail as part of the approved Railway Order and therefore the impacts of this option are known and solutions were previously developed to address those impacts of the Scheme.

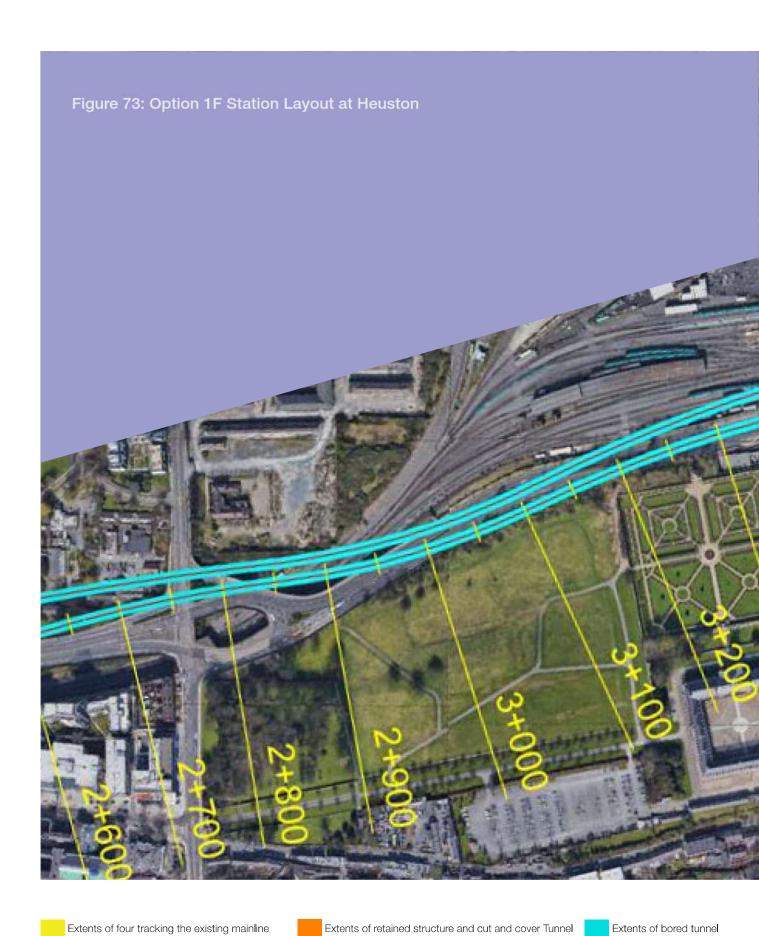






Figure 74: Option 2F Portal Layout at Inchicore

## 6.4.21 Option Twin 2F

Tunnel	Туре
Overview Description	This option is identical to that of Option Twin 1F with the only exception being that the proposed intermediate ventilation, intervention and emergency escape shaft at the eastern end of the Irish National War Memorial Park is no longer included within the Scheme.  The rail level at the western end of the proposed Heuston Underground Station Platform is circa -20.4 mOD.
Proposed Underground Station Location	Proposed Station is located on the south side of the existing Heuston Station. The bored tunnels will be enlarged to create the platform tunnels. Three cut and cover shafts are proposed; one on the east providing emergency intervention / escape and ventilation; a central escalator shaft, and a western emergency intervention / escape and ventilation shaft.  The eastern and central cut and cover shafts are separated by the Camac Culvert which will be strengthened / underpinned ahead of tunnelling and station excavation.
Proposed Location of Bored Tunnel Portal	A reception tunnel portal is located within the Inchicore Works at Chainage 1+340 m based on <b>Figure 74</b> . Thereafter a length of cut and cover tunnel of approximately 160 m is constructed to the proposed below ground but open to air station at Inchicore. This station also facilitates a twin turnback arrangement.
Commentary	This proposal matches that of the approved DART Underground Railway Order with the variation that the Irish National War Memorial Park Intervention, Ventilation and Emergency Escape shaft is removed from the Scheme, in accordance with the recommendation of the current fire safety guidance.





### 6.5 Summary of Evaluation of Identified Possible Options

**Table 26** summarises the evaluation of the identified possible options for each individual criterion and for the option as a whole. The detailed narrative of the qualitative assessment for each option is contained within **Appendix C** of this report.

To aid the identification of which options satisfied and which options failed to meet the evaluation metric, the following colours were adopted to indicate Pass and Fail.

Indicates that the Qualitative Assessment of the Option Satisfies the Individual Criterion

Indicates that the Qualitative Assessment of the Option Fails the Individual Criterion

Criteria 1 Potential ground induced damage

Criteria 2 Rail Operational Impacts

Criteria 3 Existing Heuston Station impacts

Criteria 4 Underground Station location and impacts on third parties

Criteria 5 Practicality of constructing

Criteria 6 Safety of constructing, inspecting, maintaining and operating

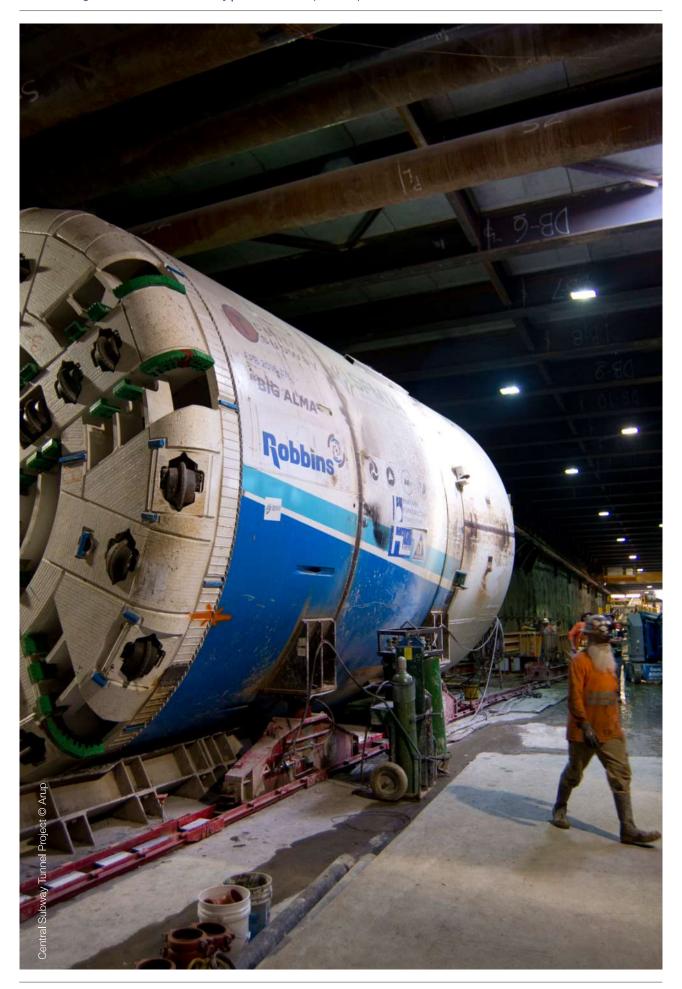






Option Name	Tunnel Configuration	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	Overall Pass/Fail Summary
Note in Option Na	n Heuston Yard & S	'A' indicate	es Station i	n the Vicini				, 'S' indicates a Southerly
1AS	Twin Bore							Pass
2AS	Twin Bore							Fail
3AS	Twin Bore							Pass
1AN	Twin Bore	•						Fail
2AN	Twin Bore							Fail
3AN	Twin Bore	•						Fail
	n Heuston Yard aming References - outherly Track Alignn						g Heuston (	Station,
1BS	Twin Bore							Fail
1BN	Twin Bore							Fail
2B	Twin Bore							Fail
3B	Twin Bore							Fail
Twin Bore and M	onotube Options wi	th the Porta	al West of	Heuston / I	slandbridg	е		
1C	Twin	•		•				Fail
1C	Monotube	•						Fail
2C	Twin							Pass
3C	Twin							Pass
3C	Monotube							Fail
Monotube Option	ns - Portal in Heusto	n Yard						
1DS	Monotube							Fail
1DN	Monotube							Fail
Terminus Underg	round Station Optio	ns						
1E	Twin Bore							Pass
2E	Monotube							Pass
Reception Portal	in Inchicore							
1F	Twin							Pass
2F	Twin							Pass

Table 26: Summary of Evaluation of Identified Possible Options



## 6.5.1 Option Twin 1AS

This Option passes the qualitative assessment for all criteria outlined in **Section 6.1** of this Study and as such is taken forward to the Phase 3 MCA Assessment. This option allows the underground station to be built largely within the existing larnród Éireann lands with the exception that the construction worksite will encroach into St. John's Road West. The extent of this construction stage impact depends on whether the TBMs would be launched from the west or this location acts as a TBM reception portal.

Four tracking of the existing Heuston Mainline is required to the track tie-in position, located at rail overbridge OB1. Accordingly, it is necessary to replace both existing rail overbridges OB1 and OB1A.

Access for construction traffic directly onto the Chapelizod Bypass / Con Colbert Road is a significant benefit at this location. The field in the Royal Hospital Kilmainham (RHK) would be a suitable location for either a TBM launch or reception chamber construction worksite.

## 6.5.2 Option Twin 2AS

This Option fails the qualitative assessment and therefore is not taken forward to the Phase 3 MCA Assessment. This option was not considered to be feasible or practicable as the effects of ground movement and induced damage on the existing protected façade of the Mainline Station and the embedded rail track slab of the Luas Red Line will be moderate or greater. Mitigation measures such as structural jacking of the existing Mainline station façade or compensation grouting in the glacial gravels and sands is not feasible at this location.

Furthermore, it was identified that the construction of the eastern ventilation and intervention shaft and ventilation adits will clash with the secant piled wall structure of the Luas traction sub-station at the front of Heuston

Station. Significant mitigation measures would be required to enable this sub-station to remain functional throughout the construction of the shaft and ventilation adits.

## 6.5.3 Option Twin 3AS

This Option passes the qualitative assessment for all criteria outlined in **Section 6.1** of this Study and therefore advances to the Phase 3 MCA Assessment. This proposal represents the extreme easterly point at which it is considered feasible to place the underground station platforms without having to significantly lower the vertical alignment to match the drop in the rockhead level.

This solution could facilitate an underground station with two cut and cover shafts, one on the southern side of the Mainline Station and one within the St. James' Gate Brewery lands. The main benefit of this proposal is the possible avoidance of demolishing rail overbridge OB1A and so a lessening of impacts at the South Circular Road junction.

Access for construction traffic directly onto the Chapelizod Bypass / Con Colbert Road is a significant benefit at this location. The field in the RHK would be a suitable location for either a TBM launch or reception chamber construction worksite.

### 6.5.4 Option Twin 1AN

This Option is not considered to be practicable and therefore fails the qualitative assessment. This proposal would require the existing Mainline Station to be reconstructed 250 m to the west of the current location, including the station concourse, facilities and transport connections. Only five mainline platforms could be operated during construction of DART Underground and the Phoenix Park Tunnel would be closed for approximately 12 months.

The trackwork would need to be reconfigured in the Heuston throat after demolishing the Valeting Depot and a new bridge required to be constructed over the River Liffey to the Dublin Bus Depot on Conyngham Road. New rail overbridges would also be required at OB1 and OB1A. Accordingly, this Option is not taken forward to the Phase 3 MCA Assessment.

## 6.5.5 Option Twin 2AN

This Option is not considered to be practicable and therefore fails the qualitative assessment. This proposal would require the existing Mainline Station to be reconstructed 200 m to the west of the current location, including the station concourse, facilities and transport connections. Similar to Option Twin 1AN, only five mainline platforms could be operated during construction of DART Underground and the Phoenix Park Tunnel would be closed for approximately 12 months.

The trackwork would need to be reconfigured in the Heuston throat after demolishing the Valeting Depot and a new bridge required to be constructed over the River Liffey to the Dublin Bus Depot on Conyngham Road. New rail overbridges would also be required at OB1 and OB1A. Accordingly, this Option is not taken forward to the Phase 3 MCA Assessment.

### 6.5.6 Option Twin 3AN

For similar reasons to Options Twin 1AN and Twin 2AN, this Option is not considered to be practicable and fails the qualitative assessment.

The existing Mainline Station would need to be reconstructed 150m to the west of the current location, including the station concourse, facilities and transport connections. Only five mainline platforms could be operated during the DART Underground works. The trackwork would need to be reconfigured in the Heuston throat after demolishing the Valeting Depot and a new bridge required to be constructed over the River Liffey to the Dublin Bus Depot on Conyngham Road.

The construction of the central escalator shaft, mined platform tunnels and mined cross passages could potentially clash with the piled wall structure of the Luas traction sub-station. Furthermore, the façade of the existing protected Mainline Station would need to be demolished as structural jacking and compensation grouting are not considered to be feasible mitigation solutions at this location to the effects of ground movement induced damage. This Option is not taken forward to the Phase 3 MCA Assessment.

## 6.5.7 Option Twin 1BS

This Option is not considered to be practicable and fails the qualitative assessment. The rockhead drops so rapidly that any station in the St. James' Gate Brewery Lands requires the vertical alignment to be significantly lowered to be feasible to construct. The construction of the proposed cut and cover shafts would require the new Brewhouse No. 4 to be demolished and relocated elsewhere to provide adequate space for the construction of these shafts.

Dropping the vertical alignment lengthens the tie-in to the Heuston Mainline and thus does not address any of the impacts in the vicinity of the Heuston throat. Reconstruction of rail overbridges OB1 and OB1A would be required with this proposal.

An underground interchange is required with the existing Mainline Station. Then the construction of the below ground interchange and shaft within the existing mainline station is considered to be problematic and challenging. The distance and journey time between the existing station and proposed underground station, to interchange at street level, is considered to be excessive and thus not attractive to potential passengers. Accordingly, this Option is not taken forward to the Phase 3 MCA Assessment.

## 6.5.8 Option Twin 1BS

For similar reasons to that of Option Twin 1BS, Option Twin 1BN is not considered to be practicable and fails the qualitative assessment. The vertical alignment of the proposed underground station in the St. James' Gate Brewery would have to be significantly lowered to reflect the rockhead level at this location. The construction of the proposed cut and cover shafts would require the new Brewhouse No. 4 to be demolished and relocated elsewhere to provide adequate space for the construction of these shafts.

An underground interchange is required with the existing Mainline Station. Then the construction of the below ground interchange and shaft within the existing mainline station is considered to be problematic and challenging. The distance and journey time between the existing station and proposed underground station to interchange at street level, is considered to be excessive and thus not attractive to potential passengers. Accordingly, this Option is not taken forward to the Phase 3 MCA Assessment.

#### 6.5.9 Option Twin 2B

This Option is not considered to be practicable and fails the qualitative assessment. The construction of enlarged mined platform tunnels under the River is very high risk and should be avoided wherever possible from a safety perspective.

Traffic access to Victoria Quay would be closed for the duration of the Station construction and this combined with the encroachment into the St. James' Gate Brewery lands would have a major impact on the operation of the Brewery.

The rail level has to be lowered given the rockhead profile and the tie-in to the Heuston Mainline could be achieved to the east of rail overbridge OB1. Accordingly, this proposal addresses none of the problems at the Heuston

throat as the TBM would be required to be lowered at the launch point to get under the river bed and quay wall, and the Phoenix Park Tunnel line would be closed for 12 months.

The distance and journey time between the existing station and proposed underground station to interchange at street level, is considered to be excessive and thus not attractive to potential passengers. Accordingly, this Option is not taken forward to the Phase 3 MCA Assessment.

## 6.5.10 Option Twin 3B

The construction of this proposal, tunnelling under the River Liffey three times over a length of 1200 m, is too great a construction and safety risk to be considered practicable and fails the qualitative assessment. Furthermore, this Option addresses none of the problems at the Heuston throat as the TBM would be required to be lowered at the launch point to get under the river bed and quay wall, and the Phoenix Park Tunnel line would be closed for 12 months.

The distance and journey time to interchange at street level between the existing station and proposed underground station, is considered to be excessive and thus not attractive to potential passengers. Accordingly, this Option is not taken forward to the Phase 3 MCA Assessment.

### 6.5.11 Option Twin 1C

Option Twin 1C is not considered to be feasible. The vertical height difference between the Chapelizod Bypass / Con Colbert Road and the surrounding lands at the base of the embankment in the Irish National War Memorial Park makes the site unfeasible as an option for either a TBM launch site or reception chamber portal.

Accordingly, this Option is not taken forward to the Phase 3 MCA Assessment.

## 6.5.12 Option Mono 1C

Option Mono 1C is not considered to be feasible. The vertical height difference between the Chapelizod Bypass / Con Colbert Road and the surrounding lands at the base of the embankment in the Irish National War Memorial Park makes the site unfeasible as an option for either a TBM launch site or reception portal.

Accordingly, this Option is not taken forward to the Phase 3 MCA Assessment.

## 6.5.13 Option Twin 2C

This Option passes the qualitative assessment for all criteria outlined in **Section 6.1** of this Study and therefore advances to the Phase 3 MCA Assessment.

Although further work is required to demonstrate the impacts on the operational railway east of Sarsfield Road Underbridge and quantify the risks of tunnelling under the Chapelizod Bypass / Con Colbert Road at the proposed launch point, this solution has many merits and thus is taken forward for detailed Phase 3 assessment. For example, it may be necessary to install piles alongside the Chapelizod Bypass / Con Colbert Road / existing railway cuttings to ensure stability of the ground during TBM launch or reception chamber with a cover of 6.0 m.

The proposed TBM Launch or Reception Portal Worksite would be well positioned for construction deliveries and spoil removal. In this option, vehicular access under Sarsfield Road would be maintained.

## 6.5.14 Option Twin 3C

This Option passes the qualitative assessment for all criteria outlined in **Section 6.1** of this Study and therefore advances to the Phase 3 MCA Assessment.

By increasing the ground cover at the TBM Launch or Reception Portal Worksite, the risks associated with tunnelling under the Chapelizod Bypass / Con Colbert Road would be greatly diminished. However, the track tie-in to the Heuston Mainline is pushed west of Sarsfield Road Underbridge and in the permanent case, vehicular access along Sarsfield Road will no longer be possible. Similar to Option Twin 2C, this proposal has many merits and is taken forward for detailed Phase 3 assessment.

The proposed TBM Launch or Reception Portal Worksite would be well positioned for construction deliveries and spoil removal.

## 6.5.15 Option Mono 3C

This Option is not considered to be practicable and therefore fails the qualitative assessment. Accordingly, this Option is not taken forward to the Phase 3 MCA Assessment.

The required depth of ground cover required at the TBM Launch or Reception portal would be such that the track tie-in to the Heuston Mainline would occur 400 m west of Sarsfield Road Underbridge. To construct such deep approach retaining structures from the tie-in to the portal, would require demolition of a number of buildings within the Inchicore Works, whilst the extent of the slewing of the Mainline to the south would result in the demolition of a significant number of residential properties at St George's Villas and Murray's Cottages.

## 6.5.16 Option Mono 1DS

This Option fails the qualitative assessment since it is neither considered to be feasible nor practicable.

This solution results in a portal location in larnród Éireann lands at the end of the existing platforms 2 and 3. To construct the TBM portal at this location with a shallow cover of 11 m, would require a piled roof slab to be constructed in advance of the portal for a length of approximately 170 m to confine the soil as the TBM is launched. In turn, this would require the closure of existing mainline platforms 1 to 5 inclusive. It would not be feasible to provide an alternative platform arrangement which can meet the required train timetable.

The Station would be located up in the St. James' Gate Brewery Lands with no interchanges to the Mainline Station. Furthermore, Victoria Quay would be closed to enable construction of the cut and cover shafts and the construction would adversely affect the operations of the St. James' Gate Brewery.

#### 6.5.17 Option Mono 1DN

This Option fails the qualitative assessment since it is neither considered to be feasible nor practicable.

This solution would result in a portal location in the existing car park to the north of existing mainline platform 8. To construct the TBM portal at this location with a shallow cover of 11 m, would require a piled roof slab to be constructed in advance of the portal for a length of 170 m to confine the soil as the TBM is launched. In turn, this would require the closure of platforms 5 to 8 inclusive. It would not be feasible to provide an alternative platform arrangement, which can meet the required train timetable.

The Station would be located in the St. James' Gate Brewery Lands with no interchanges to the Mainline Station. Furthermore, Victoria Quay would be closed to enable construction of the cut and cover shafts and the construction would adversely affect the operations of the St. James' Gate Brewery.

## 6.5.18 **Option Twin 1E**

This Option passes the qualitative assessment for all criteria outlined in **Section 6.1** of this Study and therefore advances to the Phase 3 MCA Assessment.

This proposal for a terminus station with mined central turnback is feasible and practicable, albeit the mined turnback would be complex and challenging to construct.

## 6.5.19 Option Mono 2E

This Option passes the qualitative assessment for all criteria outlined in **Section 6.1** of this Study and therefore advances to the Phase 3 MCA Assessment.

This proposal for a terminus station in a monotube tunnel configuration is feasible and practicable. Lowering the vertical alignment to ensure that the bored tunnel is within the bedrock would ensure that the tunnel drive is achievable and ground movements can be controlled. The TBM reception portal would be positioned in St. John's Road West / the Field next to the Royal Hospital Kilmainham formal gardens and there would be good construction vehicular access onto the Chapelizod Bypass / Con Colbert Road.

Obtaining Dublin Fire Brigade approval for this turnback solution in a Monotube is considered to be a high risk as there are few, if any, precedents for a turnback in a Monotube.

## 6.5.20 Option Twin 1F

This Option is identical to the original DART Underground Railway Order which was approved by An Bord Pleanála. As described in Option Twin 2F and in accordance with the Commission for Railway Regulation guidance which now invokes the European Directive on the Common Safety Method, it is possible to remove the need for the intermediate intervention and ventilation shaft at the Irish National War Memorial Park, which formed part of the previous approved Railway Order.

Accordingly, Option Twin 2F is considered to be an optimised alternative to the original Railway Order proposal and Option Twin 2F will be brought forward to the Phase 3 MCA Assessment. Option Twin 1F is not considered further as it would merely be duplicating the assessment of Option Twin 2F.

## 6.5.21 Option Twin 2F

As described above, this Option is a refinement of the original DART Underground Railway Order, which addresses recent changes in fire safety standards and specifically the adoption by the Commission for Railway Regulation of the European Directive on the Common Safety Method. As presented in the Tunnel Configuration Study for DART Underground<sup>[5]</sup>, it would be feasible to space intervention shafts for twin bore tunnels at a spacing of up to 2 km, assuming that cross passages would be provided at spacings of approximately 244 m along the running tunnels.

Thus, in Option Twin 2F, the intermediate intervention and ventilation shaft at the Irish National War Memorial Park has been removed from this proposal and Option Twin 2F is taken forward to the Phase 3 MCA Assessment.



## 6.6 Summary of Options Advancing to Phase 3 Multi-Criteria Assessment

Following completion of the Evaluation of Identified Possible Options, seven options are considered to be both feasible and practicable. These seven options are carried forward to the Phase 3 Multi-Criteria Assessment (MCA) of Options, which are described in the following chapters of this Study and lead to the identification of a 'Preferred Option' for the Western Tie-In.

In summary, the options advancing to the Phase 3 MCA Assessment are:

- Twin 1AS Twin Bore Tunnel configuration; Tunnel Portal in the Heuston Yard and tie-in to the Heuston Mainline occurring under rail overbridge OB1. The proposed Heuston Underground Station is situated along the south side of the existing station with all cut and cover shafts located within larnród Éireann lands;
- Twin 3AS Twin Bore Tunnel configuration; Tunnel Portal in the Heuston Yard and tie-in to the Heuston Mainline occurring 40 m to the east of rail overbridge OB1A. The proposed Heuston Underground Station straddles under the existing mainline station footprint, under St. John's Road West and into the St. James' Gate Brewery.
- Twin 2C Twin Bore Tunnel configuration;
   Tunnel Portal is located in an area, which is
   currently the slip lane from the Chapelizod
   Bypass leading into Ballyfermot/Con Colbert
   Road) and an area known locally as the
   "Horses Field". The tie-in to the Heuston
   Mainline occurs just east of the existing
   Sarsfield Road Underbridge. The proposed
   Heuston Underground Station is similar in
   plan arrangement to Option Twin 1AS but the
   platform level is 1 m lower;
- Twin 3C Twin Bore Tunnel configuration; Tunnel Portal is located in an area, which is currently the slip lane from the Chapelizod Bypass leading into Ballyfermot/Con Colbert Road) and an area known locally as the "Horses Field". The tie-in to the Heuston Mainline occurs 130 m west of the existing Sarsfield Road Underbridge to provide an

- increased depth of overburden at the tunnel portal. Consequently, Sarsfield Road will be permanently closed to all vehicular traffic. The proposed Heuston Underground Station is similar in plan arrangement to Option Twin 1AS but the platform level is 1 m lower;
- Twin 1E Twin Bore Tunnel configuration;
  Terminus Underground Station with a central mined Turnback. The proposed Heuston Underground Station is similar in plan arrangement to Option Twin 1AS but the platform level is 10.6 m lower to permit the safe construction of a 460 m long mined turnback beyond the underground station with sufficient rockhead cover above the mined cavern. A combined intervention and ventilation shaft is located at the end of Turnback.
- Mono 2E Monotube Tunnel configuration, Terminus Underground Station with a Turnback accommodated within the bored tunnel, which is 669 m in length beyond the end of the underground station platforms with a combined intervention and ventilation shaft at the end of the Turnback. This shaft is located within the grounds of the Royal Hospital Kilmainham, west of the Formal Gardens.
- Twin 2F This Option is similar to the original DART Underground Railway Order with the sole exception that the combined intervention and ventilation shaft previously located within the Irish National War Memorial Park is removed from the Scheme.

Since the time in which the original DART Underground Scheme was developed, the previous Railway Safety Commission guidelines have been superseded in lieu of adopting the European Common Safety Method for risk evaluation and assessment. As reported in the Tunnel Configuration Study for DART Underground [5], it is feasible to have spacings up to 2 km apart between intervention shafts. As such and with a proposed change in the operation of the rolling stock in the event of a fire in a Tunnel, it is possible to remove the Irish National War Memorial Park combined intervention and ventilation shaft.



## 7. Phase 3: Methodology for Multi-Criteria Assessment



## 7.0 Phase 3: Methodology for Multi-Criteria Assessment

This chapter of the Study presents the methodology for undertaking the Multi-Criteria Assessment (MCA) of the seven options identified in Phase 2 as being both feasible and practicable. The methodology is an objective-based comparative assessment founded on professional judgement in respect of the items to be qualitatively evaluated, and assesses the key relevant criteria in accordance with good industry practice.

## 7.1 Assessment Criteria

The MCA facilitates a structured approach to determine overall performances amongst the seven options to be comparatively assessed, across a number of criteria (or objectives) that are considered important to the DART Underground Western Tie-In Study.

The criteria identified in the Common Appraisal Framework for Transport Projects and Programmes<sup>[6]</sup> was appraised with a view to determining the appropriateness or otherwise of the criteria for the Western Tie-In comparative assessment.

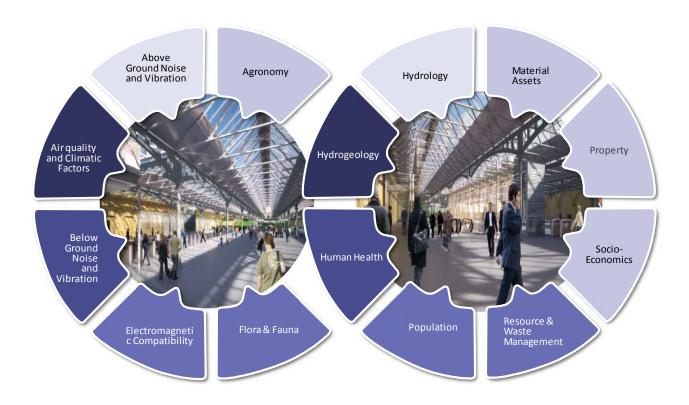
The Common Appraisal Framework recommends that the following criteria be considered in a qualitative appraisal of options:

- Economy (including non-quantifiable economic impacts);
- Safety;
- Physical Activity;
- Environment;
- Accessibility and Social Inclusion;
- Integration;
- Other Government Policies, and;
- Non-quantifiable economic impacts.

A number of the Common Appraisal Framework criteria are not considered to be differentiators between the seven options and therefore do not form part of the Multi-Criteria comparative assessment. The criteria not included are:

- Safety is concerned with the impact of the investment on the number of transport related accidents. Investment in public transport often results in car users switching to the public transport mode and there will tend to be a collision reduction benefit. Safety is considered neutral in the context of the Western Tie-In Study as all seven options will yield similar collision reduction benefits.
- The criterion of Physical Activity is considered neutral in the context of the Western Tie-In Study as all options being considered will use the same transport mode and will deliver similar health benefits for users.
- Other Government Policies relates to major Government policies around the National Spatial Strategy and regional balance. In the context of the Western Tie-In Study, all options are considered neutral in this respect.
- Non-quantifiable economic impacts are also considered to be neutral in the context of the Western Tie-In Study.

These Common Appraisal Framework criteria have therefore been excluded from the MCA comparative assessment.





## 7.2 Criteria Scoped Out

The environmental sub-criteria selected for the MCA takes cognisance of the original DART Underground Environmental Impact Statement<sup>[7]</sup> and the approved Railway Order<sup>[2]</sup>. Any environmental sub-criteria that are considered to be neutral, and therefore a non-differentiator between the seven options, are excluded from the MCA comparative assessment.

For clarity, the environmental sub-criteria scoped out of the MCA comparative assessment, since they are non-differentiators between the seven options within the context of this Study, are:

- Above Ground Noise and Vibration is considered neutral in the context of the Western Tie-In Study as above ground noise sources from surface construction works of portals, stations and ventilation shafts are applicable to all options and mitigation will be applied as necessary to these effects. Thus, above ground noise and vibration is not considered to be a sufficient differentiating factor between options;
- Agronomy: Given the urban / suburban nature
  of the tunnelled sections of any proposed
  option, it is considered that agronomy is not a
  differentiating factor for the assessment;
- Air quality and Climatic Factors was not considered to be a determining factor in the selection of a preferred option as all options have the potential to give rise to construction and operational phase air quality impacts;
- Below Ground Noise and Vibration is considered neutral in the context of the Western Tie-In Study as below ground noise sources from tunnelling works are applicable to all options and mitigation will be applied as necessary to these effects. Thus, below ground noise and vibration is not considered to be a sufficient differentiating factor between options;

- Electromagnetic Compatibility is considered neutral in the context of the Western Tie-In Study and not a determining factor in the selection of the preferred option;
- Flora & Fauna (impacts on habitats/species and biodiversity) is not considered to be a sufficient differentiating factor in the selection of a preferred option.
- Hydrology is not considered to be a determining factor in the selection of the preferred option;
- Hydrogeology is not considered to be a determining factor in the selection of the preferred option;
- Human Health, Population & Socio-Economics is considered neutral in the context of the Western Tie-In Study and not a determining factor in the selection of the preferred option;
- Material Assets relates to the impacts on valued resources either from a human or natural origin with value arising for economic or cultural reasons. These assets can be existing utilities or non-renewable resources. Within the extent of the Western Tie-In Study area, material assets is not considered to be a differentiator between the seven options;
- Property considers the impacts of property acquisition required to construct the associated temporary and permanent works. The costs of temporary and permanent land acquisition associated with each option have been identified and included within the economy criterion for the purposes of the MCA comparative assessment;
- Presource and Waste Management; The provision of tunnel and station infrastructure requires the excavation of large volumes of material, which will need to be re-used, recycled or disposed of. It is acknowledged that the management of this excavated material has the potential for environmental impact. The environmental impact of the management of the excavated material is considered to be neutral across options and not a determining factor in the selection of the preferred option.

Assessment Criteria	Asse Crite	essment Sub- eria	Metric			
1. Economy	1a	Capital Cost	Quantitative appraisal of potential infrastructure costs of proposed options.			
2. Integration	2a	Interchange	Qualitative appraisal of capacity of options to facilitate the movement of people between the street and station/rail system, other Public transport modes, and within the system, including the likely ease of navigation around the station.			
	2b	Traffic & Transportation	Qualitative appraisal of traffic and transportation impacts both on the operational and construction phases.			
3. Accessibility and Social Inclusion	3a	Accessibility	Qualitative appraisal of capacity of options to provide ease of access and circulation for users whom are either mobility or visually impaired.			
4. Environment	4a	Landscape and Visual	Qualitative appraisal of the potential impacts of the proposed options on landscape/ townscape, and the visual environment.			
	4b	Archaeology, Architectural and Cultural Heritage	Qualitative appraisal of the potential impacts of proposed options on potential sub surface archaeology and impact on foundations and above ground elements of architectural heritage.			
	4c	Settlement, Ground movement and potential third party impacts resulting from ground movements	Qualitative appraisal of ground movement effects related to each of the options in terms of the severity of impact.			

Table 27: Summary of the Criteria for the MCA Comparative Assessment

Colour	Description			
	Significant advantages over the other options			
	Some advantages over the other options			
	Comparable with other options			
	Some disadvantages over the other options			
	Significant disadvantages over the other options			

Table 28: Colour Coded Comparative Ranking System

However, volumes of excavated material are captured under the economic criteria, as the cost of excavation and disposal for each option is deemed to be included in the costs that have been developed for the MCA comparative assessment under the economy criterion.

The cost of the Maintenance, Operation and Renewal of DART Underground over the extent of the Western Tie-In Study Area, from Watling Street to Park West / Cherry Orchard Station, is considered to be neutral and therefore a non-differentiator for the purposes of the MCA comparative assessment. Iamród Éireann examined the operational costs of providing a turnback at various feasible locations along the length of the Western Tie-In, namely at Heuston Station, Inchicore and Park West / Cherry Orchard Station, and concluded that the difference in the operational costs is marginal.

# 7.3 Proposed Criteria for Comparative Assessment

The criteria considered appropriate for the MCA comparative assessment are presented in **Table 27** opposite, with a narrative for each of the criteria and sub-criteria provided thereafter.

