TP-041

Reference number - 30033212

05/10/2018

DART Expansion Programme Options Assessment

SYSTRA JACOBS Údarás Náisiúnta Iompair National Transport Authority Iarnród Éireann Irish Rail

TP-041 DART EXPANSION PROGRAMME OPTIONS ASSESSMENT

IDENTIFICATION TABLE	
Client/Project owner	NTA
Project	TP-041
Study	DART Expansion Programme Options Assessment
Type of document	Draft Options Report
Date	05/10/2018
File name	DART Expansion Programme Options Assessment - Final Report
Framework	NTA TPS Framework
Reference number	30033212
Confidentiality	Confidential
Language	English
Number of pages	108

APPROVAL					
Version	**Name**		**Position**	**Date**	**Modifications**
1	Author	Philip Kavanagh / Paul Hussey	Consultant / Principal Consultant	26/02/2018	1st Draft for Client Review
	Checked by	Paul Hussey	Principal Consultant	26/02/2018	
	Approved by	Ian Byrne	Director	26/02/2018	
2	Author	Paul Hussey	Principal Consultant	06/03/2018	Final Draft
	Checked by	Ian Byrne	Director	07/03/2018	
	Approved by	Ian Byrne	Director	07/03/2018	
3	Author	Paul Hussey	Principal Consultant	24/09/2018	Final
	Checked by	Ian Byrne	Director	05/10/2018	
	Approved by	Ian Byrne	Director	05/10/2018	

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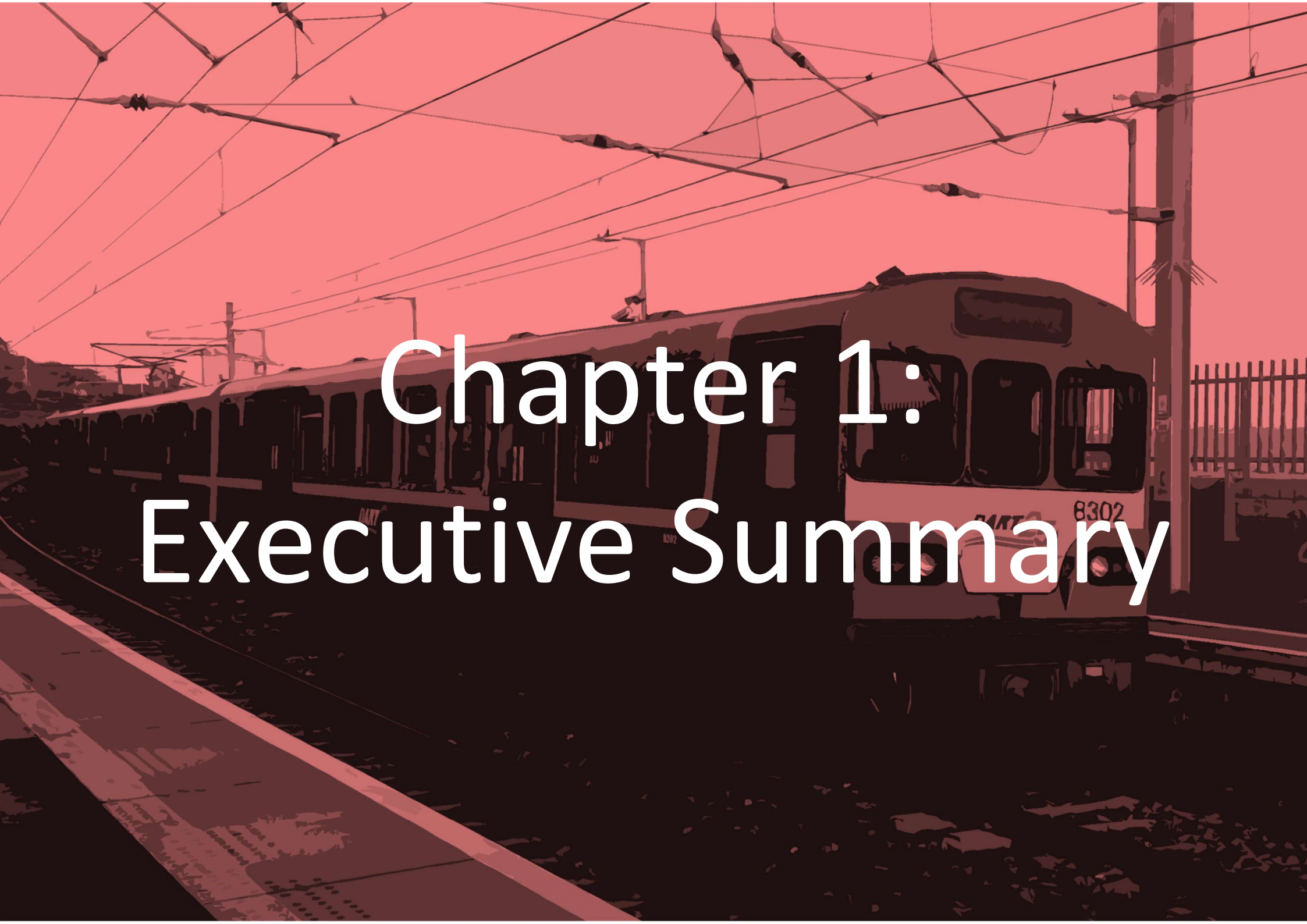


Chapter 1: Executive Summary

1. EXECUTIVE SUMMARY

1.1 Context

1.1.1 There are a number of key infrastructure measures which form part of the Government's Project Ireland 2040[1] - National Planning Framework (NPF) and National Development Plan (NDP) 2018-2027 and the National Transport Authority's (NTA) Greater Dublin Area (GDA) Transport Strategy[2].

1.1.2 These key infrastructure measures include DART Expansion, MetroLink[3], Luas and BusConnects[4]. These schemes, which will support the delivery of an environmentally sustainable low-carbon public transport system, will ensure that public transport will be able to meet the significant growth in passenger demand for public transport services in the Eastern and Midlands Region by 2040.

1.1.3 The NTA commissioned SYSTRA and Jacobs to undertake an extensive transport modelling and appraisal of one of these key infrastructure measures - DART Expansion Programme.

1.2 Background

1.2.1 The DART Expansion Programme which consists of a number of investment projects that will significantly expand the heavy rail capacity, frequency and connectivity in Dublin city centre and throughout the GDA. These projects are shown on Figure 1 below and include the following elements:

- Electrification of the Cork Line to Hazelhatch and completion of 4 tracking from Park West to Inchicore;
- Electrification of the Northern Line to Drogheda;
- Electrification of the Sligo Line to Maynooth, together with the removal of level crossings and re-signalling on this line;
- Expansion of fleet and depot facilities; and
- The ***DART Underground Project***, consisting of a 7.6km underground tunnel through Dublin city to link the Northern Line to the Cork Line.

1.2.2 The DART Expansion Programme has strong policy support at European, national, regional and local level. It is a pre-identified project on the Core Network Corridors in the Connecting Europe Facility (CEF) and a priority project in the Trans-European Transport Network (TEN-T).

1.2.3 However, due to the significant cost of the underground tunnel element (DART Underground) of the DART Expansion Programme

[1] Project Ireland 2040 is the Government's overarching planning policy initiative for development up to 2040. It was published along with its associated documents the National Planning Framework to 2040 and the National Development Plan 2018-2027 in February 2018.

[2] The Transport Strategy for the Greater Dublin Area, 2016-2035 was prepared and published by the National Transport Authority in 2016

[3] MetroLink is the combined New Metro North and Metro South metro scheme proposed to run from Swords to Sandyford with an anticipated year of opening of 2027

[4] BusConnects is a project, run by the NTA, to overhaul the current bus system in the Dublin Region (https://www.busconnects.ie/about/)

(which has an estimated cost of €2 billion) and recognising that a lower cost alternative for the tunnel element may be possible, this project has sought to identify a lower cost alternative to the proposed DART underground tunnel component of the DART Expansion Programme. It does this in the context of the importance of the DART Expansion Programme as identified in the GDA Transport Strategy and following on from the NTA recommendations on the deferral of the DART Underground Project in 2015. It also seeks to maintain similar transport user benefits, as far as practicable, to that of the original DART Underground scheme and to maintain all other elements of the DART Expansion Programme.

This report does not consider the alteration of the extent of the proposed electrified rail network as set out in the GDA Strategy i.e. electrification to Hazelhatch, Maynooth and Drogheda. In addition, all non-tunnel elements of the DART Expansion programme are considered core requirements of the project and are included in full.

1.2.4 Since the planning and design of the DART Underground Project commenced in 2002 and the granting of the DART Underground Railway Order in 2011, the public transport landscape in the GDA has changed substantially. These changes include the completion of a number of rail and Luas schemes and planning regarding Metro North.

1.2.5 These changes include the following:

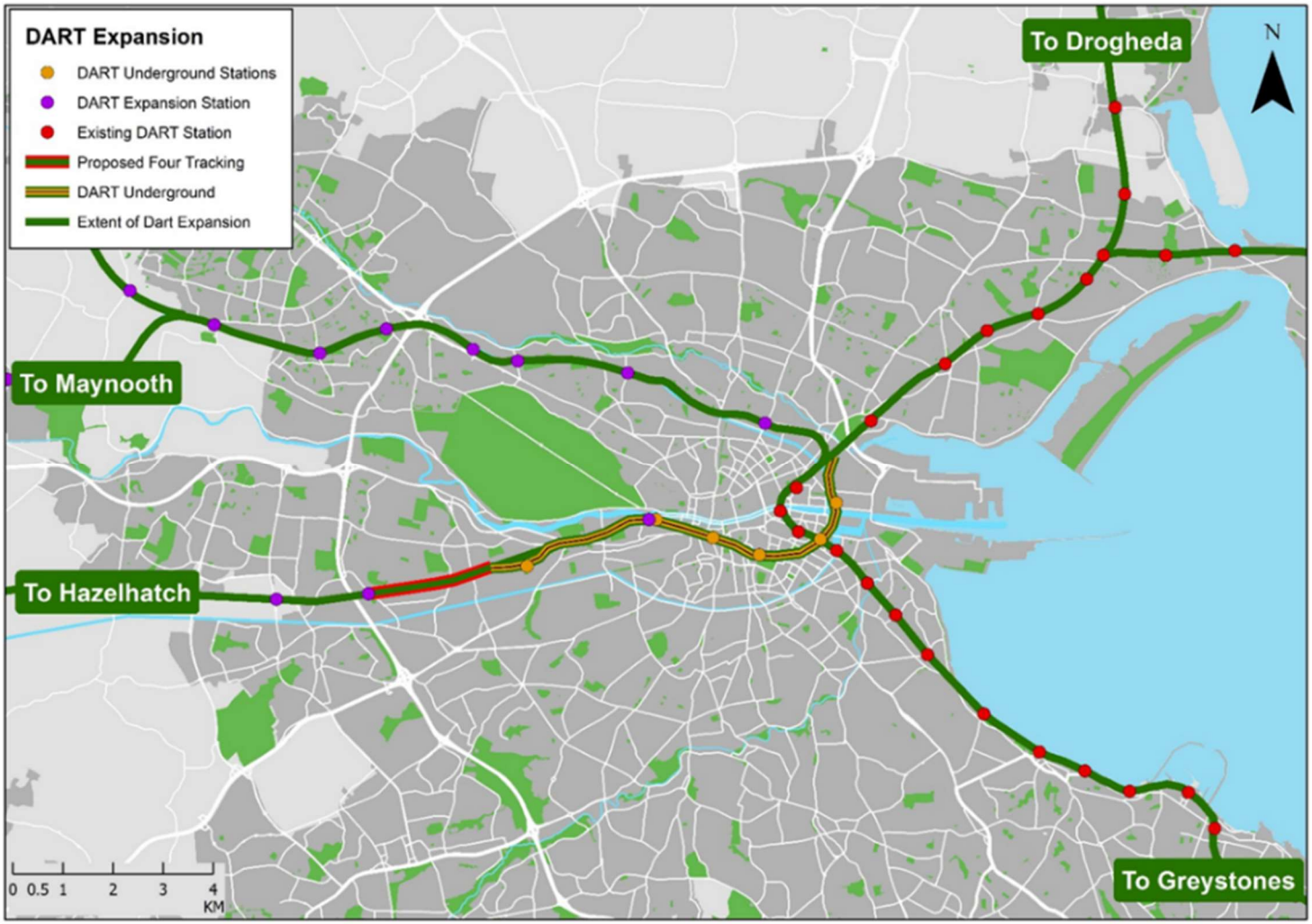
- The City Centre Re-signalling Project (CCRP)[5];
- The re-opening of the Phoenix Park Tunnel (PPT)[6];
- Luas Cross City;
- Proposed new Metro North (NMN) and Metro South (the combined scheme referred to as MetroLink); and
- Improved bus services.

1.2.6 The impact of these changes are considered in this report.

[5] The CCRP is Iarnród Éireann's re-signalling project with the aim of increasing the capacity and frequency of trains from Howth Junction to Grand Canal Dock in Dublin.

[6] The Phoenix Park Tunnel was re-opened for commuter rail services in November 2016

Figure 1. Extent of Original Proposed DART Expansion Study



1.3 The Assessment of DART Expansion

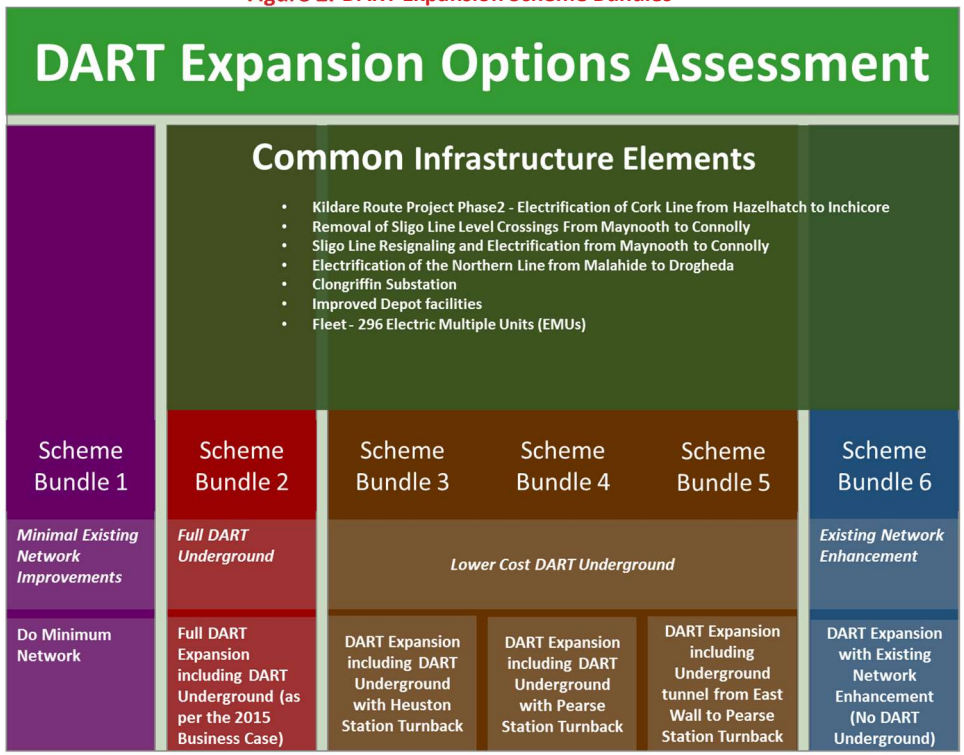
1.3.1 To assess lower cost alternatives for the DART Underground tunnel component of DART Expansion, a number of options were developed. These options or scheme bundles were developed by the NTA, Iarnród Éireann (IÉ) and SYSTRA / Jacobs. These are shown in Figure 2 below.

1.3.2 These scheme bundles cover a range of infrastructure options from a Do Minimum Network, to DART Expansion with full implementation of the DART Underground, to lower cost tunnel alternatives and to a no tunnel (no DART Underground) option. The following summarises the scheme bundles assessed:

- **Scheme Bundle 1 – Do Minimum Network** assumes limited changes which is used as the reference case against which all other scheme bundles are assessed;
- **Scheme Bundle 2 –** Full DART Expansion including DART Underground (as per the 2015 Business Case);
- **Scheme Bundle 3 –** DART Expansion including DART Underground with Heuston Station Turnback;
- **Scheme Bundle 4 –** DART Expansion including DART Underground with Pearse Station Turnback;
- **Scheme Bundle 5 –** DART Expansion including Underground tunnel from East Wall to Pearse Station Turnback; and
- **Scheme Bundle 6 –** DART Expansion with Existing Network Enhancement (No Tunnel).

1.3.3 All the scheme bundles include the same non-tunnel elements of the DART Expansion Programme outside of the city centre.

Figure 2. DART Expansion Scheme Bundles



1.3.4 An assessment process evaluated each of the scheme bundles and involved modelling each scheme bundle using the NTA's East Regional Model (ERM)[7]. The scheme bundles were comparatively assessed against Key Performance Indicators (KPIs) to identify the best performing scheme bundles. These are referred to as the Emerging Preferred Scheme Bundles (EPSB). All transport modelling was undertaken in accordance with the Common Appraisal Framework[8] (CAF). This included a number of sensitivity tests[9] on the EPSBs to account for uncertainties in the scheme appraisal. The KPIs used to measure the performance of the scheme bundles are as follows:

- Mode Share;
- Passenger Distance Travelled;
- Passenger Time Travelled;
- Average Journey Speed per PT Passenger;
- Total Boardings by PT Sub-mode;
- Lines Summary (for key bus, rail, Luas routes etc.);
- Rail Line Profiles;
- Road network assignment statistics;
- User benefits (TUBA); and
- Transfer Analysis.

1.3.5 Following the above assessment, the two best performing scheme bundles (EPSBs) were:

- **Scheme Bundle 2:** Full DART Expansion including DART Underground; and
- **Scheme Bundle 6:** DART Expansion with Existing Network Enhancement (No underground tunnel).

1.3.6 Both the above scheme bundles performed well across a range of KPIs. For example, Scheme Bundle 2 delivered the highest levels of Transport User Benefits. However, Scheme Bundle 6 (using an assumed service pattern) delivered the highest Benefit to Cost Ratio (BCR) and also delivered the highest number of public transport passengers across all public transport modes including bus, Luas and Metro

1.3.7 Following the identification of the EPSBs, further enhancements were made to Scheme Bundles 2 and 6 which included infrastructure and services pattern enhancements and engineering feasibility assessment[10] for Scheme Bundle 6.

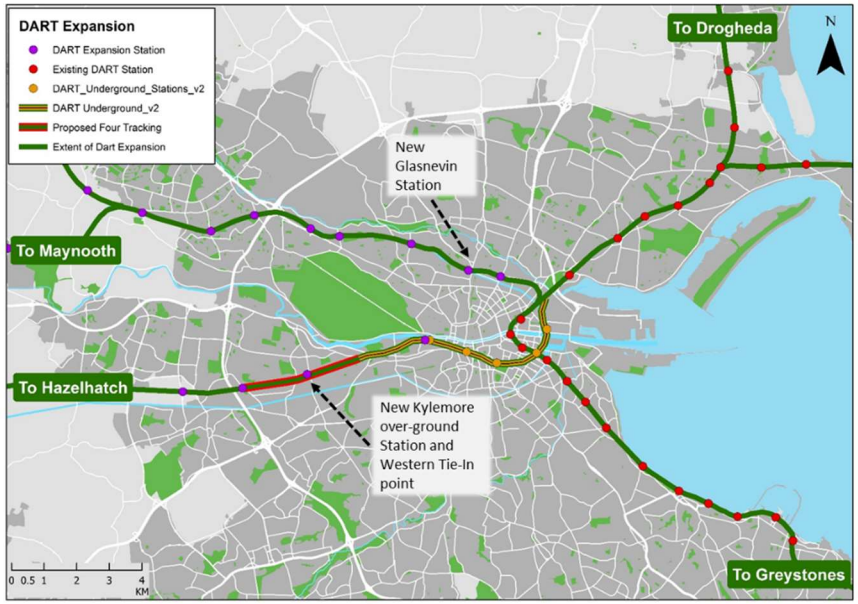
1.3.8 The alterations to Scheme Bundles 2 and 6 are illustrated in Figures 3 and 4 respectively and are detailed below.

[7] The NTA ERM is one of 5 Regional Multi-model transport models that make up the Regional Modelling System (RMS) that cover the Republic of Ireland. The ERM covers the GDA and surrounding counties.
[8] The Department of Tourism Transport and Sport (DTTaS) Common Appraisal Framework 2016
[9] Network, Land-use and Model Parameter sensitivity tests
[10] An engineering feasibility assessment was not required for Scheme Bundle 2 as this was undertaken as part of the development of the previous Railway Order.

Scheme Bundle 2 - Full DART Expansion including DART Underground

- New Glasnevin Rail Station at Whitworth Road on the Maynooth Line;
- Realignment of St. Stephen's Green Station on the DART Underground Tunnel to tie-in better with the MetroLink underground station;
- Revised Western Tie-In – which re-positions the DART Underground Tunnel portal further east and closer to Heuston Station; and
- A new above ground station at Kylemore.

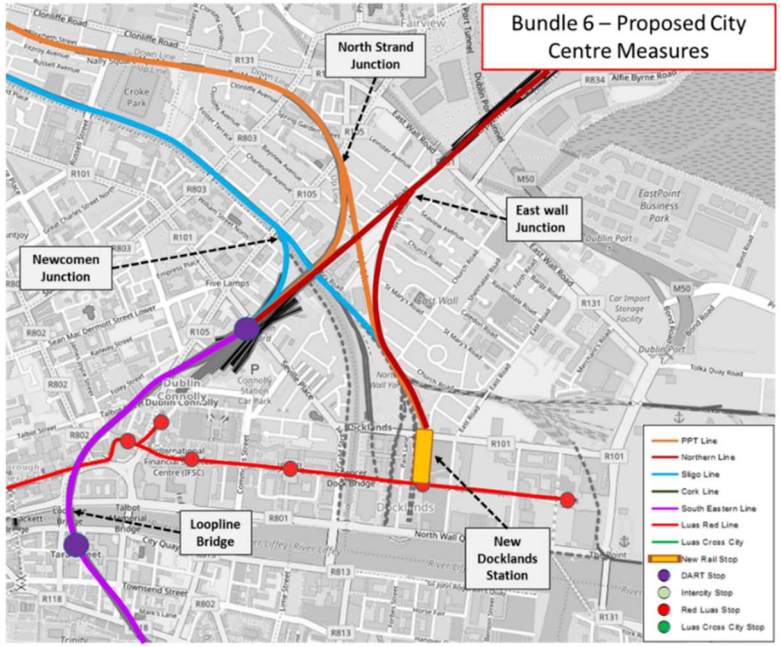
Figure 3. Optimisation of Scheme Bundle 2



Scheme Bundle 6 - DART Expansion with Existing Network Enhancement (No underground tunnel)

- New station at Kylemore on the Kildare line;
- Closing Glasnevin Junction to the crossover of services from the PPT and Maynooth lines;
- Upgrading of Newcomen Junction to a permanently open junction through the installation of a Canal Drop Lock;
- Re-opening of East Wall Junction to commuter and DART services;
- Re-opening of North Strand Junction to commuter and DART services;
- Re-configured Connolly Station;
- New Docklands Station further to the south;
- Upgrading of Tara Street Station; and
- A new turnback facility at Dun Laoghaire Station.

Figure 4. Scheme Bundle 6 – City Centre Measures



1.4 Performance Summary

1.4.1 Scheme Bundles 2 and 6 are the best performing options to deliver the DART Expansion Programme. Figure 5 below illustrates the relative performance of Scheme Bundles 2 and 6 when measured against Key Performance Indicators (KPIs). The comparative performance of Scheme Bundles 2 and 6 are shown in red and blue respectively.

1.4.2 The KPI results indicate that:

- Scheme Bundles 2 and 6 deliver similar public transport mode share levels;
- Scheme Bundle 6 is potentially €1.75 Billion less expensive than Scheme Bundle 2;
- Scheme Bundle 2 delivers higher:
  - Rail boardings;
  - Interchange levels between public transport modes; and
  - Transport user benefits.
- However, Scheme Bundle 6 delivers higher:
  - Overall public transport boardings; and
  - Public transport boardings for non-rail modes i.e. Metro, Luas, Bus etc.
- Importantly, Scheme Bundle 6 (using an assumed service pattern) delivers a Benefit to Cost Ratio (BCR) of 3.14 which is 0.65 higher than Scheme Bundle 2.

1.5 Pros and Cons Assessment

1.5.1 As the economic case for both scheme bundles is very high, a Pros and Cons assessment was undertaken. The purpose of which was to highlight the positive and negative elements of both scheme bundles when compared to one another. Table 1 below outlines the pros and cons assessment for both emerging preferred scheme bundles.

Figure 5. KPI Outputs Summary for Bundle 2 and Bundle 6

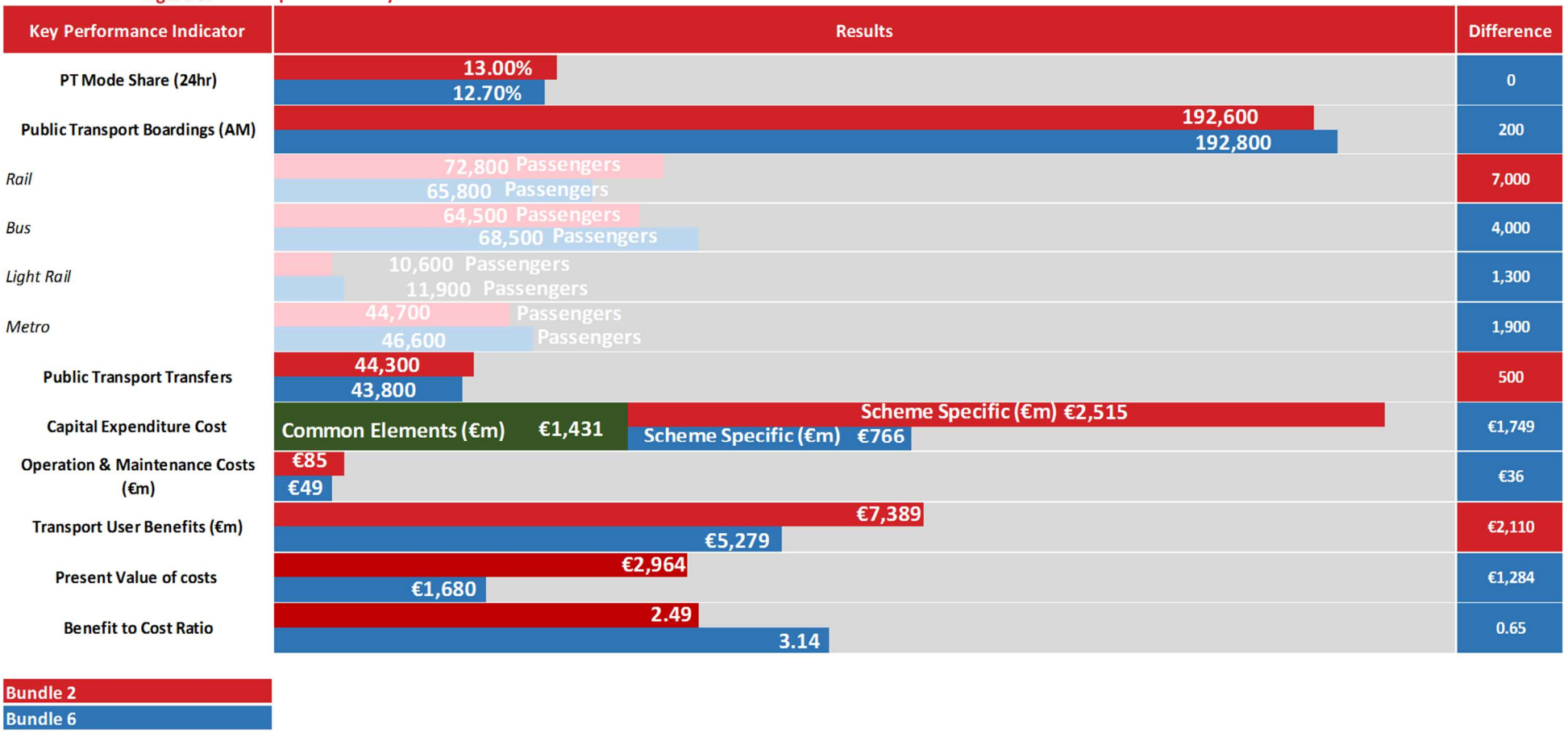


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Table 1. Pros and Cons Assessment of Scheme Bundles 2 and 6

SCHEME BUNDLE	PROS	CONS
Scheme Bundle 2	• Delivers the highest level of Transport User Benefits; • Delivers the highest level of Rail patronage; • Provides full rail network connectivity; • Strong network legibility for heavy rail; • Does not rely on interchange to the same extent as Bundle 6; • Delivers a fully grade separated network not subject to junction delays or disruption.	• Relies on interchange for South-East DART line passengers to continue northbound on the Northern line i.e. at Pearse Station; • The DART Underground tunnel is required to be built to deliver benefits, resulting in a large upfront investment requirement; • There is a long lead in time and difficulty in incrementally delivering, thereby not releasing benefits early in the scheme development; • Does not make best use of MetroLink in the short to medium term (as a ramped-up use of the PPT line is not part of this option); • Takes more public transport users away from other public transport modes (Bus, Luas, Metro), when compared to Scheme Bundle 6; • There is an impact on the development of Strategic Development Zones (SDZs) such as Clonburris, which can't develop fully until DART Underground is delivered; • Does not maximise the use of the existing available infrastructure to the same extent that Scheme Bundle 6 does.

SCHEME BUNDLE	PROS	CONS
Scheme Bundle 6	• Delivers significant benefits (€5Billion above Do Minimum); • It is the least costly option (€1.75Billion cheaper than DART Underground Option) – this money could be used to deliver other elements of the GDA Transport Strategy within the same budget envelope such as Lucan & Finglas Luas Lines and BusConnects); • Delivers a better BCR than DART Underground Option; • Makes best use of existing rail infrastructure (e.g. PPT line); • Integrates more efficiently with other PT modes (i.e. Bundle 2 results in reduced patronage on other PT Modes) • Delivers the same strategic PT mode share as the DART Underground Option; • Does not preclude building the DART Underground at a later stage when demand requires; • Can be delivered on a phased basis providing incremental benefits; • Makes more efficient use of MetroLink; • Does not require a large upfront investment to release benefits (unlike the DART Underground option which requires the tunnel to unlock any benefits) • Provides better interchange options with MetroLink and Luas Cross City; • Faster lead in time, thereby, enabling key areas to develop quicker (e.g. Clonburris SDZ).	• Does not deliver the same level of transport user benefits as the DART Underground Option (Bundle 2); • Relies more on interchange with other PT modes to work (particularly that of MetroLink and Bus) and other PT lines (i.e. South City Luas); • Requires a large interchange between Rail and Metro at Whitworth and Tara Street Stations which will be costly to construct; • Is subject to proving the operational capacity of the junctions on the system to accommodate the level of service predicted; • Does not provide grade separated solution and is subject to junction capacity delays and disruptions.

1.6 Conclusion

1.6.1 Based on the comparative modelling assessment and KPI evaluation of Scheme Bundles 2 and 6 and the assumptions contained within this report:

Scheme Bundle 6 is the preferred DART Expansion Scheme Bundle, and it is recommended that this option is brought forward for further development subsequent to a final decision on its implementation.

1.6.2 Whilst Bundle 6 is the preferred option to deliver DART Expansion, the following caveats should be noted:

- The assumed service capacities and pattern of services underpinning Bundle 6 are at maximum limits and need to be verified further by detailed timetable modelling to confirm their viability; and
- The network enhancements required to support the assumed capacities need to be developed further.

1.6.3 Notwithstanding the above, the assessment indicates that Bundle 6 will provide substantial benefits to the rail network and passengers, significantly boosting passenger numbers compared to current conditions. On this basis, it is recommended that Scheme Bundle 6 is developed further and implemented as the preferred DART Expansion Scheme Bundle.

1.6.4 Scheme Bundle 6 - DART Expansion with Existing Network Enhancement (No underground tunnel):

- makes best use of existing rail infrastructure, is not reliant on the delivery of the DART Underground tunnel and is capable of delivering the DART Expansion Programme at a much reduced cost;
- can be incrementally delivered to gradually unlock benefits as passenger demand levels increase;
- will integrate better with other public transport schemes, will maximise the patronage of MetroLink, BusConnects and Luas and, will therefore, maximise the investment in these schemes;
- will relieve some pressure on the Luas Red line in the peak periods, by reducing the need to interchange from/to Luas at Heuston for some journeys; and

should act as an interim measure while the DART Underground Project is redesigned to accommodate recent developments in the rail network.

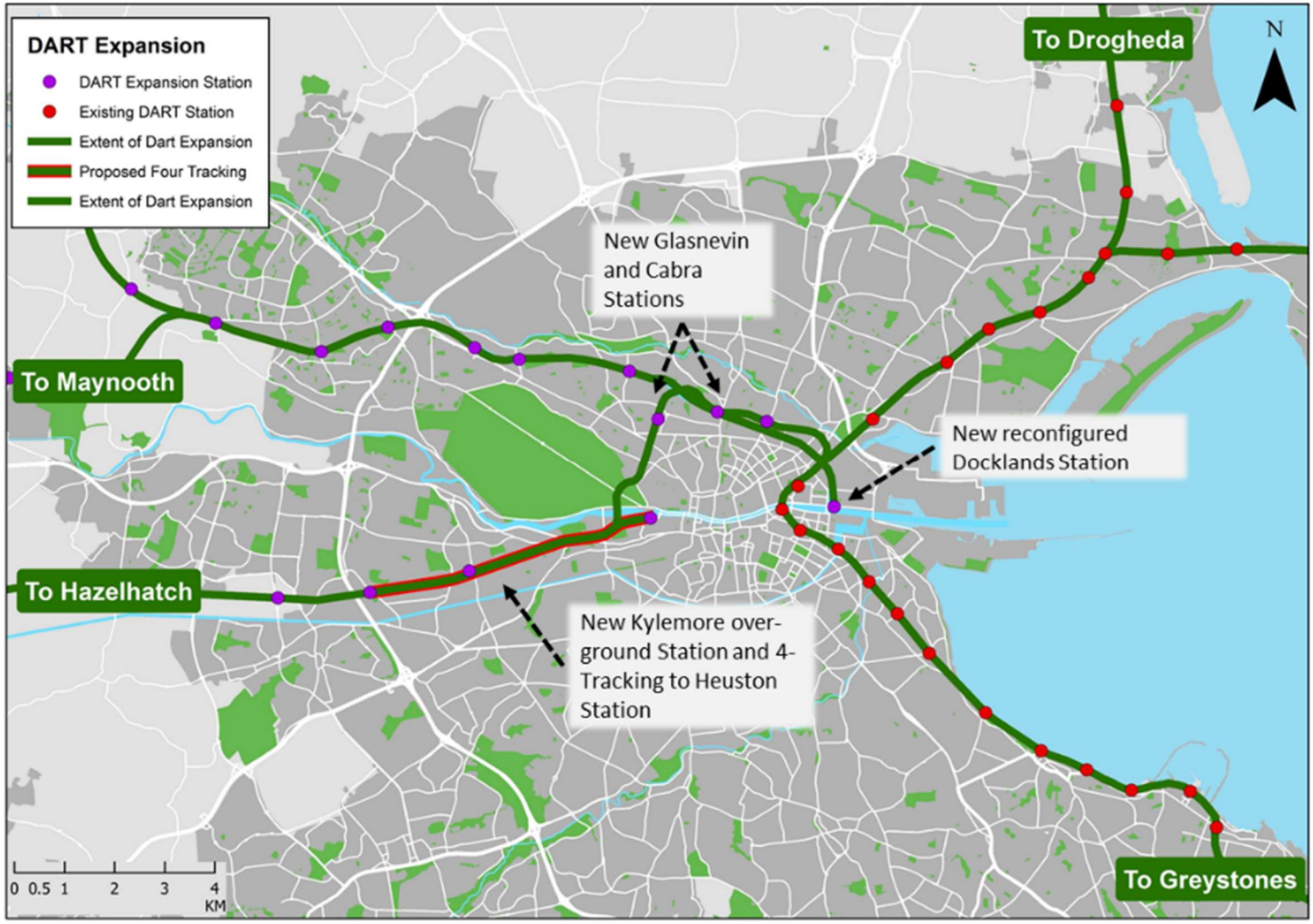
1.6.5 Important considerations for Scheme Bundle 6 are that:

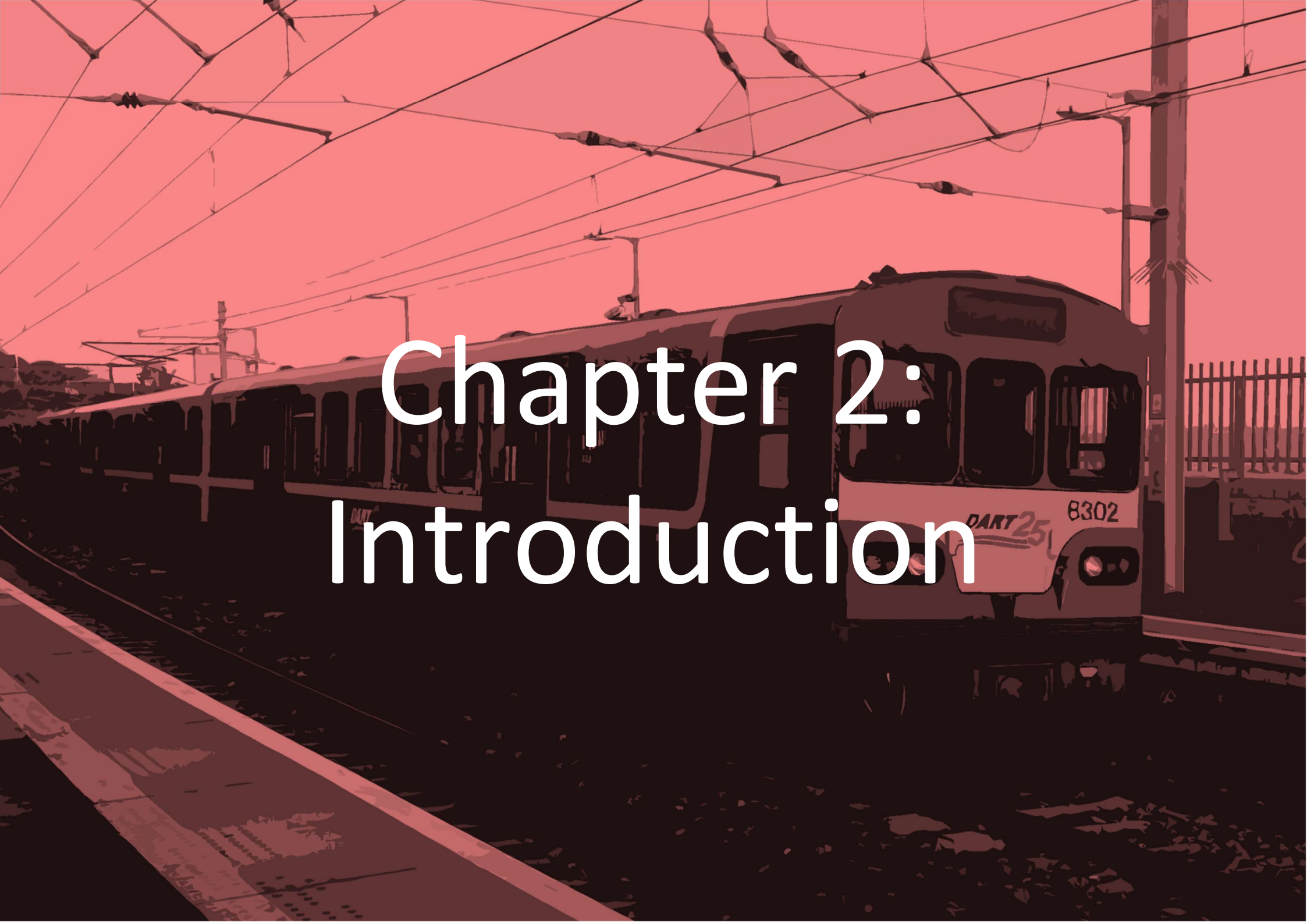
- with the Phoenix Park Tunnel (PPT) line being operational, ways should be sought to maximise the use of this tunnel, in the short to medium term, by adding additional stations, increasing frequency and capacity through the PPT and providing interchange opportunities with Luas services and with the proposed MetroLink when opened;
- the upgrading of the Phoenix Park Tunnel line, to provide higher frequency and greater capacity, does not preclude introducing the DART Underground tunnel later. Bundle 6 provides a means to incrementally improve the heavy rail

network allowing DART Expansion measures on the radial corridors to be delivered sooner thereby releasing significant benefits to rail users and other public transport users; and

- MetroLink should be viewed as more than just a means of connecting the City Centre with the Airport and Swords. It should be examined, in tandem with the PPT line, to identify how it can be optimised (through alignment and design capacity) to support the delivery of the DART Expansion Programme to offset the dependence on DART Underground, particularly in the short to medium term.

Figure 6. Recommended City Centre DART Expansion arrangement





Chapter 2: Introduction

2. INTRODUCTION

2.1 Overview

2.1.1 The National Transport Authority (NTA) has commissioned SYSTRA and Jacobs to undertake an extensive transport modelling and appraisal of the proposed DART Expansion Programme.

2.1.2 In September 2015, the revised Business Case for the DART Expansion Programme was published, and the Minister for Transport, Tourism and Sport at the time, Paschal Donohoe TD announced the NTA's recommendations based on the outcome of the Business Case, which the Minister endorsed. The NTA outlined that:

> *"The National Transport Authority carried out a review of the key transport infrastructure projects that were proposed to support the growth of the Greater Dublin Region. The Authority has now recommended to the Department of Transport, Tourism and Sport (DTTaS) that the DART Underground project be re-examined in order to deliver the required rail connectivity in the capital city with a lower cost technical solution"*

2.1.3 The NTA further stated that:

> *"The DART Expansion Programme remains a key project in the delivery of an integrated rail transport network for the Dublin region. The overall DART Expansion Programme has been assessed as a positive project from an economic perspective. While the DART Underground Project has received planning approval from An Bord Pleanála, the business case for that project, prepared by Iarnród Éireann, indicates that its development alone under the current railway order is not economically justified"*
>
> *Given the very significant cost of the DART Expansion Programme, and recognising that a lower cost alternative for the tunnel element is possible, it is intended that the Compulsory Purchase Order for the DART Underground Project should not be activated and that a new Railway Order is sought for a lower cost revised scheme."*

2.1.4 The NTA recommended that:

- the compulsory acquisition powers of the approved railway order for the DART Underground Project should not be activated – i.e. the "notices to treat" should not be issued;
- the DART Underground Project be redesigned to provide a lower cost technical solution for the project, whilst retaining the required rail connectivity;
- a new railway order be sought for the revised, lower cost DART Underground Project, together with any remaining elements of the overall DART Expansion Programme which have not already been approved under separate approval processes;
- the design and planning work of the revised DART Underground Project be advanced to be available for commencement of construction after 2020; and
- the non-tunnelled elements of the DART Expansion Programme be progressed in line with available funding.

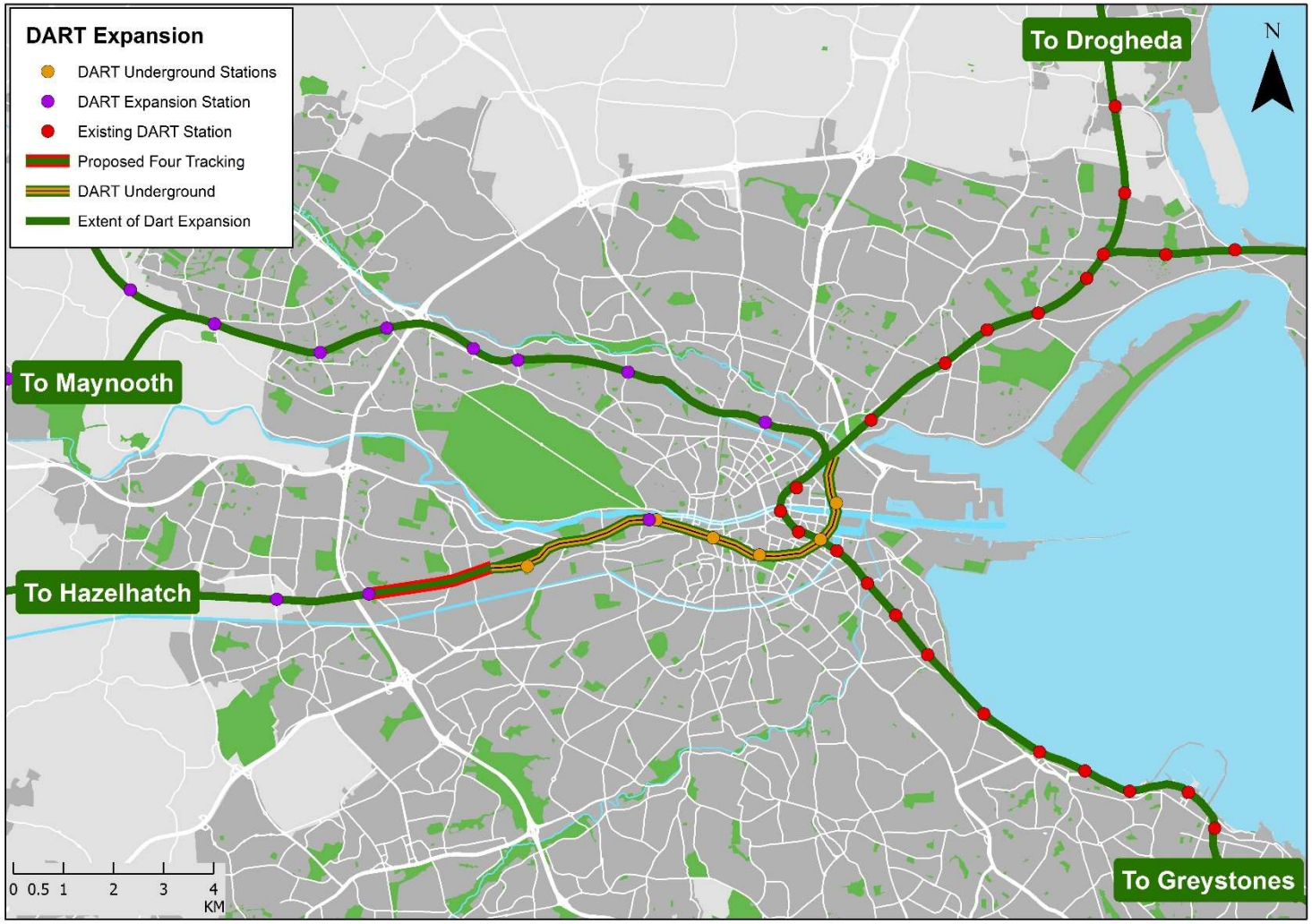
2.1.5 The Minister for Transport, Tourism and Sport indicated that the forthcoming Capital Investment Plan will make provision for advancing this expansion programme.

2.2 Background to the DART Expansion Programme and DART Underground Project

2.2.1 The DART Expansion Programme, as it currently stands, consists of a number of investment projects that will significantly expand the heavy rail capacity, frequency and connectivity in Dublin city centre and throughout the Greater Dublin Area (GDA). These projects are shown on Figure 1 below:

- Electrification of the Cork Line to Hazelhatch and completion of 4 tracking from Park West to Inchicore;
- Electrification of the Northern Line to Drogheda;
- Electrification of the Sligo Line to Maynooth, together with the removal of level crossings and re-signalling on this line;
- Expansion of fleet and depot facilities; and
- The DART Underground Project, consisting of a 7.6km underground tunnel through Dublin city to link the Northern Line to the Cork Line.

Figure 7. Extent of Original Proposed DART Expansion Study



2.2.2 The DART Expansion Programme has strong policy support at European, national, regional and local level. It is a pre-identified project on the Core Network Corridors in the Connecting Europe Facility (CEF) and a priority project in the Trans-European Transport Network (TEN-T).

2.2.3 A key part of the DART Expansion Programme is the DART Underground project which is a rail link proposal, predominately underground, from the Northern Line just north of Connolly Station, to Inchicore on the Kildare Line, and with stations proposed at Docklands, Pearse, St. Stephen's Green, Christchurch, Heuston and Inchicore.

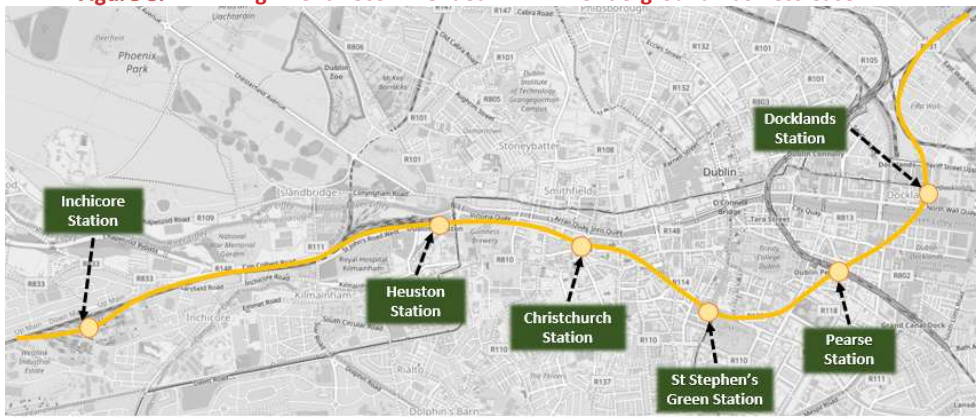
2.2.4 The estimated cost of the currently designed DART Underground Project is approximately €3 billion, while the cost of the currently envisaged full DART Expansion Programme is €4 billion.

2.2.5 In 2002, Iarnród Éireann (IÉ) commenced the planning and design of the DART Underground Project. A Railway Order application for the tunnel element of the project was submitted to An Bord Pleanála (ABP) in June 2010. Following an Oral Hearing which concluded in April 2011, planning approval was granted by ABP in December 2011. Subsequent to this determination, judicial review proceedings were initiated in the High Court against the scheme decision. This process culminated when a Railway Order for the DART Underground was granted by ABP in 2014.

2.2.6 The Railway Order provided 10 year planning consent for the construction of the DART Underground project and set September 2015 as a deadline for issuing 'Notices to Treat' for compulsory acquisitions of the lands necessary for the construction and operation of DART Underground.

2.2.7 With the onset of the economic recession, the Government subsequently decided to defer the DART Expansion Programme in the Capital Expenditure Programme 2012-2016, with a view to progressing again when funding permitted.

Figure 8. Alignment Recommended in DART Underground Business Case



2.3 NTA Greater Dublin Area (GDA) Transport Strategy 2016-2035

2.3.1 The NTA is tasked with the responsibility of developing the public transport network in the GDA and in 2016 published its future vision for the GDA transport network - *The Transport Strategy for the Greater Dublin Area 2016-2035*. The Strategy provides the framework for the planning and delivery of transport infrastructure and services in the Greater Dublin Area up to 2035. The Strategy was adopted as a statutory document in April 2016, providing a firm basis to all agencies involved in planning for the future development of this region.

2.3.2 Significant investment is planned for the GDA to help increase public transport mode share in the region. The infrastructure schemes recommended as part of this Strategy are:

- Proposed new Metro North and Metro South (referred to as MetroLink);
- DART Expansion Programme;
- Extension of Luas Cross City to Finglas, extension of the Luas Red Line further East to Docklands and a new Lucan Luas line;
- A BRT Network with two cross city lines from Clongriffin to Tallaght and Blanchardstown to UCD and a further line connecting Swords to the City Centre via Dublin Airport;
- Extension and improvement in cycling infrastructure; and
- Development of strategic rail-based park and ride facilities.

2.3.3 As part of the Strategy, the DART Expansion Programme was again identified as a key public transport intervention required to serve the future transport demand needs of the GDA region.

2.3.4 The Transport Strategy states that:

> *"The DART Expansion Programme which is a cornerstone project of the Strategy, will see the DART system expanded, providing fast, high-frequency electrified services to Drogheda on the Northern Line, Hazelhatch on the Kildare Line, Maynooth and M3 Parkway on the Maynooth/Sligo Line, while continuing to provide DART services on the South-Eastern Line as far south as Greystones".*

2.3.5 The Transport Strategy, therefore, reaffirms the need for the DART Expansion Programme and sets out the parameters and geographical extent of the programme - including the electrification of rail lines to Drogheda, Maynooth and Hazelhatch as well as the continuation of DART services to Greystones.

2.4 Other Transport Considerations

2.4.1 The public transport landscape in the GDA has changed substantially since the planning and design of the DART Underground Project commenced in 2002 and since the DART Underground Railway Order was granted in 2014. Since then, a number of Rail, Light Rail and Metro schemes have either been completed, are due for completion or are being planned. These schemes, that should be considered in the context of the DART Expansion Programme include:

- The City Centre Re-signalling Project (CCRP);
- The re-opening of the Phoenix Park Tunnel (PPT);
- Luas Cross City;
- New Metro North (NMN).

City Centre Re-signalling Project (CCRP)

2.4.2 One of the key constraints on the existing rail network is the limitation on train paths through the city centre section between Connolly and Grand Canal Dock stations. In particular the Loop-line Bridge (LLB) section between Connolly and Tara Street stations is currently restricted to 12 train paths per direction per hour. The City Centre Re-signalling project provides for significant capacity enhancement through this section by upgrading signalling and turn-back facilities to accommodate up to a potential 8 additional train paths per direction per hour (i.e. up to a total of 20 train paths per direction per hour which would allow an operational increase to 17/18 train paths per direction per hour) in this critical city centre area. This is a key project aimed at unlocking the existing major bottleneck in the city centre, which will have a positive impact for DART, Commuter and Intercity passengers. It provides the necessary capacity through the city centre to cater for other projects within the Greater Dublin area, including in particular, the Phoenix Park Tunnel Link. The city centre re-signalling project extends from Howth in the north to Grand Canal Dock in the south. The project has seen the installation of a state of the art signalling system along this section together with the construction of required turnback facilities at Grand Canal Dock station.

Implications of CCRP on the DART Expansion

- Improved journey times for rail services through the city centre
- Increased train paths through city centre and on the Loop-line bridge
- Catering for the re-opening of the Phoenix Park Tunnel line for commuter rail services

Phoenix Park Tunnel (PPT)

2.4.3 The completion of the City Centre Re-signalling project outlined above provides extra train paths through Connolly Station and across the LLB. The completion of these major signalling works, together with other engineering works has facilitated the commencement of commuter services using the Phoenix Park Tunnel (PPT) Link from the Cork/Kildare line to Connolly and through to Grand Canal Dock since November 2016.

2.4.4 The PPT is a twin-track line that runs from Islandbridge junction, just west of Heuston Station (Platform 10), to Connolly Station and the North Wall, via the Phoenix Park Tunnel. From Platform 10 west of Heuston Station, the line crosses over the River Liffey and passes under the Phoenix Park in a 692-metre-long tunnel which was constructed in 1877. Continuing northwards through Cabra in cutting, it then runs under the Royal Canal and the Maynooth line before heading eastwards around the north side of Glasnevin cemetery to Glasnevin Junction, where it joins the

Maynooth line. The line then continues eastwards through Drumcondra Station and onwards to Connolly Station. The line can also access the North Wall via North Strand Junction on existing tracks that are currently only used for freight movements.

2.4.5 Services accessing Heuston Station include a mix of Intercity trains from Cork, Waterford, Limerick and Galway, as well as commuter services from Kildare, Carlow, Newbridge and Portlaoise. Heuston station lies some 3km from the commercial core of the city and greater than 3km from the area of highest density employment in the south-eastern quadrant of the city.

2.4.6 Under the previous configuration of the IÉ network, rail services entering Dublin City on the Kildare line had to terminate in Heuston Station. Hence passengers using the Kildare line and wishing to access the commercial core of the city by public transport were required to transfer to bus or to the Luas Red line at Heuston station.

2.4.7 The PPT line has performed well since its re-opening with 4 inbound and 3 outbound trains operating in the morning period (7am-10am) and the reverse in the PM period. This provides a two-way capacity of approximately 2,000 passengers over each peak period with the trains generally full.

Implications of PPT Re-opening on the DART Expansion

- The line has performed well since its re-opening to commuter services and as such it should be considered in the context of the future rail network.
- The PPT line can provide a reasonable level of the east-west city centre penetration that would be provided by the DART Underground project, if city centre capacity constraints can be alleviated.
- The PPT line was excluded from consideration as part of the DART Expansion programme within the most recent Business Case. The Business Case document states: *"It should be noted that The Phoenix Park Tunnel project does not fulfil the needs and objectives of the DART Expansion Programme, which has substantially larger scale and impact."* As such an enhanced PPT line was not previously considered as a viable alternative to the DART Underground Project.

Luas Cross City (LCC)

2.4.8 The Luas Cross City scheme comprises a north / south Luas line extending from St. Stephen's Green in the south to connect to the Maynooth Rail line at Broombridge in Cabra at its northern end. With an overall length of approximately 5.6km, it has thirteen stops along its route, including serving the major new DIT campus at Grangegorman. LCC opened in December 2017 connecting the Green and Red Luas Lines providing interchange opportunities

with the Maynooth and PPT heavy rail lines. LCC, which provides an interchange with the Maynooth line at Broombridge in Cabra, was included in the assessment of Rail options in the previous business case for the DART expansion programme. However, the opening of LCC prior to the Metro North scheme, has influenced the alignment of the proposed New Metro North scheme in the City Centre, which is further discussed below.

Implications of Luas Cross City on the DART Expansion

- Given that LCC is now operating before DART Underground and New Metro North it will result in changes to travel patterns and city centre public transport connectivity which may not have been previously considered.
- LCC provides interchange with the Maynooth Rail line at Broombridge which allows direct access for rail passengers to the city centre via LCC

Proposed New Metro North (NMN) and MetroLink

2.4.9 The New Metro North Route Options Assessment has recently been completed and a draft Emerging Preferred Route (EPR) has been identified. The EPR has stations in Dublin city centre at Charlemont, St. Stephen's Green East, Tara Street, Parnell Square, the Mater Hospital and Glasnevin before continuing (with further stations) northwards to the Airport and Swords via Ballymun Road.

2.4.10 The alignment of the NMN EPR is further east in the city centre, compared to the previous Metro North alignment. Interchange will be provided between NMN and the heavy rail network at Tara Street station in the city centre and with the Maynooth and PPT rail lines in the Glasnevin/Phibsborough area, beside Cross Guns Bridge.

2.4.11 The potential exists to maximise the use of the PPT line to bring additional passengers from the west to interchange with the NMN line at Glasnevin. The NMN station in Glasnevin provides a 3-way interchange for the Maynooth and Kildare (via PPT) heavy rail lines with NMN. This interchange point facilitates access from the west of Dublin to the Airport (to the north) and the City Centre (to the south).

2.4.12 Additionally, NMN is to tie-in with the Luas Green Line at Charlemont which will facilitate potential access to the south city (e.g. Sandyford) with only 1 interchange required. The combined scheme of New Metro North with the upgrade of the Luas Green line to metro standard is now referred to as MetroLink.

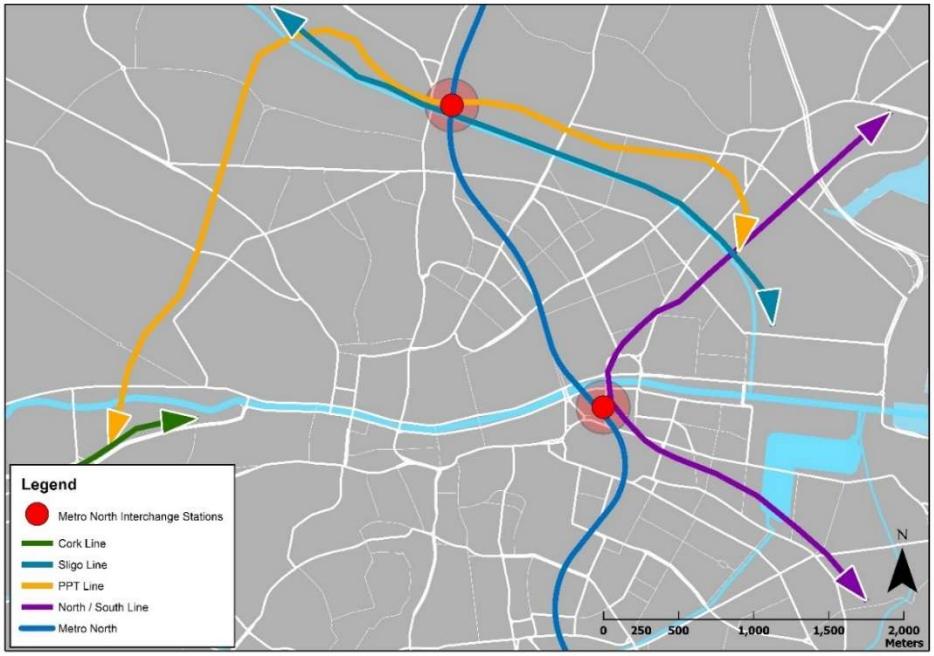
Figure 9. Interchange Opportunities of Heavy Rail Network and NMN

Implications of New Metro North and MetroLink on the DART Expansion

- The relationship between DART Underground and NMN has changed since the previous business cases for both schemes. For example, the DART Underground was included in the Do Minimum Transport Network for the assessment of Metro North previously. NMN is now anticipated to be in place before DART Underground and will connect with the **existing** heavy rail network at Tara Street to maximise public transport integration in the City Centre and for wider connectivity for the regional public transport network (Previously Metro North connected with the DART Underground at St. Stephen's Green).

- NMN will tie-in with the Luas Green Line at Charlemont, facilitating connectivity to a much larger population catchment.

- NMN will also interchange with the existing heavy rail line at Whitworth Road in Glasnevin where seamless connectivity with the Maynooth and PPT lines can be provided. Through this provision of interchange at Whitworth Road between heavy rail and metro, NMN can provide additional North-South capacity to support the limiting capacity of the Loop-line bridge for DART and Commuter services.



2.5 Purpose of this Project

2.5.1 This project seeks to identify a lower cost alternative to the proposed DART underground tunnel component of the DART Expansion Programme. It does this in the context of the importance of the DART Expansion Programme as identified in the GDA Transport Strategy and following on from the NTA recommendations on the deferral of the DART Underground Project in 2015. It also seeks to maintain similar transport user benefits, as far as practicable, to that of the original DART Underground scheme and to maintain all other elements of the DART Expansion Programme.

This report does not consider the alteration of the extent of the proposed electrified rail network as set out in the GDA Strategy i.e. electrification to Hazelhatch, Maynooth and Drogheda. In addition, all non-tunnel elements of the DART Expansion programme are considered core requirements of the project and are included in full. .

2.6 Structure of Report

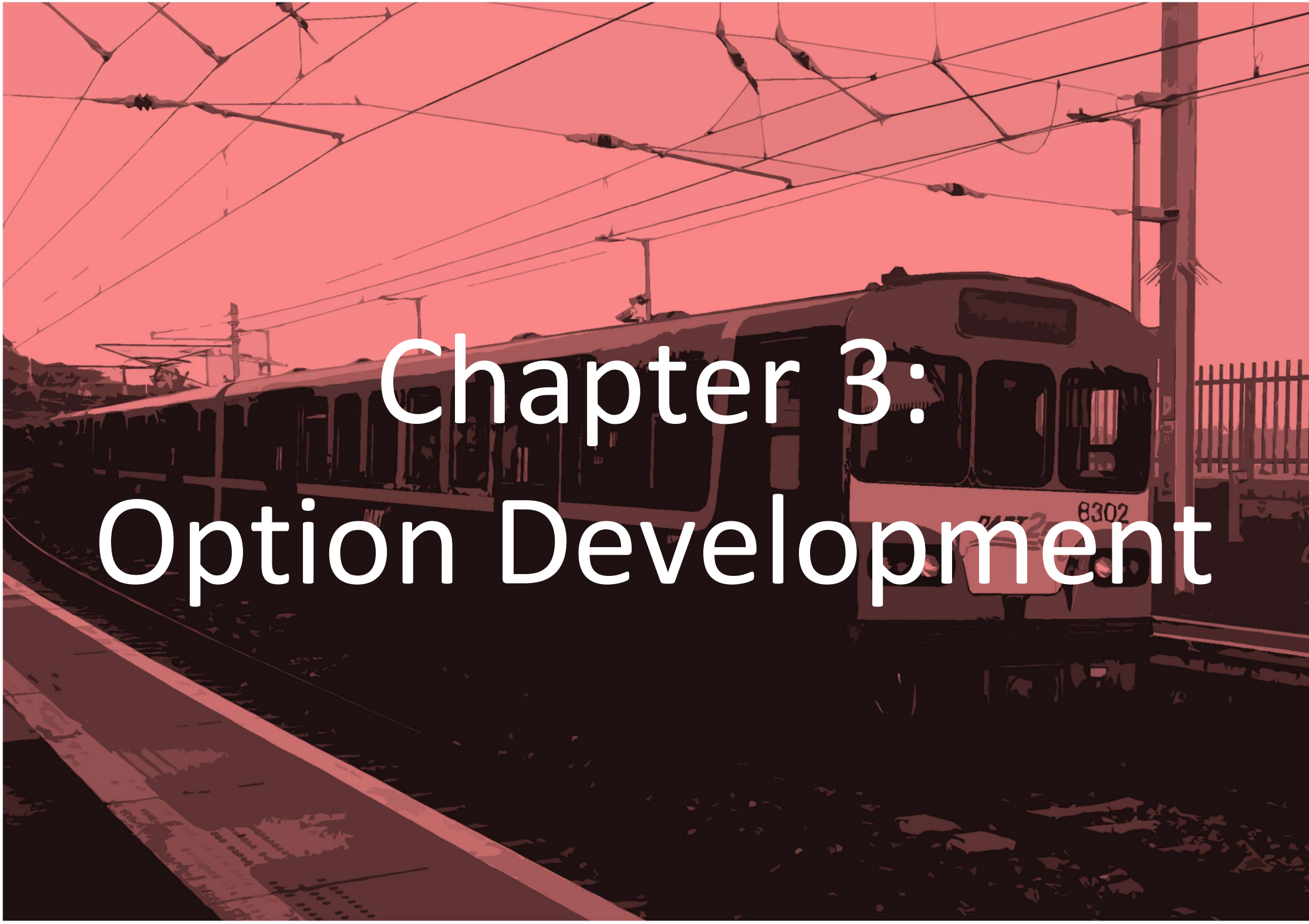
2.6.1 **Chapter 2:** This chapter includes an overview of the options development and the scheme bundles tested during this project.

2.6.2 **Chapter 3:** This chapter includes a brief explanation of the East Regional Model (ERM) used to assess and develop scheme options and a summary of the modelling assumptions related to the DART Expansion Programme assessment.

2.6.3 **Chapter 4:** contains the transport modelling results of the DART Expansion scheme bundles options.

2.6.4 **Chapter 5:** this chapter presents the sensitivity tests undertaken on the Emerging Preferred Scheme Bundles.

2.6.5 **Chapter 6:** outlines recommendations and conclusions and a series of next steps to be undertaken



Chapter 3: Option Development

3. OPTIONS DEVELOPMENT

3.1 Introduction

3.1.1 The following chapter outlines the alternative DART Expansion Scheme options (referred to as scheme bundles) that were developed as part of the project. The scheme bundles presented within this chapter were developed using work done for the previous DART Underground Business Case and in consultation with the NTA and IÉ . The scheme bundles are made up of elements of the existing Heavy Rail Network and proposed new infrastructure required to deliver the DART Expansion.

3.1.2 To assist in the understanding of the descriptions of the scheme bundles the following section gives a brief overview of the existing Heavy Rail network.

Existing Heavy Rail

3.1.3 The heavy rail network in Dublin consists of four lines as follows:

- the Northern Line – extending northwards from Connolly Station, providing an electrified DART service from Malahide and Howth (Howth is served by a branch line from Howth Junction), diesel commuter services from Drogheda / Dundalk and an Intercity service linking to Belfast;
- the Sligo Line – providing diesel commuter services from Maynooth, with a lower frequency service extending to Longford and providing Intercity services to Sligo. Through a recently constructed branch line, commuter services are provided to Hansfield, Dunboyne and M3 Parkway;
- the South-Eastern Line – extending southwards from the city centre, providing an electrified DART service as far south as Greystones and a diesel service further southwards, serving towns such as Arklow, Gorey, Enniscorthy, Wexford and Rosslare. This line is a single track south of Bray which significantly constrains its capacity; and
- the Cork line – providing diesel commuter services as far southwards as Portlaoise and Carlow plus Intercity services to Waterford, Cork, Limerick and Galway. Services from Ballina, Westport and Galway merge with the Cork line at Portarlington, and the Waterford line joins the Cork line west of Kildare town. These services all terminate at Heuston Station.

3.1.4 Both the Sligo and Northern lines merge at Connolly Station and continue south connecting with the South-Eastern Line via the Loop Line Bridge as shown in Figure 10.

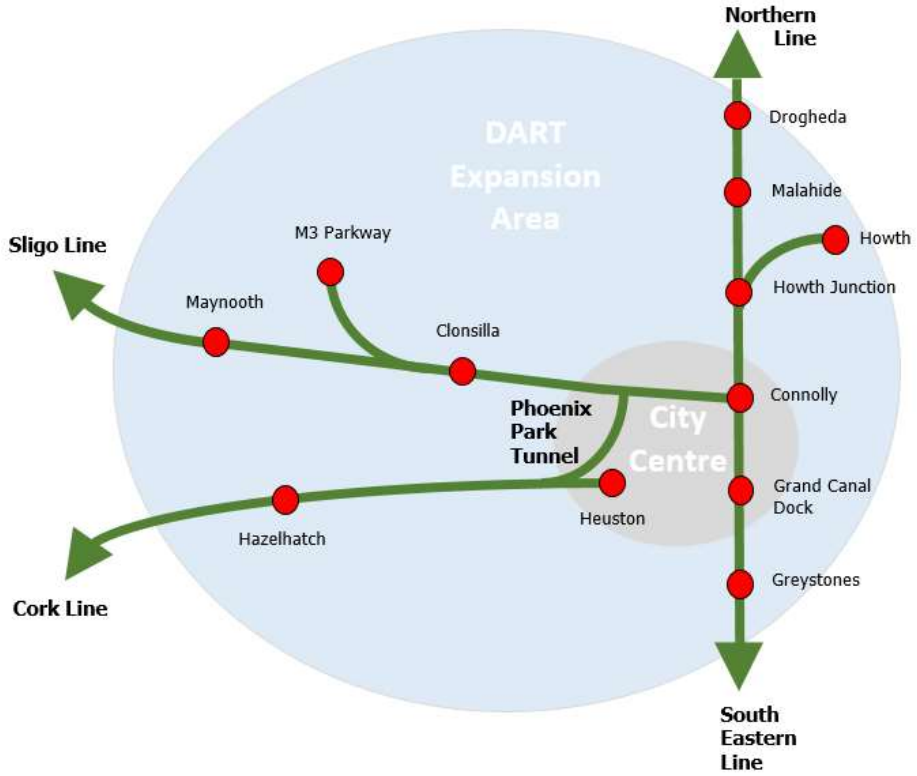
3.1.5 Recent upgrades to the Rail Network include:

- Phase one of the Navan Rail Line which is a spur on the Sligo Line extending to Dunboyne and M3 Parkway;
- the City Centre Re-signalling Project which provided additional capacity between Howth and Sandymount by modernising signalling equipment; and
- The opening of the Phoenix Park Tunnel (PPT) for commuter passenger trains. The re-opening for passenger services allows for rail connectivity from the Southwest

(Kildare) Line to the Southeast Line serving Drumcondra, Connolly Station, Tara Street, Pearse Street and Grand Canal Dock. The trains using the Phoenix Park Tunnel do not stop at Heuston Station.

3.1.6 Figure 10 below shows a schematic of the existing Heavy Rail Network in the GDA.

Figure 10. Existing Heavy Rail Network



3.2 Overview of Scheme Bundles Assessed

3.2.1 A set of six core scheme bundles were developed by the NTA, IÉ and SYSTRA / Jacobs for assessment. These are shown in Figure 5 below.