## 7.4 Comparative Ranking System

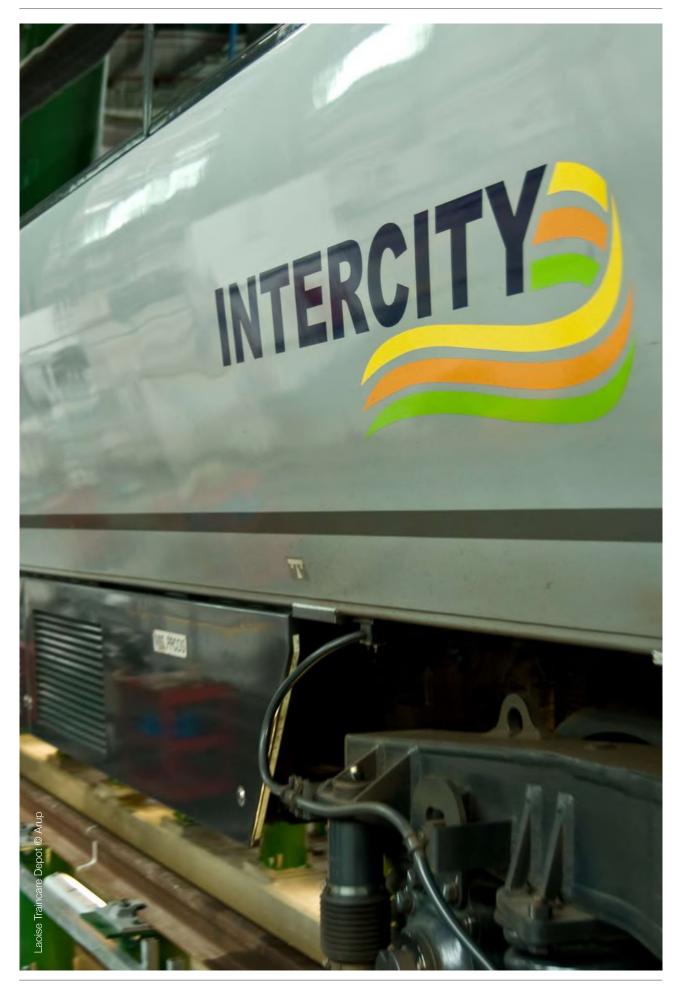
In considering the assessment criteria, a comparative ranking system is applied to the options using the five point colour coded ranking scale presented opposite in **Table 28**.

For each individual assessment criterion and sub-criterion listed in **Table 27**, the seven options are compared against one another and awarded a ranking based on the five point colour coded scale. The ranking ranges from an option having significant advantages over the other options to having significant disadvantages over the other options.

For illustrative purposes, this five point scale is colour coded, with significant advantages allocated a 'dark green' colour and significant disadvantages allocated a 'dark red'.

A balanced approach is adopted when assessing the options. All criteria are considered in undertaking the assessment and a lower ranking on one criteria does not necessarily mean that that option is not appropriate.

In addition to ranking the options under each subcriterion, a ranking using the same five point colour coded scale, is awarded to each option under the principal assessment criteria of Economy, Integration, Accessibility and Social Inclusion, and Environment. Finally, each of the seven options is awarded an Overall Ranking using the five point colour coded scale and this forms the basis for identifying the "Preferred Option".



# 8. Phase 3: Construction Planning and Worksites



# 8.0 Phase 3: Construction Planning and Worksites

Each of the seven feasible and practicable options carried forward to the Phase 3 MCA comparative assessment, require two significant construction worksites located within the extent of the Study Area, which would be required for the duration of the construction of DART Underground and therefore required for a duration in excess of six years.

Accordingly, it is appropriate to identify and incorporate the temporary construction stage impacts associated with the presence and operation of these worksites within the MCA comparative assessment, under each of the assessment criteria and sub-criteria. The principal construction worksites are required for the construction of:

- A proposed underground station in the vicinity of the existing Heuston Mainline Station;
- A tunnel portal and tunnel approach structure to tie-in with the existing Mainline, or in the case of an underground terminus arrangement, an intervention and ventilation shaft is required at the end of the turnback.

Five of the proposed options for the Western Tie-In facilitate a connection to the existing Heuston Mainline, whilst two options result in an underground terminus arrangement at Heuston with a turnback beyond the end of the proposed underground station platforms.

In the case of the options facilitating a tie-in to the Heuston Mainline and therefore result in a tunnel portal, the tunnel boring machines (TBMs) can either be launched or received at the tunnel portal. The footprint of the construction worksite and the construction traffic generated would differ between a launch and a reception portal since the TBMs must be serviced from the launch worksite.

requiring storage space for tunnel segments, a stockpile area for tunnel spoil, space for grout and tunnelling plant, and increased office and welfare facilities.

In the case of Option Twin 1E, which proposes an underground terminus arrangement with an intervention and ventilation shaft at the end of the turnback, this shaft would act as a work front from which to mine the central turnback and at a later stage in the construction programme, the shaft would aid the fit out of the running tunnels. In the case of Option Mono 2E, the intervention and ventilation shaft would be used to aid the fit out of the monotube tunnel.

Construction worksite layouts have been developed for each of the seven options taken forward to the Phase 3 MCA comparative assessment and these layouts are contained within Volume 2 of the Study. The impacts resulting from the location, size and planned operations within the construction worksites, are separately assessed and incorporated into the MCA ranking, which is awarded to each option for each assessment criterion.

The following sections provide an overview of the proposed construction layouts for each of the seven feasible and practicable options proposed for the Phase 3 MCA comparative assessment.

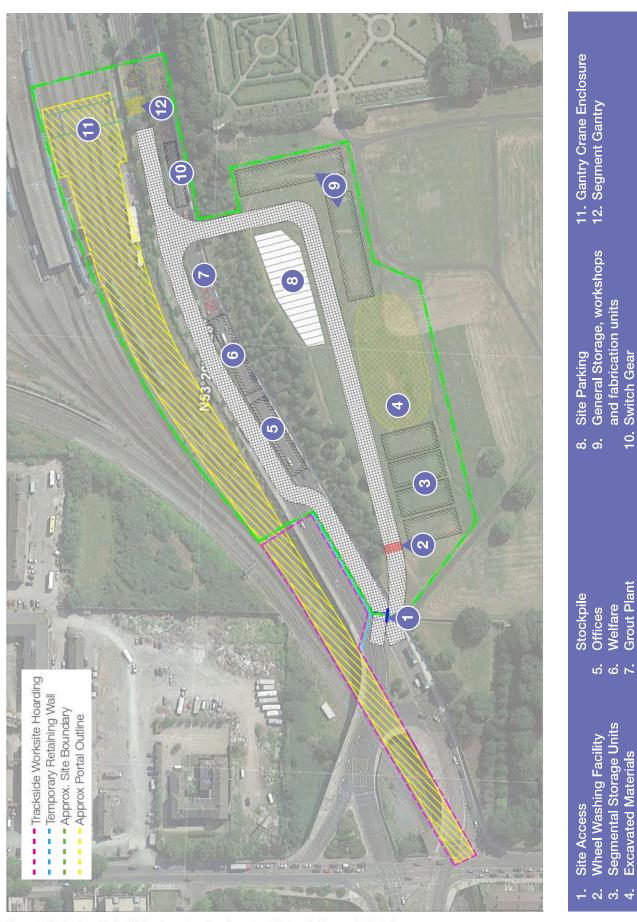


Figure 76: Option Twin 1AS - Construction layout at Potential Launch Portal

# 8.1 Option Twin 1AS Construction Planning

## 8.1.1 Overview of Option

The key components of Option Twin 1AS from a construction perspective are as follows:

- The Tunnel Portal is located in the Heuston Yard with the tie-in to the Heuston Mainline under Rail Overbridge OB1;
- The Tunnel Portal can be used as either a launch or reception chamber for construction of the running tunnels;
- Four tracking of the Heuston Mainline would be required from the end of the current four tracking, approximately 810 m to the east of Park West / Cherry Orchard Station, to the tiein under Rail Overbridge OB1;
- The proposed underground Station is on the south side of the existing station, requiring three cut and cover shafts, enlarged mined platform tunnels, mined cross passages and ventilation adits. The platform level at the western end of the station is circa -19.4 m OD with a rockhead cover of approximately 2 m above the enlarged platform tunnels;
- There would be no station at Inchicore, instead a surface station would be provided west of Kylemore Road Bridge;
- There would be a tumback provided at Park West / Cherry Orchard station, which combined with the existing tumback at Adamstown Station, would provide the required capacity of 8 trains per hour per direction with through running onto the Heuston Mainline.

## 8.1.2 Tunnel Portal Launch Site – Heuston Yard

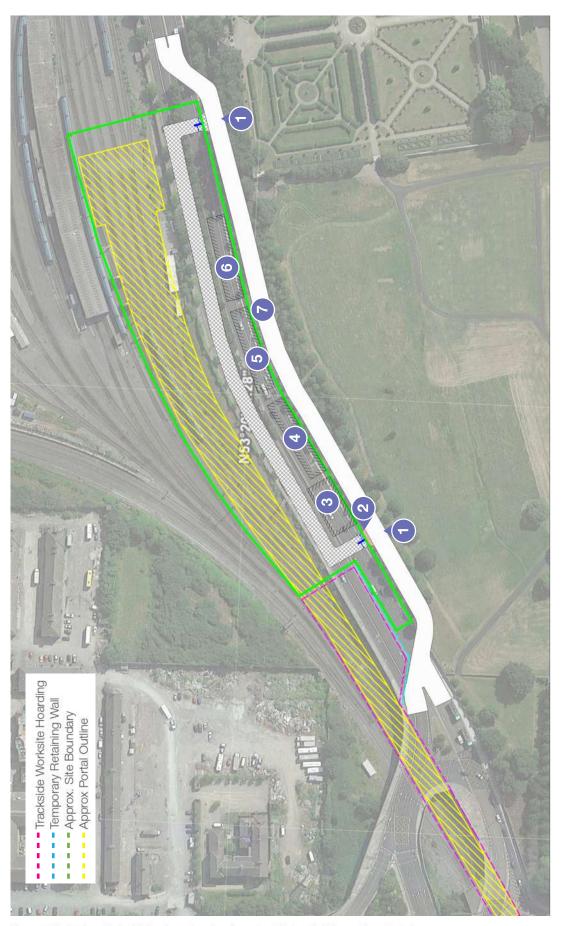
To provide the required worksite area for the construction of the running tunnels from this location, it is necessary to extend the worksite into the grounds of the Royal Hospital Kilmainham (RHK) as shown on **Figure 76**. In doing so, St. John's Road West would need to be closed to all public vehicles for the duration of the construction period from the entrance into the Heuston South Quarter (HSQ) development to the junction of St. John's Road West with the South Circular Road. The duration of the construction period for DART Underground is estimated to be in excess of six years.

There is direct access available for construction traffic from the Chapelizod Bypass / Con Colbert Road into and out of the worksite, providing a direct link with the M50 motorway.

## 8.1.3 Tunnel Portal Reception Site – Heuston Yard

If the TBMs were driven from the East and were received at the Heuston Yard tunnel portal, the layout of the construction worksite would sit partially within the Railway Yard and partially in St. John's Road West as shown on **Figure 77**. In order to provide the necessary area for the worksite, it is proposed that St. John's Road West would be diverted to the south, into the field within the grounds of the RHK, positioned between the formal gardens and Bully's Acre.

At the western end of the worksite, where the road rises up towards the junction with the South Circular Road, a temporary sheet piled retaining wall is proposed to enable the existing ground to be lowered to facilitate construction of the portal. Access to the worksite for construction traffic would be provided from the diverted St. John's Road West as shown on **Figure 77**.



Offices St John's Road West Diverted to the South

Welfare

6. 5.

Segmental Storage Units Workshop & Fabrication Unit

Wheel Washing Facility

<del>-</del>. ഗ. ც. 4.

Site Access

Figure 77: Option Twin 1AS - Construction layout at Potential Reception Portal

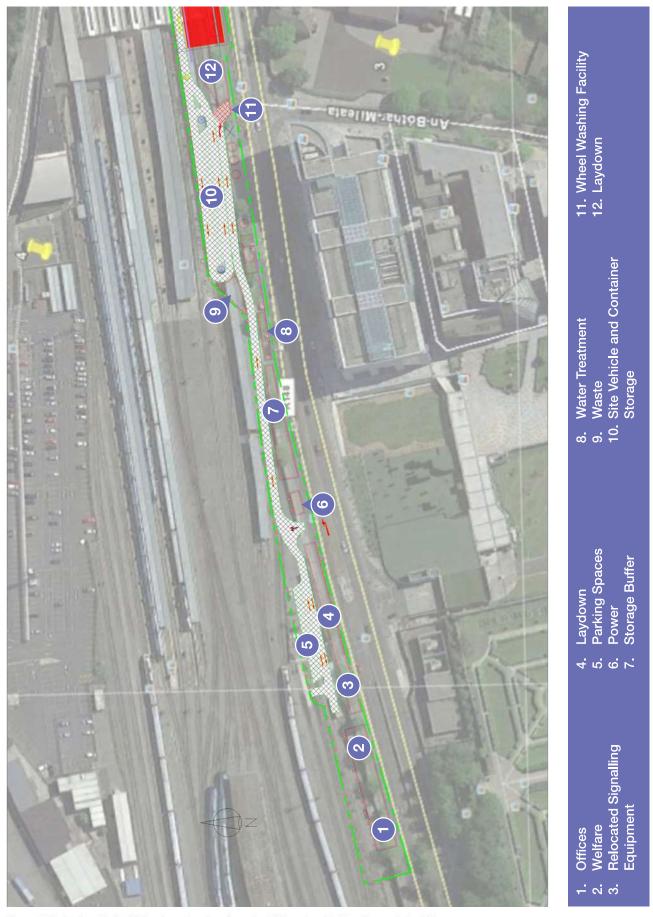


Figure 78: Option Twin 1AS - Construction layout at Heuston Station (Layout 1 of 2)

- Waste
- Site Vehicle & Container Storage
   Wheel Washing Facility
   Laydown

- 5. Gantry Crane

- 6. Signalled Alternative Site Traffic7. Facade Support & Kentledge8. Welfare

- 9. Office
- 10. Workshop



Figure 79: Option Twin 1AS - Construction layout at Heuston Station (Layout 2 of 2)

- 11. Turning Unloading Concrete12. Gantry Crane13. Facade Support & Kentledge14. Gantry Crane15. Welfare Office Store





#### 8.1.4 Heuston Station Worksite

The worksite for the construction of the proposed Heuston Underground station is shown in **Figures 78 and 79**. The arrangement requires the temporary closure of the existing platform 1, and the temporary relocation of platforms 2 and 3. The existing electrical sub-station and switchroom, offices, and station concourse facilities would need to be relocated to the north-west corner of the existing station.

## 8.1.5 Construction Methodology

## Reconstruction of Rail Overbridges OB1 and OB1A

In order to provide a safe working environment for construction of the new portal and maintain a minimum of two running lines into the Heuston Yard with connection to the Phoenix Park Tunnel, it is necessary to demolish and rebuild the existing rail overbridges OB1 & OB1A.

This work needs to be completed as early as possible in the programme to allow for diversion of the rail tracks and temporary reconfiguration of the Heuston Yard, which would then allow construction of the western half of the portal and railway tie-in to commence.

To maintain traffic flow during reconstruction, it would be necessary to reconstruct the bridges sequentially commencing with overbridge OB1A. Construction of the new rail overbridges is envisaged to be undertaken as follows and as illustrated in **Figures 80 to 85** inclusive:

- Set up temporary traffic management system including the diversion of all traffic onto overbridge OB1;
- Set up site and construct the abutments and wing walls for the new OB1A structure by installing piles behind the abutments to the existing structure;

- Locally excavate the roadway behind the existing abutments, trim the piles and construct the capping beams for the new overbridge OB1A;
- During an extended weekend closure of the railway, demolish the existing bridge and install the deck beams & precast decking units and side shutters for the new bridge;
- Fix reinforcement and cast concrete to complete construction of the bridge deck;
- Complete construction of the superstructure (crash barriers, road surfacing lighting columns etc.);
- Divert all of the services running across OB1 to the new OB1A structure;
- Switch all traffic to the new bridge and construct the new OB1 following a similar sequence to that of OB1A;
- On completion, clear the worksite and reinstate the original road layout.

## **Heuston Portal Construction**

Reconstruction of the overbridges OB1 and OB1A would enable the rail lines leading into Heuston Station to be diverted to the north, including completion of the temporary platforms 2 & 3. This would provide the necessary working space for construction of the portal and completion of the tie-in to the Heuston Mainline.

The portal would be constructed by undertaking excavation between bored pile retaining walls, which would be founded into the bedrock to provide a groundwater cut-off. It is envisaged that excavation and construction of the permanent tunnel approach structures would be undertaken in three stages, these being the TBM chamber and cut and cover section of the tunnel approach, the open U trough section of the approach structure and finally the tie-in to the existing rail lines.

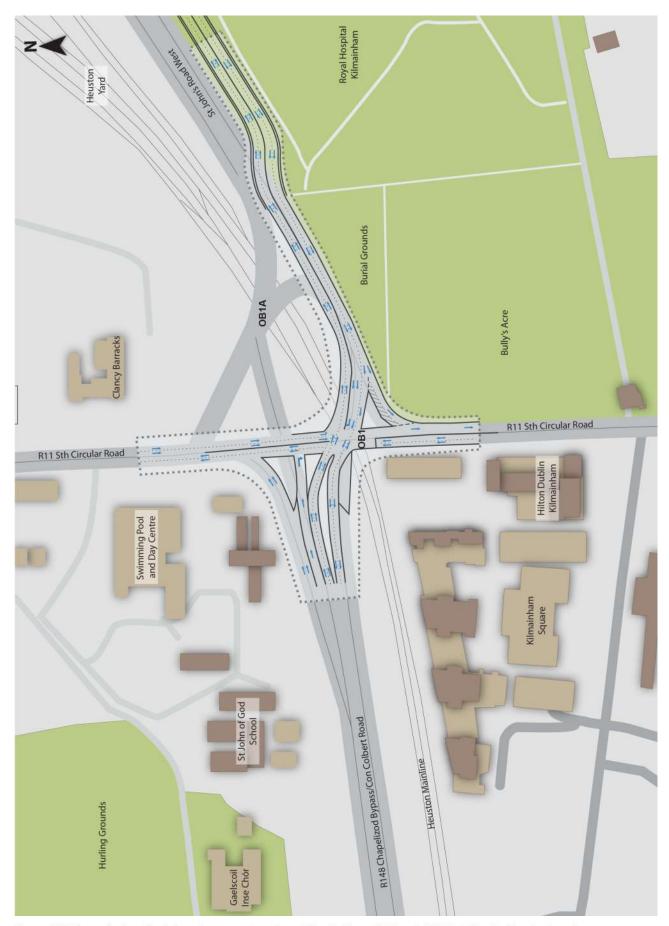


Figure 80: Phase 1 of methodology for reconstruction of Overbridges OB1 and OB1A at South Circular Junction



Figure 81: Phase 2 of methodology for reconstruction of Overbridges OB1 and OB1A at South Circular Junction

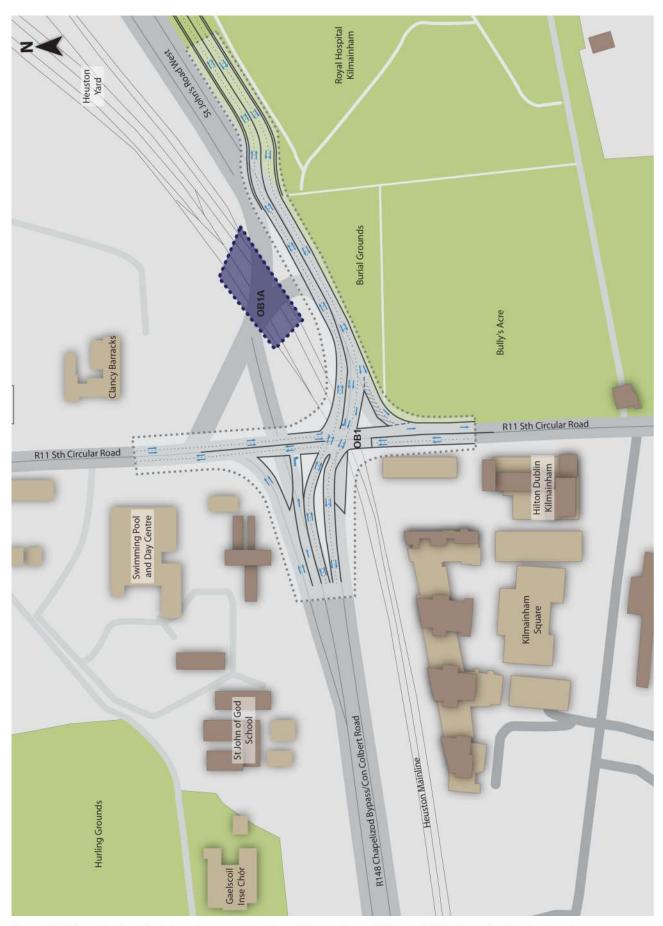


Figure 82: Phase 3 of methodology for reconstruction of Overbridges OB1 and OB1A at South Circular Junction



Figure 83: Phase 4 of methodology for reconstruction of Overbridges OB1 and OB1A at South Circular Junction

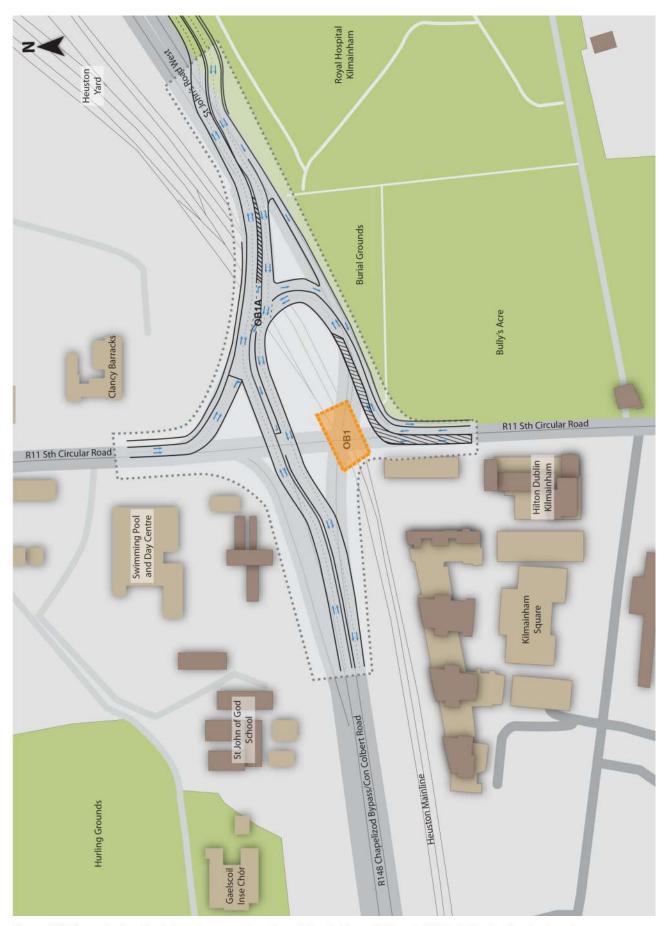


Figure 84: Phase 5 of methodology for reconstruction of Overbridges OB1 and OB1A at South Circular Junction

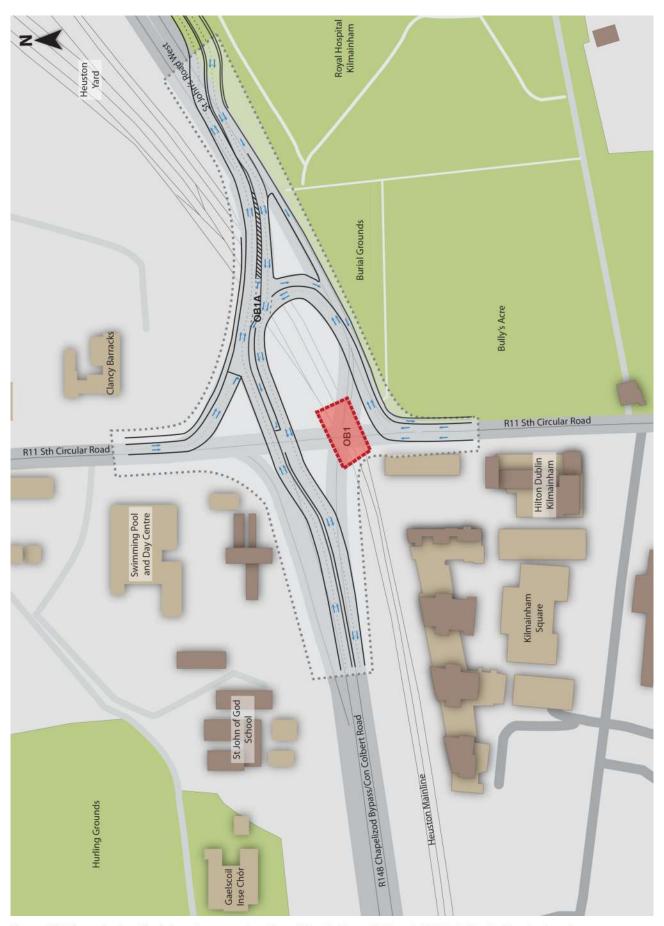


Figure 85: Phase 6 of methodology for reconstruction of Overbridges OB1 and OB1A at South Circular Junction

## Heuston DART Underground Station Construction

Construction of the Underground Station requires three cut and cover shafts being excavated in a 'Top Down' sequence. When the level of construction reaches the rockhead, the method of excavation would change to rock breaking. The methods used for excavating the rock would be chosen following trials at the site, but is likely to involve an element of high energy breaking, in the form of strictly controlled blasting. The tunnels at platform level would also be excavated by rock breaking with a sprayed concrete temporary lining.

The existing culvert for the River Camac would require strengthening before the station works can commence, and this necessitates the construction of an eastern and central cut and cover shafts, which straddles the strengthened culvert.

## **Running Tunnel Construction**

It is envisaged that earth pressure balancing TBMs would be used to drive the full length of the tunnels, as previously proposed as part of the original DART Underground. Earth pressure balancing TBMs are considered suitable for the prevailing ground conditions in Dublin City Centre and furthermore do not require additional areas within the worksite for treatment plant. At this location, road transport is the only feasible option for transporting the disposal of the excavated materials from the site.

## 8.1.6 Construction Sequence & Programme

The construction programme for Option Twin 1AS would be circa six years from commencement of the main contract for construction. This is a saving of around four months from the programme for Option Twin 2F, which is a variation of the original DART Underground.

Shortening of the main tunnel drives relative to options which tunnel to Inchicore, save around five months on the tunnel programme with further savings being made in tunnel cross-passage construction, clean out and tracklaying activities. However, significant enabling works, including the reconstruction of rail overbridges OB1 and OB1A and rail diversion works, would delay the commencement of the portal in the Heuston Yard, which would limit the benefits from constructing the shorter running tunnels.

### 8.1.7 Construction Risks

Key construction risks associated with this option include:

- The shallow rockhead cover above the enlarged platform tunnels at the proposed Heuston Underground station. This would increase the risk of water ingress and the possibility of encountering unstable ground during construction of the platform tunnels. This may require additional ground treatment or additional contingency measures to be adopted during tunnelling, increasing both cost and programme duration.
- If the TBMs were launched from the Heuston Yard, then they would be launched from below the water table level into a mixed face of Boulder Clay and Glacial Sands and Gravels. This gives an increased difficulty with controlling the TBMs vertical and horizontal alignment during the early stages of the tunnel drive. There would also be an increased risk of ground movement, particularly of rail infrastructure but including the protected structure of the existing Heuston Station. To

- limit this risk, additional ground treatment and additional support measures such as spiles may be required at the portal.
- The reconstruction of overbridges OB1 and OB1A would likely result in significant traffic disruption during the re-construction of these bridges.
- There would be significant rail interfaces during the reconstruction of overbridges OB1 and OB1A, the portal and Heuston Station. Any of which could have an impact on the operation of the railway or require an extended programme to allow works to be carried out during engineering hours / railway possessions.

# 8.2 Option 3AS Construction Planning

### 8.2.1 Overview of Option

The key components of Option Twin 3AS from a construction perspective are as follows:

- The Tunnel Portal is located in the Heuston Yard with the tie-in to the Heuston Mainline located to the east of Rail Overbridge OB1A;
- The Tunnel Portal can be used as either a launch or reception chamber for construction of the running tunnels;
- Four tracking of the Heuston Mainline would be required from the end of the current four tracking, approximately 810 m to the east of Park West / Cherry Orchard Station, to the tiein, just east of Rail Overbridge OB1A;
- Proposed Station is located on the south side of the existing Heuston Station. The bored tunnels would be enlarged to create the platform tunnels. Three cut and cover shafts are proposed; one on the east providing emergency intervention / escape and ventilation; a central escalator shaft, and a western emergency intervention / escape and ventilation shaft.

- The proposed station straddles under the existing mainline station footprint, under St. John's Road West and into the St. James' Gate Brewery. The eastern cut and cover shaft would be constructed in an area currently designated as the Kegging Yard of the Brewery whilst the central escalator cut and cover shaft would be constructed within the existing station. There is then a need to construct a mined escalator tunnel to the track level and construct a mined passenger access tunnel and adits leading onto the platforms, and leading to the eastern cut and cover shaft.
- There would be no station at Inchicore, instead a surface station would be provided west of Kylemore Road Bridge;
- There would be a turnback provided at Park West / Cherry Orchard station, which combined with the existing turnback at Adamstown Station, would provide the required capacity of 8 trains per hour per direction with through running onto the Heuston Mainline.

## 8.2.2 Tunnel Portal Launch Site – Heuston Yard

To provide the required worksite area for the construction of the running tunnels from this location, it is necessary to extend the worksite into the grounds of the Royal Hospital Kilmainham (RHK) as shown on **Figure 86 overleaf**. In doing so, St. John's Road West would need to be closed to all public vehicles for the duration of the construction period from the entrance into the Heuston South Quarter (HSQ) development to the junction of St. John's Road West with the South Circular Road. The duration of the construction period for DART Underground is estimated to be in excess of six years.

There is direct access available for construction traffic from the Chapelizod Bypass / Con Colbert Road into and out of the worksite, providing a direct link with the M50 motorway.

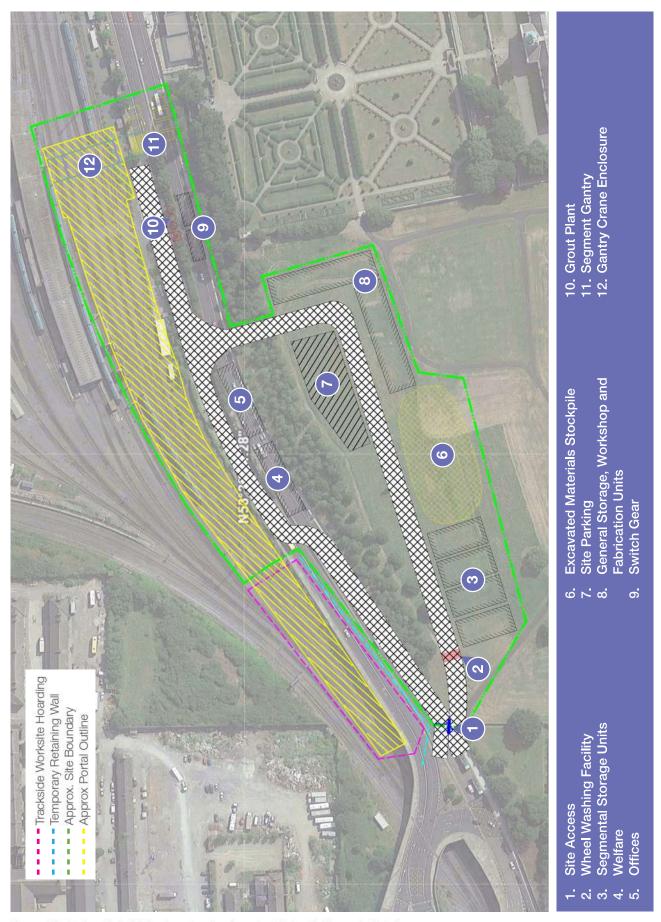


Figure 86: Option Twin 3AS - Construction layout at Potential Launch Portal

## 8.2.3 Tunnel Portal Reception Site – Heuston Yard

If the TBMs were driven from the East and were received at the Heuston Yard tunnel portal, the layout of the construction worksite would sit partially within the Railway Yard and partially in St. John's Road West as shown on **Figure 87 overleaf**. In order to provide the necessary area for the worksite, it is proposed that St. John's Road West would be diverted to the south, into the field within the grounds of the RHK, positioned between the formal gardens and Bully's Acre.

At the western end of the worksite, where the road rises up towards the junction with the South Circular Road, a temporary sheet piled retaining wall is proposed to enable the existing ground to be lowered to facilitate construction of the portal. Access to the worksite for construction traffic would be provided from the diverted St. John's Road West as shown on **Figure 87 overleaf**.

#### 8.2.4 Heuston Station Worksite

The worksite for the construction of the proposed Heuston Underground station is shown in **Figures 88, 89 and 90**. The proposed Underground Station is located further to the east than Option Twin 1AS and straddles beneath the existing mainline station and within the St. James' Gate Brewery 'Kegging Yard'.

The escalators leading from the existing station concourse to the platform level of the proposed Underground Station need to be installed largely within a mined inclined tunnel. Furthermore, a central mined passageway would be required at platform level with cross passages leading to the respective platforms. The construction of these mined tunnels would necessitate increased ground movement mitigation compared with Option Twin 1AS.

The arrangement requires the temporary closure of the existing platform 1, and the temporary relocation of platforms 2 and 3. The existing electrical sub-station and switchroom, offices, and station concourse facilities would need to be relocated to the north-west corner of the existing station.

## 8.2.5 St. James' Gate Brewery Worksite

The worksite for the eastern cut and cover shaft is illustrated in **Figure 90**. Access to the worksite would be off Victoria Quay. To minimise disruption within the St. James' Gate Brewery, it is proposed that this worksite would only be used for construction of the shaft and head structure, all other construction activities such as tunnelling works and shaft fit out being undertaken and serviced from the Heuston Station worksite.

## 8.2.6 Construction Methodology

### Reconstruction of overbridges OB1 and OB1a

In order to provide a safe working environment for construction of the new portal and maintain a minimum of two running lines into the Heuston Yard with connection to the Phoenix Park Tunnel, it is necessary to demolish and rebuild the existing rail overbridges OB1 & OB1A. The methodology would be identical to that described in **Section 8.1.5** and illustrated in **Figures 80 to 85** inclusive.

#### **Portal Construction**

Reconstruction of the overbridges OB1 and OB1A would enable the rail lines leading into Heuston Station to be diverted to the north, including completion of the temporary platforms 2 & 3. This would provide the necessary working space for construction of the portal and completion of the tie-in to the Heuston Mainline.

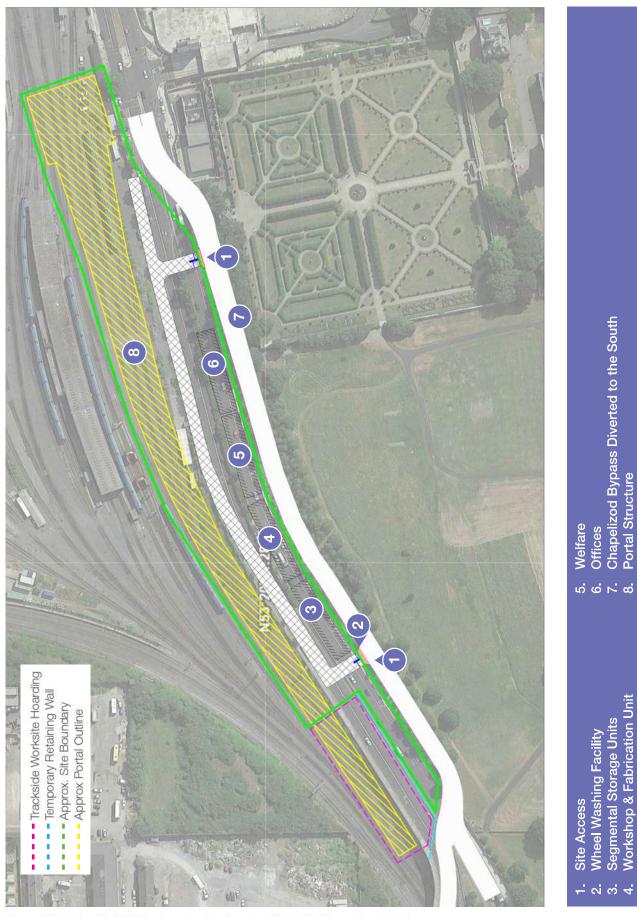


Figure 87: Option Twin 3AS - Construction layout at Potential Reception Portal

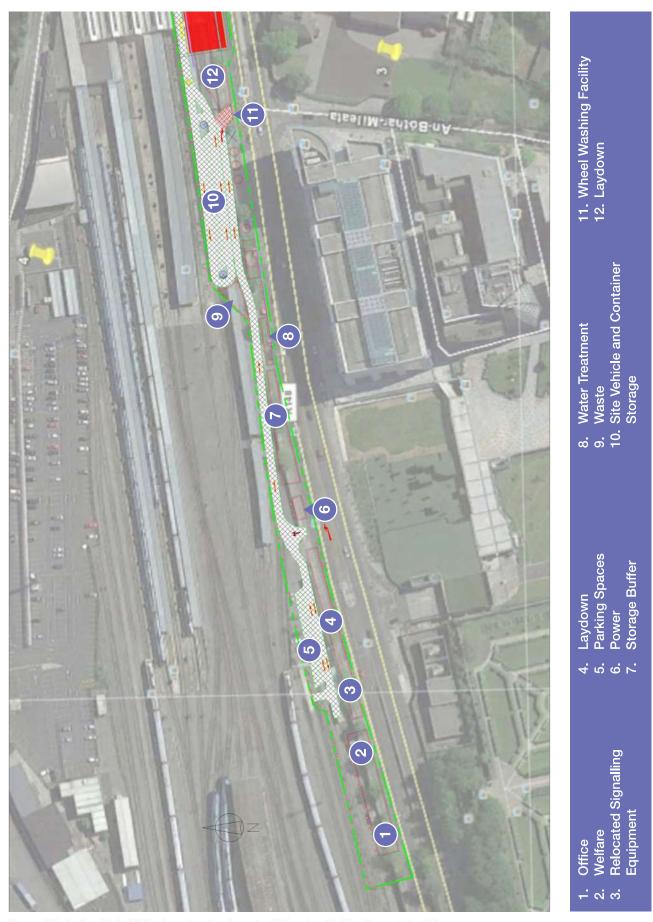


Figure 88: Option Twin 3AS - Construction layout at Heuston Station (Layout 1 of 2)

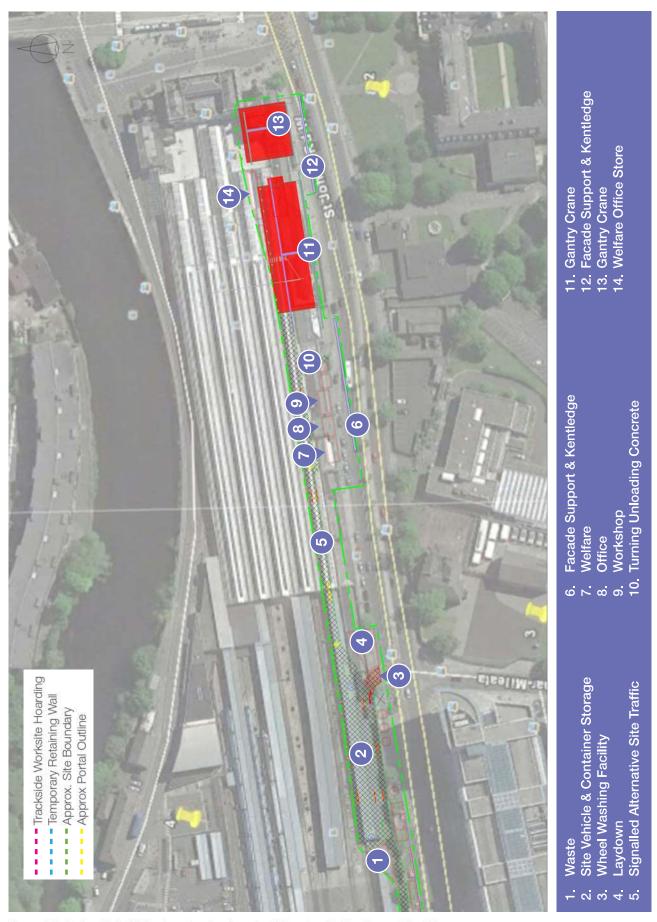


Figure 89: Option Twin 3AS - Construction layout at Heuston Station (Layout 2 of 2)

The portal would be constructed by undertaking excavation between bored pile retaining walls, which would be founded into the bedrock to provide a groundwater cut-off. It is envisaged that excavation and construction of the permanent tunnel approach structures would be undertaken in three stages, these being the TBM chamber and cut and cover section of the tunnel approach, the open U trough section of the approach structure and finally the tie-in to the existing rail lines.

#### **Heuston Station**

Construction of the Underground Station requires three cut and cover shafts being excavated in a 'Top Down' sequence. When the level of construction reaches the rockhead, the method of excavation would change to rock breaking. The methods used for excavating the rock would be chosen following trials at the site, but is likely to involve an element of high energy breaking, in the form of strictly controlled blasting. The tunnels at platform level would also be excavated by rock breaking with a sprayed concrete temporary lining.

The escalator shaft needs to be constructed as an inclined tunnel. As this tunnel would commence in the glacial sands and gravels it would require a full face of ground treatment to be undertaken extending at least three metres from the excavated profile at all times. Due to the limitations on access from ground surface, especially in the front of Heuston station it would not be possible to undertake the ground treatment from surface level. All ground treatment would need to be undertaken from the tunnel as it is advanced. All tunnelling activities would need to be undertaken from the Heuston station worksite in order to limit impacts on operations in the St. James' Gate Brewery, including minimising the landtake needed for construction.

The existing culvert for the River Camac would require strengthening before the station works can commence, and this necessitates the construction of an eastern and central cut and cover shafts, which straddles the strengthened culvert.

### **Running Tunnel Construction**

It is envisaged that earth pressure balancing TBMs would be used to drive the full length of the tunnels, as previously proposed as part of the original DART Underground. Earth pressure balancing TBMs are considered suitable for the prevailing ground conditions in Dublin City Centre and furthermore do not require additional areas within the worksite for treatment plant. At this location, road transport is the only feasible option for transporting the disposal of the excavated materials from the site.

## 8.2.7 Construction Sequence & Programme

The construction programme for Option Twin 3AS would be circa six years from commencement of the main Contract for construction. This is a saving of around four months from the programme for Option Twin 2F, which is a variation of the original DART Underground.

Shortening of the main tunnel drives relative to options which tunnel to Inchicore, save around five months on the tunnel programme with further savings being made in tunnel cross-passage construction, clean out and tracklaying activities. However, significant enabling works, including the reconstruction of rail overbridges OB1 and OB1A and rail diversion works, would delay the commencement of the portal in the Heuston Yard, which would limit the benefits from constructing the shorter running tunnels.

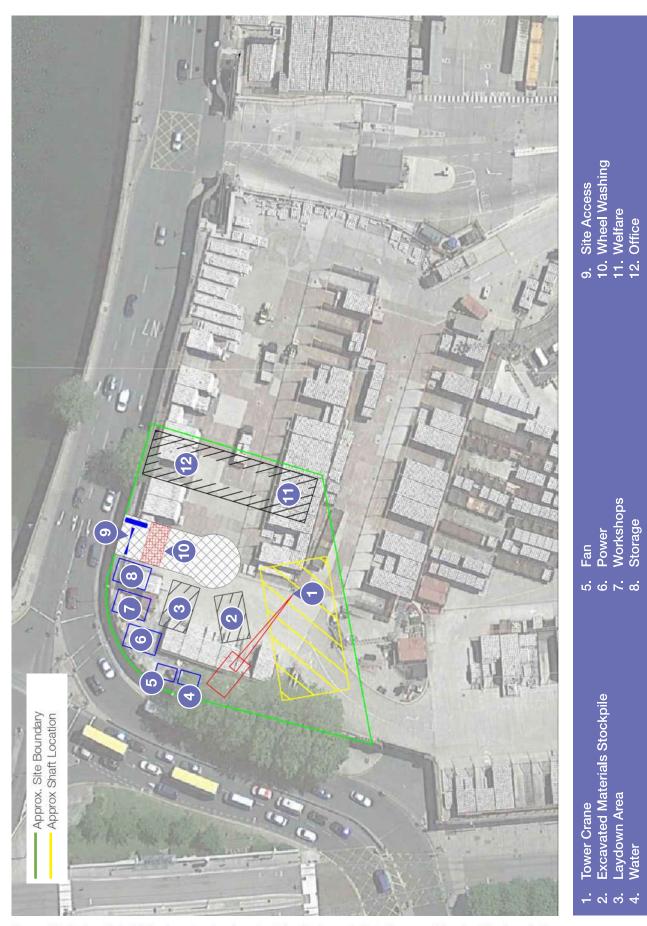


Figure 90: Option Twin 3AS - Construction layout at the St. James' Gate Brewery 'Kegging Yard' worksite

#### 8.2.8 Risks

Key construction risks associated with this option include:

- If the TBMs were launched from the Heuston Yard, then they would be launched from below the water table level into a mixed face of Boulder Clay and Glacial Sands and Gravels. This gives an increased difficulty with controlling the TBMs vertical and horizontal alignment during the early stages of the tunnel drive. There would also be an increased risk of ground movement, particularly of rail infrastructure but including the protected structure of the existing Heuston Station. To limit this risk, additional ground treatment and additional support measures such as spiles may be required at the portal.
- The reconstruction of overbridges OB1 and OB1A would likely result in significant traffic disruption during the re-construction of these bridges.
- There would be significant rail interfaces during the reconstruction of overbridges OB1 and OB1A, the portal and Heuston Station. Any of which could have an impact on the operation of the railway or require an extended programme to allow works to be carried out during engineering hours / railway possessions.
- There is a risk that constructing the eastern cut and cover shaft could adversely impact operations within the St. James' Gate Brewery.
- There would be an increased settlement risk to the listed parts of Heuston station associated with the ground treatment and excavation of the escalator shaft.

## 8.3 Option Twin 2C Construction Planning

### 8.3.1 Overview of Option

The key components of Option Twin 2C from a construction perspective are as follows:

- The Tunnel Portal for DART Underground is located in the Con Colbert Road westbound carriageway leading from the Chapelizod Bypass / Con Colbert Road in towards Ballyfermot. At this point, the Con Colbert Road separates from the Chapelizod Bypass. The portal arrangement requires purchase of the 'Horses Field' and slewing of the Heuston Mainline would require purchase of the Dan Ryan Truck Rental site;
- The portal can be used as either a launch or reception chamber for construction of the running tunnels;
- Four tracking of the mainline railway would be required from Park West / Cherry Orchard Station to the end of the tunnel approach structures, which is just east of Sarsfield Road Underbridge. This would require the construction of a new twin track rail bridge over Sarsfield Road to the south of the existing rail underbridge to carry the slewed tracks of the Heuston Mainline. The existing 'silent' rail underbridge would need to be replaced;
- The proposed Heuston Underground Station is on the south side of the existing station, requiring three cut and cover shafts, enlarged mined platform tunnels, mined cross passages and ventilation adits. The platform level at the western end of the station is circa -20.4 m OD;
- There would be no station at Inchicore, instead a surface station would be provided west of Kylemore Road Bridge;
- There would be a turnback provided at Park West / Cherry Orchard station, which combined with the existing turnback at Adamstown Station, would provide the required capacity of 8 trains per hour per direction with through running onto the Heuston Mainline.

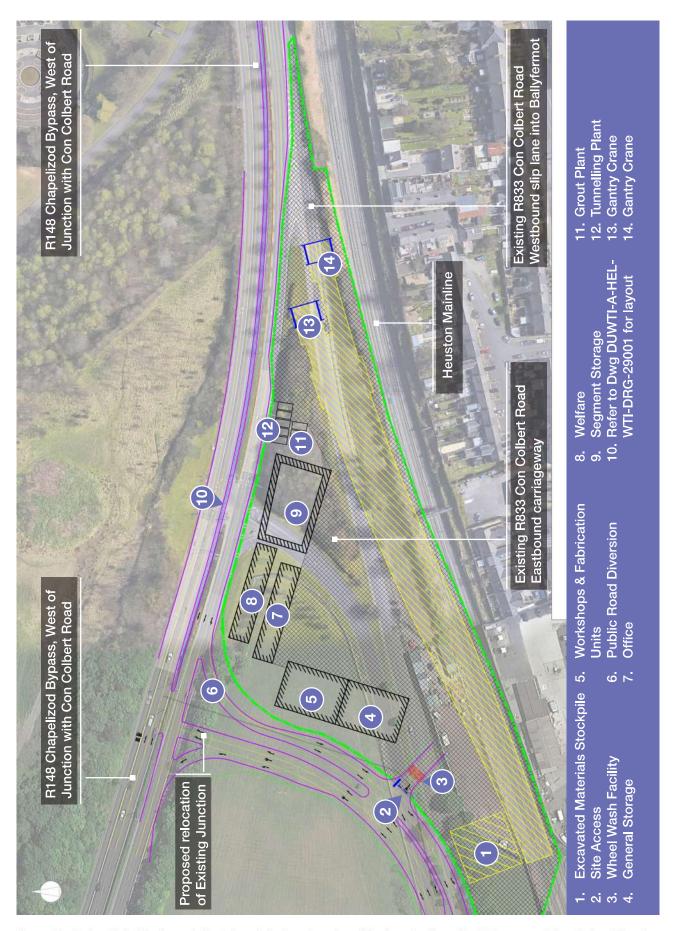


Figure 91: Option Twin 2C - Launch Portal worksite layout and modifications to Chapelizod Bypass and Con Colbert Road

#### 8.3.2 Tunnel Portal Launch Site

To provide the required worksite area for construction of the running tunnels from this location, it would be necessary to extend the worksite temporarily further into the grounds of the Liffey Gaels GAA Club as shown in **Figure 91**.

This would require a temporary diversion of the Con Colbert Road, eastbound and westbound carriageways, and a new road junction with the Chapelizod Bypass to be constructed at the eastern end of the Club's grounds.

### 8.3.3 Tunnel Portal Reception Site

The proposed arrangement for the worksite if acting as a reception portal is similar to that of the launch worksite, principally driven by the need to provide a suitable slip lane from the Chapelizod Bypass and the geometric requirements of the temporary road junction. The proposed worksite arrangement is illustrated in **Figure 92**.

### 8.3.4 Heuston Station Worksite

The worksite for the construction of the proposed Heuston Underground station is shown in **Figures 93 and 94**. The arrangement requires the temporary closure of the existing platform 1, and the temporary relocation of platforms 2 and 3. The existing electrical sub-station and switchroom, offices, and station concourse facilities would need to be relocated to the north-west corner of the existing station.

### 8.3.5 Construction Methodology

## Rail diversion and New Sarsfield Road Underbridge

The existing Heuston Mainline must be slewed to the south to create space for the DART Underground tunnel approach structure. This requires strengthening of the existing Sarsfield Road retaining walls and construction of a new rail underbridge. The rail level of the slewed tracks

would be raised to facilitate a vertical highway clearance which as a minimum achieves the same clearance of 4.37 m.

Construction of the new underbridge would broadly be undertaken as follows:

- Undertake strengthening to the existing retaining walls using ground anchors. This would require a Stop / Go traffic arrangement on Sarsfield Road for the period of the strengthening works;
- Install bored piles behind the existing masonry retaining walls to carry the new bridge deck;
- Remove coping stones and lower walls locally for capping beam to piles and new bridge deck. Capping beam to extend across the piles and lowered wall;
- Fix reinforcement and shuttering, and construct pile cap;
- Install deck to new structure, which could be lifted into place from the Dan Ryan Truck Rental site with a temporary closure of Sarsfield Road.

Following completion of the new structure, the rail lines and associated services leading towards Heuston Station would be relocated south onto the new bridge and through the Dan Ryan Truck rental site. This would free up the space required for the new portal.

### **Portal Construction**

The portal would be constructed by undertaking excavation between bored pile retaining walls, which would be founded into the bedrock to provide a groundwater cut-off. It is envisaged that excavation and construction of the permanent tunnel approach structures would be undertaken in three stages, these being the TBM chamber and cut and cover section of the tunnel approach, the open U trough section of the approach structure and finally the tie-in to the existing rail lines which would be constructed as reinforced concrete.

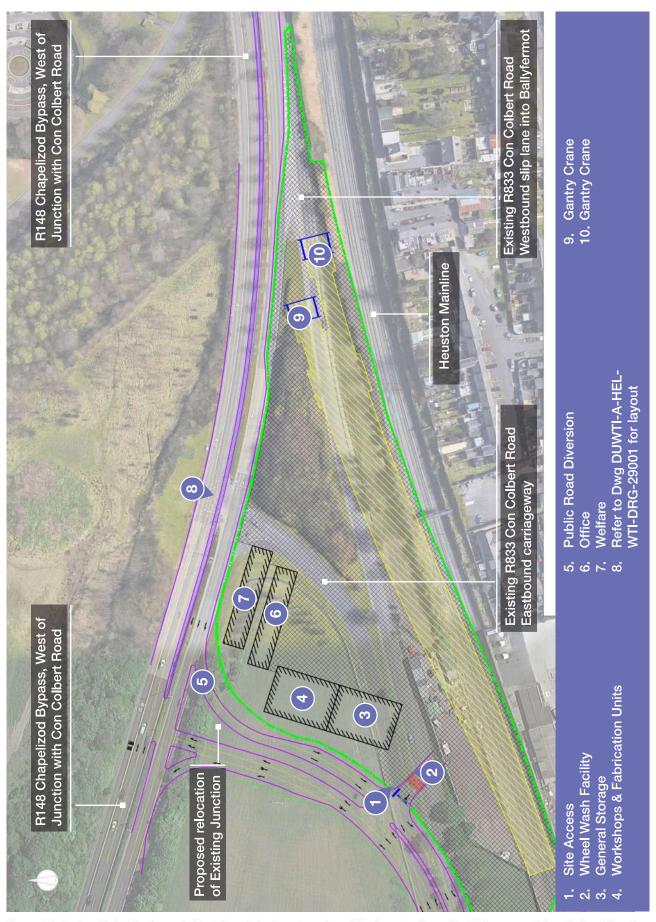


Figure 92: Option Twin 2C - Launch Portal worksite layout and modifications to Chapelizod Bypass and Con Colbert Road



Figure 93: Option Twin 2C - Construction layout at Heuston Station (Layout 1 of 2)

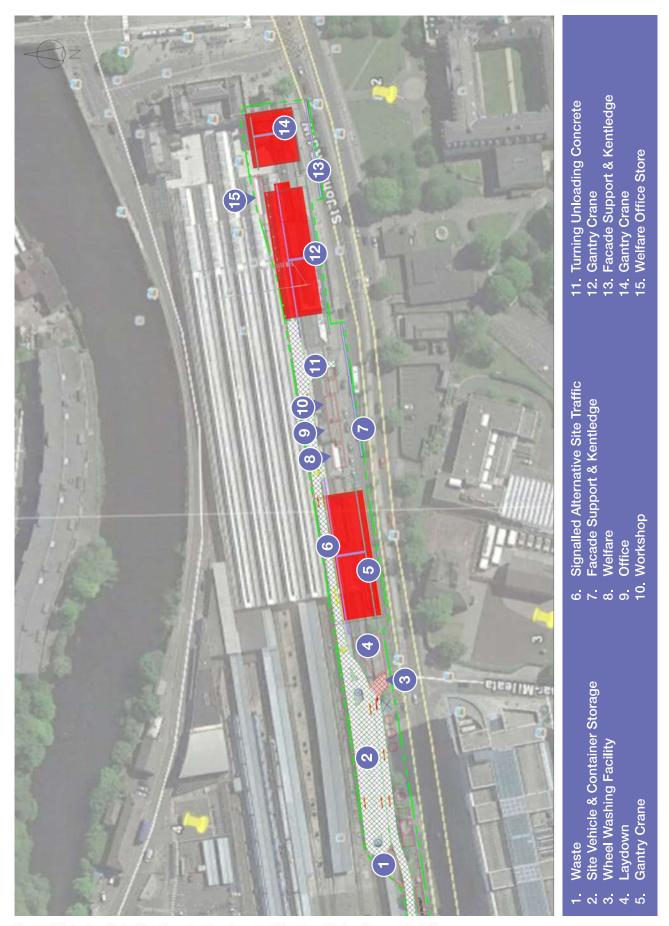


Figure 94: Option Twin 2C - Construction layout at Heuston Station (Layout 2 of 2)

## Heuston DART Underground Station Construction

Construction of the Underground Station requires three cut and cover shafts being excavated in a 'Top Down' sequence. When the level of construction reaches the rockhead, the method of excavation would change to rock breaking. The methods used for excavating the rock would be chosen following trials at the site, but is likely to involve an element of high energy breaking, in the form of strictly controlled blasting. The tunnels at platform level would also be excavated by rock breaking with a sprayed concrete temporary lining.

The existing culvert for the River Camac would require strengthening before the station works can commence, and this necessitates the construction of an eastern and central cut and cover shafts, which straddles the strengthened culvert.

### **Running Tunnel Construction**

It is envisaged that earth pressure balancing TBMs would be used to drive the full length of the tunnels, as previously proposed as part of the original DART Underground. Earth pressure balancing TBMs are considered suitable for the prevailing ground conditions in Dublin City Centre and furthermore do not require additional areas within the worksite for treatment plant. At this location, road transport is the only feasible option for transporting the disposal of the excavated materials from the site.

## 8.3.6 Construction Sequence & Programme

The construction programme for Option Twin 2C would be circa six years and three months from commencement of the main Contract for construction. This is comparable with the programme for the original DART Underground.

There are significant enabling works associated with the Sarsfield Road Underbridge and four tracking of the railway corridor. By assuming that these works are constructed as part of an Enabling Works ahead of the Main Contract, then they would not impact construction of the tunnel portal. In any case, it would be possible to commence construction of the TBM launch chamber independently of the Sarsfield road works, so there should not be any delay to construction of the running tunnels. Launching the TBMs from the eastern portal would not make any significant difference to the overall construction programme.

#### 8.3.7 Risks

Key construction risks associated with this option include:

- If the TBMs were launched from this location, then they would launched into a full face of Dublin Boulder Clay. This may give rise to the need for additional support measures such as spiles at the portal to limit the risk of ground loss and excessive ground movement.
- There would be a number of rail interfaces during construction of the tie-in of the portal to the Heuston Mainline. Whilst these could have an impact on the operation of the railway or require a longer programme to allow works to be carried out during engineering hours / rail possessions, they are not considered as significant as those options associated with a portal in the Heuston Yard or within the Inchicore railway works.

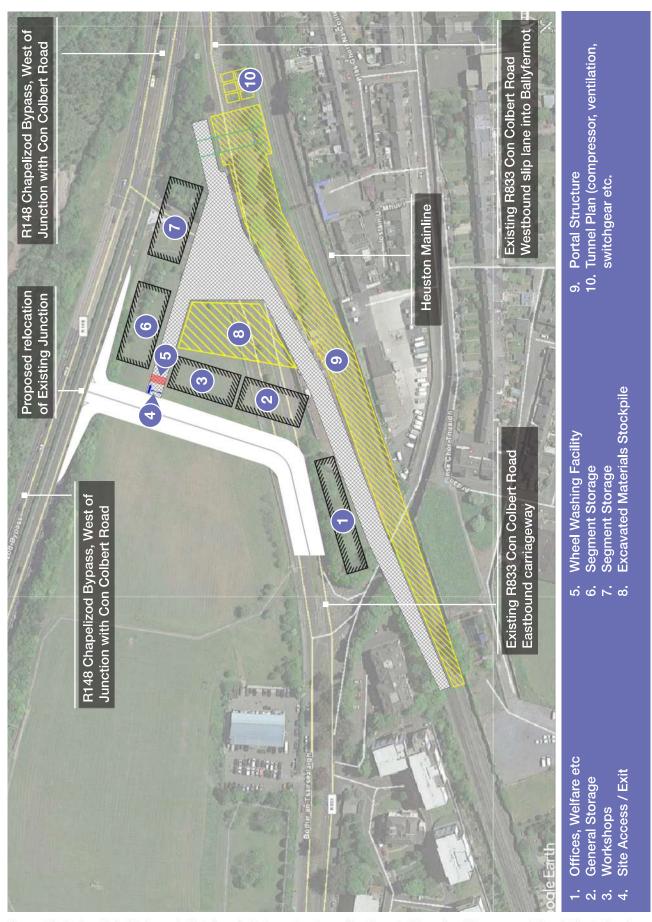


Figure 95: Option Twin 3C Launch Portal worksite layout and modifications to Chapelizod Bypass and Con Colbert Road

## 8.4 Option Twin 3C

## 8.4.1 Overview of Option

The key components of Option Twin 3C from a construction perspective are as follows:

The Tunnel Portal for DART Underground is located in the Con Colbert Road westbound carriageway leading from the Chapelizod Bypass / Con Colbert Road in towards Ballyfermot. At this point, the Con Colbert Road separates from the Chapelizod Bypass. The portal arrangement requires purchase of the 'Horses Field' and slewing of the Heuston Mainline would require purchase of the Dan Ryan Truck Rental site;

- The portal can be used as either a launch or reception chamber for construction of the running tunnels;
- Four tracking of the mainline railway would be required from Park West / Cherry Orchard Station to the end of the tunnel approach structures, which is 130 m west of Sarsfield Road Underbridge. This would require Sarsfield Road to be permanent closed to all vehicular traffic but an underpass could be provided for pedestrians and cyclists;
- The proposed Heuston Underground Station is on the south side of the existing station, requiring three cut and cover shafts, enlarged mined platform tunnels, mined cross passages and ventilation adits. The platform level at the western end of the station is circa -20.4 m OD;
- There would be no station at Inchicore, instead a surface station would be provided west of Kylemore Road Bridge;
- There would be a turnback provided at Park West / Cherry Orchard station, which combined with the existing turnback at Adamstown Station, would provide the required capacity of 8 trains per hour per direction with through running onto the Heuston Mainline.

### 8.4.2 Tunnel Portal Launch Site

Similar to Option Twin 2C, to provide the required worksite area for construction of the running tunnels from this location, it would be necessary to extend the worksite temporarily further into the grounds of the Liffey Gaels GAA Club as shown in **Figure 95**.

This would require a temporary diversion of the Con Colbert Road, eastbound and westbound carriageways, and a new road junction with the Chapelizod Bypass to be constructed at the eastern end of the Club's grounds.

## **8.4.3 Tunnel Portal Reception Site**

The proposed arrangement for the worksite if acting as a reception portal can be reduced in size relative to the launch portal arrangement. Furthermore as the tie-in to the Heuston Mainline occurs west of Sarsfield Road Underbridge, so the portal on Option Twin 3C is west of that proposed in Option Twin 2C which provides more flexibility in terms of the road junction arrangement and the potential for reduced landtake. The proposed worksite arrangement is illustrated in **Figure 96**.

### 8.4.4 Heuston Station Worksite

The worksite for the construction of Heuston Underground Station is similar to that proposed with Option Twin 2C and shown in **Figures 93** and **94**.

### 8.4.5 Construction Methodology

#### Rail diversion and Sarsfield Road access

The existing Heuston Mainline must be slewed to the south to create space for the DART Underground tunnel approach structure. This would require the possession of the Dan Ryan Truck rental site in order to free up the space required for the new portal structure.

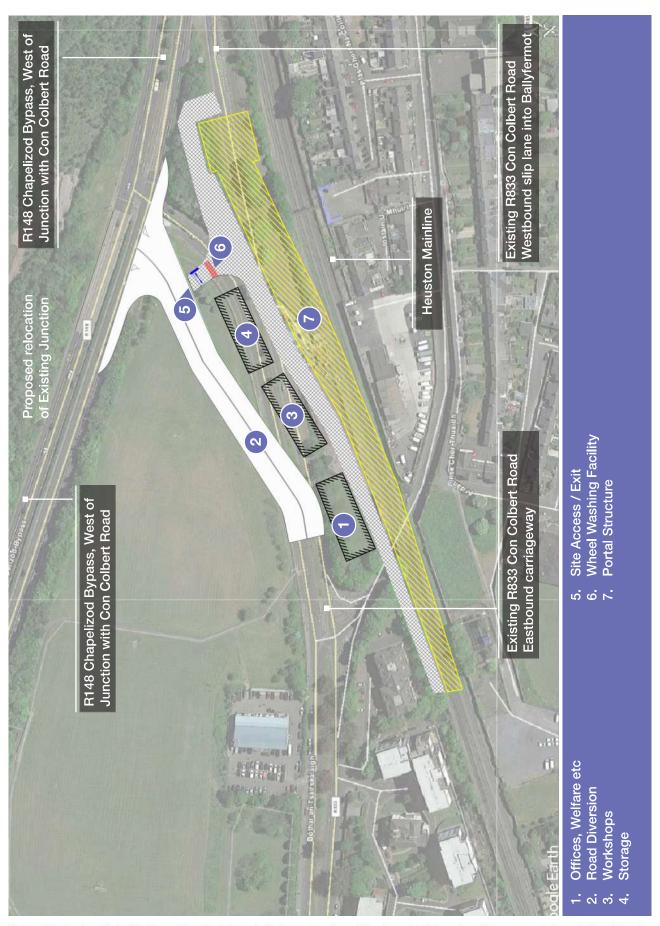


Figure 96: Option Twin 3C Reception Portal worksite layout and modifications to Chapelizod Bypass and Con Colbert Road

Unlike Option Twin 2C, it would not be possible to maintain vehicular access along Sarsfield Road. The road would need to be closed in the permanent condition so that the existing rail underbridge can be demolished, the area backfilled and levels generally lowered for the new portal. The slewing of the Heuston Mainline would require a phased construction and the diverted Mainline could either be supported on a new bridge deck or by filling in a length of Sarsfield Road to carry the Mainline.

#### **Portal Construction**

The portal would be constructed by undertaking excavation between bored pile retaining walls, which would be founded into the bedrock to provide a groundwater cut-off. It is envisaged that excavation and construction of the permanent tunnel approach structures would be undertaken in three stages, these being the TBM chamber and cut and cover section of the tunnel approach, the open U trough section of the approach structure and finally the tie-in to the existing rail lines which would be constructed as reinforced concrete.

## Heuston DART Underground Station Construction

Construction of Heuston DART Underground Station would be identical to that of Option Twin 2C.

### **Running Tunnel Construction**

It is envisaged that earth pressure balancing TBMs would be used to drive the full length of the tunnels, as previously proposed as part of the original DART Underground. Earth pressure balancing TBMs are considered suitable for the prevailing ground conditions in Dublin City Centre and furthermore do not require additional areas within the worksite for treatment plant. At this location, road transport is the only feasible option for transporting the disposal of the excavated materials from the site.

## 8.4.6 Construction Sequence & Programme

There are significant enabling works associated with the Sarsfield Road Underbridge and four tracking of the railway corridor. By assuming that these works are constructed as part of an Enabling Works ahead of the Main Contract, then they would not impact construction of the tunnel portal. In any case, it would be possible to commence construction of the TBM launch chamber independently of the Sarsfield road works, so there should not be any delay to construction of the running tunnels. Launching the TBMs from the eastern portal would not make any significant difference to the overall construction programme.