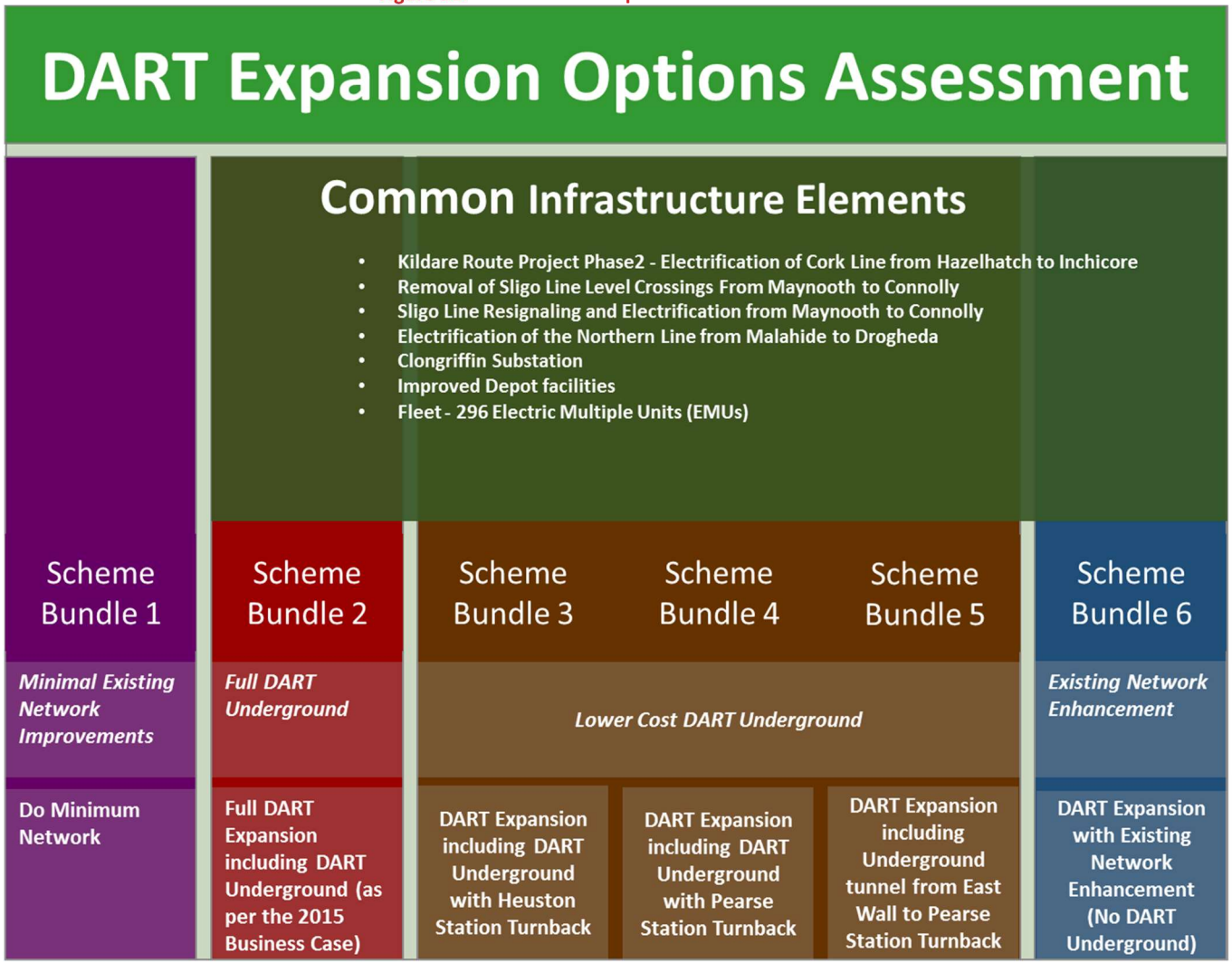
3.2.2 These scheme bundles cover a range of infrastructure options from a Do Minimum Network, to DART Expansion with full implementation of the DART Underground, to lower cost tunnel alternatives and to a no tunnel (no DART Underground) option. The following summarises the scheme bundles assessed:

- **Scheme Bundle 1 – Do Minimum Network** which is used as the reference case against which all other scheme bundles are assessed.
  - **Scheme Bundle 1B**, was tested with the Do Minimum package of measures and included the 4-Tracking of the Northern line to Malahide. This was tested in isolation on top of the Do Minimum network to see if the scheme provided significant benefits to warrant its inclusion as a measure within DART Expansion and in subsequent options.
- **Scheme Bundle 2** – Full DART Expansion including DART Underground (as per the 2015 Business Case);
- **Scheme Bundle 3** – DART Expansion including DART Underground with Heuston Station Turnback;
- **Scheme Bundle 4** – DART Expansion including DART Underground with Pearse Station Turnback;
- **Scheme Bundle 5** – DART Expansion including Underground tunnel from East Wall to Pearse Station Turnback; and
- **Scheme Bundle 6** – DART Expansion with Existing Network Enhancement (No Tunnel).

3.2.3 The scheme bundles are made up of infrastructure elements which includes existing and committed public transport schemes, as outlined in Appendix A of this report, and additional infrastructure upgrades to the rail network which are unique to each Bundle, e.g. variations in tunnel configuration.

3.2.4 Also included in each scheme bundle is a train path service plan which includes the number of train services running on the rail network for each of the scheme bundles. The service plan differs for each of the scheme bundles, in response to the variation in network offering.

Figure 11. DART Expansion Scheme Bundles



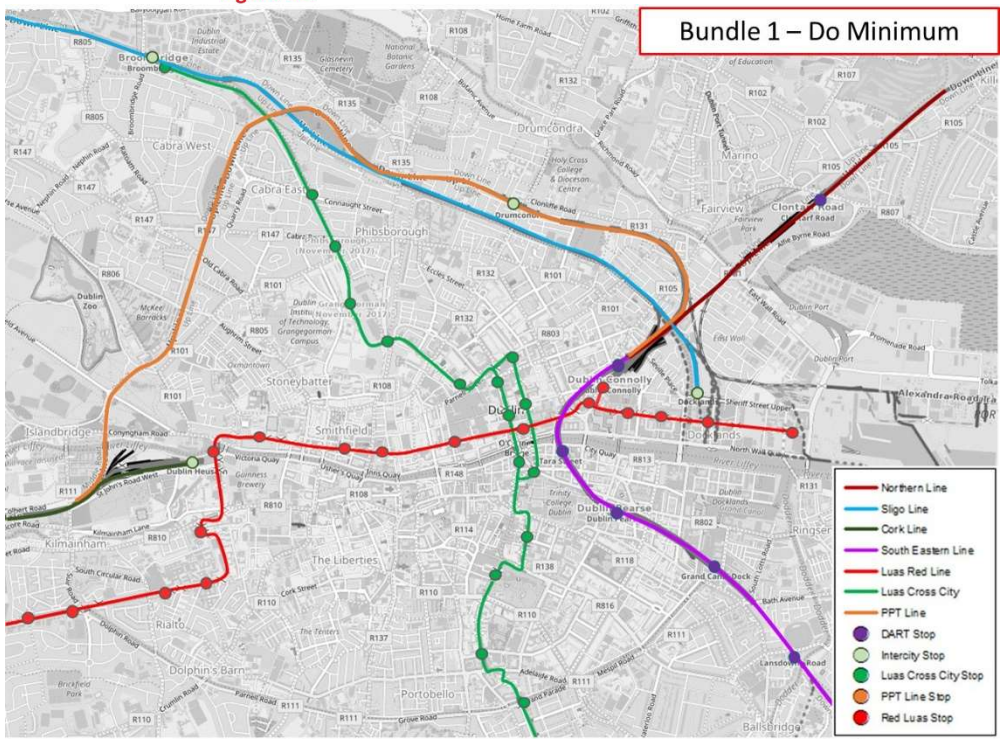
3.3 Scheme Bundle 1 – Do Minimum Network

3.3.1 Scheme Bundle 1 is the Do Minimum network, as outlined within Appendix A of this report and includes the following:

- Luas Cross City;
- Phoenix Park Tunnel services; and
- 10-minute DART frequencies.

3.3.2 This Do Minimum is used as the reference case against which all other scheme bundles are assessed against. Figure 12 outlines the Light Rail and Heavy Rail components of the Do Minimum.

Figure 12. Rail Network Scheme Bundle 1



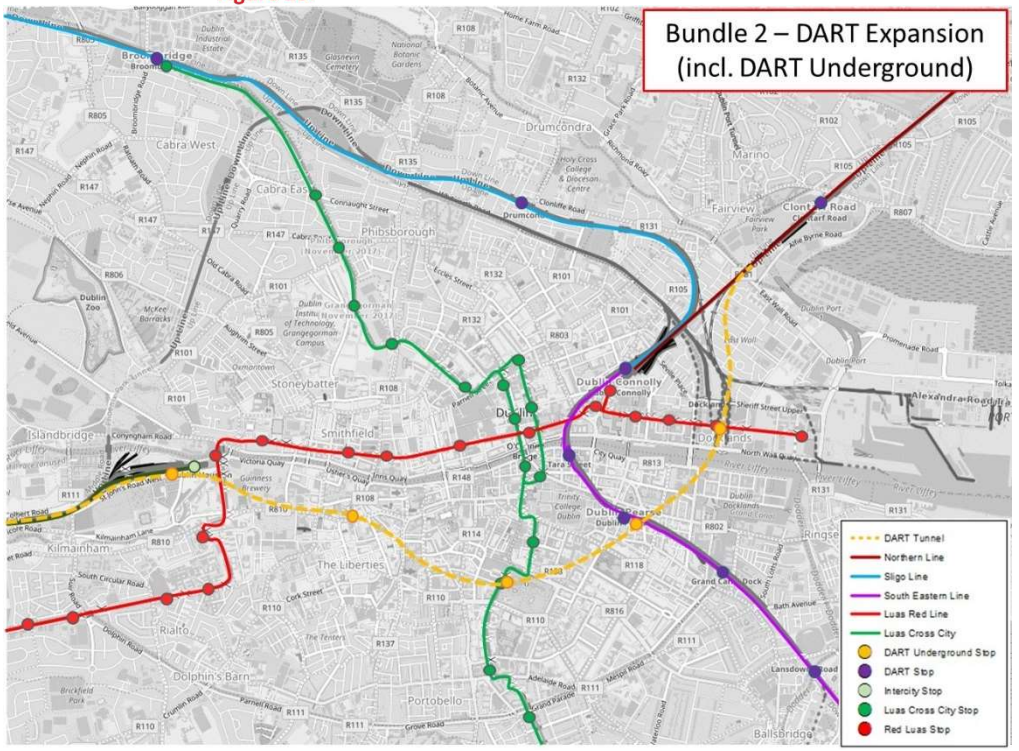
3.4 Scheme Bundle 2 – Full DART Expansion including DART Underground (as per the 2015 Business Case)

3.4.1 Scheme Bundle 2 includes the full DART Underground Project as recommended by the 2015 Business Case. The project is enabled through the construction of a rail tunnel underneath Dublin City Centre, linking the Cork Line west of Heuston station to the Northern Line north of Connolly station. This line includes a number of underground stations, as shown previously in Figure 2, including:

- Docklands;
- Pearse;
- St. Stephen's Green;
- Christchurch;
- Heuston; and
- Inchicore.

3.4.2 Within this Bundle the PPT Line and the existing Docklands Station are closed. Figure 13 provides an overview the Light Rail and Heavy Rail components that form Scheme Bundle 2.

Figure 13. Rail Network Scheme Bundle 2



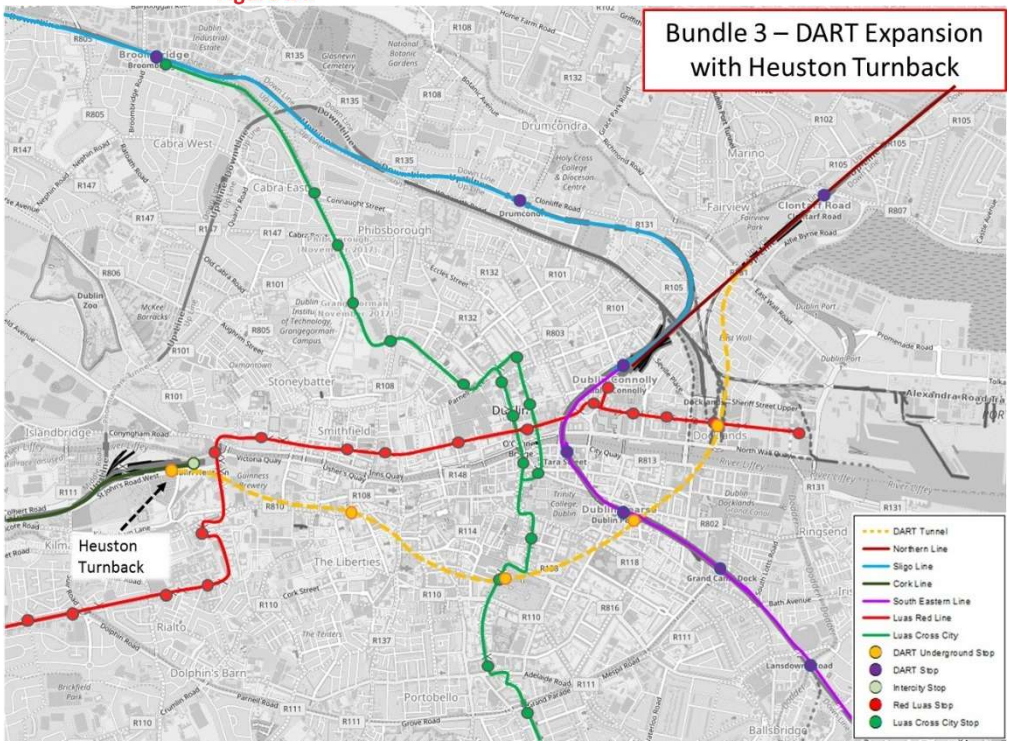
3.6 Scheme Bundle 3 – DART Expansion including DART Underground with Heuston Station Turnback

3.6.1 Scheme Bundle 3 is similar to Scheme Bundle 2, however it differs in that the DART Underground terminates at an underground turnback at Heuston Station. In addition, this bundle does not provide for a station at Inchicore.

3.6.2 This scheme bundle does not allow for through-running of services from the Northern Line to the Cork Line. Instead passengers must disembark and interchange between the over-ground and underground stations proposed at Heuston.

3.6.3 This scheme bundle represents a lower cost tunnel alternative to deliver the DART Underground Project. The tunnel has underground stations at the same locations as in Scheme Bundle 2 and includes the closure of the PPT Line and the existing Docklands Station. Figure 14 outlines the Light Rail and Heavy Rail components of this Scheme Bundle 3.

Figure 14. Rail Network Scheme Bundle 3



3.7 Scheme Bundle 4 - DART Expansion including DART Underground with Pearse Station Turnback

3.7.1 Scheme Bundle 4 provides for a revised DART Underground tunnel option compared to Scheme Bundle 2. The tunnel extends eastwards from Inchicore and terminates at Pearse Station where there is a new underground turnback provided. Passengers are required to interchange at Pearse Station between DART services operating on the Cork Line to/from services operating on the Southern/Northern Lines.

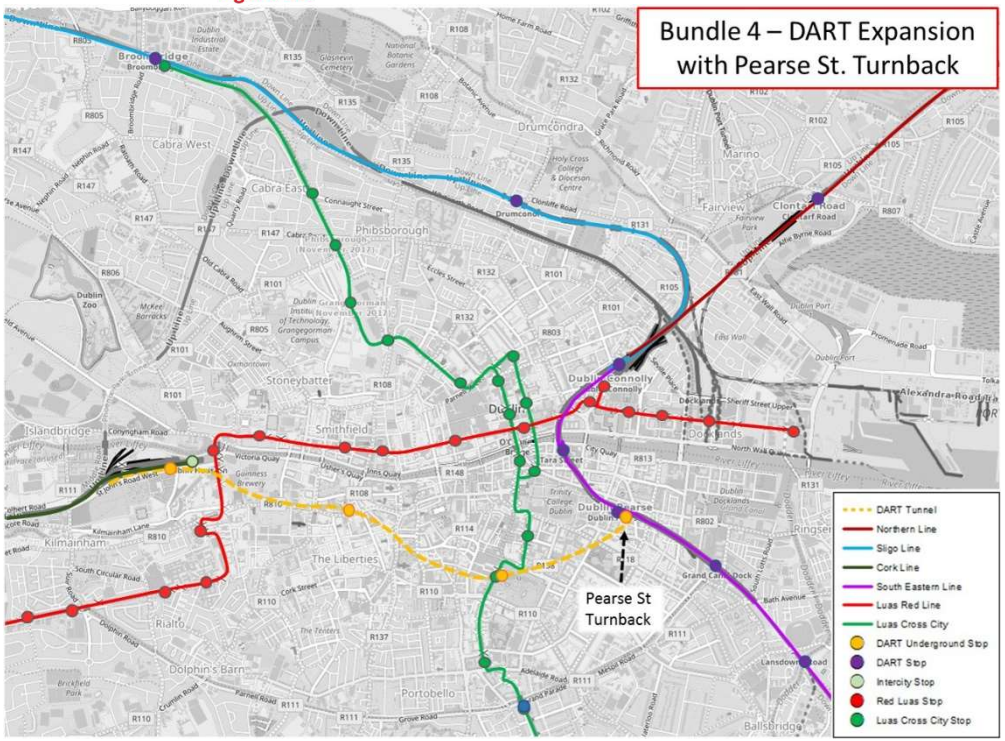
3.7.2 The underground stations on the DART Underground in Bundle 4 include:

- Pearse Station;
- St. Stephen's Green;
- Christchurch;
- Heuston; and
- Inchicore

3.7.3 Similar to Scheme Bundle 3, this option represents a lower cost tunnel alternative to deliver the DART Underground Project. As in Scheme Bundles 2 and 3 this scheme bundle does not have any services using the PPT line or using the existing Docklands Station.

3.7.4 Figure 15 outlines the Light Rail and Heavy Rail components associated with this scheme bundle.

Figure 15. Rail Network Scheme Bundle 4



3.8 Scheme Bundle 5 – DART Expansion including Underground tunnel from East Wall to Pearse Station Turnback

3.8.1 Scheme Bundle 5 is a departure from the original DART Underground Project, whereby the tunnel element included within this scheme bundle extends southwards from East wall to Pearse Station where it terminates at an underground turnback.

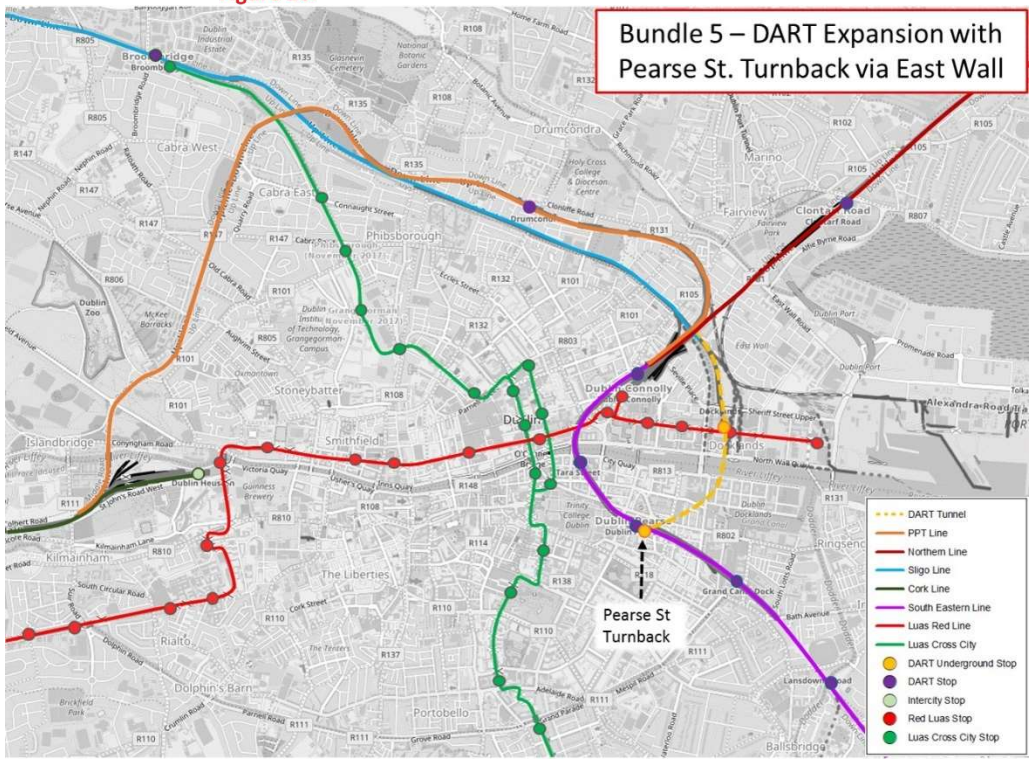
3.8.2 This scheme bundle also includes maintaining the use of the currently operating PPT Line, bringing passengers to Connolly Station and further south via the Loop-line Bridge.

3.8.3 In Scheme Bundle 5, Maynooth Line services use the underground tunnel and terminate at the underground turnback at Pearse station where passengers are required to interchange to access services on the South East Line and vice versa.

3.8.4 This option requires 4-tracking of the Cork Line from Park West to Heuston station and a potential interchange station on the Sligo Line at Cross Guns Bridge in Glasnevin. The interchange station is to provide transfer opportunities between services operating on the Sligo Line and services operating on the PPT line.

3.8.5 Figure 16 outlines the Light Rail and Heavy Rail components of Scheme Bundle 5.

Figure 16. Rail Network Scheme Bundle 5



3.9 Scheme Bundle 6 – DART Expansion with Existing Network Enhancement (No Tunnel)

3.9.1 Scheme Bundle 6, is similar to Scheme Bundle 5 in terms of its use of the PPT line as an alternative to the DART Underground tunnel. In this scheme bundle the PPT line is upgraded and includes three new stations:

- Heuston West (Platform 10);
- Cabra Station;
- Glasnevin; and
- New Docklands Station.

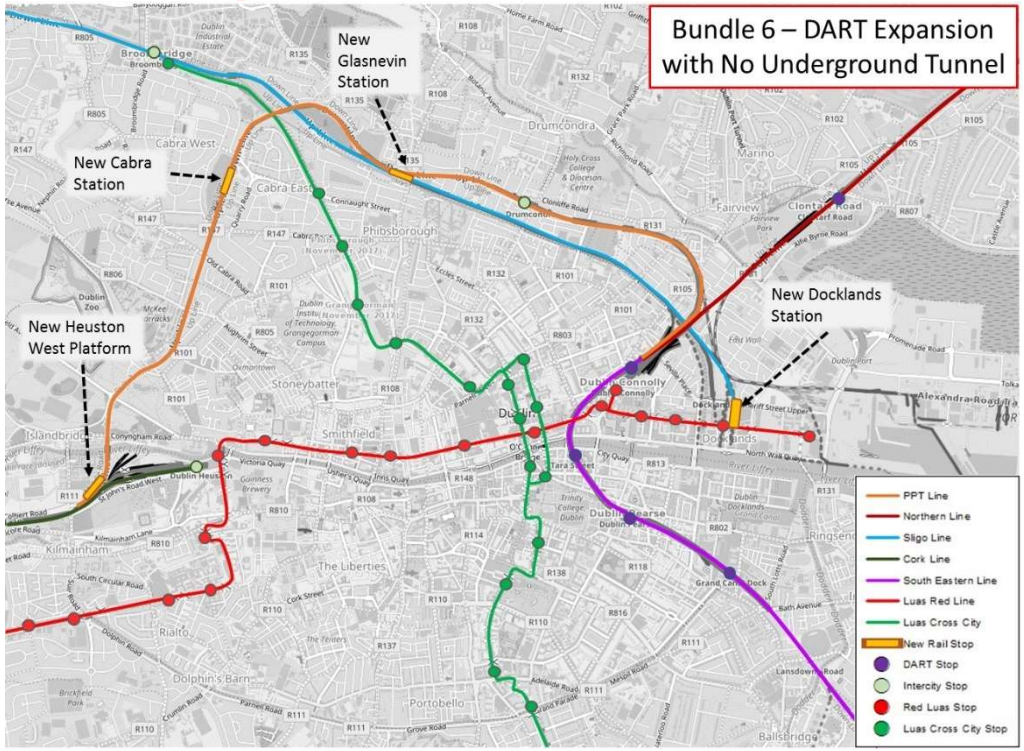
3.9.2 The PPT line will serve Connolly Station and the South East line via the loop-line bridge. Maynooth Line services can access Connolly or a new Docklands Station as per the current arrangement at Glasnevin junction.

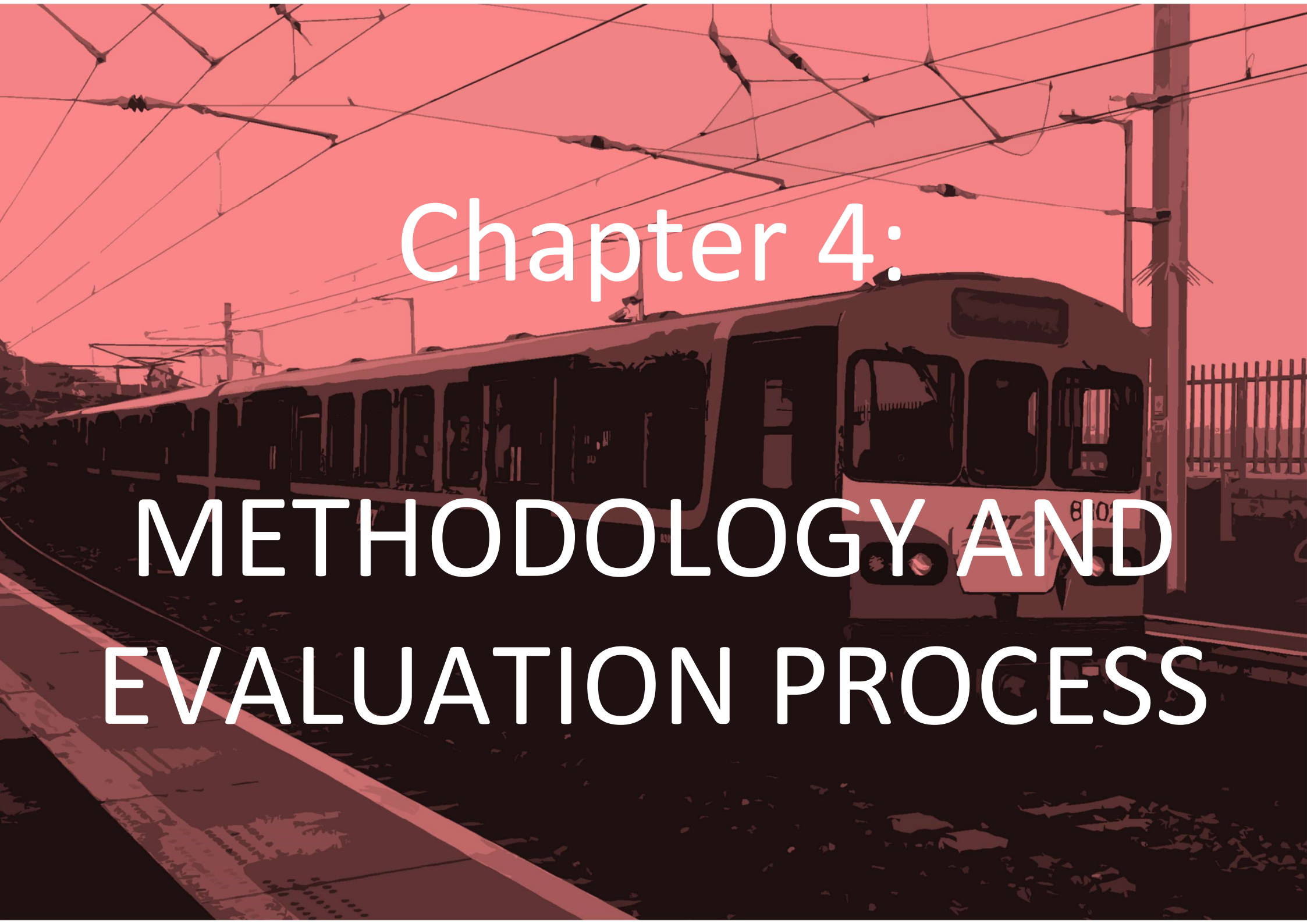
3.9.3 The new Docklands Station is located further south than the existing station which provides better integration with the Luas Red Line station at Spencer Dock. The new station will also provide more platforms and increased train capacity.

3.9.4 Similar to Scheme Bundle 5, this option requires 4-tracking on the Cork Line from Park West to Heuston station. Scheme Bundle 6 is the only scheme bundle that does not include any additional underground tunnelling in effect making maximum use of the existing rail infrastructure with some additional surface improvements.

3.9.5 Figure 17 outlines the Light Rail and Heavy Rail components of Scheme Bundle 6.

Figure 17. Rail Network Scheme Bundle 6





Chapter 4:

METHODOLOGY AND EVALUATION PROCESS

4. METHODOLOGY AND EVALUATION PROCESS

4.1 Introduction

4.1.1 This chapter set out the methodology and the evaluation process employed to assess the scheme bundle options outlined previously in Chapter 3. The assessment of the scheme bundles involved modelling each option using the NTA's Eastern Regional Model (ERM) and comparatively assessing them against a number of Key Performance Indicators (KPIs) to identify emerging preferred options for further evaluation and refinement in Chapter 5..

4.2 Transport Modelling and Economic Assessment Requirements

4.2.1 To undertake a comprehensive and robust assessment of the DART Expansion scheme bundle options, thorough transport modelling is appropriate for scheme assessments of this scale. Transport modelling allows for the performance and attractiveness of the scheme bundles to be analysed by considering how transport demand is served by the Rail system within a multi-modal network (i.e. including the public transport modes of rail, bus, Luas, Metro as well as that of car, walking and cycling). The undertaking of transport modelling and analysis of model outputs enables a robust assessment of the overall benefits and impacts associated with alternative scheme bundles measured against key KPI criteria, including the following which are included in further detail in Table 2 below:

- Passenger boardings and alightings at stations;
- Level of interchange with other public transport services;
- Transport benefits as a result of travel time savings, travel cost savings and environmental benefits; and
- Impact on achieving policy objectives, particularly in reducing car mode share.

4.2.2 An economic appraisal of the scheme bundles is also undertaken whereby the benefits of the scheme bundle options is quantified from transport modelling outputs and compared against the associated cost of delivering each scheme bundles. This economic evaluation process is called Cost Benefit Analysis (CBA).

4.2.3 The methodology followed in undertaking the transport modelling and economic assessment takes into account the "Common Appraisal Framework for Transport Projects and Programmes" (Department of Transport Tourism and Sport - March 2016) (CAF).

4.3 Suitability of the East Regional Model for DART Expansion Modelling

4.3.1 The ERM is used in the transport modelling of DART Expansion scheme bundles because it:

- has been developed from first principles making best use of the most recently available data (POWSCAR11 and NHTS12) to replicate travel choices and transport network conditions as accurately as possible;
- has a good level of detail and representation of the demand and transport networks within the DART Expansion study area;
- is a multi-model model that reflects all the travel choices available across the four main modes of travel: private car, public transport, walking, and cycling, with each mode calibrated individually, for each journey purpose, to replicate observed trip cost distributions within the Rail corridors and the wider GDA;
- includes several distinct journey purposes and characteristics including car availability, employment status, and education level are considered within the model to evaluate travel choices more accurately;
- is calibrated and validated in line with best practice guidelines whereby a substantial amount of observed transport data has been incorporated;
- accurately reflects existing conditions and 'costs' associated with travel, allowing changes in the forecasting of transport demand and impact of DART Expansion to be modelled and tested;
- extends across the GDA and can pick up on the wider impact of DART Expansion across the region to give an understanding of how DART Expansion will integrate with Dublin's transport network;
- is an all-day model built on separate time periods to allow all day demand and potential DART Expansion rail patronage to be examined in addition to providing data on the performance of DART Expansion during critical time periods such as the AM peak; and
- it is designed for the appraisal and assessment of major transport schemes such as DART Expansion.

4.3.2 In summary. the ERM provides a comprehensive representation of travel patterns across the Greater Dublin Area.

4.4 ERM Input Assumptions

4.4.1 The DART Expansion involves multiple schemes that will be delivered over an extended timeframe. For this reason, a common appraisal design year of 2035 has been used for the assessment of the scheme bundle options as it 2035 aligns with the demand year used for the development of the GDA Transport Strategy.

4.4.2 The impact of DART Expansion will also extend over many years beyond the design year (2035). For schemes with a long lifespan such as DART Expansion, a 30-year appraisal period is used as per CAF guidance. 2035 and 2065 are, therefore, used as the transport modelling assessment years.

4.4.3 To assess the performance of DART Expansion in 2035 and 2065 a number of assumptions are inputted into the ERM to reflect future conditions. The key assumptions relate to future transport

[11] Place of Work, School or College - Census of Anonymised Records

[12] National Household Travel Survey

demand arising from population changes and land use developments and to other future transport network improvements in addition to DART Expansion. These assumptions are described in more detail later in this section.

Forecasting Transport Demand (2035 & 2065)

4.4.4 Forecasts of population, employment and education data are defined by the NTA at the Census Small Area (CSA) level for standard reference years of 2026 and 2035. As mentioned, 2035 represents the GDA Transport Strategy horizon year (2016 to 2035).

4.4.5 To forecast transport demand, the planning data (population, employment and education) is converted into people trips. The NTA's regional modelling system includes the National Demand Forecasting Model (NDFM) that converts planning data forecasts to trip forecasts. The process to develop the 2035 GDA Strategy Forecast Demand is described in Appendix B.

Do Nothing Network

4.4.6 A Do Nothing base year model is developed to examine the model's detail and performance in reflecting the existing transport network with particular focus on the Rail corridors. The ERM Base Year network represents a 2012 situation. A 2017 network, called 'Do Nothing', was developed to include modifications to the network between 2012 and 2017 that could have a potential impact on DART Expansion. Luas Cross City (LCC) is not included in the 2017 Do Nothing scenario as it was not in operation for the majority of 2017 or at the time of modelling and so its operational impacts could not be observed.

4.4.7 A full model run of the 2017 Do Nothing is undertaken to check that network modifications were correctly coded and didn't create any traffic assignment issues particularly within the Rail corridors.

Do Minimum Network

4.4.8 The Do Minimum network includes forecast transport demand and additional transport schemes that are either under construction or committed to be implemented post-2017. A Do Minimum network is defined for the forecast design year (2035). The 2035 Do Minimum scenario is coded on top of the 2017 Do Nothing scenario and includes a train path service plan developed by IÉ.

4.4.9 In effect, the Do Minimum represents the anticipated future year situation without DART Expansion. The Do Minimum scenario includes the following set of road and public transport schemes and are explained in further detail below:

- Completed and committed road and traffic management schemes in the GDA;
- Completed public transport schemes delivered 2012-2017 (also contained in the Do Nothing); and
- Committed public transport schemes or those under construction to be delivered by 2018.

Do Something Networks

4.4.10 Do Something networks are created for each of the DART Expansion scheme bundle options to be modelled in the ERM. The scheme bundle options are coded on top of the Do Minimum 2035 scenario, to facilitate their assessment in the ERM and comparison against each other.

Model Parameter Assumptions

4.4.11 All modelling assumptions, including Rail operating assumptions, Transfer Penalties and Public Transport Schemes coded in the Do Minimum Network are detailed in the Appendix B.

4.5 Key Performance Indicators used for Assessment

4.5.1 To comparatively assess the six scheme bundles it was necessary to develop a set of Key Performance Indicators (KPIs). The KPIs were extracted from the ERM for each of the scheme bundles tested within the ERM.

4.5.2 The KPIs extracted for each scheme bundle include the following with further detail provided in Table 2 below:

- Mode Share;
- Passenger Distance Travelled;
- Passenger Time Travelled;
- Average Journey Speed per PT Passenger;
- Total Boardings by PT Sub-mode;
- Lines Summary (for key bus, rail, Luas routes etc.);
- Rail Line Profiles;
- Road network assignment statistics;
- User benefits (TUBA); and
- Transfer Analysis.

4.5.3 The performance of each of the DART Expansion scheme bundles was assessed across the range of KPIs in determining the best performing bundle options.

Table 2. Key Performance Indicators (KPIs) used to inform the Process

PERFORMANCE INDICATOR (PI)	SUB-LEVEL	UNIT	TIME PERIOD	GEOGRAPHICAL EXTENT	DESCRIPTION
Mode Share	Origin Destination	Trips	AM, IP1, IP2, PM	Zonal, sectoral, and regional	Multi- modal performance of each alignment in terms of the modal shift from Car to Public Transport mode
Passenger Distance Travelled	-	km	AM, IP1, IP2, PM	Global and sectoral	Total distance travelled on public transport services across the network. Gives an overall indication of the performance of the public transport network and the integration of the Rail scheme bundles with other PT modes.
Passenger Time Travelled	-	hrs	AM, IP1, IP2, PM	Global and sectoral	Total time travelled on public transport services across the network. Gives an overall indication of the performance of the public transport network and the integration of the Rail scheme bundles with other PT modes.
Average Journey Speed per PT Passenger	-	km/hr	AM, IP1, IP2, PM	Global	Combines PT Passenger Travel Time and Distance. It removes the variation in the number of PT trips between each scenario and provides an indication of the overall efficiency of the PT network for each scenario
Total Boarding's by PT Sub-mode	DART Heavy Rail LUAS Dublin Bus Other Bus BRT Metro	Trip Boarding's	AM, IP1, IP2, PM	Global and sectoral	Total boarding's for each PT sub-mode within the model. This indicator is used to compare the performance of Rail to other PT sub-modes and also how each alignment performs in the context of all PT modes.

PERFORMANCE INDICATOR (PI)	SUB-LEVEL	UNIT	TIME PERIOD	GEOGRAPHICAL EXTENT	DESCRIPTION
Lines Summary (for key bus, rail, Luas routes etc.)	Total Boarding's per service	Boarding's	AM, IP1, IP2, PM	By individual PT service	This indicator enables a comparison of the performance of the individual Rail bundles within each scenario in terms of its total patronage, speed and journey time.
	Average vehicle speed	km/hr			
	Journey Time	min/secs			
Rail Line Profiles	-	Patronage	AM, IP1, IP2, PM	By service or corridor	Boarding and alighting profile by direction and time period. Provides the maximum loading of demand across Rail services and also the performance of each station in terms of overall patronage.
Road network assignment statistics	Overcapacity Queuing	pcu.hrs	AM, IP1, IP2, PM	Global	Gives an overall indication of congestion levels on the road network and the impact of the potential modal shift from Car to Rail for each scenario
	Average Network Speed	km/hr		Global	Gives an overall indication of the performance of the road and the impact of the potential modal shift from Car to Rail for each scenario
User benefits (TUBA)	Present Value of Benefits	€	n/a	Zonal, sectoral, and regional	Key indicator of the overall performance of each of the Rail scheme bundle combinations. Provides the overall level of monetised travel time savings over a 60 year appraisal period for each option.
Transfer Analysis	Transfer levels at Rail Stations	Trips	AM, IP1, IP2, PM	Station	Provides the level of transfer to other PT modes at key Rail stations. This gives an indication of how well each Rail scheme bundle option integrates with other PT modes

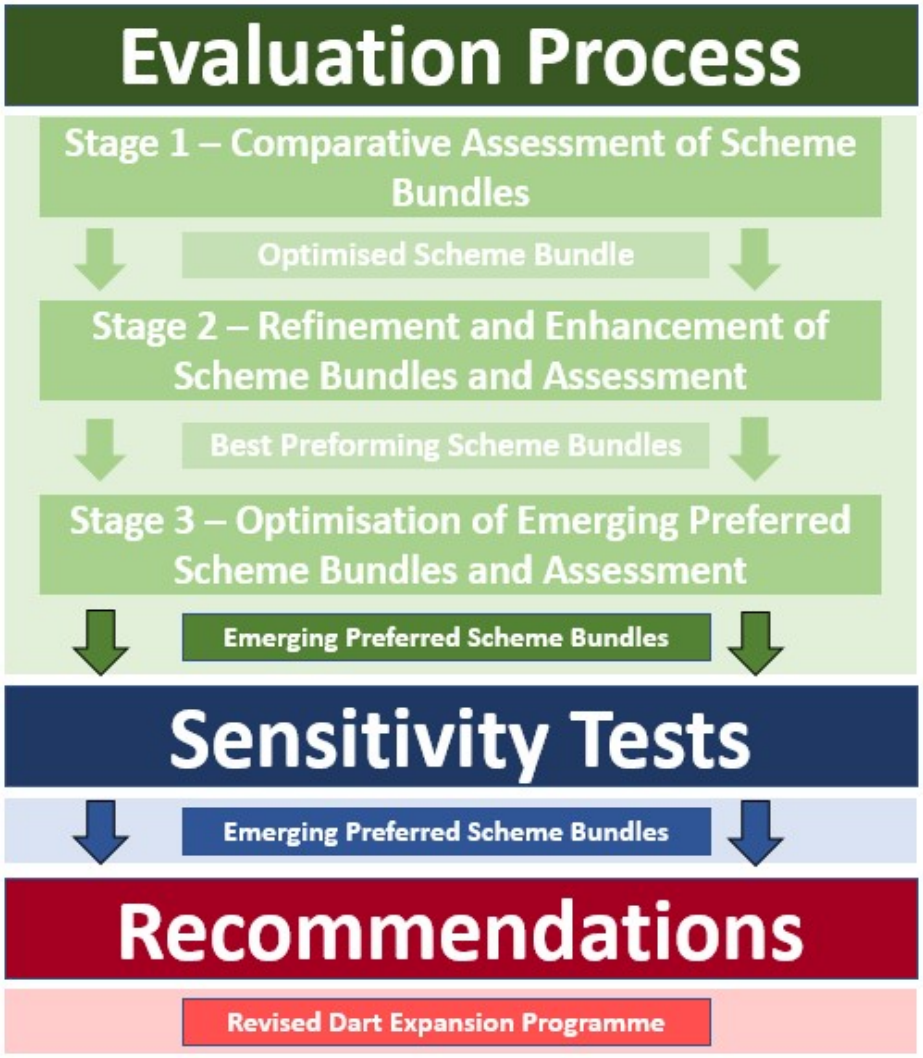
4.6 Overview of Transport Modelling Evaluation Process

4.6.1 An assessment process was developed to evaluate each of the DART Expansion scheme bundles and to determine the best possible package of infrastructure schemes to deliver the DART Expansion Programme. The assessment process is set out below:

- Formulation of a 3 step Evaluation Process which includes:
  - Stage 1: a comparative assessment using the scheme bundle option (Bundle 2) from the previous DART Expansion Business Case and a set of alternative options developed by NTA, IÉ and SYSTRA / Jacobs.
  - Stage 2: the refinement and enhancement of the service plans and networks from Stage 1.
  - Stage 3: following the identification of the Emerging Preferred Scheme Bundles (EPSBs) at Stage 2, further improvements were made to the EPSBs which included infrastructure and services pattern enhancements and an engineering feasibility assessment.
- Sensitivity Tests were then undertaken to assess how the EPSBs performed with other planned Public transport Schemes or changes to modelling parameters or assumptions.
- Recommendations are then made for the delivery of a revised DART Expansion Programme.

4.6.2 All scheme bundles were tested using the ERM and outputs were comparatively assessed using the KPIs outlined in Section 3.5. The evaluation process is outlined in further detail below.

Figure 18. Flow Chart of Assessment Process



Stage 1: Scheme Bundles Comparative Assessment

4.6.3 Five scheme bundles were provided by the NTA and IÉ for evaluation at stage 1. [These scheme bundles are presented in detail in Chapter 2 of this report]. A brief overview of these options is given below:

- **Scheme Bundle 1:** Do Minimum Network.
  - Scheme Bundle 1B: Four Tracking of the Northern Line was tested as a standalone scheme on top of the Do Minimum;
- **Scheme Bundle 2:** Full DART Expansion including DART Underground (as per the 2015 Business Case);
- **Scheme Bundle 3:** DART Expansion including DART Underground with Heuston Station Turnback;
- **Scheme Bundle 4:** DART Expansion including DART Underground with Pearse Station Turnback; and
- **Scheme Bundle 5:** DART Expansion including Underground tunnel from East Wall to Pearse Station Turnback.

4.6.4 The five scheme bundles were comparatively assessed across a number of KPIs using outputs from the ERM, to determine which bundles preformed the best.

4.6.5 Following the comparative assessment, the best preforming scheme bundles from Stage 1 were identified and brought forward to Stage 2 of the assessment, described below.

Stage 2: Refinement and Enhancement of Scheme Bundles

4.6.6 Following the modelling and assessment of the scheme bundles carried out at Stage 1 the bundles that progressed to Stage 2 were reviewed and a process of optimisation was undertaken. The optimisation process focused on infrastructure requirements and service plan improvements.

4.6.7 The service plans for the scheme bundles were optimised using the ERM outputs from Stage 1 with new infrastructure measures also suggested at this stage to ensure optimal performance of each bundle at the Stage 2 assessment.

4.6.8 The enhanced bundles were tested again using the ERM and comparatively assessed against the KPIs as per Stage 1.

Stage 3: Optimisation of Emerging Preferred Scheme Bundles

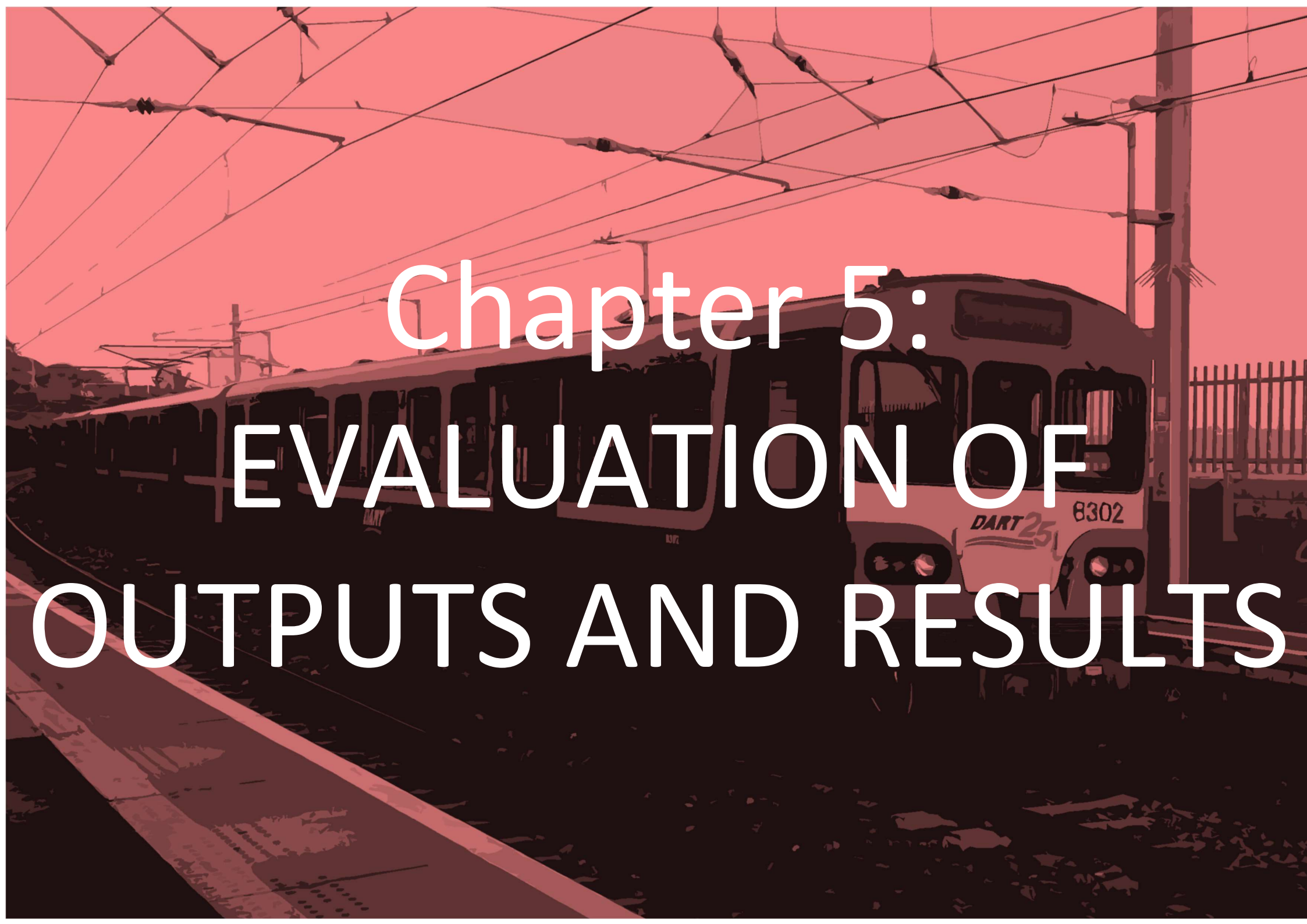
4.6.9 Following the conclusion of Stage 2 a number of the scheme bundle options were brought forward to Stage 3. These options were identified as the best performing and are called the Emerging Preferred Scheme Bundles (EPSBs).

4.6.10 The EPSBs were then amended further using feedback from the NTA and IÉ and also following an independent engineering feasibility review (undertaken by Jacobs). The EPSB were then re-tested using the ERM and KPIs comparatively assessed.

4.6.11 The outputs of Stage 3 were then used in the formation of recommendations.

Sensitivity Analysis and Recommendations

4.6.12 Following the testing and optimisation of scheme bundles and the selection of EPSB, further sensitivity tests were undertaken to assess the performance of the scheme bundles in the context of changes to modelling parameters and future demand assumptions. A set of recommendations were then made detailing the refined DART Expansion Programme and next steps to be taken in the development of the project.



Chapter 5:
EVALUATION OF OUTPUTS AND RESULTS

5. EVALUATION OF OUTPUTS AND RESULTS

5.1 Stage 1 – Comparative Assessment

5.1.1 As outlined in Chapter 3 of this report there were 6 unique scheme bundles to be tested as part of this project. To recap, five of these bundles were tested at Stage 1 of the project:

- **Scheme Bundle 1**: Do Minimum Network:
  - Scheme Bundle 1B: A variant of Bundle 1 was tested which included 4-Tracking of the Northern Line
- **Scheme Bundle 2**: Full DART Expansion including DART Underground (as per the 2015 Business Case);
- **Scheme Bundle 3**: DART Expansion including DART Underground with Heuston Station Turnback;
- **Scheme Bundle 4**: DART Expansion including DART Underground with Pearse Station Turnback; and
- **Scheme Bundle 5**: DART Expansion including Underground tunnel from East Wall to Pearse Station Turnback.

5.1.2 Each of the scheme bundles were tested using the East Regional Model (ERM) and the outputs were then used to form a comparative assessment.

5.1.3 [Note, Scheme Bundle 6 was not tested in Stage 1 and was developed later as part of the Stage 2 optimisation process].

For each of the subsequent KPI output tables, where scheme bundles are compared against each other, the darker the shade of green indicates a better performance under each KPI

Scheme Bundle 1B: 4-Tracking of the Northern Line

5.1.4 As stated previously, a standalone test was undertaken to assess the benefit of the ***4-Tracking of the Northern Line*** as part of the Stage 1 assessment**.** 4-Tracking involves the doubling of the number of tracks on the Northern Line between Connolly Station and Malahide. This facilitates Commuter and Inter-City Trains on this section to be separated from DART services allowing trains to bypass DART Services that will be stopping. These services can therefore operate at higher speeds along this section. In addition to higher speeds for non-DART services, 4-Tracking allows for 2 additional 2-way DART train paths per hour on the northern line above the Do Minimum scenario.

5.1.5 Potential increases in DART services for the 4-Tracking option are limited by existing capacity constraints at Connolly Station and the Loop-line Bridge, which restricts the available capacity for additional train paths on this section.

5.1.6 4-Tracking was assessed at the start of the Stage 1 assessment process to examine its performance and to determine the potential benefits of including 4-Tracking within the DART Expansion Programme and within the subsequent scheme bundles. Table 3 below outlines the KPIs output from the ERM for the test.

Table 3. KPI Results Northern Line Assessment

KPI	DO MIN	4 TRACKING NORTHERN LINE
PT Mode Share (AM)	18.0%	18.1%
PT Loadings (AM)	148,200	150,100
Rail	38,400	40,300
Bus	83,800	83,700
LRT	26,000	26,200
PT Transfers (AM)	25,700	25,700

5.1.7 As shown above, 4-Tracking adds an additional 1,900 rail boardings with a 0.1% improvement in public transport mode share in the morning peak hour. However, the results indicate that the potential benefits it delivers are outweighed by the capital cost involved in delivering 4-tracking. Hence, this project was not considered a viable infrastructure element for inclusion within other scheme bundles and it did not progress past the Stage 1 assessment.

Scheme Bundle Results

5.1.8 Following the initial testing of 4-Tracking the Northern Line, Scheme Bundles 2 to 5 were tested within the ERM using the network infrastructure assumptions described in Chapter 3 and the service plans provided by IÉ (these are detailed in Appendix C). Each of the scheme bundles was tested with Metro North[13] included. Table 4 below contains the KPI results extracted from the ERM outputs for each of the scheme bundles (2-5). Further detail on the modelling approach employed and the results for each of the scheme bundles modelled at Stage 1 are contained in Appendix F. As can be seen from Table 4, all scheme bundles perform well compared to the Do Minimum scenario. Scheme Bundles 2 and 4 perform similarly in terms of public transport mode share, with Scheme Bundle 2 performing the best in terms of total rail boardings.

5.1.9 Scheme Bundle 5, which includes the tunnel via East Wall to Pearse Station, does not perform as well as the other bundles and attracts a significantly lower level of rail boardings than Scheme Bundles 2 and 4. It can be seen that all scheme bundles reduce the number of bus boardings, as more people choose to travel by rail due to its increased performance and network connectivity. Each of the curtailed DART Underground tunnel scheme bundle options (3-5) result in higher levels of transfers due to the requirement to interchange within the city.

[13] The Metro North alignment used in the tests was the old Metro North Alignment from Swords to St. Stephen's Green. The NMN EPR was not known at the time of Stage 1 testing

5.1.10 Table 5 contains a commentary on the Stage 1 results for each of the scheme bundles and explains why each scheme bundle was or was not taken to the subsequent stages in the assessment process.

Table 4. KPI Results for Stage 1 Assessment

KPI	SCHEME BUNDLE 1 (DOMIN)	SCHEME BUNDLE 2	SCHEME BUNDLE 3	SCHEME BUNDLE 4	SCHEME BUNDLE 5
PT Mode Share (AM)	18.0%	20.1%	19.4%	20.1%	19.8%
PT Loadings (AM)	148,200	168,000	167,400	168,600	166,300
Rail	38,400	58,900	52,900	57,400	54,000
Bus	83,800	65,200	69,400	66,100	67,500
LRT	26,000	24,200	25,100	25,200	25,300
Metro	-	19,700	20,000	19,800	19,500
PT Transfers (AM)	25,700	32,900	34,000	33,600	32,800

Table 5. Outcome of Stage 1 Assessment

SCHEME BUNDLE	COMMENT ON RESULTS	ACTION
Scheme Bundle 1B	4-Tracking of the Northern Line was tested in the Stage 1 modelling assessment to see if it warranted inclusion as an element of the DART Expansion Programme. The performance of 4-Tracking was not considered enough to warrant its inclusion as part of the DART Expansion Programme considering its considerable capital cost and limited performance, and as such was not brought forward for inclusion within the other scheme bundles.	**Four Tracking of Northern Line No Longer Considered**
Scheme Bundle 2	DART Underground performs the best across all KPIs, particularly on public transport boardings with a significant increase in passengers using DART services.	**Brought Forward to Stage 2**
Scheme Bundle 3	The Heuston turnback option does not perform as well as the Pearse turnback option due to the requirement to interchange at Heuston station which in most cases is not a final destination for passengers. This results in a significant drop in the DART boardings on the Kildare line compared to Bundles 2 and 3 and also results in the highest level of transfers across the options. It was considered that the interchange opportunities could be further improved at Heuston station, and hence it was deemed appropriate that Bundle 3 should remain under consideration in subsequent stages of the project.	**Brought Forward to Stage 2**
Scheme Bundle 4	The Pearse Turnback option performs similarly well to the performance of Scheme Bundle 2 and is brought forward to the next stage of assessment.	**Brought Forward to Stage 2**
Scheme Bundle 5	The Pearse Turnback option via East Wall performs well compared to the DoMinimum scenario and attracts higher Rail boardings than the Bundle 3 option. In addition, it has the shortest length of underground tunnel and is consequently less costly than other options. On this basis, Bundle 5 is brought forward to the next stage of assessment.	**Brought Forward to Stage 2**

5.2 Stage 2 – Optimisation of Scheme Bundles and Comparative Assessment

During the optimisation process it was decided in consultation with the NTA and IÉ to develop an additional scheme bundle. The aim of this additional bundle was to identify an option that made optimum use of the existing rail network infrastructure to enable the delivery of the DART Expansion Programme without DART Underground. This option is called Scheme Bundle 6.

5.2.1 The scheme bundles brought forward from Stage 1 are outlined below and also include a new 'No-tunnel' option called Scheme Bundle 6:

- **Scheme Bundle 2**: Full DART Expansion including DART Underground (as per the 2015 Business Case);
- **Scheme Bundle 3**: DART Expansion including DART Underground with Heuston Station Turnback;
- **Scheme Bundle 4:** DART Expansion including DART Underground with Pearse Station Turnback; and
- **Scheme Bundle 5**: DART Expansion including Underground tunnel from East Wall to Pearse Station Turnback.
- **Scheme Bundle 6**: DART Expansion with Existing Network Enhancement (No DART Underground Tunnel)

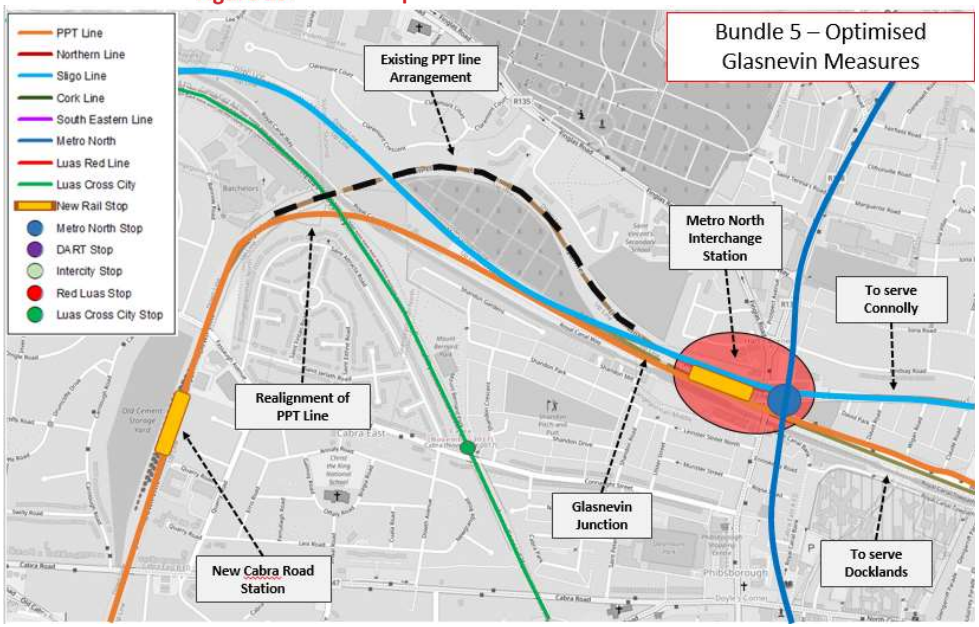
5.2.2 Following the modelling and assessment of the scheme bundles carried out at Stage 1 the scheme bundles that progressed to Stage 2 were reviewed and a process of optimisation was undertaken. The optimisation process focused on infrastructure requirements and service plan improvements. This optimisation process was necessary for a number of reasons:

- The variation in service plans, provided at Stage 1, between the scheme bundles made it difficult to make a direct comparisons between them; and
- The scheme bundles at Stage 1 were based on the service plans developed for the 2015 DART Underground Business Case. This work pre-dated the NTA's new Regional Modelling System (RMS) and were developed based on outputs from an older strategic model of the Greater Dublin area, which was not as advanced as the new RMS, particularly with regard to the time periods represented, the coverage of the modelled area and the land-use demand forecasts, which meant there was scope to use the RMS to optimise the scheme bundle service plans to match the latest forecast demand for the GDA region.

5.2.3 All scheme bundles were optimised to ensure optimal performance of each scheme bundle at the Stage 2 assessment. For Scheme Bundles 2-4 this optimisation process only involved a service plan review as the infrastructure elements underpinning these scheme bundles were considered optimal.

5.2.4 Scheme Bundle 5 was the subject of infrastructure optimisation to seek ways to better utilise existing infrastructure where possible. Scheme Bundle 6 was also developed at this stage and includes some of the Scheme Bundle 5 optimisation measures.

Figure 19. Optimisation of Glasnevin Junction



Glasnevin Junction Optimisation

5.2.5 To allow services operating on the Maynooth Line to access Connolly station it was necessary for these services to use Glasnevin Junction. This would allow use of the Upper line thereby bringing services to Connolly Station via Drumcondra (which is the existing operating arrangement). However, as this line is also used by services operating on the PPT Line it would mean reducing the number of train paths through Glasnevin junction. This was considered a less than optimal arrangement as it results in less train paths operating on both the Maynooth and PPT lines. To overcome this issue, the prevention of any crossover of services was examined through the realignment of the PPT Line, thereby keeping it beneath the Maynooth Line and making use of the Lower line to access the Underground Tunnel to Docklands and Pearse underground stations in Scheme Bundle 5. This also allowed access to the existing Docklands Station in Scheme Bundle 6. In this arrangement, the Maynooth Line continues to use the Upper line to access Connolly Station only.

5.2.6 This optimisation also provides the opportunity to interchange with New Metro North (NMN) if a Metro and Rail station are provided in close proximity at Glasnevin Junction. This would allow passengers to interchange to/from both the PPT and Maynooth Lines to access the City Centre via NMN.

Stage 2 Glasnevin Junction Actions

1. **Prevent Crossover of services at Glasnevin Junction**
2. **PPT Line realigned keeping it under the Sligo / Maynooth line and using the existing Lower line serving new Docklands and Pearse Stations via an underground tunnel (Bundle 5) and the existing Docklands Station (Bundle 6).**
3. **The Maynooth Line to use the existing Upper line to access Connolly Station.**
4. **Provide for a new Glasnevin Rail-Metro Interchange station, that provides an interchange point for New Metro North and the Maynooth and PPT lines.**

City Centre Optimisation

5.2.7 The Glasnevin Junction arrangement adjustments were the only infrastructure changes associated with Scheme Bundle 5, however, further infrastructure optimisation proposals were identified to Scheme Bundle 6 which are detailed below .

5.2.8 Within Scheme Bundle 6, the effect of removing the crossover of services at Glasnevin Junction is that services on the PPT line can no longer access Connolly Station and this line goes directly to Docklands Station instead. For this reason, interchange is provided with NMN at Glasnevin to allow passengers to access the City Centre.

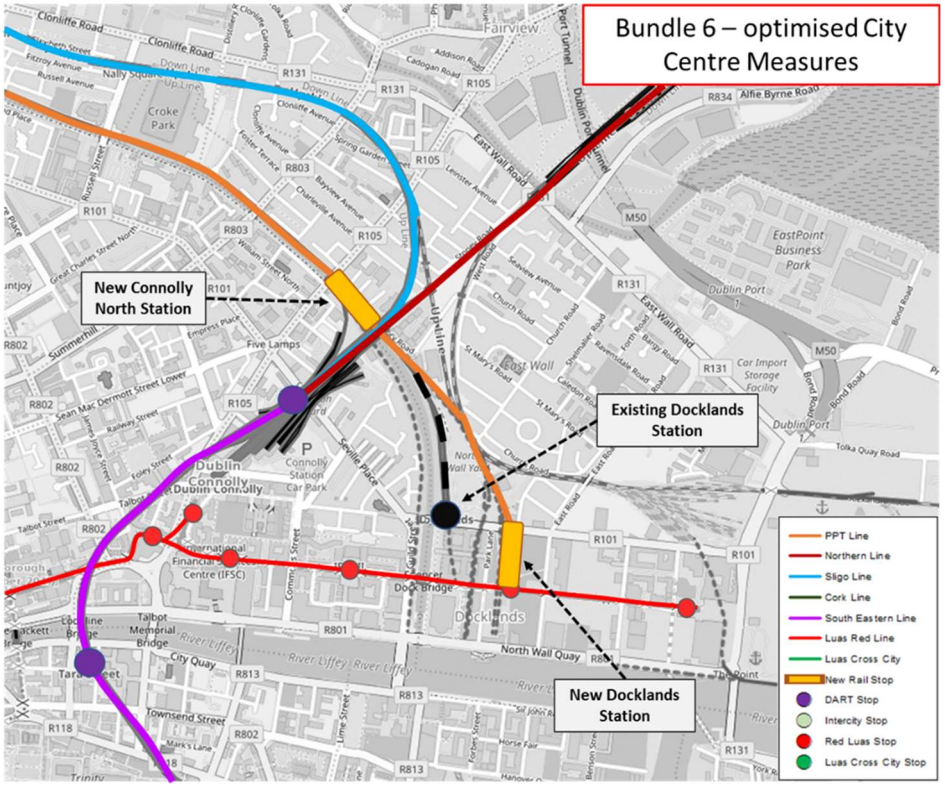
5.2.9 To allow passengers using the PPT Line to access Connolly Station a new **Connolly North Station** was included on the PPT Line at Ossory Road where the PPT Line crosses the Northern and Maynooth Lines. This new Connolly North Station allows PPT Line passengers to disembark and access Connolly station to access Northern and South East rail line services.

5.2.10 A new Docklands Station is also proposed in Scheme Bundle 6 to better integrate with the Luas Red Line at Spencer Dock. The new Docklands Station will use an existing disused rail line to bring PPT services further south.

Stage 2 City Centre Optimisation Actions

1. **New Connolly North Station**
2. **New Docklands Station further south**
3. **Close existing Docklands Station**

Figure 20. Bundle 6 Optimised City Centre Measures



Stage 2 Services Plan Reviews

5.2.11 Following optimisation of the physical infrastructure underpinning Scheme Bundles 5 and 6, the services plans for all scheme bundles were then reviewed to determine where they could be optimised to provide better performance.

5.2.12 To determine the improvements to the service plans for each scheme bundle a technical meeting was held with the NTA and IÉ to discuss the service plans and Rail Line Demand Profiles, as output from the Stage 1 modelling. The outcome of this meeting was a deeper understanding of the existing service patterns and the demand profiles of the lines across the Rail Network. This allowed for an informed review of the proposed service plans with a focus on ensuring the service plans better matched the demand profiles.

5.2.13 The focus was, therefore, to optimise the Service Plans to:

- maximise the potential of each Line;
- maintaining consistency in service offerings across scheme bundles as far as practicable; and
- provide a consistent basis for comparison across each scheme bundle.

5.2.14 The key outcomes of the Service Plan review process were:

- Prioritisation of end to end service frequencies;
- All DART Services on the Kildare Line to begin at Hazelhatch;
- Increasing the maximum potential of each line on the busiest sections, which resulted in:
  - Loop-line Bridge capacity being increased to 18 trains per hour per direction (TPHPD);
  - Maynooth and PPT Lines being increased to 16 TPHPD.
- Providing peak service patterns throughout the day resulted in an overprovision of capacity in the inter-peak periods. To overcome this, 4-Car DART trains would be used at two thirds of the peak period frequency.

5.2.15 Table 6 below provides the service patters on all key sections of the rail network that emerged as an outcome of the Service Plan review. Further detail on the specific service patterns used within the modelling assessment is contained in Appendix D. It should be noted that where possible, services on each of the lines have been consistently applied across the scheme bundles based on the following capacity constraints:

- Loop-line Bridge – 18 trains per direction per hour;
- For option with a tunnel turnback configuration – 15 trains per direction per hour

Table 6. Service Patterns Tested at Stage 2

Route	Existing Network	Scheme Bundle 2: DART Expansion	Scheme Bundle 3: Heuston Turnback	Scheme Bundle 4: Pearse Turnback	Scheme Bundle 5: PPT-Pearse Turnback	Scheme Bundle 6: PPT-Docklands
Loop-line Bridge	14	18	18	18	18	18
Heuston DART Line	0	16	16	15	15	16
Heuston DMU Line	12	12	12	12	12	12
DART Underground Tunnel	0	16	15	15	15	0
Maynooth Line	9	16	16	16	16	16
Bray -Greystones section	3	3	3	3	3	3
North of Connolly	13	21	20	19	19	19
South of Connolly	13	17	17	17	17	17
Phoenix Park Tunnel	4	0	0	0	15	16

Stage 2 Economic Appraisal – Benefit Cost Ratio

5.2.16 The estimation of Benefit Cost Ratio (BCR) is undertaken using the NTA Economic Appraisal tool. TUBA (Transport User Benefits Appraisal) software has been run for all scheme bundle options. The TUBA outputs include a BCR. The scheme files are prepared based on the following:

- Benefits to accrue from 2035 – Nominal assumed start of benefits accrual for the DART Expansion components;
- 2% per annum Construction inflation rate;
- 1% per annum Operation & Maintenance escalation rate;
- Cost estimates developed by IÉ for each of the end to end options;
- Shadow pricing included - Labour (80%) and Public Funds (130%);
- 25% Tunnel Risk Allowance, 10% for other elements;
- 30 year residual value; and
- 2065 model run assuming 16.8% growth from 2035 to 2065 (CSO M2F2 population forecasts).

5.2.17 In consultation with IÉ and the NTA each of the scheme elements were costed based on the detailed costings developed for the DART Expansion Business Case. Table 7 below shows the breakdown of costs for common infrastructure elements and also the scheme specific elements for each scheme bundle .

5.2.18 The total cost of the common infrastructure elements, and the non-tunnel elements that make up the DART Expansion Programme, total just under €1.340 billion in 2017 prices.

5.2.19 The scheme bundle with the most expensive scheme specific work package is Scheme Bundle 2 with a total cost of just under €2.7 billion and an overall cost of just over €4.1 billion, due to the greater length of underground tunnel in this option.

5.2.20 Scheme Bundle 6 has the lowest cost of the five scheme bundles, due largely to the absence of any tunnelling with this bundle. The total cost of Scheme Bundle 6 is just under €1.8 billion which is over €2.3 billion less than Scheme Bundle 2.

Table 7. Cost Used for Stage 2 Assessment

Common Infrastructure	Work Package Description	Scheme Costs (,000)	Source
	Kildare Route Project Phase2 - Four tracking of Cork Line from Hazlehatch to Inchicore	€207,253	Irish Rail
	Removal of Sligo Line Level Crossings From Maynooth to Connolly	€42,963	
	Sligo Line Resignaling and Electrification from Maynooth to Connolly	€211,586	
	Electrification of the Northern Line from Malahide to Drogheda	€154,916	
	Clongriffin Substation	€8,859	
	Improved Depot facilities	€166,753	
	Fleet - 296 Electric Multiple Units (EMUs)	€547,600	
	Total Costs - Common Infrastructure	€1,339,931	

Scheme Specific Infrastructure						
Work Package	Bundle 2 -Scheme Costs (,000)	Bundle 3 -Scheme Costs (,000)	Bundle 4 -Scheme Costs (,000)	Bundle 5 -Scheme Costs (,000)	Bundle 6 -Scheme Costs (,000)	Source
Total Costs - Enabling Works	€62,822	€32,314	€63,179	€35,510	€23,888	Irish Rail / Bundle 6 Preliminary Estimates
Total costs - Stations	€707,214	€557,170	€454,498	€278,408	€115,988	
Total Costs - System Upgrades	€116,924	€100,250	€108,541	€82,297	€78,444	
Total Costs - Tunnelling	€535,584	€556,335	€604,034	€269,449	€0	
Total Costs - Planning / Land Acquisition / Risk / Taxation	€1,230,982	€968,169	€1,050,730	€524,953	€213,192	
Commissioning	€21,595	€22,429	€22,145	€11,982	€5,229	
Total Scheme Specific Elements	€2,675,120	€2,236,667	€2,303,126	€1,202,598	€436,741	
Total Scheme Costs	€4,015,051	€3,576,598	€3,643,057	€2,542,529	€1,776,672	

Stage 2 Model Outputs

5.2.21 In a similar fashion to the Stage 1 assessment, Scheme Bundles 2, 3, 4, 5 and 6 were retested within the ERM using the network infrastructure and the optimised service plans (developed in consultation with the NTA and IÉ, which are detailed in Appendix D). Each of the scheme bundles was tested with New Metro North[14] included.

5.2.22 Table 8 below contains the KPI results for each of the scheme bundles extracted from the ERM. The darker shades of green indicate the best performing scheme bundle within each category. Stage 2 includes additional KPIs related to the Economic Assessment including costs and transport user benefits. Further detail on the modelling approach employed and the results for each of the scheme bundles modelled at Stage 2 are given in Appendix G.

5.2.23 As can be seen from Table 8below, the best preforming option is Scheme Bundle 2, which performs the best in terms of overall PT boardings and PT mode share. Bundle 6 performs the best in terms of BCR as it provides over €4 billion in transport user benefits and is the lowest cost option. The other tunnel options (i.e. Scheme Bundles 3 to 5) perform well but do not perform as well in BCR terms compared to Scheme Bundle 2. Scheme Bundle 5, which has the shortened tunnel option preforms similarly to Scheme Bundle 2 in BCR terms due to its lower cost.

5.2.24 Scheme Bundles 3 and 4 perform similarly now compared to the Stage 1 assessment, due to the improvement in the interchange distances coded in the model at Heuston Station in Scheme Bundle 3.

5.2.25 Table 9 is a summary of the Stage 2 results for Scheme Bundles 2 to 6 providing an explanation on which scheme bundles are taken forward to the next stages in the assessment process and which ones are not.

[14] it should be noted that the alignment of Metro North used at Stage 2 was the draft Emerging Preferred Route from the New Metro North Alignment Options Study at the time of modelling (September 2017). This also included a tie-in with the Luas Green Line and upgrading of Luas Green Line to Metro Standard. This includes a direct interchange with the heavy rail lines at Whitworth Road (proposed new station) and Tara Street.