#### 8.4.7 Risks

Key construction risks associated with this option include:

- If the TBMs were launched from this location, then they would launched into a mixed face of Dublin Boulder Clay / Calp Limestone. This may give rise to the need for additional support measures such as spiles at the portal to limit the risk of ground loss and excessive ground movement.
- There would be a number of rail interfaces during construction of the tie-in of the portal to the Heuston Mainline. Whilst these could have an impact on the operation of the railway or require a longer programme to allow works to be carried out during engineering hours / rail possessions, they are not considered as significant as those options associated with a portal in the Heuston Yard or within the Inchicore railway works.

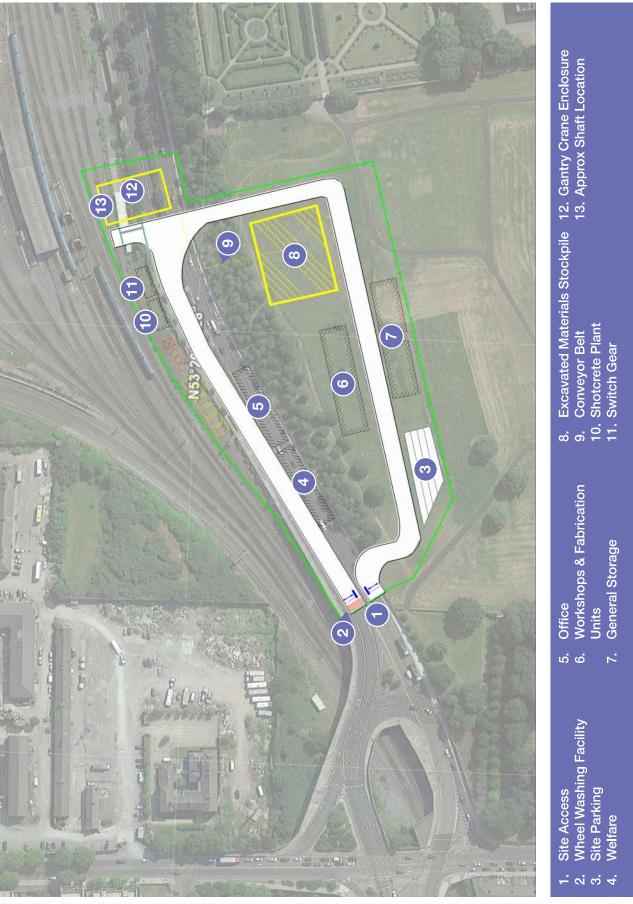


Figure 97: Option Twin 1E – Construction site for the Ventilation / Intervention shaft and construction of the mined central turnback

## 8.5 Option Twin 1E

### 8.5.1 Overview of option

The key components of Option Twin 1E from a construction perspective are as follows:

- Terminus Station at Heuston with a 460m long enlarged mined turnback beneath Heuston rail yard;
- Ventilation / intervention shaft to be constructed at end of turnback partially located within the Heuston yard and partially beneath St. John's Road West, with the above ground building structure located within existing IÉ lands at Heuston Station:
- The layout precludes the Heuston vicinity being a site for the driving of the running tunnels, the intention is to bury the TBMs beyond the end of the Heuston Underground station platforms;
- Four tracking of the mainline railway would be required from Park West / Cherry Orchard to Heuston Station, this would require the reconstruction of rail overbridge OB1 as a minimum;
- The vertical level of the Heuston Underground Station would be approximately 10 m deeper than similar through running twin bore tunnel options at Heuston. This increased depth is driven by the need to have sufficient rockhead cover above the mined turnback;
- There would be no station at Inchicore, instead a surface station would be provided west of Kylemore Road Bridge.

## 8.5.2 Ventilation and Intervention Shaft at end of Turnback

The worksite for construction of the ventilation / intervention shaft and turnback is to be partially located in the Heuston Yard, partially in St. John's Road West and partially in the grounds of the Royal Hospital Kilmainham as shown in **Figure 97**.

Due to the location of the shaft, positioned partially under St. John's Road West, it would be necessary to close the road to traffic for the duration of the shaft and turnback construction. On completion of the works, St. John's Road West would be reinstated. Access to the worksite for construction traffic would be provided from the roundabout forming the junction between the South Circular Road and N4 Chapelizod Bypass.

#### 8.5.3 Heuston Station Worksite

The principle for the arrangement of the construction worksite would be similar to that illustrated in **Figures 93 and 94** for Option Twin 2C. However, in Option Twin 1E, the track level is approximately 10 m deeper than Option Twin 2C and therefore the plan size of the shafts would be greater and the construction programme would be significantly longer.

### 8.5.4 Construction Methodology

## Ventilation and Intervention Shaft and Mined Turnback Construction

It is envisaged that the construction methodology chosen for the shaft would be 'Bottom-Up' as this would give the shortest excavation duration and provide a clear access for construction of the turnback tunnel. Installation of piled perimeter walls would be followed by excavation with temporary frames or ground anchors being used to support the piles. When the level of excavation reaches the rockhead, the method of excavation would change to rock breaking. The methods used for excavating the rock would be chosen following trials at the site, but is likely to involve an element of high energy breaking, in the form of strictly controlled blasting.

The turnback tunnels and associated crossovers at platform level would also be excavated by rock breaking, working from the base of the combined ventilation and intervention shaft. Following completion of excavation, the permanent concrete lining to the tunnels would be cast followed by the permanent lining to the shaft.

## Heuston DART Underground Station Construction

Construction of Heuston DART Underground Station would be similar to that proposed in Option Twin 2C, in that three cut and cover shafts are required and would be excavated using 'Top down' techniques. The difference in the proposed station is that the track level is approximately 10 m deeper in Option Twin 1E and therefore the shaft sizes will be greater.

When the level of construction reaches the rockhead, the method of excavation would change to rock breaking. The methods used for excavating the rock would be chosen following trials at the site, but is likely to involve an element of high energy breaking, in the form of strictly controlled blasting. The tunnels at platform level would also be excavated by rock breaking with a sprayed concrete temporary lining.

The station enlargement tunnelling works would be undertaken and serviced from the worksite located within the grounds of the RHK, utilising the ventilation and intervention shaft to minimise impacts on the existing Heuston Station. The existing culvert for the River Camac would require strengthening before the main works at Heuston Station could commence.

## 8.5.5 Construction Sequence & Programme

The construction programme for Option Twin 1E would be in the order of six years and five months from commencement of the Main Contract for construction excluding rail diversions, diversion of utilities and the closure of St. John's Road West, which would be undertaken prior to site set-up. Piling and excavation of the ventilation shaft at the end of the turnback would be of the order of 12 months, which is compatible with the time required to excavate the TBM chambers at the eastern portal. Construction of the mined central turnback and crossover tunnels could be carried out concurrently with other construction activities,

to avoid any impact on the overall programme. The construction programme would be of a similar duration to that of Option Twin 2F.

#### 8.5.6 Risks

Key construction risks associated with this option are:

- Launching of the TBMs from the Heuston vicinity is not considered a viable option as it would require an extensive temporary underground development to form launch chambers and provide facilities for the operation of the trains needed to service the TBMs. Increasing the extent of the tunnels excavated without a shield would increase the level of tunnelling risk.
- For the combined ventilation and intervention shaft at the end of the turnback, significant utilities would need to be diverted along St. John's Road West. There is a risk that these diversions could have a significant impact on both the construction programme and costs.

## 8.6 Option Mono 2E

#### 8.6.1 Overview of Option

The key components of Option Mono 2E from a construction perspective are as follows:

- Monotube tunnel with terminus station at Heuston and turnback constructed within the monotube tunnel, west of the proposed Underground Station;
- Ventilation / intervention shaft to be constructed at the end of the turnback located within the grounds of the Royal Hospital Kilmainham;
- The layout precludes the Heuston vicinity being a site for the driving of the monotube tunnel;
- Four tracking of the mainline railway would be required from Park West / Cherry Orchard to Heuston Station, this would require the reconstruction of bridge OB1;

- By constructing the Underground Station in a monotube, shafts housing the station ticket hall, plant and egress / intervention facilities would be required within the forecourt to Dr Steevens' Hospital and the existing car park at the north west corner of the existing Heuston Station;
- The invert of the station tunnel is approximately 17 m lower at the proposed Heuston Underground Station than the through running twin bore tunnel options, this is dictated by the outer diameter of the TBM and the need to tunnel within the bedrock at this location to mitigate against excessive ground movements and ground induced damage;
- There would be no station at Inchicore, instead a surface station would be provided west of Kylemore Road Bridge.

## 8.6.2 Ventilation and Intervention Shaft at end of Turnback

The worksite for construction of the ventilation / intervention shaft and tumback at the end of the monotube tunnel would be located in the grounds of the Royal Hospital Kilmainham as shown in **Figure 98 overleaf**. Access to the worksite for construction traffic would be provided from the roundabout forming the junction between the South Circular Road and the Chapelizod Bypass / Con Colbert Road.

#### 8.6.3 Heuston Station

The worksite for construction of the main shaft and associated tunnels linking the monotube tunnel to the Heuston Underground station would be located in the forecourt of Dr Steevens' Hospital as shown in **Figure 99**.

In order to provide a below ground link from this shaft to the existing Heuston Station, a temporary closure of St. John's Road West would be required. In addition to this, a second worksite would be required located within the car park of Heuston for the construction of a combined ventilation / emergency escape / intervention shaft as shown in **Figure 100**.

## 8.6.4 Construction Methodology

## Ventilation and Intervention Shaft at end of Turnback

It is envisaged that the construction methodology chosen for the shaft would be 'Bottom-Up' as this would give the shortest excavation duration and provide a clear access for removal of the TBM. Installation of piled perimeter walls would be followed by excavation with temporary frames or ground anchors being used to support the piles. When the level of excavation reaches the rockhead, the method of excavation would change to rock breaking. The methods used for excavating the rock would be chosen following trials at the site, but is likely to involve an element of high energy breaking, in the form of strictly controlled blasting.

## Heuston DART Underground Station Construction

It is envisaged that the construction methodology chosen for the station ticket hall and ancillary facilities at Dr Steevens' Hospital and the ventilation / intervention shaft in the Heuston car park, would be 'Top-Down'.

Installation of piled perimeter walls would be followed by the casting of a top slab and progressive excavation and concrete lining of the underground space. When the level of construction reaches the rockhead, the method of excavation would change to rock breaking. The methods used would be chosen following trials at the site, but is likely to involve an element of high energy breaking, in the form of strictly controlled blasting.

Following excavation of the shaft, the tunnels linking to the platforms would be excavated again using rock breaking methods. Temporary support to these tunnels would be by a combination of rock bolting and sprayed concrete lining before the permanent concrete lining is constructed. Careful consideration would be needed for the design of



Figure 98: Option Mono 2E - Construction site for the Ventilation / Intervention shaft and construction of the turnback at the end of the tunnel drive

the openings from these tunnels to the monotube tunnel to ensure that stability of the larger tunnel is maintained during their formation.

Following completion of the monotube tunnel drive and removal of the TBM, a horizontal dividing slab would be constructed for the full length of the tunnel. This would permit construction of the platforms, and MEP and architectural fit out of the platform tunnels to the station to take place along with tracklaying and fit out of the running tunnels.

## 8.6.5 Construction Sequence & Programme

The construction programme for Option Mono 2E would be of the order of six years and ten months from commencement of the Main Contract for construction. Although the length of the monotube tunnel drive would be shorter than for the options with a portal near to Inchicore, additional time would be required to install and dismantle the TBM, and the rate at which the tunnel is constructed would be reduced due to the significant increase in diameter and need to primarily tunnel in the Calp limestone.

Further time would be required to construct the horizontal dividing slab within the tunnel before tracklaying and fit out of the platform tunnels could commence. Savings would be made in the timescales for platform tunnel and cross-passage construction, which would no longer be required. However these works are not on the critical path for the overall construction programme and so they would not provide any overall saving in the construction programme. The overall programme duration would be longer for this option than for all other MCA options.

#### 8.6.6 Construction Risks

Key Construction risks associated with this option are:

- The construction of a much larger tunnel could lead to significantly greater ground movements without mitigation, such as lowering the vertical alignment of the monotube tunnel. At the eastern end of any route alignment option, the tracks would need to be brought to surface to tie-in with the existing rail infrastructure, and there is the potential for significant ground movements and ground induced damage at the location of the launch chamber and tunnel portal approach structures.
- It is considered that the monotube tunnel would need to be primarily constructed in the Calp limestone bedrock throughout any proposed route alignment, in order to limit ground movements. This would impact the depth and configuration of the station cut and cover shaft structures.

## 8.7 Option Twin 2F

### 8.7.1 Overview of Option

The key components of Option Twin 2F from a construction perspective are as follows:

- The Tunnel Portal for DART Underground is to be located within the CIÉ Inchicore Works;
- The Tunnel Portal would only act as a reception chamber with the TBMs driven from the East;
- Four tracking of the Heuston Mainline would be required from Park West / Cherry Orchard Station to the Inchicore Works with provision for a grade separated junction to tie the DART tracks into the Mainline;

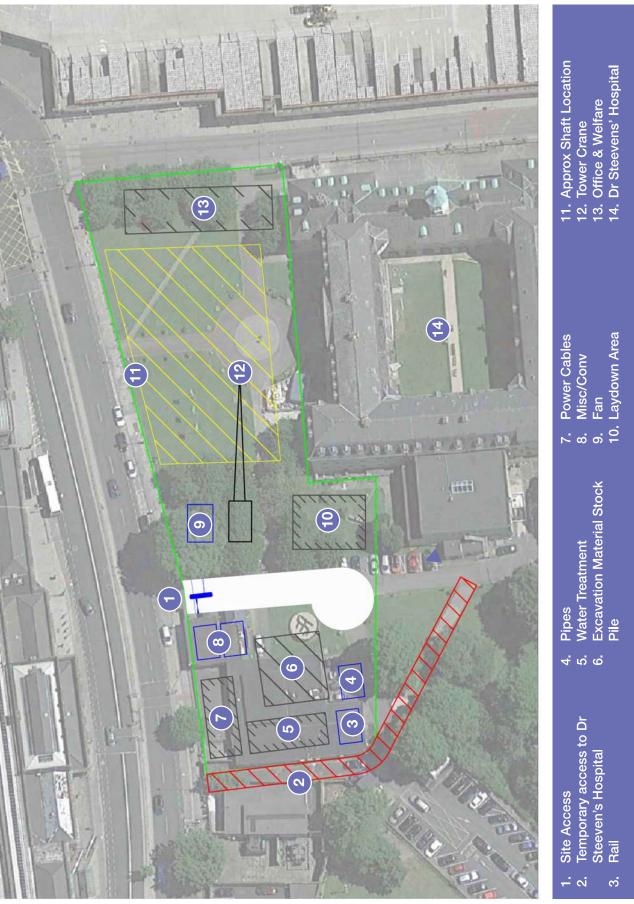


Figure 99: Option Mono 2E – Construction site for the Ticket Hall and Underground Station shaft in the forecourt of Dr Steevens' Hospital

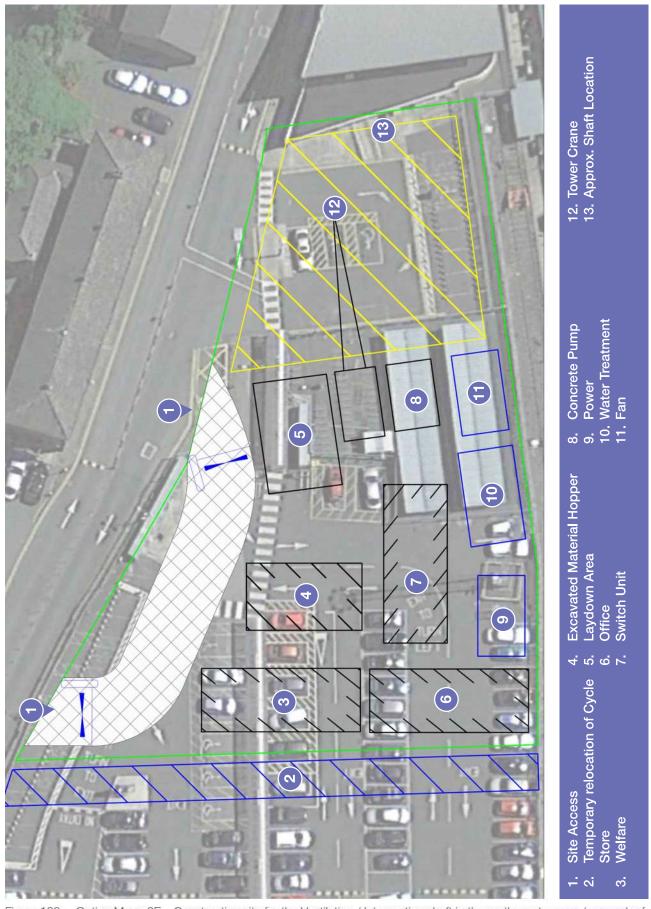


Figure 100: Option Mono 2E – Construction site for the Ventilation / Intervention shaft in the north west corner / car park of the existing Mainline Station

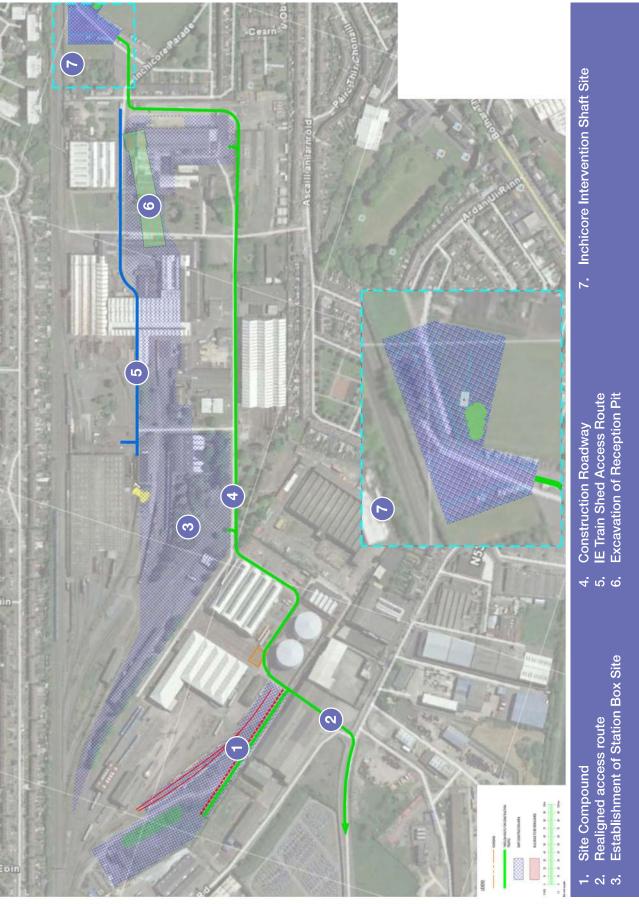


Figure 101: Option Twin 2F - Construction site for the Reception Chamber and cut and cover tunnel, and Inchicore Intervention shaft

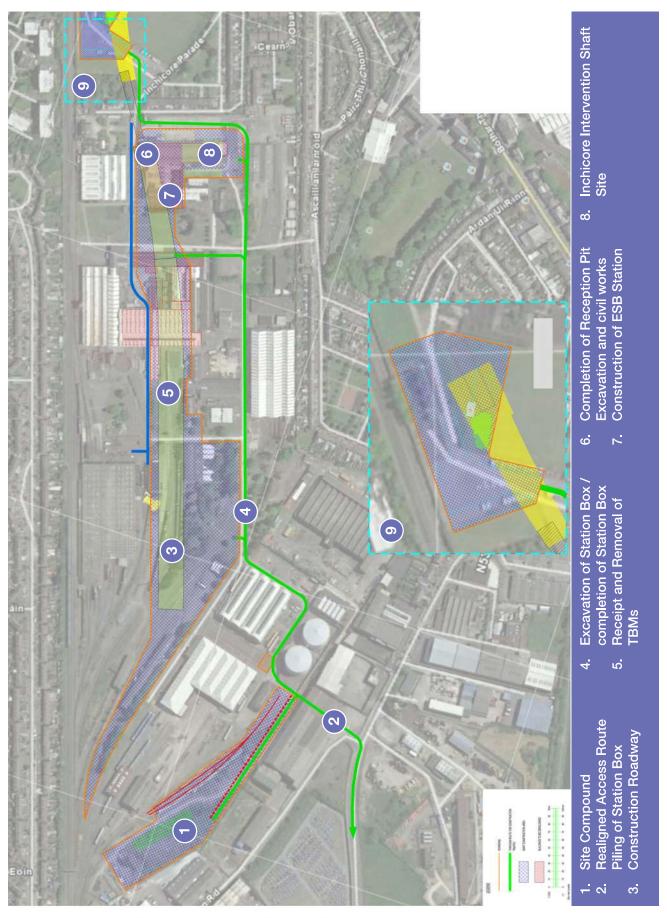


Figure 102: Option Twin 2F - Construction site for Inchicore Station and Inchicore Intervention shaft



- The proposed Heuston Underground Station is on the south side of the existing station, requiring three cut and cover shafts, enlarged mined platform tunnels, mined cross passages and ventilation adits. The platform level at the western end of the station is circa -20.4 m OD;
- There would be a station at Inchicore:
- The turnback would be located at Inchicore.

#### 8.7.2 Tunnel Portal Worksite

As shown on **Figures 101 to 102**, the TBM reception chamber would be within the Inchicore Works with a length of cut and cover tunnel to the open U section of the turnback and proposed Inchicore Station.

#### 8.7.3 Heuston Station Worksite

The worksite for the construction of Heuston Underground Station is similar to that proposed with Option Twin 2C and shown in **Figures 93** and **Figure 94**.

### 8.7.4 Construction Methodology

### **Portal Construction**

Several existing buildings would be demolished within the Inchicore Works to allow piled retaining walls for the portal, turnback and station to be installed. Upon completion of the piling works, the ground between the piles would be excavated to form an open box structure and a structural concrete base slab would be constructed. The structure would remain predominantly open until the reception and removal of the two TBMs, at which point the roof slab would be constructed over the reception chamber and cut and cover portion.

## Heuston DART Underground Station Construction

Construction of Heuston DART Underground Station would be identical to that of Option Twin 2C.

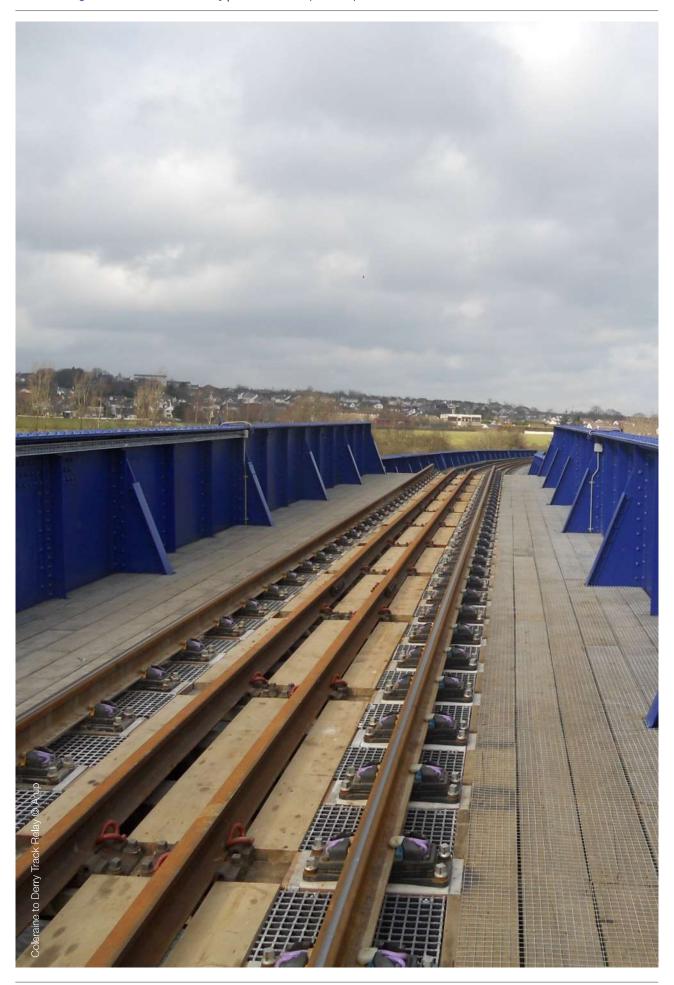
## 8.7.5 Construction Sequence & Programme

The construction programme for Option Twin 2F would be circa six years and five months from commencement of the main Contract for construction.

The critical path for this programme, which is based on driving 2 TBMs from North Wall Yard to the Inchicore Works, follow through TBM procurement, the running tunnel drives, enlargement of the Heuston station platform tunnels and the running tunnel fit out. There is approximately six months float on construction of the Heuston Underground station. There is approximately seven months float between the construction of the Inchicore portal and the arrival of the TBMs. Construction of the station at Inchicore is on the programme critical path.

## 8.7.6 Risks

There are no significant construction risks associated with this option that have not previously been identified and addressed as part of the original DART Underground.



## 9. Phase 3: Overview of MCA Criteria



## 9.0 Phase 3: Overview of MCA Criteria

This chapter of the Study provides an explanation of the background to each of the MCA criterion. An overview of the subject matter is provided together with a description of the principal issues and objectives, which inform the assessment of each of the respective MCA criterion.

## 9.1 Capital Cost

For each of the MCA Options, a feasibility working cost estimate has been prepared, covering the extent of the Western Tie-In Study, namely from Park West / Cherry Orchard Station to Watling Street. The comparative assessment of the MCA Options under the criterion of Capital Cost is therefore based around the quantitative cost of each respective option and the relative cost differences between options.

**Chapter 10** of this Study describes in further detail the methodology for preparing the working cost estimates, and provides a summary breakdown of the costs associated with each option.

## 9.2 Interchange

The Interchange criterion considers how the design and operation of each MCA Option could facilitate the movement of people between:

- The existing Mainline Terminus Station at Heuston and the proposed Underground Station;
- The streetscape and the underground rail system;
- Other modes of public transport and the underground rail system.

Good station design promotes the efficient movement of people leading to an enhanced level of passenger experience. The station layout at Heuston should promote a clear understanding of how the above ground Mainline Station and streetscape are connected to the underground platforms. The ease and simplicity of being able to navigate between the station levels in a logical manner is a key component of this criterion. This would reflect the spatial layout and organisation of the functional areas of the station.

The Interchange assessment is qualitative, reflecting the depth of the platforms, the platform arrangement (island, lateral or stacked), the number of intermediate floors and estimated time required to travel between platform and existing station concourse.



Figure 103: Study Area, indicating existing Mainline Railway alignment

#### 9.3 Traffic & Transportation

The provision of the required rail infrastructure has the potential to impact on the movement of traffic, buses, cyclists and pedestrians during both the operational and construction stages. A qualitative assessment of these impacts has been undertaken as part of the MCA comparative assessment.

The following items have been considered in determining the impact of the MCA options on traffic and transportation:

- Temporary/short-term/permanent road closures and associated rerouting for all modes;
- Temporary/short-term/permanent reduction in capacity of roads/junctions;
- Daily volume of construction vehicles;
- Construction vehicle access arrangements.

The qualitative assessment considers each option on its individual merits against the potential impacts listed above, and then compares the findings of the assessment relative to one another to provide a ranking for this criterion.

The preliminary worksite compound arrangements and construction requirements presented in **Chapter 7** and **Volume 2** of the Study, have informed this assessment. Where applicable, the qualitative assessment incorporates the relative impacts of the TBM portal worksite being a location from which the TBMs would be driven or would be received.

#### 9.4 Accessibility

The aspiration for DART Underground is to provide an inclusive environment throughout. Inclusion, based on the social model of disability, is the philosophy adopted in seeking to achieve an inclusive design that maximises access for disabled people. The term "disability" has been viewed in its broadest sense and includes impaired

mobility, sight, comprehension or hearing. This approach addresses not only the short-term compliance with the intent of the Disability Act together with the relevant planning policies but also the long-term implications of sustainability.

The accessibility criteria appraises the capacity of an option to provide ease of access for disabled people on a qualitative basis.

#### 9.5 Landscape & Visual

The landscape and visual qualitative assessment of the route corridor options has taken account of:

- Land use zonings (amenity, open space, recreation, sport);
- Protected views and prospects;
- Recreation Access Routes / Designated Walk Ways;
- Tree Preservation Orders (TPO) and tree preservation/protection objectives;
- The location of Protected Structures:
- The location of sites on the Record of Monuments and Places (including Areas of Archaeological Potential);
- The designation of Architectural and candidate Architectural Conservation Areas (cACA).

The baseline information has been gathered from:

- Dublin City Development Plan 2016-2022:
   Written Statement;
- Dublin City Development Plan 2016-2022:
   Maps D & E.

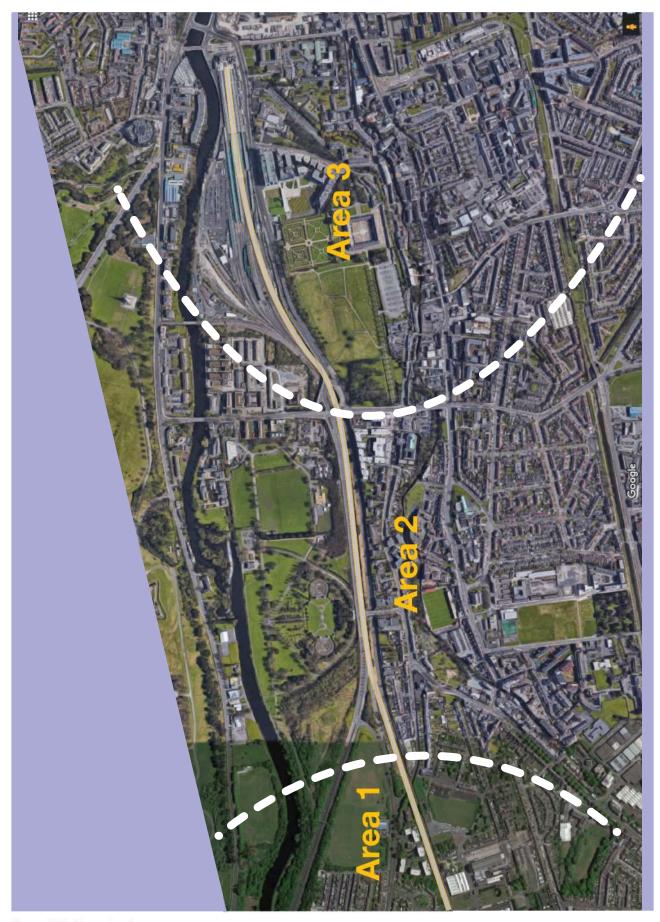


Figure 104: Character Areas

#### 9.5.1 Baseline Environment

The Study area for the DART Underground Western Tie-In extends from Heuston Station to the Inchicore Works and takes in important and significant townscape and cultural features of Dublin City. These include parts of St. James' Gate Brewery; Heuston Station; Dr Steevens' Hospital; the Royal Hospital Kilmainham and its attendant grounds; Lutyens designed Irish National War Memorial Gardens and CIÉ Railway Works at Inchicore.

The main roads serving the Study area are St. John's Road West and Chapelizod Bypass / Con Colbert Road, which meet at the junction of the South Circular Road.

#### 9.5.2 Character Areas

For the purpose of landscape and visual qualitative assessment, the baseline environment is considered in three distinct sections, or character areas as illustrated in **Figure 104**:

- 1. Heuston and Kilmainham;
- 2. Islandbridge;
- 3. Inchicore.

### 9.5.3 Character Area 1 – Heuston and Kilmainham

The Kilmainham and Heuston area lies immediately east of Islandbridge and extends to the City Quays and Dr. Steevens' Lane in the east. The northern boundary of the area is partly defined by IÉ's Mainline Railway and the River Liffey, while the southern boundary is defined by Old Kilmainham Road, Prospect Avenue, Mount Brown, Faulkner's Terrace and James' Street.

#### Description

The area is one of the key cultural suburbs of Dublin containing significant historic buildings and landmarks such as Seán Heuston Station, Dr. Steevens' Hospital and the Royal Hospital Kilmainham all of which are protected structures falling within a conservation area, (see Dublin City Council Development Plan, 2016-2022, Zoning Map E).

Heuston Station is a key historic and townscape landmark, effectively terminating the visual axis of the City Centre Quays. To the south and southeast are a mix of commercial, office and residential development, including the protected structures of Dr. Steevens' Hospital and St. James' Gate Brewery. To the north, is a mix of residential and other developments, including Parkgate Street bus depot.

The former Royal Hospital Kilmainham now houses the Irish Museum of Modern Art (IMMA) and the formal gardens have been restored to a very high standard so that the facility is both a city amenity and a major visitor and tourist attraction.

While still maintaining its cultural and historic characteristics, the area also includes a significant level of urban regeneration – a result of its strategic location and proximity to the city centre and transport links. Recent developments off St. John's Road West and to either side of Military Road adjoining the Royal Hospital Kilmainham present a contrasting modern mixed-use development. Re-development of Clancy Barracks, immediately west of Heuston Station and a series of apartment developments along the north bank of the Liffey prominently overlook Heuston Station.

Heuston Station lands are zoned Z5 "to consolidate and facilitate the development of the central area, and to identify, reinforce and strengthen and protect its civic design character and dignity". The Dublin City Development Plan 2016-2022 includes Policy SC7: "to protect and enhance important

views and view corridors into, out of and within the city, and to protect existing landmarks and their prominence". Furthermore, Objective SCO4 includes the requirement: "to undertake a views and prospects Study, with the aim of compiling a list of views and prospects for protection and/or enhancement which would be integrated with and complement the urban form and structure of the city".

St. John's Road West runs from east to west through this character area. Towards the east, it is defined by the Heuston Station buildings and walls on the northern side, and by Dr. Steevens' Hospital and the commercial buildings of Heuston Quarter on the southern side. Further west, it is defined by the stone boundary wall of the Heuston Yard on the north and the stone retaining wall running along the northern boundary of the Royal Hospital Kilmainham grounds.