Table 8. KPI's for Scheme Bundles Tested at Stage 2

KPI	SCHEME BUNDLE 2	SCHEME BUNDLE 3	SCHEME BUNDLE 4	SCHEME BUNDLE 5	SCHEME BUNDLE 6
PT Mode Share (AM)	20.6%	20.1%	20.4%	20.5%	20.2%
PT Boardings (AM)	173,300	173,100	173,100	172,500	170,900
Rail	64,200	61,000	59,000	57,000	55,800
Bus	61,100	63,700	64,200	66,000	65,900
Light Rail	11,200	12,000	12,400	12,600	12,600
Metro	36,800	36,400	36,400	36,900	36,600
Cap Ex Cost (€m)	3,761	3,414	3,390	2,832	2,010
Cap Ex + O&M Costs (€m) (60yrs)	11,970	11,280	10,865	8,814	7,102
Transport User Benefits (€m)	7,561	5,867	6,024	5,420	4,611
Present Value of costs (€m)	3,215	2,952	2,910	2,372	1,790
BCR	2.35	1.99	2.07	2.29	2.58

Table 9. Outcome of Stage 2 Assessment

SCHEME BUNDLE	COMMENT ON RESULTS	ACTION
Scheme Bundle 2	Although the highest cost option, Scheme Bundle 2 is the best preforming and delivers the highest level of User Benefits, as it provides for full network connectivity. There is potential to further enhance the performance of this bundle by reducing the tunnelling cost by placing the tunnel portal at Heuston Station and not Inchicore as currently proposed. This option is brought forward as a potential Emerging Preferred Scheme Bundle option.	**Brought Forward to Stage 3 as an Emerging Preferred Scheme Bundle**
Scheme Bundle 3	Scheme Bundle 3 is the worst performing option in terms of overall mode share across the five scheme bundles. It has a good BCR of 1.99 however this is the lowest of the Bundles. This is mainly due to the requirement to transfer at Heuston Station which limits the patronage on the Kildare line, although the through running of the Northern line into the underground tunnel still provides significant benefits and rail patronage. This option is the second most expensive option and does not perform as strongly as other option, so is therefore not considered a viable option to deliver the DART Expansion Programme.	**Not Brought Forward for Further Assessment**
Scheme Bundle 4	This option does performs well across the range of KPIs due to the through running of services into the underground tunnel from the Kildare line. The requirement to interchange at Pearse station does not have a significant negative impact as most passengers can access their preferred destination within the city centre before alighting. This option, however is still reliant on the building of a tunnel to deliver all its benefits which is costly and requires a long lead in time. It has a good BCR of 2.07 which is the 4th highest across the options. This option is approximately €400m cheaper than Scheme Bundle 2 although does not perform as strongly. This option is therefore not considered a viable option to deliver the DART Expansion Programme.	**Not Brought Forward for Further Assessment**
Scheme Bundle 5	This is the cheapest tunnel option and makes good use of existing infrastructure as it maintains the use of the PPT line. It performs well on most KPIs however it delivers the lowest transport user benefits and rail patronage of the tunnel options. It is approximately €800m more expensive than Bundle 6 and has a lower BCR, therefore it is not considered a viable option to deliver the DART Expansion Programme and is excluded from the next stage of assessment.	**Not Brought Forward for Further Assessment**
Scheme Bundle 6	This option has a BCR of 2.58 which is the highest across the scheme bundles. This option makes best use of existing infrastructure and maintains the use of the PPT line. It does not require a tunnel to be built to deliver the benefits which makes it a good low cost alternative to the DART Underground project whereby its benefits can be delivered much more quickly in comparison to other options. This option is brought forward as a potential Emerging Preferred Scheme Bundle option.	**Brought Forward to Stage 3 as an Emerging Preferred Scheme Bundle**

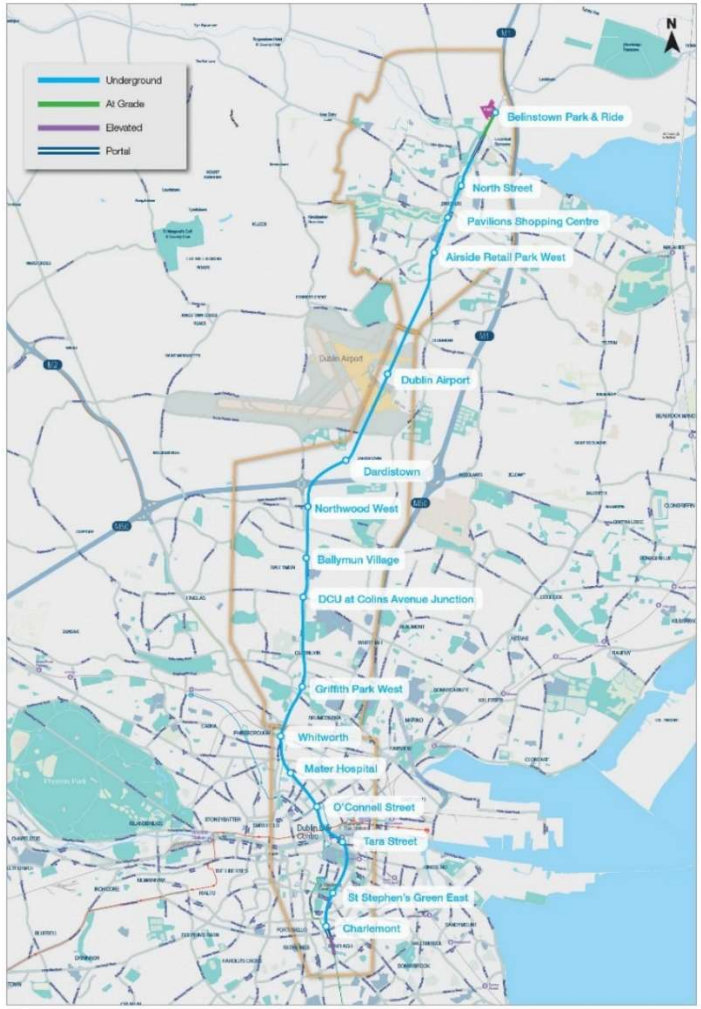
5.3 Stage 3 – Optimisation of Emerging Preferred Scheme Bundles and Comparative Assessment

5.3.1 The scheme bundles brought forward from the Stage 2 Comparative Assessment are the Emerging Preferred Scheme Bundles 2 and 6. Scheme Bundle 2 was the best performing tunnel option and Scheme Bundle 6 has the highest BCR and performs strongly as a no-tunnel option. In bringing both options forward to Stage 3 for further assessment it was necessary to ensure that both options were further optimised to deliver their full potential thereby allowing a fair comparison between both Scheme bundles.

Scheme Bundle 2 – Review and Optimisation

5.3.2 A review was undertaken of the infrastructure elements included within Scheme Bundle 2 to ensure that it had been enhanced to its full potential. Scheme Bundle 2 (which represents the previous DART Expansion Business Case) required little further optimisation given the considerable amount of optimisation work that has already been invested in it. However, based on the most recent information available, the scheme bundle infrastructure elements could be adjusted slightly, to include for additional stations, to tie-in better with the New Metro North Emerging Preferred Route (EPR) proposals as shown in Figure 21 and also to include for potential cost savings attributable to the Western Tie-in Study, described further in Section ¢.

Figure 21. New Metro North EPR Alignment



5.3.3 The following final adjustments were made to Scheme Bundle 2:

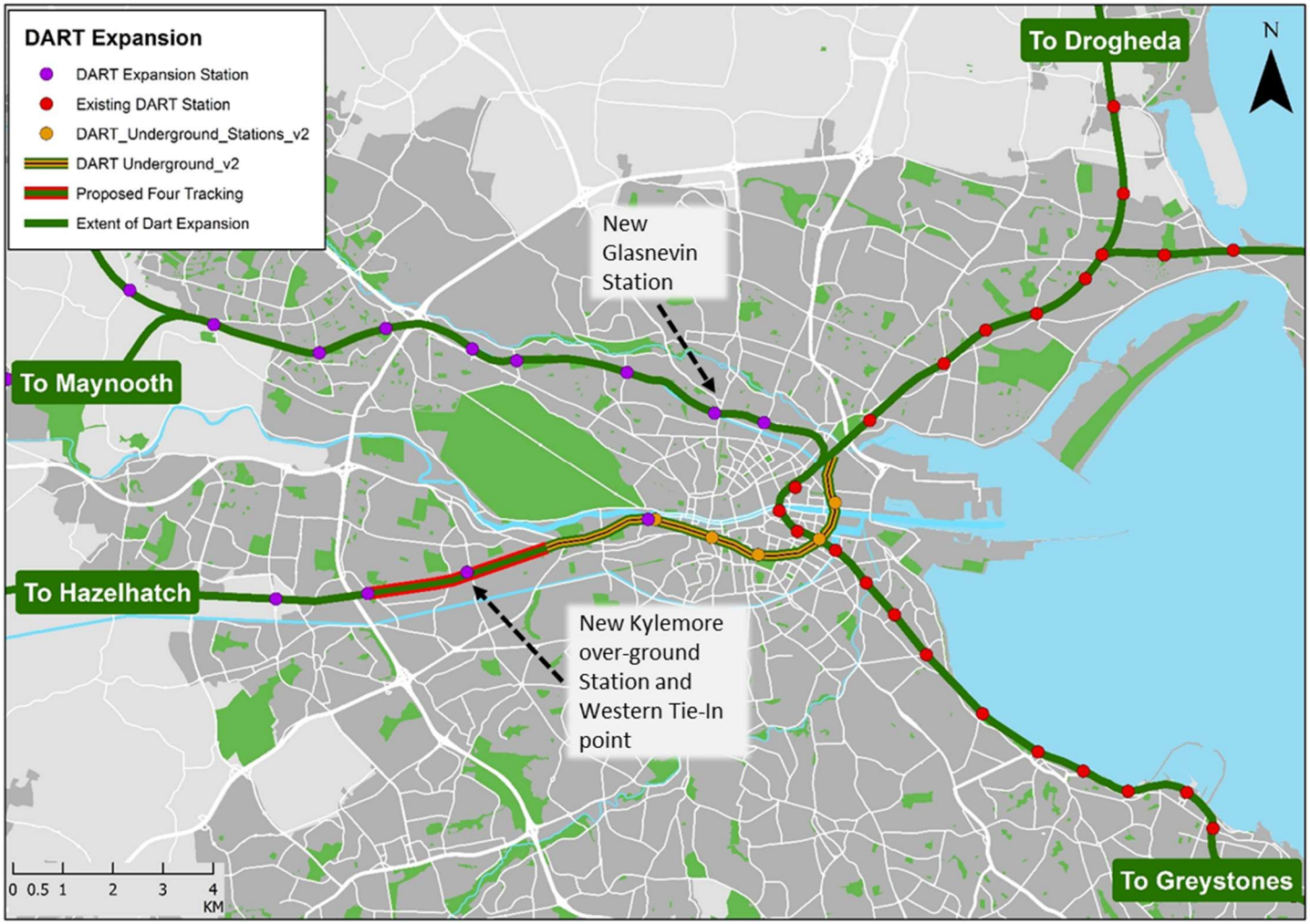
- New **Glasnevin Station:**
  - Similar to Scheme Bundle 6, a new station on the Maynooth Line at Glasnevin was included to allow for integration and interchange between services operating on the Maynooth Line and New Metro North (NMN).
- Realignment **of St. Stephen's Green Station:**
  - NMN includes a station at St. Stephen's Green (SSG) which is further east compared to the previous Old Metro North alignment. For this reason, the SSG DART Underground Station in Scheme Bundle 2 has been realigned to better integrate with the NMN station on the East side of SSG. This allows for better integration and interchange opportunities between services operating on the DART Underground Line and NMN.
- Adjustment **of the Tunnel Western Tie-In (WTI):**
  - A WTI Study was recently undertaken which looked at the potential option to move the DART Underground western tunnel portal further east and positioned closer to Heuston Station rather than Inchicore Station. This would result in significant tunnelling cost savings. Although this has to be balanced with additional 4-Tracking on the Kildare line.
  - By moving the WTI closer to Heuston station the cost of tunnel within Scheme Bundle 2 is reduced and the underground station at Inchicore can now be replaced with a lower cost above-ground station at Kylemore.
  - The cost savings associated with the WTI adjustments, amount to approximately €280m.

5.3.4 **Bundle 2 Optimisation Actions:**

1. **New Glasnevin Station at Whitworth Road on the Maynooth Line**
2. **Realignment of St. Stephen's Green Station on the DART Underground Tunnel to tie-in better with the NMN underground Station.**
3. **Revised Western Tie-In – which moves the DART Underground Tunnel portal further east and closer to Heuston Station and an above ground station at Inchicore / Kylemore**

5.3.5 Figure 22 below shows Scheme Bundle 2 including the adjustments outlined above:

Figure 22. Final Optimisation of Scheme Bundle 2



Bundle 6 – Review and Optimisation

5.3.6 For Stage 3, Scheme Bundle 6 required an Engineering Feasibility Review to ensure that the proposals being put forward in terms of infrastructure improvements were viable. In particular, this review examined whether the network was capable of handling the train path service plans being proposed, which included up to 16 Trains (per direction per hour) on each of the PPT, Maynooth and Northern Line corridors. The review set out to determine the best possible rail path configuration for Scheme Bundle 6 and to identify where new infrastructure could be incorporated.

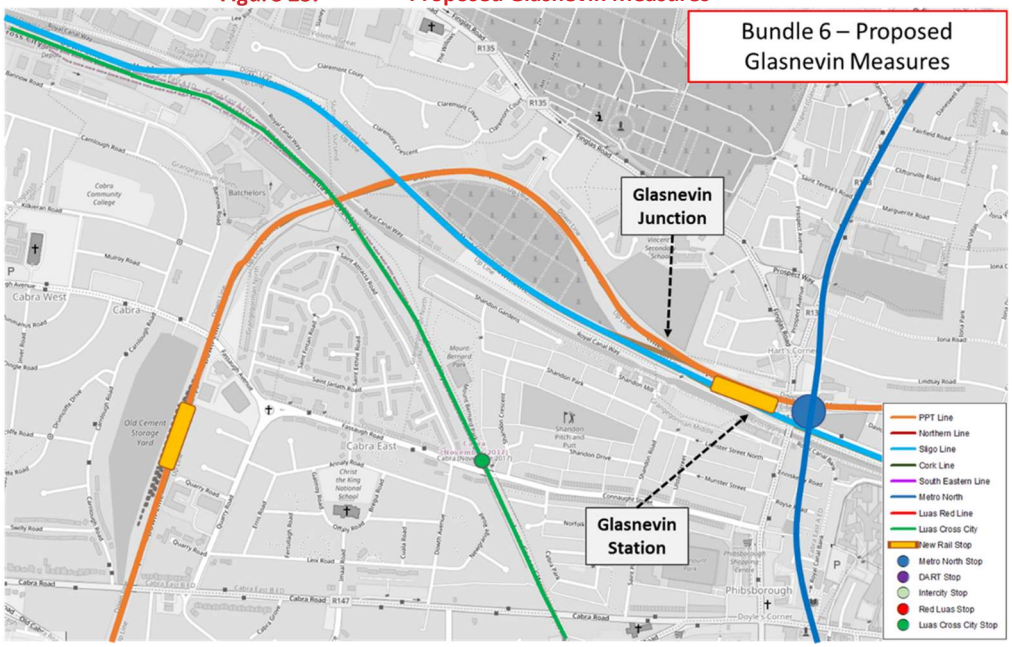
5.3.7 Additionally, it was important that the Scheme Bundle 6 elements were appropriately costed to ensure a robust comparative assessment with Scheme Bundle 2.

5.3.8 The major outcome of the review was an adjustment to the configuration of Glasnevin Junction and Connolly Station to handle the level of train paths proposed. This meant that major engineering works were not required at Glasnevin but instead the reconfiguration of Newcomen and East Wall Junctions could ensure the connectivity required.

5.3.9 The changes to Glasnevin Junction involved closing the junction to remove the potential for the crossover of services from the PPT or Maynooth lines from the Upper to the Lower Lines (the Maynooth line can currently use the junction to access both the Upper and Lower lines). This new arrangement means Maynooth line services must only use the Lower line and PPT line services use the Upper Line (as per the existing arrangement for PPT services). This arrangement allows the PPT Line access to Connolly Station and the Maynooth Line (via the Lower Line) to access Docklands Station. The proposed Glasnevin Station is also maintained.

5.3.10 Figure 23 shows the proposed Glasnevin measures, namely the closing of the junction to the crossover of services which separates the two lines and the installation of a new Glasnevin Station. This new station also provides interchange potential to New Metro North via its proposed Whitworth Road Station.

Figure 23. Proposed Glasnevin Measures

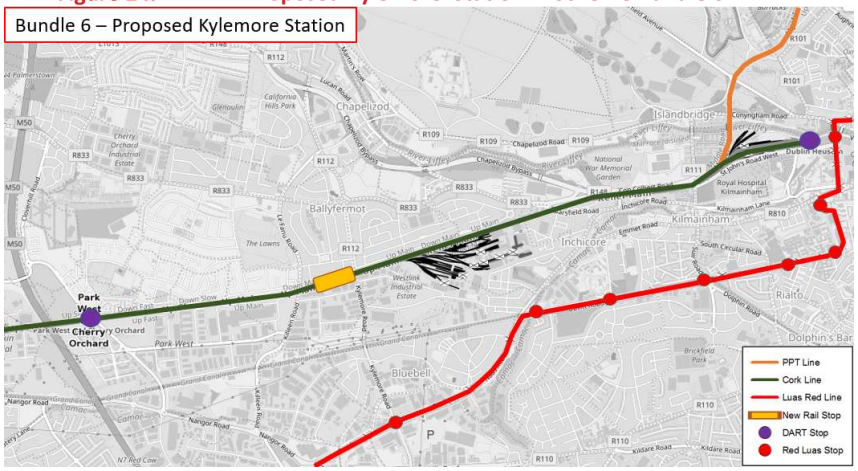


5.3.11 Following discussions with IÉ, it was agreed that a proportion of the proposed 16 DART services on the Kildare line could be re-directed from the PPT to the Heuston Mainline Station. This follows on from the proposal to 4-track the Kildare line to Heuston in the Bundle 6 option. In addition, as per WTI proposals as part of Scheme Bundle 2 the above-ground station at **Kylemore** is to be included in Scheme Bundle 6.

5.3.12 The Kylemore Road Station is accessed off Kylemore Road and would provide passengers on Commuter and Intercity services or DART Services an interchange opportunity. Passengers could choose between services terminating at Heuston Station, which provides access to the South City, or services using the PPT line, which provides access to the North City and Docklands.

5.3.13 Figure 24 shows the location of the Kylemore Station, east of Le Fanu Road and west of Kylemore Road.

Figure 24. Proposed Kylemore Station in Scheme Bundle 6



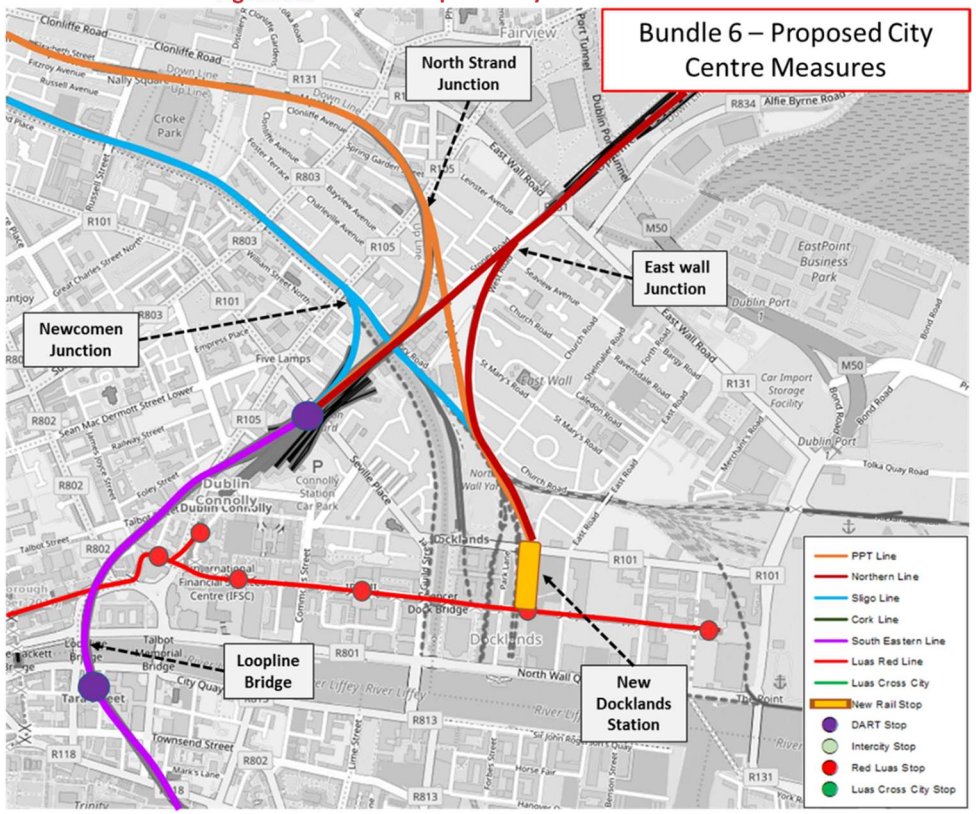
5.3.14 The above measures mean that the **Heuston West (Platform 10)** station is no longer required and has been removed from the Scheme Bundle 6 package of measure going forward.

5.3.15 In addition to measures on the Kildare line and at Glasnevin, the following City Centre measures are proposed on the approach to Connolly Station to allow access from all rail corridors to Connolly and Docklands Stations, which are also shown in Figure 25 below:

- **Newcomen Junction**
  - It is proposed to use Newcomen Junction to allow Maynooth Line services to access Connolly Station whilst also being able to continue to Docklands Station;
  - To enable the permanent opening of Newcomen Junction, a new Canal Drop Lock will be required on the Royal Canal to allow the Junction to be permanently open to 2-way trains whilst Canal barge traffic can use the new drop lock system to pass under the upgraded Newcomen Junction. A similar arrangement has been successfully constructed in Dalmuir, Scotland and works well;
  - North Strand Bridge will also require upgrading to have a larger span to allow clearance of the proposed 2-track layout at this location.
- **Loop Line Bridge (LLB)**
  - LLB capacity maintained at capacity of 18 Trains Per Direction Per Hour (TPDPH);
  - Access to the Loop-Line will be provided from and to all rail line corridors in the city centre;

- **Docklands Station**
  - New re-configured Docklands Station to handle 18 TPDPH;
  - The Station is to be moved further south to provide better interchange opportunities with the Luas Red line at Spencer Dock;
  - Upgraded to a 4-no. platform station compared to the 2 platforms currently at the existing Docklands Station, with passive provision for a 5th if required.
- **East Wall Junction**
  - Opened for services from the Northern Line to allow access to the new Docklands Station.
- **North Strand Junction**
  - Opened for services from the PPT Line to allow access to Docklands Station.
- **Revised Connolly Station**
  - Rebuilt to accommodate 4 through line platforms which connect to services coming through Newcomen Junction and the Northern Line;
  - Redesigning all platforms to accommodate up to 10- Car DART train sets; and
  - New access and egress arrangements with a new access on Preston Street.
- In **addition**, upgrades are planned to **Tara Street Station**, including wider and longer platforms to accommodate 10-car trains and safely accommodate more passengers.
- A new turnback platform at **Dun Laoghaire Station** in addition to the two **existing** platforms, this is to facilitate the increase in services over the Loop-line Bridge, which can't all be handled at Grand Canal Dock or Bray stations.

Figure 25. Proposed City Centre Measures

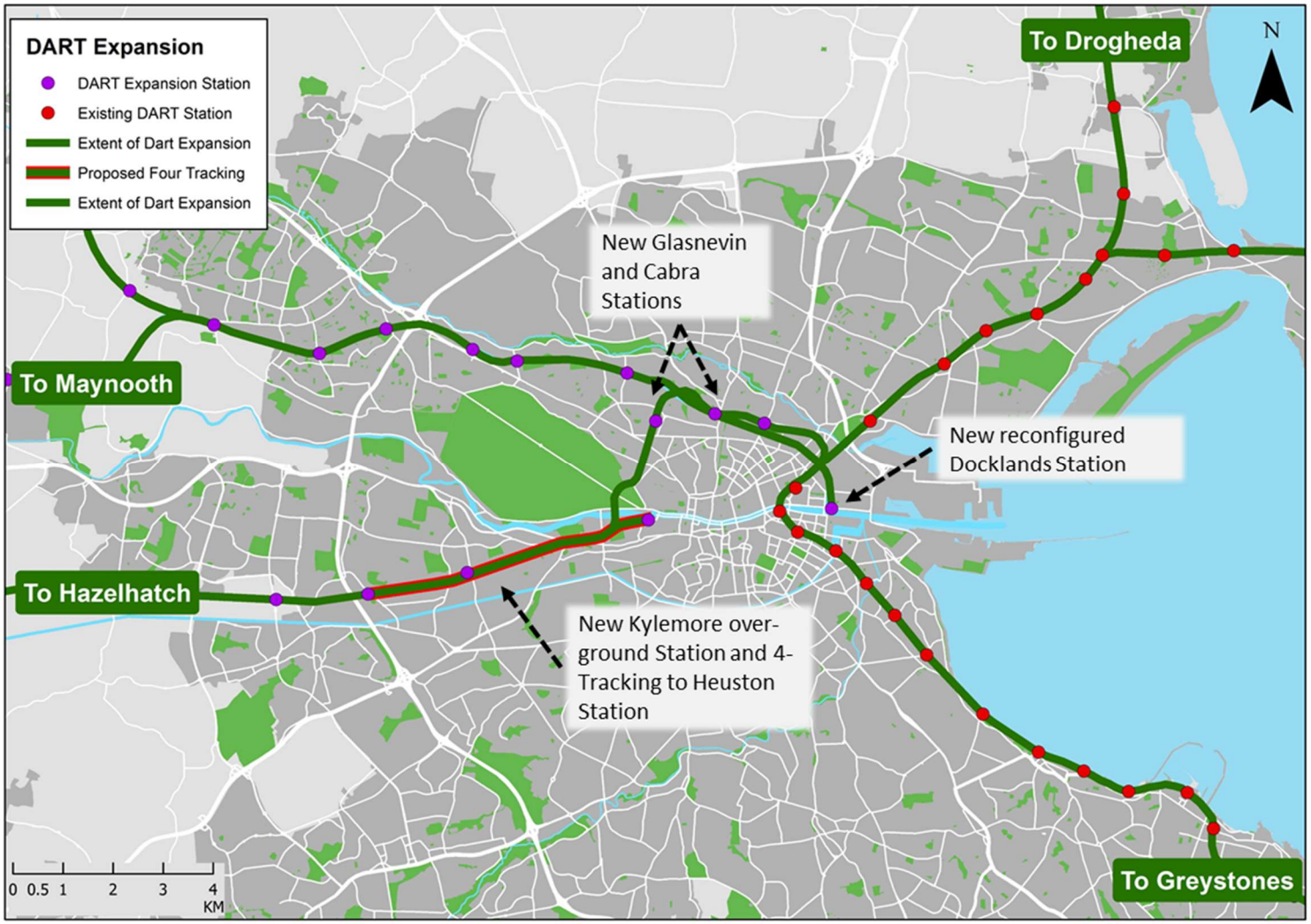


5.3.16 **Scheme Bundle 6 Optimisation Actions:**

1. **New station at Kylemore on the Kildare line.**
2. **4 DART services diverted to Heuston mainline station.**
3. **Heuston West Station (Platform 10) removed from further consideration**
4. **Close Glasnevin Junction to the crossover of services.**
5. **Upgrade Newcomen Junction to a permanently open Junction through the installation of a Canal Drop Lock.**
6. **Re-open East Wall Junction to commuter and DART services.**
7. **Re-open North Strand Junction to commuter and DART services**
8. **Re-configure Connolly Station.**
9. **Construct a new Docklands Station.**
10. **Upgrade Tara Street Station.**
11. **Construct a turnback facility at Dun Laoghaire Station.**

5.3.17 The optimised Scheme Bundle 6 is shown in full in Figure 26 below.

Figure 26. Optimised Scheme Bundle 6



Optimisation of Service Plans for Scheme Bundle 6

5.3.18 Once the infrastructure elements of Scheme Bundle 6 were developed and finalised, it was then important to understand the optimal balance of services and the appropriate distribution of train paths across the regional rail network, to make best use of the proposed network.

5.3.19 In the optimised Scheme Bundle 6, there is now the ability for services from the PPT, Maynooth and Northern Line corridors to terminate at either Docklands or Connolly or continue south over the Loop-line Bridge. This represents a considerable enhancement to the previous version of Scheme Bundle 6. Hence it was important to determine how services should be distributed between Connolly and Docklands and which services should utilise the Loop-line Bridge to ensure the optimal performance of Scheme Bundle 6.

5.3.20 To determine the optimum service plan for Bundle 6, a series of tests were undertaken using the ERM. In these tests, the balance of services from the rail corridors was adjusted and model outputs were evaluated.

5.3.21 As described above, the distribution of services affects services operating on three corridors, the PPT Line, the Maynooth Line and the Northern Line. In testing the optimal distribution from these corridors, the terminating capacity of Connolly and Docklands Station was held constant along with the capacity of the Loop-line bridge while the allocation of services from the three corridors was varied to identify the best performing combination of services. Further detail on the service plans used in the Stage 3 testing are included in Appendix E.

5.3.22 The main outcome of the tests was as follows which are displayed in Table 10 below:

- Passengers from the PPT line transfer to Metro North Services at twice the level of Maynooth line passengers at Glasnevin, as such PPT services do not require Connolly or LLB capacity;
- Maynooth line services are therefore prioritised over PPT services into Connolly and over the Loop-line bridge; and
- Northern Line services should have the highest priority on the Loop-line bridge.

Table 10. Scheme Bundle 6 – Service Plan Distribution

CORRIDOR	HEUSTON	CONNOLLY	DOCKLANDS	LOOP-LINE BRIDGE	*TOTAL PER TEST*
Kildare Line	4	0	12	0	*16*
Northern Line	0	5	3	11	*19*
Maynooth Line	0	6	3	7	*16*
TOTAL	**4**	**11**	**18**	**18**	***51***

Scheme Bundle Costs

5.3.23 Table 11 below provides a detailed breakdown of the cost estimates for both Scheme Bundles 2 and 6. The cost estimates for Scheme Bundle 2 include for the savings associated with the Western Tie-In Study. The table also outlines a breakdown of the costs of the common elements to both scheme bundles. These common elements are essentially the infrastructure included in the DART Expansion Programme such as 4-Tracking, electrification and fleet upgrade costs etc.

5.3.24 As can be seen from the table below there is a significant variation in the costs between both scheme bundles with the main cost differential being the underground tunnel element included within Scheme Bundle 2. Scheme Bundle 6 is approximately €1.75 Billion less expensive than Scheme Bundle 2.

Table 11. Cost Breakdown of Scheme Bundles 2 and 6

Scheme Bundle 2 - DART Expansion including DART Underground			Scheme Bundle 6 - DART Expansion with PPT upgrade		
Common Infrastructure	**Scheme Description**	**Scheme Costs (,000)**	**Source**		
	Electrification / Signalling Heuston	€115,612	Irish Rail		
	4-Track Parkwest to Inchicore	€94,526			
	Electrification / Signalling Maynooth	€245,007			
	Electrification / Signalling Northern Line	€210,208			
	Level Crossings - Maynooth Line	€53,286			
	Improved Depot facilities	€164,695			
	Fleet - 296 Electric Multiple Units (EMUs)	€548,000			
	Total Costs - Common Infrastructure	**€1,431,334**			
Scheme Specific Infrastructure				**Scheme Specific Infrastructure**		
Work Package	**Scheme Costs (,000)**	**Source**		**Work Element**	**Scheme Costs (,000)**	**Source**
• DU - Watling St to East Wall	€1,779,076	Irish Rail		• Newcomen Junction link to Connolly	€33,998	Irish Rail / Jacobs Engineering
• WTI Option from Sarsfield Bridge	€617,914			• Connolly Station Platform Remodelling	€203,860	
• 4-Track Inchicore to Sarsfield	€32,688			• Docklands Station (Spencer Dock)	€164,151	
• Dún Laoghaire Station - Turnback	€49,018			• Tara Street upgrade	€23,458	
• Inchicore works for B4T	€6,333			• Dún Laoghaire Station - Turnback	€49,018	
• FFSS Adjustment	€12,666			• Glasnevin Station	€69,712	
• Parkwest Turnback	€9,047			• Cabra Station	€16,430	
• Kylemore Station	€8,504			• 4-Track Inchicore to OB1	€108,805	
Total Scheme Specific Elements	**€2,515,244**			• Inchicore works for B4T	€6,333	
Bundle 2 - Total Scheme Cost	**€3,946,578**			• FFSS Adjustment	€12,666	
				• OB1 Bridge Adjustments	€29,855	
				• Kylemore Station	€8,504	
				• PPT upgrade / Electrification / Signal	€33,473	
				• Electrification OB1 - Heuston	€5,428	
				Total Scheme Specific Elements	**€765,691**	
				Bundle 6 - Total Scheme Cost	**€2,197,025**	

Stage 3 Model Outputs

5.3.25 Similar to Stages 1 and 2, Scheme Bundles 2 and 6 were tested within the ERM using the network infrastructure described above and the optimised service plans developed in consultation with the NTA and IÉ, which are detailed in Appendix E. The two scheme bundles were tested with New Metro North[15] included as per the Stage 2 assessment.

5.3.26 Table 12 below contains the KPI results for Scheme Bundles 2 and 6 as extracted from the ERM. Further detail on the modelling approach employed and the results for each of these scheme bundles for Stage 3 are given in Appendix H.

5.3.27 As can be seen from the table below, the best preforming option is Scheme Bundle 6, which now performs the best in terms of overall PT Boardings (2,100 greater) and PT mode share (0.1% higher). Bundle 6 is also the best performing in terms of BCR as it provides almost €5 billion in Transport User Benefits and is €1.75 billion cheaper than Scheme Bundle 2.

5.3.28 The key outcomes of the comparative assessment at Stage 3 are summarised below with a summary of the key outcomes from the Stage 3 assessment outlined in Table 13 also:

- Scheme Bundle 2 delivers the highest level of Transport User Benefits;
- Scheme Bundle 6 delivers the highest Benefit to Cost Ratio (BCR);
- the differential in Transport User Benefits between the two options is €1.6 billion;
- the Capital Expenditure difference is approx. €1.75billion and approximately €37m in annual Operation & Maintenance costs;
- Bundle 6 takes away less boardings from other PT modes compared to Bundle 2, so is therefore more complimentary to other modes Metro/Luas/Bus etc.
- Including Glasnevin Station in Bundle 2 improved performance across the network, as Maynooth line services can now access Metro North at Glasnevin.
- The new re-configured Docklands Station performs strongly and relieves the terminating pressure at Connolly;
- Providing the Loop-line Bridge capacity for the Northern Line and Maynooth lines boosts patronage significantly;
- Glasnevin performs strongly as an interchange between Metro and Rail services; and
- The new stations at Cabra and Glasnevin perform strongly.

[15] It should be noted that the alignment of Metro North used at Stage 3 was the draft Emerging Preferred Route from the New Metro North Alignment Options Study at the time of modelling (October 2017), this also included a tie-in with the Luas Green Line and upgrading of Luas Green Line to Metro standard (the combined scheme termed MetroLink)

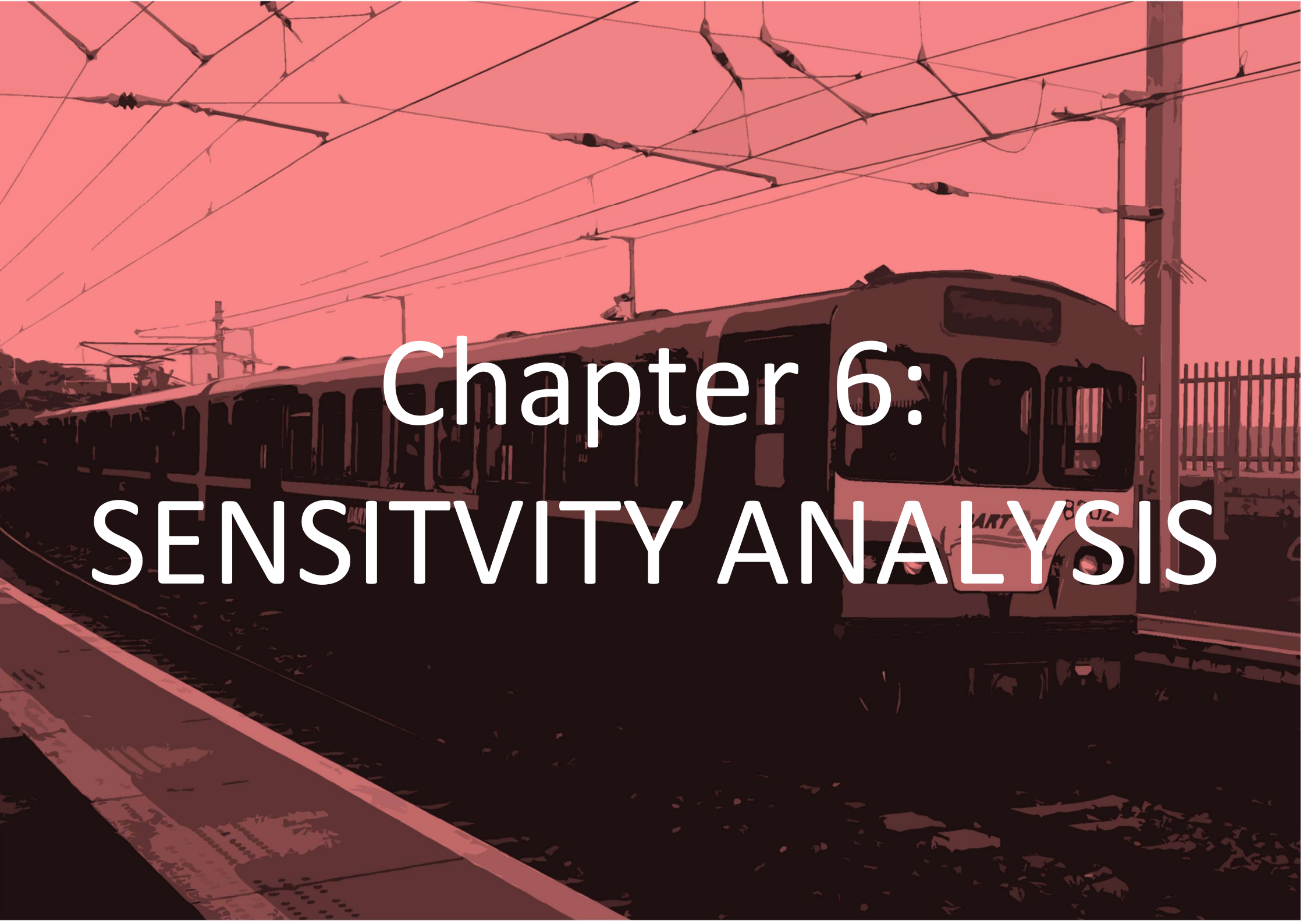
Table 12. Stage 3 KPI Results

KPI	SCHEME BUNDLE 2	SCHEME BUNDLE 6
PT Mode Share (AM)	22.00%	21.90%
PT Mode Share (24Hr)	12.70%	12.55%
PT Boardings (AM)	179,500	181,600
Rail	63,600	57,100
Bus	63,200	68,100
Light Rail	10,100	11,700
Metro	42,700	44,700
PT Boardings (24Hr)	1,137,800	1,144,300
Rail	394,900	353,200
Bus	389,300	416,700
Light Rail	74,000	84,500
Metro	279,600	289,900
PT Transfers (AM)	35,400	36,300
Cap Ex Cost (€m)	3,947	2,197

KPI	SCHEME BUNDLE 2	SCHEME BUNDLE 6
O&M Costs (Annual) (€m)	85	49
Transport User Benefits (€m)	6,518	5,030
Present Value of costs (€m)	2,964	1,680
BCR	2.2	2.92

Table 13. Outcome of Stage 3 Assessment

SCHEME BUNDLE	COMMENT ON RESULTS	ACTION
Scheme Bundle 2	Scheme Bundle 2 remains the best preforming option in terms of overall Rail patronage, with approx. 6,500 higher Rail Boardings than Bundle 6. The additional Boardings, are however, facilitated mostly by reductions in other modes (Bus down 4,900, Luas down 1,600 and Metro down by 2,000 compared to Bundle 6). Scheme Bundle 2 does, however have the highest level of Transport User Benefits at around €6.5billion which is €1.6billion higher than Scheme Bundle 6. This indicates that Scheme Bundle 2 carries similar levels of public transport passengers than Bundle 6, but facilitates passengers to access their final destination more efficiently with a shorter journey time.	**Not Brought Forward**
Scheme Bundle 6	Scheme Bundle 6 carries the highest number of public transport passengers across the system and is also €1.75 billion cheaper than Scheme Bundle 2. This results in a BCR of 2.92 which is higher than Scheme Bundle 2 at 2.20. The higher level of PT passengers indicates that Scheme Bundle 6 integrates more efficiently with the existing network and the proposed Metro North scheme, whereby both schemes benefit by the interchange provided at Glasnevin and Tara Street stations. This option makes best use of existing infrastructure and maintains the use of the PPT line. It does not require a tunnel to be built to deliver the benefits which makes it a good low cost alternative to the DART Underground project whereby its benefits can be delivered much more quickly in comparison to other options. This option is chosen as the Emerging Preferred Scheme Bundle option.	**Emerging Preferred Scheme Bundle**



Chapter 6:
SENSITVITY ANALYSIS

6. SENSITIVITY ANALYSIS

6.1 Introduction

6.1.1 In accordance with Common Appraisal Framework (CAF), a number of sensitivity tests are required to account for uncertainties in scheme appraisal. Following the identification of the Emerging Preferred Scheme Bundle (EPSB) it is necessary to stress test both Scheme Bundles 2 and 6 with alternative assumptions to ensure that the assumptions employed within the modelling process are robust.

6.1.2 The following sensitivity tests were undertaken on Scheme Bundles 2 and 6:

- Network Sensitivity Testing:
  - An examination of how the EPSB (Scheme Bundle 6) performs in the context of other high capacity transport measures proposed within the GDA Transport Strategy e.g. Lucan / South City Luas;
- Land Use Sensitivity Testing:
  - An examination of how the preferred bundles would perform with lower population growth; and
- Model Parameter Sensitivity Testing:
  - An examination of the scheme bundles with adjusted model parameters. e.g. Reduced Interchange Penalty.

6.2 Network Sensitivity Tests

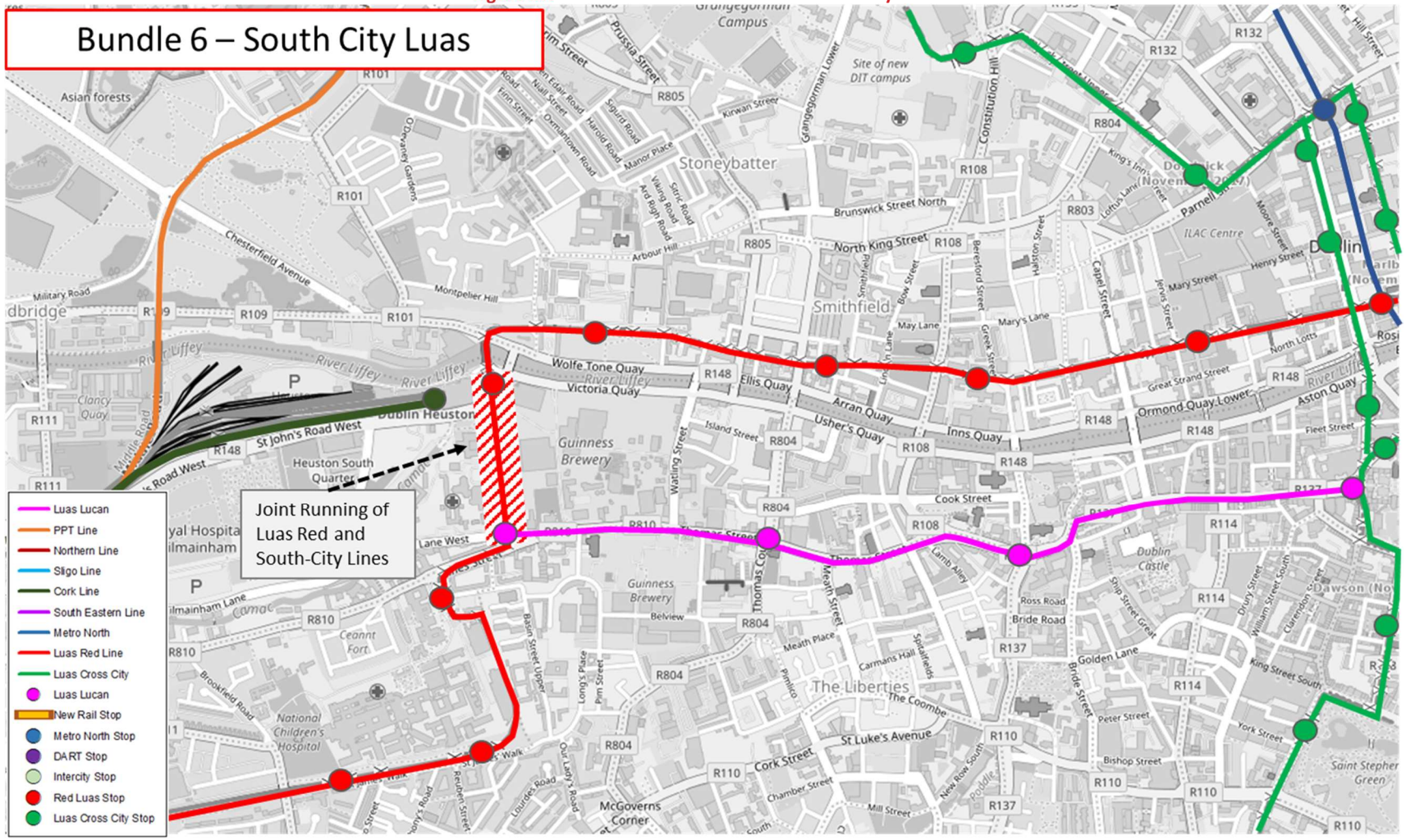
6.2.1 One important consideration in the assessment of the scheme bundles is, how well they perform in the context of the existing transport network and additionally how well they perform in the context of other high capacity transport measures which are proposed within the GDA Transport Strategy i.e. whether there are additional potential synergies that could be exploited to further improve the performance of the scheme bundles.

6.2.2 As shown in previous chapter, Scheme Bundle 6 performs very well in terms of its performance relative to Scheme Bundle 2 which includes DART Underground. Scheme Bundle 6, however, does not perform as well as Scheme Bundle 2 in terms of its penetration to the core south city centre area.

6.2.3 For this reason, Scheme Bundle 6 has been tested with the inclusion of a South-City Luas line from Heuston Station to Trinity College, based on the Lucan Luas proposal within the GDA Transport Strategy. The potential line could extend westwards from Trinity College to Thomas Street where it could join with the current Luas Red Line via joint running on Steeven's Lane, serving Heuston Station. This would complement Scheme Bundle 6 as it could provide connectivity from Heuston station to the south inner city and serve as an alternative to the DART Underground tunnel to cater for this demand movement.

6.2.4 This scheme is the most likely to enhance the performance of Scheme Bundle 6 other than MetroLink. Figure 27 shows the potential South-City Luas line and how this would integrate with other network elements of Scheme Bundle 6.

Figure 27. Scheme Bundle 6 and South-City Luas



6.2.5 Figure 28 and Figure 29 below present the Kildare rail line and the South City Luas - Flow Profiles eastbound in the morning peak. As shown on these graphs, the inclusion of the South City Luas boosts the patronage on the Kildare line inbound in the AM peak. There are approximately 1,600 passengers boarding the Luas link from Heuston Station in the morning peak hour.

6.2.6 Figure 28 below contains the KPI results extracted from the ERM for Scheme Bundle 6 with and without the South City Luas. While both options perform similarly in terms of overall PT Boardings and Mode Share, Light Rail patronage is increased by 17% with the inclusion of the short Luas line.

6.2.7 The BCR however for the combined scheme is 2.67 which is lower than main Scheme Bundle 6 option. This is due to the €175m estimated cost of the short Luas extension and the €45m increase in User Benefits with the inclusion of the scheme. The South City Luas would of course benefit further with its extension to Lucan.

Figure 28. Bundle 6 Kildare Line – Loading Profile

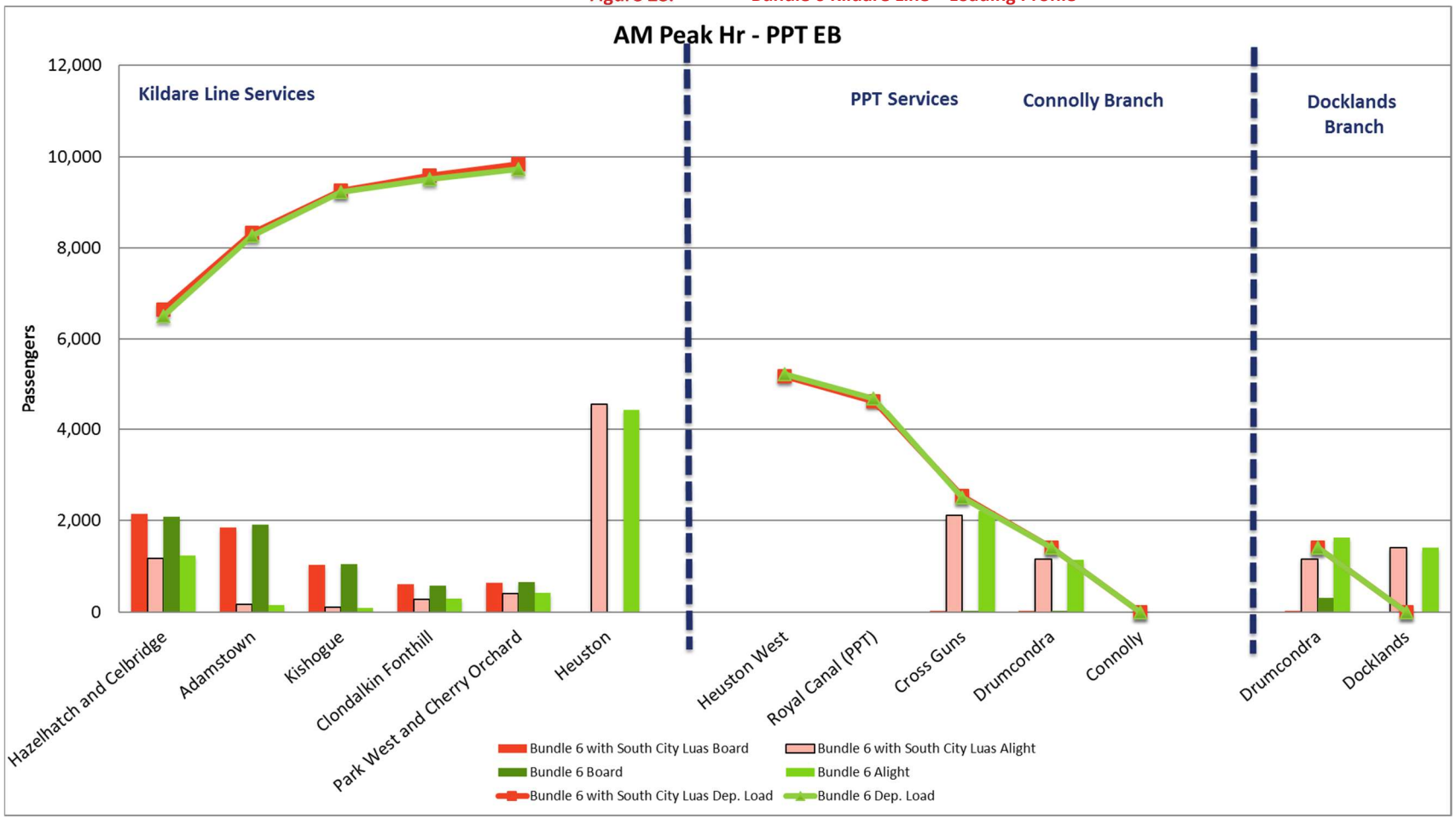


Figure 29. South City Luas EB Loading Profile

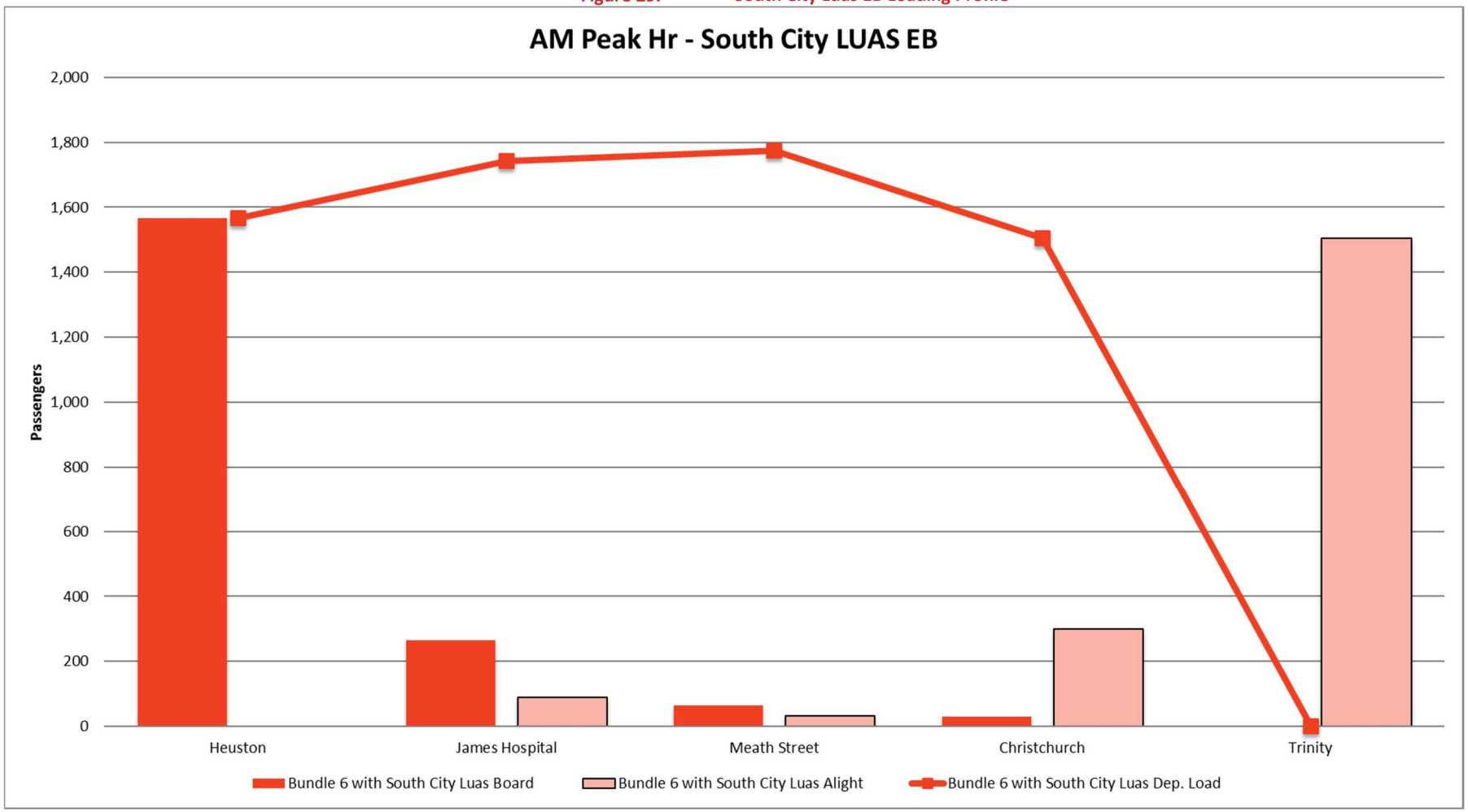


Table 14. Bundle 6 KPI Results

KPI	SCHEME BUNDLE 6 - PPT EXPANSION WITH KYLEMORE STATION	SCHEME BUNDLE 6 - PPT EXPANSION WITH SOUTH CITY LUAS
PT Mode Share (AM)	21.90%	21.90%
PT Mode Share (24Hr)	12.50%	12.60%
PT Boardings (AM)	181,600	181,400
Rail	57,100	57,100
Bus	68,100	66,500
Light Rail	11,700	13,700
Metro	44,700	44,200
PT Boardings (24Hr)	1,144,300	1,147,400
Rail	353,200	352,400
Bus	416,700	409,100
Light Rail	84,500	96,700
Metro	289,900	289,200
PT Transfers (AM)	36,300	36,800

KPI	SCHEME BUNDLE 6 - PPT EXPANSION WITH KYLEMORE STATION	SCHEME BUNDLE 6 - PPT EXPANSION WITH SOUTH CITY LUAS
Cap Ex Cost (€m)	2,197	2,356
O&M Costs (Annual) (€m)	49	57
Transport User Benefits (€m)	4,914	4,959
Present Value of costs (€m)	1,680	1,854
BCR	2.92	2.67

6.3 Land-Use Sensitivity Tests

6.3.1 To test the sensitivity of the scheme bundle options to changes in land-use assumptions, a scenario has been tested where the assumed growth in demand due to population and land use development is lower than the standard growth forecasts. This is undertaken to examine the robustness of the economic case to changes in future demand.

6.3.2 To assess this, a 20% lower than expected growth between 2011 and 2035 has been modelled to assess the performance of Scheme Bundles 2 and Bundle 6 in this context.

6.3.3 Table 15 below contains the KPI results extracted from the ERM for Scheme Bundles 2 and 6, for both the original demand and the reduced demand scenarios.

6.3.4 The economic basis for both scheme bundle options is shown to perform well in the reduced demand tests, with very similar BCRs present with and without the demand reduction. It must be noted that the Do Minimum reference case demand levels also contain reduced demand.

6.3.5 For each scheme bundle, the 20% reduction in growth levels results in reductions in the KPI performance by approximately 5-6% across both bundle options. This indicates that both scheme bundles have a strong economic case even with reduced demand levels as both options provide substantial improvements to the existing rail offering.

Table 15. Land-Use Sensitivity Test KPI Outputs

KPI	SCHEME BUNDLE 2 – FULL DART EXPANSION	SCHEME BUNDLE 2 – FULL DART EXPANSION WITH REDUCED DEMAND	SCHEME BUNDLE 6 – PPT EXPANSION	SCHEME BUNDLE 6 – PPT EXPANSION WITH REDUCED DEMAND
PT Mode Share (AM)	22.00%	21.14%	21.90%	21.02%
PT Mode Share (24Hr)	12.70%	12.33%	12.50%	12.14%
PT Boardings (AM)	179,500	169,000	181,600	170,600
Rail	63,600	59,500	57,100	53,400
Bus	63,200	60,000	68,100	64,700
Light Rail	10,100	9,700	11,700	11,100
Metro	42,700	39,800	44,700	41,400
PT Boardings (24Hr)	1,137,800	1,080,400	1,144,300	1,081,000
Rail	394,900	371,900	353,200	329,800
Bus	389,300	373,400	416,700	398,600
Light Rail	74,000	71,100	84,500	80,300
Metro	279,600	264,000	289,900	272,200

KPI	SCHEME BUNDLE 2 – FULL DART EXPANSION	SCHEME BUNDLE 2 – FULL DART EXPANSION WITH REDUCED DEMAND	SCHEME BUNDLE 6 – PPT EXPANSION	SCHEME BUNDLE 6 – PPT EXPANSION WITH REDUCED DEMAND
PT Transfers (AM)	35,400	33,600	36,300	34,100
Cap Ex Cost (€m)	3,947	3,947	2,197	2,197
O&M Costs (Annual) (€m)	85	85	49	49
Transport User Benefits (€m)	6,518	6,539	4,914	4,793
Present Value of costs (€m)	2,964	2,964	1,680	1,680
BCR	2.20	2.21	2.92	2.85

6.4 Model Parameter Sensitivity Tests

6.4.1 The generalised costs within the NTA ERM Public Transport Model are made up of various components such as 'actual' experienced costs i.e. fares, travel time, waiting time etc. Additional parameters also account for 'perceived' travel costs, examples of this are boarding, transfer and crowding penalties. Both the 'actual' and 'perceived' costs make up the full range of generalised costs associated with traveller mode and route choices.

6.4.2 The calibrated Base 2012 ERM PT model uses different transfer penalties by sub-mode e.g. Bus to Metro, Rail to Rail etc. The transfer penalties range between 5min and 15min depending on the mode of travel. This reflects PT users current perceived reluctance to transfer, as is evident from observed data.

6.4.3 Based on the outcome of a number of tests and to account for the fact that passenger transfers with Rail services in a more integrated PT system will be more seamless and therefore should not be over penalised – a consistent 5min transfer penalty has been used in the sensitivity modelling for all PT sub-modes.

6.4.4 Table 16 below contains the KPI results extracted from the ERM for Scheme Bundle 2 and Scheme Bundle 6, for both the original parameters and with the 5 Minutes Rail Interchange Penalty adjustments.

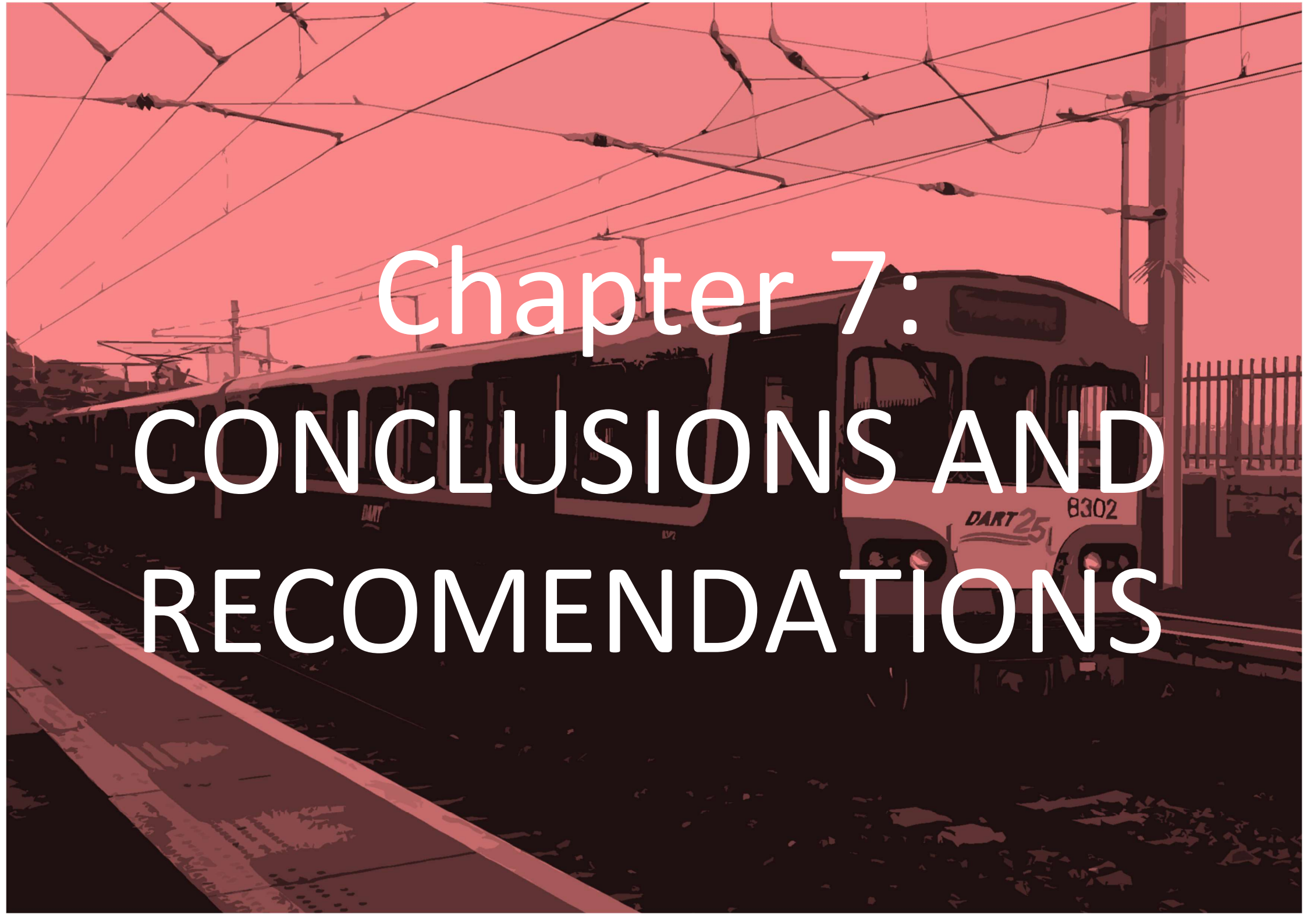
6.4.5 For both scheme bundles, the testing with a 5 minute rail interchange penalty improves the performance of each scheme bundle with rail boardings and user benefits increasing significantly.

6.4.6 The BCR for Scheme Bundle 6 increases to 3.14 from 2.92 showing the substantial return on investment provided by this option. The BCR for Scheme Bundle 2 also moves from 2.2 to 2.42. The overall PT Boardings provided by Scheme Bundle 6 are slightly higher than Scheme Bundle 2 in the AM peak, demonstrating how well the option integrates with the wider PT network.

Table 16. 5 Min Rail Interchange Sensitivity Test KPI Outputs

KPI	SCHEME BUNDLE 2 – FULL DART EXPANSION	SCHEME BUNDLE 2 – FULL DART EXPANSION WITH 5MIN RAIL INTERCHANGE PENALTY	SCHEME BUNDLE 6 - PPT EXPANSION	SCHEME BUNDLE 6 – PPT EXPANSION WITH 5MIN RAIL INTERCHANGE PENALTY
PT Mode Share (AM)	22.00%	22.30%	21.90%	22.10%
PT Mode Share (24Hr)	12.70%	13.00%	12.50%	12.70%
PT Boardings (AM)	179,500	192,600	181,600	192,800
Rail	63,600	72,800	57,100	65,800
Bus	63,200	64,500	68,100	68,500
Light Rail	10,100	10,600	11,700	11,900
Metro	42,700	44,700	44,700	46,600
PT Boardings (24Hr)	1,137,800	1,212,100	1,144,300	1,207,100
Rail	394,900	452,400	353,200	403,500
Bus	389,300	392,700	416,700	416,400
Light Rail	74,000	76,200	84,500	86,000

KPI	SCHEME BUNDLE 2 – FULL DART EXPANSION	SCHEME BUNDLE 2 – FULL DART EXPANSION WITH 5MIN RAIL INTERCHANGE PENALTY	SCHEME BUNDLE 6 - PPT EXPANSION	SCHEME BUNDLE 6 – PPT EXPANSION WITH 5MIN RAIL INTERCHANGE PENALTY
Metro	279,600	290,900	289,900	301,200
PT Transfers (AM)	35,400	44,300	36,300	43,800
Cap Ex Cost (€m)	3,947	3,947	2,197	2,197
O&M Costs (Annual) (€m)	85	85	49	49
Transport User Benefits (€m)	6,518	7,389	4,914	5,279
Present Value of costs (€m)	2,964	2,964	1,680	1,680
BCR	2.2	2.49	2.92	3.14



Chapter 7:
CONCLUSIONS AND RECOMENDATIONS

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

7.1.1 The National Transport Authority (NTA) commissioned SYSTRA and Jacobs to undertake an extensive transport modelling appraisal of the proposed DART Expansion Programme.

7.1.2 This project sought to identify a lower cost alternative to the proposed DART underground tunnel component of the DART Expansion Programme. This was done in the context of the importance of the DART Expansion Programme as identified in the GDA Transport Strategy and following on from the NTA recommendations on the deferral of the DART Underground Project.

7.1.3 A number of infrastructure scheme bundle options have been presented in this report, with two options emerging as preferred scheme bundle options to deliver DART Expansion:

- **Scheme Bundle 2**: Full DART Expansion including DART Underground (including Western Tie-In cost savings); and
- **Scheme Bundle 6**: DART Expansion with Existing Network Enhancement (No Tunnel).

7.2 Conclusions and Recommendations

7.2.1 Following the comprehensive assessment and review process, and based on the assumptions contained within this report, the key recommendations are as follows:

Scheme Bundle 6 is the preferred DART Expansion Scheme Bundle, and it is recommended that this option is brought forward for further development subsequent to a final decision on its implementation.

7.2.2 Whilst Bundle 6 is the preferred option to deliver DART Expansion, the following caveats should be noted:

- The assumed service capacities and pattern of services underpinning Bundle 6 are at maximum limits and need to be verified further by detailed timetable modelling to confirm their viability; and
- The network enhancements required to support the assumed capacities need to be developed further.

7.2.3 Notwithstanding the above, the assessment indicates that Bundle 6 will provide substantial benefits to the rail network and passengers, significantly boosting passenger numbers compared to current conditions. On this basis, it is recommended that Scheme Bundle 6 is developed further and implemented as the preferred DART Expansion Scheme Bundle.

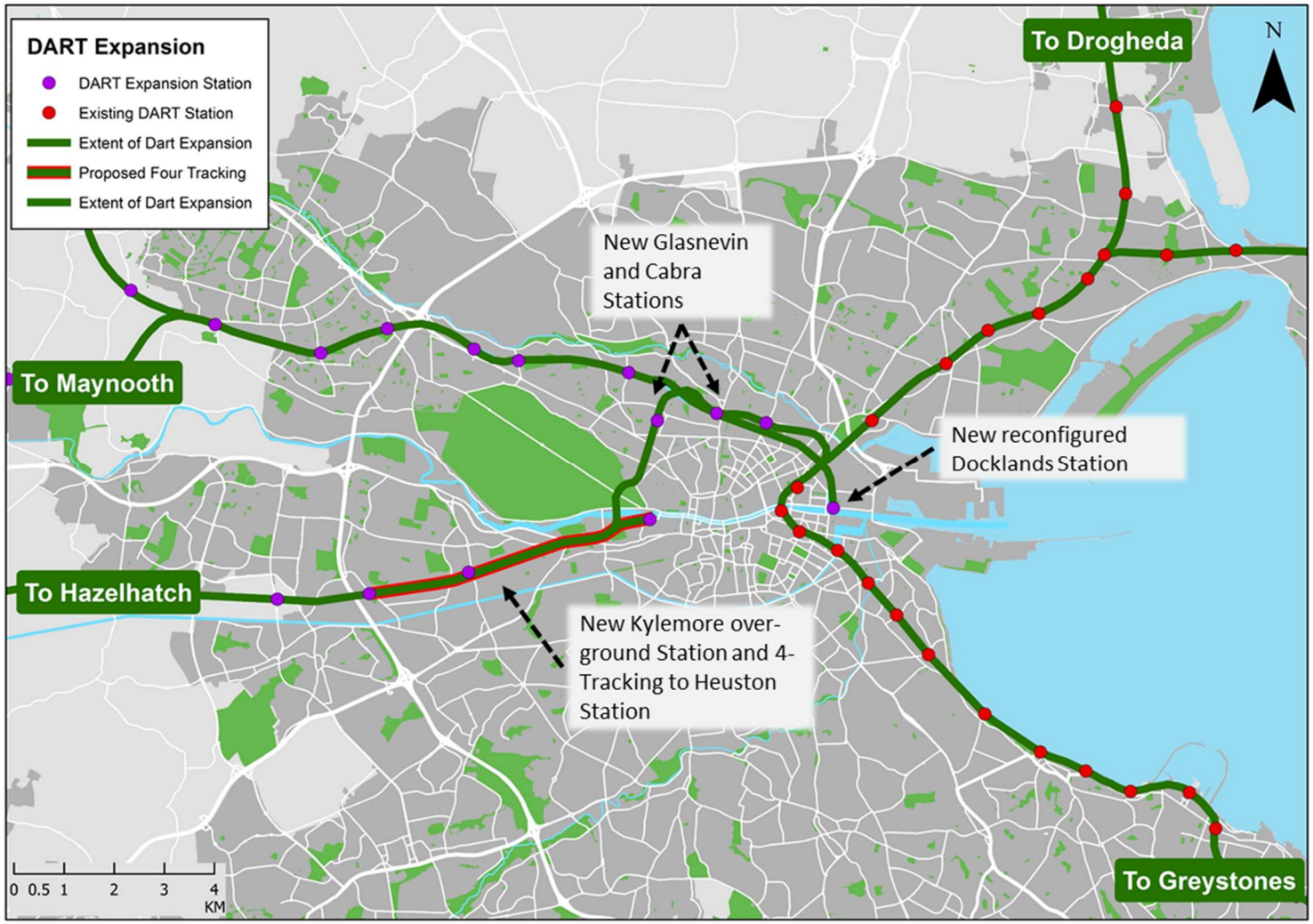
7.2.4 Scheme Bundle 6 - DART Expansion with Existing Network Enhancement (No underground tunnel):

- makes best use of existing rail infrastructure, is not reliant on the delivery of the DART Underground tunnel and is capable of delivering the DART Expansion Programme at a much reduced cost;
- can be incrementally delivered to gradually unlock benefits as passenger demand levels increase;
- will integrate better with other public transport schemes, will maximise the patronage of MetroLink, BusConnects and Luas and, will therefore, maximise the investment in these schemes;
- will relieve some pressure on the Luas Red line in the peak periods, by reducing the need to interchange from/to Luas at Heuston for some journeys; and
- should act as an interim measure while the DART Underground Project is redesigned to accommodate recent developments in the rail network.

7.2.5 Important considerations for Scheme Bundle 6 are that:

- With the Phoenix Park Tunnel (PPT) line being operational, ways should be sought to maximise the use of this tunnel, in the short to medium term, by adding additional stations, increasing frequency and capacity through the PPT and providing interchange opportunities with Luas services and with the proposed MetroLink when opened;
- the upgrading of the Phoenix Park Tunnel line, to provide higher frequency and greater capacity, does not preclude introducing the DART Underground tunnel later. Bundle 6 provides a means to incrementally improve the heavy rail network allowing DART Expansion measures on the radial corridors to be delivered sooner thereby releasing significant benefits to rail users and other public transport users; and
- MetroLink should be viewed as more than just a means of connecting the City Centre with the Airport and Swords. It should be examined, in tandem with the PPT line, to identify how it can be optimised (through alignment and design capacity) to support the delivery of the DART Expansion Programme to offset the dependence on DART Underground, particularly in the short to medium term.