The Royal Hospital Kilmainham grounds, including the building area, the formal gardens, the meadows and Bully's Acre, are zoned Z9 "to preserve, provide and improve recreational amenity and open space and green infrastructure", and also falls within a conservation area, See Map E, Dublin City Development Plan 2016-2022.

#### Significance and Sensitivity

Heuston and Kilmainham is an area of strong cultural and townscape significance containing many protected structures and designated views. The area has a High sensitivity.

#### 9.5.4 Character Area 2 - Islandbridge

#### **Character Area Boundary**

The relatively small and confined area of Islandbridge lies to the immediate east of Ballyfermot, with the River Liffey and Chapelizod Road to the north and the Con Colbert Road to the south. The South Circular Road and Clancy Barracks define the eastern end of the area. The Irish National War Memorial Gardens has a central location within this landscape character area, and the Liffey Gaels GAA grounds and Sarsfield Road define its western boundary.

#### Description

Much of this character area is physically and visually separated from Character Area 3 (Inchicore) by the Chapelizod Bypass / Con Colbert Road, and the mainline railway, which runs in cutting along the south of the Con Colbert Road, and by virtue of its lower elevation within the southern valley of the River Liffey.

The Irish National War Memorial Gardens designed by Sir Edwin Lutyens were laid out between 1933 and 1939 what is now Longmeadows Park on the southern banks of the River Liffey. The construction of the Chapelizod Bypass / Con Colbert Road in 1987 truncated the southernmost end of the War Memorial Gardens and its outer tree-lined avenue. The gardens and the wider park are zoned for recreational amenity and open space & green networks (Z9) and are identified as being within a Conservation Area (see Dublin City Council Development Plan, 2016-2022, Zoning Map E).

A small park maintenance compound and two schools, Gaelscoil Inse Chór and St. John of God, lie at the base of an embankment along the Chapelizod Bypass / Con Colbert Road, to the east of the Gardens.

The area around the Liffey Gaels GAA grounds and Sarsfield Road is at a higher elevation than the War Memorial Gardens and defines the transition

between both character areas. The junction of the Con Colbert Road with the Chapelizod Bypass is formed by a slip lane and a signalised junction, and the area is strongly road and vehicle dominated with limited landscape and visual appeal.

#### Significance and Sensitivity

Islandbridge is a small area of built and open space areas. It includes the significant feature of the Irish National War Memorial Gardens, designated as a National Monument. The area has a Moderate sensitivity, but High at the Memorial Gardens.

#### 9.5.5 Character Area 3 - Inchicore

#### **Character Area Boundary**

Inchicore is centred on the CIÉ Railway Works, which dates back to 1844. IÉ's Mainline Railway and Landen Road that runs along the northern side of the railway defines the northern boundary of the area while the southern boundary with Walkinstown is defined by the Grand Canal. The area runs east from Park West / Cherry Orchard Business Park in the west to Kilmainham in the east.

#### Description

Inchicore has a long-standing association with the development of railways in Ireland. This association led to the development of the area as a significant industrial and residential suburb in the late nineteenth century.

Today Inchicore is a long-established residential suburb of Dublin that still retains its strong character and association with the CIÉ Railway Works. The Works are bounded to the north by the Mainline and Landen Road, and to the south by the residential streets of Railway Avenue and Tyrconnell Park. Jamestown and Westlink Business Parks lie to the west while the residential terraces of St. George's Villas, St. Patrick's Terrace, Abercorn Terrace and West Terrace all lie to the immediate east of the Works. These residential

areas are zoned (Z2) as residential conservation areas (see Dublin City Council Development Plan, 2016-2022, Map D).

The CIÉ Railway Works are zoned Z6 in the Dublin City Development Plan 2016-2022 Map D "to provide for the creation and protection of enterprise and facilitate opportunities for employment creation." The railway works also contains a number of buildings of historic and architectural interest.

#### Significance and Sensitivity

Inchicore is a long-established area of residential and mixed use development strongly influenced by the railway works. The area has a Moderate to High sensitivity.

## 9.6 Archaeology, Architectural and Cultural Heritage

The area under investigation as part of the DART Underground Western Tie-in Study extends along the south side of the River Liffey from Inchicore to Heuston Station / St. James's Gate Brewery and includes the Kilmainham-Islandbridge area. The entire 'Historic City of Dublin' has one generic reference, DU018-020 and includes all of Kilmainham, which consists of the former villages of Kilmainham, Goldenbridge, Inchicore and Islandbridge.

The Kilmainham – Islandbridge area is characterised by a gravel ridge that runs on an east to west axis, sloping down to the River Liffey to the north and the River Camac to the south. This ridge, prior to land development in the nineteenth century, extended from the confluence of the two rivers at Heuston Bridge to the western edge of the Irish National War Memorial Park at Islandbridge, and was of considerable strategic importance in military offences against Dublin up to the time of the Anglo-Norman invasion.

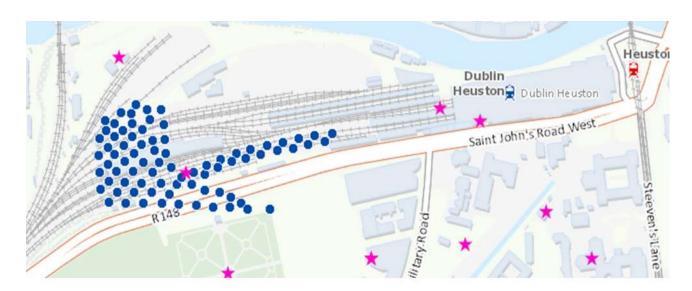


Figure 105: National Museum of Ireland Topographical files as blue dots and excavation licensed sites as pink stars

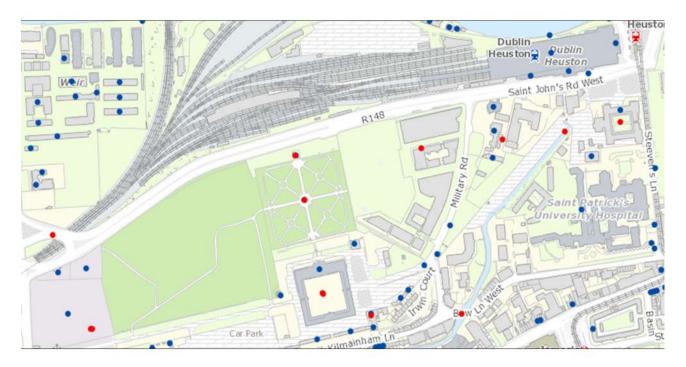


Figure 106: Recorded monuments in red and NIAH structures in blue at Heuston and Kilmainham

This ridge, prior to nineteenth and twentieth century development such as the construction of the railway line and Kingsbridge (now Heuston) station (1840s), gravel quarrying and the digging of the Irish National War Memorial Park (1930s), rose to a height of approximately 23 mOD (O'Brien 1998, 204).

Cultural heritage areas of interest that were identified as part of this Study include the following:

- St. James' Gate Brewery;
- Heuston Station and railway works;
- Dr Steevens' Hospital;
- Royal Hospital Kilmainham Complex including Bully's Acre;
- Irish National War Memorial Park; and
- Inchicore Works Depot.

#### 9.6.1 Heuston Station and railway works

Kingsbridge station was commissioned in 1846 from Sancton Wood following a design competition and was renamed in 1966 by ClÉ, in honour of Seán Heuston, one of the executed leaders of the 1916 Easter Rising whom had worked in the station's office. It is a protected structure (Record of Protected Structures RPS 7576, terminal building and offices) and recorded on the National Inventory of Architectural Heritage (NIAH) record as national significance (50080035).

During construction of the station, the River Camac was culverted and later the River Liffey was walled to form a private road along the north side of the station.

During the period from 1842-48, a number of archaeological finds were uncovered as a result of trench cutting for the Great Southern and Western Railway. Finds from this period donated to the Royal Irish Academy (RIA) comprised 21 knife blades, some tools, two pairs of shears, two pincers or tongs, twelve shield-bosses, two axe

heads, four spearheads, five swords, one sickle and miscellaneous iron objects.

Studies by O'Brien (1998) have concluded that two Viking Age cemeteries existed concurrently in the Kilmainham–Islandbridge area. The Study deduced that the railway and station works at the eastern end (Kilmainham) produced a minimum number of seventeen burials, while at Islandbridge (Memorial Park) a minimum of eighteen burials were recovered (Record of Monuments and Places RMP DU018-020272) (O'Brien 1998, 303-21).

However, the possible identification of two burials closer to Bully's Acre on the ridge suggests that the general breadth of the spread of the burials is not only east-west but also north-south, suggesting a combination of concentrated and dispersed burial pattern. This fits in with Ó Floinn's suggestion of 'grave fields that are strung out on both sides of the Liffey, some of which were located on the sites of earlier pre-historic or Early Christian cemeteries, and which, for the most part, are located close to water' (Ó Floinn 1998, 137).

Heuston Station is located within the zone of archaeological potential for Dublin City (RMP DU018-020). The station terminus building and its offices are protected (RPS 7576). Part of the Heuston Station area is a designated Conservation Area.

#### 9.6.2 St. James's Gate Brewery

Monitoring of geotechnical investigations in St. James' Gate Brewery took place under archaeological supervision in 2008, for the original DART Underground Project (License Numbers 08E915). Boreholes within St. James's Gate Brewery were all located close to Victoria Quay and indicated that the lands were reclaimed in the early 19th century when the River Liffey was straightened and new quays built. Up to 1.5 m below the existing ground's surface contained a number of brick walls and surfaces, below that level from 2 m - 4 m mixed rubble and sedimentary silts including organic waste with bone and shell

were revealed. This suggested that the area was close to the old shoreline as illustrated on the Rocque map of Dublin (1756).

A pair of granite piers (RPS 8203) situated within the boundary wall of St. James's Gate Brewery along Victoria Quay is protected, as is the Guinness building (RPS 8204) located along the same wall.

#### 9.6.3 Dr Steevens' Hospital

This hospital was designed by Thomas Burgh in 1718 to house the poor and sick of Dublin. The property was bequeathed by Richard Steevens to his sister Grizel. The hospital was opened by the mid 1730s and the design included a clock tower and an internal arched courtyard for patients to walk in. The building underwent major refurbishment and conservation works, before reopening as the headquarters of the Eastern Health Board.

The structure is clearly visible to the street as it has no boundary walls and is an important example of a public institutional building in Dublin. The hospital is recorded in the NIAH (50080083) as being of national importance and is recorded in the RMP as a hospital (DU018-020341). It is a protected structure (RPS 7840).

### 9.6.4 The Royal Hospital Kilmainham (RHK)

The Royal Hospital was constructed in 1680–84 as a new retirement home for soldiers of the Irish forces. It was occupied by 1684, but work was not finally complete until the tower was added in 1701.

The RHK is listed in the Dublin City Record of Protected Structures (RPS No. 5244; the record specifies the hospital and various associated buildings, such as the former Adjutant General's office, former Deputy Master's offices, steel house, tower at western gate, garden house in formal gardens, garden features, entrance, gates and walls).

The walled garden is square in plan and surrounded by limestone boundary walls. It was laid out in circa 1700 and is recorded in the NIAH and the RMP (garden NIAH 50080067 and designed landscape feature RMP DU018-020528) as is the garden structure (NIAH 50080068, RMP) DU018-020255) adjacent to the R148 sited at the north end of the garden, it is also a protected structure. The structure was possibly designed by Sir Edward Lovett Pearce, who was appointed overseer for the Royal Hospital in 1731. During recent restoration work of this pavilion, excavation revealed a selection of clay pipes and 19th century pottery. The hospital was built on lands previously associated with the medieval priory of the Knights Hospitallers.

The early Christian monastery (RMP DU018-020283) associated with St Maighnenn, now Bully's Acre, is believed to have been the focus of the cemetery in Kilmainham. The remains of a high cross (9th – 11th century AD) is located in the south-eastern quadrant of the burial ground, while the site of St. John's holy well is recorded to the north (RMP DU018-020284). The site is thought to contain burials from c.1200 onwards and is of significant importance in the social history of the area and is traditionally associated with the burial of Murrugh, son of Brian Boru, who died at the Battle of Clontarf in 1014 (NIAH 50080054).

To the north of Bully's Acre is a military cemetery known as the Privates and In-Pensioners graveyard for occupants of the RHK and for soldiers who died during the 1916 Rising. There is a limestone rubble wall that divides the earlier graveyard established in 1880 (NIAH50080052) from the later established in 1905 and in use until 1931 (NIAH 50080051). During road widening works in the 1960s, burials were exhumed and re-interred and a new wall erected to the north to replace the original rubble limestone boundary wall.

### 9.6.5 The Irish National War Memorial Park

Numerous items of archaeological interest and burial sites have been revealed in the Irish National War Memorial Park and along Con Colbert Road. Viking warrior burials (DU 018-020272) were found during the quarrying in 19th century, during the development of the Lutyens War Memorial Park in the 1930s and during works related to the Chapelizod Bypass / Con Colbert Road in 1988 and 1989. The area was previously investigated during a series of three archaeological 'rescue' campaigns by Patrick Healy and Dr E. O'Brien in 1988 and 1989 (Licence ref. E472). A number of truncated features, including pits and a ditch. were found and resolved at the time; one yielded a Viking-period strap end. Therefore, despite subsequent disturbance to possible deposits from later phases of development and the insertion of services, the possibility that archaeological features may be revealed must always be considered.

A test excavation by Simpson (2010 Licence No. 10E128) of a small pocket of land within the War Memorial Park along the Con Colbert Road, established that the natural deposits form part of a gravel esker in the flood plain of the River Liffey and that there was some very limited evidence of Early Medieval activity in the form of several pits, along with very scattered remains of Post-Medieval material. No human burials or evidence of any disturbed burials were found during the assessment.

Memorial Park is a protected structure (RPS 2028).

#### 9.6.6 Inchicore rail works

To support the massive undertaking of the construction of the railways, GS and WR Company purchased a 73 acre site in Inchicore for engine workshops and depot. Before the development of the railway on the 1843 OS map, Inchicore is depicted as two townlands, Inchicore North and Inchicore South, which are subdivided by the main road from Dublin.

The Inchicore Railway Works opened in 1846 and became the largest engineering complex of its kind in the country. The original buildings, in a Tudor style of substantial limestone, were designed by Sancton Wood, and the general contractor was Copthorne. Apart from a small works at Limerick, the Inchicore depot represents the sole survivor of a number of independent railway works in Ireland.

When the first workshops were opened, the company had to house the workers in what was an isolated area, they erected several terraces (e.g. St. George's Villas and St. Patrick's terraces) of cottage-style houses. A dining hall, library and recreation centre were also provided, and the company paid part of the cost of a school for the children of the employees.

The original works include a running shed; two erecting shops; a boiler; carriage, paint and wagon shops; a smithy and foundry; and administration and design offices. The roofs of a number of the buildings are supported by iron roof trusses carried on cast-iron columns (Grainger 1994). These date from the 1840s and were supplied by the Dublin foundry of J. and R. Mallet; they are similar to those found at Kingsbridge. The foundry building at the Inchicore depot has an interesting timber-trussed roof from the same period. The façade of the original and existing station building at Inchicore is distinctive and durable with its castellated form and durable blue limestone.

The Inchicore works contain many structures listed in the NIAH and these include:

•	Signal box, c. 1850	50080417
•	Locomotive shed, c. 1850 (including three stage tower to centre north front elevation)	50080418
•	Office, c. 1850	50080468
•	Workshop, c. 1850	50080428
•	Office, c. 1870	50080425
•	Office, c. 1850	50080422

DCIHR	Site Name	Street
18-10-7	Kingsbridge Terminus (Great Southern and Western Railway) now Heuston Station	Kingsbridge
18-10-6	Goods Shed (Goods Depot) (no remains)	Kingsbridge
18-10-8	Goods Shed (Granary) (no remains)	Kingsbridge
18-10-1	Great Southern and Western Railway	
18-09-1	Great Southern Railways – from Cork; (Great Southern and Western Railway – from Queenstown	
18-09-2	Bridge	Sarsfield Road
18-09-3	Gasworks (no remains)	Inchicore Railway Works
18-09-7	Level Crossing (no remains)	Jamestown Road
18-09-4	Inchicore Railway Works	Inchicore Parade

Table 29: Extracts from National Inventory of Architectural Heritage (NIAH)



•	Workshop, c.1850	50080423
•	Office, c. 1900	50080426
•	Workshop, c. 1870	50080427
•	Workshop, c. 1850	50080424
•	Workshop, c. 1850	50080421
•	Workshop, c. 1850	50080419
•	Store/warehouse, c 1850	50080416
•	Turntable, c. 1910	50080415
•	Workshop, c 1870	50080420
•	Workshop, c. 1920	50080412
•	Water pump, c. 1890	50080411
•	Gates/ railings/ walls, c. 1850	50080055
•	Workshop, c. 1850	50080485

Structures associated with the Inchicore Works are also recorded in the Dublin City Industrial Heritage Record (DCIHR) as 18 09 004; 18 09 028-038 and are described as comprising 18-09-028 running shed, 18-09-029 fitting shop, 18 09-030 boiler shop, 18-09-031 smithy, 18-09-032 signal box, 18-09-033 office, 18-09-034 carriage shed, 18-09-035 permanent way office, 18-09-036 foundry, 18-09-037 pattern shop and 18-09-038 saw mills and power house.

The complex also includes a three-bay two storey former sand house, turntable and terraces of workers houses (96 in number) and boundary walls. The industrial record, documents the site as largely intact and as such it is considered a significant element of the city's industrial heritage. In relation to the Inchicore Works, it is a zoning objective (Zone Z7) to provide for the protection and creation of industrial uses and facilitate opportunities for employment creation.

#### 9.6.7 Industrial Heritage

Industrial heritage refers to industrial activities of the past and associated infrastructure. Dublin City Council is committed to the implementation adopted jointly by the International Committee for Conservation of Industrial Heritage and the 17th ICOMOS General Assembly as guiding principles to assist in the documentation, protection, conservation and appreciation of the industrial heritage as part of the heritage of Dublin and Ireland (Dublin City Development Plan 2016-2022).

Dublin City Council initiated a comprehensive Document Inventory, or 'Paper Survey' of sites of industrial heritage interest throughout Dublin City in 2003. The Inventory thus created is known as DCIHR – Dublin City Industrial Heritage Record. The aims and objectives of the DCIHR are:

- To record and evaluate Dublin City's industrial heritage;
- To produce an administrative tool for Dublin City Council in the evaluation of industrial sites in the planning process;
- To provide a research tool for the analysis of Dublin City's industrial development over the past 250 years;
- To act as a resource in the development of educational and leisure activities.

Although these sites have no statutory protection, Dublin City Council recognises the role that industry has played in the creation and development of the city and shall seek to protect buildings and features of an industrial heritage nature where appropriate. It is furthermore the objective of the Council to review the Ministerial recommendations arising from the National Inventory of Architectural Heritage (NIAH) in relation to Dublin's industrial heritage (Objective CHCO10. 6). It is also an objective (CHCO10.14) to implement and promote The Dublin Principles (ICOMOS 2011).

The DCIHR (**Table 29**) records Sarsfield Road Bridge (1809002) as a single span masonry Railway Bridge, erected in 1845 to carry the Great Southern and Western Railway over Sarsfield Road. This structure was extended to the north in the late 20th century and the deck was replaced with a 'Silent' steel deck. Squared rock-faced limestone is present on the east pier with random rubble to the west pier; northern pier extensions are in



Figure 107: Recorded monuments in red and NIAH structures in blue at Heuston and Kilmainham

random rubble. Random coursed stone is present on the abutments to the north and the south of bridge, and to retaining walls along the road to the south.

This bridge is recorded as displaying a robustness in design typical of Victorian railway bridge engineering with the stonework to its piers imparting a sense of solidity to the structure, particularly the rock-faced stonework of the eastern pier. Together with the impressive retaining walls to its south, the bridge forms a noteworthy addition to the industrial and engineering heritage of Dublin City. It is given a regional rating within the record.

#### 9.6.8 Conservation Areas

The policy mechanisms used to conserve and protect area of special historic and architectural interest are:

Land use zonings – Residential Conservation
 Areas - delineated by the Z2 zoning objective
 are recognised for their distinctive character
 and have extensive groupings of buildings and
 associated open spaces, which are visually
 important to the character of the area.

- Architectural and Civic Design Character Areas (land use zoning Z8) for example Z8 Georgian Conservation Areas are designed to protect the special interest of Dublin's Georgian stock.
- It is not only the visual elements that contribute to the character of a Conservation Area, land uses and activities are fundamental to the character and appearance of Dublin's Conservation Areas,
- The red-lined conservation areas of certain land uses are of historic importance and have influenced the built form within the area and may continue to have a strong effect on its character at present, for example Heuston Station.
- Architectural Conservation Areas are intended to preserve the character of townscapes that are of special architectural, historical, archaeological, artistic, cultural, scientific, technical or social interest.

It is an objective of Dublin City Council (CHCO4) to review zoning objectives and the red-lined hatched conservation designations as part of the conservation strategy and to review the Record of Protected Structures and to designate Architectural Conservation Areas.

Red lined Conservation areas along the proposed options include:

- The River Liffey and the Quays;
- Heuston Station; and
- The entire Royal Hospital Kilmainham complex south of St. John's Road West, east of the South Circular Road and west of Military Road.

#### 9.7 Settlement

The best practice methodology for determining the effects of ground movement on building structures, as described in **Section 2.4.3** of this Study, has been followed to determine damage predictions arising from the MCA Options. A comparative assessment of these predicted impacts has been undertaken to identify if any options have some or significant advantages or disadvantages over other options.

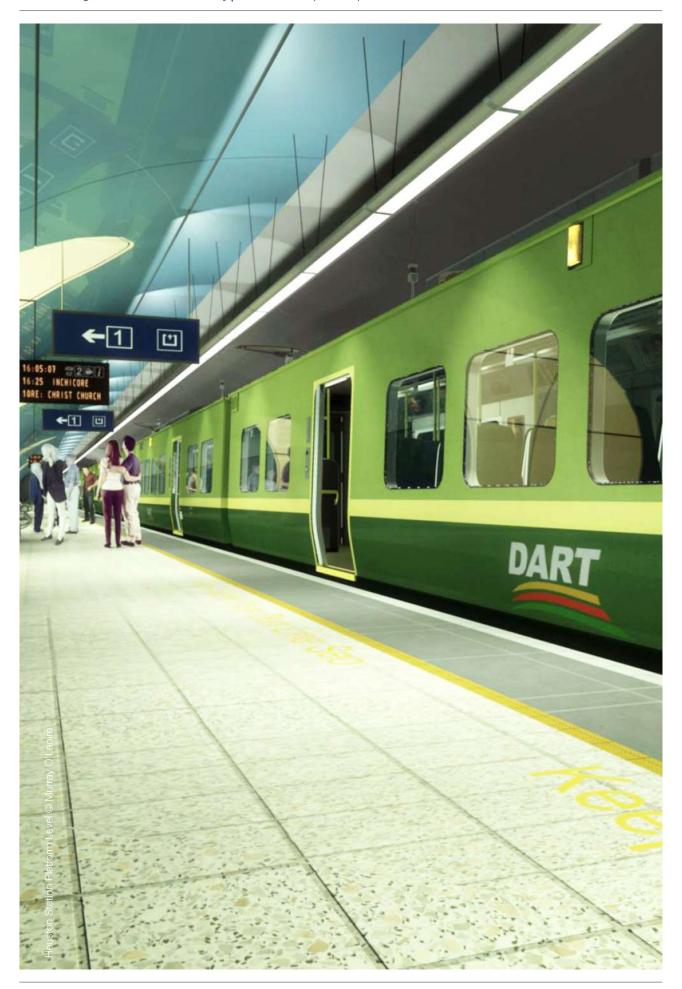
Ground movements have been determined using closed form solutions and finite element methods. Damage predictions have been based on combined horizontal strains and angular distortions. Based on the geotechnical investigations and ground conditions identified in the original DART Underground, volume loss V<sub>L</sub> and trough width parameters have been identified for varying forms of tunnelling and underground station construction depending on the ground conditions encountered. The values of these input parameters are listed in **Table 1** of the Study.

The construction of the DART Underground would involve excavation through the overburden (soil) and into rock, and tunnelling through predominantly rock and some overburden. Geological conditions along the route have been defined through previous site investigations for the original DART Underground project.

Between Inchicore and Heuston Station, the MCA Options would be excavated through a combination of boulder clay, glacial sands and gravels and underlying bedrock. The underlying bedrock is the Lucan Formation (also referred to as "Calp" limestone) of the Fingal Group. The Lucan Formation is a succession of the following lithologies and is generally referred to as Carboniferous Limestones and Shales:

- Sandy Limestone grey to dark grey, calcisitite Limestone (fine grained limestone comprising silt sized carbonate particles) with calcilutite and calcarenite Limestone (fine grained and coarser grained limestone),
- Argillaceous Limestone muddy, carbonaceous or "earthy" limestones (marlstones)
- Mudstone / shale Calcareous shales, mudstones and argillites.

Drawings illustrating the approximate geotechnical longitudinal profile for each of the respective MCA Options over the proposed tunnel drive length to Watling Street are presented in Volume 2 of this Study.



# 10. Phase 3: Methodology for Preparing MCA Feasibility Working Cost Estimates



## 10.0 Phase 3: Methodology for Preparing MCA Feasibility Working Cost Estimates

#### 10.1 Basis of Cost Estimate

The feasibility working cost estimates for the MCA Options adopted the original DART Underground Basis of Estimate with an escalation rate to reflect construction inflation in the fields of tunnelling and underground construction from the original base date of 1st January 2009 to the year 2017. For the costs of the at grade four track widening of the existing rail corridor from Inchicore to the end of KRP Phase 1, the feasibility working cost estimate is based on larnród Éireann construction cost estimates dating from 2010.

The original DART Underground Basis of Estimate provided a basis of understanding on the development of the capital cost estimate for the DART Underground Project at the time of the Reference Design.

The original Basis of Estimate outlined the critical aspects of the estimating process including the:

- Scope of the estimate;
- Breakdown of the work into accounts:
- Basis of pricing, including allowances, assumptions, exclusions; and
- Methods used to gain confidence in the basis of pricing, independent review and benchmarking.

As part of the original DART Underground, an independent check on the costing process and budget, was commissioned by larnród Éireann and undertaken by Gardiner & Theobald in 2010. Separately in 2014, the National Development Finance Agency appointed Aecom to undertake

an independent review of the original DART Underground Basis of Estimate. Each independent review was broadly in agreement with the pricing of the original Capital Cost Estimate.

The objective of the original Basis of Estimate was to prepare the Capital Cost Estimate in a manner that comprised:

- The Main Works;
- All infrastructure works to create a contract to minimise interface risks and have a clear scope demarcation;
- Costs outside the main works, which included:
  - (i) Enabling works by or procured through lamród Éireann, which are to be undertaken prior to, during or after the main works;
  - (ii) larnród Éireann's management costs;
  - (iii) Land and property costs.

Costs outside the main works contract included works undertaken directly by lamród Éireann or separately contracted by lamród Éireann in order to facilitate the main works. It was envisaged that these enabling works would mostly be undertaken prior to the main works but with some undertaken during or after the main works. An example of works outside the main works contract, is the design and provision of the main ESB power connection required by the tunnelling contractor, which is a long-lead item separately contracted by lamród Éireann to accelerate the main works programme.

Costs outside the main works contract also include larnród Éireann's direct costs, such as management costs, and other areas of larnród Éireann responsibility, such as the acquisition of land and property.

The operations, maintenance and renewals (OMR) costs were addressed separately and formed part of the Operational Costs as opposed to the Capital Cost Estimate.

## 10.2 Quantities derived for the Feasibility Working Cost Estimate

The quantities derived for the feasibility working cost estimate of each MCA option, were adjusted from the original DART Underground estimate to cover only the extent of the Western Tie-In from Watling Street to the tie-in with the existing four tracking at the end of KRP Phase 1, near Le-Fanu.

Where unit items were priced in the original DART Underground Capital Cost Estimate and were found to be outside of the scope of the Western Tie-In Study, this scope was omitted from the feasibility working cost estimate by amending the original DART Underground priced bill of quantities.

Where unit items were priced in the original DART Underground Capital Cost Estimate and found to be within the scope of the Western Tie-In Study, these unit items were included in the feasibility working cost estimate using the original DART Underground priced bill of quantities.

Where linear items were priced in the original DART Underground Capital Cost Estimate, these items have been re-quantified for each MCA Option over the extent of the Western Tie-In Study, and unit rates applied as per the original DART Underground priced bill of quantities.

Where the scope of the Western Tie-In Study extends beyond the original DART Underground scope which finished at the western end of the

previously proposed DART Inchicore Station, these items have been priced using quantities and rates from the lamród Éireann Kildare Route Project Phase 2 (KRP2) cost estimate.

Where additional items are required to reflect the scope of the proposed MCA Options and were not previously included in either the original DART Underground or KRP2 scope, for example a station at Kylemore Road, these items have been priced using allowances or costs from equivalent larnród Éireann installations.

Permanent and temporary property acquisition costs have been provided by larnród Éireann property division.

#### 10.3 Construction Inflation

For the MCA feasibility working cost estimates, the original Basis of Estimate accounts were adopted and updated using an escalation index from the original base date of 1st January 2009.

As there are no recent city centre tunnelling projects in Ireland of a comparable scale and complexity, the construction escalation was derived using a blended rate of civil engineering construction indices in Ireland and the United Kingdom (UK) from 2009 to the end of 2017. Thus, the construction escalation derived reflects a combination of changes in the Irish civil engineering market over this period and the cost escalation, which has occurred in large scale tunnelling projects.

Since 2009, major tunnelling contracts which have been procured and are either completed or under construction in the UK, include the Elizabeth Line (Crossrail), Thames Tideway Tunnel, Northern Line Extension and Hinkley Point. It is considered that the UK marketplace will strongly influence the cost of tunnelling labour and supervision for any underground tunnelling project in Ireland whilst the European market will influence the cost of tunnelling equipment, as this is the likely source of the Tunnel Boring Machine(s) and underground plant.

Year	Ireland	UK
2009	1.1%	2.8
2010	-2.6%	-0.4
2011	0.8%	1.4
2012	0.9%	2.4
2013	1.1%	2.4
2014	1.0%	4.0
2015	0.7%	2.4
2016	4.5% (Estimated)	2.0
2017	3.7% (Estimated)	1.5
Total Escalation (1st January 2009 - 31st December 2017)	11.60%	20.0%

Source data for Ireland - KCMS Ltd Construction Market Overview & Outlook Q4 2016  $^{[9]}$  Source data for UK  $^{[10]}$ :

http://ec.europa.eu/eurostat/statistics-explained/index.php/File:EU28 EA19 Countries construction cost annual rates of change 2005-2016.png

Table 30: Construction indices in Civil Engineering for UK and Ireland, 2009-2017

**Table 30** summarises the construction indices for Ireland and the UK from 1st January 2009 until the end of 2017 using estimated rates for 2016 and 2017. The construction escalation over this period for Ireland is 11.6% and 20% for the UK. The blended escalation rate considered appropriate for the feasibility working cost estimate, which is reflective of the specialist nature of tunnelling works was derived as follows:

Blended Escalation Rate = 
$$\frac{(1 \times 11.6\%) + (2 \times 20\%)}{(1+2)} = 17.2\%$$

Option Name	Short Description of Proposed Option	Capital Cost Estimate (€ Million)	Savings from Original DART Underground (Option 1F) (€ Million)	Savings as a % of the Original DART Underground
Twin 1F	Original DART Underground Scheme	1,080.5	-	-
Twin 1AS	Twin Bore Tunnel, Portal in the Heuston Yard, Tie-In at Rail Overbridge OB1	897.9	182.6	16.9%
Twin 3AS	Twin Bore Tunnel, Portal in the Heuston Yard, Tie-In occurs east of OB1	921.8	158.7	14.7%
Twin 2C	Twin Bore Tunnel, Portal in Con Colbert Road, Tie-In at east end of existing Sarsfield Underbridge	817.8	262.7	24.3%
Twin 3C	Twin Bore Tunnel, Portal in Con Colbert Road, Tie-In occurs 130 m west of existing Sarsfield Underbridge	931.1	149.4	13.8%
Twin 1E	Twin Bore Tunnel, Terminus Station at Heuston with central mined Tumback	966.4	114.1	10.6%
Mono 2E	Monotube Tunnel Terminus Station at Heuston with tumback	1,138.4	-57.9	-5.4%
Twin 2F	Original DART Underground Scheme less the combined ventilation and intervention shaft at Memorial Park	1,055.1	25.4	2.4%

Table 31: Summary of Feasibility Working Cost Estimates for the MCA Options proposed scope of work from Watling Street to the tie-in at the end of KRP Phase 1, near Le Fanu

## 10.4 Adjustment to reflect Level of Design Development

The level of design development differs for each of the MCA Options in that the original DART Underground had been developed to a Reference Design level of detail, an Environmental Impact Statement produced and a Railway Order application had been approved. Accordingly, the level of detail and certainty around the scope of work is greater for the original DART Underground than the alternative MCA feasible and practicable options, with the exception of Option Twin 2F, which is a minor variation on the original DART Underground Scheme.

To ensure that all MCA Options are considered on a level basis and a true comparative assessment can be undertaken, it is appropriate to adjust the costs of the respective MCA Options to reflect the level of design development and certainty around the scope of work to be undertaken.

This approach seeks to avoid the phenomenon often referred to as "Optimism Bias", which is a tendency to expect better than average outcomes. Optimism bias has been shown to lead to an underestimation of project duration, overestimation of its benefits and underestimation of its total cost.

In the context of the Western Tie-In Study, the feasibility working cost estimates for the MCA Options have been adjusted as follows:

- For Option Twin 2F No adjustment has been made to the feasibility working cost estimate since this option is a minor variation of the original DART Underground Scheme;
- For Options Twin 1AS, Twin 3AS, Twin 2C, Twin 3C and Twin 1E These options are twin bore tunnels, all with a proposed Underground Station at Heuston on the southern side of the existing Station, which is similar in form to that of the Original DART Underground. Therefore, many of the uncertainties around impacts at Heuston Station are similar to the original DART Underground, the scope of work is well defined, and construction rates for the twin bore tunnels have previously been market tested, independently checked and verified. As such, an 8% level of adjustment to reflect the level of design development has been adopted for these options;
- For Option Mono 1E, which is a monotube tunnel with a different arrangement of the proposed underground station at Heuston, the level of certainty around the final scope of work is not as great as the other MCA options. Construction rates have not been market tested or verified. As such, the adjustment level for Option Mono 2E is 17%.

## 10.5 Feasibility Working Cost Estimates

The summary of the feasibility working cost estimates for each option is provided opposite in **Table 31**. Although the original DART Underground project is not an MCA Option under consideration, it was considered critical to cost this option as it would serve a benchmark by which all other options could be contrasted.

In preparing the estimates, the additions for Client indirect costs including insurances, design, project management, risk and contingency have been

included using the original DART Underground Basis of Estimate calculation which equated these indirect costs to a roll up factor of 68%.

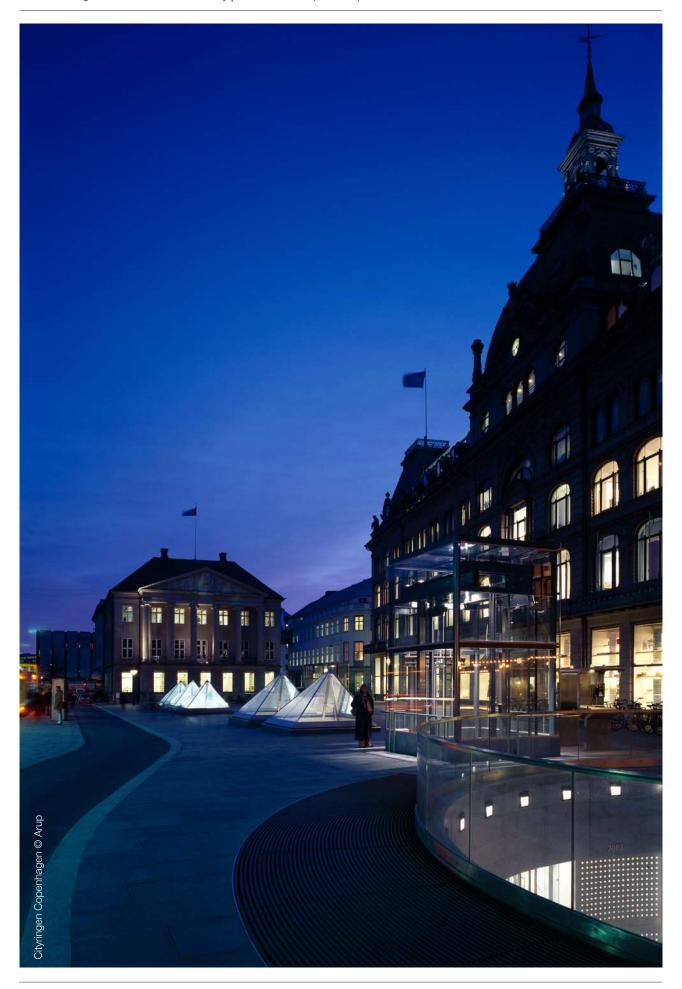
No addition has been included for cost escalation (inflation) through the period of the construction phase, all costs have been derived using a base year of 2017.

The breakdown of the feasibility working cost estimate for each of the MCA Options and the original DART Underground is provided in **Appendix D** of this Study. **Chapter 11** of this Study presents the comparative assessment of the MCA Options, including the criterion of Capital Cost.

It should be noted from **Table 31** opposite that Option Mono 2E is more expensive than the original DART Underground and it is estimated that the additional cost for the length of the Western Tie-In would be €57.9 Million

## 10.6 Concept Engineering Design Feasibility Working Cost Estimate

Having identified a Preferred Option following the completion of the MCA assessment, a concept engineering design and feasibility working cost estimate has been undertaken of that Preferred Option. This feasibility working cost estimate and basis of the Preferred Option is set out in **Chapter 13** of this Study.



## 11. Phase 3: Multi-Criteria Assessment of Options



## 11.0 Phase 3: Multi-Criteria Assessment of Options

A multi-criteria comparative assessment has been undertaken using a structured approach to determine overall performance amongst the seven MCA options, using the criteria presented in Chapter 7 of the Study.

The seven MCA Options contain five options with through running connection onto the Heuston Mainline and two options, which terminate below ground at Heuston with an underground turnback and interchange to the existing surface Mainline Station.

It is acknowledged that the transport benefits of a through running connection and that of a terminus arrangement differ. The scope of this Study is limited to a tunnel(s), which extends beyond Watling Street but the remainder of the route alignment is not yet defined and is dependent upon the outcome of future transport benefit studies and an overall route alignment options Study.

As such, whilst the MCA comparative assessment is able to assess the relative advantages and disadvantages of the seven options and select a Preferred Option, the selection of the Preferred Option is limited to the scope of this Study. In a similar manner, the selection of a twin bore tunnel configuration or a monotube tunnel configuration cannot be finalised until the outcome of the future transport benefit studies and overall route alignment options Study is known.

The costs derived for the MCA Options from this Study can be incorporated into and inform the future transport benefit analyses. In addition, the Preferred Option identified from this Study, and the relative merits of through running and terminus arrangements, will contribute to the outcome of the future overall route alignment Study.

The MCA Options assessed are:

- Twin 1AS Twin Bore Tunnel configuration; Tunnel Portal in the Heuston Yard and tie-in to the Heuston Mainline occurring under rail overbridge OB1. The proposed Heuston Underground Station is situated along the south side of the existing station with all cut and cover shafts located within Irish Rail lands;
- Twin 3AS Twin Bore Tunnel configuration; Tunnel Portal in the Heuston Yard and tie-in to the Heuston Mainline occurring 40 m to the east of rail overbridge OB1A. The proposed Heuston Underground Station straddles under the existing mainline station footprint, under St. John's Road West and into the St. James' Gate Brewery.
- Twin 2C Twin Bore Tunnel configuration; Tunnel Portal is located in an area, which is currently the slip lane from the Chapelizod Bypass leading into Ballyfermot and an area known locally as the "Horses Field". The tie-in to the Heuston Mainline occurs just east of the existing Sarsfield Road Underbridge. The proposed Heuston Underground Station is similar in plan arrangement to Option Twin 1AS but the platform level is 1 m lower;
- Twin 3C Twin Bore Tunnel configuration; Tunnel Portal is located in an area, which is currently the slip lane from the Chapelizod Bypass leading into Ballyfermot and an area known locally as the "Horses Field". The tie-in to the Heuston Mainline occurs 130 m west of the existing Sarsfield Road Underbridge

Option Reference	Option Twin 1AS	Option Twin 3AS	Option Twin 2C	Option Twin 3C	Option Twin 1E	Option Twin Option Twin Option Mono Option Twin 3C 1E 2E 2F	Option Twin 2F
Assessment Criteria	Deep Mined Ladder	Monotube	Deep Mined Ladder				
Capital Cost based on Feasibility Working Cost Estimate	€897.9M	€921.8M	€817.8M	€931.1M	€966.4M	€1,138.4M	€1,055.1M
Rank under Sub-Criterion of Capital Cost and Principal Criterion of Economy							

Table 32: MCA Comparative Assessment ranking for the sub-criterion of Capital Cost and also the principal criterion of Economy

to provide an increased depth of overburden at the tunnel portal. Consequently, Sarsfield Road will be permanently closed to all vehicular traffic. The proposed Heuston Underground Station is similar in plan arrangement to Option Twin 1AS but the platform level is 1 m lower;

- Twin 1E Twin Bore Tunnel configuration; Terminus Underground Station with a central mined Turnback. The proposed Heuston Underground Station is similar in plan arrangement to Option Twin 1AS but the platform level is 10.6 m lower to permit the safe construction of a 460 m long mined turnback beyond the underground station with sufficient rockhead cover above the mined cavern. A combined intervention and ventilation shaft is located at the end of Turnback,
- Mono 2E Monotube Tunnel configuration, Terminus Underground Station with a Turnback accommodated within the bored tunnel, which is 669 m in length beyond the end of the underground station platforms with a combined intervention and ventilation shaft at the end of the Turnback. This shaft is located within the grounds of the Royal Hospital Kilmainham, west of the Formal Gardens.
- Twin 2F This Option is similar to the original DART Underground Railway Order with the sole exception that the combined intervention and ventilation shaft previously located within the Irish National War Memorial Park is removed from Scheme.

#### 11.1 Economy

#### 11.1.1 Capital Cost

The previous chapter of this Study described the methodology for preparing the Feasibility Working Cost Estimate for the MCA Options, and quantified the Capital Cost Estimates. The comparative assessment of each MCA Option is based on the relative differences in the Capital Cost Estimates.

Option Twin 2C is the lowest capital cost and has significant advantages over the other options, yielding an estimated saving of €237.3 Million over Option Twin 2F, which is a minor variation of the original DART Underground.

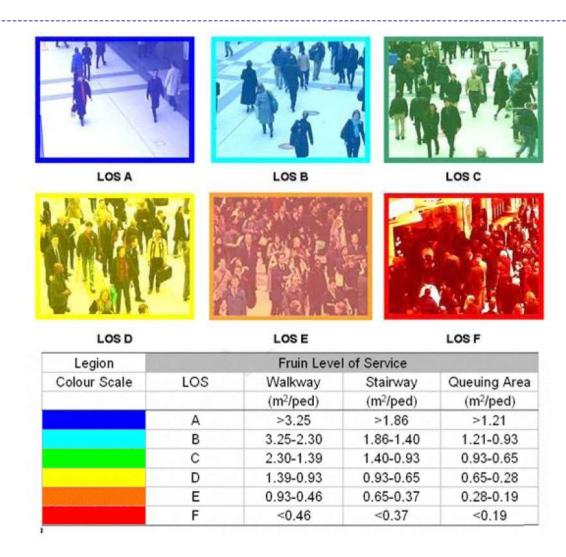
The capital cost estimate for options Twin 1AS, Twin 3AS and Twin 3C are more expensive than Option Twin 2C by €80.1 Million, €104.0 Million and €113.3 Million respectively. These options when compared against the capital cost estimates for other options are considered to have some advantages over other options.

Option Twin 1E is more expensive than Option Twin 2C by €148.6 Million. This option when compared against the capital cost estimates for other options is considered to be mid-range.

Option Twin 2F, a minor variant of the original DART Underground and estimated to be €237.3 Million more expensive than Option Twin 2C. Accordingly, Option Twin 2F has some disadvantages compared to other options.

Option Mono 2E is estimated to be €320.6 Million more expensive than Option Twin 2C and is considered to have significant disadvantages over Option Twin 2C.

A summary of the MCA comparative assessment ranking for Capital Cost is provided in **Table 32**. As Capital Cost is the only sub-criterion under the assessment principal criterion entitled Economy, these same rankings also apply to Economy.



Option Reference	Option Twin 1AS	Option Twin 3AS	Option Twin 2C	Option Twin 3C	Option Twin 1E	Option Mono 2E	Option Twin 2F
	Q-0-Q	Q-Q Q-0-Q	Q-Q Q-0-Q	Q-0-Q	Q-0-Q		Q-0-Q
Assessment Criteria	Deep Mined Ladder	Deep Mined Ladder	Deep Mined Ladder	Deep Mined Ladder	Deep Mined Ladder	Monotube	Deep Mined Ladder
Interchange Rank							

Table 33: MCA Comparative Assessment for Interchange

#### 11.2 Integration

#### 11.2.1 Interchange

Each MCA Option was assessed through a qualitative appraisal of capacity to facilitate the movement of people between the streetscape and underground station/rail system, between other Public transport modes and within the system, including the likely ease of navigation from platform level to the existing Heuston surface station concourse.

Options Twin 1AS, Twin 3AS, Twin 2C, Twin 3C and Twin 2F facilitate good, direct and seamless interchange from the proposed Underground Station to the existing station concourse, and subsequently with Luas, bus and cycle facilities. Pedestrian modelling undertaken as part of the original DART Underground, confirmed that the existing station concourse area is sufficient to accommodate forecast peak passenger demand and that the arrangement of escalators and passageways onto and exiting the platforms, generally results in a FRUIN level of service C for future peak hour demand. The proposed island platform arrangement facilitates decision making at platform level. With just one bank of escalators contained within a mined escalator shaft, from platform level to the surface station concourse, navigation has been greatly simplified. These MCA options are considered to have some advantages compared to Options Twin 1E and Mono 2E.

Option Twin 1E is deeper than all other stations except Option Mono 2E. The depth of the station necessitates the use of at least two escalator runs to make the journey from the existing station concourse to the platform level. This increases the journey time marginally and makes navigation more complex as an intermediate floor level will be required and there will be potential conflict between passenger movements in opposite directions at the level of the intermediate floor. Therefore this option has some disadvantages compared to Options Twin 1AS, Twin 3AS, Twin 2C, Twin 3C and Twin 2F.

The station configuration proposed for Option Mono 2E requires all passengers to make their way via a multi-level underground station configuration and underpass below St. John's Road West, to the existing Heuston station surface concourse. The navigation is the most complex of all options and the interchange time from platform level to the existing station surface concourse is the greatest compared to all other MCA Options.

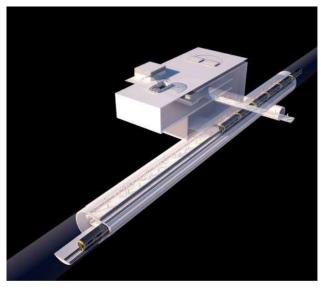
Passengers must be aware at which of the vertically stacked platforms within the monotube tunnel, they wish to travel to and must make their way from a multi-level underground station to the Ticket Hall level and then cross beneath St. John's Road West within an underpass and finally via a bank of escalators, arrive at the level of the existing surface station concourse. Consequently, this option is considered to have significant disadvantages compared to other options.

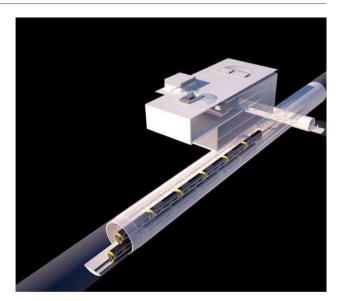
A summary of the MCA comparative assessment ranking for Interchange is provided in **Table 33.** 

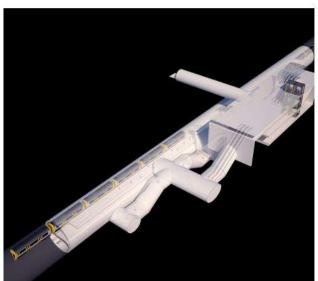
#### 11.2.2 Traffic & Transportation

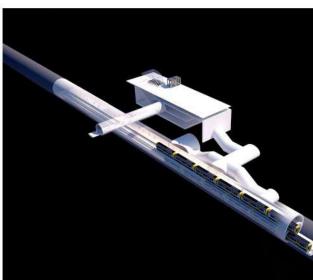
As described in **Section 9.3**, the comparative assessment of the MCA Options under the criterion of Traffic and Transportation has considered the impacts during construction and in operation for each assessment option. The impacts arising during construction have been identified based on the temporary traffic impacts associated with the principal construction worksites presented in **Chapter 7**.

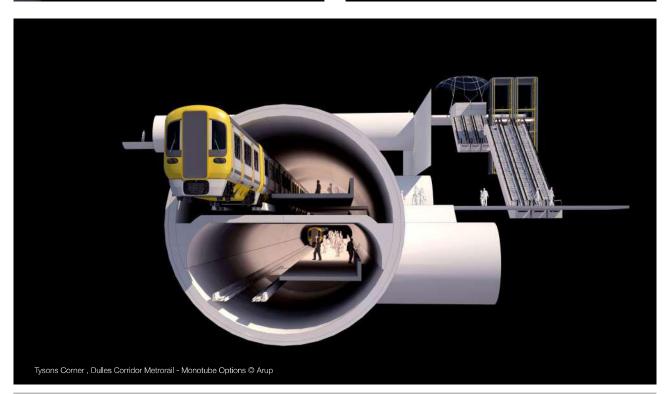
With the exception of Option Twin 3C, there are no material long term impacts associated with the MCA Options. As such, the comparative rankings are in the main, influenced by the construction stage impacts associated with each of the MCA Options.











In general terms, during construction, all MCA Options will result in an impact on traffic conditions in the local area. With regards to the generation of construction traffic, although considered in the assessment criteria, the forecast construction traffic movements are broadly similar across all MCA Options and are not considered to be a distinguishing factor in terms of impact. The primary impact of each MCA Option is related to the closure or reduction in capacity of the road network due to the location and arrangement of the principal construction worksites.

If the TBMs were launched from the western portal, Options Twin 1AS and Twin 3AS will require the closure of St. John's Road West. Equally, the construction of the mined turnback for Option Twin 1E would necessitate the closure of St. John's Road West. This will result in a significant impact on traffic, buses, pedestrians and cyclists for the duration of the Works (approximately six years). Whilst alternative routes are available, these routes are already under pressure and will struggle to accommodate the increase in traffic associated with the required rerouting. Additionally, there are 11 bus routes currently running along St. John's Road West that will need to be rerouted to facilitate the works. The rerouting of buses associated with the closure will impact on bus passengers currently using the services along St. John's Road West. Furthermore, the ease of interchange between these bus services and rail and vice versa at Heuston Station, will also be impacted.

Options Twin 1AS and Twin 3AS will also require a temporary reduction in capacity at the junction of the Chapelizod Bypass / Con Colbert Road and South Circular Road, to facilitate reconstruction of the overbridges across the rail line. Combined with the short-term closure of St. John's Road West, these options are considered to have significant disadvantages compared to other options.

Option Twin 2C would require the existing junction between the Chapelizod Bypass and Con Colbert Road to be relocated further west to facilitate the main worksite. There would be a minor reduction in capacity for traffic on the Chapelizod Bypass / Con Colbert Road westbound carriageway as there would be a reduction in the number of traffic lanes from three to two, immediately before the reconfigured junction. A dedicated westbound slip lane would be provided for traffic leading into Ballyfermot on a reconfigured westbound Con Colbert Road.

In addition, the existing footpath on the Con Colbert Road from the Sarsfield Road junction to the Memorial Road junction will be closed for the duration of the Works, and pedestrians will be rerouted via Sarsfield Road, Inchicore Road and Memorial Road. However, the numbers of pedestrians using this route are very low and the impact is considered to be minor. The impact of the relocation and reconfiguration of the junction of the Chapelizod Bypass and Con Colbert Road is considered to be minor, and compared to other options it ranks favourably. As such, this option is considered to have some advantages compared to other options.

Option Twin 3C would also require the junction of the Chapelizod Bypass and Con Colbert Road to be relocated west of the present configuration. However, as the proposed tunnel portals are positioned west of the configuration proposed in Option Twin 2C, it would be unnecessary to close the footpath along the Con Colbert Road and three westbound traffic lanes could be maintained on the Chapelizod Bypass / Con Colbert Road.

The most significant impact associated with Option Twin 3C though is the requirement to close Sarsfield Road from the Dan Ryan Truck Rental entrance to the junction with the Con Colbert Road. This length of road would be closed to all road, pedestrian and cycle users during construction. This would require local diversions for traffic currently using the route.

Option Reference	Option Twin 1AS	Option Twin 3AS	Option Twin 2C	Option Twin 3C	Option Twin 1E	Option Mono 2E	Option Twin 2F
	Deep Mined Ladder	Monotube	Deep Mined Ladder				
Traffic & Transportation Rank based on Impacts							•

Table 34: MCA Comparative Assessment ranking for Traffic and Transportation

Option Reference	Option Twin 1AS	Option Twin 3AS	Option Twin 2C	Option Twin 3C	Option Twin 1E	Option Twin Option Mono 1E	Option Twin 2F
	00 00 00 00 00 00	(B) (B)					
Assessment Criteria	Deep Mined Ladder	Deep Mined Ladder	Deep Mined Ladder	Deep Mined Ladder	Deep Mined Ladder	Monotube	Deep Mined Ladder
Overall Ranking under the Principal Criterion of Integration	•	•					•

Table 35: Overall MCA Comparative Rankings for Integration

Furthermore, buses would need to be rerouted, with the Con Colbert Road being the likely new route. This would have a direct impact on bus passengers currently using the services along Sarsfield Road and the Inchicore Road. The most significant impact of this closure would be on pedestrians and cyclists originating or with a destination on Sarsfield Road which would have to divert by over 1 km.

Whilst access for pedestrians and cyclists would be reintroduced following construction, this length of Sarsfield Road would be permanently closed to buses and vehicular traffic. It is worth noting that Sarsfield Road currently forms part of the emerging preferred route for the Lucan to City Centre Core Bus Corridor and would need to be rerouted to facilitate this option. Option Twin 3C is considered to have some disadvantages compared to other options.

Option Mono 2E would require a phased partial closure of St. John's Road West to facilitate the construction of a cut and cover underpass from the proposed Ticket Hall under the forecourt of Dr Steevens' Hospital to the existing Heuston Station. This could be constructed in phases and all traffic movements maintained, with some reduction in capacity for the duration of the cut and cover underpass construction. Option Mono 2E is considered to have some advantages compared to other options.

Option Twin 2F does not require any road closures or reductions in capacity to facilitate the works and any impacts such as traffic generation or access routes can be appropriately mitigated. As such, this option is considered to have significant advantages compared to other options.

If the TBMs are received at the western portal as opposed to being launched from the west, then in the case of Options Twin 1AS and Twin 3AS, it will be possible to divert St. John's Road West around the reception portal worksite and maintain traffic movements but with a reduced capacity. However, Option Twin 1AS will still require the construction of new rail overbridges OB1 and OB1A, whilst Option

Twin 3AS will necessitate a new rail overbridge OB1. Regardless of whether the TBMs are driven from the east or the west, it is still considered that Options Twin 1AS and Twin 3AS would have significant disadvantages compared to other options. Furthermore, it is considered that the rankings of the other options are unaffected by the choice of driving the TBMs from the eastern or western end of the route.

A summary of the MCA comparative assessment ranking for Traffic and Transportation is as provided in **Table 34.** 

### 11.2.3 Overall Ranking of Principal Criterion - Integration

**Table 35** over summarises the Overall Ranking for the MCA Options under the principal criterion of Integration, which combines the respective rankings for Interchange and Traffic and Transportation.

## 11.3 Accessibility and Social Inclusion

#### 11.3.1 Accessibility Sub-Criterion

Each of the MCA Options was assessed through a qualitative appraisal of the capacity of the options to achieve an inclusive design that maximises access for disabled people.

Options Twin 1AS, Twin 3AS, Twin 2C, Twin 3C, Twin 1E and Twin 2F provide direct access from the existing Heuston Station surface concourse to the platform level of the Underground Station via a 26 person lift located in the eastern cut and cover shaft. In addition, the station platform layout is an island arrangement, facilitating ease of access and circulation for users whom are either mobility or visually impaired.

Option Mono 2E is the deepest station configuration. In this arrangement, passengers of reduced mobility are required to travel in an underpass beneath St. John's Road West to the

Option Reference	Option Twin 1AS	Option Twin 3AS	Option Twin 2C	Option Twin 3C	Option Twin 1E	Option Mono 2E	Option Twin 2F
	GB GB						
Assessment Criteria	Deep Mined Ladder	Monotube	Deep Mined Ladder				
Rank under Sub-Criterion Accessibility and Principal Criterion of Accessibility and Social Inclusion							

Table 36: MCA Comparative Assessment ranking for the sub-criterion of Accessibility and also the principal criterion of Accessibility and Social Inclusion

Option Mono Option Twin 2E 2F	<b>B</b>		tube
Option Twin Option 1E			P
Option Twin 3C	000	BI)	Deep Mined Ladder
n Option Twin 2C	8 6	BI	
in Option Twin 3AS	<b>0</b>	80	Deek
Option Reference Option Twin 1AS	8	Bi	
Option			Assessment Criteria

Table 37: MCA Comparative Assessment ranking for the sub-criterion of Landscape and Visual

proposed Underground Station Ticket Hall. This requires a lift from the existing station surface concourse to the underpass floor level. Then passengers of reduced mobility must get a lift from the Ticket Hall level to the platform level, selecting the correct level in the vertical stacked arrangement. Overall, the journey time at the Heuston Underground Station is longer and more difficult to navigate than all other options.

Consequently, Option Mono 2E is considered to have some disadvantages over the other six options, whilst the same six options are considered to have some advantages over Option Mono 2E.

A summary of the MCA comparative assessment ranking for accessibility is given in **Table 36**. As Accessibility is the only sub-criterion under the assessment principal criterion entitled Accessibility and Social Inclusion, these same rankings also apply to Accessibility and Social Inclusion.

#### 11.4 Environment

#### 11.4.1 Landscape and Visual

Each MCA Option has been assessed from a Landscape (Townscape) and Visual point of view using a qualitative appraisal of the potential impacts of the proposed options on landscape/ townscape, and the visual environment.

Option Twin 2C is the most preferable option is as it confines the extent of any large scale open excavations and above ground interventions to areas of relatively low sensitivity and avoids direct impacts on areas of high sensitivity such as the Irish National War Memorial Gardens and the Royal Kilmainham Hospital and its attendant grounds. This option does require the removal of the Sancton Wood tower and Signal Box from within the Inchicore Works Depot. However, in doing so it minimises any further impact to the structures within the Works. Option Twin 2C is considered to have significant advantages over the other options assessed.

Option Twin 3C is generally similar to Option Twin 2C except that it would give rise to significant localised effects at Sarsfield Road through the removal of the existing bridge and filling in the space between the existing walls over the width of the DART Underground and Mainline tracks. The end return walls, between the existing walls and parallel to the existing underbridge, would create a local visual impact. In addition, there would be a penetration in these end walls to facilitate an underpass for pedestrians and cyclists. The impact could be reduced by facing the end walls in a similar stonework to that of the existing retaining walls. As a result, Option Twin 3C is considered to have some advantages over the other options assessed.

Option Twin 2F is considered to have some advantages over the other options assessed by virtue of limiting the extent of above ground works to within and immediately east of the ClÉ Inchicore Works. It nonetheless results in significant changes to the existing built fabric including protected structures at the ClÉ Inchicore Works, and the installation of a new intervention shaft just outside the ClÉ Inchicore Works, to the north of the existing sports pitch.

Options Twin 1AS, Twin 3AS, Twin 1E and Mono 2E have a lesser physical extent to other options assessed. However, all involve significant excavations within landscapes of high sensitivity, including the Royal Hospital Kilmainham and Dr Steevens' Hospital, and will alter the setting and character of these important landscapes and architectural landmarks. All of these options will give rise to significant landscape effects during construction, but also post construction in the medium to longer term, and even permanently.

Option Twin 1E involves significant excavation and construction related activity within the meadow grounds of the Royal Hospital Kilmainham (RHK), establishment of two short-term openings in the boundary wall onto St. John's Road West, including the removal of trees and masonry stone wall, and also the closure of St. John's Road West to traffic for the duration of construction. There will

be significant landscape effects within the curtilage of the RHK, but also in the streetscape along St. John's Road West. Option Twin 1E is considered to have some disadvantages over the other options assessed.

Option Twin 1AS will have similar landscape effects at the RHK to Option Twin 1E. However, the extent and nature of the effect will be determined by whether the RHK serves as a launch portal or reception portal worksite. As a launch site, landscape effects will be similar in extent and nature to Option Twin 1E, with significant landscape effects within the curtilage of the RHK, but also in the streetscape along St. John's Road West. As a reception portal site, landscape effects will not extend so far into the RHK grounds, however the full extent of the boundary trees and stone wall along St. John's Road West, including most of the trees and wall adjoining the boundary of the formal gardens, will be removed and will have to be reinstated following construction. Option Twin 1AS, as a launch portal or reception portal site, is considered to have some disadvantages over other options assessed.

Option Twin 3AS will have very similar landscape effects at the RHK to Option Twin 1AS. However, if utilised as a reception portal worksite, the extent of boundary planting and wall along St. John's Road West impacted will be slightly greater and will include all of the trees and wall adjoining the boundary of the formal gardens. Additionally, this option will have a permanent intervention, emergency escape and ventilation shaft constructed immediately inside the Diageo lands east of Steevens' Lane. Option Twin 3AS, as a launch or reception portal site, is considered to have some disadvantages over other options assessed.

Option Mono 2E has been identified as the least preferred option. It involves significant interventions to the setting and character to the Royal Hospital Kilmainham (RHK) during the construction stage but also permanently by virtue of the placement of an intervention shaft within the RHK grounds,

and in the short to medium term through the reinstatement of the boundary wall and tree planting along St. John's Road West. Additionally, this option requires demolition of buildings adjacent to Dr Steevens' Hospital, excavation of the forecourt of the hospital, and construction of an intervention, emergency escape and ventilation shaft in front of Dr Steevens' Hospital, giving rise to permanent significant effects. This option is considered to have significant disadvantages over other options assessed.

MCA comparative assessment ranking for Landscape and Visual is given in **Table 37**.

### 11.4.2 Archaeology, Architectural and Cultural Heritage

A qualitative appraisal of the potential impacts of the MCA Options on potential sub surface archaeology, and the potential impacts on foundations and above ground elements of architectural heritage has been conducted.

All works are located within the zone of archaeological potential for Dublin City (DU018-020).

From an archaeological, architectural heritage and cultural heritage perspective, the most preferable option is Option Twin 2C. This option would minimise the need for large scale open excavation in areas of recorded below ground archaeological significance, and removes the potential of works taking place within areas of architectural heritage significance such as the parklands associated with the RHK and/or the Irish National War Memorial Park.

The extent of works to be undertaken at Heuston Station are generally similar to that previously permitted as part of the original DART Underground Scheme. Whilst Option Twin 2C requires the partial removal of structures of industrial and architectural interest within the CIÉ Inchicore Works Depot, namely the castellated Sancton Wood tower of the Locomotive Shed NIAH 50080418 and the

Signal Box NIAH 50080417, this option minimises the overall impacts, by widening within the area occupied by the existing tracks, thereby leaving the majority of structures intact to the south of the proposed option.

Option Twin 2C requires excavation in the playing pitches of Liffey Gaels GAA club, which is of Archaeological potential. Option Twin 2C also requires demolition, strengthening and reinstatement of the rubble stone retaining walls along Sarsfield Road. Option Twin 2C is considered to have significant advantages when compared to all other options.

Option Twin 3C is considered to have some advantages when compared to the other options. This option is very similar to the afore mentioned Option Twin 2C in terms of potential impacts. However, it would have a greater impact on the retaining walls along Sarsfield Road and if the TBMs are driven from the west, the worksite will have a greater impact on the greenfield environment at Liffey Gaels GAA club.

Whilst there are significant impacts associated with both Options Twin 2C and Twin 3C, they emerge as more advantageous than any of the other five MCA Options.

In terms of architectural heritage, Option Twin 2F would impact the local environment of the CIÉ Inchicore Works, as it would entail the removal of a number of structures listed on the NIAH and DCIHR registers. Option Twin 2F is considered to have some disadvantages against the other options assessed due to the removal of structures, and the resultant loss of character and setting of the CIÉ Inchicore Works.

All the remaining options, namely Twin 1AS, Twin 3AS, Twin 1E and Mono 2E, involve large scale excavations within the zone of potential for Dublin City (DU018-020) and in areas with a known significance for archaeological remains. There is also the potential to alter the streetscape, setting and character of some of Dublin's historic and

architectural landmark sites. This includes the RHK and Dr Steevens' Hospital during the construction phase of the project, while Options Twin 3AS, Twin 1E and Mono 2E involve permanent interventions in these areas with the placement of intervention, emergency escape and ventilation shaft structures. All of these options would result in significant to very significant impacts in the construction phase and are considered to have significant disadvantages during the construction phase when compared to other options.

When assessing the combined impacts during the approximate six year construction duration with the long term operational impacts, the assessment considered that:

- Option Twin 1E involves a worksite on former parkland within the RHK (RPS 5244) now used for concerts and other events. During construction, this will alter the character and setting of the landscapes gardens and there is the potential to reveal archaeological remains including burials within the greenfield environment. This also applied to the intervention and ventilation shaft at the end of the turnback, which straddles under St. John's Road and the Heuston Yard, where significant Viking remains and grave goods were revealed during the 1940's development of the railway (RMP DU018-020272). However, the extent of excavation is limited compared to other options where a tunnel portal is proposed. Option Twin 1E is considered to have some disadvantages against the other options assessed when combining both construction and operational phase impacts.
- Option Twin 1AS involves a portal structure within an area of railway works of Heuston Station, where Viking remains and grave goods (RMP DU 018-020272 Viking cemetery) were revealed in the 1890s during the development of the railway. Whilst this area may be disturbed by past excavation, there is the potential to reveal significant archaeological features and burials. Other outlying burials were also revealed by Healy during the

Option Reference	Option Twin 1AS	Option Twin 3AS	Option Twin 2C	Option Twin 3C	Option Twin 1E	Option Twin Option Mono Option Twin 1E 2E 2F	Option Twin 2F
					00 00 1 0 00		
Assessment Criteria	Deep Mined Ladder	Monotube	Deep Mined Ladder				
Archaeology, Architectural and Cultural Heritage Rank based on Impacts	•					•	

Table 38: MCA Comparative Assessment ranking for the sub-criterion of Archaeology, Architectural and Cultural Heritage

Option Reference	Option Twin 1AS	Option Twin 3AS	Option Twin 2C	Option Twin 3C		Option Twin Option Mono Option Twin 1E 2E 2F	Option Twin 2F
	(B) (B)	00 00 1 0 00 00	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	00 00 1 0 00 00	0 0 0 0		G G
Assessment Criteria	Deep Mined Ladder	Deep Mined Ladder	Deep Mined Ladder	Deep Mined Ladder	Deep Mined Ladder	Monotube	Deep Mined Ladder
Settlement, Ground Movement and potential for third party impacts Rank based on Impacts	•	•	•	•		•	•

Table 39: MCA Comparative Assessment ranking for the sub-criterion of Settlement, Ground Movement and potential third party impacts resulting from ground movements

widening works associated with St. John's Road West in the 1960s. This option involves extensive excavations and the potential to reveal extensive archaeological remains. The worksite also incorporates former parkland within the RHK now used for concerts and events. During construction, this will alter the character and setting of the landscape gardens as well as the garden pavilion and walled garden, all protected structures and recorded monuments. Option Twin 1AS is considered to have some disadvantages when compared with other options assessed.