Figure 30. Recommended City Centre DART Expansion arrangement



7.3 Performance Summary

7.3.1 Figure 31 below illustrates the relative performance of Scheme Bundles 2 and 6 when measured against Key Performance Indicators (KPIs). The comparative performance of Scheme Bundles 2 and 6 are shown in red and blue respectively.

7.3.2 The KPI results indicate that:

- Scheme Bundles 2 and 6 deliver similar public transport mode share levels;
- Scheme Bundle 2 is potentially €1.75 Billion more expensive than Scheme Bundle 6;
- Scheme Bundle 2 delivers higher:
  - Rail boardings;
  - Interchange levels between public transport modes; and
  - Transport user benefits.
- However, using the assumed service pattern, scheme Bundle 6 delivers higher:
  - Overall public transport boardings; and
  - Public transport boardings for non-rail modes i.e. Metro, Luas, Bus etc.

Scheme Bundle 6, using the assumed service patterns, delivers a Benefit to Cost Ratio (BCR) of 3.14 which is 0.65 higher than Scheme Bundle 2.

7.4 Pros and Cons Assessment

7.4.1 As the economic case for both scheme bundles is very high, a Pros and Cons assessment was undertaken. The purpose of which was to highlight the positive and negative elements of both scheme bundles when compared to one another.

7.4.2 Table 17 below outlines the pros and cons assessment for both emerging preferred scheme bundles.

Figure 31. KPI Outputs Summary for Bundle 2 and Bundle 6

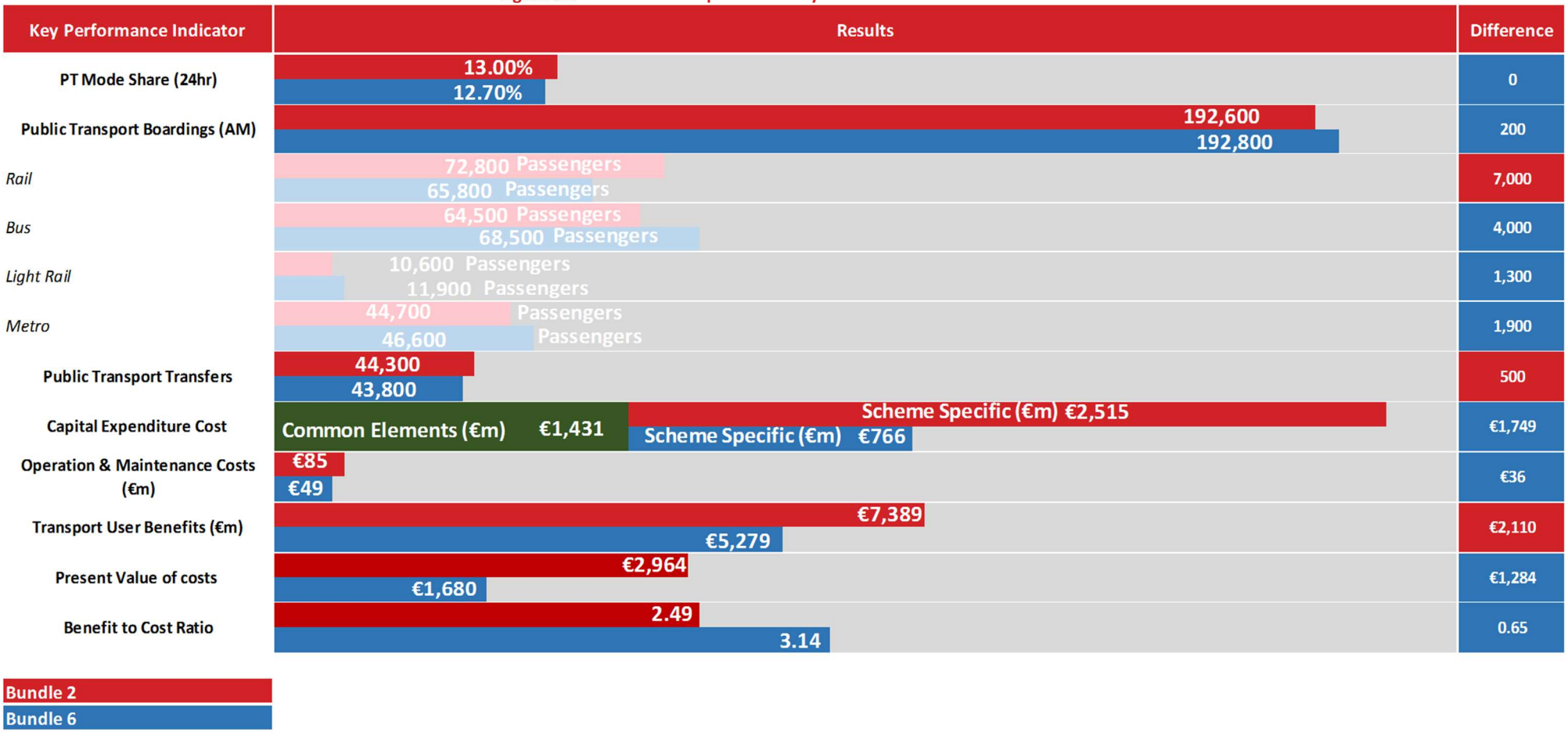


Table 17. Pros and Cons Assessment of Scheme Bundles 2 and 6

SCHEME BUNDLE	PROS	CONS
Scheme Bundle 2	• Delivers the highest level of Transport User Benefits; • Delivers the highest level of Rail patronage; • Provides full rail network connectivity; • Strong network legibility for heavy rail; • Does not rely on interchange to the same extent as Bundle 6; • Delivers a fully graded separated network not subject to junction delays or disruption.	• Relies on interchange for South-East DART line passengers to continue northbound on the Northern line i.e. at Pearse Station; • The DART Underground tunnel is required to be built to deliver benefits, resulting in a large upfront investment requirement; • There is a long lead in time and difficulty in incrementally delivering, thereby not releasing benefits early in the scheme development; • Does not make best use of MetroLink in the short to medium term (as a ramped-up use of the PPT line is not part of this option); • Takes more public transport users away from other public transport modes (Bus, Luas, Metro), when compared to Scheme Bundle 6; • There is an impact on the development of Strategic Development Zones (SDZs) such as Clonburris, which can't develop fully until DART Underground is delivered; • Does not maximise the use of the existing available infrastructure to the same extent that Scheme Bundle 6 does.

SCHEME BUNDLE	PROS	CONS
Scheme Bundle 6	• Delivers significant benefits (€5Billion above Do Minimum); • It is the least costly option (€1.75Billion cheaper than DART Underground Option) – this money could be used to deliver other elements of the GDA Transport Strategy within the same budget envelope such as Lucan & Finglas Luas Lines and BusConnects); • Delivers a better BCR than DART Underground Option; • Makes best use of existing rail infrastructure (e.g. PPT line); • Integrates more efficiently with other PT modes (i.e. Bundle 2 results in reduced patronage on other PT Modes) • Delivers the same strategic PT mode share as the DART Underground Option; • Does not preclude building the DART Underground at a later stage when demand requires; • Can be delivered on a phased basis providing incremental benefits; • Makes more efficient use of MetroLink; • Does not require a large upfront investment to release benefits (unlike the DART Underground option which requires the tunnel to unlock any benefits) • Provides better interchange options with MetroLink and Luas Cross City; • Faster lead in time, thereby, enabling key areas to develop quicker (e.g. Clonburris SDZ).	• Does not deliver the same level of transport user benefits as the DART Underground Option (Scheme Bundle 2); • Relies more on interchange with other PT modes to work (particularly that of MetroLink and Bus) and other PT lines (i.e. South City Luas); • Requires a large interchange between Rail and Metro at Whitworth and Tara Street Stations which will be costly to construct; • Is subject to proving the operational capacity of the junctions on the system to accommodate the level of service provided; • Does not provide grade separated solution and is subject to junction capacity delays and disruptions.

7.5 Potential Next Steps

7.5.1 In line with the Public Spending Code and the DTTAS "Common Appraisal Framework for Transport Projects and Programmes 2016" (CAF), government departments are required to submit a Business Case for capital projects greater than €20 million in value.

7.5.2 This report is considered a Stage 1 - Preliminary Appraisal (as defined in CAF), in that it includes the background, initial specification of the needs and objectives, identification of potential options and a preliminary assessment of the costs and benefits of the options.

7.5.3 The next steps in the project will be to move to the Stage 2 – Detailed Appraisal stage, which will include:

- A full Economic Appraisal;
  - This will include the further development of the scheme to prove the viability of the assumptions within this report and to allow full detailed costing of the scheme elements.
- Financial Appraisal; and
- Risk Analysis.

7.5.4 This should culminate in the submission of a full Business Case to secure project approvals and funding. In parallel to this, it is recommended that an Implementation and Phasing Strategy is undertaken to understand the incremental benefit of delivering the scheme bundle elements and sequencing of delivery to give the best return on investment.

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For more information visit www.systra.co.uk

Birmingham – Newhall Street
5th Floor, Lancaster House, Newhall St,
Birmingham, B3 1NQ
T: +44 (0)121 233 7680 F: +44 (0)121 233 7681

Birmingham – Innovation Court
Innovation Court, 121 Edmund Street, Birmingham B3 2HJ
T: +44 (0)121 230 6010

Bristol
10 Victoria Street, Bristol, BS1 6BN
T: +44 (0)117 922 9040

Dublin
2nd Floor, Riverview House, 21-23 City Quay
Dublin 2,Ireland
T: +353 (0) 1 905 3961

Edinburgh – Thistle Street
Prospect House, 5 Thistle Street, Edinburgh EH2 1DF
United Kingdom
T: +44 (0)131 220 6966

Edinburgh – Manor Place
37 Manor Place, Edinburgh, EH3 7EB
Telephone +44 (0)131 225 7900 Fax: +44 (0)131 225 9229

Glasgow – St Vincent St
Seventh Floor, 124 St Vincent Street
Glasgow G2 5HF United Kingdom
T: +44 (0)141 225 4400

Glasgow – West George St
250 West George Street, Glasgow, G2 4QY
T: +44 (0)141 221 4030 F: +44 (0)800 066 4367

Leeds
100 Wellington Street, Leeds, LS1 1BA
T: +44 (0)113 397 9740 F: +44 (0)113 397 9741

Liverpool
Cotton Exchange, Bixteth Street, Liverpool, L3 9LQ
T: +44 (0)151 230 1930

London
3rd Floor, 5 Old Bailey, London EC4M 7BA United Kingdom
T: +44 (0)203 714 4400

Manchester – 16th Floor, City Tower
16th Floor, City Tower, Piccadilly Plaza
Manchester M1 4BT United Kingdom
T: +44 (0)161 831 5600

Newcastle
Floor B, South Corridor, Milburn House, Dean Street, Newcastle,
NE1 1LE
United Kingdom

T: +44 (0)191 260 0135

Perth
13 Rose Terrace, Perth PH1 5HA
T: +44 (0)1738 621 377 F: +44 (0)1738 632 887

Reading
Soane Point, 6-8 Market Place, Reading,
Berkshire, RG1 2EG
T: +44 (0)118 334 5510

Woking
Dukes Court, Duke Street
Woking, Surrey GU21 5BH United Kingdom
T: +44 (0)1483 728051 F: +44 (0)1483 755207

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Appendix :
DO MINIMUM NETWORK ELEMENTS

1. APPENDIX A: DO MINIMUM NETWORK ELEMENTS

1.1 Base Network included in Scheme Bundles

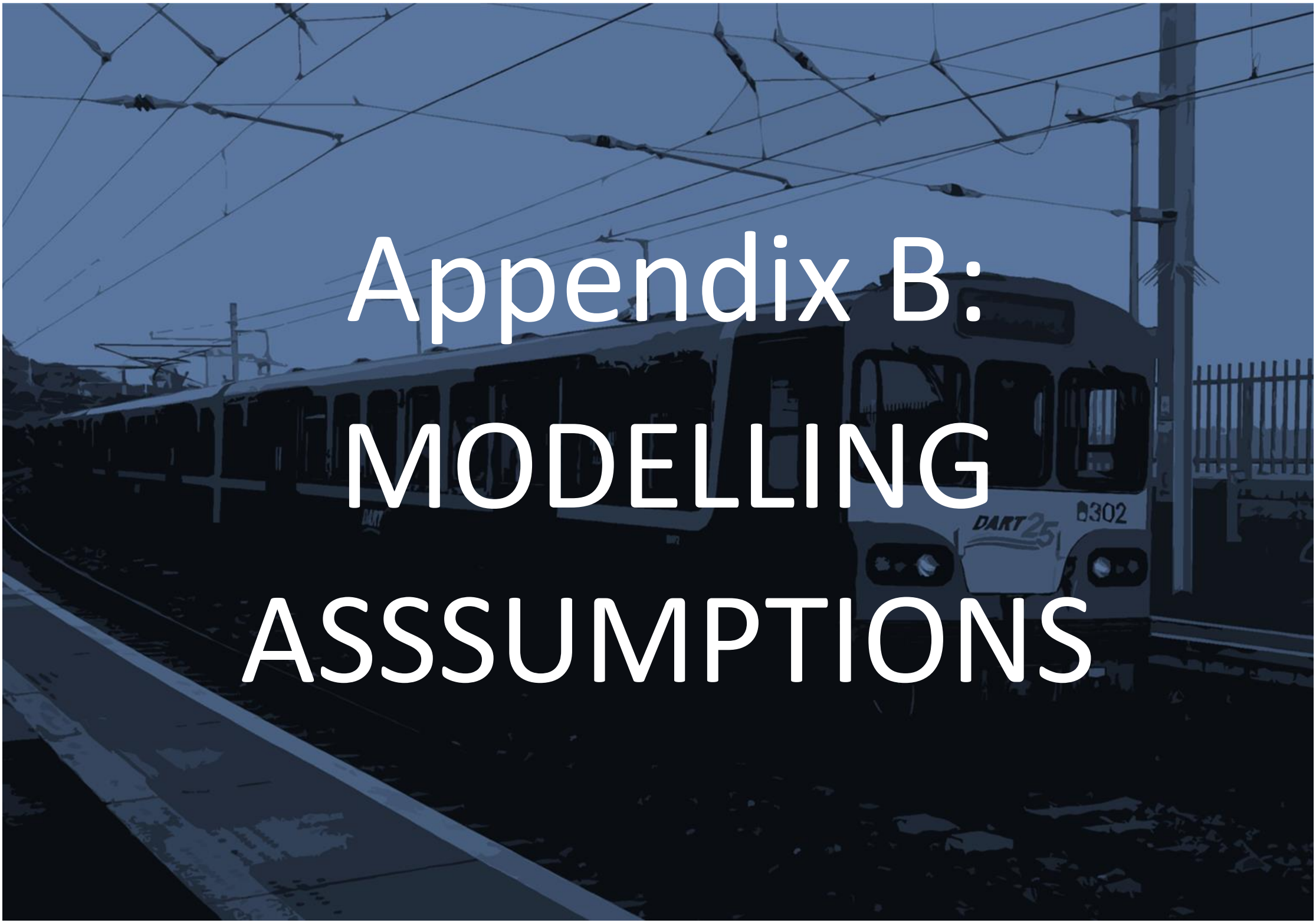
- **Competed and committed road and traffic management schemes:**
  - Rosie Hackett Bridge;
  - Camden Street, Wexford Street and Aungier Street Area Traffic Management;
  - N7 Newlands Cross Junction Upgrade;
  - Swords Road Corridor upgrade and bus lanes (Cat & Cage);
  - St Stephen's Green Area Traffic Management;
  - Lincoln Place, Merrion Street and Westland Row Area Traffic Management;
  - Braemor Road Improvement Scheme;
  - Sandyford Industrial Estate Junction improvements;
  - Holywell Village improvement and associated Distributor Road completion;
  - N3 Mulhuddart Interchange Upgrade;
  - R132 Swords Road Upgrade: Airport Roundabout to Collinstown Cross; and
  - Ratoath Road including Reilly's Bridge.
- **Additional road network coding changes**
  - PT (bus & taxi) only from O'Connell Street to Rosie Hackett Bridge, with local access from Harbour Court.
  - No right turn to Nassau Street from Dawson Street. Two way traffic all along Dawson Street to Molesworth Street, PT only north of Duke Street.
  - Kildare Street converted to bus-only with the exception of local access in the form of one traffic lane northbound from St Stephen's Green to Molesworth Street and one traffic lane southbound from Setanta Place to Molesworth Street.
  - Two bus lanes and one traffic lane along George's Quay. (one for stopping, not modelled)
  - One bus lane and one traffic lane on Burgh Quay. Left, right and straight movements for all, and additional right turn lane at junction with O'Connell Bridge.
  - One bus lane and one traffic lane along Aston Quay, Wellington Quay and Essex Quay. No left turn from Wellington Quay at Grattan Bridge, straight ahead only.
- **Completed public transport schemes;**
  - **Luas Cross City:** is an extension of the existing Luas Green Line beginning at the current Green Line Terminus at St. Stephen's Green, connecting with the Luas Red Line at O'Connell's Street / Abbey Street and continuing northbound to the DIT Grangegorman Campus, Phibsborough and terminating at the Broombridge Rail Station. Details of the coded service plan data within the model are shown in **Error! Reference source not found.** below.
  - **Phoenix Park Tunnel:** project involves using the existing tunnel for passenger trains. The Phoenix Park Tunnel is a single bore tunnel of c. 750m with two rail lines. The re-opening for passenger services

allows for rail connectivity from the Southwest (Kildare) Line to the Southeast Line serving Drumcondra, Connolly Station, Tara Street, Pearse Street and Grand Canal Docklands. The trains using the Phoenix Park Tunnel will not stop at Heuston Station. Details of the coded service plan data within the model are shown in Table 4.1 below. It has been assumed that 4 trains operate inbound in the AM peak with 3 outbound trains, with the reverse operation in the PM peak to accommodate the peak tidal demand. 2 trains per hour will use the tunnel in both directions during the inter-peak.

- **DART Frequency Increase:** will provide for increased rail throughput, in particular an increase of up to 18 trains per hour (tph) running across the Loop Line Bridge across the Liffey. Details of the coded service plan data within the model are shown in Table 4.1 below

Figure 1. **Do Minimum Public Transport Service Plan**

SERVICE	VEHICLES	AM HEADWAY (MINS)	IP HEADWAYS (MINS)	PM HEADWAYS (MIN)
DART	DART	10	10	10
Luas Cross City	53m trams	4	6	4
Phoenix Park Tunnel	Commuter Rail	15 NB and 20 SB	30	20 NB and 15 SB



Appendix B: MODELLING ASSSUMPTIONS

APPENDIX - MODELLING ASSSUMPTIONS

Assumptions for DART Expansion Modelling are detailed in this Appendix.

Table B-1 Modelling Assumptions table

	Model Assumptions
Service Pattern	Varies by Scheme Bundle option
Headways	Varies by Scheme Bundle option
Fares	Distance based fare system **DART** (min €1.38, max €4.50 in 2012 prices) **Inter-City** varies by Corridor (min €1.49, max €18 in 2012 prices)
Capacity (per vehicle)	DART (8-Car – Peaks, 4-Car Interpeak) 8-Car Crush capacity: 1382 8-Car Seat capacity: 512
Crowding curve	ERM Base Model Rail crowding curve (from PDFH)
Waiting curve	Same as other modes (single curve defined in the ERM)
Boarding penalties	15 min for all modes
In Vehicle Time (IVT) Factor	DART – 1.3 Inter-City / Commuter – 1.4
Transfer penalties	See table below

The table below outlines the calibrated Public Transport sub-mode transfer penalties in the ERM base.

Table B-2 Transfer Penalties coded in the ERM (in min)

	DART	RAIL	LUAS	URBAN BUS	OTHER BUS	BRT	METRO
DART	15	15	15	15	15	15	15
RAIL	15	15	15	15	15	15	15
LUAS	15	15	5	5	5	5	5
URBAN BUS	15	15	5	15	5	5	5
OTHER BUS	15	15	5	5	5	5	5
BRT	15	15	5	5	5	5	5
METRO	15	15	5	5	5	5	5

Committed public transport schemes

The major completed public transport schemes delivered in the period from 2012 to 2017 are:

- Lucan Quality Bus Corridor (QBC) Enhancements;
- North Wall Quay Environmental Improvement and Bus Priority Scheme;
- ClaNorthboundrassil St / Patrick St and Bride St QBC;
- Thomas Street / James's Street QBC;
- Custom House Quay Contra Flow Bus Lane;

- Firhouse-Ballycullen QBC; and
- Revised bus services to accommodate Luas Cross City and City Centre traffic management schemes.

Luas Cross City

The Luas Cross City is an extension of the existing Luas Green Line beginning at the current Green Line Terminus at St. Stephen's Green, connecting with the Luas Red Line at O'Connell's Street / Abbey Street and continuing northbound to the DIT Grangegorman Campus, PhibSouthboundorough and terminating at the Broombridge Rail Station. Details of the coded service plan data within the model are shown in Table B-1 below.

Phoenix Park Tunnel

The Phoenix Park Tunnel project involves using the existing tunnel for passenger trains. The Phoenix Park Tunnel is a single bore tunnel of c. 750m with two rail lines. The re-opening for passenger services allows for rail connectivity from the Southwest (Kildare) Line to the Southeast Line serving Drumcondra, Connolly Station, Tara Street, Pearse Street and Grand Canal Dock. The trains using the Phoenix Park Tunnel will not stop at Heuston Station. Details of the coded service plan data within the model are shown in the Figure below.

It has been assumed that 4 trains operate iNorthboundound in the AM peak with 3 outbound trains, with the reverse operation in the PM peak to accommodate the peak tidal demand. 2 trains per hour will use the tunnel in both directions during the inter-peak.

DART Frequency Increase

The DART frequency increase will provide for increased rail throughput, in particular an increase of up to 17 trains per hour (tph) running across the Loop Line Bridge across the Liffey. Details of the coded service plan data within the model are shown in Table B-3 below.

Table B-3 Do Minimum Public Transport Service Plan

Service	Vehicle	AM headway (mins)	IP headway (mins)	PM headway (mins)
DART	DART	10	10	10
Luas Cross City	53m tram	4	6	4
Phoenix Park Tunnel	Commuter Rail	15 Northbound and 20 Southbound	30	20 Northbound and 15 Southbound

The Do Minimum public transport proposals are illustrated in the Figure below.

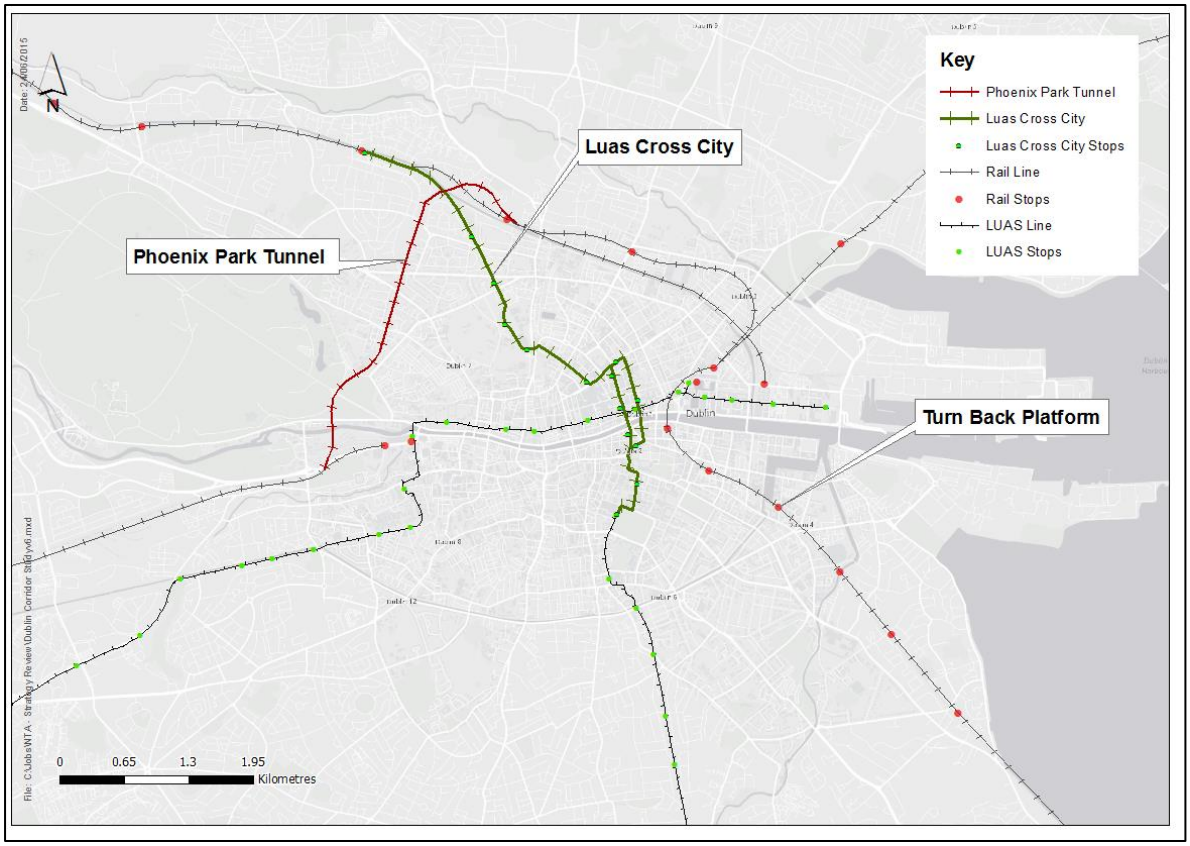


Figure B-Error! No text of specified style in document.**-1 Do Minimum Proposed Public Transport Provision**

Strategy Demographic and Demand Inputs

Introduction

This section outlines the methodology by which population, employment, education places and retail activity have been distributed within the GDA for the purposes of creating the travel demand inputs into the transport modelling process. This involves the disaggregation of the regional figures for 2035, down to the ERM zone level to provide a picture of the GDA for the strategy horizon year. The primary drivers for transport demand are population and employment, from which education and retail are also derived.

The overall process for developing demographic forecasts at local GDA zone level is as follows:

1. National forecasts for the GDA have been developed based on the Central Statistics Office's (CSO) M2F2 'Traditional' Scenario[1];
2. Data from the Regional Planning Guidelines for the Greater Dublin Area 2010 – 2022 was then used to distribute population and employment into the counties within the GDA;
3. The distribution within each county was undertaken through a process of defining settlements and distributing growth locally within these settlements. This was undertaken by the NTA and the local authorities of the GDA.

[1] Taken from the CSO Regional Population and Labour Force Projections 2016-2046, April 2013. The M2F2 Traditional scenario represents a set of assumptions in relation to migration and fertility which are considered the most probable.

4. The final step, undertaken by the NTA and local authorities, was to breakdown the forecasts within each settlement to GDA zone level, based on planning data and advice from local authorities.

All future growth was constrained to CSO forecasts, in order to provide a forecast scenario that is consistent with established national projections.
The demographic and demand data are then input into the PDAT and the NTEM to develop base year and forecast year trip ends. The PDAT controls the planning data inputs core to the NDFM system, and is used to amend planning data to represent the combination of general changes over time and the relevant land-use planning scenarios. The NTEM then converts the planning data into person trips.

Greater Dublin Area Projections
The Greater Dublin Area (GDA) total population for 2035, which is the forecast year for the GDA Strategy, has been derived from the CSO forecast for M2F2 and based on 'Traditional' Scenario' presented in the Regional forecasts. Based on these assumptions the population for the GDA in 2035 is estimated to be 43% of the *state*, as shown in the Table below. It is notable that this will result in 67% of the population growth in this period being located within the GDA.

Table B-4 National and GDA Population for 2011 and 2035

Population	2011	2035	Growth 2011-2035
State	4,588,252	5,307,520	719,268
GDA	1,804,156	2,286,869	482,713
GDA % of State	39.32%	43.09%	67.11%

The employment forecasts relate to fixed places of employment to which the population travelled. Using the 2011 POWSCAR data the proportion of fixed employment places was 35% of the population. It was assumed that this proportion remains constant and is used to derive the fixed places of employment for 2035. The Table below shows the employment estimates for the State and the GDA.

Table B-5 National and GDA Employment for 2011 and 2035 Employment

Employment	2011	2035	Growth 2011-2035
State	1,362,742	1,739,131	376,389
GDA	627,877	868,178	240,301
GDA % of State	46.07%	49.92%	63.84%
GDA Empl. as prop of Pop	34.8%	37.96%	49.78%

Distribution to County Level

Population
The GDA consists of seven local authority areas: Dublin City, South Dublin, Fingal, Dun Laoghaire-Rathdown, Kildare, Meath and Wicklow. The Regional Planning Guidelines for the Greater Dublin Area 2010 - 2022 (RPG) provides guidance on the future growth of population within each of the areas covered by the local authorities. The local authorities, working with these guidelines, have developed "core strategies" which provides strategic direction as to where future housing will be provided within each county. Working with the Local Authorities for the purposes of the transport model, the 2035 GDA population has been distributed in accordance with the RPG. The Table below shows that the proportions of population within each county are planned to remain broadly similar in 2035 when compared to 2011.

Table B-6 Population within Each Local Authority for 2011 and 2035

Population	Population 2011	% of GDA 2011	Population 2035	% of GDA 2035	Growth 2011 to 2035	% Growth 2011 to 2035
Dublin City	527,612	29%	637,246	28%	109,634	21%
South Dublin	265,205	15%	332,722	15%	67,517	25%
Fingal	273,991	15%	350,036	15%	76,045	28%
Dún Laoghaire-Rathdown	206,261	11%	257,073	11%	50,812	25%
Kildare	210,312	12%	282,408	12%	72,096	34%
Meath	184,135	10%	235,707	10%	51,572	28%
Wicklow	136,640	8%	191,666	8%	55,026	40%
GDA	**1,804,156**	**100%**	**2,286,858**	**100%**	**482,702**	**27%**

Employment

In terms of employment, the RPG provides guidance on the consolidation of development into a planned settlement hierarchy. The future growth in employment follows this hierarchy and keeps a similar proportion of employment in 2035 that existed in 2011 from Local Authority areas; however, the distribution of future employment is concentrated into the planned settlements within the Local Authority areas. The Table below shows the employment distribution for 2035 by Local Authority area.

Table B-7 GDA Employment with each Local Authority for 2011 and 2035

Employment	Jobs 2011	% of GDA 2011	Jobs 2035	% of GDA 2035	Growth 2011 to 2035	% Growth 2011 to 2035
Dublin City	287,788	46%	364,787	46%	76,999	27%
South Dublin	77,699	12%	98,488	12%	20,789	27%
Fingal	79,452	13%	100,710	13%	21,258	27%
Dún Laoghaire-Rathdown	68,626	11%	86,987	11%	18,361	27%
Kildare	52,260	8%	66,242	8%	13,982	27%
Meath	34,478	5%	43,703	5%	9,225	27%
Wicklow	27,574	4%	34,952	4%	7,378	27%
GDA	**627,877**	**100%**	**795,869**	**100%**	**167,992**	**27%**

Education and Retail

For education and retail, the total figures were derived by relating the numbers in education, and the numbers employed in retail to the total population and jobs figures, according to the evidence from the CSO, e.g. 7% of the National Population were of Secondary School going age. Numbers employed in retail is used as an indicator of retail activity rather than floor space, as the various retail formats mean floor space is less useful as an indicator of travel demand than retail employment.

Distribution within Each County

Settlements

As a means of distributing each demographic variable below the Local Authority level, the NTA defined a number of settlements in the region. Any Hinterland town with a population of over 2,000 people was defined as a settlement, while the Metropolitan Area was split on a more informal geographical basis.

Population and Employment Breakdown

In order to distribute the total population and employment figures assumed for each county, the local authorities assigned growth to each of the NTA settlements, within their county, on a percentage basis. Retail and education were distributed to settlements based on existing patterns (proportion of population to retail and education in each settlement) and the assigned growth in population.

Distribution into NTA Model Zones

At this point, the NTA had the distribution of land use at settlement level across the region. The next and final step involved breaking these settlement figures down into NTA model zones. These zones were based on the CSA, and as such represent a very fine level of detail. In collaboration, once again, with the Local Authorities, and on examination of land use zoning patterns across the region, each model zone was allocated a percentage of each settlements population, employment, education and retail on the basis of available planning data and advice from the local authorities.

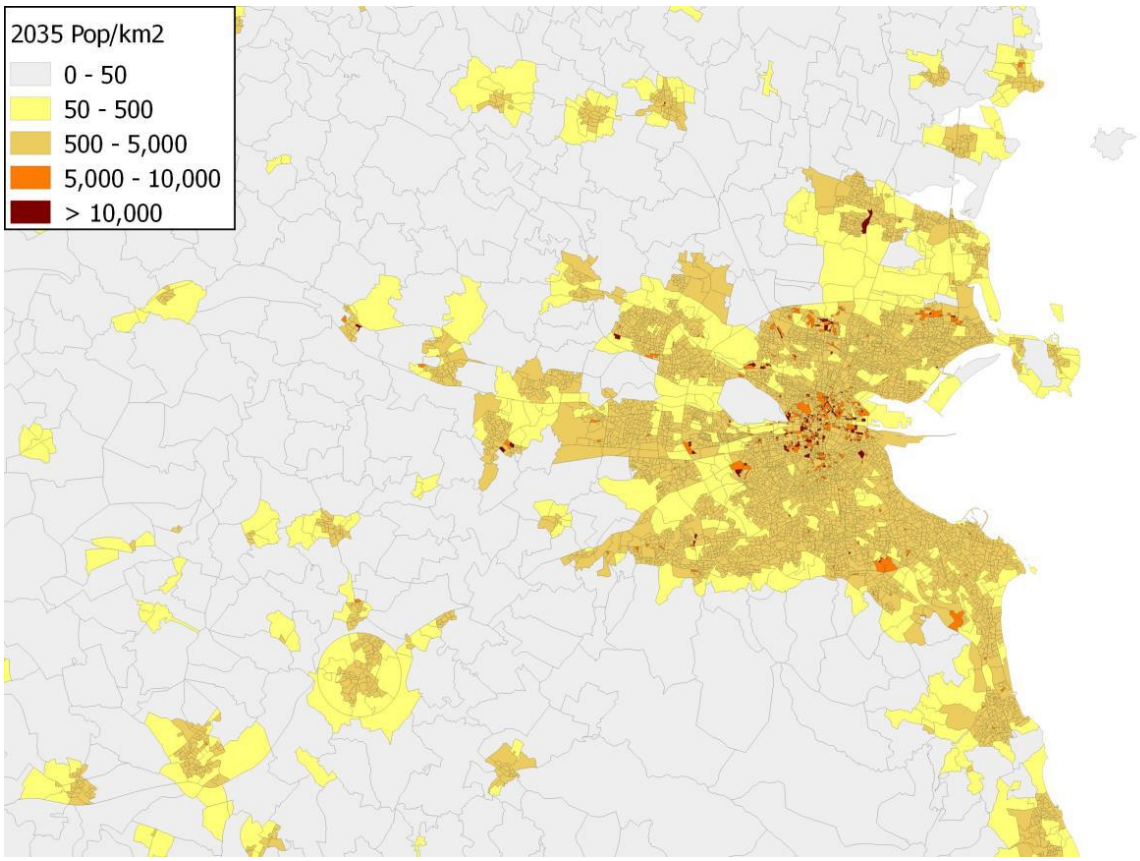


Figure B-Error! No text of specified style in document.**-2 Population Density per CSA**

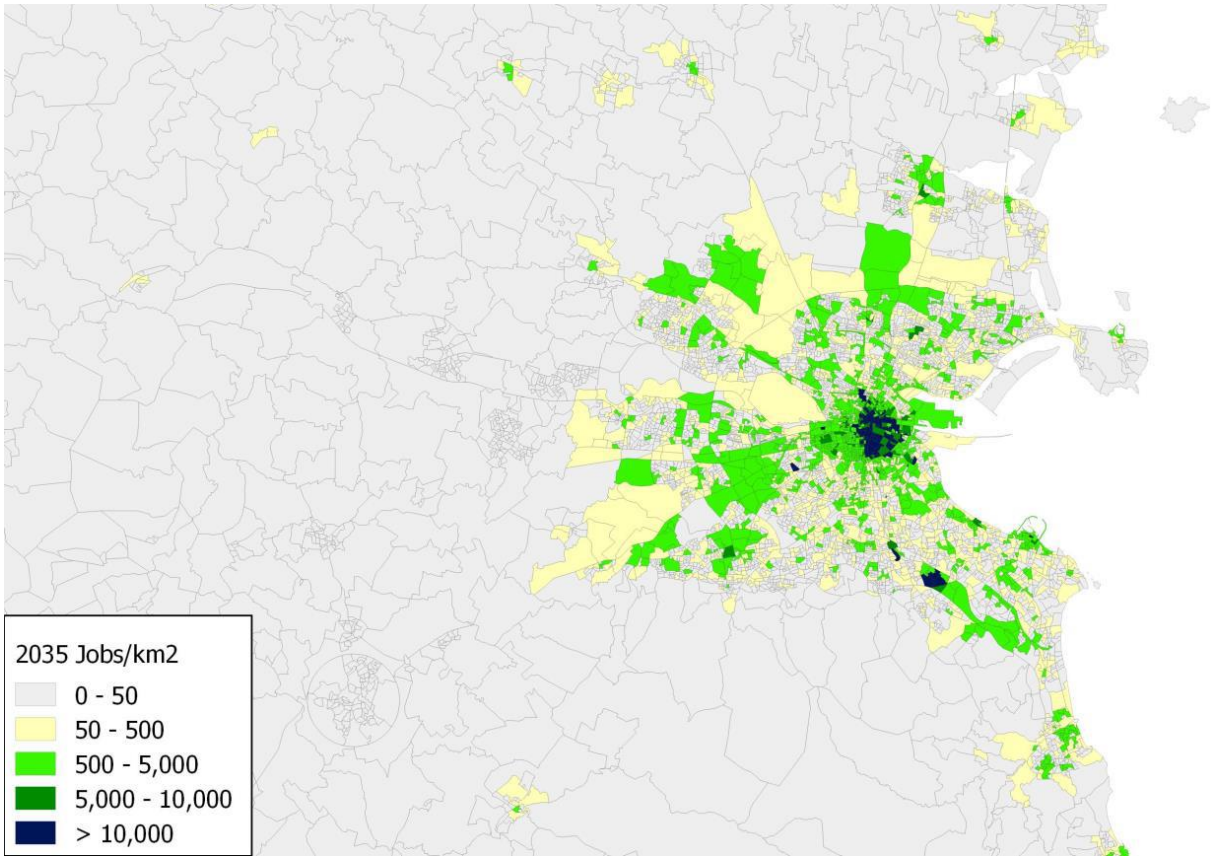


Figure B-Error! No text of specified style in document.**-3 Employment Density per CSA**

Creating the Demand Forecast for Use within the Model

Following the allocation of population, employment, education places and retail activity within the GDA for the Strategy horizon year, the National Demand and Forecasting Model (NDFM) was used to predict the future year national trip demand.

The NDFM includes the set of models and tools that are used to derive levels of trip making (nationally) from planning data for input to each of the regional models. The NDFM outputs levels of trip making at the smallest available spatial aggregation (CSA).

Within the NDFM, the Planning Data Adjustment Tool (PDAT) was used to adjust the base year planning input data to reflect the new forecast year. The planning sheet was updated and adjusted based on forecasts for the following 8 planning variables:

Production Variables

- Population;
- Total Employed
- Total Unemployed

Attraction Variables

- Primary School Students;
- Secondary School Students;
- Tertiary Students;
- Retail Employment; and
- Non-Retail Employment.

Adjustments were made at the CSA level within the GDA area and at the NUTS3 (Nomenclature of Territorial Units for Statistics) Regional level outside of the GDA area for the rest of Ireland. Tables below outline the overall growth across the various regions with the NUTS3 regions.

Table B-8 Population Adjustments

Population			
Region	**2011**	**2035**	**%**
South-East (IE)	497,578	556,852	12%
Border(IE)	514,891	535,033	4%
Mid-West(IE)	379,327	415,938	10%
South-West (IE)	664,534	744,805	12%
West(IE)	445,356	457,170	3%
Midland(IE)	282,410	310,852	10%
GDA	1,804,156	2,286,858	27%
TOTAL	4,590,263	5,309,544	16%

Table B-9 Employments Adjustments

Employment			
Region	**2011**	**2035**	**%**
South-East (IE)	127,602	155,777	22%
Border(IE)	122,140	138,449	13%
Mid-West(IE)	104,235	124,680	20%
South-West (IE)	195,000	238,412	22%
West(IE)	118,181	132,338	12%
Midland(IE)	67,707	81,297	20%
GDA	627,877	868,178	38%
TOTAL	1,364,753	1,739,131	27%

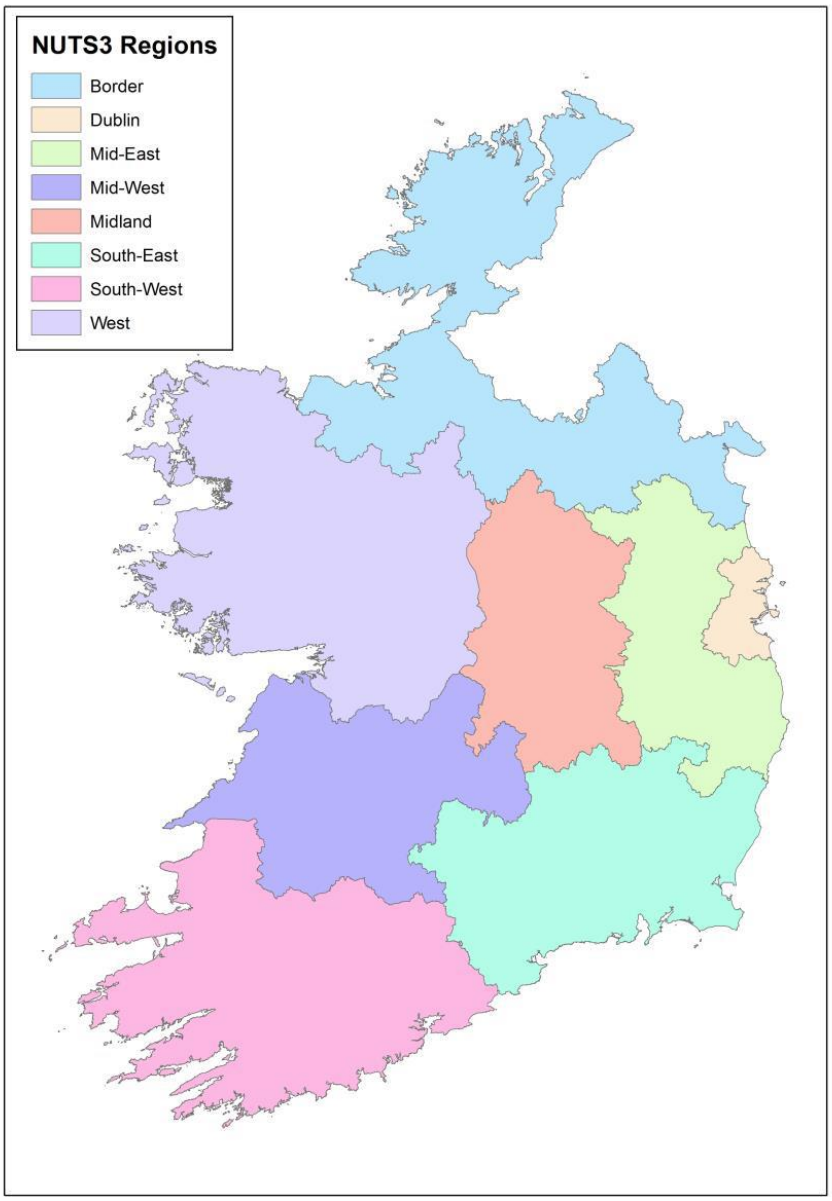


Figure B-Error! No text of specified style in document.**-4** **NUTS3 Regions**

The PDAT allows for the changes that were applied to the above variables to then cascade through all other inter-dependent variables as implicated by the dependency diagram overleaf in the figures below for production variables and the attraction variables.
The final step before use in the model was to convert the planning data into 24-hour level person trips at the CSA level using the NTEM.

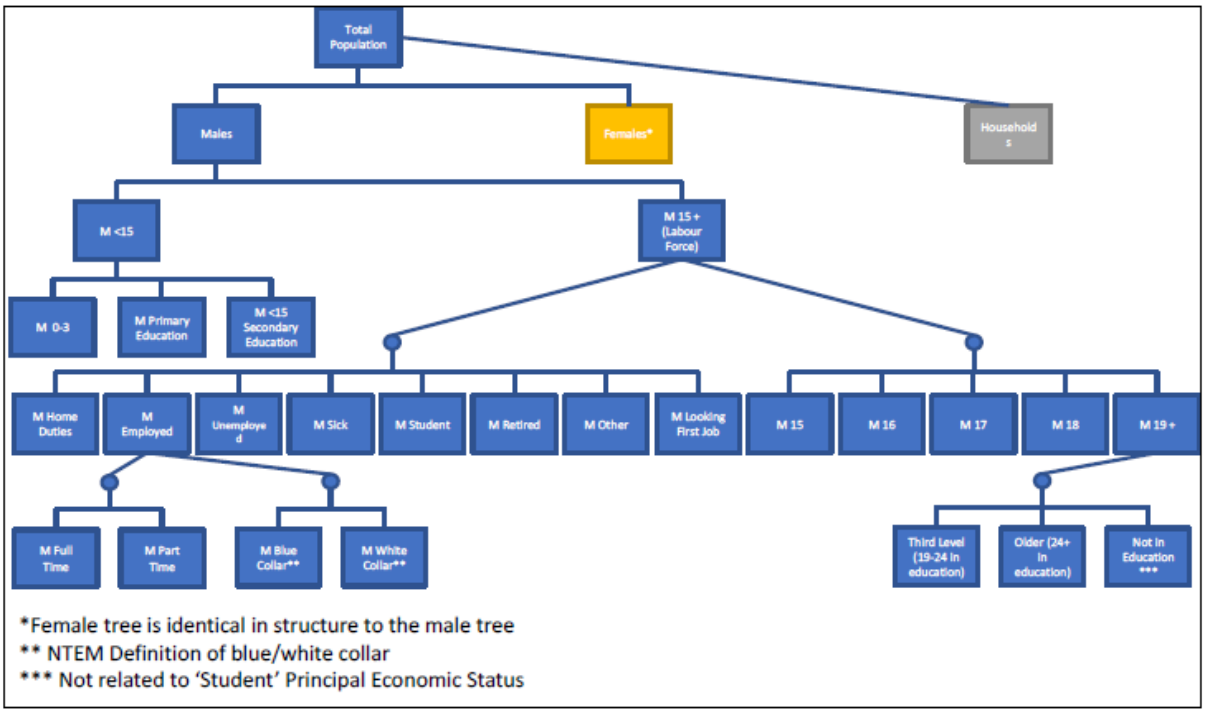


Figure B-Error! No text of specified style in document.**-5 PDAT Production Variables Dependency Diagram**

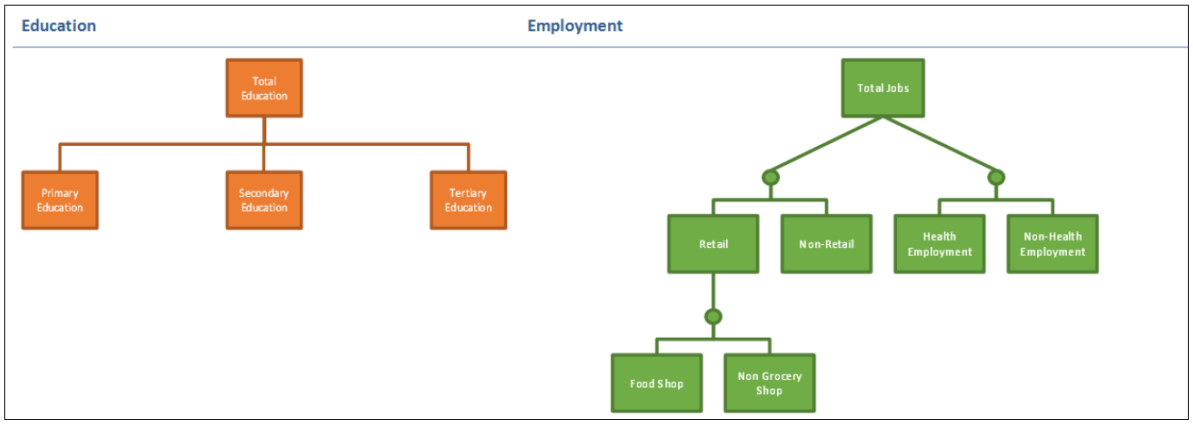
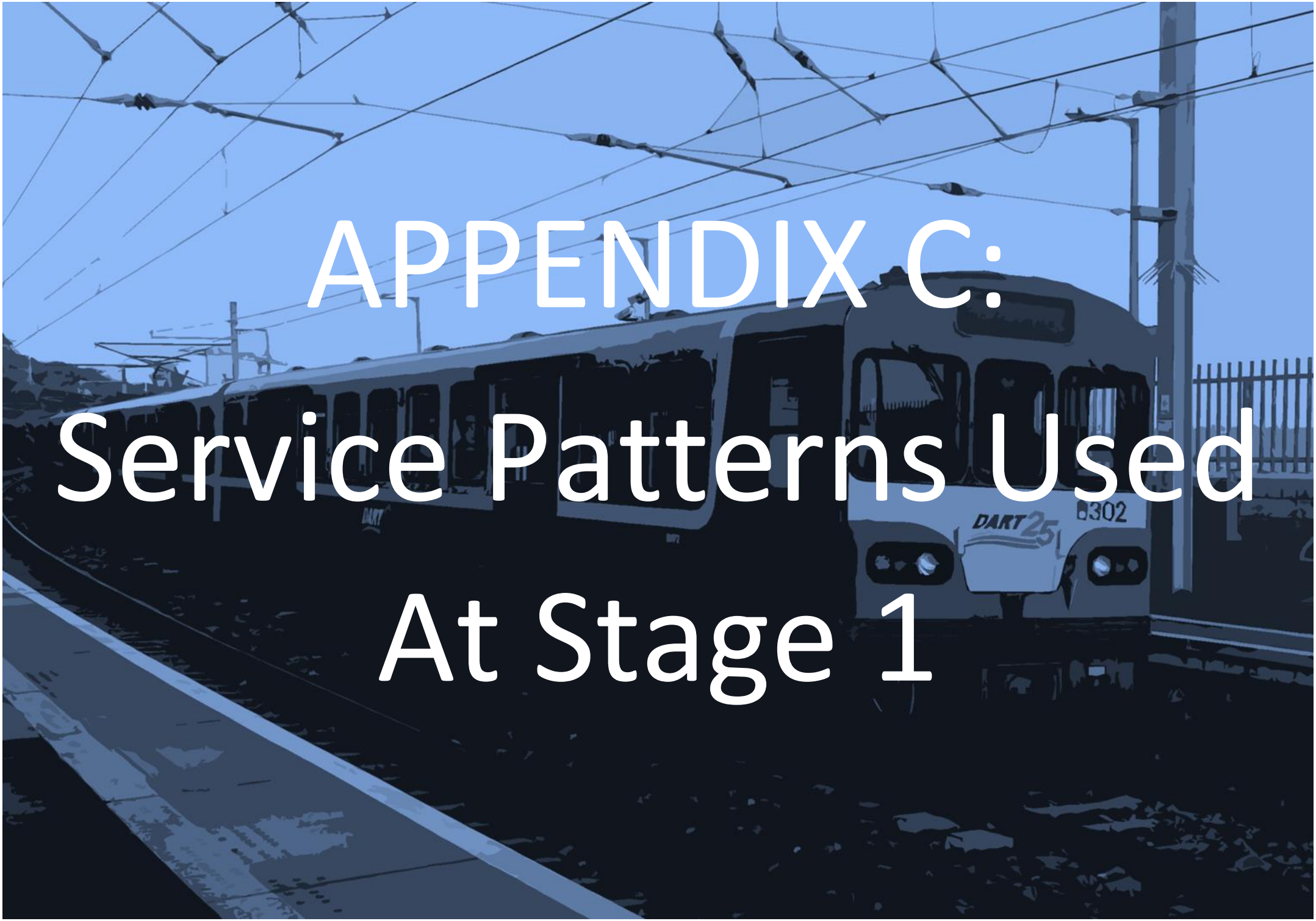


Figure B-Error! No text of specified style in document.**-6 PDAT Attraction Variables Dependency Diagram**

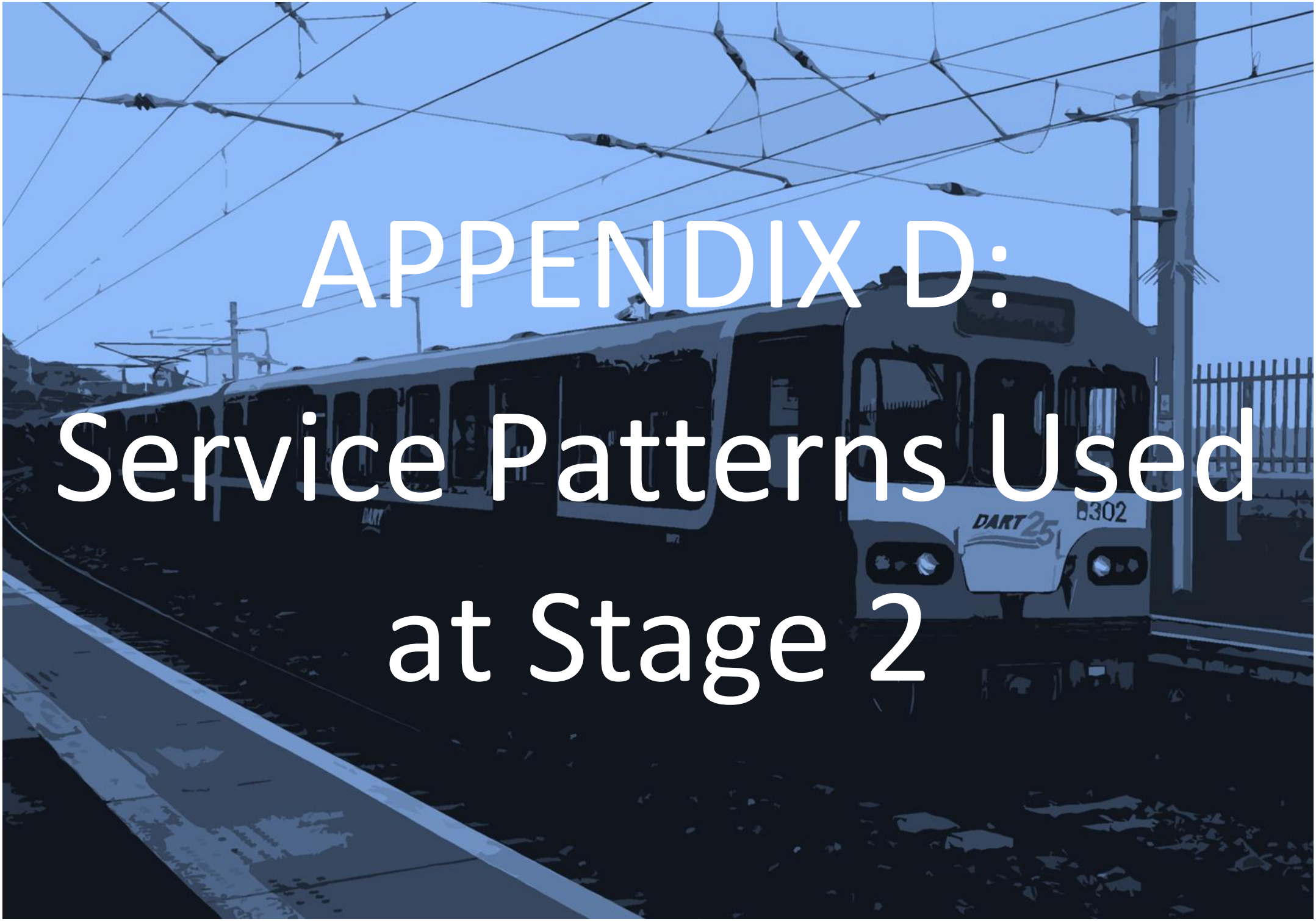


APPENDIX C:

Service Patterns Used At Stage 1

Note The below table contains a breakdown of the DART Services modeled at this stage of the Assessment Process.

	Bundle 1	Bundle 2	Bundle 3	Bundle 4	Bundle 5
Route	Do Minimum Network	Full DART Expansion including DART Underground	DART Expansion including DART Underground with Heuston Station Turnback	DART Expansion including DART Underground with Pearse Station Turnback	DART Expansion including Underground tunnel from East Wall to Pearse Station Turnback
Northern					
Dundalk to Drogheda		2	2	2	
Dundalk to Connolly	2	2	2	2	
Dundalk to Pearse	1				
Dundalk to Bray	1				
Drogheda to Connolly				2	4
Drogheda to Pearse				2	
Drogheda to Bray	1			5	12
Drogheda to GCD				1	
Northern & DART					
Drogheda to Heuston			12		
Clongriffin to Heuston			3		
Hazelhatch to Pearse				7	
Heuston to Pearse				8	
Drogheda to Inchicore		6			
Drogheda to Hazelhatch		6			
Clongriffin to Inchicore		2			
Clongriffin to Hazelhatch		2			
Howth to Howth Jn		6	6	6	6
Connolly to Bray		2	2		
Connolly to Greystones					2
Malahide to Bray	2				
Malahide to Greystones	1				
Clongriffin to Bray	2			2	
Howth to Bray	2				
Howth to Dun Laoghaire	1				
Howth to Greystones	1				
Maynooth & M3 Parkway					
Maynooth to Connolly	3			3	
Maynooth to Pearse	1				12
Maynooth to GCD				1	
Maynooth to Bray	1	8	8	4	
Maynooth to Greystones		2	2	2	
M3 Parkway to Docklands	2				
M3 Parkway to Clonsilla		4	4	4	
Heuston Mainline & Commuter					
Mainline to Heuston	8	10	10	10	
Newbridge to Heuston		2	2	2	
Kildare to GCD	2				
Newbridge to GCD	2				
Hazelhatch to GCD					8
Total Services	**33**	**54**	**53**	**63**	**44**

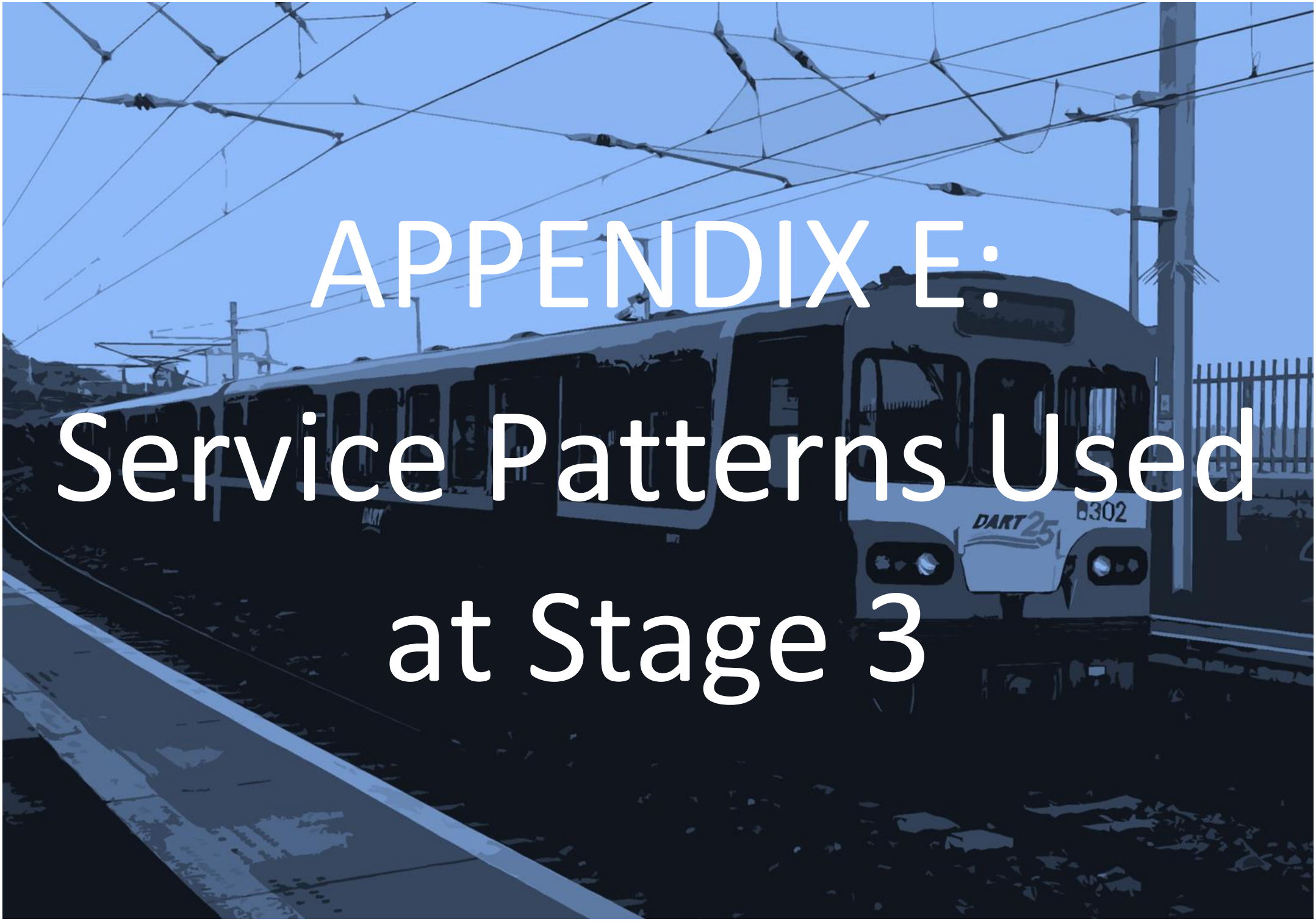


APPENDIX D:

Service Patterns Used at Stage 2

Note The below table contains a breakdown of the DART Services modeled at this stage of the Assessment Process.

	Bundle 2	**Bundle 3**	**Bundle 4**	**Bundle 5**	**Bundle 6**
Route	**DART Expansion including DART Underground**	**Dart underground via Heuston Turnback**	**Dart underground via Pearse Turnback**	**Dart underground with Pearse turnback tunnel via East**	**DART Expansion with Existing Network Enhancement**
Northern					
Dundalk to Drogheda [Shuttle]	2	2	2	2	2
Dundalk to Connolly	2	2	2	2	2
Drogheda to Connolly	2	2	2	2	2
Drogheda to Bray			8	8	8
Northern & DART					
Drogheda to Heuston		8			
Clongriffin to Heuston		7			
Hazelhatch to Pearse			15		
Drogheda to Hazelhatch	8				
Clongriffin to Inchicore	4				
Clongriffin to Hazelhatch	8				
Howth to Howth Jn [Shuttle]	6	6	6	6	6
Connolly to Bray	2	2			
Clongriffin to Bray			6	6	6
Maynooth & M3 Parkway					
Maynooth to Connolly			6		12
Maynooth to Docklands			6		
Maynooth to Pearse U/G via Tunnel				14	
Maynooth to Bray	12	12			
Maynooth to Greystones	2	2	2		2
M3 Parkway to Clonsilla [Shuttle]	4	4	4	4	4
Heuston Mainline					
Mainline to Heuston	10	10	10	10	10
Newbridge to Heuston	2	2	2	2	2
Hazlehatch - Heuston [Shuttle]		16			
Hazelhatch to Greystones, via PPT & Loop Line				2	
Hazelhatch to Connolly				14	
Hazelhatch to Docklands					16
Total Services	**64**	**75**	**71**	**72**	**72**



APPENDIX E:

Service Patterns Used at Stage 3

Note The below table contains a breakdown of the DART Services modeled at this stage of the Assessment Process.