- Option Twin 3AS is very similar in the type and level of impact associated with that of Option Twin 1AS, with the potential for impacts to the recorded monument of the Viking cemetery and also with the extent of works proposed within the existing boundary walls for the RHK. In addition, there would also be a permanent impact within the curtilage of St. James' Gate Brewery due to the presence of an intervention, emergency escape and ventilation shaft. Therefore, it is considered that Option Twin 3AS has some significant disadvantages when compared with other options.
- Option Mono 2E not only involves the insertion of a permanent shaft structure within the boundary of the RHK resulting in the loss of land and a realignment of the boundary wall of the RHK, it also requires large scale excavation works in the grounds of the forecourt to Dr Steevens' Hospital. A permanent intervention, emergency escape and ventilation shaft structure is proposed within this area, altering the setting and approach to the refurbished hospital. This option is deemed to have significant disadvantages when compared against other options during the construction and the operational phases of the project.

A summary of the MCA assessment ranking for Archaeological, Architectural and Industrial Heritage is provided in **Table 38.** 

## 11.4.3 Settlement, Ground movement and potential third party impacts resulting from ground movements

A comparative assessment of the predicted effects from each MCA Option has been undertaken to identify if any options have some or significant advantages or disadvantages over other options.

Analysis models for Options Twin 2C and Twin 3C to examine the likely ground movement and ground stability at the proposed portal locations, indicate acceptable impacts on the adjacent existing Mainline railway cutting.

The proposed alignment of option Twin 2C is principally in the Dublin Boulder Clay at the portals and below the Chapelizod Bypass / Con Colbert Road. There is a risk of settlement sink holes under the road where gravel lenses/inclusions may be encountered.

The proposed alignment for Option Twin 3C is principally in mixed face conditions (Dublin Boulder Clay and Calp limestone), therefore no reduction in ground movement impacts are expected compared to the shallower vertical alignment of Option Twin 2C.

At the location and vertical level of the proposed Heuston Underground Station associated with Options Twin 2C, Twin 3C and Twin 2F, generally low rockhead cover and the presence of glacial sands and gravels above, remains a risk, which will need to be managed throughout the design and construction phases with appropriate allowance for mitigation included.

For Option Twin 1E, the sprayed concrete lining (SCL) turnback structure will occur fully within the Calp limestone with a minimum of 5 m rock cover between the crown of the mined tunnel and the top of the rockhead. Settlement risk is always an issue in mining large SCL caverns. However, this has been mitigated by lowering the level of the turnback and underground station.

Option Reference	Option Twin 1AS	Option Twin 3AS	Option Twin 2C	Option Twin 3C	Option Twin 1E	Option Mono 2E	Option Twin 2F
		(B) (B) (B)					
Assessment Criteria	Deep Mined Ladder	Monotube	Deep Mined Ladder				
Overall Ranking under the Principal Criterion of Environment	•		•				•

Table 40: MCA Comparative Assessment ranking for the principal criterion of Environment

With Option Mono 2E, the monotube tunnel is fully within the limestone bedrock with a minimum cover of 5 m below the top of the rockhead. At the location of the proposed Heuston Underground Station, increased rockhead cover reduces the tunnelling risks.

Option Twin 2F only considers a reception portal within the CIÉ Inchicore Works. The largest predicted damage category resulting from ground movements associated with tunnelling, mining cross passages, and cut and cover works is Slight, and this is deemed to be acceptable.

Therefore, Options Twin 2C, Twin 3C, Twin 1E, Mono 2E & Twin 2F are considered to have some advantages compared to the other two options.

Options Twin 1AS and Twin 3AS have some disadvantages when compared to the other five options. Both of these options have tunnel portals located in the Heuston Yard. Ground treatment will be required ahead of the portal to ensure that the ground around the TBM will be dry at time of launch for a length of approximately 15-20 m. Operational speed limits will be required in the Heuston Yard and Mainline Station, fettling of the track is anticipated as ground movement occurs and this will inevitably result in delays and disruption to train services.

For Option Twin 1AS, at the location of the proposed Heuston Underground Station, the bored tunnel, platform enlargement and ventilation adits will be constructed in the vicinity of the boundary between the rock and glacial sands and gravels. Therefore greater ground movement is anticipated to occur than all other options, mitigation in the form of ground treatment and spiles will therefore have to be more extensive than all other options.

At the location of the proposed Heuston Underground Station in Option Twin 3AS, the rail level is lower than Options Twin 1AS, Twin 2C, Twin 3C and Twin 2F. However, the proposed station is east of the location shown in Option Twin 1AS and the rockhead level falls east of Heuston.

Therefore, significant ground movement mitigation is anticipated at the eastern end of the tunnels and the intervention, emergency escape and ventilation shaft located in the St. James' Gate Brewery. The proposed mined escalator barrel from the Mainline Terminus to platform level will take place through the glacial sands and gravels, which is a complex and challenging construction operation, requiring substantial mitigation and which has the potential to cause building and infrastructure damage.

A summary of the MCA assessment ranking for Settlement, Ground Movement and potential third party impacts resulting from ground movements, is provided in **Table 39**.

### 11.4.4 Overall Ranking of Principal Criterion - Environment

**Table 40** opposite summarises the Overall Ranking for the MCA Options under the principal criterion of Environment, which combines the respective rankings for Landscape and Visual, Archaeology, Architectural and Industrial Heritage and Settlement, Ground Movement and potential third party impacts resulting from ground movement.

Table 41: Overall Multi-Criteria Assessment Findings for the seven MCA Options

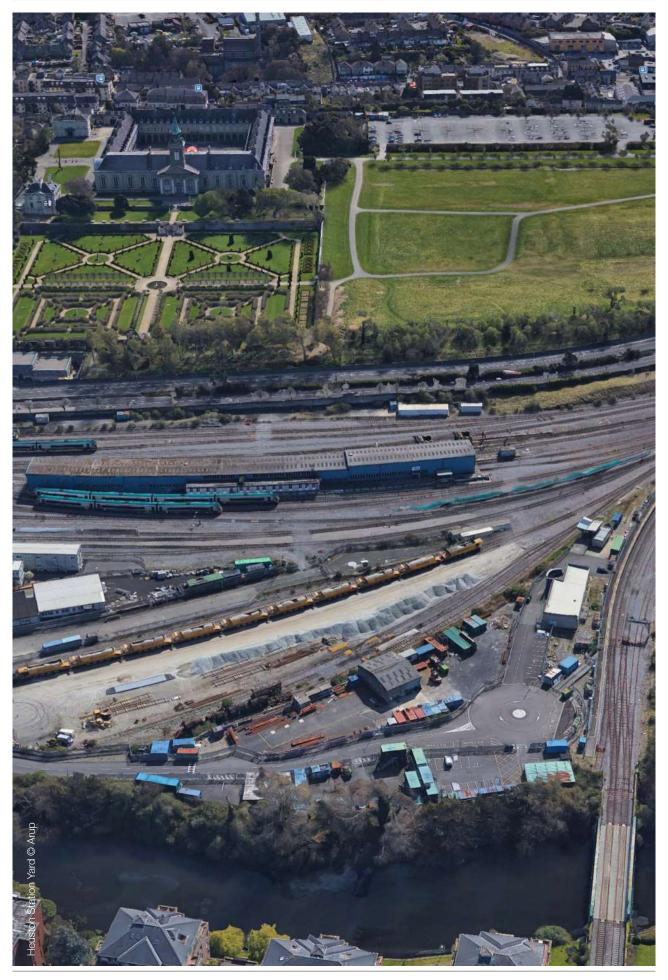
### 11.5 Overall Summary of Multi-Criteria Assessment

**Table 41** opposite presents the findings of the comparative assessment for the seven MCA Options under each of the principal criteria.

As discussed earlier in this Chapter, the selection of a Preferred Option is limited to the scope of this Study and a recommendation on the final tunnel configuration and choice of through running versus terminus station at Heuston, cannot be made until future Transport Benefit studies and an overall route alignment options Study are completed.

However, based on the extent and scope of this Study, and the findings of the multi-criteria comparative assessment, Option Twin 2C is the 'Emerging Preferred Option'. Option Twin 2C has significant advantages over all other options with respect to the principal criteria of Economy and Environment. Option Twin 2C also has some advantages over all other options except Option Twin 2F in respect of the principal criterion of Integration.

The Concept Engineering Design and Feasibility Working Cost Estimate of Option Twin 2C is described in the following Chapters of this Study and the engineering design drawings are contained in **Volume 3** of the Study.



# 12. Phase 4: Concept Engineering Design of Emerging Preferred Option



# 12.0 Phase 4: Concept Engineering Design of Emerging Preferred Option

The concept engineering design drawings of Option Twin 2C, the emerging preferred option, are presented in Volume 3 of the Study and are split into the following disciplines.

These disciplines are as follows:

- Permanent Way;
- Temporary and Permanent highway diversion works to the Chapelizod Bypass / Con Colbert Road junction;
- Architectural drawings of proposed Heuston Underground Station;
- Structural drawings of proposed Heuston Underground Station;
- Structural drawings of proposed Tunnel Portal;
- Property Line Interface drawings;
- Tunnelling drawings;
- Proposed replacement and new underbridge at Sarsfield Road;
- Proposed new Kylemore Road overbridge;
- Proposed Le Fanu Road overbridge
- Mechanical and Electrical schematics for the tunnelled portion of the Study.

In the following sections of the Study, the rationale and design basis, which supports the proposed permanent way alignment, is described. Furthermore, any areas, which require further development for future stages of the Project are identified.

### 12.1 Overview of Concept Design

As described in earlier sections of the Study, Option Twin 2C is a twin bore tunnel from Watling Street to the tunnel portal positioned in an area, which currently forms the Con Colbert Road westbound slip lane from the Chapelizod Bypass. The alignment rises to grade at a location just east of the existing Sarsfield Road Underbridge and the existing rail corridor is widened to accommodate four tracks from Sarsfield Road to the end of the previous KRP Phase 1 Works, located approximately 800 m east of the existing Park West / Cherry Orchard Station.

The main features along the proposed route are described below.

### **12.1.1 Heuston Underground Station**

The proposed underground station at Heuston is identical to that proposed in the original DART Underground in terms of horizontal and vertical position, and arrangement. There are three proposed cut and cover structures at Heuston. The structures at the east end and west end accommodate the combined ventilation and fire fighting shafts, whilst the central shaft accommodates the passenger escalators from the underground platform to the existing ticket concourse level. The existing River Camac Culvert straddles the eastern and the central cut and cover shaft structure.

The track alignment and station configuration are positioned in a manner, which enables the DART Underground to be constructed safely whilst minimising the impact of the construction works on existing train operations and passenger movements. The existing platforms 2 and 3 would be moved west during the period of construction, whilst platform 1 would be closed.

Access to and egress from the underground station construction site is proposed to be via St John's Road West, whilst the existing southern façade of Heuston station would be retained in position during the works.

The internal structure of the existing terminus station would be reconstructed following completion of the underground station. The existing basement to the southern entrance building that runs along St John's Road West would be partially removed or backfilled to facilitate the construction of the underground structures. In order to construct DART Underground, elements of the existing station building would require demolition, but would be re-instated to replicate their current appearance in so far as is practicable. The most significant of these are the internal wall to the south of Platform 2 and the ceiling to the ticket hall (St. John's Road West entrance). Other back-of-house areas would be altered to improve their functionality.

In order to accommodate the new DART Underground facilities, the existing platform buffers must be moved approximately 20 m to the west. The line of ticket gates and glazed screen that separate the existing concourse from the platform, are required to be relocated and the floor between the current and proposed glazed screen locations would be finished to match the existing internal concourse finish.

The track vertical alignment at platform level runs on a constant gradient of -0.2% gradient to allow for tunnel drainage. The depth from proposed rail track level to existing ground level is approximately 25.5m.

### 12.1.2 Alignment of the Running Tunnels and the Tunnel Portal Structure

The plan and vertical alignment is approximately similar to that of the original DART Underground from Watling Street to Heuston Underground Station.

West of the proposed Heuston Underground Station to the east end of the Irish National War Memorial Park, the plan alignment is approximately similar to that of the original DART Underground, whilst the proposed vertical alignment starts to rise from a point under St. John's Road West, approximately 130 m east of overbridge OB1A. The alignment rises at 3.5% to east of Sarsfield Road Underbridge for a length of approximately 1400 m. From a point approximately 160 m east of Memorial Road to the location of the tunnel portals, the plan alignment of the twin bore tunnels is directly below the Chapelizod Bypass / Con Colbert Road, along which there are no major utilities.

The tunnel portals are staggered to provide a cover of approximately 6.0 m above the crown of the tunnel at the portal location, which is considered adequate to provide an acceptable level of ground movement at surface level. Due to the existing ground level profile at the location of the tunnel portals, it is necessary to stagger the Up and Down line portals to achieve a ground cover of approximately 6.0 m at each location.

The retaining structure on the approaches to the tunnel portals is proposed as a 1200mm diameter Hard-Hard secant pile wall, which would be temporarily propped during excavation. It may be possible to alter the secant pile wall to a Hard-Firm solution once the chemical composition of the groundwater is determined and the durability of a firm pile solution over the required 120 year design life can be reviewed.

The construction planning of the proposed portal necessitates that the westbound carriageway of the Chapelizod Bypass / Con Colbert Road be reduced to two lanes for the duration of the

Worksite at this location. There is adequate space available to launch the TBMs from this location if future studies demonstrate that it would be beneficial to the Project as a whole to launch the TBMs from the western end of any proposed route. However, the structural layout of the portal contained in Volume 3 of the Study, is based on the tunnel portals at the western end acting as a reception chamber. Thus if the TBMs are launched from the west, the geometry of the retaining walls and the structure of the intervention shaft and base slab will need to alter to provide the required clear space from which to launch and service the TBMs.

An intervention and emergency escape shaft is located just west of the tunnel portals and this is integrated into the structure of the tunnel approach structure. This intervention and emergency escape shaft is position approximately 1,760 m from the tunnel intervention point at the western end of the proposed Heuston Underground Station platforms.

### 12.1.3 New bridge Structures

Two new underbridges are required at Sarsfield Road, one to accommodate the DART Underground tracks and which also acts as a replacement for the existing underbridge, and a second to carry the diverted Mainline tracks to the south of the proposed DART tracks. The rails are fixed to the structure of the existing 'Silent' underbridge and as the track geometry differs for the proposed DART Underground, this existing bridge must be replaced. It is proposed that both new underbridges at Sarsfield Road be 'E' type steel decks supported on piled abutments which are positioned behind the existing Sarsfield Road retaining walls, and the piles be sleeved over a length equal to the retained wall height, to prevent any additional horizontal pressures acting on the retained face of the existing masonry retaining walls.

A new overbridge is required at Kylemore Road to support the highway and to act as a station entrance concourse for a future proposed station at Kylemore Road. A shallow braced steel composite deck is proposed with integral abutments and

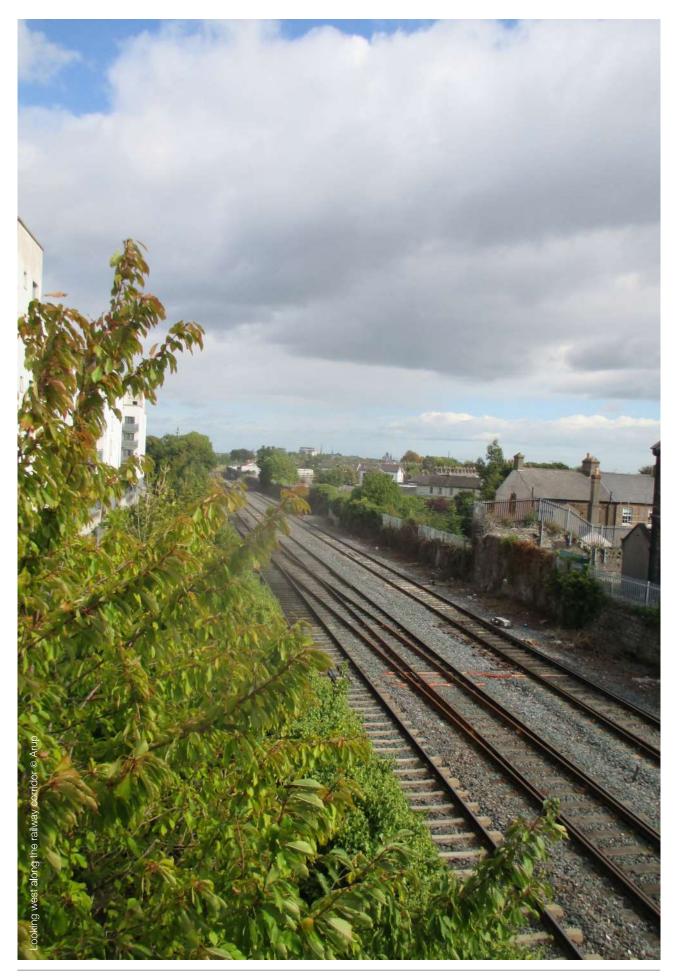
an integral intermediate pier connection. It is envisaged that by building the station concourse structure to the west of the existing overbridge, it would be feasible to maintain two lanes of traffic along Kylemore Road by phasing the construction sequence to use the station concourse as a temporary highway deck, whilst the existing overbridge is demolished and rebuilt. This construction and traffic phasing is recommended for the next stage of design development of the project.

The vertical clearance from top of the highest rail to the soffit of the bridge deck, proposed at Kylemore Road, is 4830 mm. There is no opportunity to alter the road levels on the approaches to Kylemore Road overbridge. The geotechnical site investigation previously undertaken in the vicinity of Kylemore Road overbridge is inconclusive. However, the water table at Le Fanu overbridge was found to be approximately 1000mm below track formation level and without undertaking a detailed site investigation at track bed level, it is considered prudent to assume that the proposed rail levels in the area of Kylemore Road overbridge should not significantly alter from the current rail levels.

A new overbridge is proposed at Le Fanu Road, similar to that previously developed by IÉ as part of the proposed KRP2 Works. The proposed bridge is an integral deck consisting of precast pretensioned concrete beams supported on piled reinforced concrete abutments. The vertical alignment of Le Fanu Road is raised locally at the bridge and the approaches to achieve sufficient vertical clearance from track level to the soffit of the proposed bridge deck.

### 12.1.4 Retaining Walls

Retaining walls are required along the length of the widened rail corridor to accommodate the four tracking, from Sarsfield Road to the end of the KRP Phase 1 Works. The extent of the envisaged retaining walls is indicated in the Property Line interface drawings in Volume 3 of the Study. The retaining walls are typically formed of contiguous



bored piles for retained height greater than 3 m, due to rock being encountered or anticipated at relatively low depths below the existing track formation. For retained heights less than 3 m, a number of options are feasible including a king post wall and crib wall.

### 12.1.5 Kylemore Road Station

A new station is proposed to the west of Kylemore Road, which would act as a replacement for the Inchicore Station proposed in the original DART Underground. The station would only serve the DART train services; the fast mainline tracks would be located to the south of the slow tracks. The Station configuration proposed is modelled to some extent on that of the existing Park West / Cherry Orchard Station, but amended to suit the track configuration and only to have access to an island platform configuration.

The existing tracks at this location are rising on a vertical gradient of approximately 1,20%, heading west. At a station, the desired maximum vertical gradient is 0.2%. Over a platform of length 174 m, this would mean that the DART tracks would have to be lowered by approximately 1,74 m. Without a detailed site investigation and knowledge of the highest groundwater levels in this area, it is not feasible to propose a platform with 0.2% maximum gradient. Such a proposal could require the DART tracks to be constructed within a concrete U trough structure, which would have to be watertight, the rail corridor would need to be widened and additional landtake acquired.

It is recommended that following a detailed site investigation, the alignment of the DART tracks and platforms at Kylemore Road can be studied, examining the possibility of achieving a vertical gradient of 0.2% over the length of the station platform. A further option is to rotate the track using the level at Kylemore Road overbridge as a pivot point, raise the track levels on the Inchicore approach and lower the track levels to the west of the pivot point, and achieve an acceptable gradient. For the purposes of this Study, a vertical

gradient of 0.40%, 1 in 250, has been proposed over the length of the platform. This gradient was adopted as there is precedence elsewhere on the Hazelhatch Line for a station with this vertical gradient.

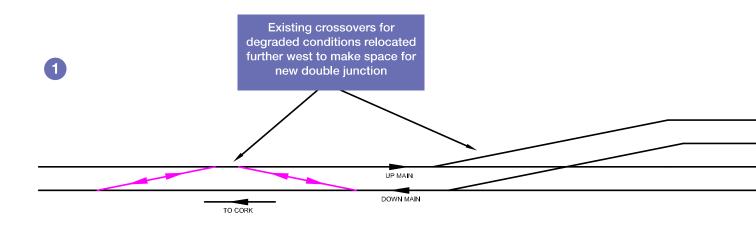
### 12.1.6 Park West / Cherry Orchard Station Turnback

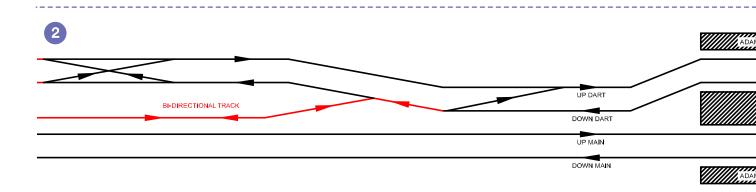
A single turnback is proposed at Park West / Cherry Orchard Station, which has a capacity of four trains per hour per direction onto the Up Slow and Down Slow lines. The turnback is positioned to the east of the current island platform. A minimum single sided platform of width 3 m is provided to the train which is terminating / turning around.

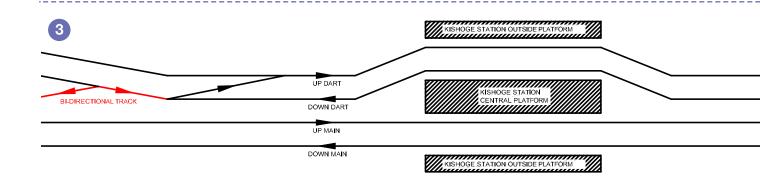
The existing turnback at Adamstown Station also provides a capacity of four trains per hour per direction. Thus, together these two turnbacks can achieve the required capacity of eight trains per hour per direction and satisfies the operational requirement specified in the Brief for this Study. It should be noted that in the original DART Underground, a twin turnback arrangement was proposed at Inchicore Station, which had a total capacity of 12 trains per hour per direction.

### 12.1.7 Track Configuration

The track configuration proposed in the original DART Underground was Fast, Slow, Slow, Fast to align with the Kildare Route Project track configuration, and this necessitated a grade-separated junction to the west of Kylemore Road Bridge. As part of this Study, IÉ confirmed that the track configuration was not a constraint. The Emerging Preferred Solution has a Slow, Slow, Fast, Fast track configuration at Sarsfield Road and then continues with this arrangement to the end of the Kildare Route Project, Phase 1. The proposed track layout schematic for the Emerging Preferred Option is shown in **Figure 108 overleaf**.







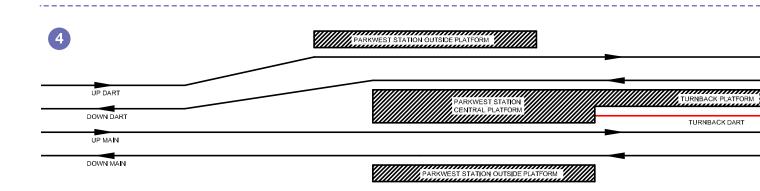
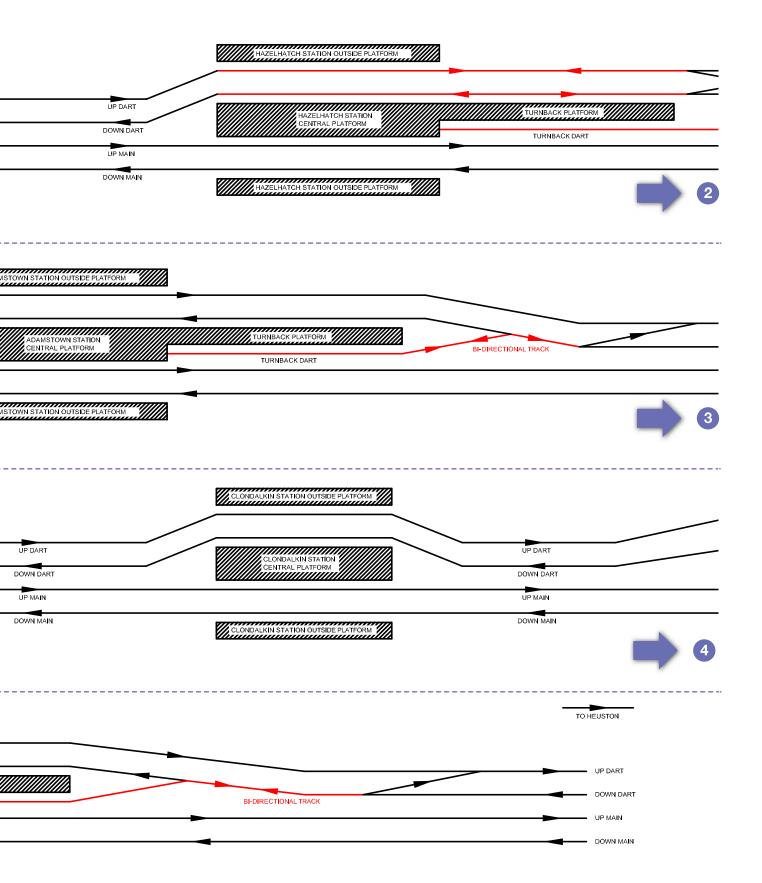


Figure 108: Proposed Track Layout Schematic for the Emerging Preferred Option



### 12.1.8 Track alignment through Inchicore Works

The existing Mainline tracks will be slewed to the south through Inchicore to widen the existing rail corridor. As a consequence, it is necessary to:-

- Remove and relocate the Sancton Wood Tower (also referred to as the Turret) which projects from the Old Running Shed;
- Remove and relocate the Signal Box opposite the Sancton Wood Tower;
- Remove the lean back portion of the Maintenance Shed Building;
- Provide new crossovers to provide connection from the Mainline, into and out of the Works Depot. This includes a rearrangement of the sidings to include trap points and a head shunt;
- Remove some annexes behind the New Works Director Building;
- Impacts the boundary wall and property of No. 4 St George's Villas;
- Requires a new footbridge at the location of the current Khyber Pass footbridge and requires amendments to the access road at the northern side of the Track and Signal Building;
- Requires the current track drainage attenuation facility, located north of the CIÉ Sports Ground to be relocated;
- Construct a new underbridge at Sarsfield Road;
- Acquire the Dan Ryan Truck Rental site.

The proposed Mainline diversion ties back into the rail corridor just west of Murray's Cottages. The Mainline track is proposed to be vertically higher than that of the current track levels in order to achieve the road clearance at the location of the new Sarsfield Road Underbridge. Consequently, the actual tie-in to the existing Mainline levels occurs just west of Memorial Road overbridge. The current Relief line, which exists over Sarsfield Road and on the approach to Heuston will be removed from Memorial Road to the CIÉ Inchicore Works.

### 12.1.9 Property

As discussed in the sections above, the Emerging Preferred Solution has sought to minimise landtake throughout the Project and this is reflected in the Property Interface drawings contained in Volume 3 of the Study. By bringing the track alignment to grade within the existing rail corridor, property impacts are largely limited to the widening of the existing rail corridor. The location of the original DART Underground resulted in an opening of the ClÉ Inchicore Works to the Public, with new vehicular access routes, provision for Luas Line F, pedestrian and cycle facilities. These works will no longer be required and the Inchicore Works will remain closed to the Public.

### 12.2 Alignment Objectives

The alignment of the emerging preferred concept is based on satisfying the design and operating principles as set out in Section 3.1 of this Study, together with a desire to:

- Minimise any alterations to existing infrastructure;
- Minimising any potential landtake;
- Ensure the longevity of the system and facilitate ease of maintenance;
- Ensuring safety for all users of the system.

### 12.3 Iarnród Éireann Track Design Standards

The IÉ track design standards adopted to develop the alignment design are based upon the following standards:

- 1. IÉ standard I-PWY-1101: Requirements for Track and Structures Clearances;
- 2. CCE-TMS-300: Track Construction Requirements and Tolerances;

- 3. IÉ standard I-PWY-1141: Engineering Requirements for Passenger Platforms and Barrow Paths;
- 4. IÉ standard I-PWY-1150 Track Design requirements Points & Crossings;
- 5. CCE-TMS-340: Horizontal Curvature Design;
- 6. CCE-TMS-341: Vertical Curvature Design.

### **12.4 DART System Requirements**

- A new proposed overground station is to be provided in the vicinity of Kylemore Road with a Slow, Slow, Fast, Fast track arrangement;
- DART rolling stock will not be maintained in the CIÉ Inchicore Works:
- DART rolling stock will only be permitted to use
  the slow tracks. Mainline rolling stock will be
  permitted to run on the slow tracks as a result
  of major events or operational perturbation.
  Allowance is made in the cost estimates for
  the provision of crossovers from the Mainline to
  the slow DART tracks, but the exact location is
  not yet defined. Mainline services running on
  the slow DART tracks will operate under speed
  restrictions and therefore be limited to the
  DART surface line speeds.

### 12.5 Key Constraints along Route

The key constraints along the route, which affect the alignment design, are as follows:

- Maximum grade of 3.5% for a length of no more than 1.66 km, and 3.0% over longer distances;
- Maintaining the current vertical clearance requirements at Sarsfield Road underbridge;

- Various boundaries along the route, including:
  - » Murray's Cottages
  - » St. George's Villas
  - » Rear gardens of the properties along Landen Road
  - » Industrial units between Kylemore and Inchicore Works
  - » Rear gardens of the properties along Barnville Park / Cherry Orchard Court
- Structural Clearances, both horizontal and vertical, at the following locations:
  - » M50 overbridge
  - » Park West / Cherry Orchard Station and overbridge
  - » Building located within the CIÉ Inchicore Works
  - » Maximise the vertical cover at the tunnel portal and thereby the depth of cover under the Chapelizod Bypass / Con Colbert Road
- Water table along the route, west of Kylemore Road which limits the available lowering of the track level
- The presence of protected structures

	Limiting Design Criteria
Maximum Line Speed, Surface DART	100 km/h
Maximum Line Speed, Surface Mainline Services (See Note 1)	120 km/h
Maximum Line Speed, DART Tunnel Sections	75 km/h
Minimum Line Speed, Tie-in Junctions between DART and Mainline	50 km/h
Minimum Design Speed, Switches and Crossings	30 km/h
Maximum Line Speed, Yard	15 km/h (Design Speed)

Table 42: Design Speeds

Note 1: The maximum design line speed east of Park West Cherry Orchard Station is 120 km/h and west of this station is  $\geq$  160 km/h

	Limiting Design Criteria
Absolute Minimum Element Length	30 m
Minimum Element Length, 75 km/h	41.667 m*
Minimum Element Length, 100 km/h	55.556 m*
Minimum Element Length, 120 km/h	66.667 m*

<sup>\*</sup>This is based on 2 seconds of travel at linespeed.

Table 43: Minimum Element Length

Jerk Rate	Limiting Design Criteria
Desirable	0.2mm/s <sup>3</sup>
Limiting	0.3mm/s³

Table 44: Minimum Element Length

# 12.6 Track Design Speeds and Horizontal Geometry Requirements

The design speeds adopted in the developments of the proposed alignment are listed in **Table 42**.

It is noted that the Drivers Rule book limits actual speeds in a siding to 8 km/h.

### 12.6.1 Horizontal Track Geometry

**Table 43** opposite lists Minimum Element Length for straights and curves.

### 12.6.2 Transitions

**Figure 109** below shows a typical transition curve, according to IÉ standards, the cubic parabola is used for all transition curves. IÉ standards also permit the use of a clothoid transition curve as Section 2.1.3.5 of standard CCE-TMS-340.

The equation of a cubic parabola is  $Y = X^3/6LR$  and curvature at a given point = X/RL (curvature is proportional to distance).

The shift (S) of a circular curve is found as follows:

The ordinate at the shift point = S/2 and X = L/2

 $Y = S/2 = (L/2)^3/6LR = L^3/48R = L^2/48R$ 

 $S = L^2/24R$ 

#### 12.6.3 Jerk Rate

Table 44 opposite lists Jerk Rates.

### 12.6.4 Circular Curves and Tangents

Minimum horizontal curve for CWR track is a radius of 400 m.

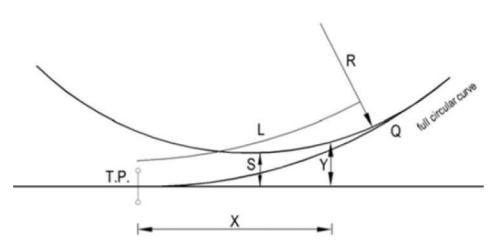


Figure 109: Recorded monuments in red and NIAH structures in blue at Heuston and Kilmainham

Rate of Change of Cant	Limiting Design Criteria
Maximum Desirable	40mm/s
Maximum Allowable	60mm/s

Table 45: Rate of Change of Cant

Limiting Design Criteria
40mm/s
60mm/s

Table 46: Rate of Change of Cant Deficiency

Rate	Limiting Design Criteria
Absolute Maximum Cant Allowable in Standards	165mm (I-PWY-115 3.1.1)
Maximum Cant Allowable	100 mm (Technical Requirements)
Maximum Cant through platforms	90 mm
Maximum Cant Used	90 mm

Table 47: Maximum Cant

Rate	Limiting Design Criteria
Maximum Cant Deficiency Allowable in Standards	110 mm (I-PWY-1154 3.7.1)
Maximum Cant Deficiency Used	68 mm

Table 48: Maximum Cant Deficiency

Rate	Limiting Design Values
Maximum Cant Excess Allowable in Standards	90 mm (I-PWY-1154 3.10.1)
Maximum Cant Excess Used	32 mm

Table 49: Maximum Cant Excess

### 12.7 Track Cant

To counteract the effect of the lateral acceleration and the resulting centrifugal force, the outside rail of a curve is raised by a distance above the inside rail 'E'. A state of equilibrium is reached in which both wheels exert equal force on the rails, that is, where 'E' is sufficient to bring the resultant force to right angles with the plane of the top of the rails.

To determine the distance that the outside rail must be raised to reach a state of equilibrium, cant shall be applied by rotating the track about the crown of the head of the low rail.

The equilibrium equation is defined as follows:

 $E_{eq} = (13.14V^2)/R$  (I-PWY-1154 3.4.1)

### 12.7.1Rate of Change of Cant / Cant Deficiency

The values for the rate of change of cant and cant deficiency are set out opposite in **Table 45** and **Table 46**.

#### 12.7.2 Maximum Cant

Table 47 Maximum Cant.

#### 12.7.3 Maximum Cant Deficiency

Table 48 Maximum Cant Deficiency.

#### 12.7.4 Maximum Cant Excess

Table 49 Maximum Cant Excess.





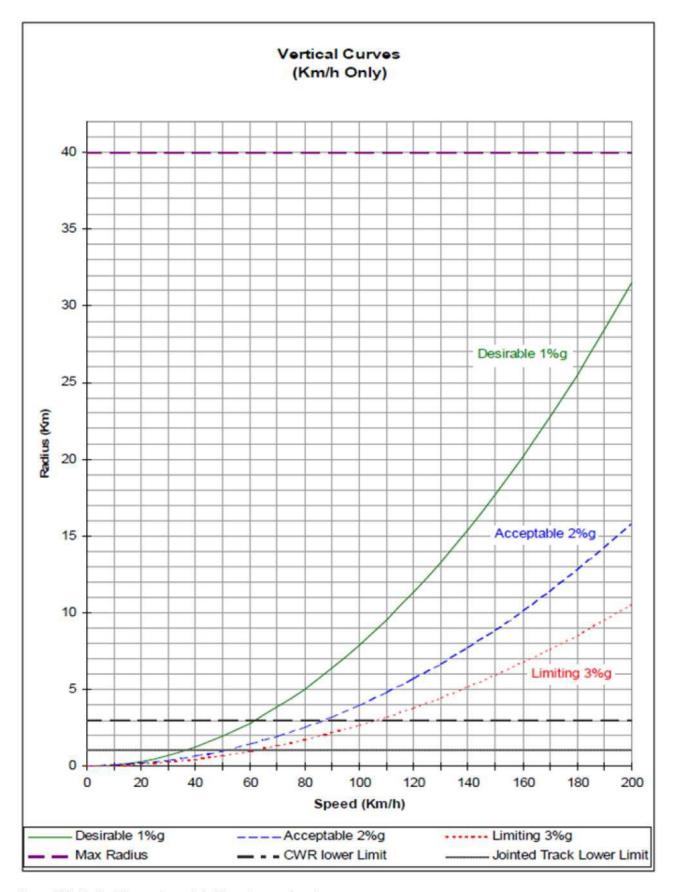


Figure 109: Vertical Curves (speeds in kilometres per hour)

IÉ Comfort Levels	Limiting Design Values
Desirable	1% g (I-PWY-1158 3.1.2)
Acceptable	2% g (I-PWY-1158 3.1.2)
Limiting	3% g (I-PWY-1158 3.1.2)

Table 50: IE Passenger Comfort Levels

IÉ Comfort Levels	Limiting Design Values
Minimum Vertical Curve Radius, CWR Track	3,000 m (I-PWY-1158 Fig. 2)
Maximum Vertical Curve Radius	40,000 m (I-PWY-1158 3.3.2)

Table 51: Limiting Vertical Curve Radii

Selected Rate of Acceleration		le Formula V (km/h)	
Desirable (1%g)	$R = \frac{V^2}{1271}$	$V = \sqrt{Rx1271}$	
Acceptable (2%g)	$R = \frac{V^2}{2543}$	$V = \sqrt{Rx2543}$	
Limiting (3%g)	$R = \frac{V^2}{3814}$	$V = \sqrt{Rx3814}$	

Table 52: Formulae for vertical curves

	Limiting Design Criteria	Comment
Absolute Maximum Grade	3.5%	For a maximum length of 1.66 km and 3% over longer distances
Maximum Grade	3%	
Minimum Grade	0.2%	To Facilitate Track Drainage
Maximum Grade, Freight	2%	

Table 53: Limiting Vertical Grades

### **12.8 Vertical Track Geometry**

The vertical alignment in this Study is taken from the low rail of each track. Circular curves were used in this Study, despite there being little practical difference between circular and parabolic curves due to the size of the curves in use.

IÉ sets three levels of comfort, which can be seen in **Table 50** opposite.

### 12.8.1 Limiting Values for Radius

Table 51 Limiting Vertical Curve Radii

### 12.8.2 Vertical Curve Values for Radius and Speed

Minimum vertical curves are dictated by the formulae in **Table 52** opposite.

The minimum vertical curve used in the design meets the minimum value for continuous welded rail of a 3000 m radius (I-PWY-1158 Fig. 2), for a design speed of 75 km/h giving an acceptable rate of acceleration of 2% g. All other vertical curves meet the desirable rates of acceleration of 1% g.

#### 12.8.3 Vertical Grades

Table 53 Limiting Vertical Grades.

### 12.8.4 Calculation of Equivalent Gradients

In locations where there are both vertical and horizontal curvature, it may be necessary to determine the equivalent gradient. This allows a train traction unit to have consistent demands and ensures that the maximum allowable gradient is not exceeded. The actual gradient can be found using the following method:

- Establish criteria.
   Radius of curve in metres = R
- 2. Calculated gradient as a percentage = G
- 3. Find the degree of curvature,
  Degree of curvature, D = 2 Sin-1 (15.24/R)
- 4. Determine compensation value, p, from **Table 54** overleaf;
- 5. Apply compensation to the gradient Effective final gradient =  $G + D \times p$ , where p is the applied % as shown in **Table 55** overleaf.
- 6. All gradients in this design are taken from the low rail level.

Track Type	CWR	CWR	JTD	JTD	JTD
For Degree of Curvature, D	<5°	5° - 6°	<5°	5° - 10°	>10°
Under 50 km/h, value of p is:	0.04	0.03	0.05	0.04	0.03
50 km/h & over, value of p is:	0.03	0.02	0.04	0.03	0.02

Table 54: Formulae to determine compensation value

	Limiting Design Criteria
Maximum Grade Proposed at Kylemore Station*	0.40%*
Maximum Grade in Stations, Underground	0.20%

<sup>\*</sup> A derogation is required to permit the use of platforms at Kylemore Road at 0.40% gradient for the reasons previously outlined in relation to the vertical clearance at Kylemore Road overbridge and the anticipated groundwater level at this location Table 55: Limiting Station Grade

The ten-foot (10') is maintained where practical, with reduction in this dimension subject to approval on a case by case basis. The rationale for the reduction in the 10' is excluding this as a place of safety for track crossing of site staff. This has recently been adopted in the UK with Network Rail as best practice and in prioritising passing and structural clearances above the maintenance of a 10'. Required Permanent Way Derogations & TNCs Applicable to the Project are as follows:

Areas with Reduced 10'	Chainage (m)	Reasoning
Park West / Cherry Orchard Station Turnback	13,856.081- 13,548.911*	To allow for safe standing area on back of platform
Inchicore Works	10,428.180- 10,537.852* 10,654.905- 10,866.508*	Available width of rail corridor too narrow

<sup>\*</sup>Chainages taken from the Up Mainline

Table 56: Proposed derogations to the 10 foot at locations along the proposed alignment

### 12.9 Horizontal and Vertical Geometry at Stations

### 12.9.1 Horizontal Alignment at Stations

The horizontal track alignment through station platforms is on a straight section of track for the entire length of the platform.

The absolute minimum length beyond the end of each platform is 5m.

#### 12.9.2 Vertical Grade at Stations

Table 55 Limiting Station Grade.

### 12.10 Track and Structure Clearances

#### 12.10.1 Platform Clearances

Platform clearances were taken as 760 mm from the running edge of the rail. All the platforms in the current design are positioned on straight sections of track and so no curvature effects needed to be taken into account.

### 12.10.2 Spacing a of Lines and Lineside Clearances

### 12.10.2.1 New Works and Alteration to Existing Works

The primary new works that have an impact on this Study is the construction of new overbridges to replace the existing infrastructure. The bridge abutments of these new structures causing the greatest concern.

The new overbridge at Le Fanu provides 4500 mm lateral clearance plus allowance for throw and cant effects from the nearest running edge to the new bridge abutment.

The new overbridge at Kylemore is to provide the minimum lower lateral clearance of 2500 mm plus allowance for throw and cant effects. The abutments in this case will be designed to withstand derailment collision loading.

### 12.10.2.2 Clearance Between Tracks and Sidings

The standard six-foot (1970mm) has been maintained between a pair of running lines, measured between the running edges and on straight and level track. Spacings have been increased to allow for the effects of throw and cant as necessary. At crossovers, the minimum track spacing increases to 2000 mm, the change from 1970 mm taking place over a distance greater than or equal to 10 m.

Between the second and third pair of running rails, the required 10 foot (3580 mm) is generally maintained as per IÉ track standards, with increased allowance for throw and cant, with the following proposed derogations to be applied, which are agreed in principle by IÉ. (**Table 56**).

#### 12.10.2.3 Lineside Clearances to Structures

The alignment design adheres to IÉ standards with regards to clearances between tracks and wayside structures / OHLE masts.

Wherever possible a greater clearance between the tracks and structures has been provided than the minimum specified by the IÉ track standards.

Cant	Н	Cant	Н	Cant	Н
0	4830	60	4910	120	4989
10	4843	70	4923	130	5002
20	4857	80	4936	140	5016
30	4870	90	4949	150	5029
40	4883	100	4963	160	5042
50	4896	110	4976	165	5055

Table 57: Additional Allowance for Cant Effect (in mm)

	Design Track	R	Rail		То
	CAT	Section	Grade	From	10
Up DART	1	54E1	260	7+440	14+500
Down DART	1	54E1	260	7+460	14+500
UP Main	1	54E1	260	9+432.115	13+050.551
Down Main	1	54E1	260	9+432.917	13+031.187

Table 58: P-Way Line - New Works Specification

Track Radius	Gauge	Check Rail Flangeway
200-141 m	1606 mm	57 mm
140-111 m	1613 mm	64 mm
≥110 m	1619 mm	70 mm

#### Notes:

- 1. Rate of change in gauge and flangeway widening must not exceed 1 in 400, e.g. 3 mm in 1200 mm (or two sleepers).
- 2. The dimension from the running edge of the non-checked rail to the inner flangeway facae of the check rail must be 1556 (+1, -3) mm.

Table 59: Gauge for Track less than 200m Radius

#### 12.10.3 Overhead Clearances

Overhead clearances have been designed to a minimum vertical height of 4830mm with additional clearance being provided in areas with canted track as per **Table 57** opposite. At Le Fanu overbridge, a minimum vertical clearance of 5300 mm is proposed. At Kylemore Road Bridge, the vertical clearance proposed is 4830 mm, which will require a derogation from standards. As previously outlined, it is not feasible to achieve 5300 mm unless the trackbed is lowered in this area and contained within a watertight concrete trough.

### 12.10.4 Rail Types

### 12.10.4.1 Running Rail

All tracks shall be continuously welded CEN 54E1 profile rails inclined at 1:40 towards the centre of the track as per **Table 58** opposite.

### 12.10.5 Track and Effective Gauge

The track gauge shall be 1602mm measured at right angles between the running edges of the rails in a plane 14mm below their top surface.

In the CIÉ Inchicore Works Yard, there are numerous curves, which have a radius below 200m. For curves of 200m radius or less, the nominal gauge must be widened as per **Table 59** opposite.

### 12.10.6 Rail Support System

#### 12.10.6.1 Ballasted Track

All surface track is to be ballast track in accordance with IÉ Standards.

#### 12.10.6.2 Slab Track

The track in the tunnels shall be a low maintenance slab-track providing the optimum noise and vibration attenuation. It shall have high electrical insulation properties to mitigate stray currents.

### 12.10.7 Switches and Crossings

Turnouts and Crossovers comply with lÉ standard geometries. See **Table 60** overleaf.

#### 12.10.8 Vehicle Overrun Protection

In the proposed alignment design, there are two buffer stops and one trap point to prevent vehicle overruns as per **Table 61** overleaf.

The current IÉ standard friction buffer type is a RAWIE 4 ZEB/6. This should be reviewed at the time of implementation to check if the standard buffer has changed.

The trap points are positioned on the eastern end of the Inchicore works to prevent vehicles entering the mainline without permission. The trap point is to use a P8 switch.

### 12.11 Rolling Stock

It is proposed that the existing DART rolling stock will be used on the Slow tracks with allowance for the Mainline services to run on the Slow tracks as a result of a major event or operational perturbation. Mainline services would operate on the Slow tracks under speed restrictions. This Study has not taken freight traffic into consideration for clearances at the various structures along the route.

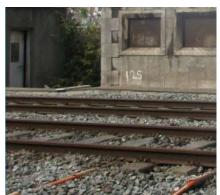
P-Way S&C - New Works Specification							
Chainage IP Point	Unit	Desigr Through	Speed Diverging	Switch Size	Crossing Angle	Bearer Material	Design Track CAT
10+768.433 Up Main	54E1	100	30	P10	10	Concrete	1
10+735.436 Down Main	54E1	100	50	P15	18.5	Concrete	1
11+650.062 Down Main	54E1	120	30	P10	10	Concrete	1
11+779.753 Up Main	54E1	120	50	P15	18.5	Concrete	1
13+113.537 Up DART	54E1	120	30	P10	10	Concrete	1
13+427.260 Down DART	54E1	120	50	P15	18.5	Concrete	1
Inchicore Works Multiple Units*	54E1	15	15	P8	8	Concrete	3

<sup>\*16</sup> P8/8 Units used in the revised Inchicore Works layout.

Table 60: P-Way S&C - New Works Specification

	Limiting Design Criteria	Comment
Absolute Maximum Grade	3.5%	For a maximum length of 1.66 km and 3% over longer distances
Maximum Grade	3%	
Minimum Grade	0.2%	To Facilitate Track Drainage
Maximum Grade, Freight	2%	

Table 61: Buffer Stops







### 12.12 Further Alignment Work Required

Areas identified as requiring further work at the next stage of design development are:

- An investigation into the effects of the new yard layout at Inchicore on rail operations and maintenance;
- Investigation into the effects of the new proposed turnback at Park West / Cherry Orchard Station and the redesign of the station platforms. It should be noted that due to the re-designation of the lines from a Fast-Slow-Slow-Fast configuration to a Slow-Slow-Fast-Fast configuration, this has an impact on line capacity at all of the turnbacks as the trains will now have to crossover the Down Slow track in order to reach the Up Slow track when leaving any of the turnbacks.
- Investigation into the on-track auxiliary equipment required such as rail lubricators for some of the tighter radius curves;
- Ground Investigation including track bed investigation from Sarsfield Road to Le Fanu overbridge. Accordingly investigate the possibility of providing 5.3 m vertical clearance at Kylemore Road overbridge and achieving a platform at the proposed Kylemore Road station with a vertical gradient of 0.2%;
- Construction planning of the phased railway
  works related to the slewing of the Mainline
  tracks and construction of the four tracking
  from the end of KRP Phase 1 Works to
  Sarsfield Road. This shall include the phased
  construction of the retaining walls, ensuring
  that IÉ operational and access into the
  Inchicore Works are maintained, identifying the
  need for railway possessions and night-time
  working;

- Construction and traffic phasing for the demolition and construction of the proposed Kylemore Road overbridge and new station concourse area;
- Identification of the location of OHLE Masts and confirmation of all landtake. Identify areas where a relaxation in the 10 foot requirements can be accommodated which would influence the form and location of the OHLE masts, and any derogations from standard in terms of placing OHLE Masts closer to the running rails to avoid acquiring lands beyond the existing IÉ property boundary.

### 12.13 Potential Options for Future Development of the Alignment

Potential areas for further design development in the next stage of the Project include:

- Removal of reverse curves in the tunnel section:
- Facilitate access from DART lines into the Inchicore Works if desired by IÉ;
- Review of the track alignment to identify the optimal crossover locations from the Mainline track onto the slow DART tracks;
- Changing bearing on Park West / Cherry Orchard Station to allow turnback and crossover to be placed closer together.



# 13. Phase 4: Feasibility Working Cost Estimate of the Emerging Preferred Option



# 13.0 Phase 4: Feasibility Working Cost Estimate of the Emerging Preferred Option

Chapter 10 of the Study sets out the basis for deriving the Feasibility Working Cost Estimate for the MCA Options. This Chapter presents the basis for undertaking the Feasibility Working Cost Estimate of the Emerging Preferred Option, summarises the outcome of the cost studies and discusses changes in the cost estimate since 2010, when the original DART Underground cost estimates were produced.

#### **13.1 Running Tunnels**

The entire cost of the running tunnels including preliminaries has been repriced from first principles using 2017 rates. This approach was adopted to ensure complete independence from the original cost estimates and provide a basis for undertaking an effective comparison of the previous work undertaken.

To better understand the magnitude and reasoning for any differences from the previous cost estimates, the repricing of the running tunnels has adopted the same structure as that of the original DART Underground cost estimates, completed in 2010.

Having calculated the cost of the total tunnelled length, a unit price per metre length of running tunnel has been derived. As such, the length of running tunnel east of Watling Street is assumed to be identical to that of the original DART Underground and added to the length of running tunnel proposed for the emerging preferred option, to the west of Watling Street. For the emerging preferred option, the length of running tunnels from

the tunnel portals to Watling Street represents approximately 35% of the total tunnel length considered.

A price has been developed for both the Direct Works element and the Contractor Preliminaries associated with the tunnel drives. The developed preliminaries costing has been used to review the percentage preliminaries additions used in the original DART Underground cost estimates.

The comparison of the tunnel repricing derived from first principles with the rates used in the original DART Underground, inflated from the original base date of 1st January 2009 to 2017, has demonstrated a good correlation between the independent approaches; the calculated costs being of a similar magnitude.

Preliminary Costs For Running Tunnel Drives	% of Prelims Costs
1. Technical and Administrative Staff	58.95%
2. Attendant Labour	6.53%
3. Site Accommodation/temp buildings	23.19%
4. Plant / transport & tools (not in rates)	2.03%
5. Contractor Insurance	2.49%
6. Skips/protection/clean/testing/samples	0.80%
7. Health/safety/environmental	1.63%
8. IT equipment and setup costs	1.98%
9. Temporary works & services	0.26%
10. Design services/fees/surveys	1.92%
11. Other fees / licences / consents	0.22%
TOTAL	100.00%

Table 62: Breakdown of Preliminaries Costs for Running Tunnels







#### 13.1.1 Direct Works

The pricing of the Direct Works has been undertaken from first principles using an activity and resource usage approach linked to programme durations to determine the labour and equipment costs.

Both underground and pithead labour has been costed on a shift basis derived from the developed programme for the total tunnel drives. Equipment has been costed on a purchase and resale basis, as is normal for tunnelling projects. Costed activities include not only those comprising the underground work, but also those surface service activities at the pithead directly linked to the tunnelling activity and having a duration governed by time taken to drive the tunnel bores.

Materials have been costed on a measured and purchased basis using current material prices.

The Direct works have been priced using known current rates for similar tunnelling activities based on recent tunnelling projects in London, such as Crossrail and Thames Tideway Tunnel. The pricing at this level has been carried out using rates in Sterling and converted to Euro using an assumed currency rate of €1.00 = £0.91.

#### 13.1.2 Contractor Preliminaries

Preliminaries have been calculated using a bespoke system to break down the overall preliminaries into 11 sub-accounts. The analysis is based on identifying which costs are fixed and which are applicable to variable works, then subsequently the preliminaries are reduced to an equivalent percentage of the Direct Works, to enable a comparison with the original DART Underground cost estimates, as presented in **Table 62**.

In considering the general management aspect of the preliminaries, costs have been developed to reflect the total project scope. An estimate of the elements attributable to the tunnelling works has been derived, by assuming that the underground works represent 60% of the total direct cost of the project. Preliminaries directly associated with the underground works, have been identified and estimated separately within the sub-accounts.

This approach offers a good correlation and confirms the preliminaries rate of 40% of Direct Costs, which was developed previously as part of the original DART Underground. On this basis, the 40% addition for preliminaries has been used to evaluate the contractor preliminaries associated with the tunnelling and underground aspects of the Feasibility Working Cost Estimate for the Emerging Preferred Option.

A review of the build up to these preliminaries offers the breakdown.

### 13.2 Cross Passages and Platform Tunnels

The cross passages associated with the Emerging Preferred Option, from Watling Street to the tunnel portals has been quantified and priced using the original DART Underground 2009 inflated base rates on the basis of the correlation between direct pricing and preliminaries percentage addition established for the running tunnels.

Similarly, the platform tunnel enlargements have been priced also adopting the 2009 inflated base rates and tunnel preliminaries percentage of 40%.

	Description	Cost (€) 2017
A) Bore	ed Tunnels, Cross Passages, Running Tunnels and Underground Station	
1	Tunnel Portal	37,892,131
2	Tunnelling Works from Watling St	111,059,665
3	TBM Procurement (TBM costs on a pro-rata basis equal to 35% of total TBM procurement costs)	10,258,658
4	Heuston Station	109,476,416
5	Heuston Station - Enabling Works	7,723,480
	(A) Direct works Sub-Total	€276,410,350
B) Tracl	Widening Park West / Cherry Orchard Station to Tunnel Portal	
6	Inchicore Works & Contractor Surveys	2,257,000
7	Park West / Cherry Orchard Station Turnback	10,000,000
8	Kylemore Station	4,700,000
9	Four Track Widening Memorial Road - Inchicore	20,582,198
10	Inchicore Building Removals / relocations	2,750,000
11	Inchicore Access Works	1,000,000
12	Fast Fast Slow Slow track adjustments	7,000,000
13	Provisional allowance for Temporary Closure of Sarsfield Road	750,000
14	Property for Park West / Cherry Orchard Station, Kylemore, B4T	7,500,000
15	Le Fanu – Kylemore Works	28,183,000
16	Kylemore – Inchicore Works	22,034,000
	B) Direct Works Sub-Total	€161,038,396
C) Estim	pated Risk	2101,000,000
15	Uplift on Estimate for level of Design Risk	4,608,716
	C) Direct Works Sub-total	4,608,716
D) Servi		1,000,110
16	Trackworks	24,668,531
17	Signalling System	9,959,355
18	Telecommunications System	6,667,237
19	HV & LV Power Supplies	15,259,671
20	HV & LV Power Connections	7,443,597
21	Overhead Line Electrification	3,951,990
22	Tunnels - M&E Services	12,929,125
23	Ticketing	1,093,828
	Service Diversions	4,278,086
24	55.7155 2.751.5151.5	
25	Testing and Commissioning (1.0%)	2,358,797
	D) Direct Works Sub-Total	€89,789,614
E) Implies	A + B + C + D Overall Direct Works Sub-Total	€477,564,878
	ct Costs	10 110 007
26	Insurance	12,416,687
27	Design	30,623,848
28	Management	44,251,460
29	Risk	141,214,218
30	Vat	95,319,597
	Overall Indirect Works Sub-Total	<b>€</b> 323,825,810

Table 63: Detailed Breakdown of Feasibility Working Cost Estimate

### 13.3 Tunnel Portals and Approach Structures

The tunnel portals and approach retaining structures have been recalculated to derive the new quantities based on the drawings contained within Volume 3 of the Study. The rates used for the cost estimates of these structures is based on a combination of the recent Crossrail Project in London, rates for similar tunnel portal piling projects and the original DART Underground 2009 inflated base rates for items related to finishes.

Sub-accounts for works other than the running tunnels, cross passages, mined platform enlargements and mined elements of the underground stations, have a preliminaries allowance of 20% of Direct Works costs, which is similar to that derived as part of the original DART Underground cost estimates. This 20% rate of preliminaries allowance was reviewed as part of this Study and no change was deemed necessary for the non-tunnelling and non-mined activities.

### 13.4 Contractor's Overhead, Profit and Bonds

These elements have been priced using the percentages applied to Direct Works costs adopted in the original DART Underground cost estimates.

### 13.5 Feasibility Working Cost Estimate

The Feasibility Working Cost Estimate for the Emerging Preferred Option is summarised in **Table 63** overleaf and the detailed breakdown is provided in Appendix F of this Study. These rates for disposal of material are assumed the same as the original DART Underground base inflated from 2009 to 2017 rates. Since 2009, levies on the disposal of waste material have substantially increased and Section 13.6 of this Study, explains the potential impacts of these waste levies.

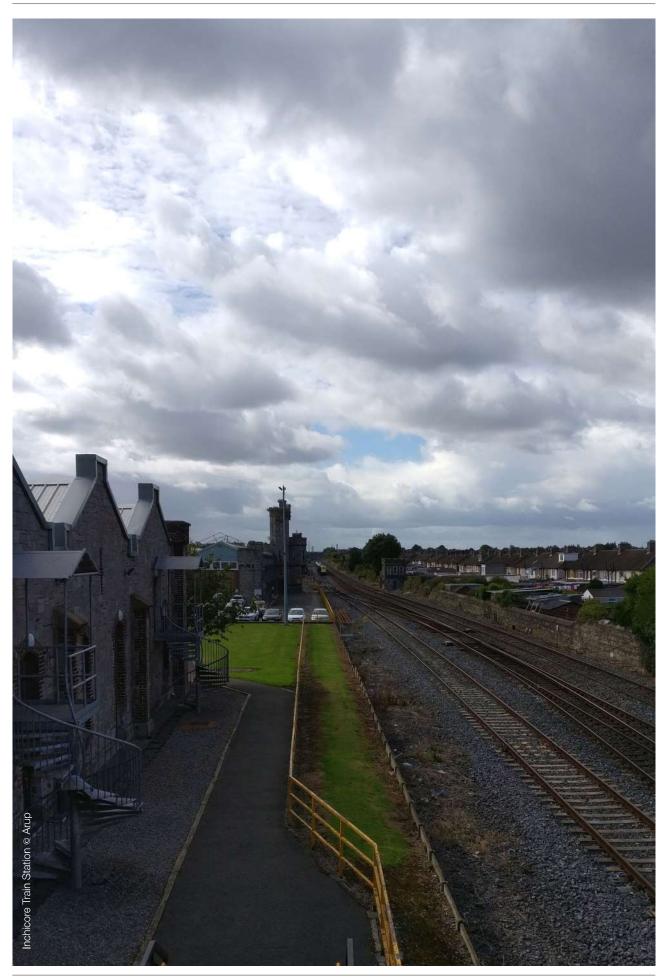
The Working Cost Estimate for the Emerging Preferred Option is €801,390,689 based on 2017 rates. No provision is made for future construction inflation.

### 13.6 Additional Costs due to Disposal

The landfill levy in Ireland at the time of the original DART Underground was €20 per tonne as of 1st January 2009. The current landfill levy rates is €75 per tonne. Any excavated material from the DART Underground Project deemed to be non-hazardous or inert material but disposed of at a quarry or landfill site, could potentially be subject to the landfill levy.

The Feasibility Working Cost Estimate is based on the original 2009 rates for the disposal of excavated material, base inflated to 2017. An analysis was undertaken to determine the financial impact if the increased landfill levy is applied to inert and non-hazardous waste material. The financial impact on the Western Tie-In Project is estimated to be an increase in the Feasibility Working Cost Estimate of €45.5 Million.

It is recommended for future stages of the Project, that the treatment of excavated material, the method of disposal and clarification as to whether or not the landfill levy is to be applied to inert or non-hazardous material be determined.



### 14. Conclusions & Recommendations



### 14.0 Conclusions & Recommendations

The NTA in collaboration with larnrod Éireann (IÉ) commissioned Arup to evaluate possible options and recommend a Preferred Option for linking the proposed DART Underground tunnel project to the existing surface rail line serving Heuston Station.

#### 14.1 Brief and Objectives

The scope of this Study, entitled the "Western Tie-In", is from Watling Street in the east to Park West / Cherry Orchard Station in the west.

The primary objectives of the Western Tie-In Study were:

- To carry out a comprehensive and robust selection Study, identifying all feasible and practicable options;
- To develop concept designs for key relevant options;
- To carry out data collection, research, studies and appraisals necessary to support a robust and comprehensive options selection process leading to the identification of an optimal design (the Preferred Option);
- To ensure that the design west of the tunnel connection point is capable of supporting four tracks on the surface to connect with the existing four track system at Park West / Cherry Orchard Station;
- To ensure that the design facilitates passenger interchange between DART Underground Heuston Station and the existing surface at Heuston Terminus Station;
- To prepare a concept engineering design for the Preferred Option;
- To prepare a Feasibility Working Cost for the Preferred Option.

### 14.2 Options Identification and Assessment

The methodology devised in response to the brief for this Study has four distinct phases, namely:

Phase 1: Review

Phase 2: Identification of Options

Phase 3: Assessment of Options

Phase 4: Concept Engineering

In **Phase 1** of the Study, 28 potential solutions were identified during a Brainstorming Workshop. Through screening for compliance with the requirements of the Study, 21 of the 28 potential solutions were found to be compliant. These compliant solutions, entitled "Identified Possible Options", advanced to Phase 2 of the Study to be evaluated.

In **Phase 2** of the Study, an options sifting and appraisal process was employed to evaluate, which of the 21 Identified Possible Options were both feasible and practicable. Following completion of the evaluation, seven options were found to be feasible and practicable. These seven options were then carried forward to the Phase 3 Multi-Criteria Assessment (MCA) of Options.

The **Phase 3** MCA facilitated a structured approach to determine overall performances amongst the seven options to be comparatively

assessed, across a number of criteria, which were considered important to the DART Underground Western Tie-In Study.

The four MCA criteria identified included Economy, Integration, Accessibility and Social Inclusion, and the Environment. Within each of the criteria, there was one or more assessment sub-criteria identified, which were separately, comparatively assessed using a colour coded ranking system. An overall ranking was assigned under each of the four main criteria to each of the seven options.

The seven MCA Options contained five options with through running connection onto the Heuston Mainline and two options, which terminated below ground at Heuston with an underground tumback and interchange to the existing surface Mainline Station. It is acknowledged that the transport benefits of a through running connection and that of a terminus arrangement differ.

Whilst the MCA comparative assessment was able to assess the relative advantages and disadvantages of the seven options and select a Preferred Option, the selection of the Preferred Option is limited to the scope of this Study, namely a tunnel(s), which extends east of Watling Street but the remainder of the route alignment is not yet defined. In a similar manner, the selection of a twin bore tunnel configuration or a monotube tunnel configuration cannot be finalised until the outcome of the future transport benefit studies and overall route alignment options study is known.

Notwithstanding the need to revisit the outcome of this Study once the transport benefit studies have been finalised, the Phase 3 MCA identified that Option Twin 2C was the Preferred Option. This Option is a twin bore tunnel configuration with the western tunnel portal located in the Con Colbert Road, at the junction with the Chapelizod Bypass, and also incorporates an area known locally as the "Horses Field". The tie-in to the Heuston Mainline occurs just east of the existing Sarsfield Road Underbridge. The proposed Heuston Underground Station is identical to that of the original DART Underground.

The MCA comparative assessment identified that Option Twin 2C has significant advantages over all other MCA options with respect to the principal criteria of Economy and Environment. Option Twin 2C also has some advantages over all other options except Option Twin 2F, in respect of the principal criterion of Integration.

#### 14.3 Concept Engineering and Feasibility Working Cost Estimate

A concept engineering design of the Emerging Preferred Option has been undertaken and Volume 3 of the Study contains the design drawings along the length of the Western Tie-In.

The Feasibility Working Cost of the Emerging Preferred Option is €801.4 Million, which represents a saving of €228.4 Million from an optimised version of the original DART Underground and therefore achieves one of the primary goals of the Study, which was to provide a lower cost technical solution, whilst retaining the required rail connectivity.

The Feasibility Working Cost Estimate has been calculated for Quarter 4, 2017 and includes no construction inflation beyond this baseline date.

In undertaking the Feasibility Working Cost Estimate, a repricing was undertaken of the tunnel drives, for both the Direct Works element and the Contractor Preliminaries associated with the tunnel drives. The comparison of the tunnel repricing derived from first principles with the rates used in the original DART Underground, inflated from the original base date of 1st January 2009 to 2017, has demonstrated a good correlation between the independent approaches; the calculated costs being of a similar magnitude.

#### 14.4 Recommendations

In the course of undertaking the Study, a number of recommendations for future investigations and refinements of the Emerging Preferred Option have been identified and these are summarised as:

- Complete the Transport Benefits Study and an overall route alignment options study to confirm the selection of the preferred tunnel configuration and whether the DART Underground should have through running onto the Heuston Mainline or terminate below ground at Heuston Station;
- 2. Following completion of the Transport Benefits Study and the overall route alignment options study, re-examine the findings of this Study and confirm that Option Twin 2C remains the Emerging Preferred Option;

- 3. Confirm if the provision for a future Station at Kylemore Road is to be included in the next stage of the DART Expansion Programme;
- 4. There are a number of surveys, studies and options suggested in **Chapter 12** to refine the alignment, operations and minimise landtake. It is recommended that these additional investigations be undertaken to further optimise the Scheme.



## References

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