	Bundle 2	**Bundle 6**
Route	**DART Underground**	**Enhanced PPT**
Northern		
Dundalk to Drogheda [Shuttle]	2	2
Dundalk to Connolly (Diesel)	2	2
Drogheda to Docklands		3
Drogheda to Connolly		2
Drogheda to Dún Laoghaire		6
Northern & DART		
Drogheda to Hazelhatch	8	
Clongriffin to Hazelhatch	8	
Howth to Howth Jn [Shuttle]	6	6
Connolly to Bray	3	
Clongriffin to Bray		4
Maynooth & M3 Parkway		
Maynooth to Connolly		5
Maynooth to Docklands		3
Maynooth to Bray	12	5
Maynooth to Greystones	2	2
M3 Parkway to Clonsilla [Shuttle]	4	4
Heuston Mainline		
Mainline to Heuston (DMU)	12	12
Hazelhatch to Heuston		4
Hazelhatch to Docklands		12
Total Services	**59**	**72**

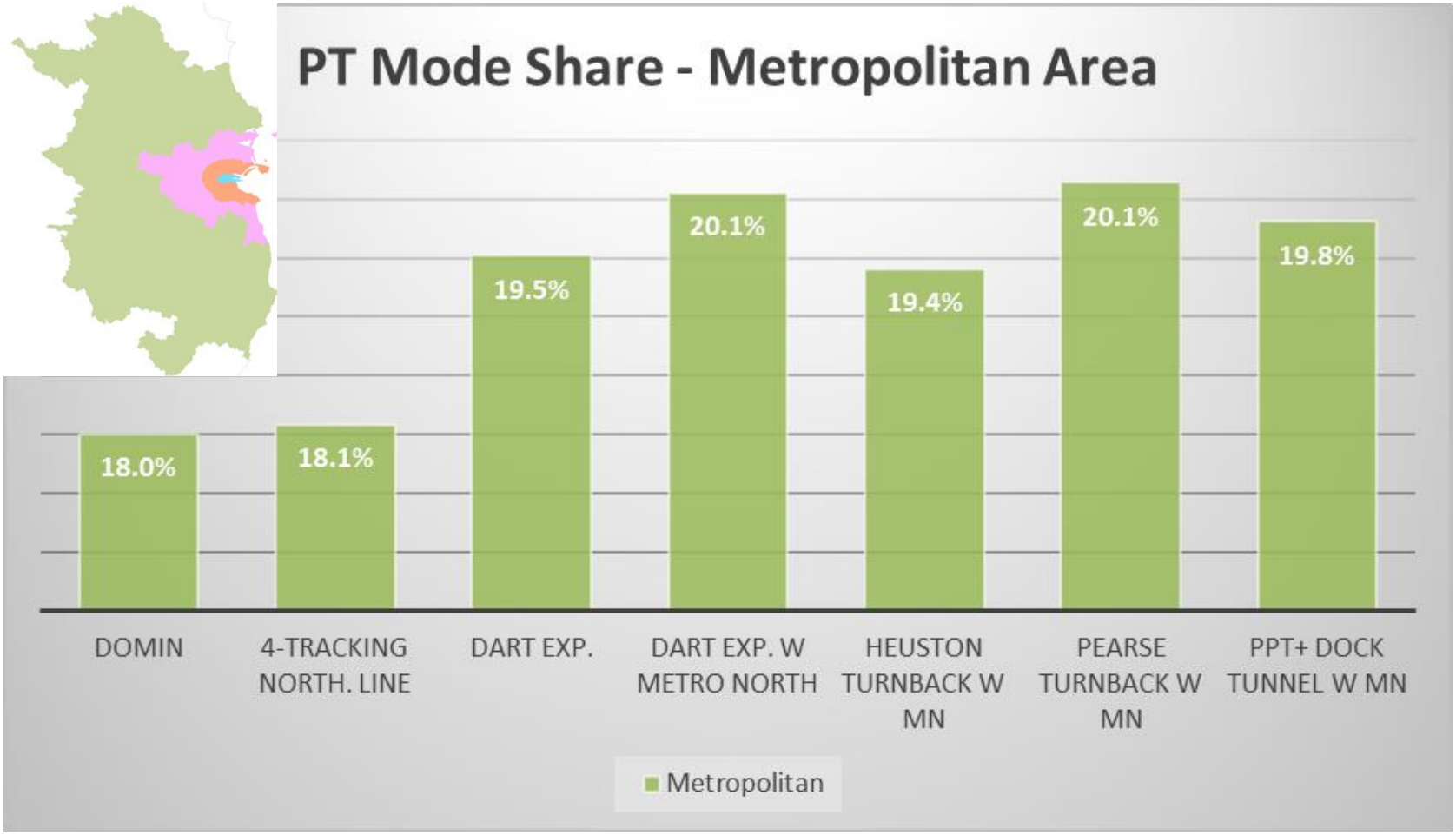
Appendix F
DART Expansion – Stage 1 - Initial Model Outputs Summary

SYSTRA

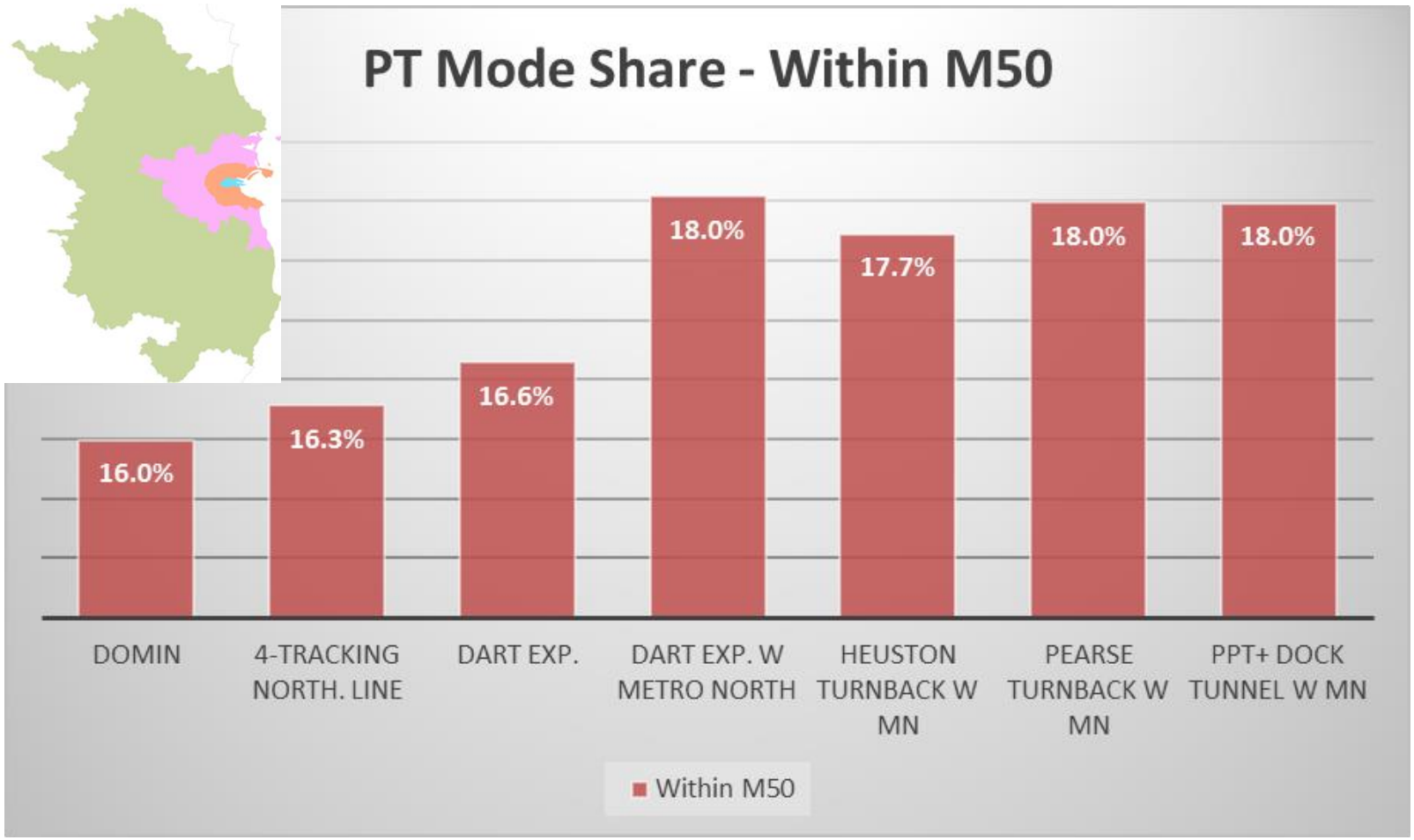
Summary of Key Performance Indicators

- **The following KPI's have been extracted from the model for each scenario:**
  - **Mode Share**
  - **Total Boardings by PT Sub-mode**
  - **Lines Summary**
  - **Line Profiles for each Rail Line**
  - **Average Journey Speed per PT Passenger**
    - Combines PT Passenger Travel Time and Distance
    - Used to identify the efficiency improvements across each scenario
  - **Road Assignment Statistics**

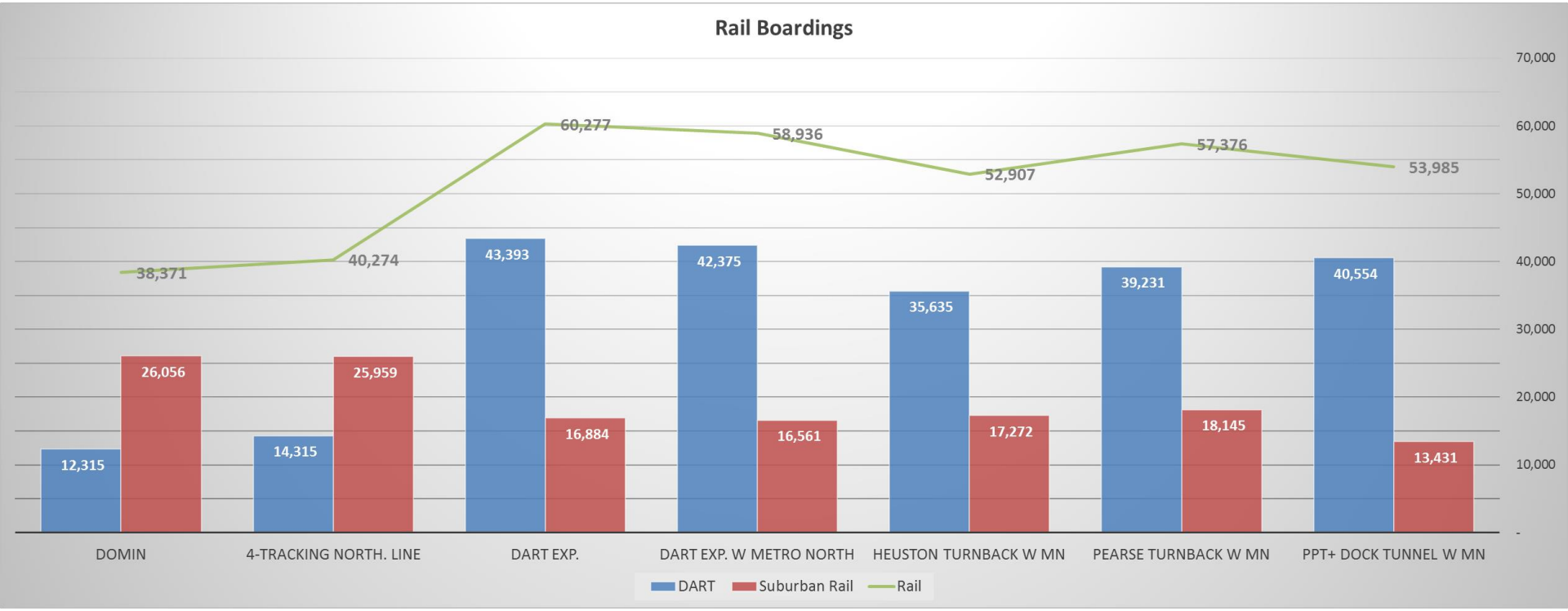
Public Transport Mode Share – AM Origin



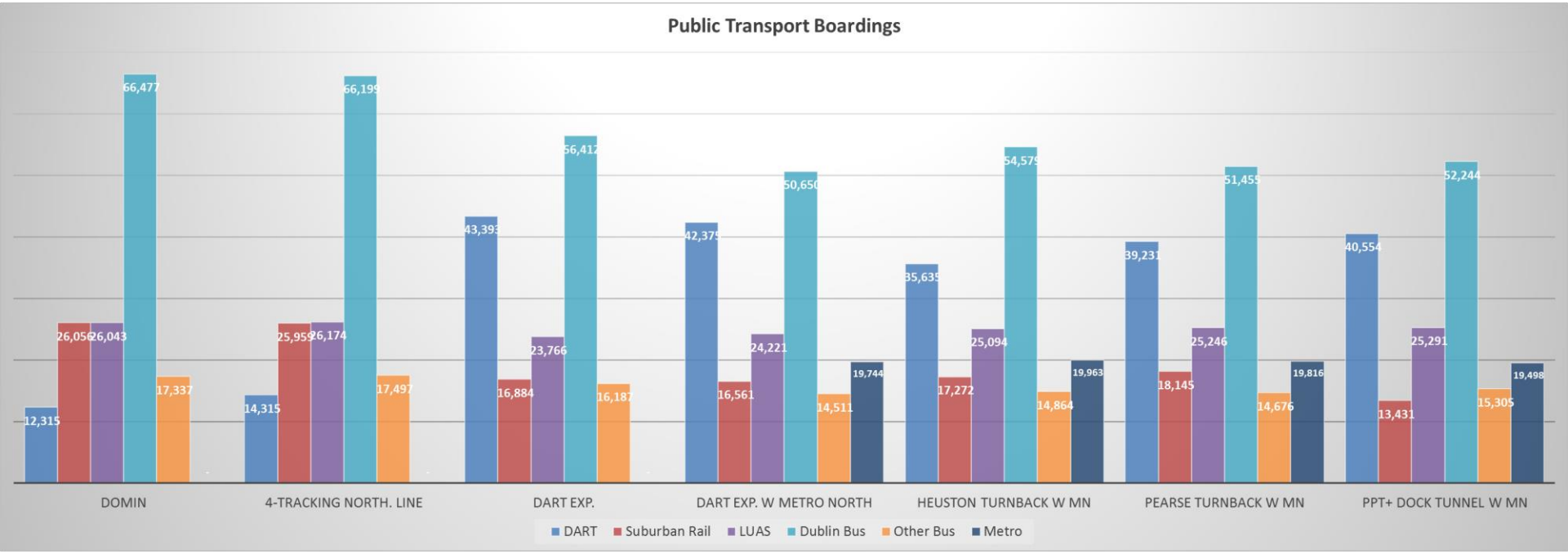
Public Transport Mode Share – AM Origin



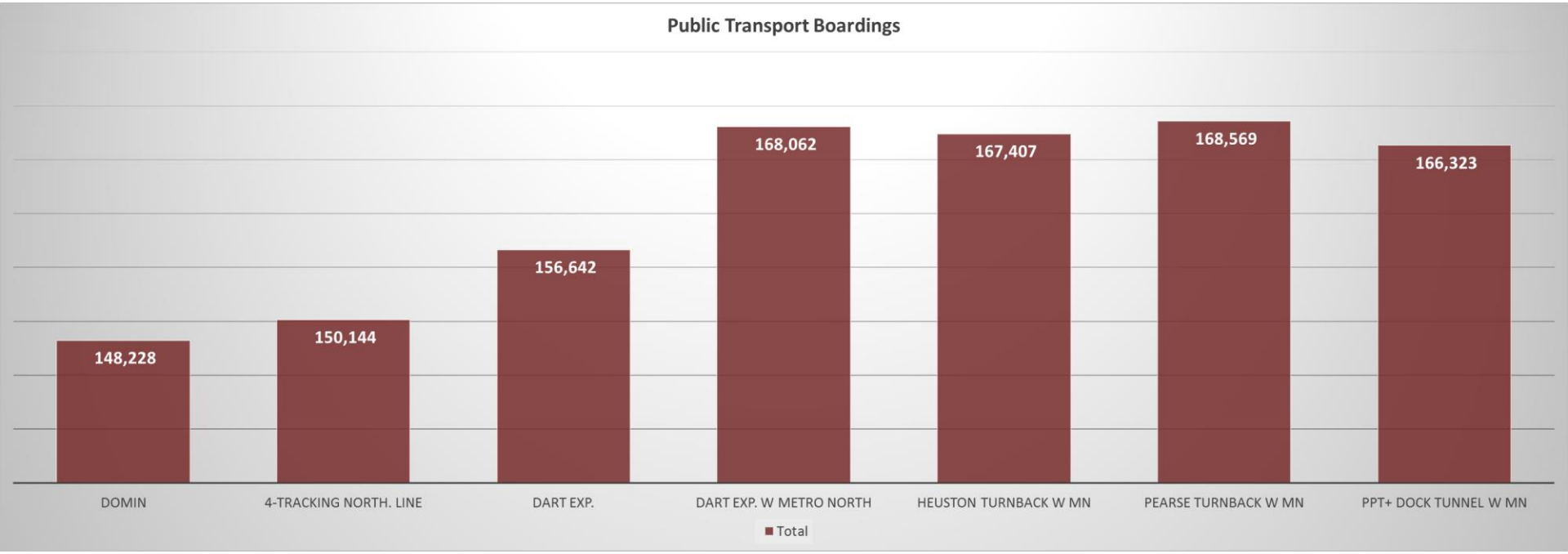
Public Transport AM Boardings Summary



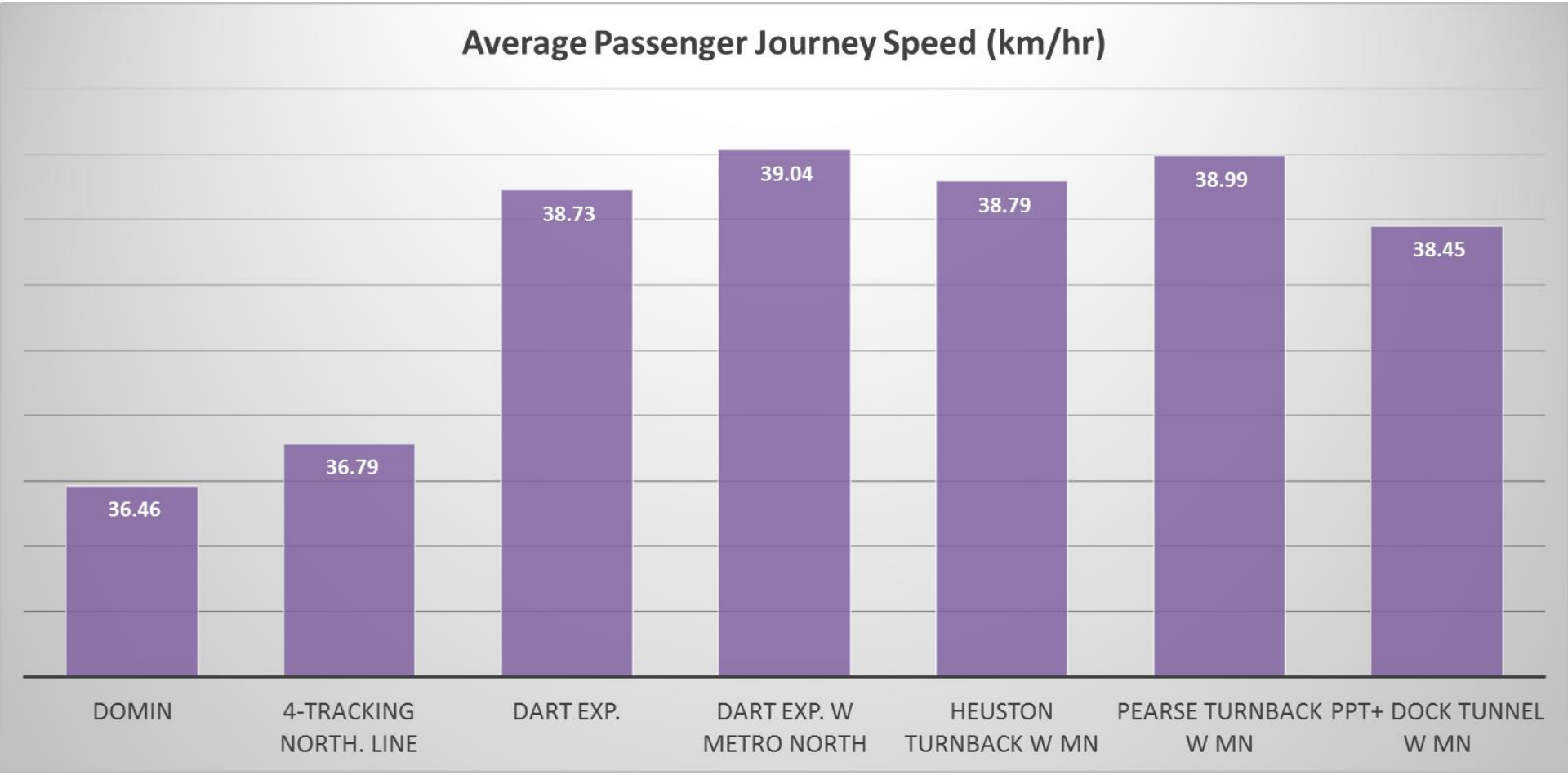
Public Transport Boarding Summary



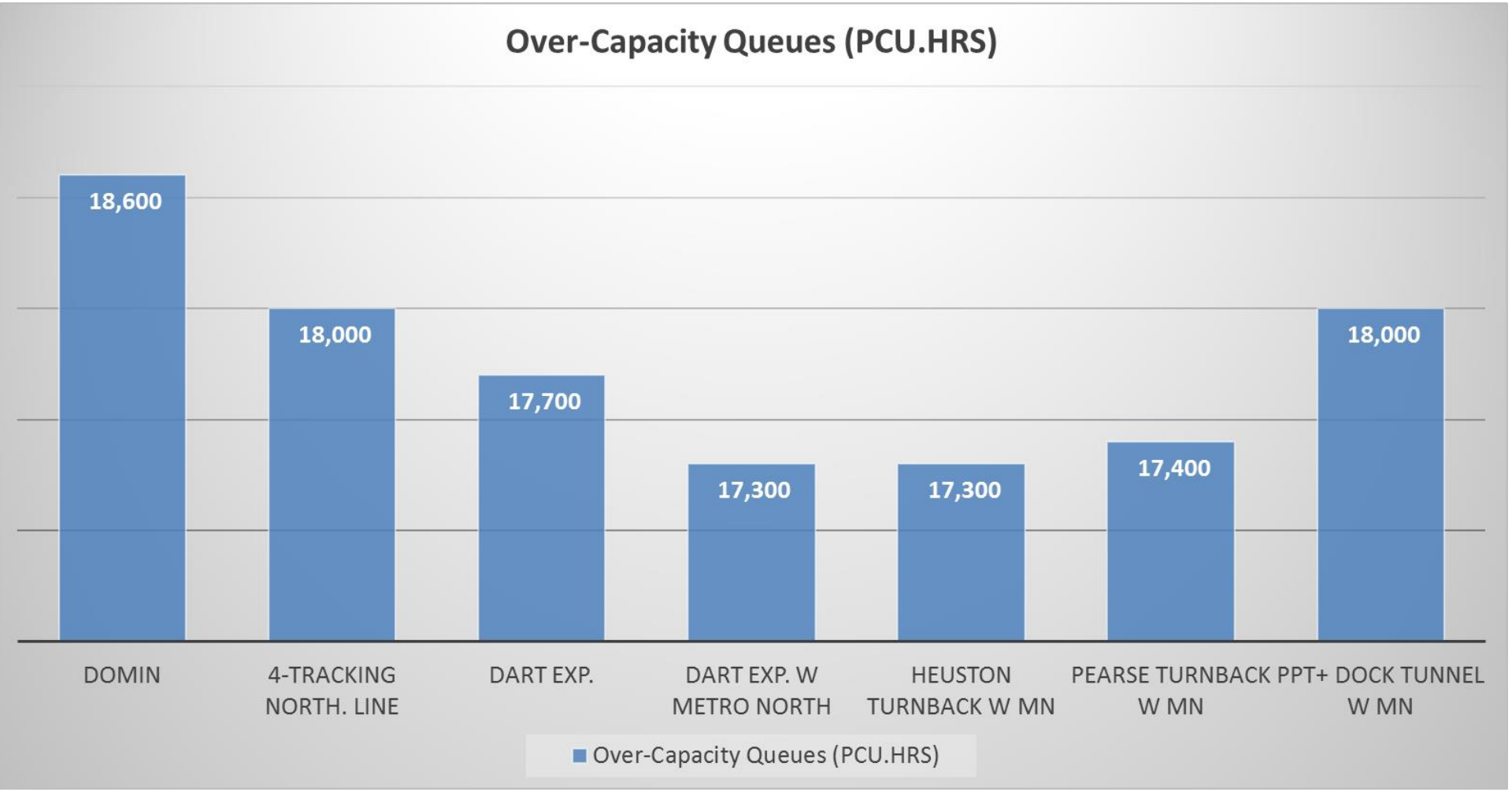
Public Transport Boarding Summary – Total (All Modes)



Public Transport Average Journey Speed



Road Assignment Summary

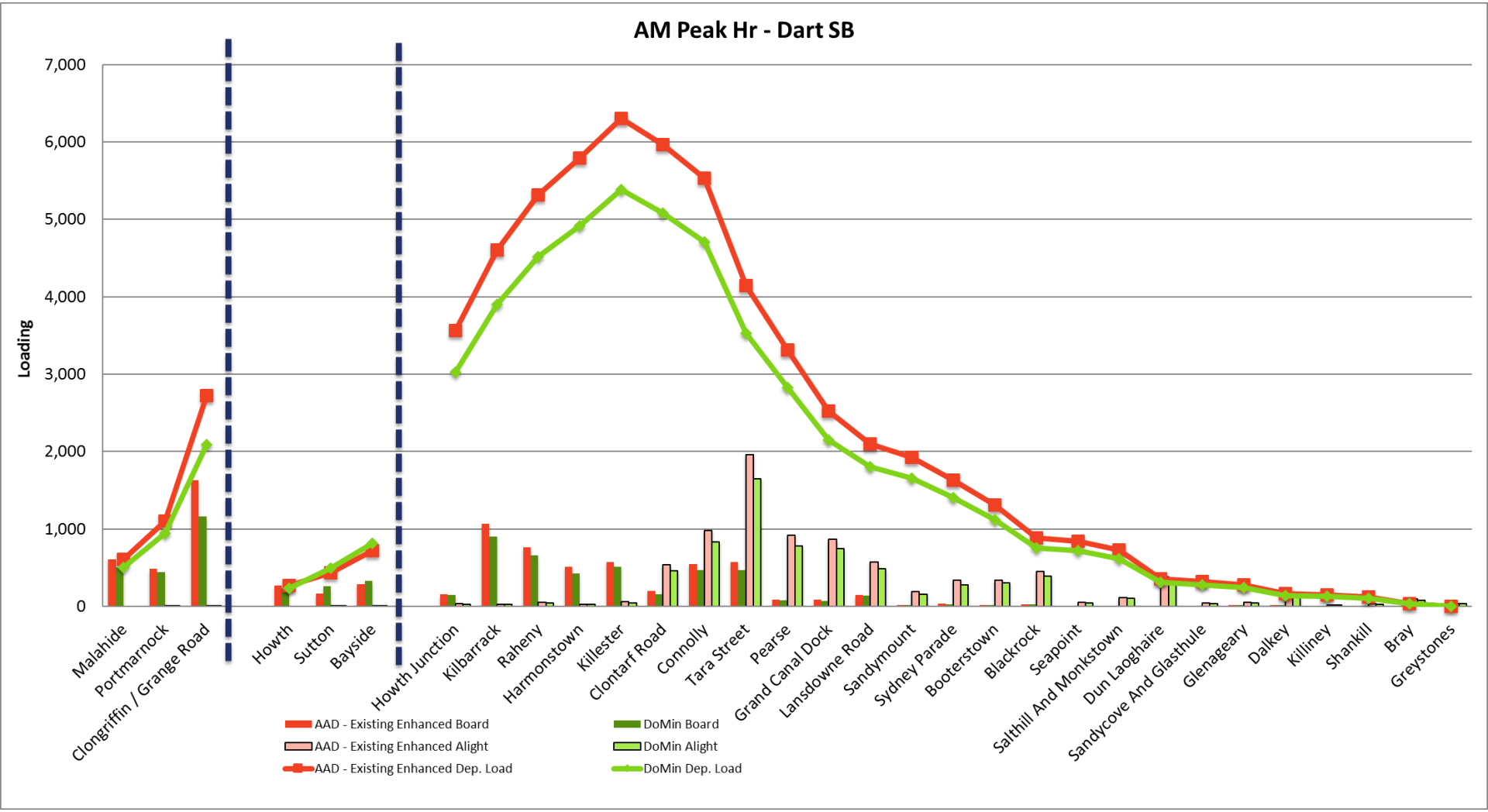


Bundle 1B – 4 Tracking Northern Line to Malahide

- **Overall Summary:**
  - 16% increase in DART Boardings
  - 5% increase in overall Heavy Rail Boardings
  - 1% increase in overall Public Transport Boardings
  - Approx. 1,000 increase in AM max. loadings on the southbound line at Killester

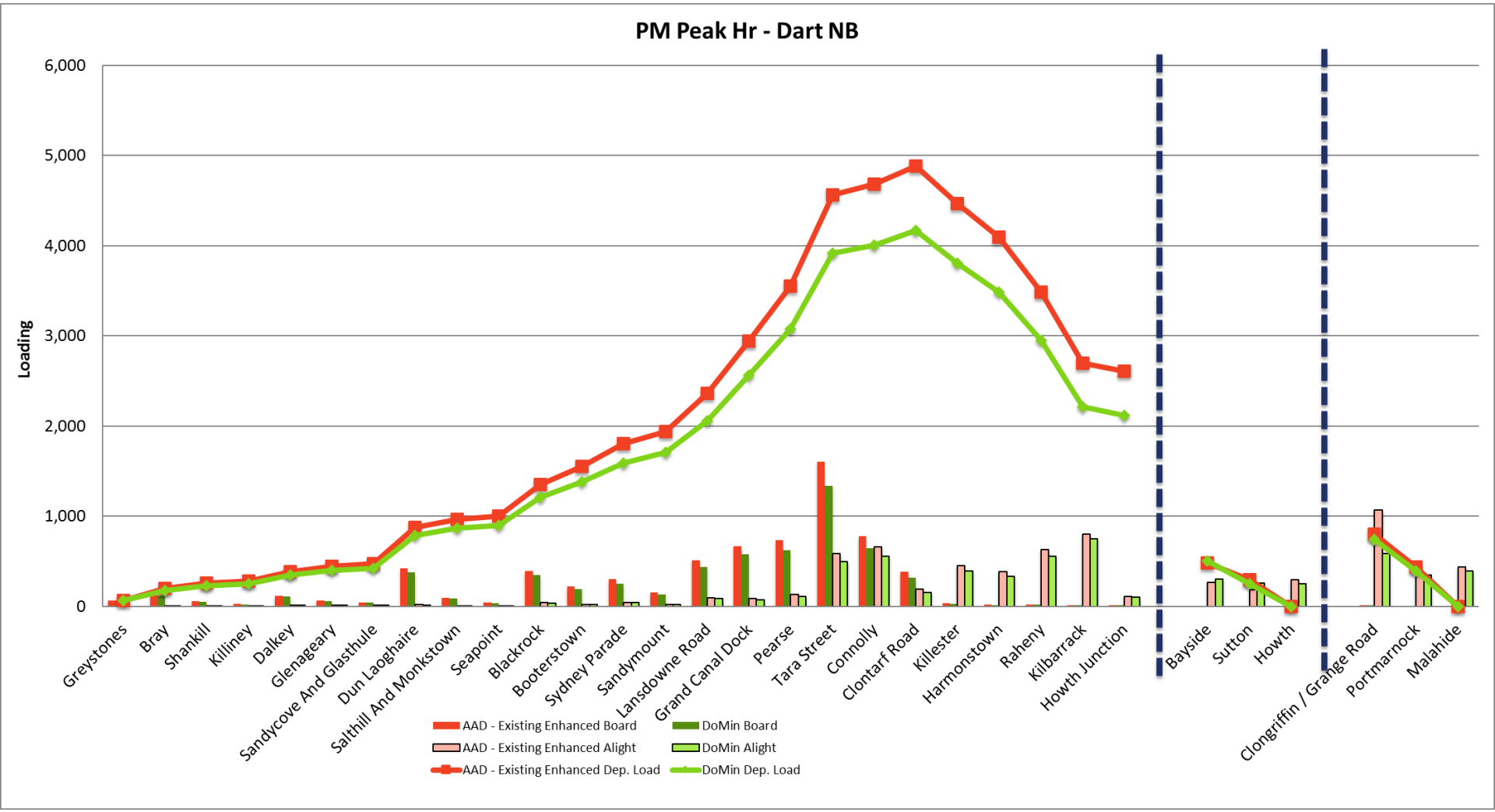
- **Issues:**
  - Although rail speeds are increased for existing services, there are only 2 additional morning services provided from Clongriffin to Bray. Is this correct?
  - The introduction of Metro North may have impacts on the performance of this scheme

Bundle 1B - Scenario AAD - Line Profiles



SYSTRA

Bundle 1B - Scenario AAD - Line Profiles



Bundle 2A – DART Expansion

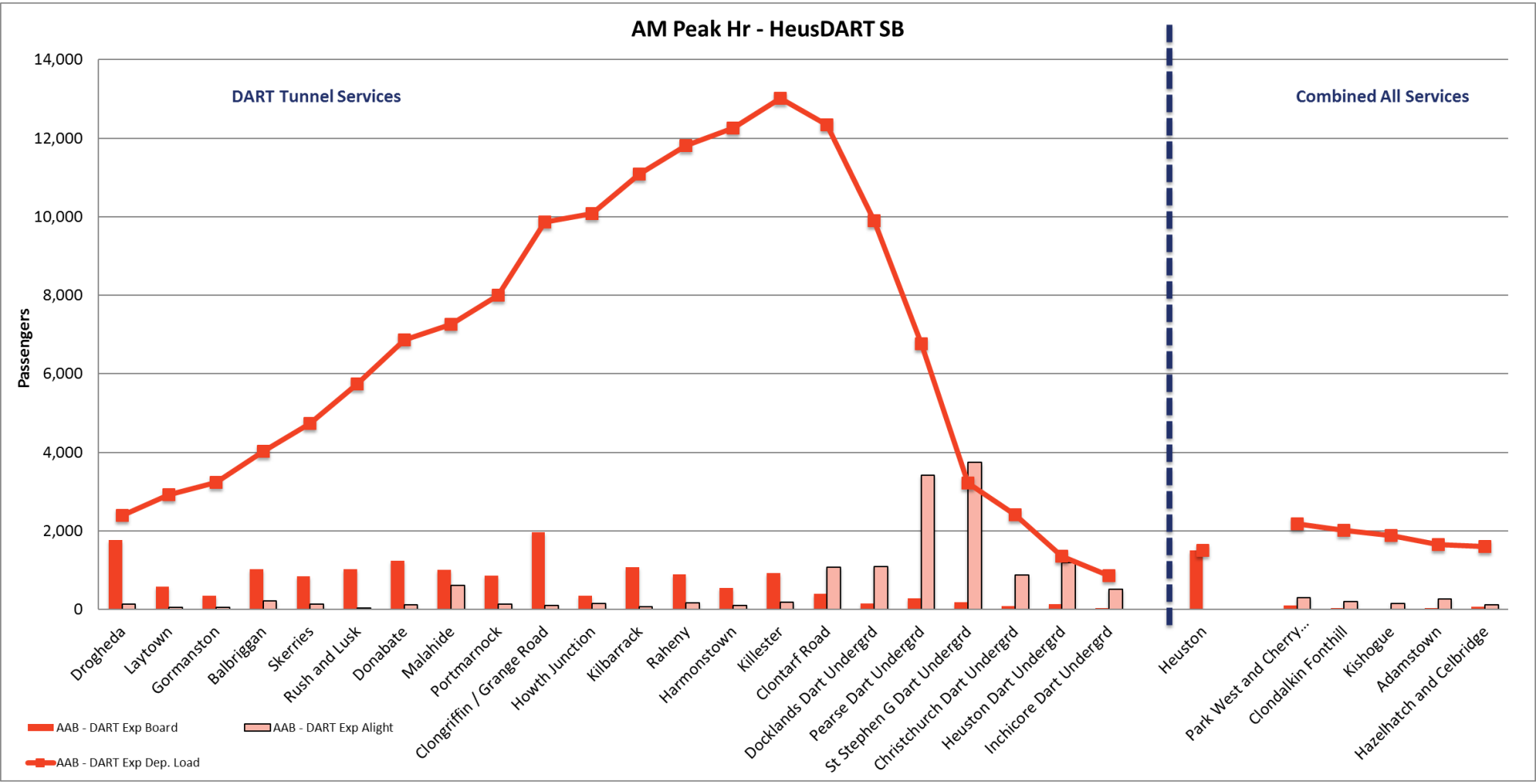
- **Overall Summary:**
  - **252% increase in DART Boardings**
  - **57% increase in overall Heavy Rail Boardings**
  - **8% increase in overall Public Transport Boardings**

  - **Peak Loading**
    - **Northern Line - 13,000 - AM Southbound at Killester**
    - **Maynooth Line – 8,500 – AM Southbound at Broombridge**

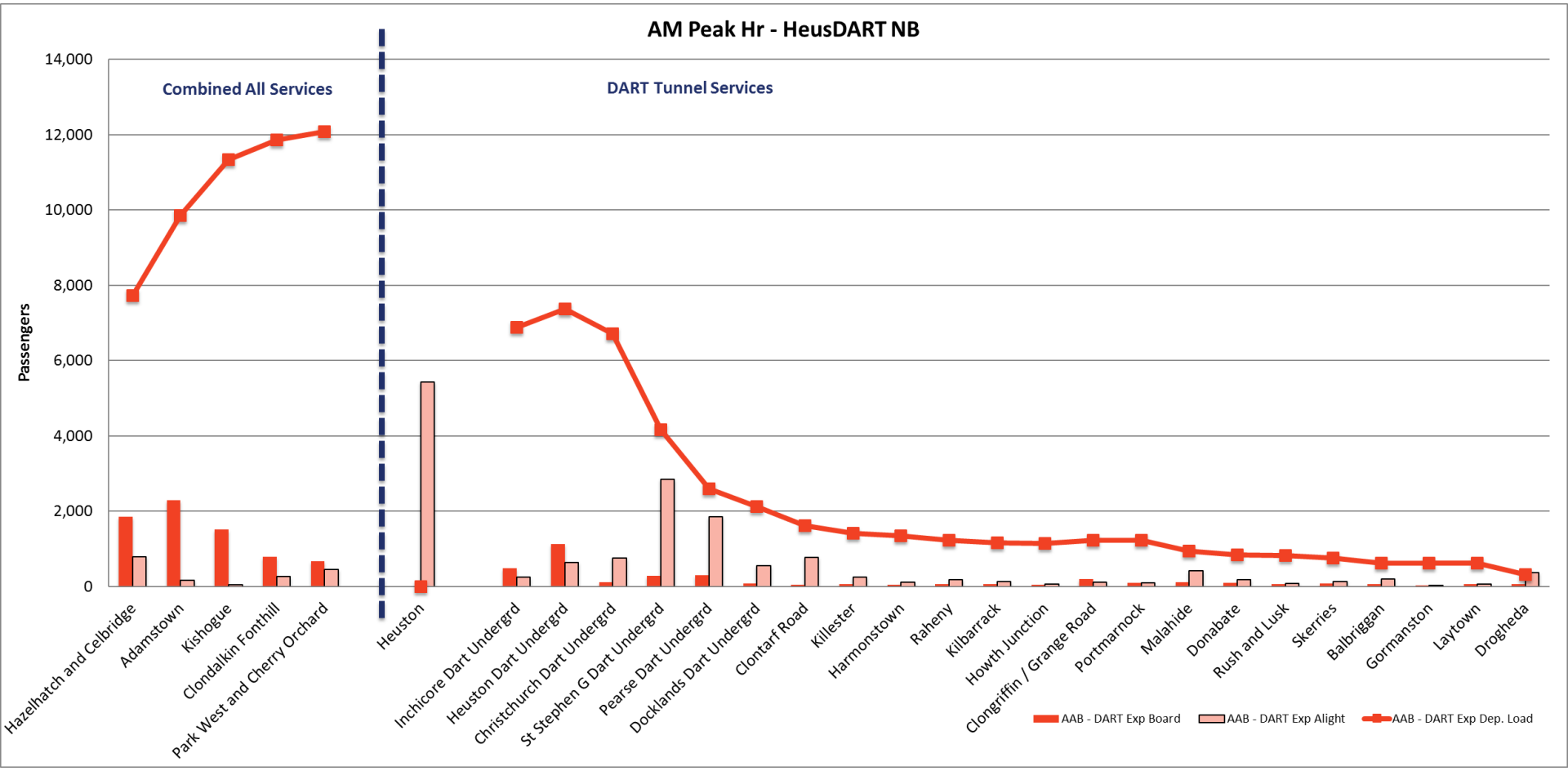
New NTA ERM - DART Expansion – Line Summary

Description	Sum of Boardings	Sum of Veh Kms	Sum of Veh Hrs	Average of Veh Spd	Sum of Pass Kms	Sum of Pass Hrs	Sum of Distance	Sum of Time
Inchicore to Drogheda – all stops	2,173.93	471.44	10.00	47.14	29,376.76	677.10	58.93	75.00
Hazelhatch to Clongriffin – all stops	3,950.85	117.64	3.13	37.55	49,763.89	1,263.18	29.41	47.00
Hazelhatch to Balbriggan – all stops	4,309.11	220.96	5.13	43.04	57,160.43	1,446.18	55.24	77.00
Drogheda to Inchicore – all stops	8,522.13	471.44	10.13	46.52	185,210.01	4,330.68	58.93	76.00
Balbriggan to Hazelhatch – all stops	3,861.92	220.96	5.07	43.61	59,315.64	1,561.38	55.24	76.00
Clongriffin to Hazelhatch – all stops	2,369.28	117.64	3.07	38.36	21,173.34	629.85	29.41	46.00
Howth to Howth Junction (Shuttle) – all	217.85	32.40	0.90	36.00	733.44	24.31	5.40	9.00
Howth Junction to Howth (Shuttle) – all	64.40	32.40	0.90	36.00	269.36	7.93	5.40	9.00
Maynooth to Bray – all stops	7,559.97	298.02	7.80	38.21	114,172.03	2,980.52	49.67	78.00
Connolly to Bray – all stops	418.82	46.70	1.43	32.58	2,673.02	94.49	23.35	43.00
Maynooth to Greystones – all stops	2,560.14	114.78	2.83	40.51	39,207.51	1,021.33	57.39	85.00
Greystones to Maynooth – all stops	2,112.71	114.78	2.80	40.99	43,182.55	1,112.34	57.39	84.00
Bray to Maynooth – all stops	4,174.06	298.02	7.70	38.70	57,097.34	1,669.74	49.67	77.00
Bray to Connolly – all stops	843.90	46.70	1.43	32.58	11,077.10	342.38	23.35	43.00
M3 Parkway to Clonsilla (Shuttle) – all	147.13	28.60	0.67	42.90	770.34	17.47	7.15	10.00
Clonsilla to M3 Parkway (Shuttle) – all	106.65	28.60	0.67	42.90	552.39	12.28	7.15	10.00
	43,392.85	**2,661.08**	**63.67**	**39.85**	**671,735.15**	**17,191.16**	**573.08**	**845.00**

New NTA ERM - Line Profiles – DART Expansion

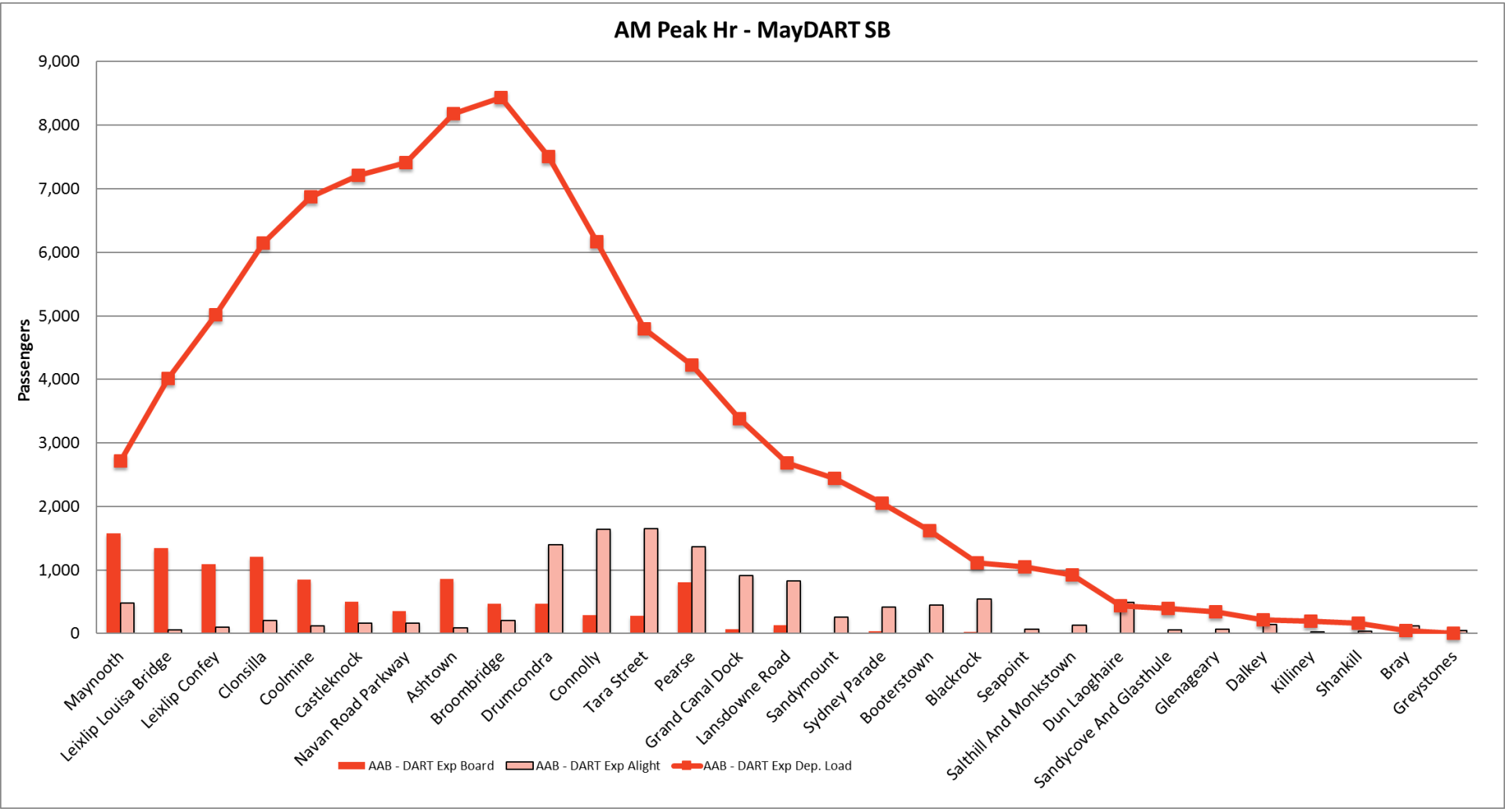


New NTA ERM - Line Profiles – DART Expansion



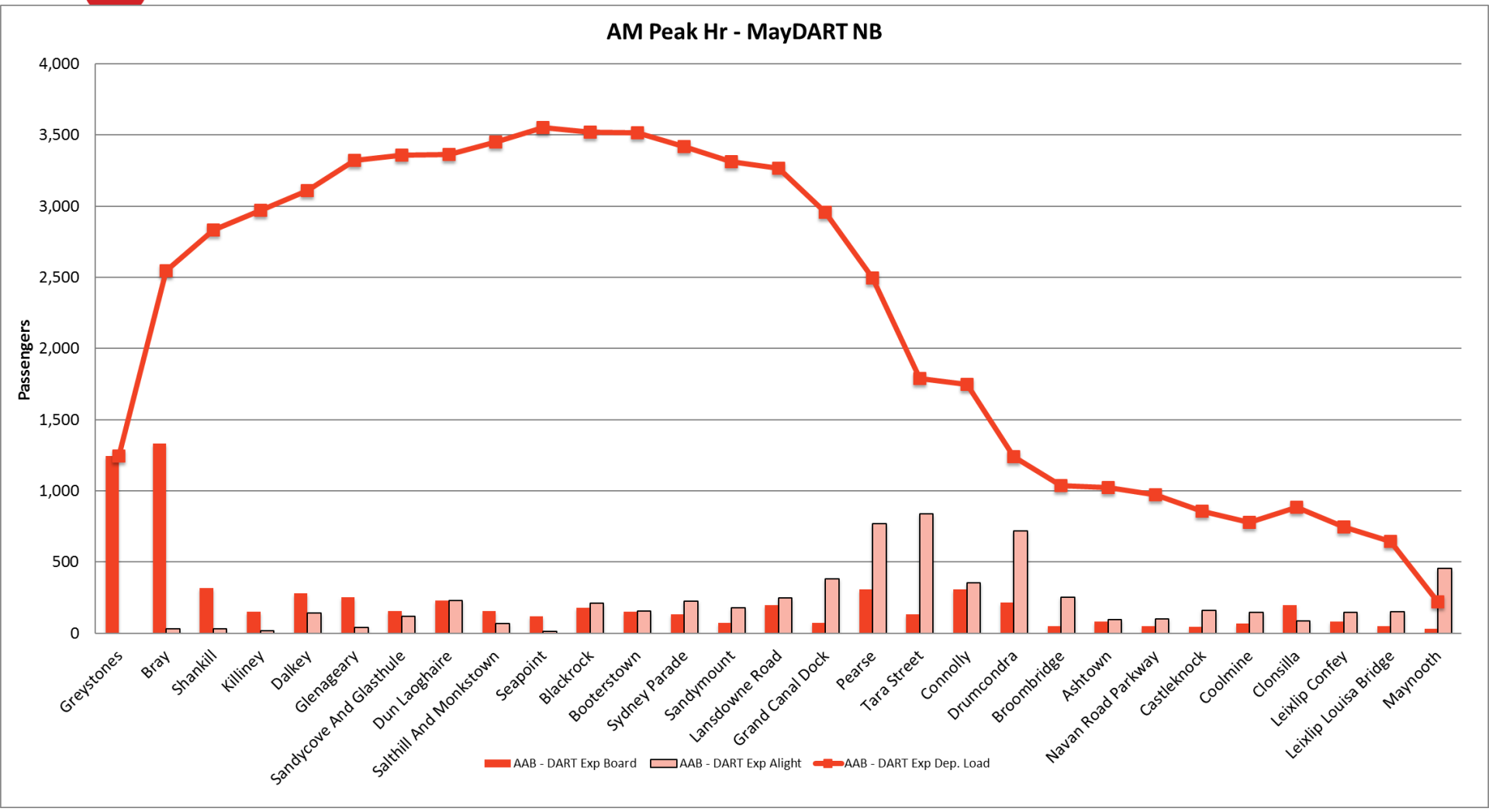
SYSTRA

New NTA ERM - Line Profiles – DART Expansion



SYSTRA

New NTA ERM - Line Profiles – DART Expansion



SYSTRA

Bundle 2B – DART Expansion with Metro North

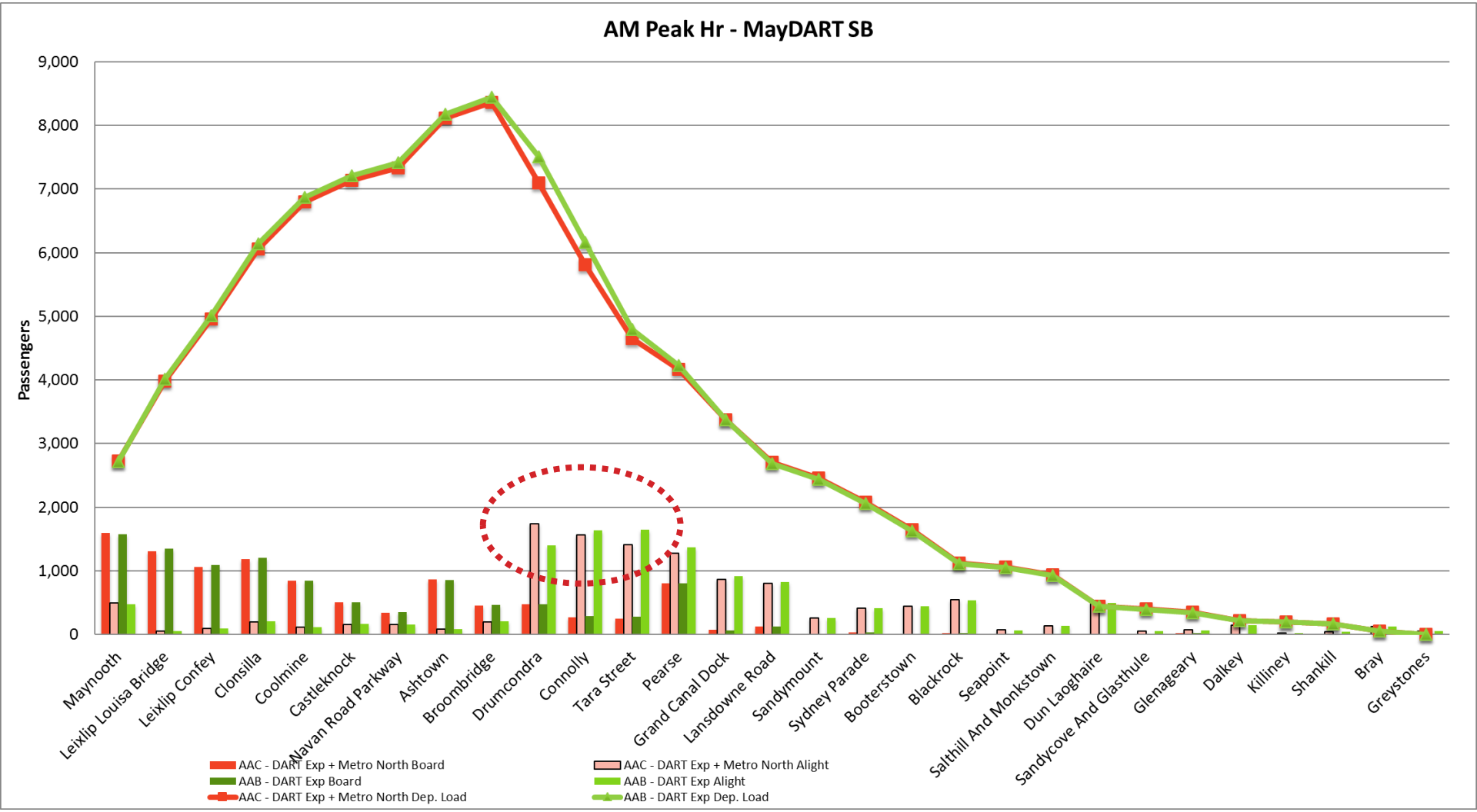
- **Overall Summary:**
  - **244% increase in DART Boardings**
  - **54% increase in overall Heavy Rail Boardings**
  - **13% increase in overall Public Transport Boardings**

- **Observation:**
  - **The introduction of Metro North leads to reduced loadings on DART Services**
  - **Impact of Interchange at Drumcondra and Stephen's Green**

New NTA ERM - Line Summary– DART Expansion with Metro North

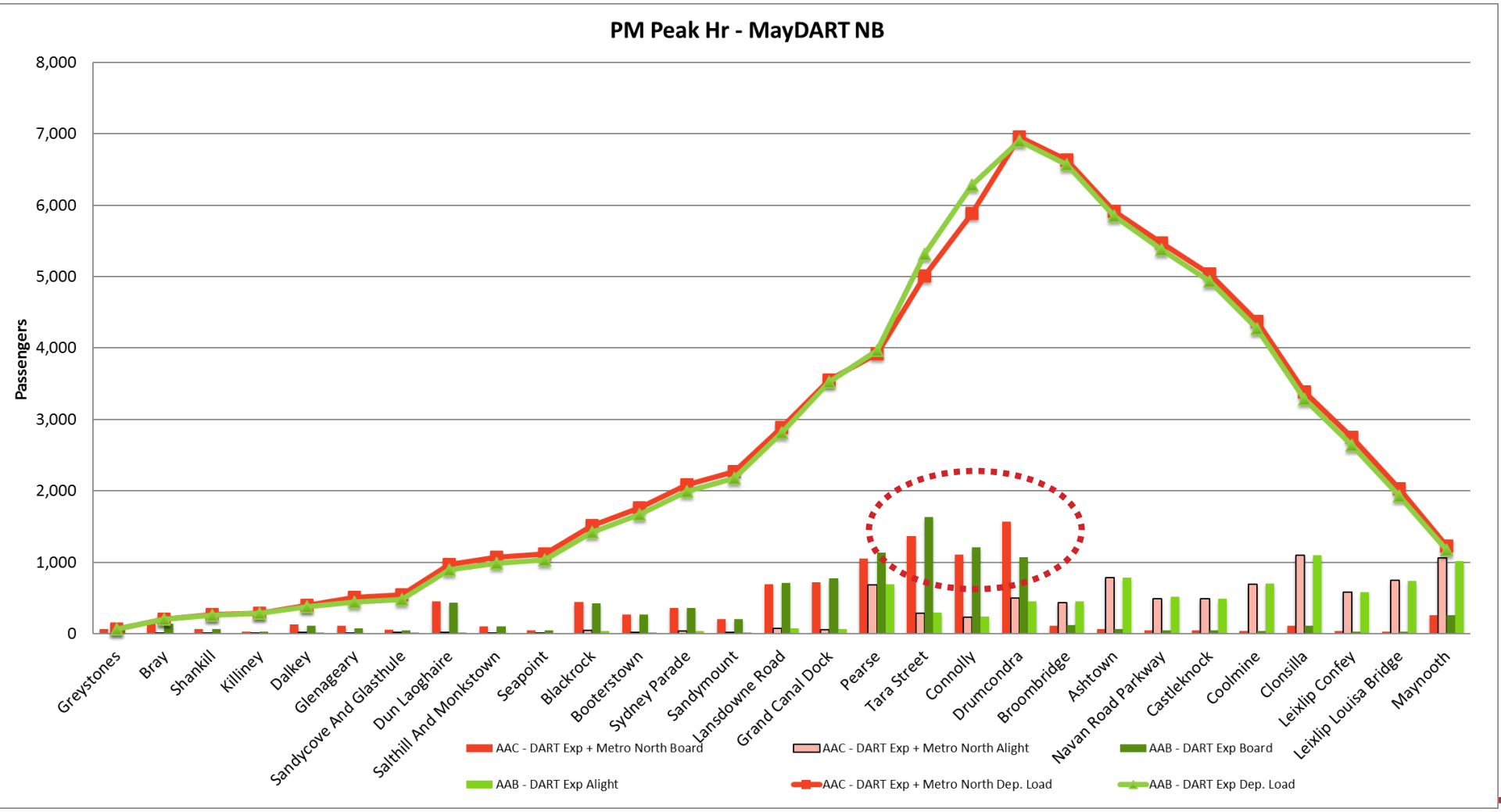
Description	Sum of Boardings	Sum of Veh Kms	Sum of Veh Hrs	Average of Veh Spd	Sum of Pass Kms	Sum of Pass Hrs	Sum of Distance	Sum of Time
Inchicore to Drogheda – all stops	2,140.31	471.44	10.00	47.14	28,899.13	667.48	58.93	75.00
Hazelhatch to Clongriffin – all stops	3,916.72	117.64	3.13	37.55	49,301.43	1,251.14	29.41	47.00
Hazelhatch to Balbriggan – all stops	4,253.91	220.96	5.13	43.04	56,490.72	1,429.11	55.24	77.00
Drogheda to Inchicore – all stops	8,165.64	471.44	10.13	46.52	178,838.75	4,175.08	58.93	76.00
Balbriggan to Hazelhatch – all stops	3,672.53	220.96	5.07	43.61	55,533.52	1,464.15	55.24	76.00
Clongriffin to Hazelhatch – all stops	2,263.14	117.64	3.07	38.36	20,260.03	600.84	29.41	46.00
Howth to Howth Junction (Shuttle) – all	206.98	32.40	0.90	36.00	688.90	22.85	5.40	9.00
Howth Junction to Howth (Shuttle) – all	61.67	32.40	0.90	36.00	248.95	7.43	5.40	9.00
Maynooth to Bray – all stops	7,461.51	298.02	7.80	38.21	112,688.20	2,941.30	49.67	78.00
Connolly to Bray – all stops	405.63	46.70	1.43	32.58	2,598.05	91.60	23.35	43.00
Maynooth to Greystones – all stops	2,527.57	114.78	2.83	40.51	38,758.82	1,009.50	57.39	85.00
Greystones to Maynooth – all stops	2,083.89	114.78	2.80	40.99	42,860.89	1,104.10	57.39	84.00
Bray to Maynooth – all stops	4,139.15	298.02	7.70	38.70	57,336.42	1,678.32	49.67	77.00
Bray to Connolly – all stops	831.06	46.70	1.43	32.58	10,887.16	336.59	23.35	43.00
M3 Parkway to Clonsilla (Shuttle) – all	135.64	28.60	0.67	42.90	712.18	16.15	7.15	10.00
Clonsilla to M3 Parkway (Shuttle) – all	109.39	28.60	0.67	42.90	566.32	12.59	7.15	10.00
Metro North: Stephens Green to Estuary	7,733.54	478.20	16.51	28.97	57,922.05	1,768.72	15.94	33.01
Metro North: Estuary to Stephens Green	12,010.07	478.20	16.51	28.97	95,496.66	3,046.71	15.94	33.01
	62,118.35	**3,617.48**	**96.68**	**38.64**	**810,088.18**	**21,623.67**	**604.96**	**911.02**

New NTA ERM - Line Profiles– DART Expansion with Metro North
(AAB vs AAC)



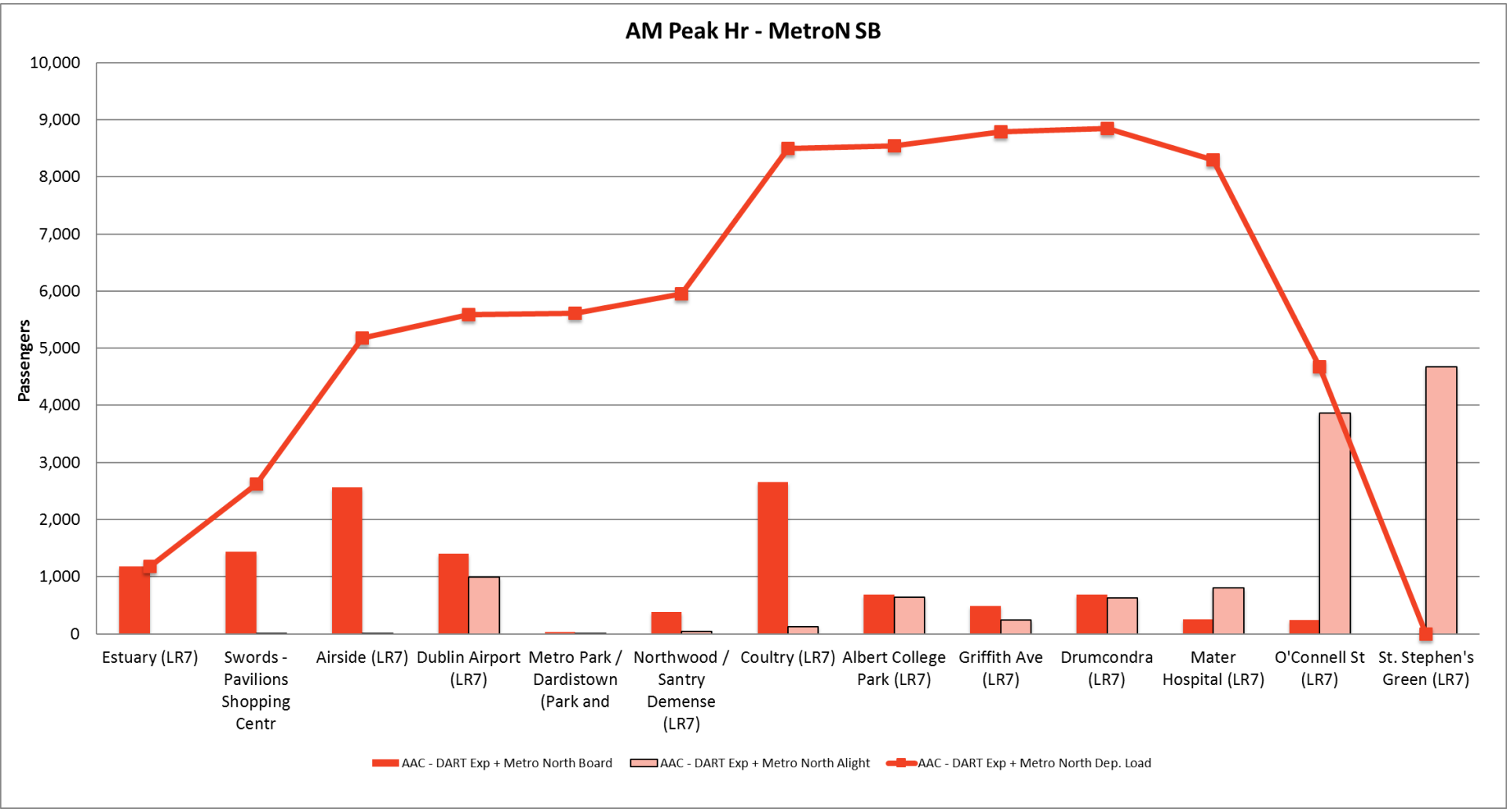
New NTA ERM - Line Profiles– DART Expansion with Metro North

(AAB vs AAC)

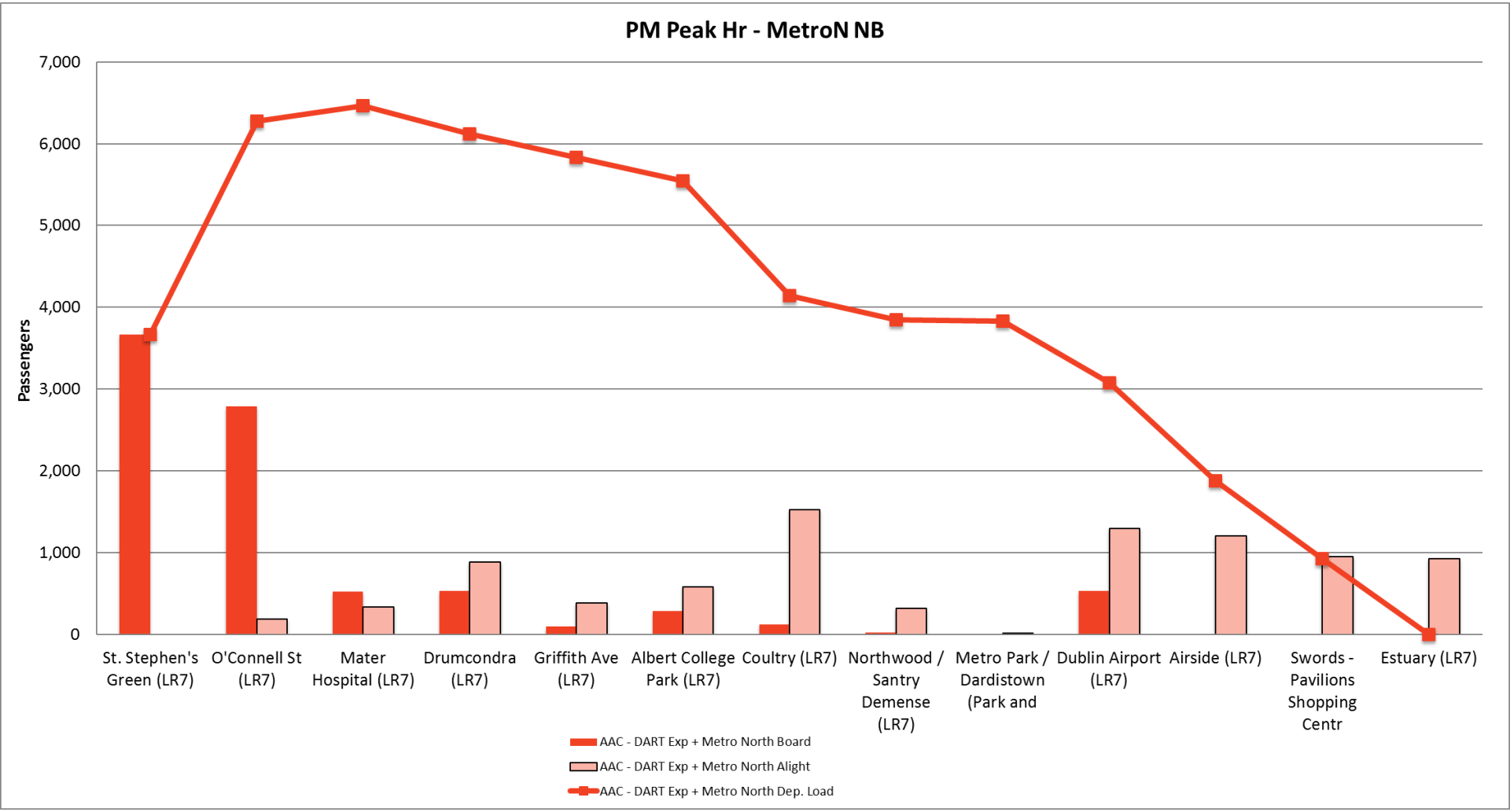


SYSTRA

New NTA ERM - Line Profiles– DART Expansion with Metro North
(AAB vs AAC)

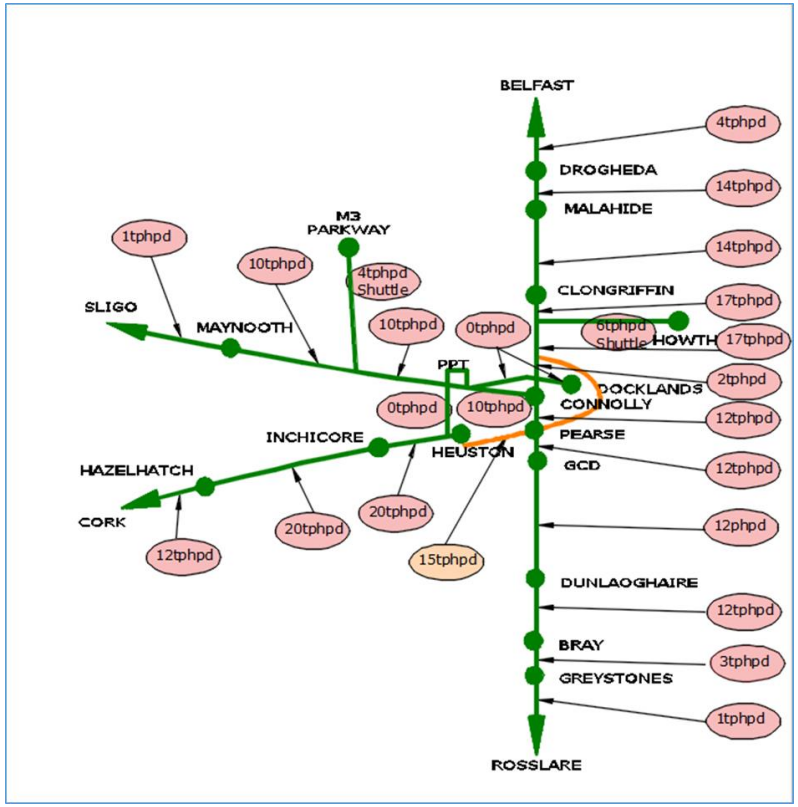


New NTA ERM - Line Profiles– DART Expansion with Metro North
(AAB vs AAC)



Bundle 3A – DART Expansion with Heuston Turnback

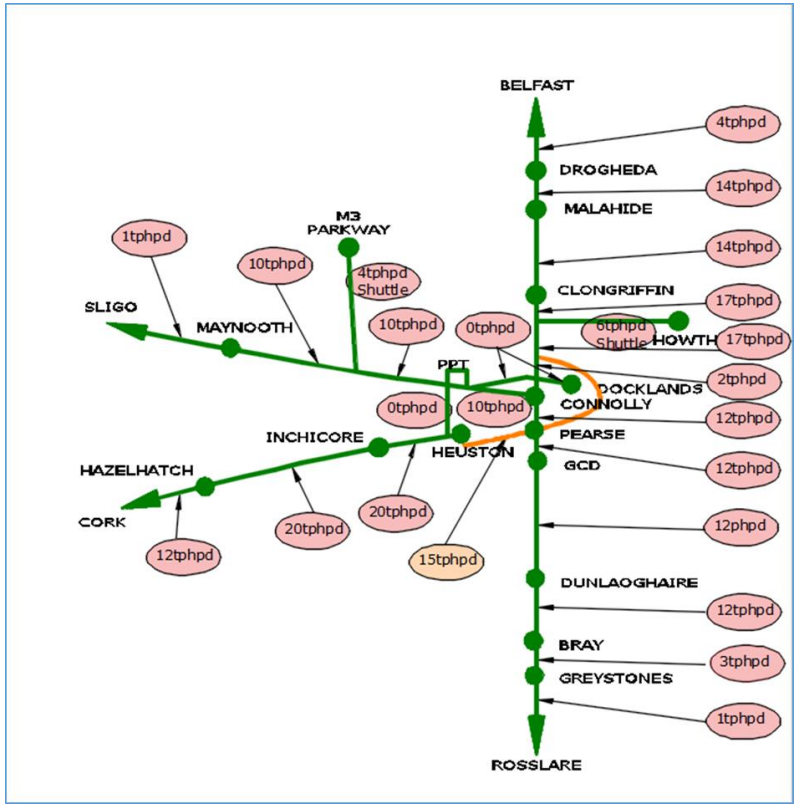
- **Overall Summary:**
  - 189% increase in DART Boardings
  - 38% increase in overall Heavy Rail Boardings
  - 13% increase in overall Public Transport Boardings
- **Observation:**
  - 7,000 reduction in overall AM DART boardings compared to Dart Expansion with Metro North
  - Overall PT boardings are not too much lower than AAC due to the greater balance between other modes and additional transfer opportunities.



SYSTRA

Bundle 3A – DART Expansion with Heuston Turnback

- **Observation:**
  - Large reductions in passengers on the Kildare line, with substantial impacts to Adamstown, Kishogue etc.
  - Almost 5,000 reduction in max loading within the tunnel eastbound.
  - Coming from the north, line flows are higher due to the 5min DART frequencies from Drogheda but drop off on the approach to the tunnel
  - Further analysis required on the level of interchange and also the pressure on the LUAS Red line and Bus services without the complete tunnel.
  - Impact of not retaining PPT services?

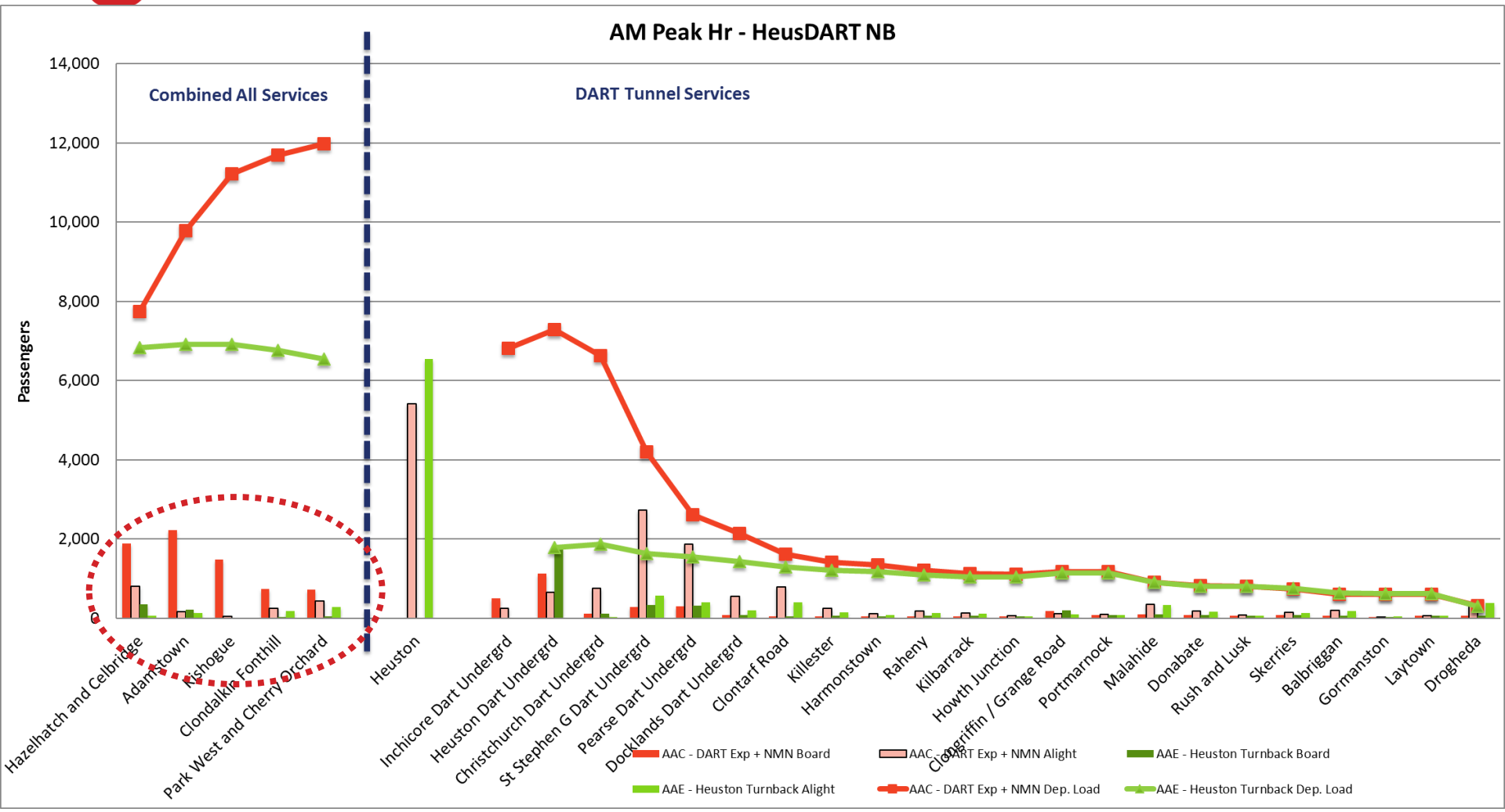


SYSTRA

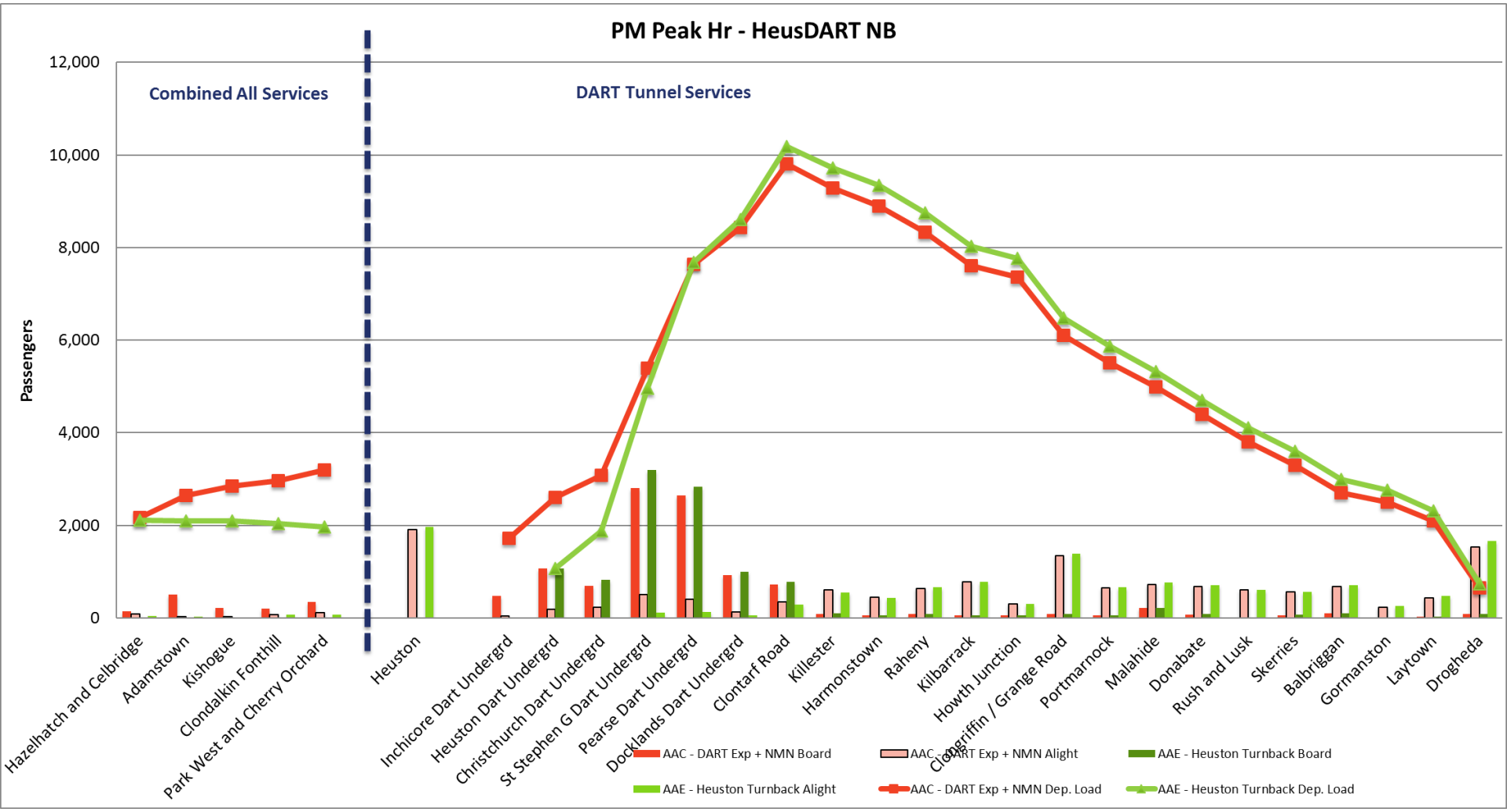
Bundle 3A - Scenario AAE – Heuston Turnback - Line Summary

Description	Sum of Boardings	Sum of Veh Kms	Sum of Veh Hrs	Average of Veh Spd	Sum of Pass Kms	Sum of Pass Hrs	Sum of Distance	Sum of Time
Howth to Howth Junction (Shuttle) – all	205.14	32.40	0.90	36.00	685.38	22.65	5.40	9.00
Howth Junction to Howth (Shuttle) – all	53.96	32.40	0.90	36.00	223.88	6.59	5.40	9.00
Maynooth to Bray – all stops	7,544.72	298.02	7.80	38.21	117,060.69	3,041.06	49.67	78.00
Connolly to Bray – all stops	349.12	46.70	1.43	32.58	2,305.50	81.38	23.35	43.00
Maynooth to Greystones – all stops	2,557.67	114.78	2.83	40.51	40,199.20	1,042.55	57.39	85.00
Greystones to Maynooth – all stops	2,115.71	114.78	2.80	40.99	44,146.22	1,133.88	57.39	84.00
Bray to Maynooth – all stops	4,188.64	298.02	7.70	38.70	58,754.86	1,720.89	49.67	77.00
Bray to Connolly – all stops	849.77	46.70	1.43	32.58	11,313.66	349.11	23.35	43.00
M3 Parkway to Clonsilla (Shuttle) – all	146.83	28.60	0.67	42.90	766.35	17.37	7.15	10.00
Clonsilla to M3 Parkway (Shuttle) – all	109.36	28.60	0.67	42.90	564.05	12.54	7.15	10.00
Heuston Turnback: DART: Drogheda to Heus	12,354.16	659.64	14.40	45.81	244,433.85	5,709.25	54.97	72.00
Heuston Turnback: DART: Heuston to Drogh	3,198.05	659.64	14.20	46.45	37,505.14	909.14	54.97	71.00
Heuston Turnback: DART: Clongriffin to H	1,510.36	39.30	1.25	31.44	12,025.98	342.72	13.10	25.00
Heuston Turnback: DART: Heuston to Clong	450.31	39.30	1.25	31.44	2,015.83	70.02	13.10	25.00
Metro North: Stephens Green to Estuary	7,799.39	478.20	16.51	28.97	58,226.64	1,777.74	15.94	33.01
Metro North: Estuary to Stephens Green	12,164.79	478.20	16.51	28.97	96,705.95	3,082.52	15.94	33.01
	55,597.98	**3,395.28**	**91.24**	**37.15**	**726,933.18**	**19,319.39**	**453.94**	**707.02**

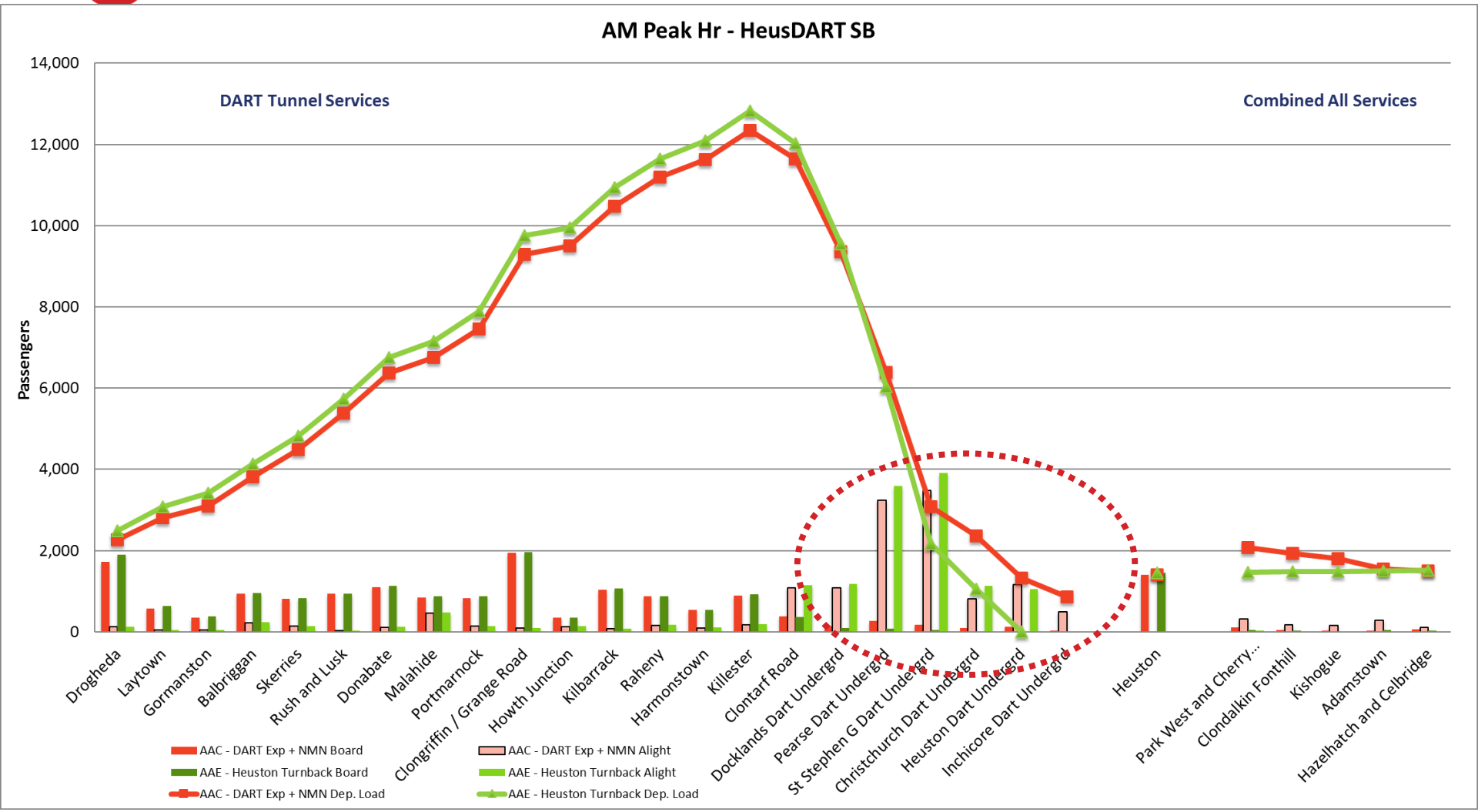
Bundle 3A - Scenario AAE – Heuston Turnback - Line Profiles



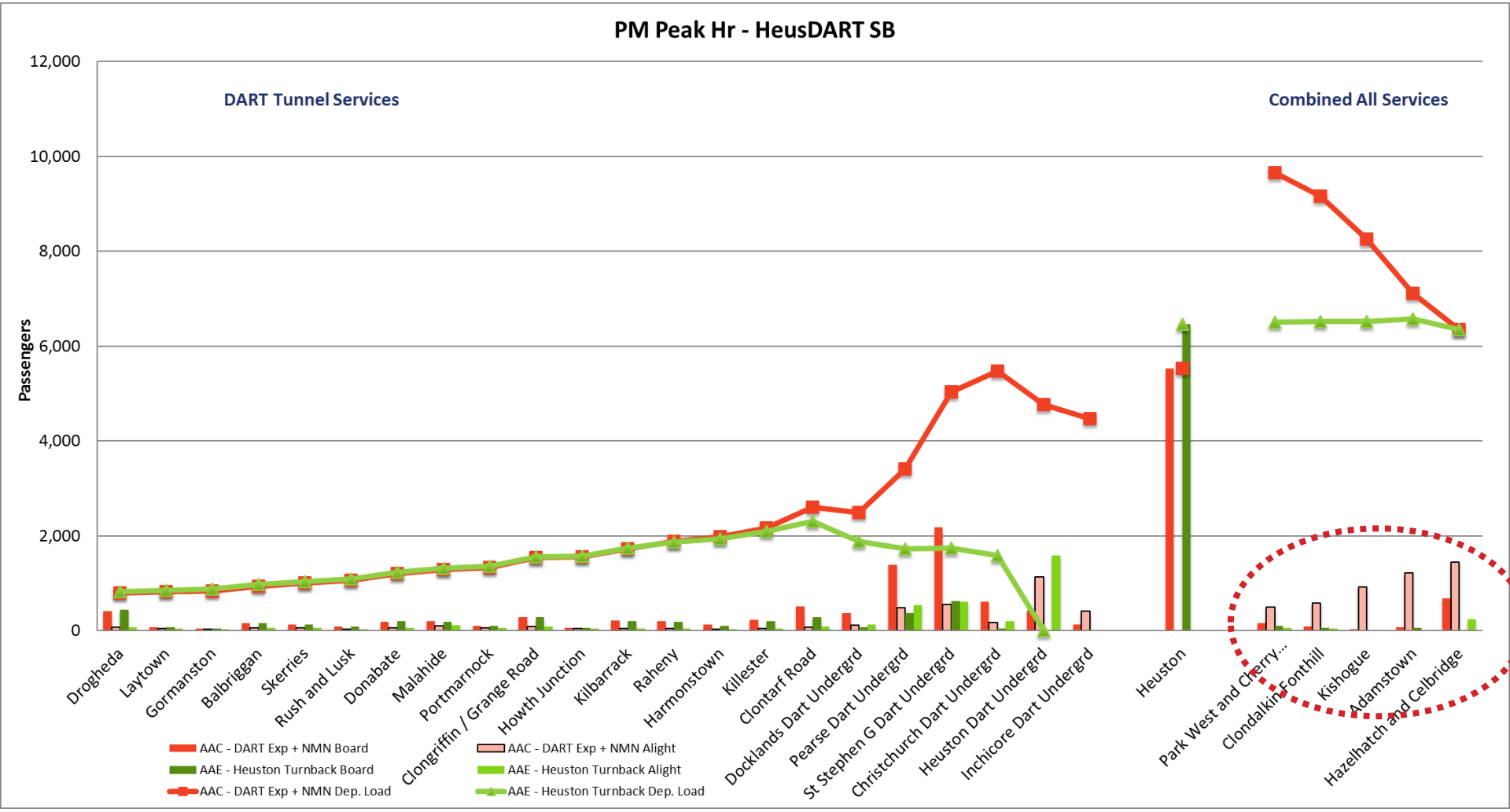
Bundle 3A - Scenario AAE – Heuston Turnback - Line Profiles



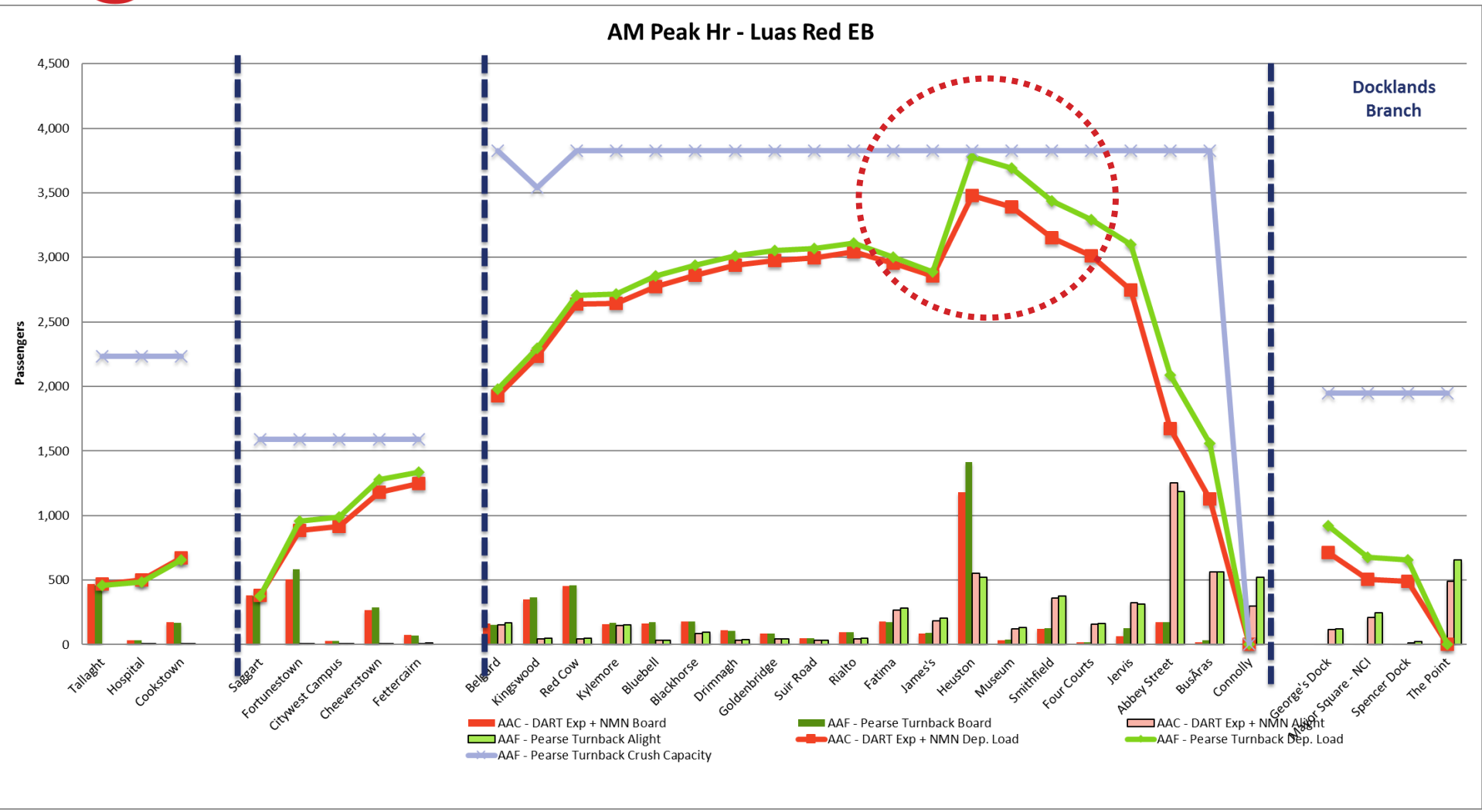
Bundle 3A - Scenario AAE – Heuston Turnback - Line Profiles



Bundle 3A - Scenario AAE – Heuston Turnback - Line Profiles



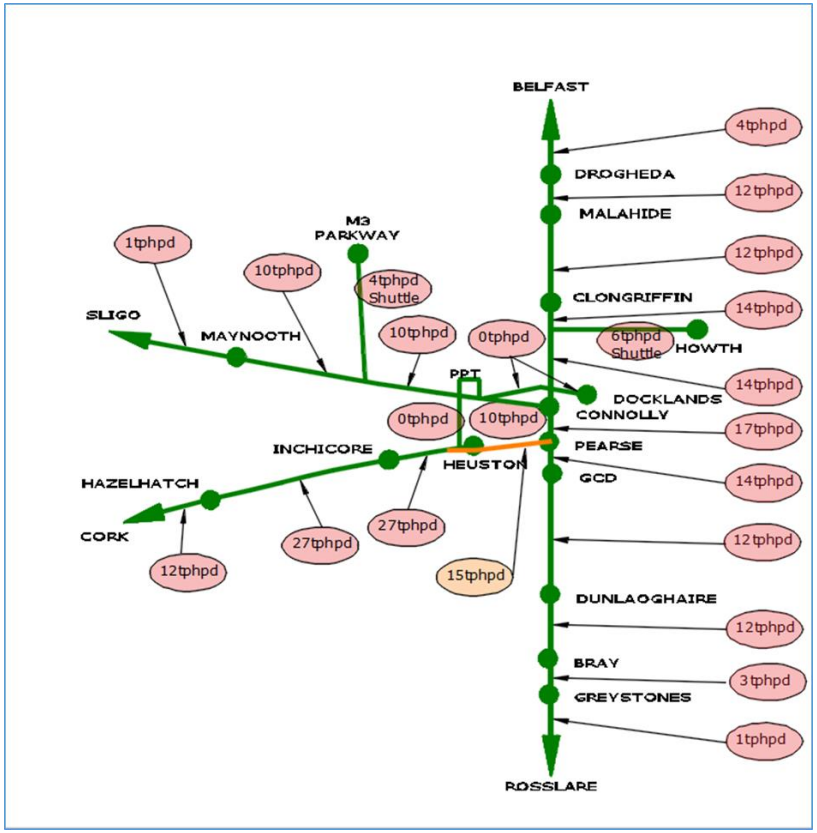
Bundle 3A - Scenario AAE – Heuston Turnback - Line Profiles



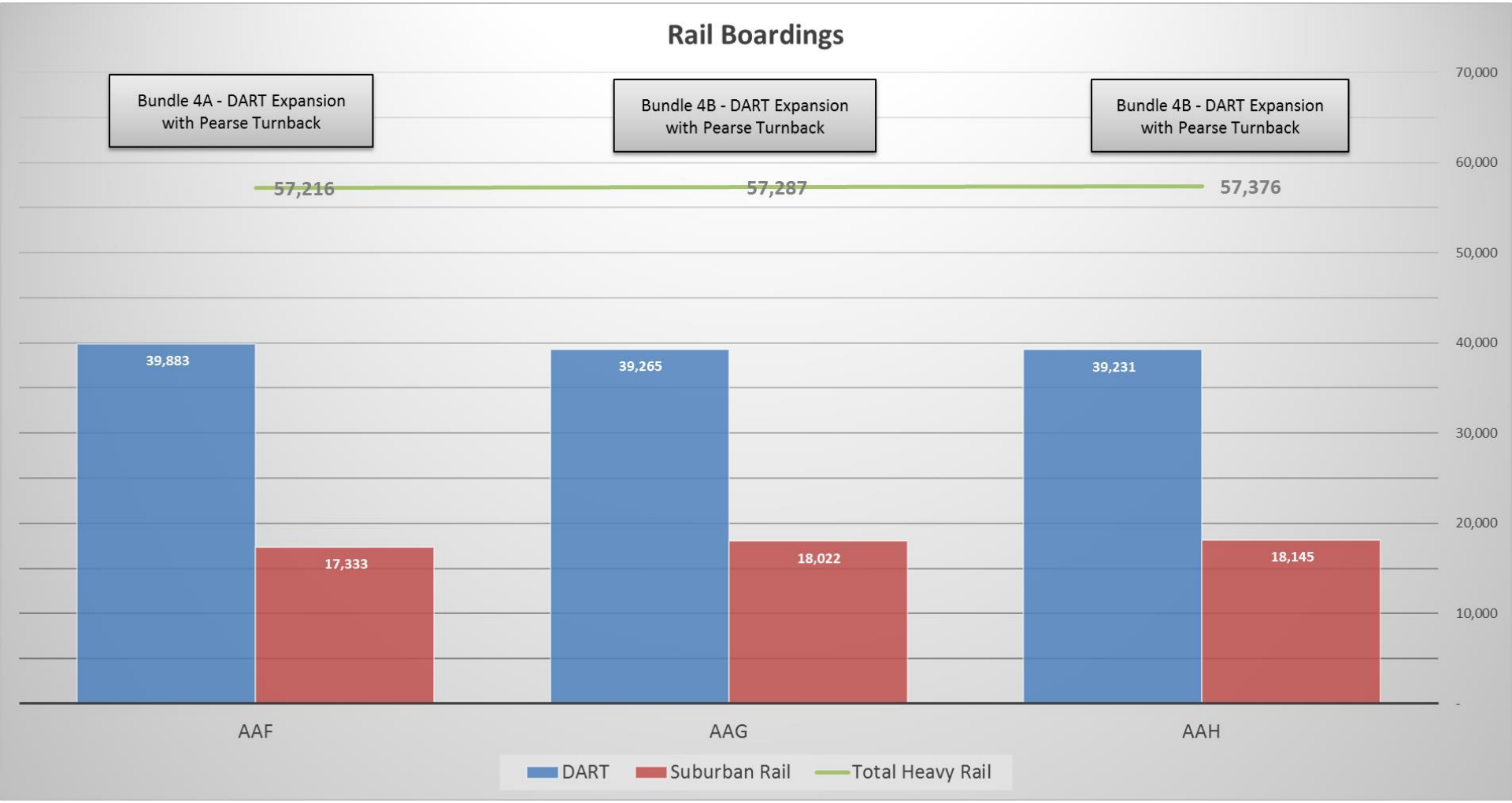
Bundle 4 – DART Expansion with Pearse Turnback

- **Scenarios:**
  - **4A – 10 tphpd Maynooth to Connolly**
  - **4B – 3 additional trains Maynooth to Docklands**
  - **4C – 4B plus 3 additional trains Maynooth to Connolly**

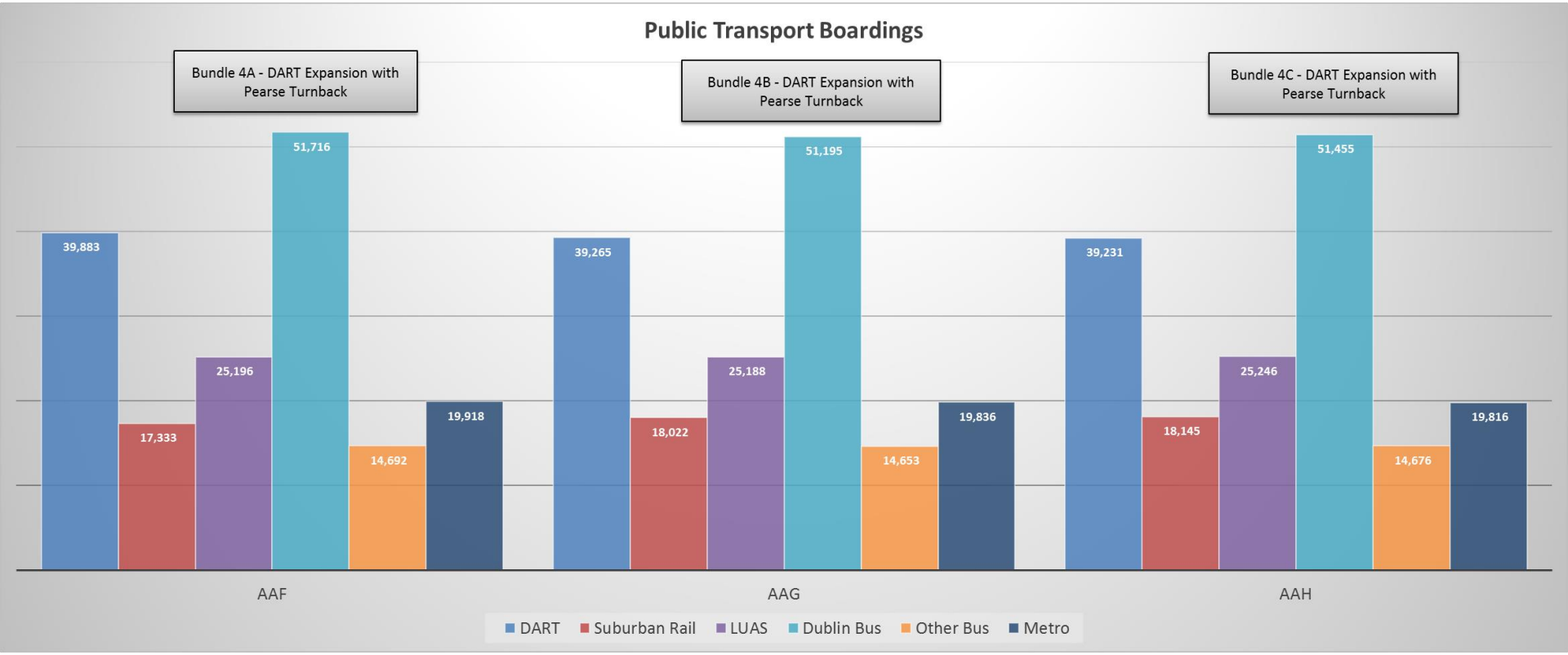
- **Summary**
  - **4C is the best performing sub-option**
  - **Summary outputs below provided for scenario 4C**



Bundle 4 – DART Expansion with Pearse Turnback



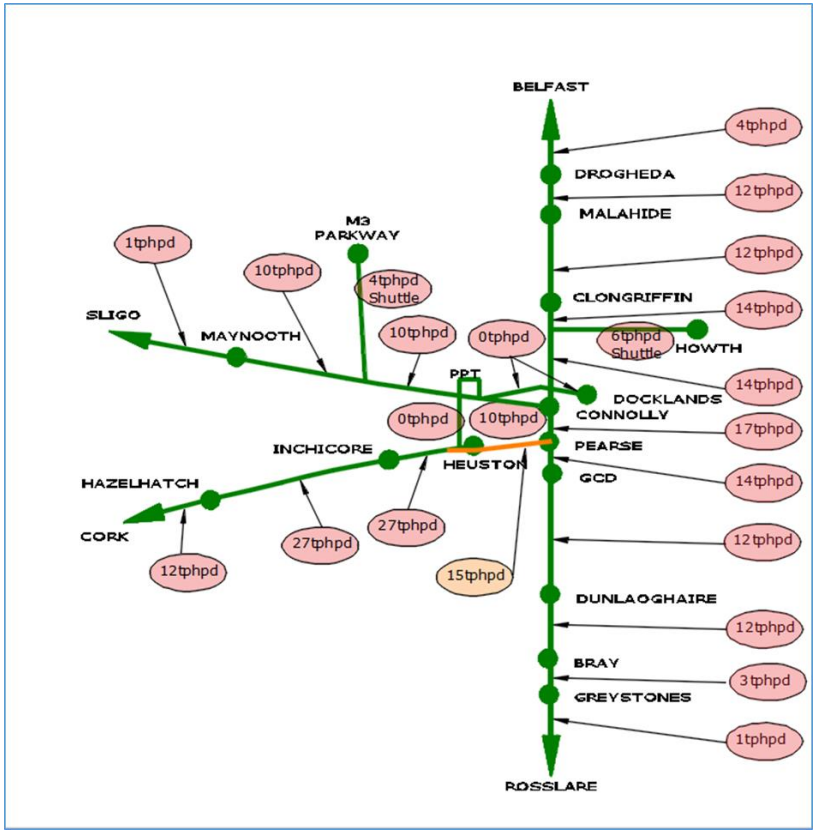
Bundle 4 – DART Expansion with Pearse Turnback



Bundle 4C – DART Expansion with Pearse Turnback

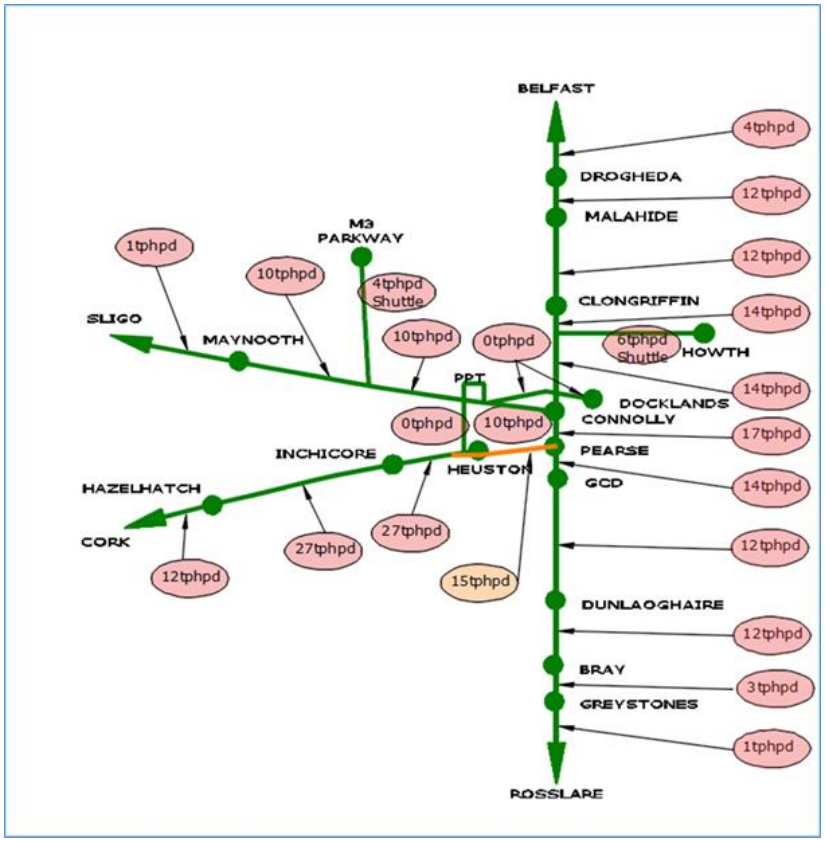
- **Overall Summary:**
  - 219% increase in DART Boardings
  - 50% increase in overall Heavy Rail Boardings
  - 14% increase in overall Public Transport Boardings

- **Observations:**
  - 3,000 reduction in overall AM DART boardings compared to Dart Expansion with Metro North
  - Overall PT boardings are slightly higher than AAC due to the greater balance between other modes and additional transfers.
  - This scenario has the best balance across all sub-modes. Although this is likely to increase pressure across Bus and Luas



Bundle 4C – DART Expansion with Pearse Turnback

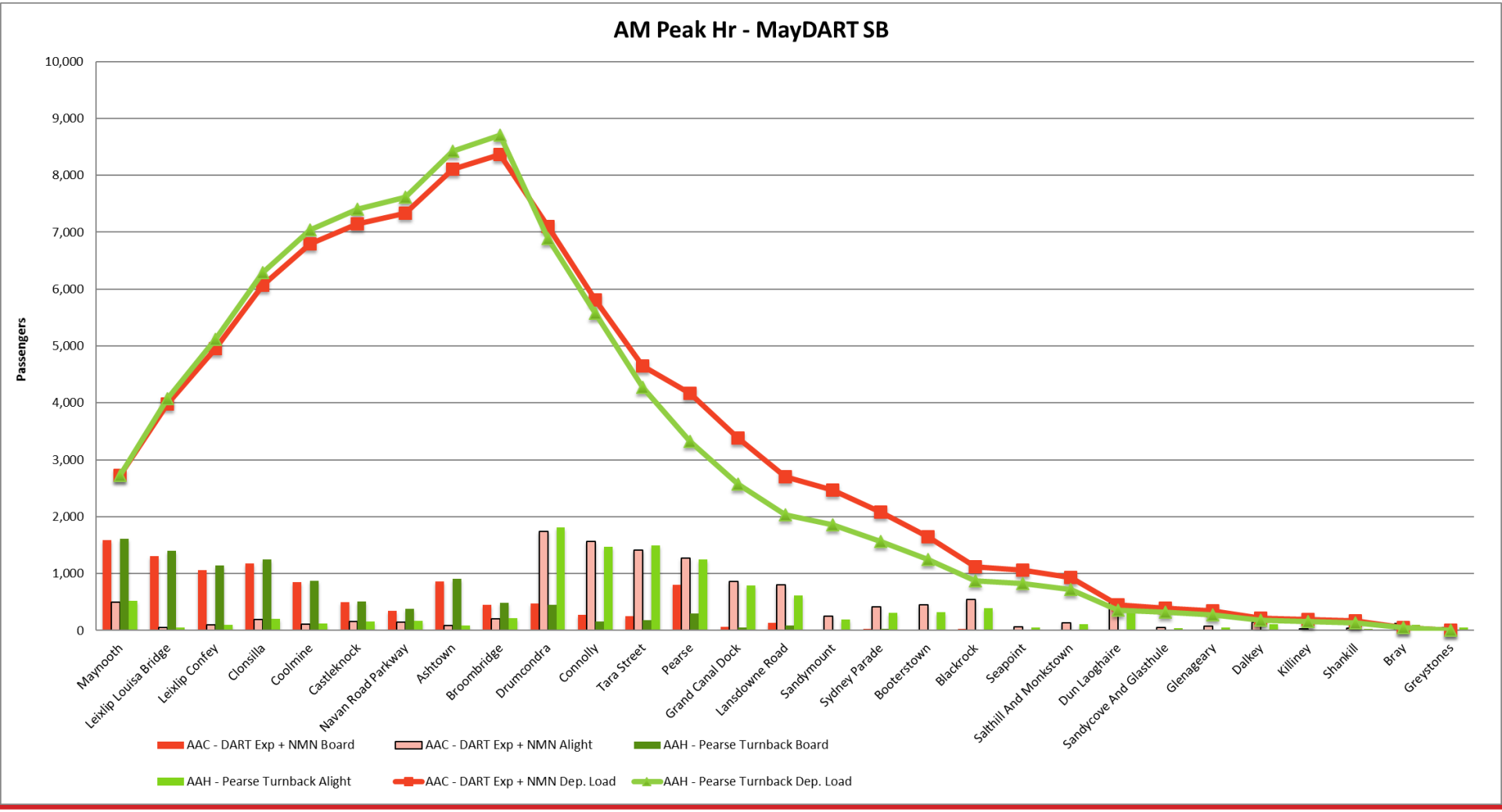
- **Observations:**
  - Large reductions entering the tunnel on the Northern line. Much of the demand transfers back to the Loop-line Bridge
  - Almost 7,000 reduction in max loading within the tunnel westbound in AM and eastbound in PM.
  - Kildare Line services remain at high levels due to the continued through running of services through Heuston
  - Further analysis required on the level of interchange and also the pressure on the LUAS Red line and Bus without the complete tunnel
    - 1,000 additional LUAS boardings in AM
  - Impact of not retaining PPT services?



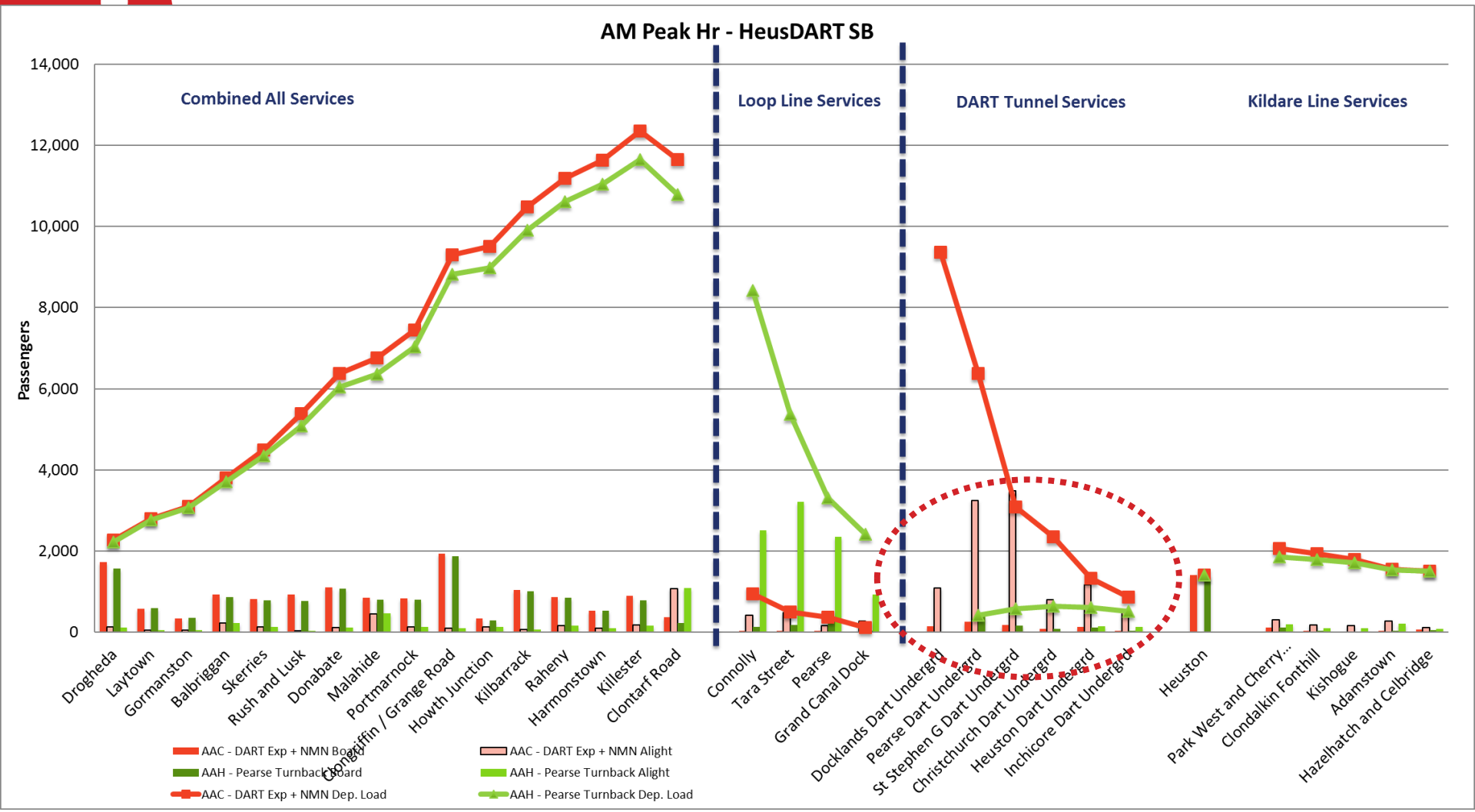
Bundle 4C - Scenario AAH – Pearse Turnback - Line Summary

Description	Sum of Boardings	Sum of Veh Kms	Sum of Veh Hrs	Average of Veh Spd	Sum of Pass Kms	Sum of Pass Hrs	Sum of Distance	Sum of Time
Howth to Howth Junction (Shuttle) – all	159.48	32.40	0.90	36.00	552.67	17.82	5.40	9.00
Howth Junction to Howth (Shuttle) – all	51.44	32.40	0.90	36.00	213.00	6.25	5.40	9.00
Maynooth to Bray – all stops	6,163.80	298.02	7.80	38.21	97,830.47	2,535.57	49.67	78.00
Maynooth to Greystones – all stops	2,096.81	114.78	2.83	40.51	33,754.00	873.13	57.39	85.00
Greystones to Maynooth – all stops	1,923.05	114.78	2.80	40.99	41,269.49	1,058.51	57.39	84.00
Bray to Maynooth – all stops	3,227.19	298.02	7.70	38.70	44,670.73	1,289.10	49.67	77.00
M3 Parkway to Clonsilla (Shuttle) – all	137.05	28.60	0.67	42.90	715.79	16.23	7.15	10.00
Clonsilla to M3 Parkway (Shuttle) – all	109.56	28.60	0.67	42.90	565.80	12.58	7.15	10.00
Irish Rail: DART Enhanced: Clongriffin t	1,389.11	64.70	2.13	30.33	11,879.04	435.58	32.35	64.00
Irish Rail: DART Enhanced: Bray to Clong	715.60	64.70	2.03	31.82	9,306.82	285.15	32.35	61.00
Drogheda to Connolly	1,215.78	101.74	2.10	48.45	22,556.19	509.59	50.87	63.00
Connolly to Drogheda	228.66	101.74	2.07	49.23	3,242.71	66.36	50.87	62.00
Drogheda to Pearse	2,141.44	104.70	2.23	46.88	40,307.94	963.81	52.35	67.00
Pearse to Drogheda	357.27	104.70	2.20	47.59	4,901.19	108.95	52.35	66.00
Drogheda to Bray	7,080.79	371.10	8.83	42.01	136,117.89	3,449.70	74.22	106.00
Bray to Drogheda	2,704.50	371.10	8.75	42.41	39,012.45	1,086.36	74.22	105.00
Drogheda to GCD	1,145.67	53.14	1.15	46.21	21,812.65	525.70	53.14	69.00
GCD to Drogheda	190.53	53.14	1.13	46.89	2,586.16	57.85	53.14	68.00
DART: Hazelhatch to Pearse	6,777.47	136.31	3.41	39.95	81,506.89	2,033.31	19.31	29.00
DART: Pearse to Hazelhatch	885.33	136.31	3.41	39.95	7,263.34	186.43	19.31	29.00
DART: Heuston to Pearse	432.90	24.00	0.93	25.71	1,022.91	40.56	3.00	7.00
DART: Pearse to Heuston	98.93	24.00	0.93	25.71	231.35	9.10	3.00	7.00
Metro North: Stephens Green to Estuary	7,677.86	478.20	16.51	28.97	57,384.46	1,752.65	15.94	33.01
Metro North: Estuary to Stephens Green	12,140.56	478.20	16.51	28.97	97,042.73	3,095.70	15.94	33.01
	59,050.78	**3,615.37**	**98.60**	**39.05**	**755,746.66**	**20,415.98**	**841.58**	**1,231.02**

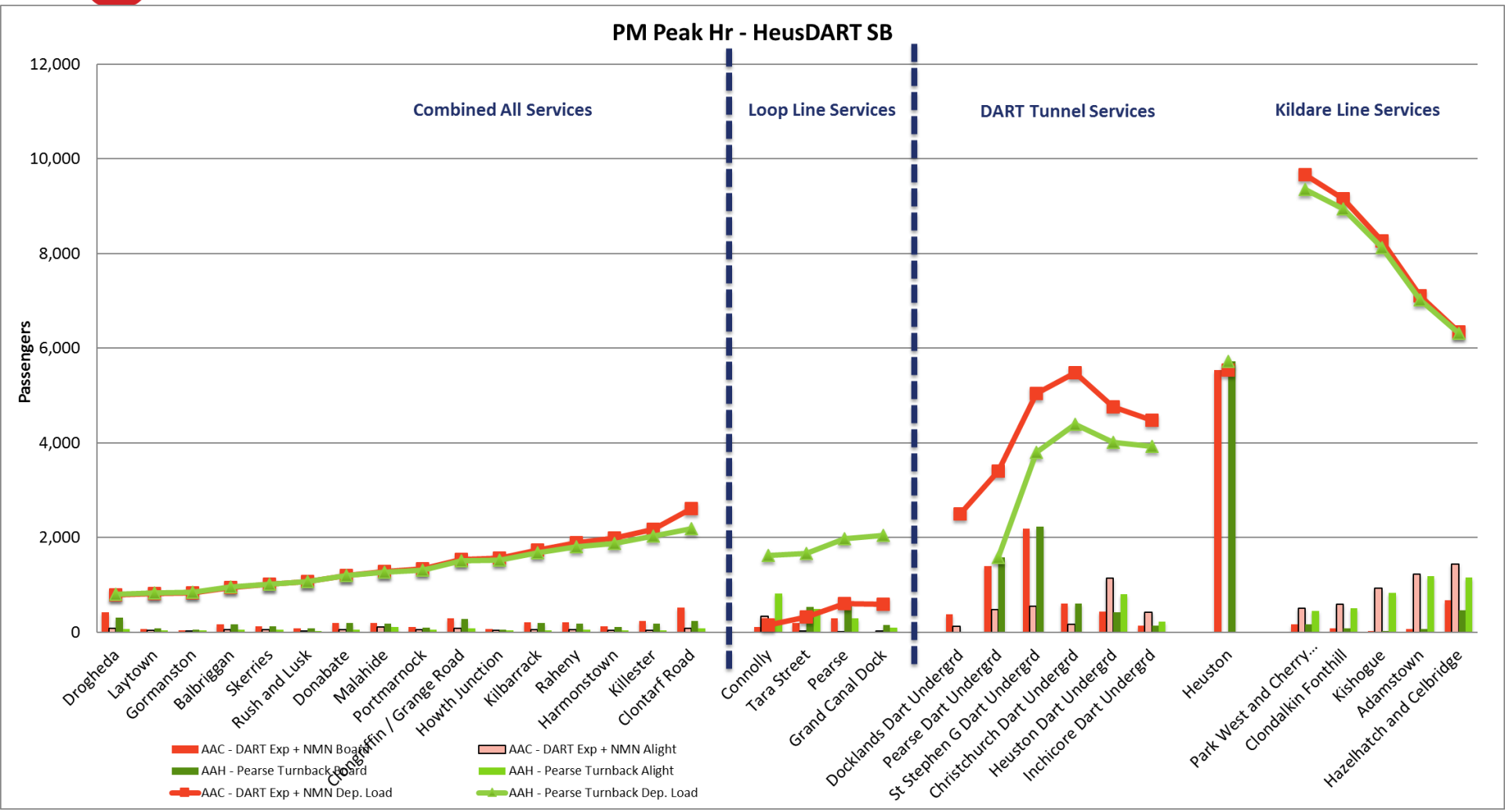
Bundle 4C - Scenario AAH – Pearse Turnback - Line Profiles



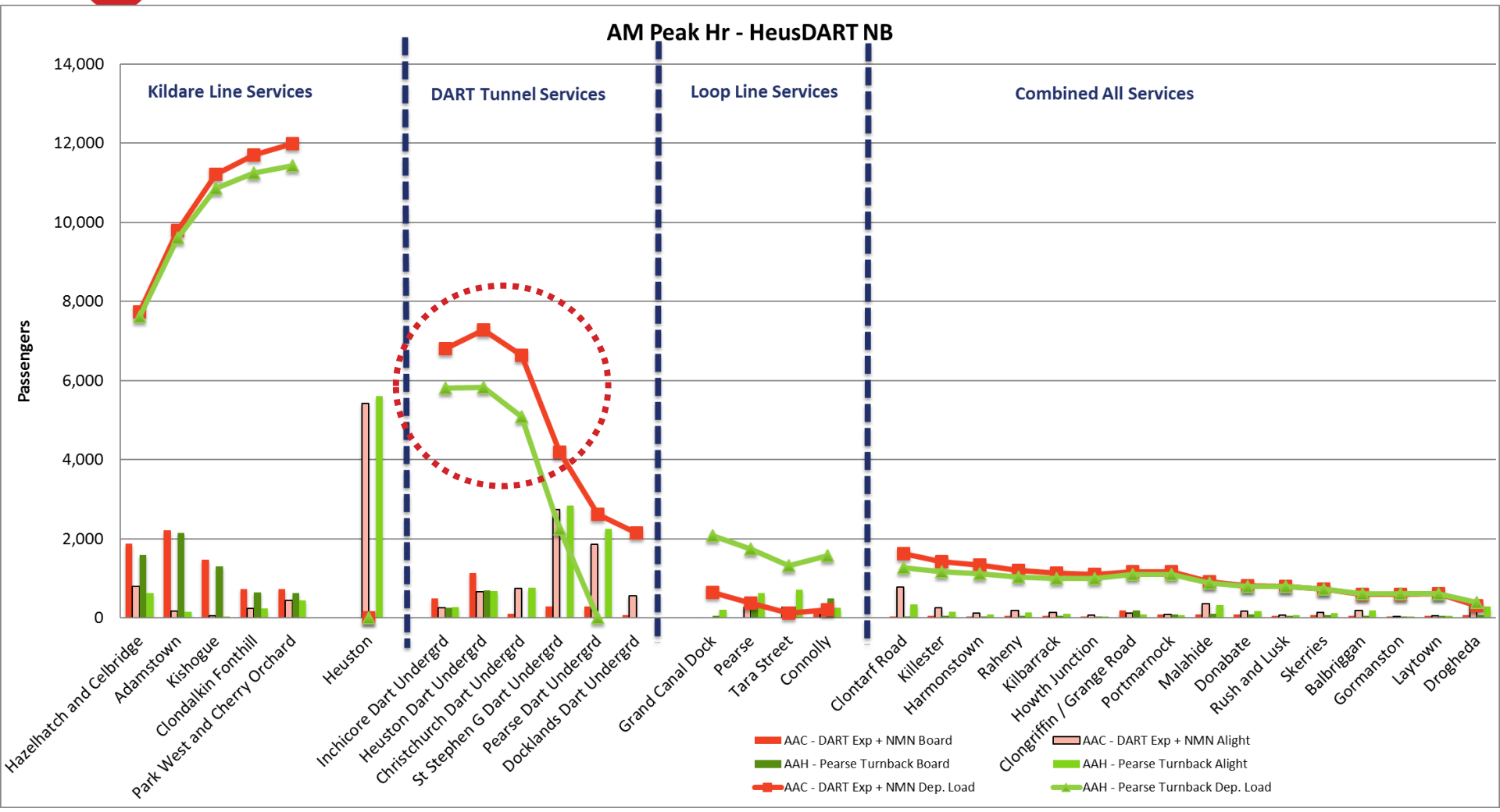
Bundle 4C - Scenario AAH – Pearse Turnback - Line Profiles



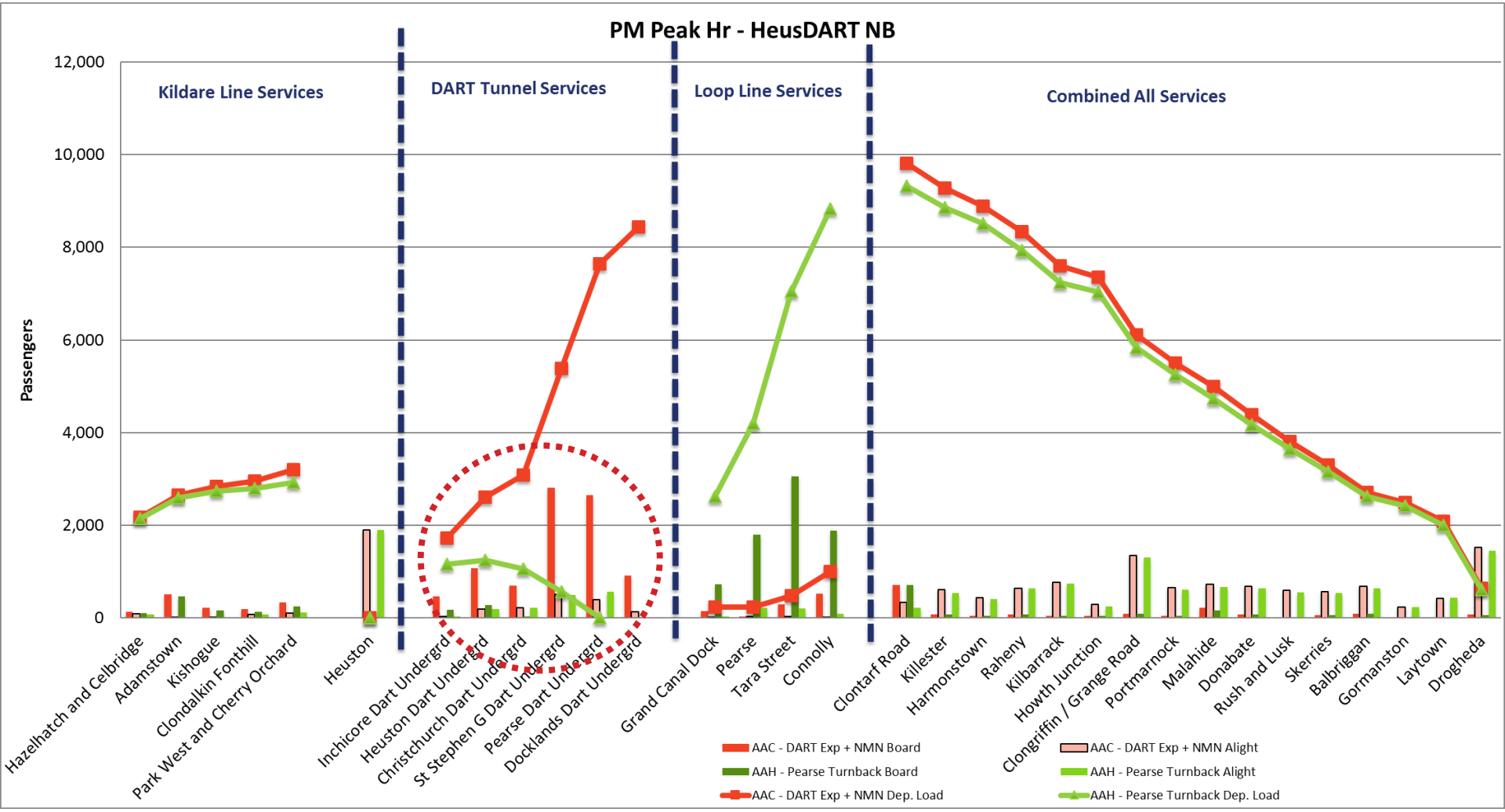
Bundle 4C - Scenario AAH – Pearse Turnback - Line Profiles



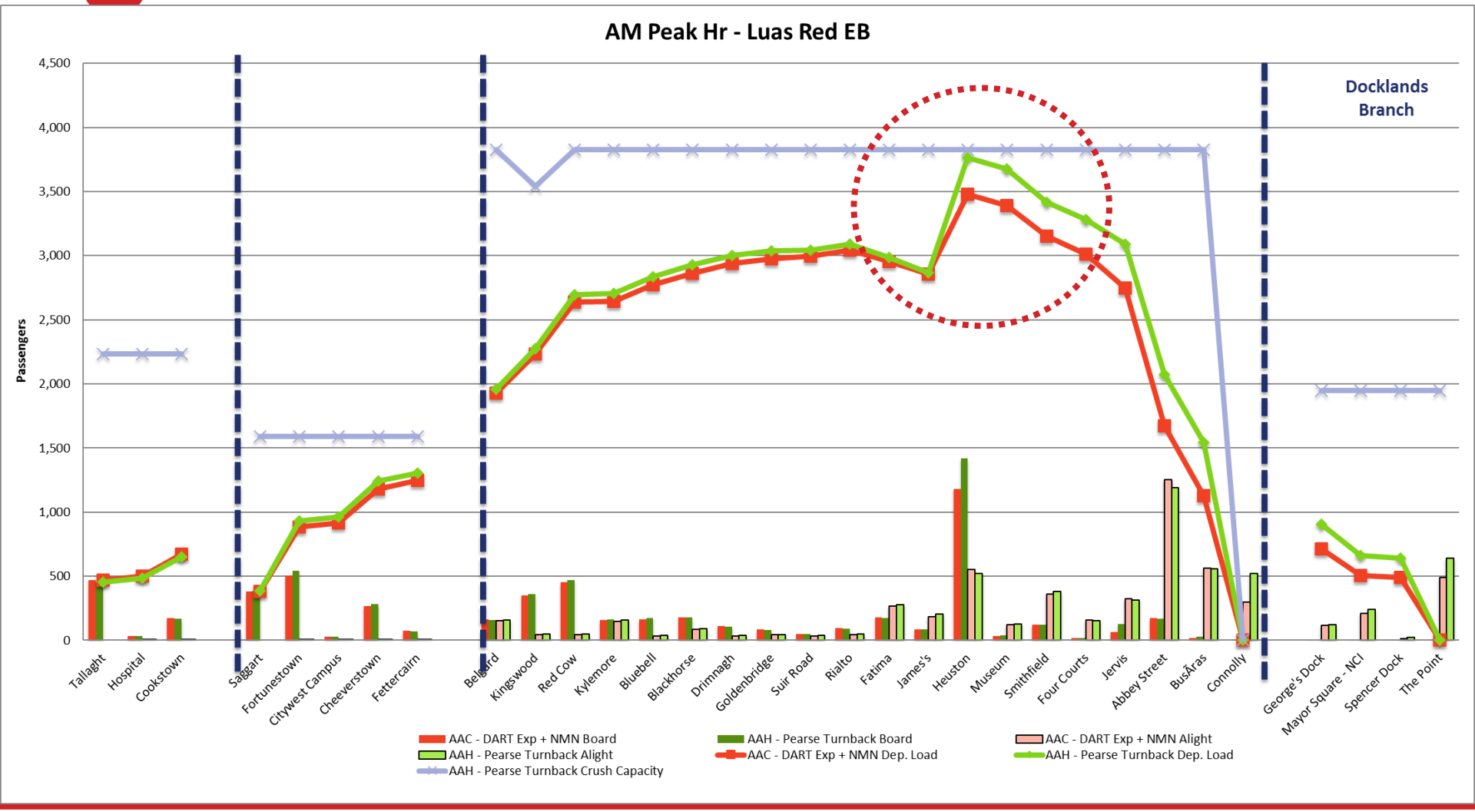
Bundle 4C - Scenario AAH – Pearse Turnback - Line Profiles



Bundle 4C - Scenario AAH – Pearse Turnback - Line Profiles

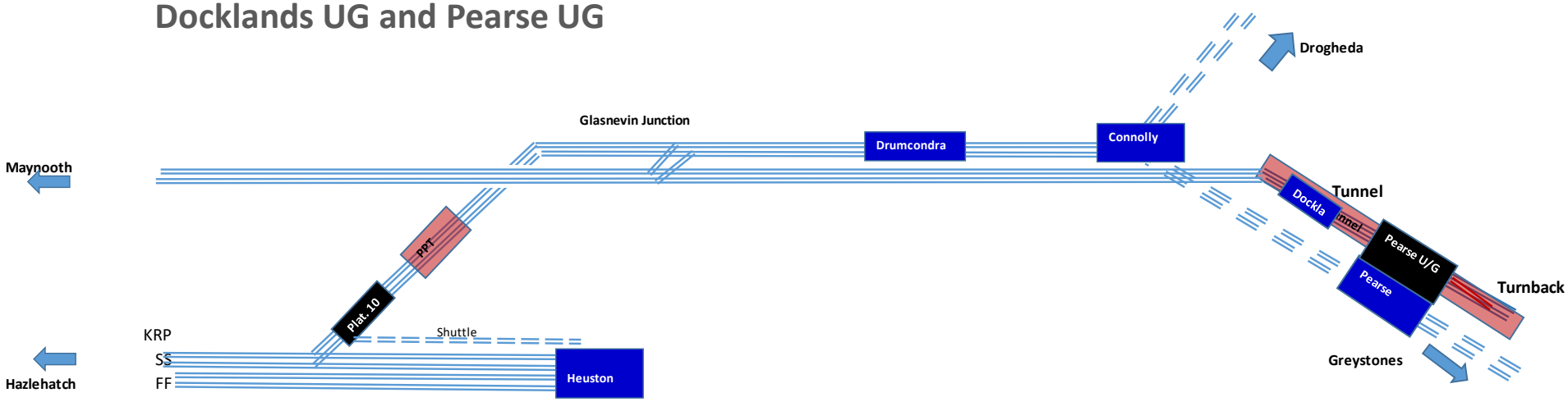


Bundle 4C - Scenario AAH – Pearse Turnback - Line Profiles



Bundle 5A – DART Expansion Alternative (PPT and MGWR Tunnel)

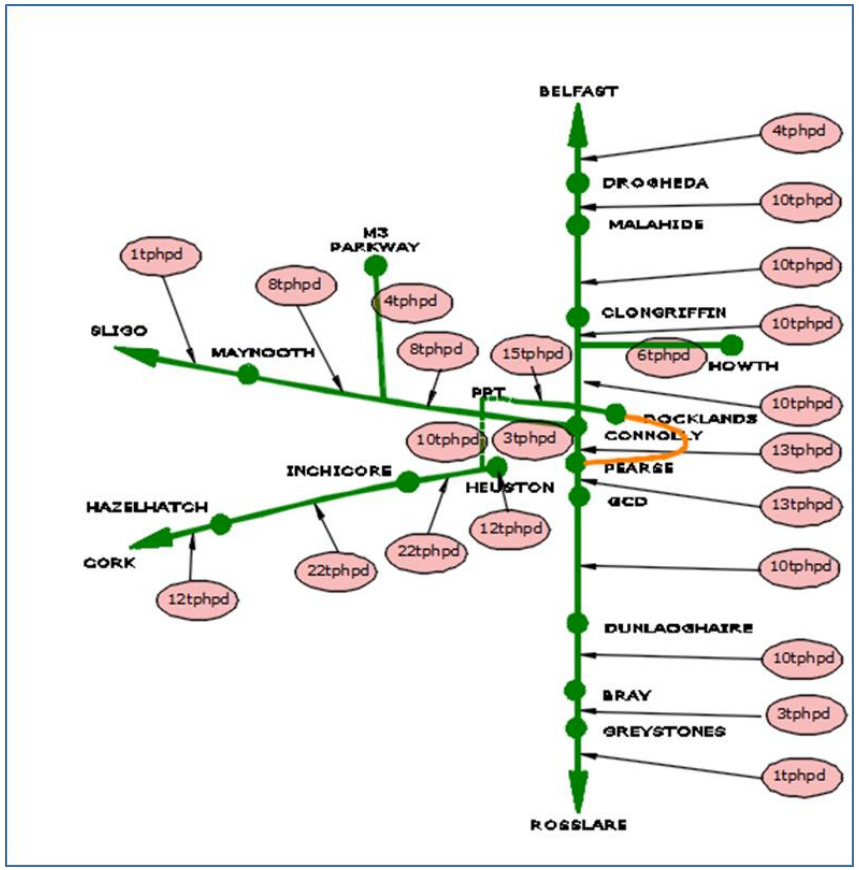
- **Notes:**
  - **PPT Services use Loop line bridge via Drumcondra and Connolly**
  - **Maynooth services use proposed tunnel via Docklands UG and Pearse UG**



Bundle 5A – DART Expansion Alternative (PPT and MGWR Tunnel)

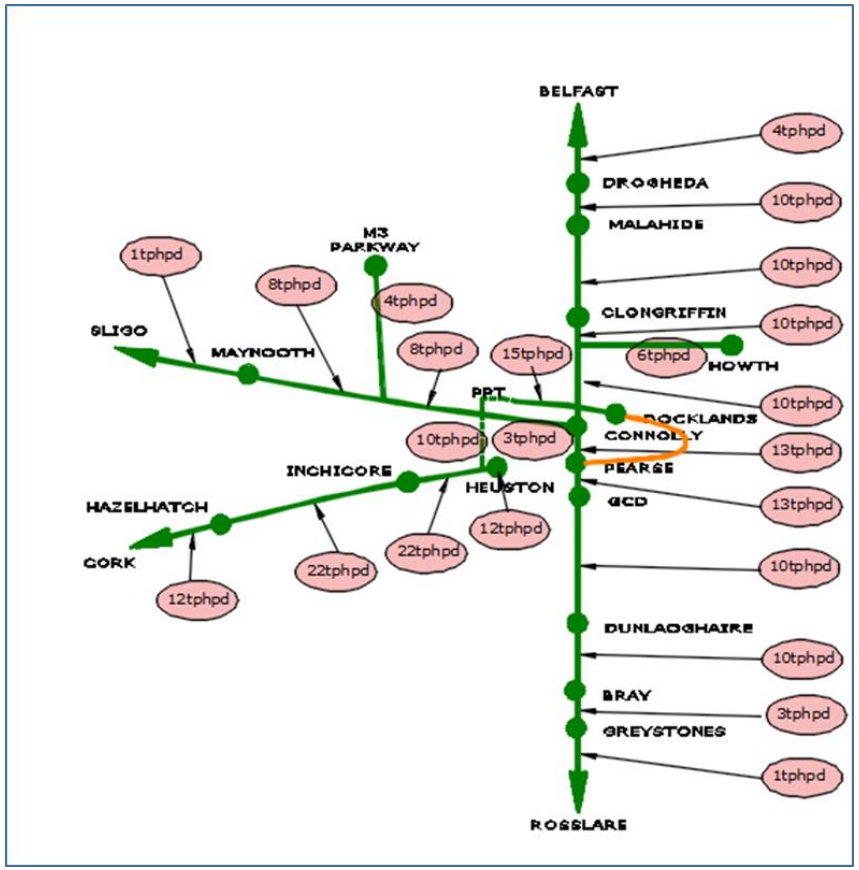
- **Overall Summary:**
  - 229% increase in DART Boardings
  - 41% increase in overall Heavy Rail Boardings
  - 12% increase in overall Public Transport Boardings

- **Observations:**
  - Approx. 2,000 lower AM DART boardings compared to Dart Expansion with Metro North.
  - Suburban Rail boardings 3,000 lower.
  - Overall PT boardings are 2,000 lower than AAC predominatly due 5,000 less Rail boardings.



Bundle 5A – DART Expansion Alternative (PPT and MGWR Tunnel)

- **Observations:**
  - Approx. 6,000 max loading using the tunnel WB in AM and 5,000 EB in PM.
    - Over 4,000 alighting at Pearse UG station
  - Northern line performs very well due to 5min frequencies Drogheda to Bray. Max loadings over 2,000 higher.
  - Kildare Line services perform well due to PPT Services with almost 4,000 additional max. loading in the PPT tunnel compared to the DoMin
  - Further analysis required on the level of interchange and also the pressure on the Bus network without the complete DART Exp. Tunnel
    - Luas Red line under less pressure with PPT tunnel services in place

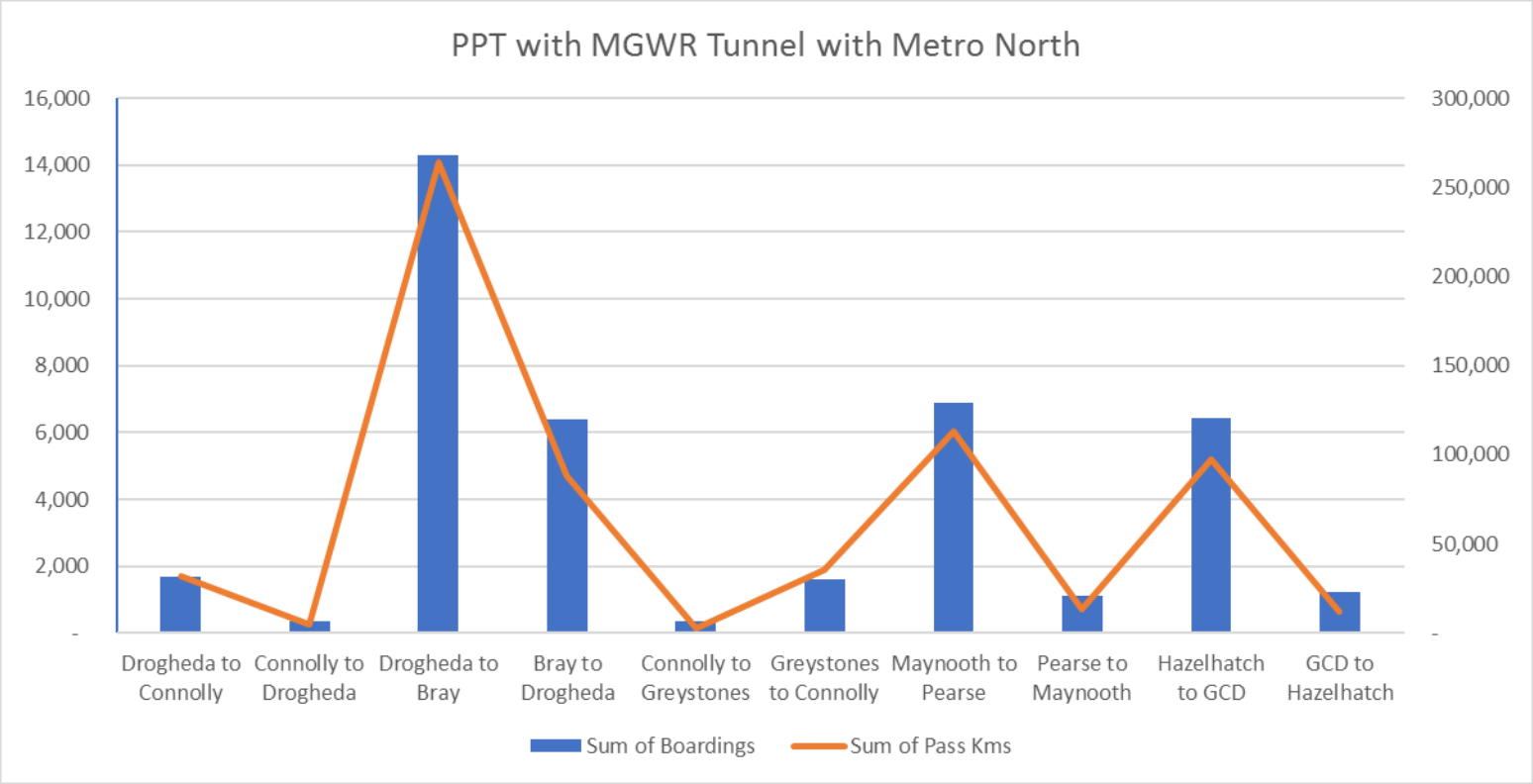


SYSTRA

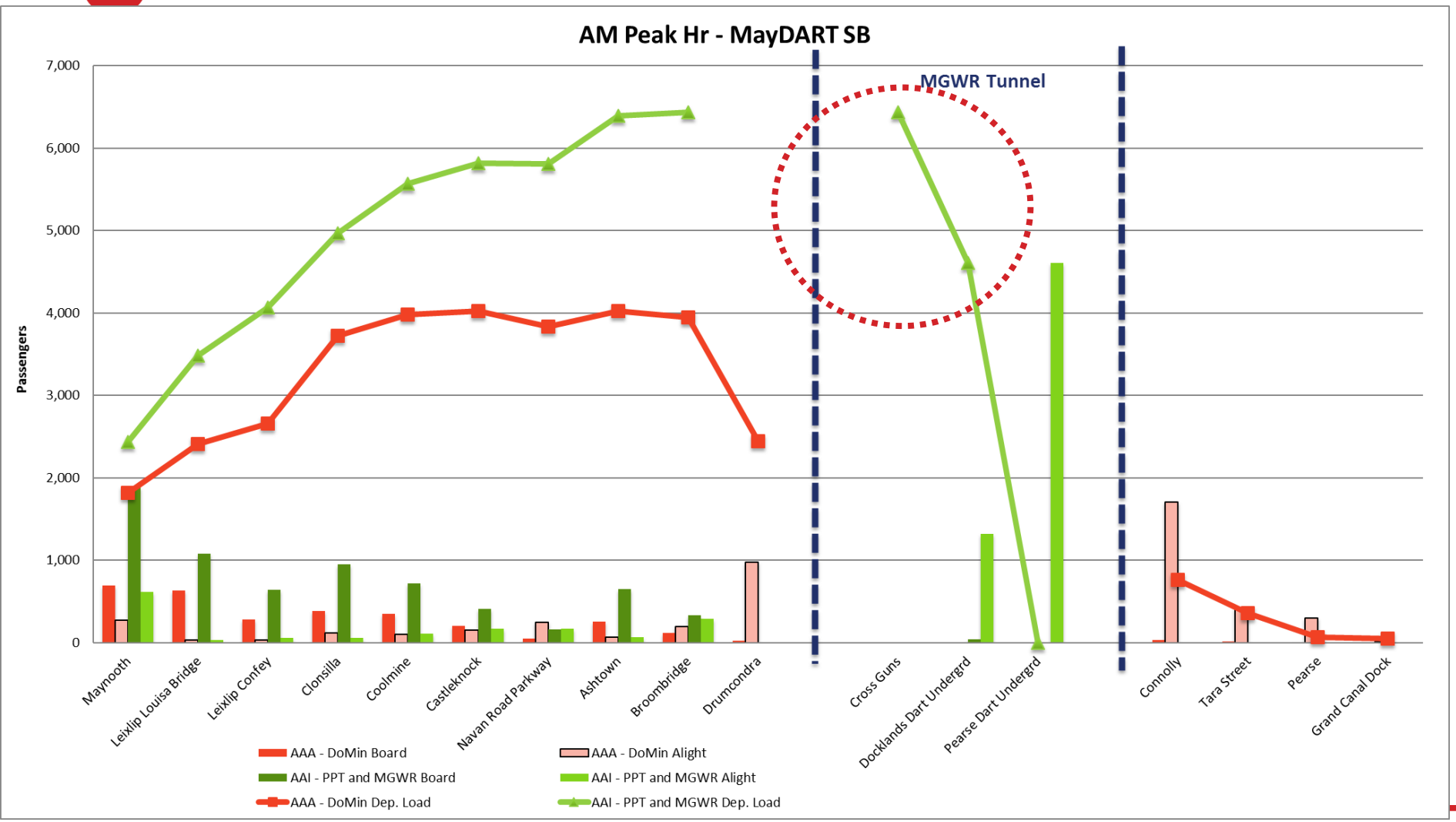
Bundle 5A - Scenario AAI – PPT and MGWR Tunnel - Line Summary

Description	Sum of Boardings	Sum of Veh Kms	Sum of Veh Hrs	Average of Veh Spd	Sum of Pass Kms	Sum of Pass Hrs	Sum of Distance	Sum of Time
Howth to Howth Junction (Shuttle) – all	170.77	32.40	0.90	36.00	590.45	19.08	5.40	9.00
Howth Junction to Howth (Shuttle) – all	57.31	32.40	0.90	36.00	232.28	6.92	5.40	9.00
Drogheda to Connolly - all stops	1,698.10	203.48	4.20	48.45	31,999.42	721.41	50.87	63.00
Connolly to Drogheda - all stops	341.90	203.48	4.13	49.23	4,546.44	93.41	50.87	62.00
Drogheda to Bray - all stops	14,312.26	890.64	21.20	42.01	264,223.98	6,705.36	74.22	106.00
Bray to Drogheda - all stops	6,406.02	890.64	21.00	42.41	88,447.94	2,543.91	74.22	105.00
Connolly to Greystones – all stops	334.12	62.14	1.67	37.28	2,860.99	90.85	31.07	50.00
Greystones to Connolly – all stops	1,598.86	62.14	1.70	36.55	35,453.78	921.56	31.07	51.00
Maynooth to Pearse - all stops	6,869.72	328.20	7.40	44.35	113,379.66	2,658.35	27.35	37.00
Pearse to Maynooth - all stops	1,112.19	328.20	7.20	45.58	13,473.33	297.14	27.35	36.00
Hazelhatch to GCD - all stops	6,434.58	199.76	4.80	41.62	97,712.54	2,272.14	24.97	36.00
GCD to Hazelhatch - all stops	1,215.65	199.76	4.80	41.62	11,782.19	278.33	24.97	36.00
	40,551.48	**3,433.24**	**79.90**	**41.76**	**664,703.00**	**16,608.46**	**427.76**	**600.00**

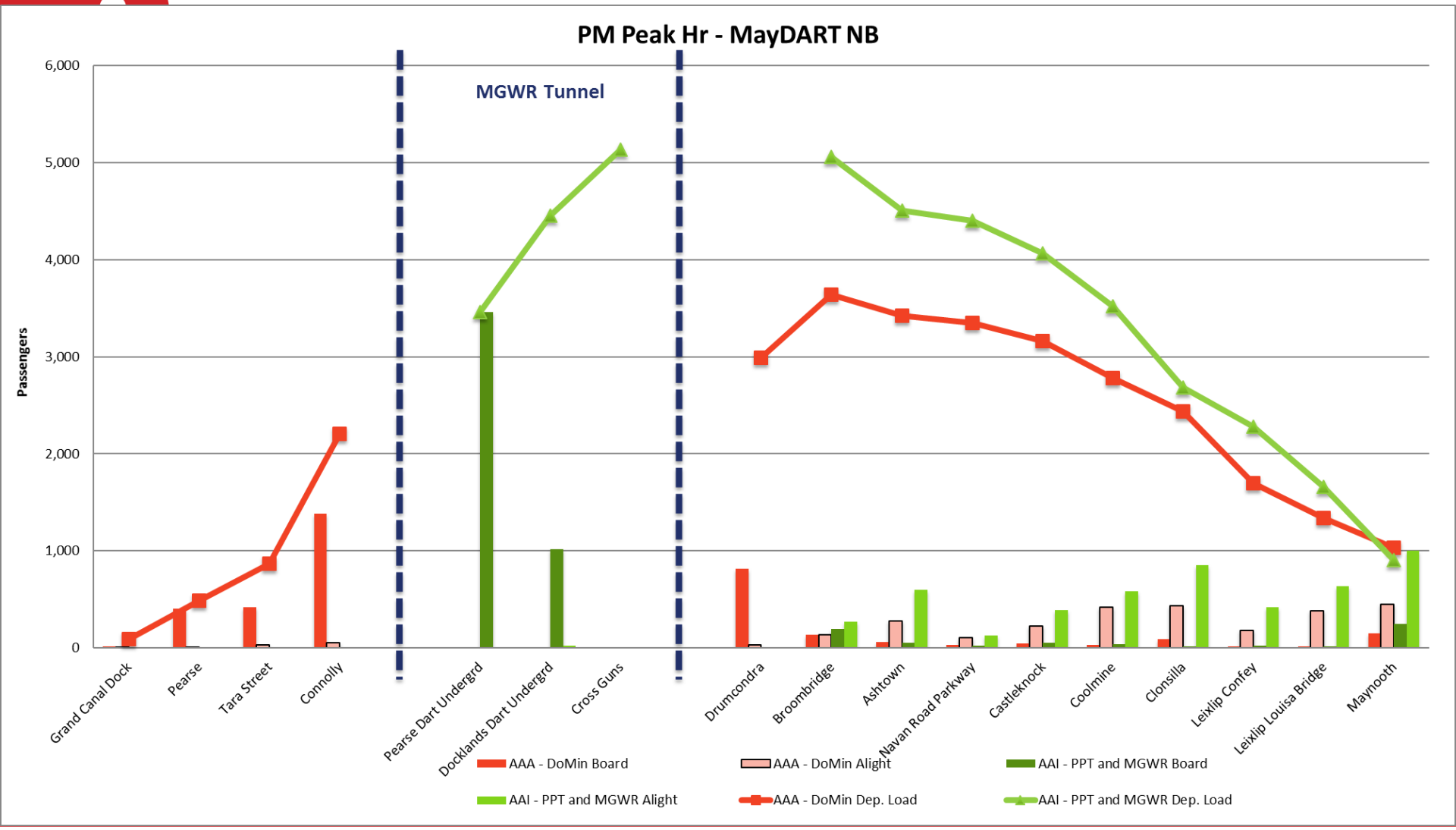
Bundle 5A - Scenario AAI – PPT and MGWR Tunnel - Line Summary



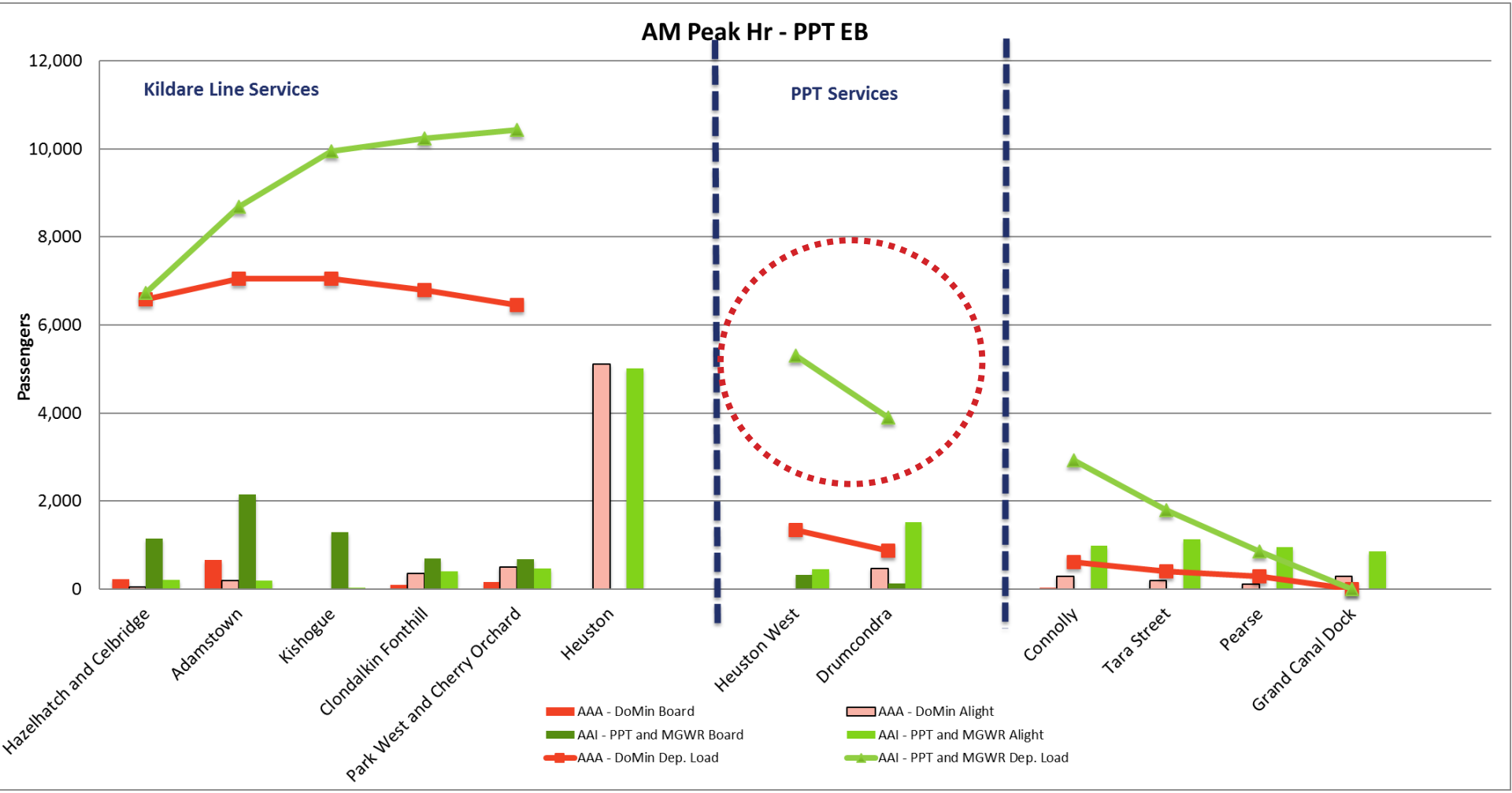
Bundle 5A - Scenario AAI – PPT and MGWR Tunnel - Line Profiles



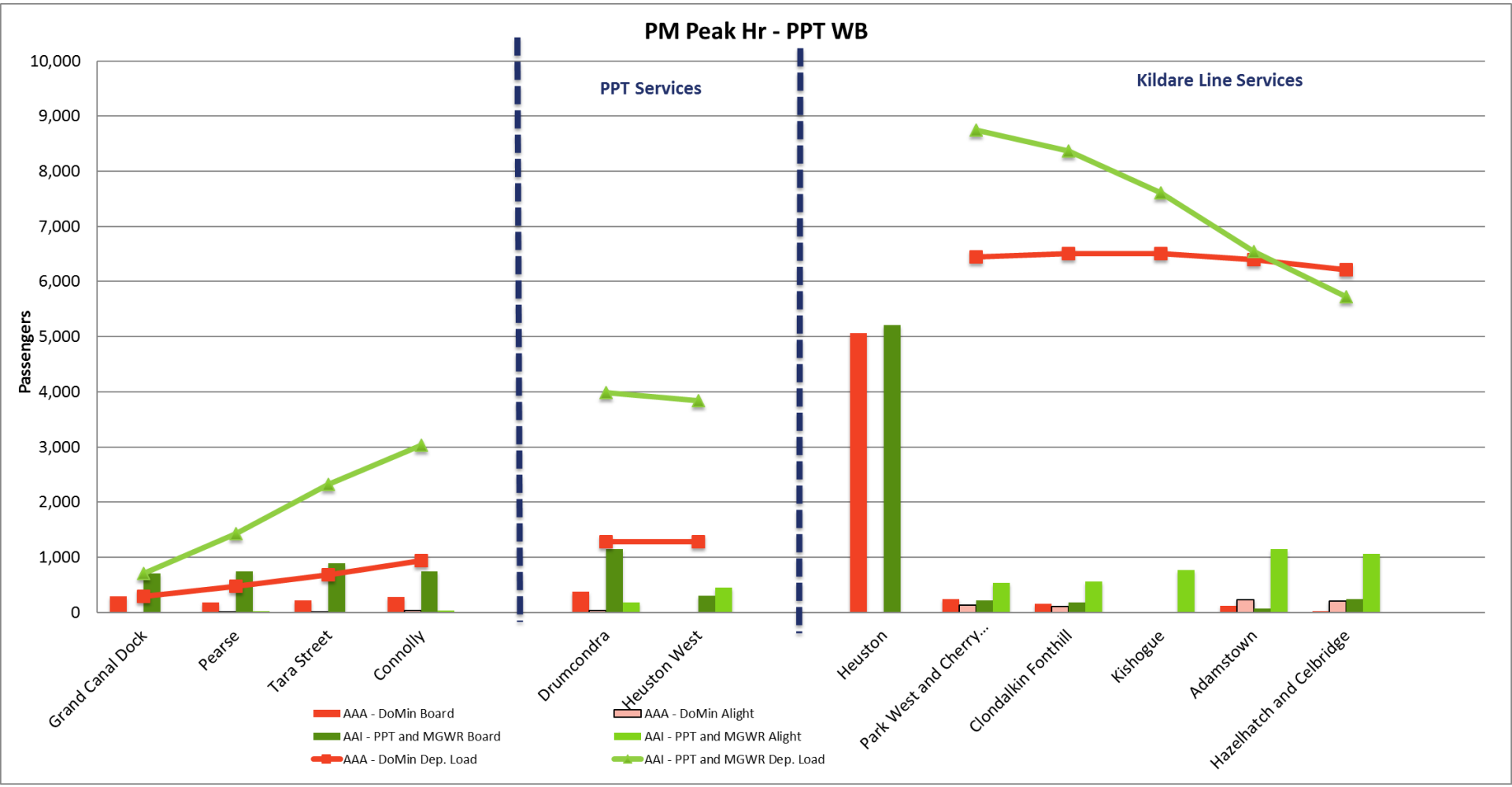
Bundle 5A - Scenario AAI – PPT and MGWR Tunnel - Line Profiles



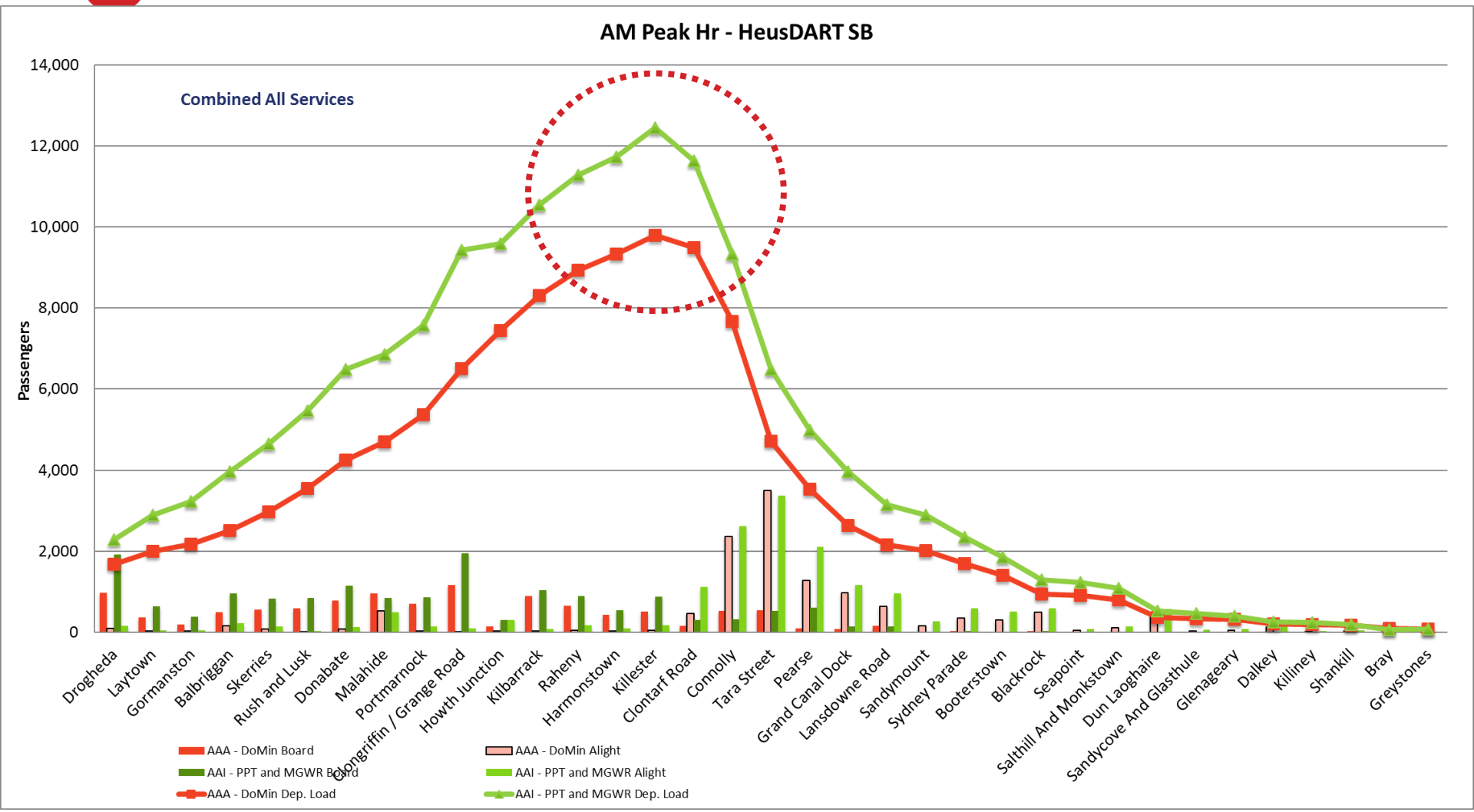
Bundle 5A - Scenario AAI – PPT and MGWR Tunnel - Line Profiles



Bundle 5A - Scenario AAI – PPT and MGWR Tunnel - Line Profiles

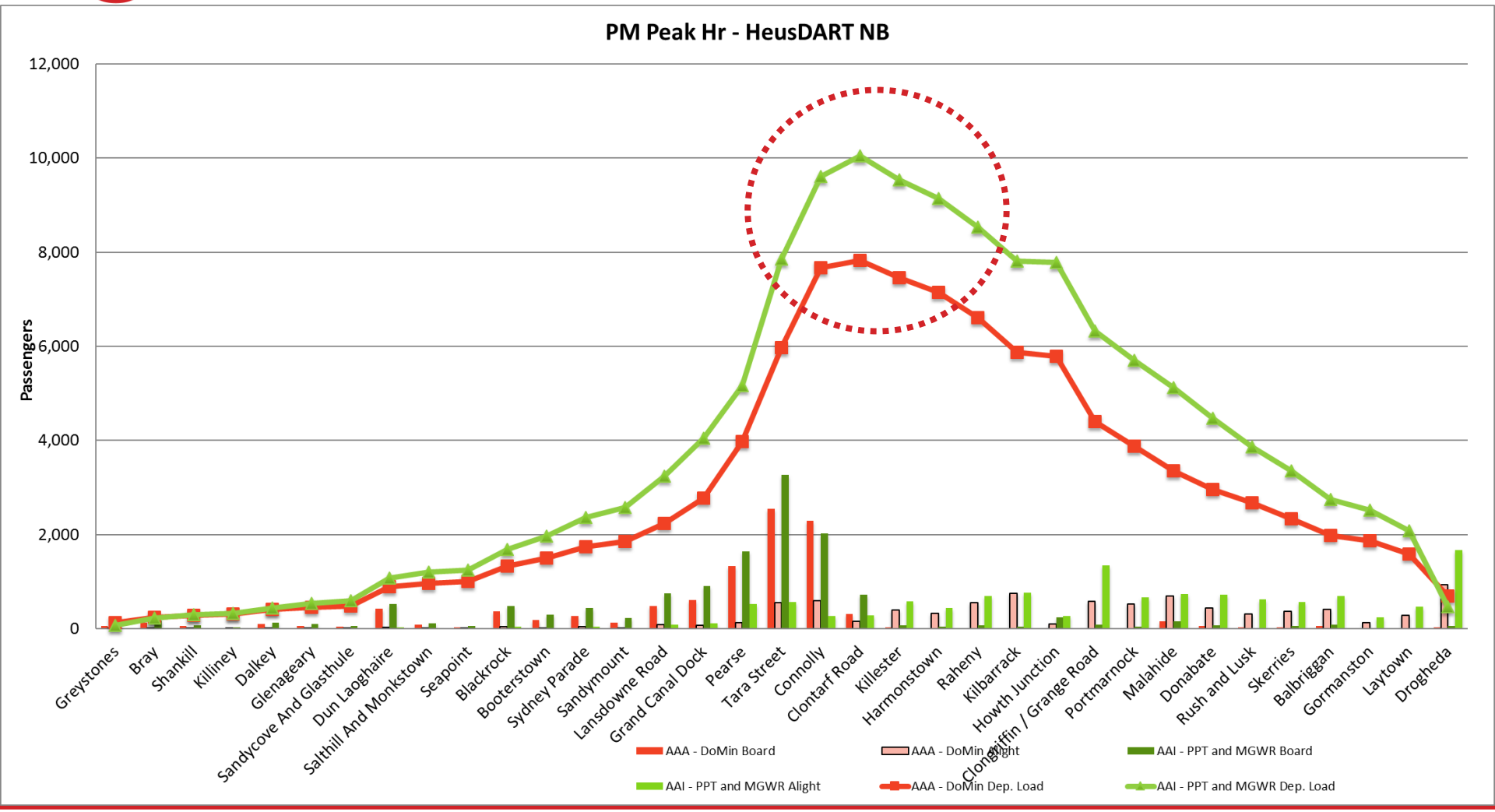


Bundle 5A - Scenario AAI – PPT and MGWR Tunnel - Line Profiles

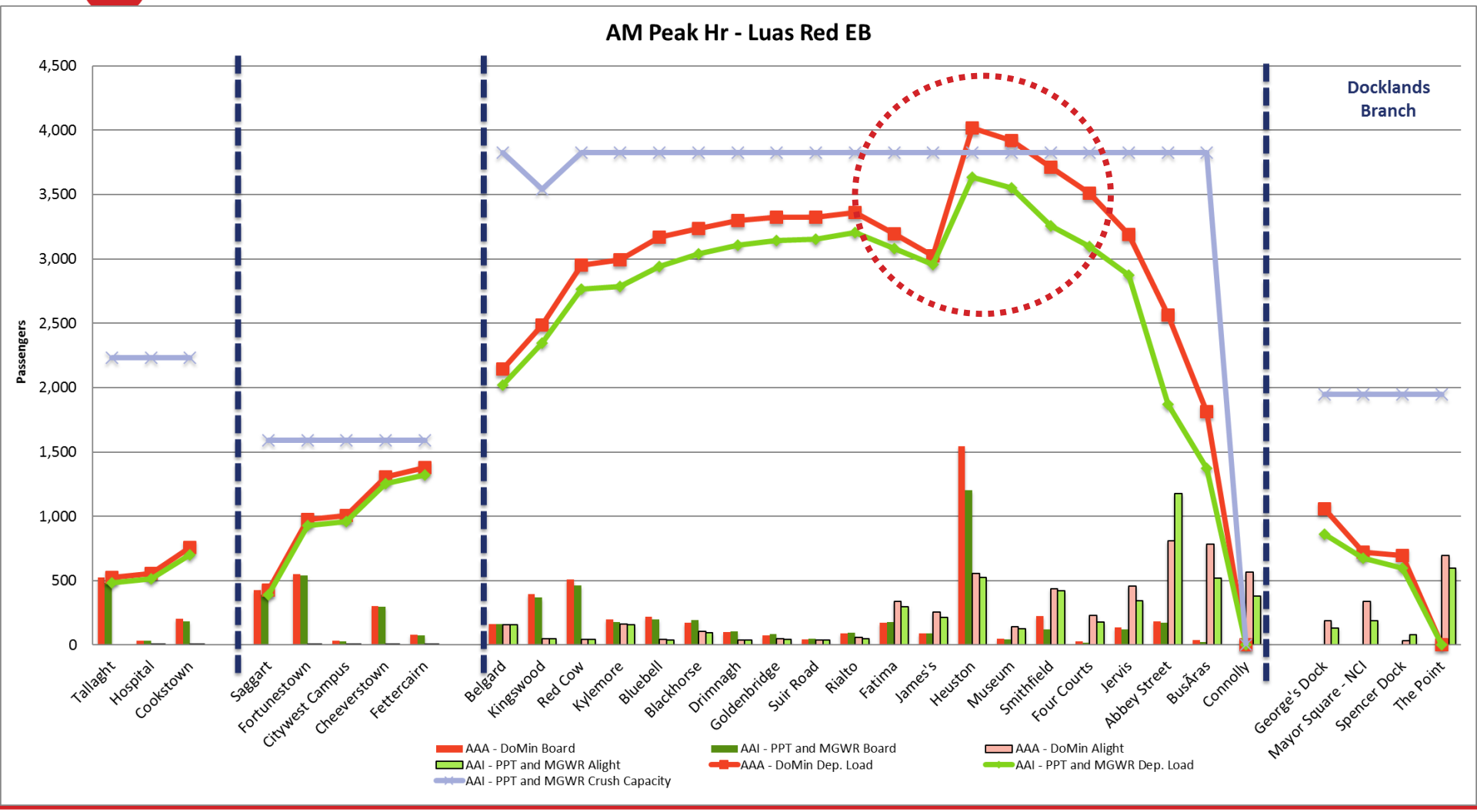


SYSTRA

Bundle 5A - Scenario AAI – PPT and MGWR Tunnel - Line Profiles



Bundle 5A - Scenario AAI – PPT and MGWR Tunnel - Line Profiles



SYSTRA

Appendix G
DART Expansion – Stage 2 – Strategic Model Outputs Summary

SYSTRA

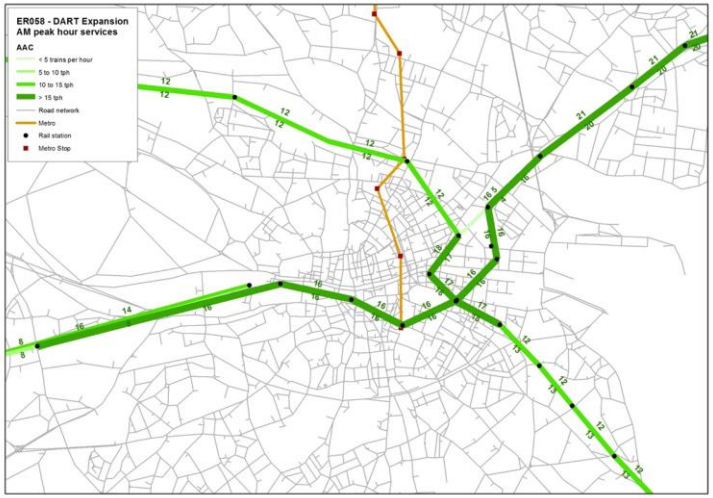
DART Expansion - Stage 2 Modelling

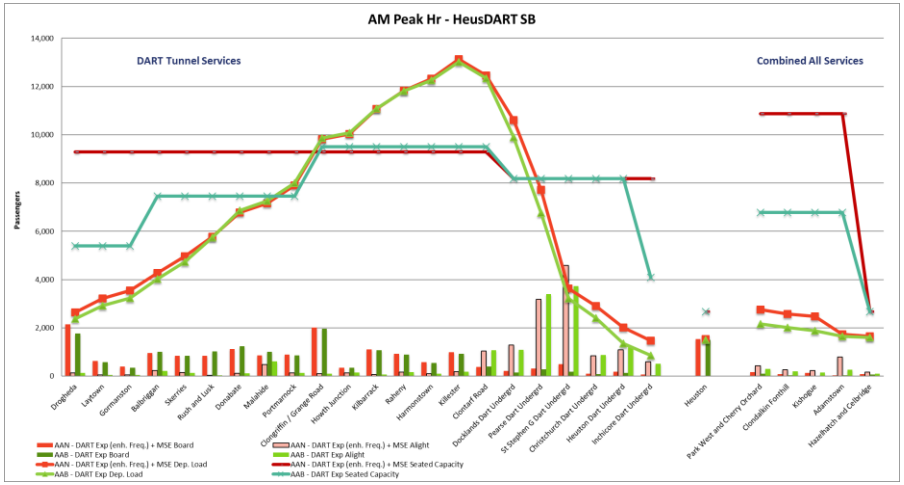
5 Bundles from Stage 1 brought forward for further refinement and enhancement

- **Bundle 2 – Full DART Expansion**
- **Bundle 3 – DART Expansion with Underground Turnback at Heuston**
- **Bundle 4 – DART Expansion with Underground Turnback at Pearse**
- **Bundle 5 – PPT and MGWR (Maynooth Line) to Pearse turnback via Tunnel from North Wall**
- **Bundle 6 – Phoenix Park Tunnel Expansion (No Tunnel) Option**

Service Plan Review

- **Technical meeting with Irish Rail discuss service plans and individual line demand profiles**
  - **Maximising potential on each line**
  - **Maintaining consistency in service offering across scheme bundles as far as practicable**
  - **To provide a consistent basis for comparison across each scenario**





Service Plan Review – Key Outcomes

Key outcome of service plan review meeting:

- End to End service frequencies prioritised
  - Inchicore turnback removed, services to Drogheda reduced
  - All services on DART services on the Kildare line begin at Hazelhatch
- Each line increased to maximum potential on busiest sections
  - Increased frequencies to maximise Loop-line Bridge capacity (18TPHPD)
  - Maynooth, PPT line frequencies increased to 16 TPHPD
- Peak service capacity across the whole day results in an overprovision of capacity in the inter-peaks.
  - 4 Car DARTs to be used in inter-peaks (1/2 capacity), with 2/3 peak period frequency

Networks Review

Networks reviewed in consultation with Irish Rail to identify potential schemes that could unlock service frequency

- Glasnevin Junction
  - Potential to remove conflict between Maynooth and Phoenix Park Tunnel services
- East Wall Junction
  - Possible grade separated junction, to remove conflict between northbound services from the Underground Tunnel and the Connolly Line. Allows for 20 TPDPH in tunnel.
- New Station Locations
  - Heuston West (Platform 10), Cabra (on PPT line)
  - Glasnevin (providing interchange between Maynooth and Docklands lines)
  - Connolly North

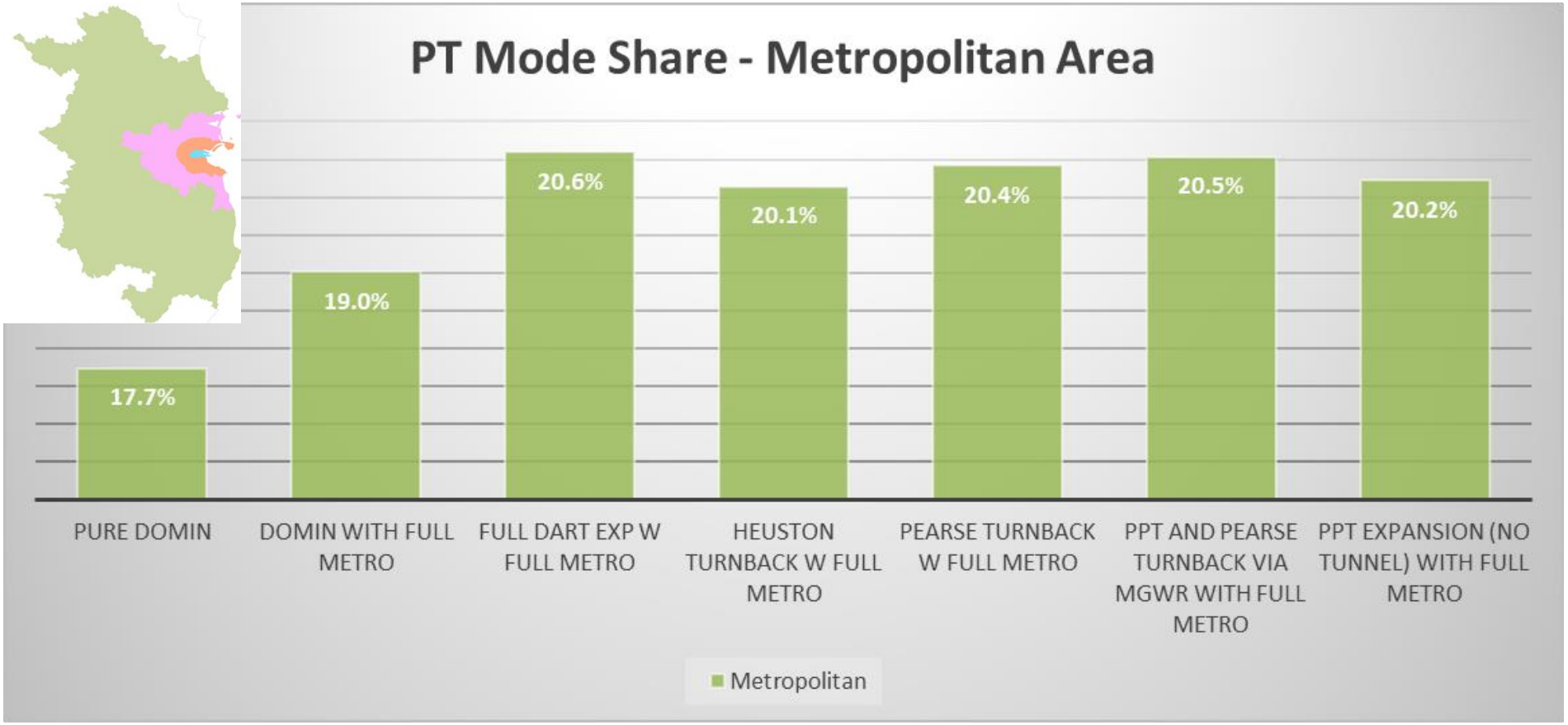
DART Expansion – Model Runs Undertaken

Description	*Note*
Pure DoMin	Revised DoMin to correspond with Irish Rail service plans and also to resolve some instability and coding issues in the road model
DoMin with Full Metro	**Bundle 1C** - Pure DoMin as per AAQ with Full Metro included
Full DART Expansion with Full Metro	**Bundle 2D** - Dart Expansion with SYSTRA optimised service plans
Heuston Turnback with Full Metro	**Bundle3B** - Heuston Turnback with SYSTRA optimised service plans. Model altered to account for shorter interchange opportunities at Heuston Station than previously modelled.
Pearse Turnback with Full Metro	**Bundle 4E** - Pearse Turnback with SYSTRA optimised service plans
PPT and Pearse Turnback via MGWR with Full Metro	**Bundle 5B** - Pearse Turnback (2) with SYSTRA optimised service plans. Slight variation to the previous Bundle 5 option. This option involves the realignment of the PPT line at Glasnevin to run on the Docklands line. There is no crossover of the Maynooth line which will run via Drumcondra and Connolly. A new Stations at Glasnevin would be retained allowing interchange between lines and also a Cabra Station between Cabra Rd and Fassaugh Road. The opportunity then exists to divert Metro to this location instead of Drumcondra.
PPT Expansion (No Tunnel) with Full Metro	**Bundle 6B** - PPT Expansion with SYSTRA optimised service plans. Slight variation to the previous no tunnel option. This option is similar to the Bundle 5B option without the tunnel to Pearse. This option also includes a new station at Connolly North.
Full DART Expansion (with Grade Separated junction at East Wall) with Full Metro	**Bundle 2E** - A grade separated junction on the northern line allows for additional train paths on the northern line and in the DART underground. This run is similar to AAR with 4 additional underground services Clongriffin to Inchicore
Full DART Expansion (Heuston Portal) with Full Metro	**Bundle 2F** - Dart Expansion with SYSTRA optimised service plans (Heuston Portal - No Inchicore Station)
Pearse Turnback (Heuston Portal) with Full Metro	**Bundle 4F** - Pearse Turnback with SYSTRA optimised service plans (Heuston Portal - No Inchicore Station)
PPT Expansion (No Tunnel) with Full Metro via Tara St	**Bundle 6C** - PPT Expansion with SYSTRA optimised service plans. Slight variation to the previous no tunnel option. This option is similar to the Bundle 5B option without the tunnel to Pearse. This option also includes a new station at Connolly North - Metro via Pearse

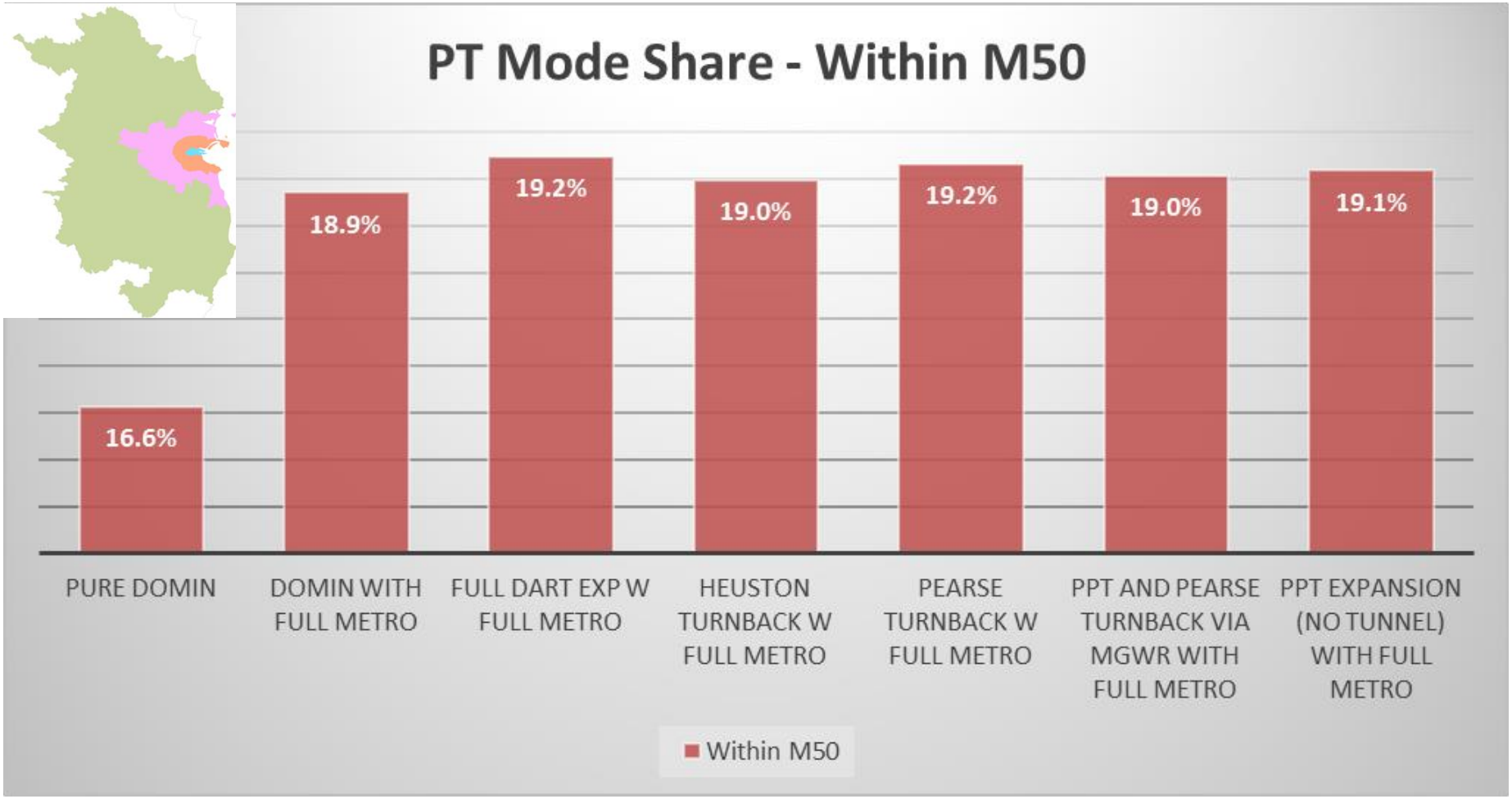
MODEL RESULTS

- **The following KPI's have been extracted from the model for each scenario:**
  - **Mode Share**
  - **Total Boardings by PT Sub-mode**
  - **Transfers levels by PT Sub-mode**
  - **Average Journey Speed per PT Passenger**
    - Combines PT Passenger Travel Time and Distance
    - Used to identify the efficiency improvements across each scenario
  - **Road Assignment Statistics**
  - **Economic Appraisal (TUBA)**
  - **Key Station analysis**

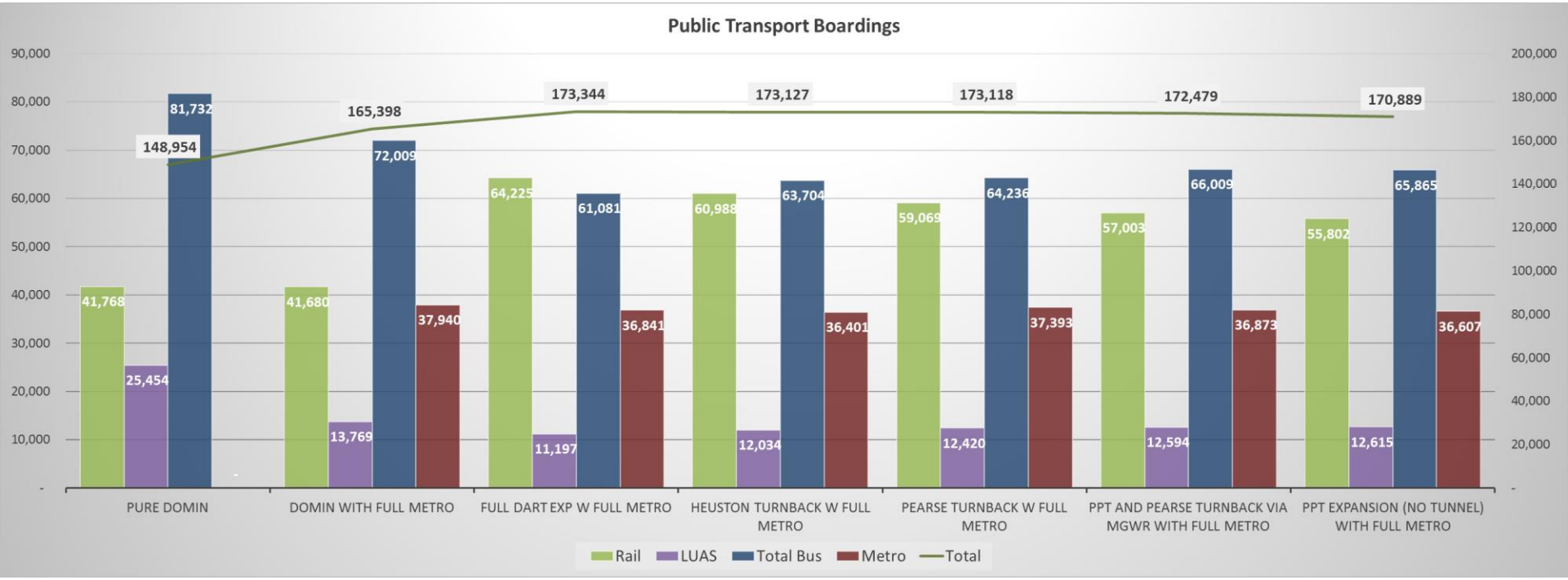
Public Transport Mode Share – AM Origin



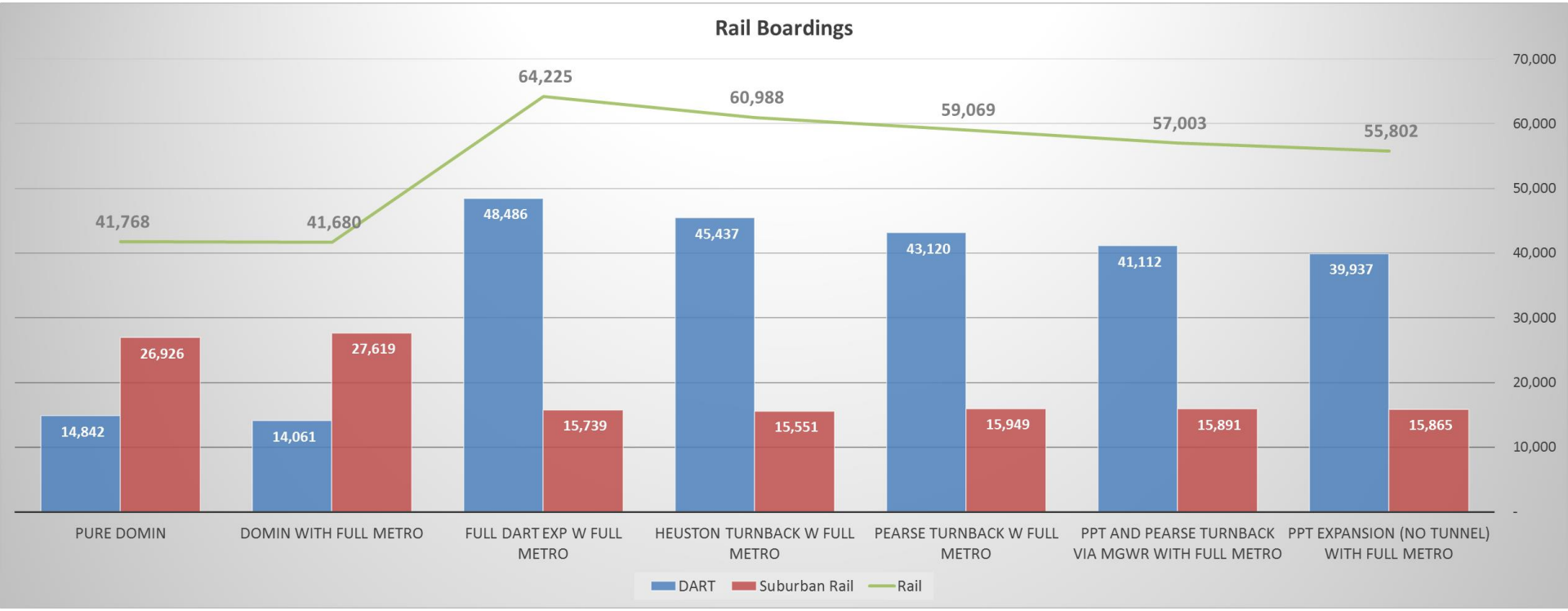
Public Transport Mode Share – AM Origin



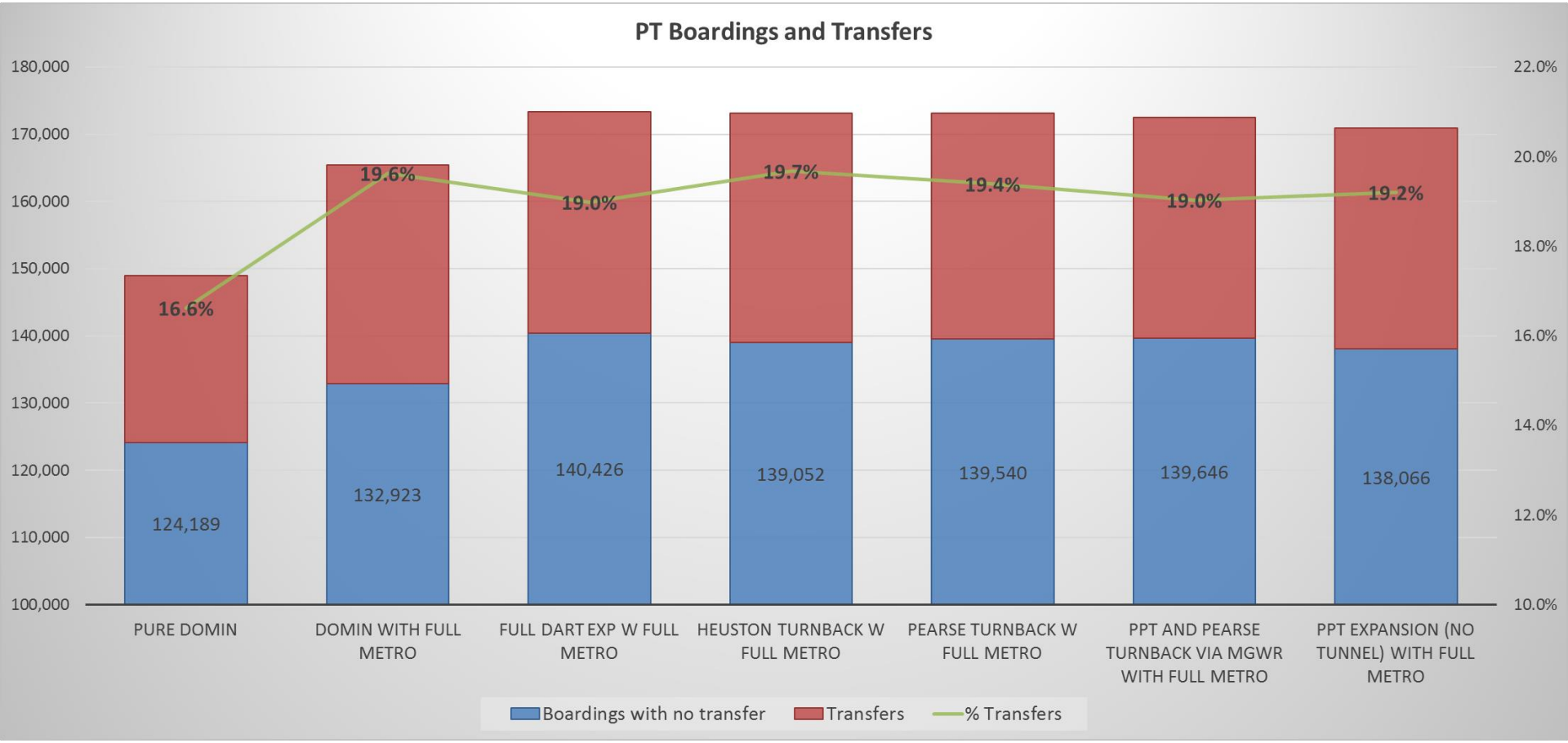
Public Transport Boarding Summary (AM Peak)
(Includes Transfers)



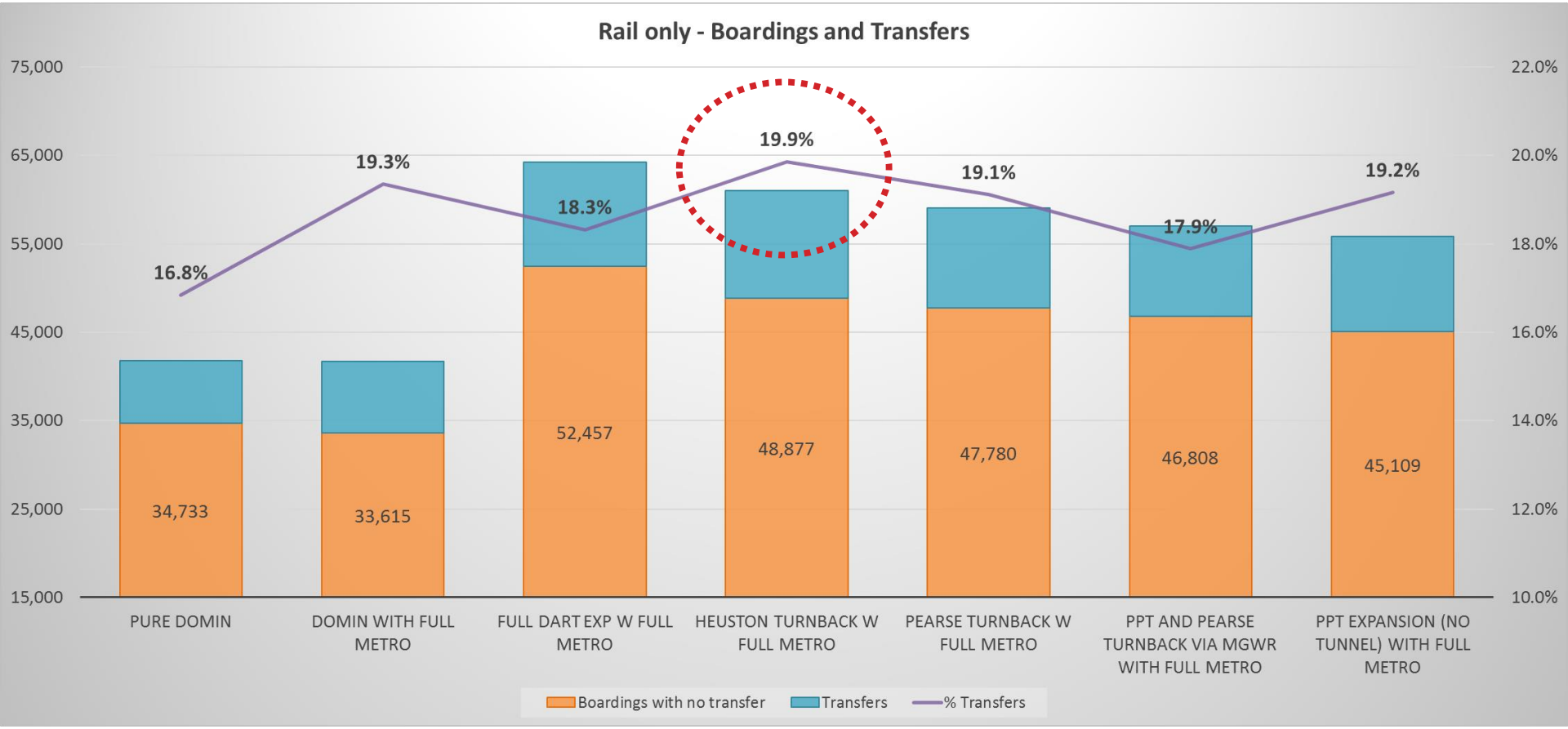
Public Transport Boardings Summary (AM Peak) (Includes Transfers)



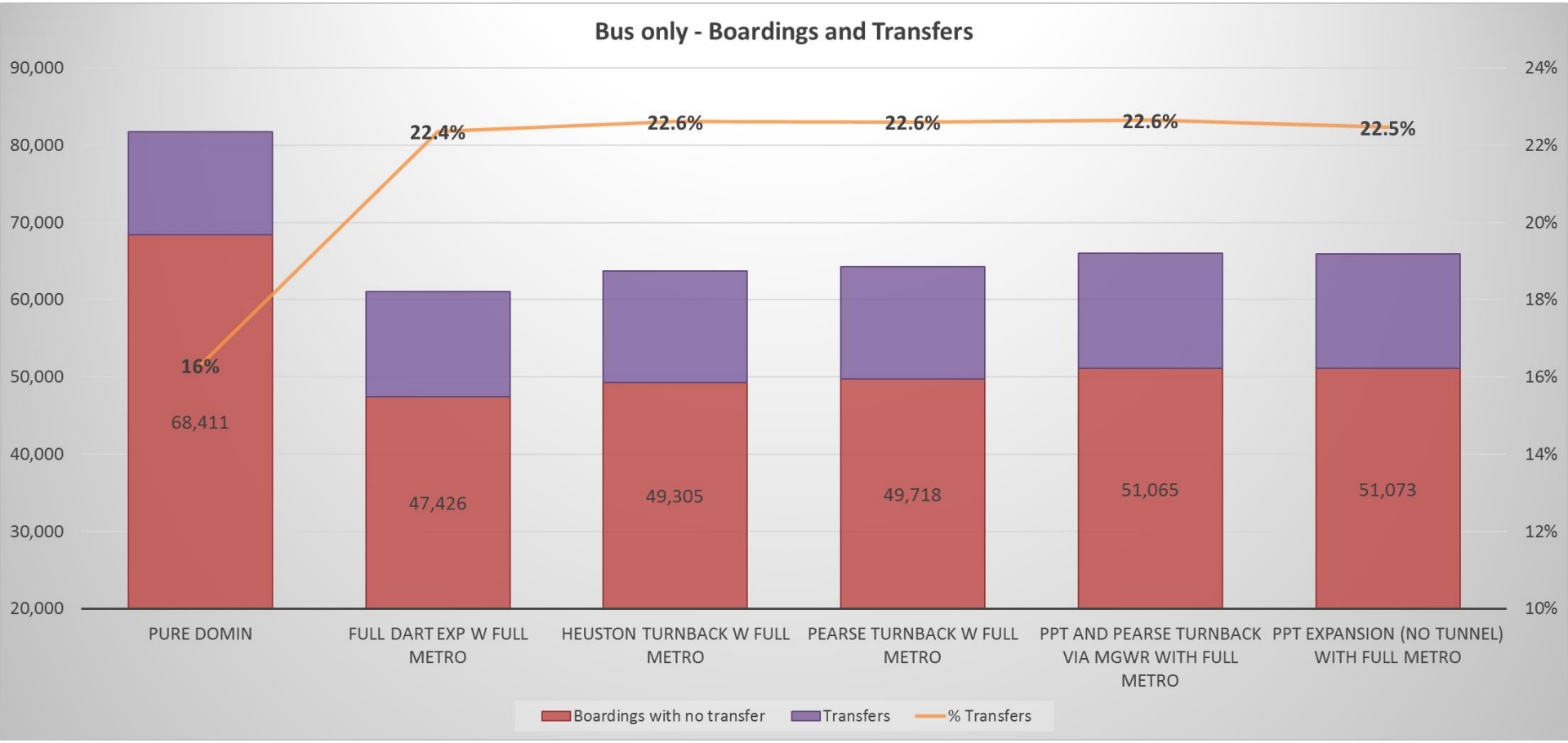
Public Transport Boarding Summary (Transfers)



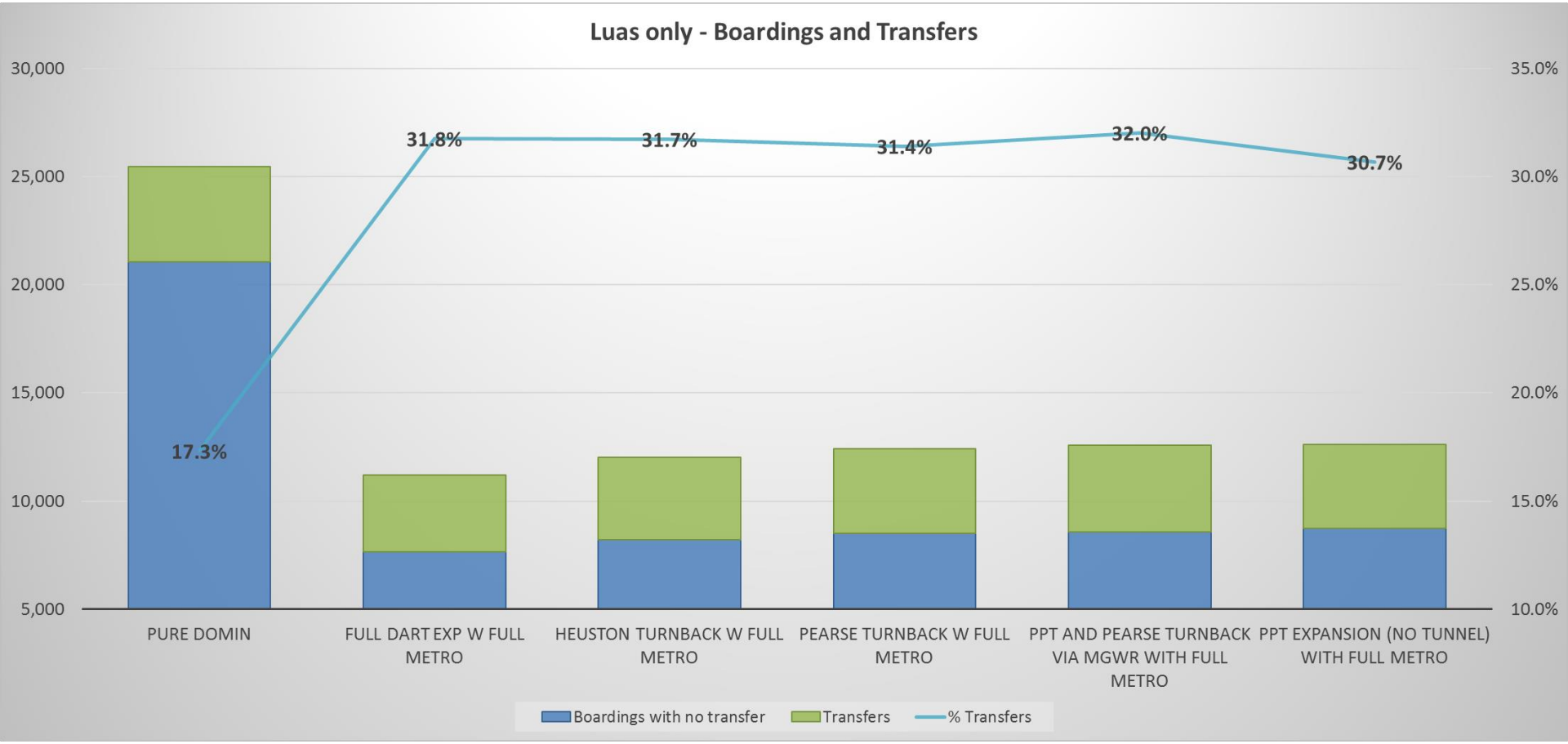
Public Transport Boarding Summary (Transfers)



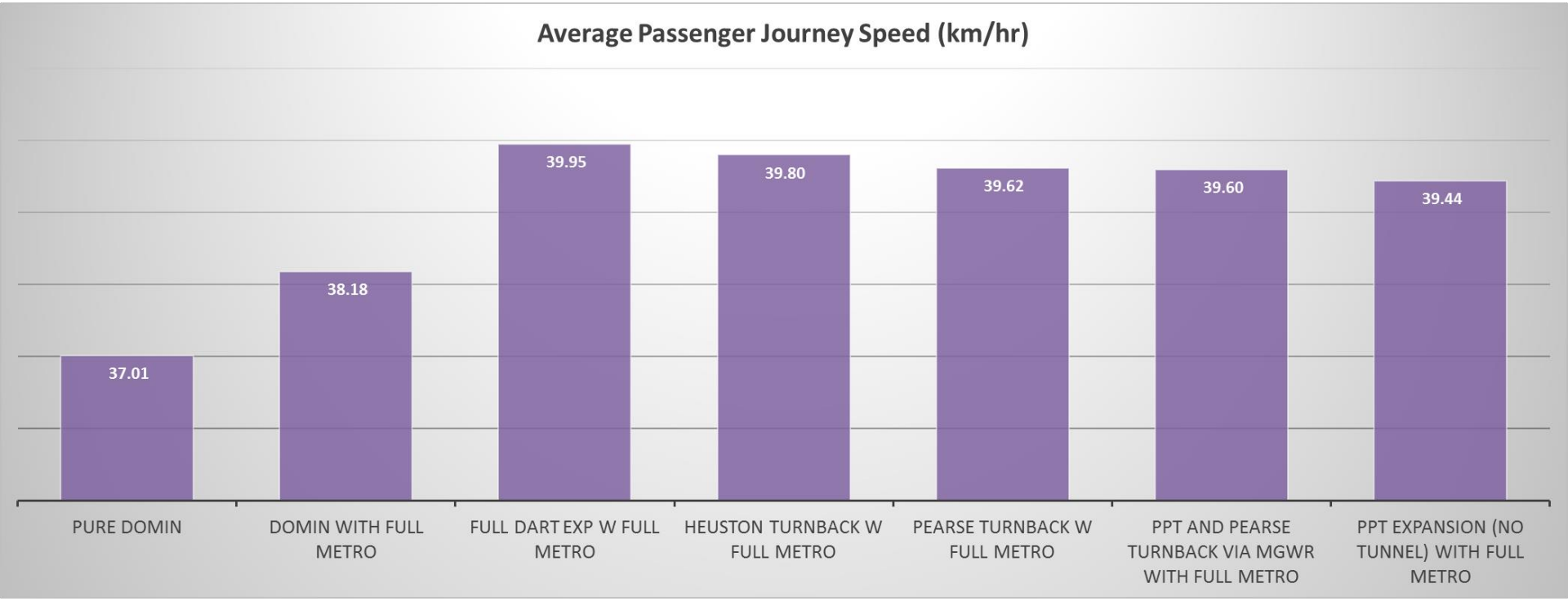
Public Transport Boarding Summary (Transfers)



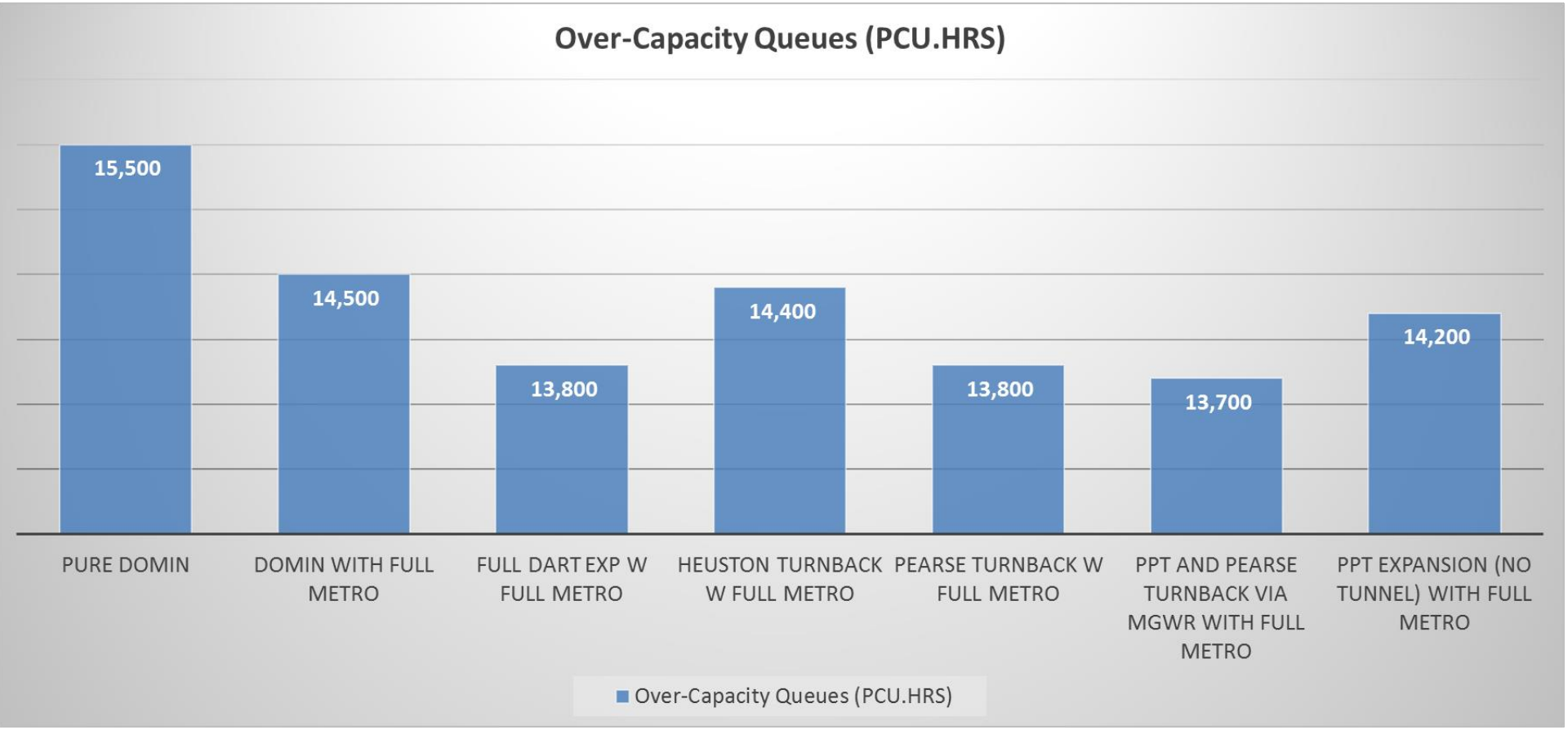
Public Transport Boarding Summary (Transfers)



Public Transport Average Journey Speed (In-vehicle)



Road Assignment Summary

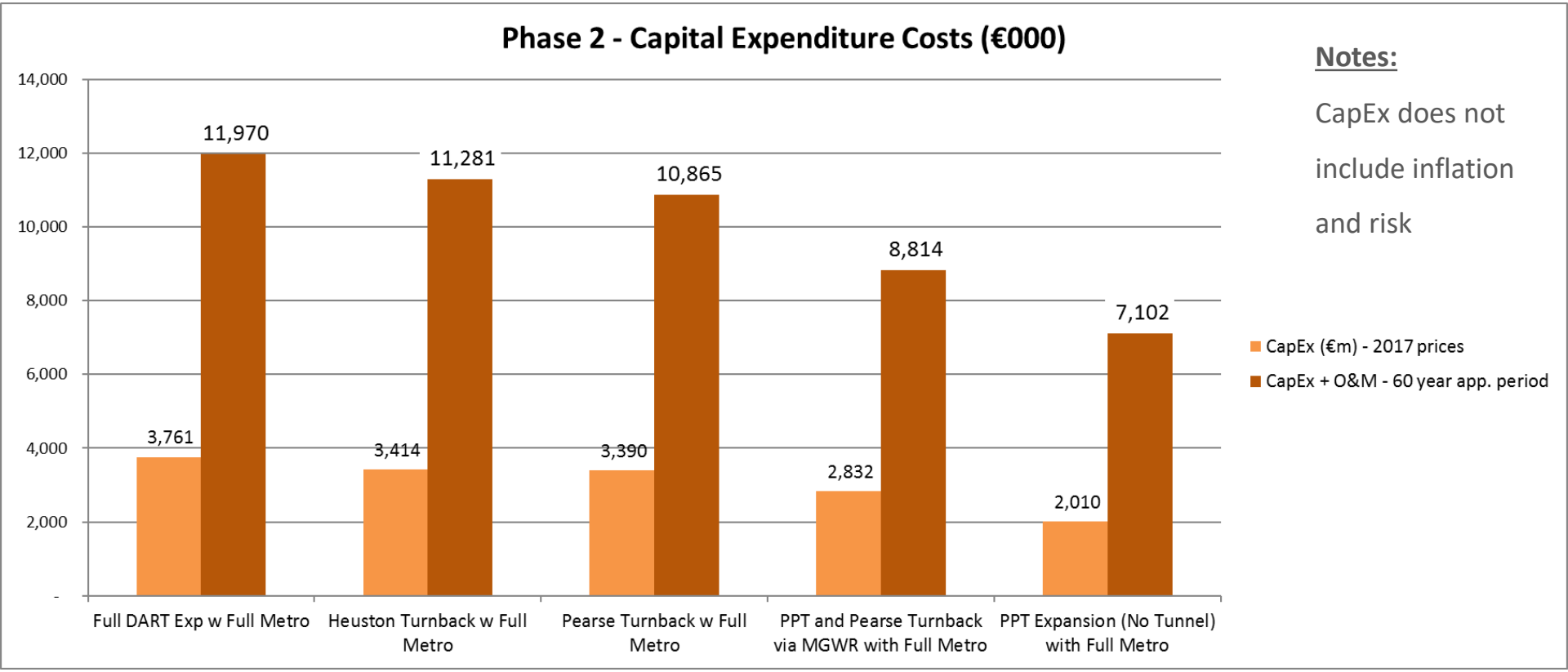


Economic Appraisal (TUBA Analysis)

- **Economic Appraisal undertaken using the NTA Economic Appraisal tool**

- **Assumptions**
  - **Benefits to accrue from 2026, full DART Expansion scheme operational in 2029.**
  - **2% per annum Construction inflation rate**
  - **1% per annum Operation & Maintenance escalation inflation rate**
  - **Cost estimates for the full DART Expansion provided by Paul Barrett (Irish Rail)**
    - **(15% increase from previous business)**
  - **Shadow pricing included (Labour and Public Funds)**
  - **Risk - 25% Risk Allowance for Tunnel, 10% Risk Allowance for other DART Exp. elements**
  - **30 year residual value**
    - **2065 model run assuming 16.8% growth from 2035 to 2065 (CSO population forecasts)**

DART Expansion - Stage 2 Modelling - Costings



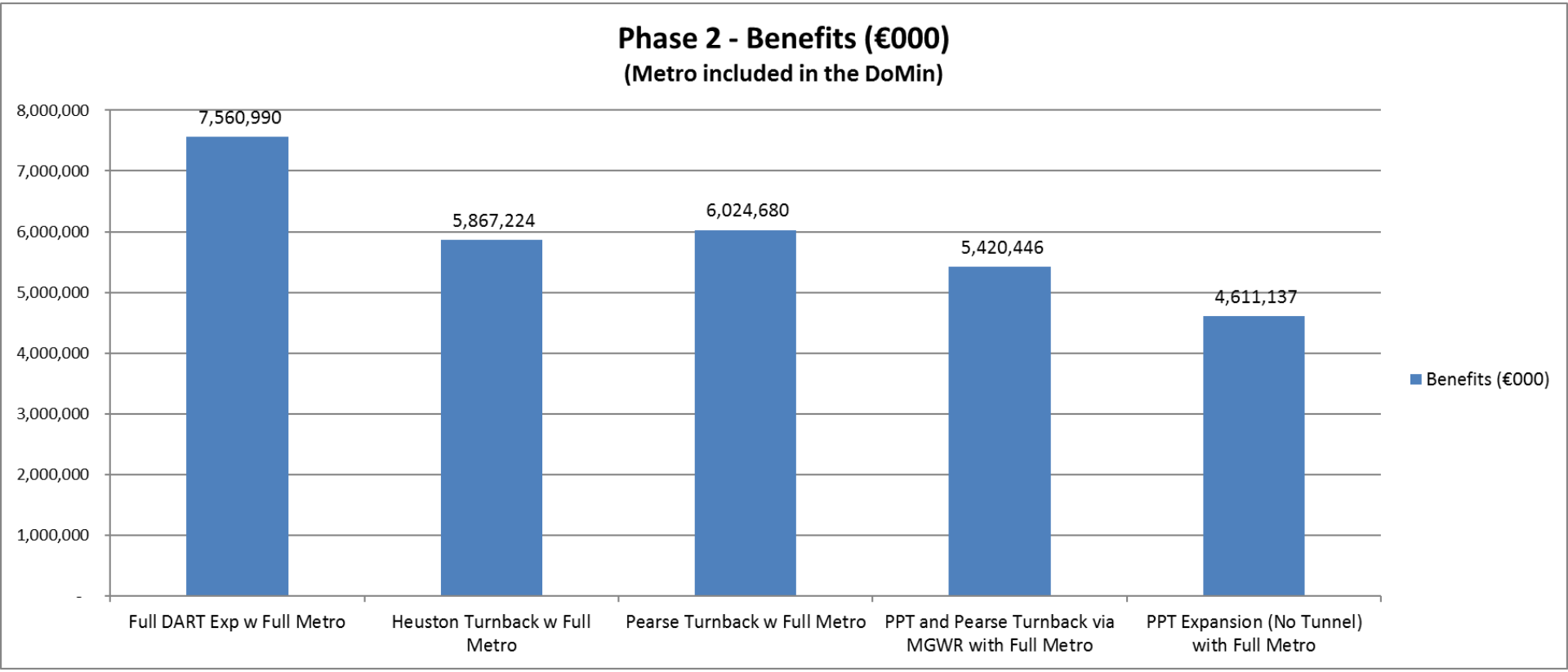
Notes:

CapEx does not include inflation and risk

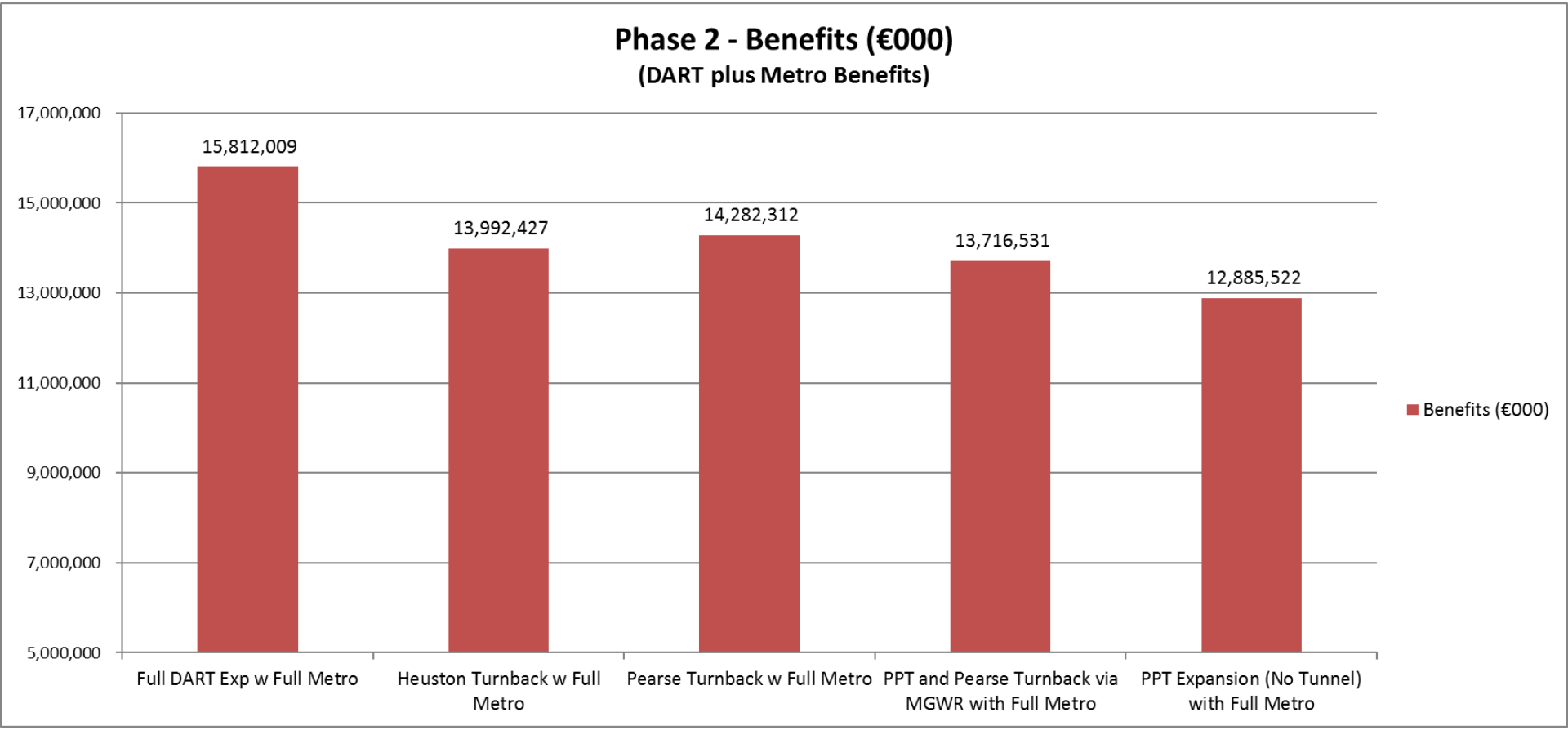
Notes:

All include approx. €800m in Fleet Requirements and DART Expansion basic elements of €720m

DART Expansion - Stage 2 Modelling Outputs



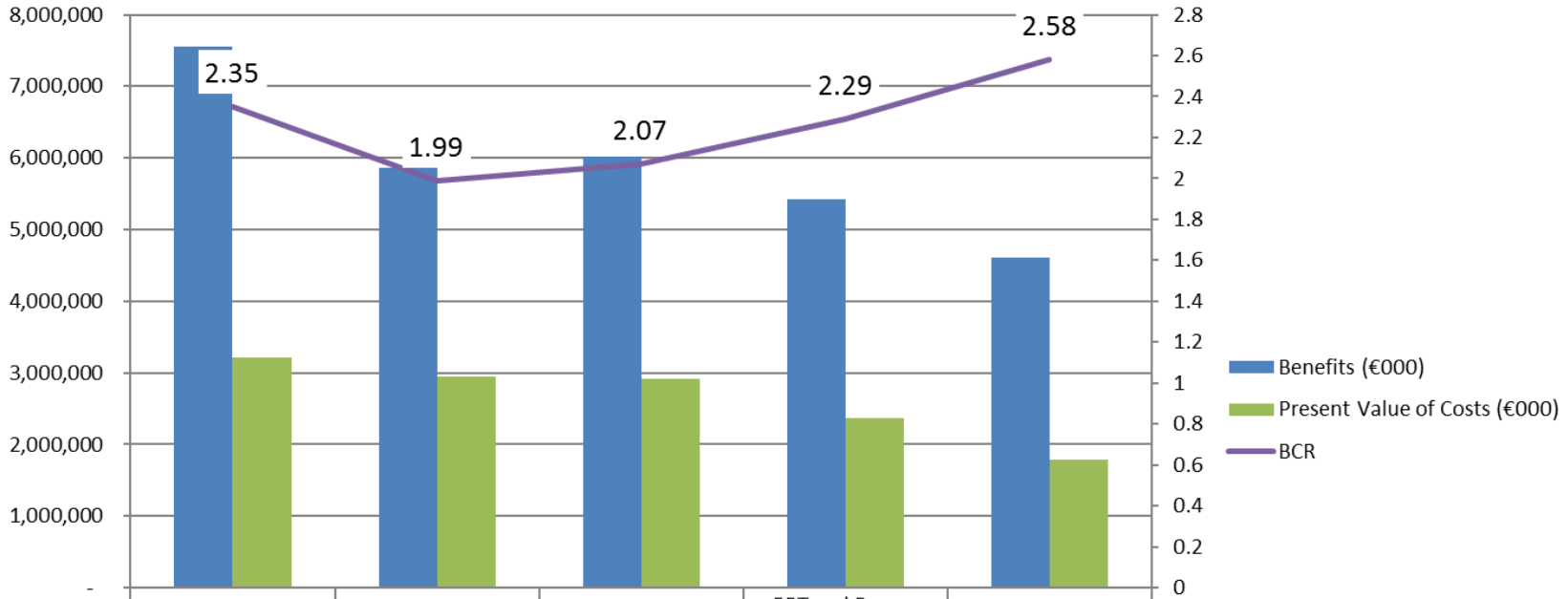
DART Expansion - Stage 2 Modelling Outputs



DART Expansion - Stage 2 Modelling Outputs

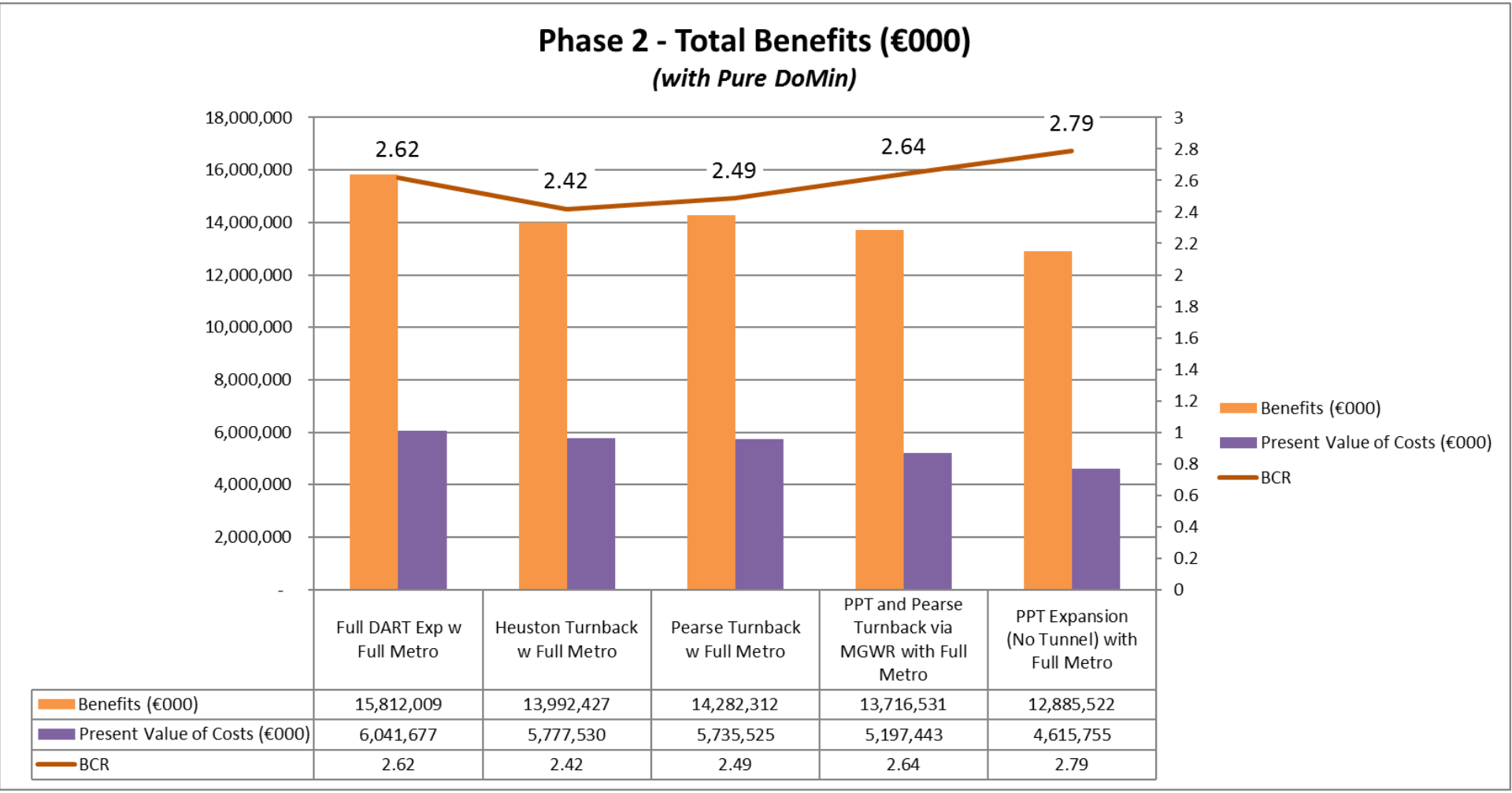
Phase 2 - Total Benefits (€000)

(with Metro included in DoMin)



	Full DART Exp w Full Metro	Heuston Turnback w Full Metro	Pearse Turnback w Full Metro	PPT and Pearse Turnback via MGWR with Full Metro	PPT Expansion (No Tunnel) with Full Metro
Benefits (€000)	7,560,990	5,867,224	6,024,680	5,420,446	4,611,137
Present Value of Costs (€000)	3,215,209	2,951,850	2,909,792	2,371,693	1,789,712
BCR	2.35	1.99	2.07	2.29	2.58

DART Expansion - Stage 2 Modelling Outputs



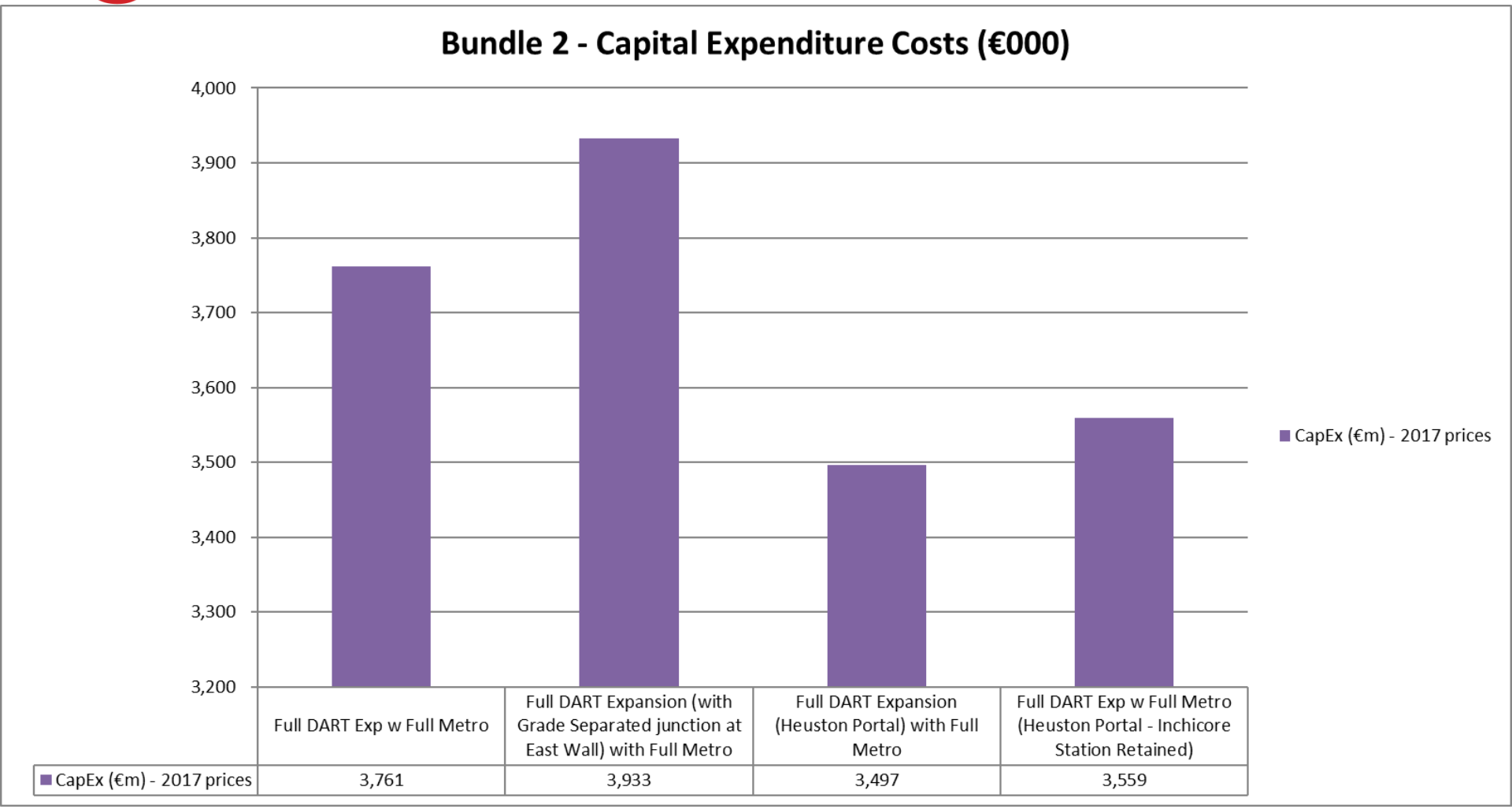
	Full DART Exp w Full Metro	Heuston Turnback w Full Metro	Pearse Turnback w Full Metro	PPT and Pearse Turnback via MGWR with Full Metro	PPT Expansion (No Tunnel) with Full Metro
Benefits (€000)	15,812,009	13,992,427	14,282,312	13,716,531	12,885,522
Present Value of Costs (€000)	6,041,677	5,777,530	5,735,525	5,197,443	4,615,755
BCR	2.62	2.42	2.49	2.64	2.79

DART Expansion - Stage 2 Modelling Outputs – Bundle 2 Variations

There are a number of variations to the full DART Expansion option:

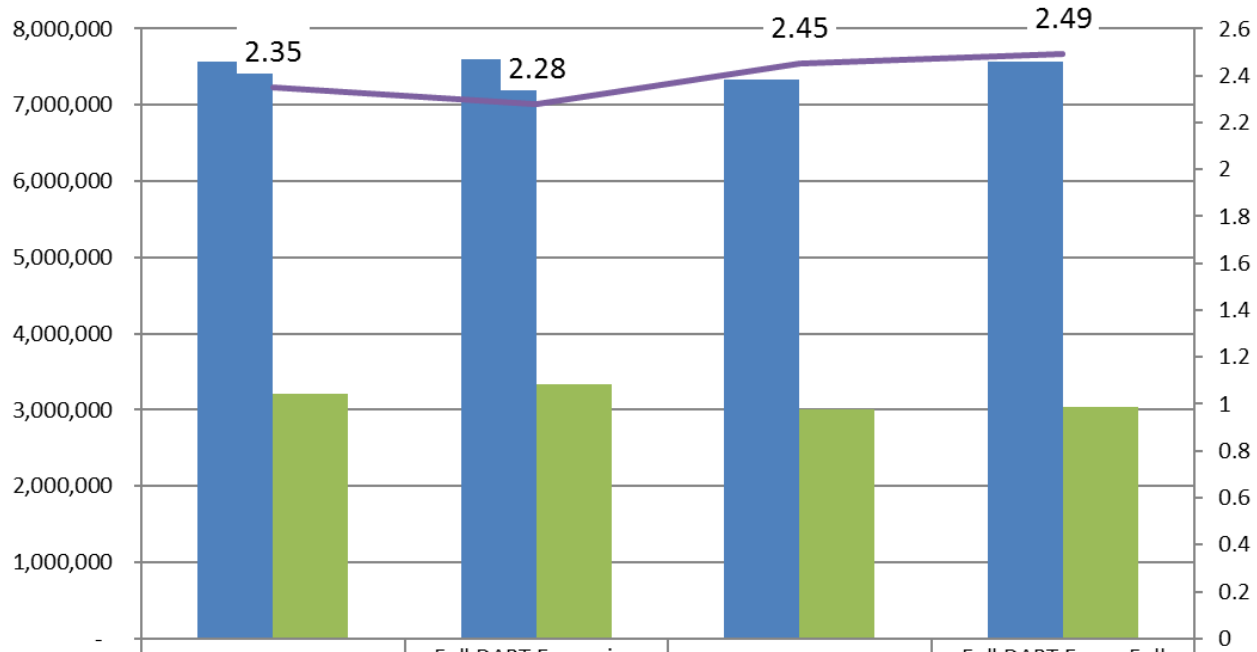
- **Western tunnel portal at Heuston instead of Inchicore**
  - **Requires 4-tracking to Heuston**
  - **Savings in tunnelling costs**
  - **With and without Inchicore Station**
- **Grade separated junction at East Wall – €170m**

DART Expansion - Stage 2 Modelling Outputs – Bundle 2 Variations



	Full DART Exp w Full Metro	Full DART Expansion (with Grade Separated junction at East Wall) with Full Metro	Full DART Expansion (Heuston Portal) with Full Metro	Full DART Exp w Full Metro (Heuston Portal - Inchicore Station Retained)
CapEx (€m) - 2017 prices	3,761	3,933	3,497	3,559

DART Expansion - Stage 2 Modelling Outputs – Bundle 2 Variations



	Full DART Exp w Full Metro	Full DART Expansion (with Grade Separated junction at East Wall) with Full Metro	Full DART Expansion (Heuston Portal) with Full Metro	Full DART Exp w Full Metro (Heuston Portal - Inchicore Station Retained)
Benefits (€000)	7,560,990	7,605,363	7,335,806	7,560,990
Present Value of Costs (€000)	3,215,209	3,340,156	2,998,812	3,033,363
BCR	2.35	2.28	2.45	2.49

DART Expansion - Stage 2 Modelling Outputs – Bundle 2 Variations

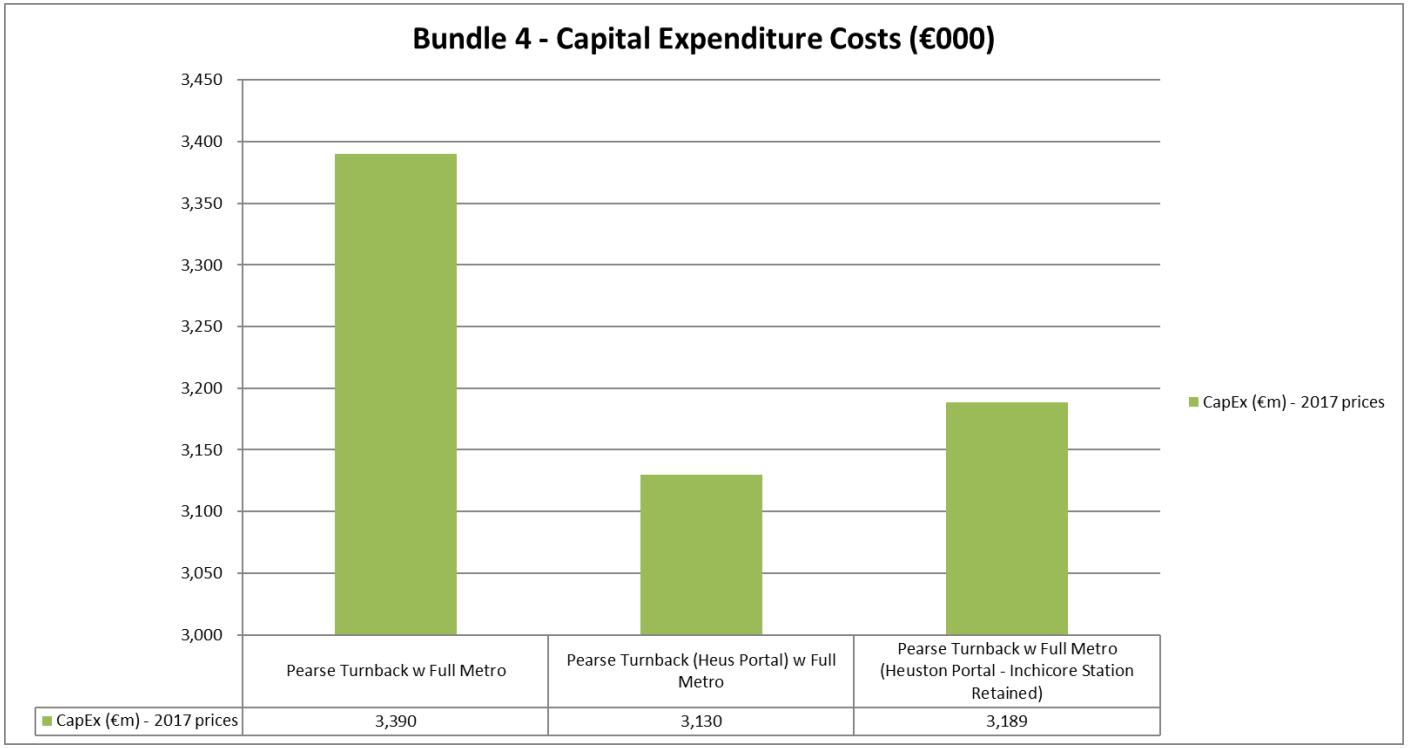
Outcomes and Recommendations

- As expected Heuston Portal delivers an increased BCR
  - To be balanced against the effects of tunnelling at the existing Heuston terminus
- Overground Station at Inchicore should be retained
- Grade separated junction at East Wall does not deliver value for money

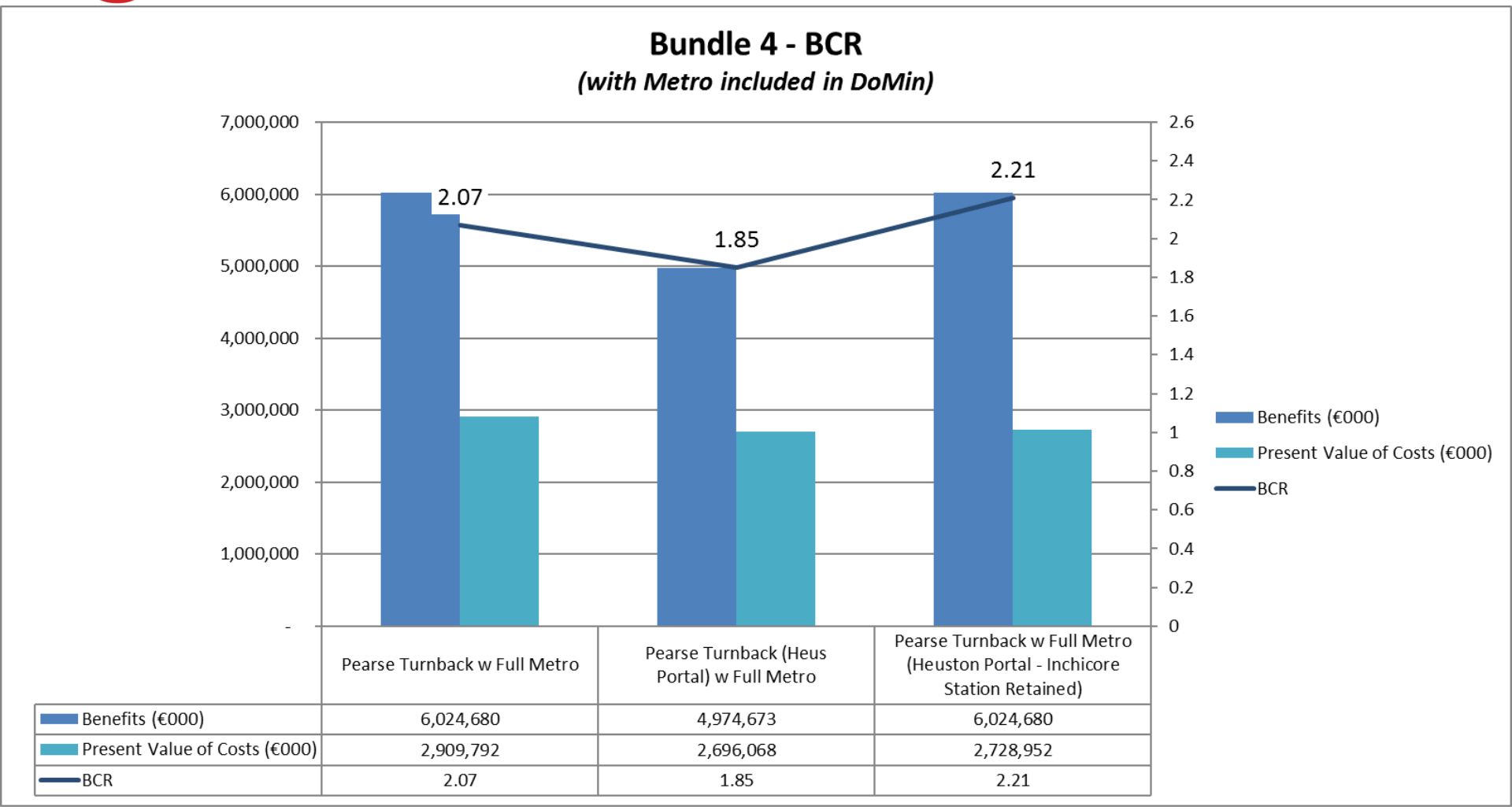
DART Expansion - Stage 2 Modelling Outputs – Bundle 4 Variations

As with Bundle 2, there are a number of variations to the Pearse turnback option:

- **Western tunnel portal at Heuston instead of Inchicore**
  - **Requires 4-tracking to Heuston**
  - **Savings in tunnelling costs**
  - **With or without Inchicore stations**



DART Expansion - Stage 2 Modelling Outputs – Bundle 4 Variations



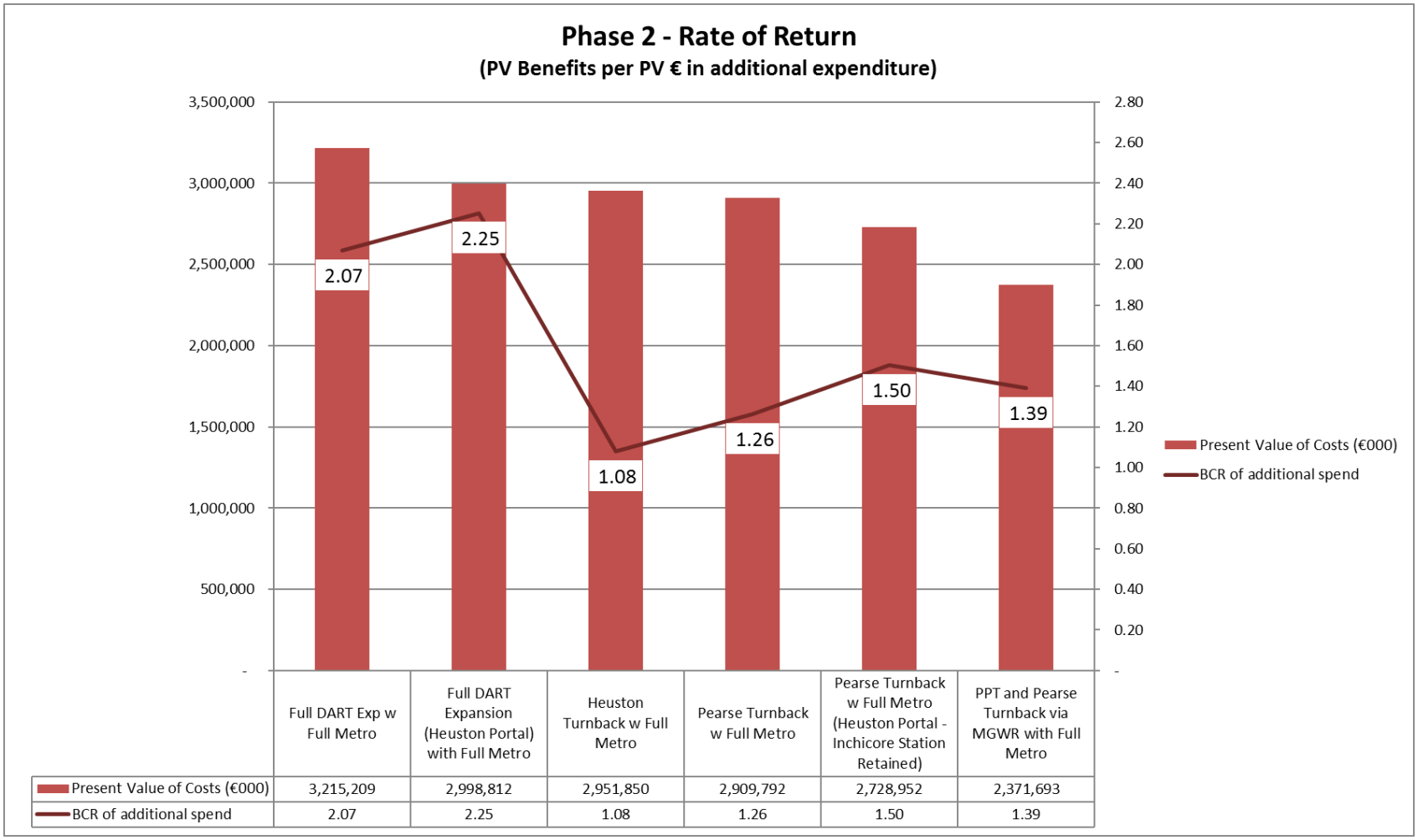
	Pearse Turnback w Full Metro	Pearse Turnback (Heus Portal) w Full Metro	Pearse Turnback w Full Metro (Heuston Portal - Inchicore Station Retained)
Benefits (€000)	6,024,680	4,974,673	6,024,680
Present Value of Costs (€000)	2,909,792	2,696,068	2,728,952
BCR	2.07	1.85	2.21

DART Expansion - Stage 2 Modelling Outputs – Bundle 4 Variations

Outcomes and Recommendations

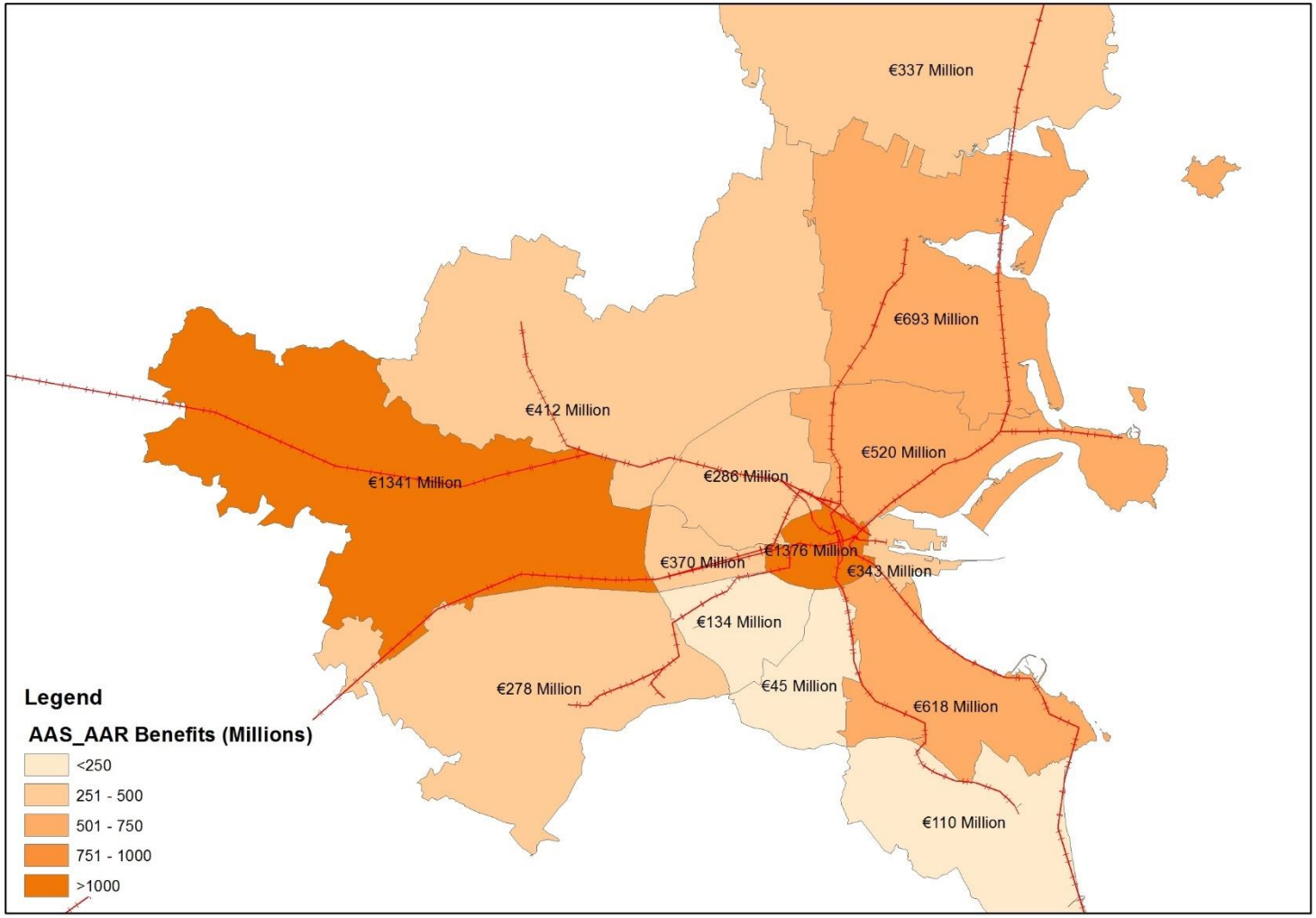
- As expected Heuston Portal delivers an increased BCR
- Overground Station at Inchicore should be retained
  - Pearse turnback does not perform well with Inchicore station removed

DART Expansion - Stage 2 Modelling Outputs –Return on expenditure above No Tunnel Option

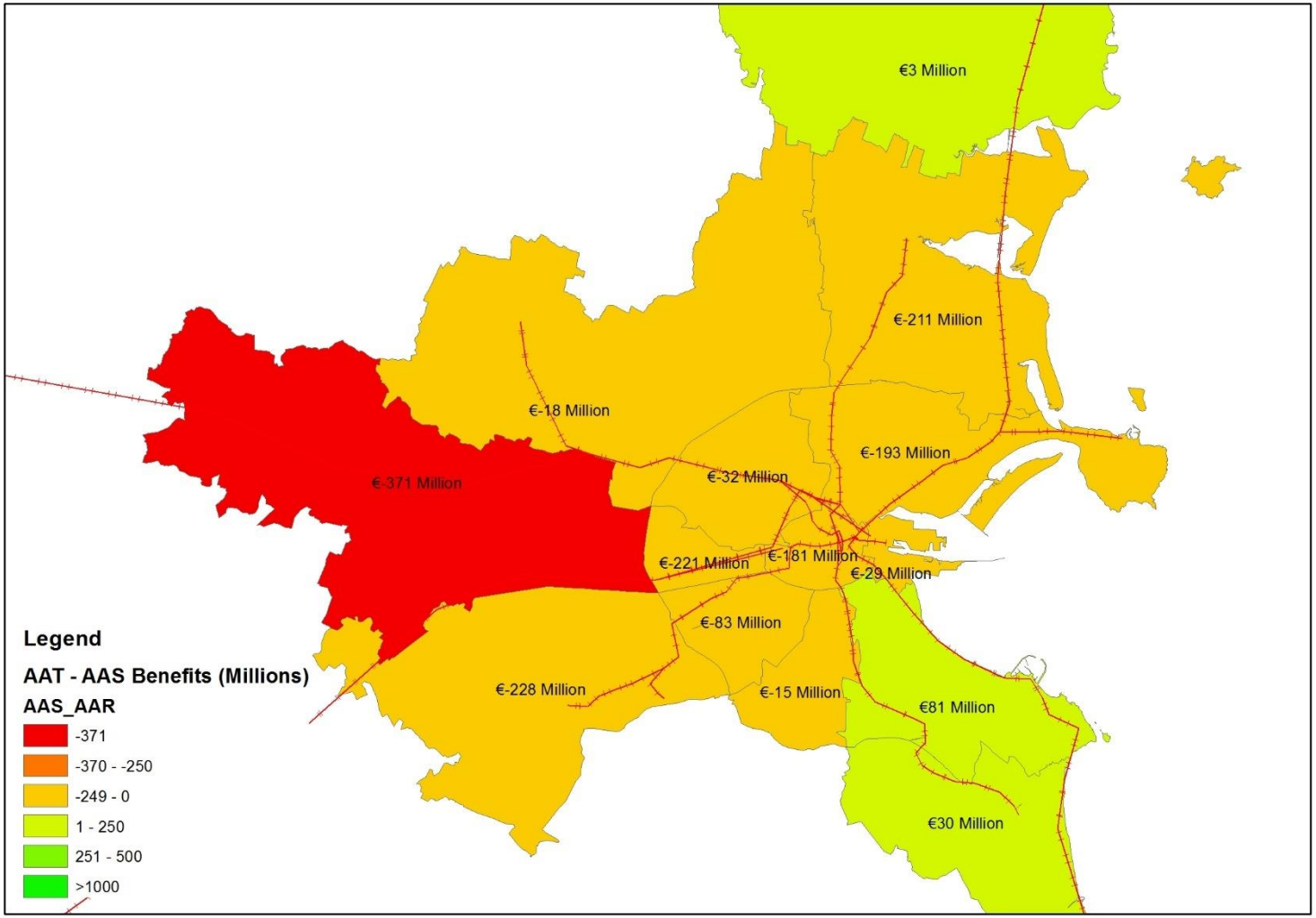


	Full DART Exp w Full Metro	Full DART Expansion (Heuston Portal) with Full Metro	Heuston Turnback w Full Metro	Pearse Turnback w Full Metro	Pearse Turnback w Full Metro (Heuston Portal - Inchicore Station Retained)	PPT and Pearse Turnback via MGWR with Full Metro
Present Value of Costs (€000)	3,215,209	2,998,812	2,951,850	2,909,792	2,728,952	2,371,693
BCR of additional spend	2.07	2.25	1.08	1.26	1.50	1.39

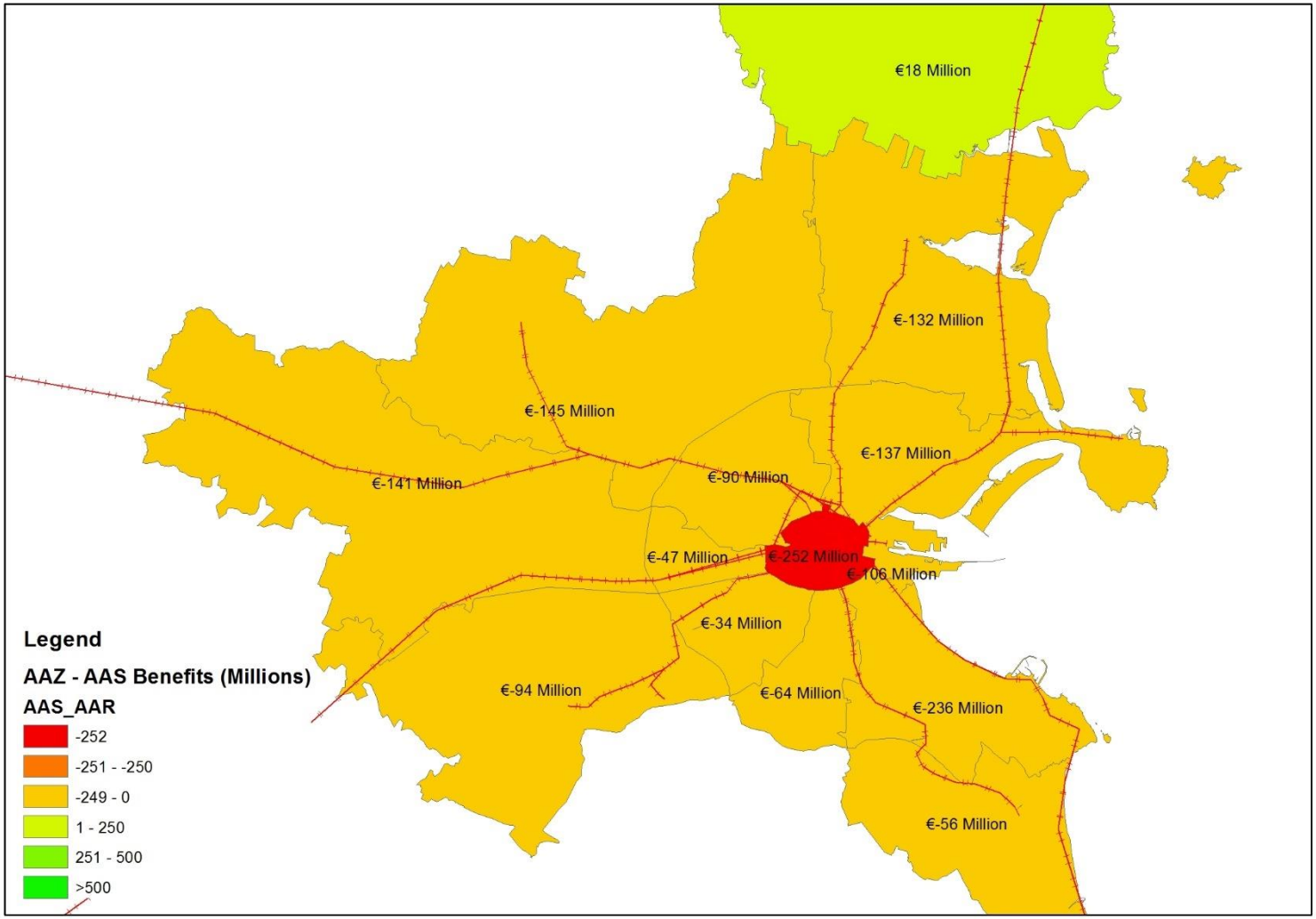
Geographical Distribution of User Benefits
- Full DART Expansion vs DoMin with Full Metro



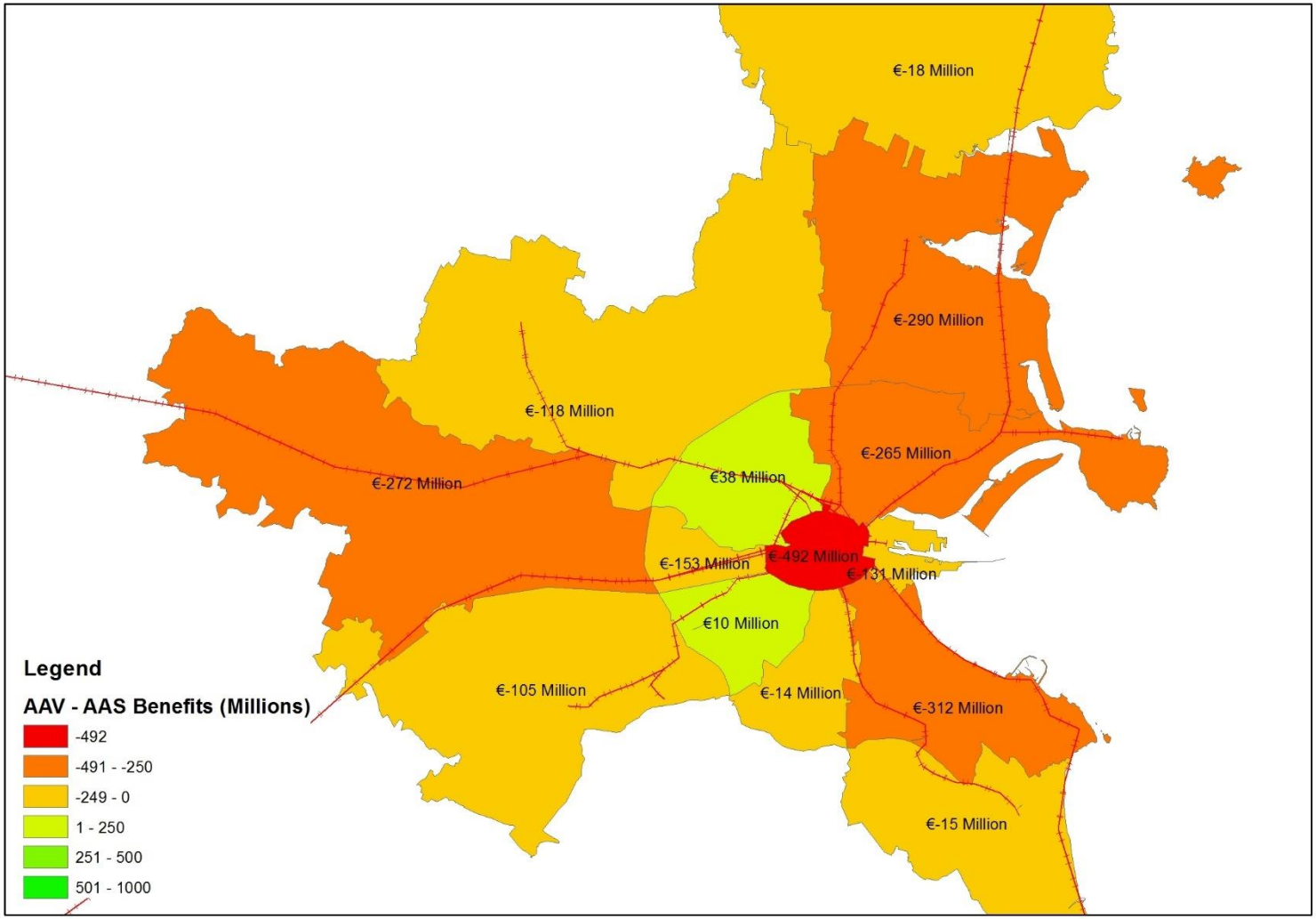
Geographical Distribution of User Benefits - Heuston Turnback vs Full DART Expansion



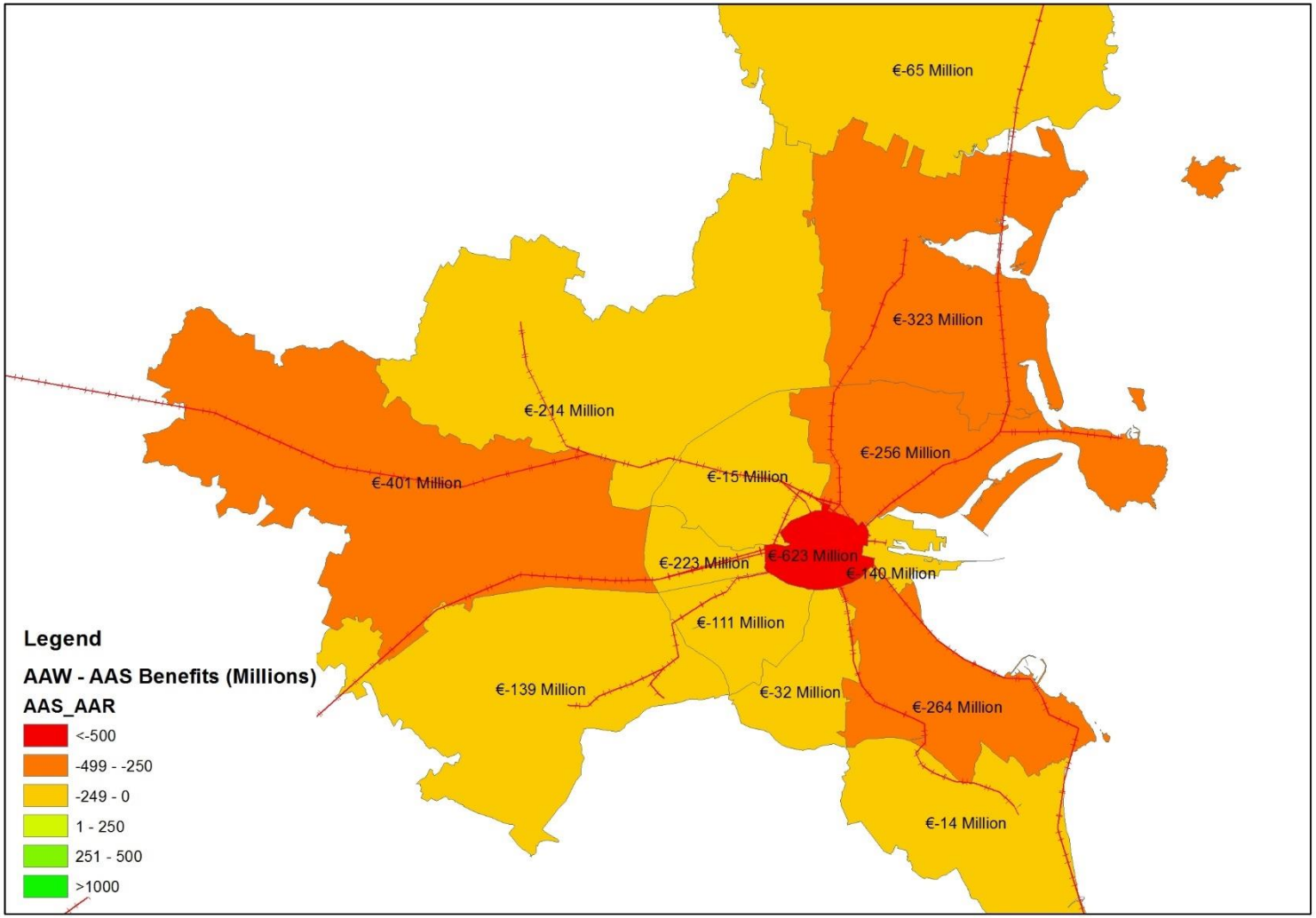
Geographical Distribution of User Benefits - Pearse Turnback vs Full DART Expansion



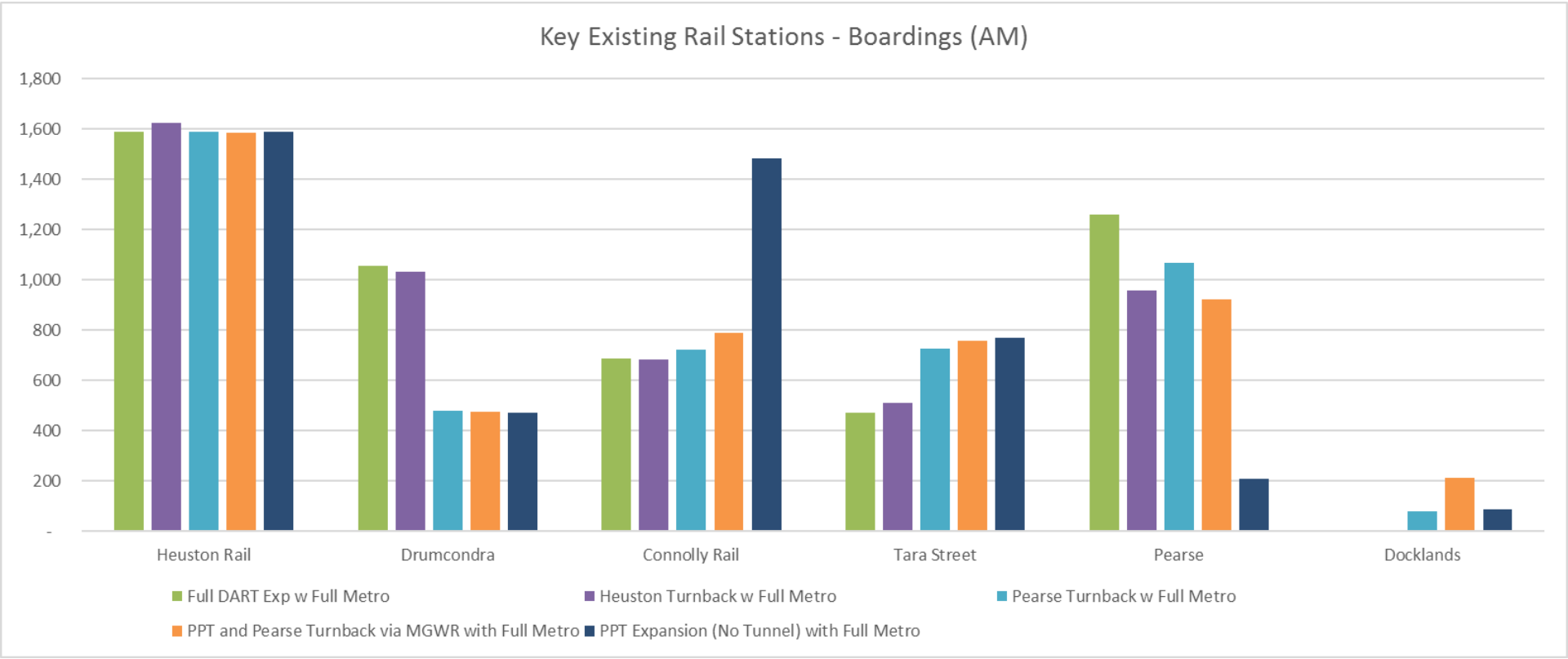
Geographical Distribution of User Benefits
- PPT and Pearse Turnback vs Full DART Expansion



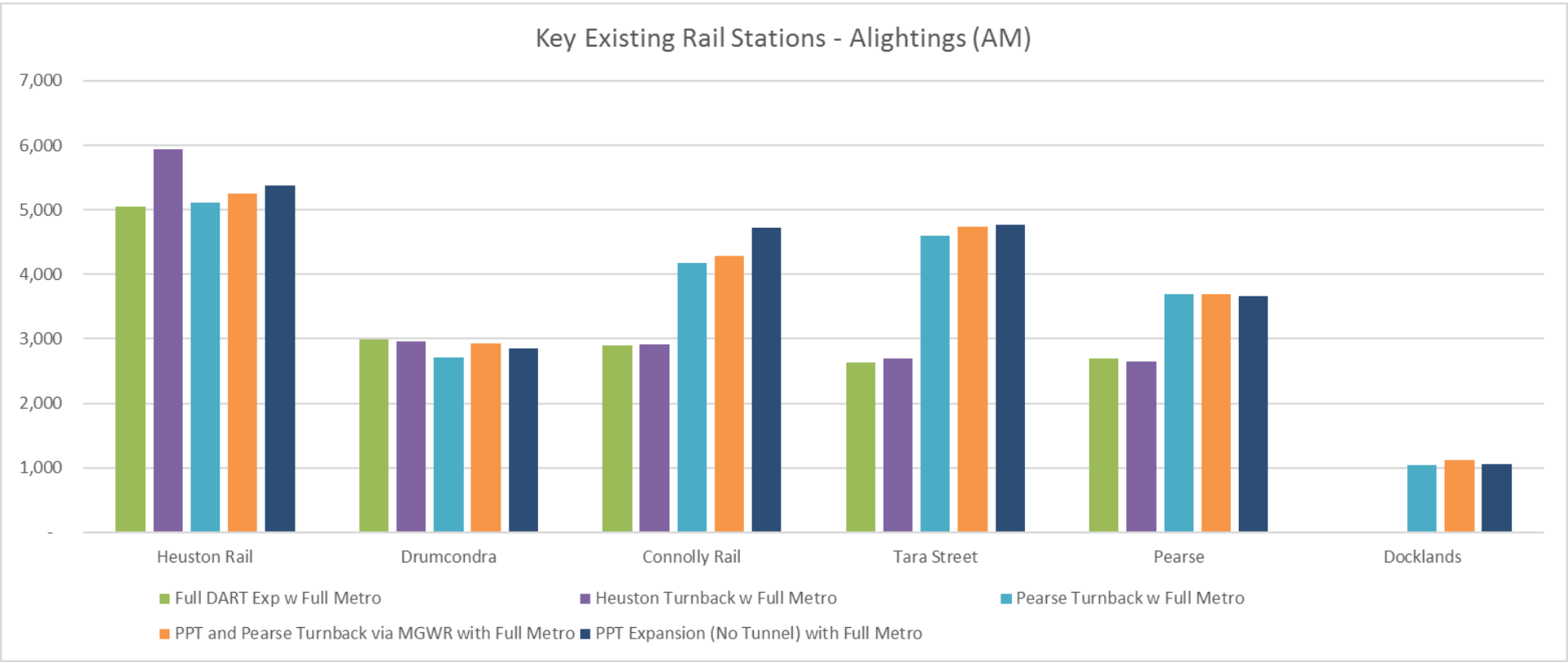
Geographical Distribution of User Benefits - PPT Exp. (No Tunnel) vs Full DART Expansion



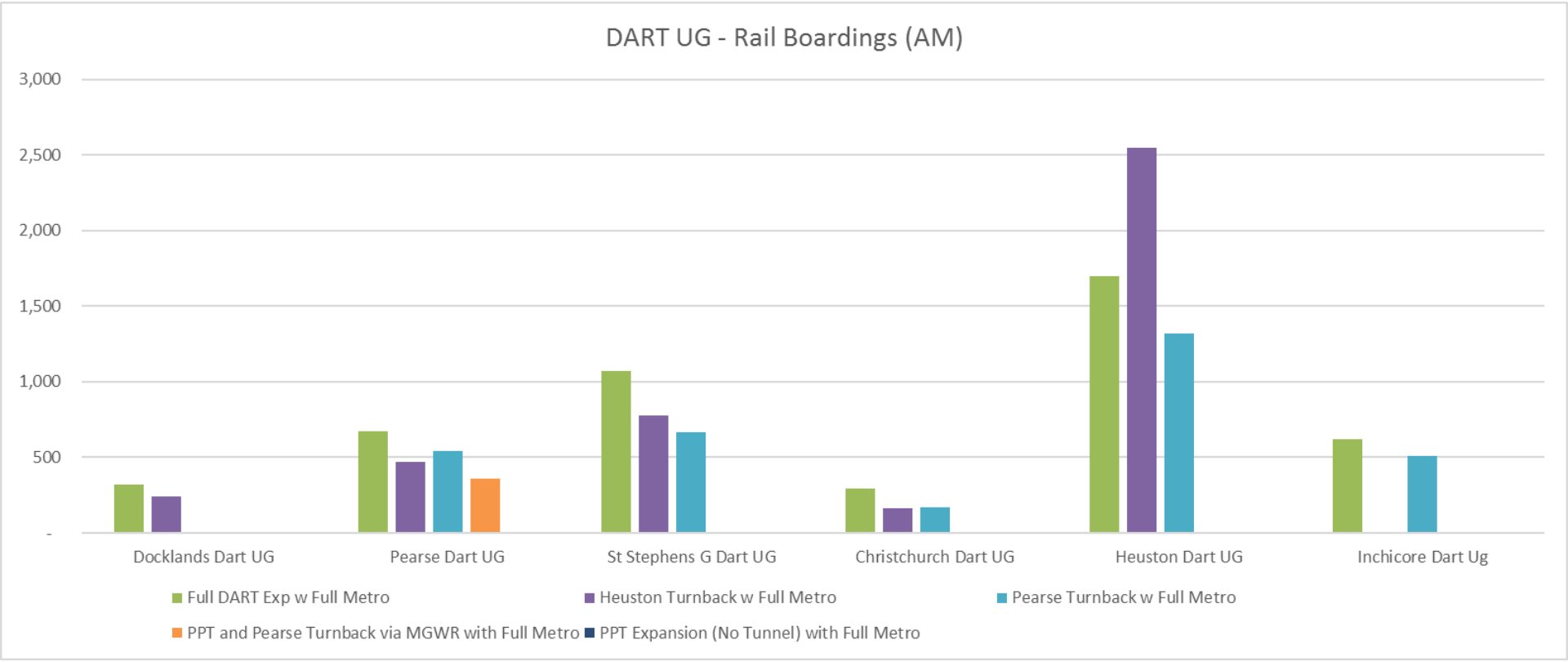
Key Station Analysis – Existing Stations



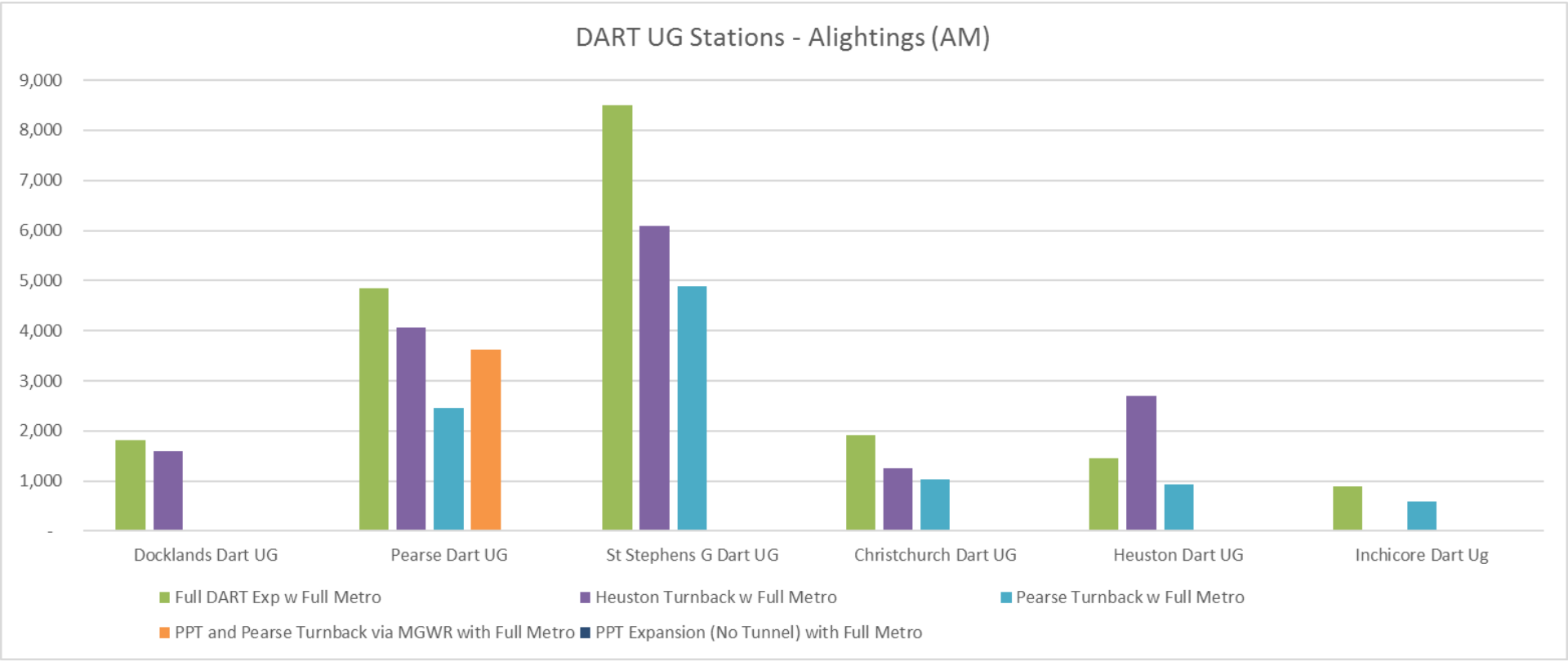
Key Station Analysis – Existing Stations



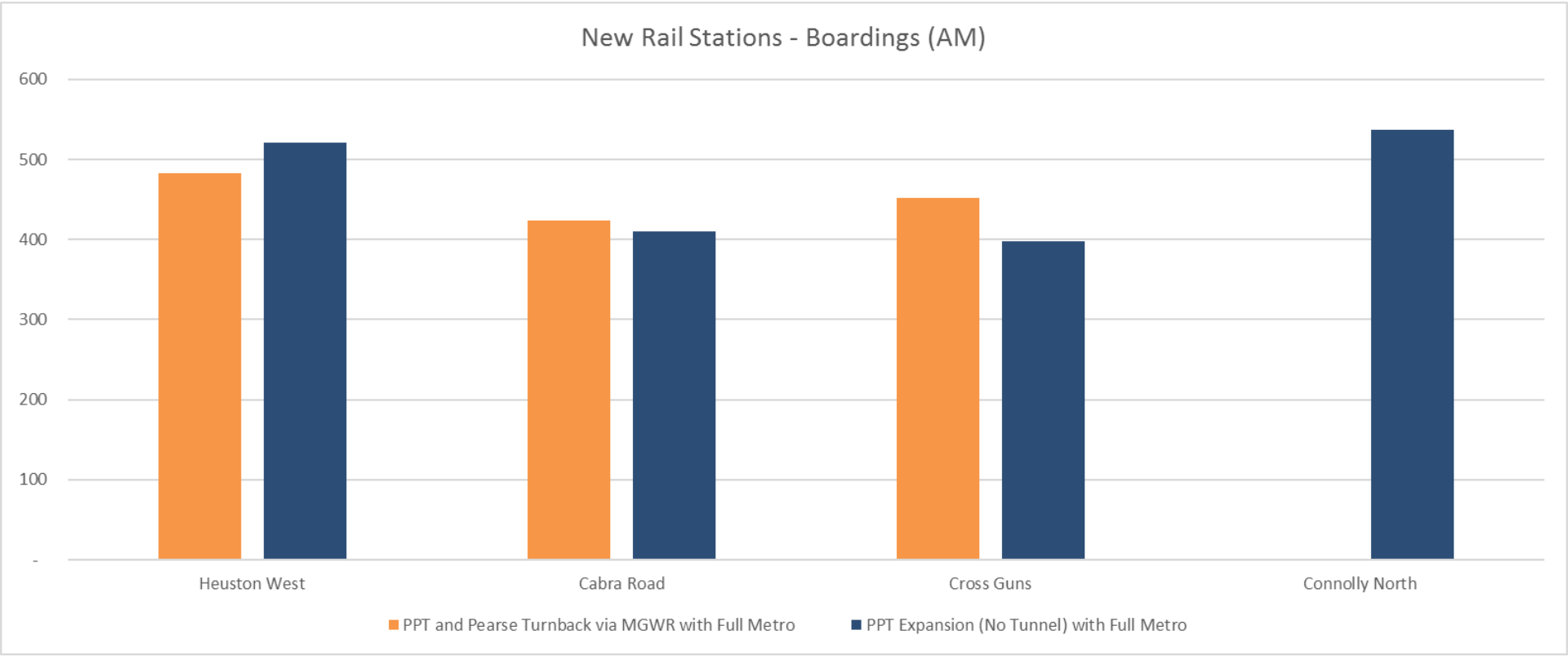
Key Station Analysis – Underground Stations



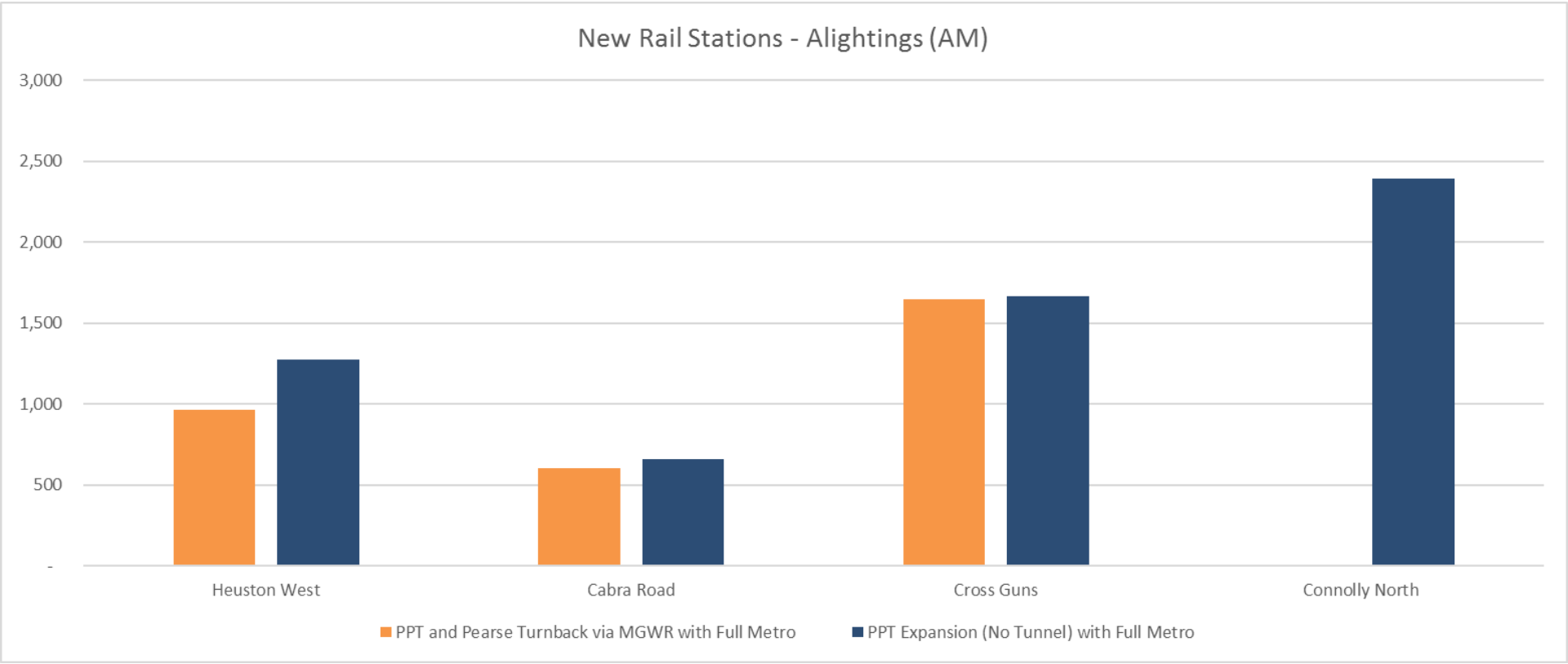
Key Station Analysis – Underground Stations



Key Station Analysis – New Overground Stations



Key Station Analysis – New Overground Stations



Key Station Analysis – Bundle 6 Station Transfers

Transfer at Heuston - Bundle 6

	Heuston Rail	Heuston Luas	Heuston Dart UG	Heuston West	Other (Bus)
Heuston Rail		1,459	0	372	2,095
Heuston Luas	752		0	24	239
Heuston Dart UG	0	0		0	0
Heuston West	198	137	0		251
Other (Bus)	494	468	0	29	

6,518

Transfer at Drumcondra - Bundle 6

		To		
		99099	*99635*	
From		Drumcondra	Drumcondra (Metro)	Other (Bus)
99099	Drumcondra		1,808	131
99635	Drumcondra (Metro)	303		258
	Other (Bus)	47	892	

3,439

Transfer at Connolly - Bundle 6

		To		
		99100	*99417*	
From		Connolly Rail	Connolly North	Other (Bus)
99100	Connolly Rail		300	821
99417	Connolly North	750		314
	Other (Bus)	274	91	

2,551

SYSTRA

Appendix H
DART Expansion Project – Stage 3 - Model Outputs Summary

SYSTRA

DART Expansion - Stage 3 Modelling

Bundle 6 - DART Expansion No Tunnel option

- **No Dart Underground**
- **Phoenix Park Tunnel (PPT)** – Line to be electrified with improved running times
- **Maynooth Line** – Electrified and level crossings removed
- **4-tracking** to Heuston Station
- **New High Capacity Docklands Station**
  - **Access provided from Maynooth line via Newcomen Junction**
  - **Access provided from PPT Line via North Strand Junction**
  - **Access provided from Northern Line via East Wall junction**
- **New Rail Stations to be provided at:**
  - **Heuston West** – PPT services to stop at Heuston platform 10;
  - **Cabra Rail station** on the Phoenix Park Tunnel line;
  - **Glasnevin** allowing transfer between the PPT and Maynooth lines and also interchange with Metro services
- **Full Metro** included as per the NMN Emerging Preferred Route at 3min Peak headways, 6min Inter-peak

Bundle 6 – PPT Expansion – No Tunnel Option

- **Requirement** to understand the most appropriate balance of services to terminate at either Connolly or Docklands (reconfigured), or to proceed over the Loop-line bridge
- **Three different combinations of services have been tested**
  - Terminating capacity of Docklands, Connolly and the loop-line bridge capacity has been held constant in each option but with the allocation of services from each of the 3 corridors varying
- These model runs provide an understanding of the **maximum benefits** that can be derived from the Bundle 6 option

Bundle 6 – PPT Expansion – No Tunnel Option

- **Connolly** Terminating Capacity Assumed to be 12
  - **Reduced from 17 in previous Bundle 6 options which was considered unfeasible**
- Reconfigured **Docklands Station** terminating capacity assumed to be 18
- **Loopline Bridge** Capacity maintained at 18 TPDPH

		Test 1			Test 2			Test 3		
Corridor	***TOTAL per Test***	Connolly	Docklands	Loop-line Br.	Connolly	Docklands	Loop-line Br.	Connolly	Docklands	Loop-line Br.
Phoenix Park Tunnel	***16***	5	8	3	5	7	4	6	7	5
Northern Line	***16***	2	2	12	3	3	10	4	4	8
Maynooth Line	***16***	5	8	3	4	8	4	4	7	5
TOTAL	***48***	***12***	***18***	***18***	***12***	***18***	***18***	***12***	***18***	***18***

Bundle 6 – Performance Summary Sheet

KPI	Bundle 6 - PPT Expansion - Test 1	Bundle 6 - PPT Expansion - Test 2	Bundle 6 - PPT Expansion - Test 3
Mode Share (PT)	21.90%	22.00%	22.00%
PT Boardings	174,200	173,800	173,600
Rail	55,000	54,600	54,000
Bus	67,400	67,200	67,800
LRT	12,800	12,800	12,900
Metro	39,000	39,100	38,900
PT Transfers	35,100	34,900	34,700
Cap Ex Costs (€m)	1,896	1,896	1,896
O&M Costs (€m)	51	51	51
Transport User Benefits (€m)	3,820	3,630	3,600
Present Value of Costs (€m)	1,543	1,545	1,546
BCR	2.47	2.35	2.33

Bundle 6 Comparison of Service Plan Tests - Conclusions

- **Test 1** is the best performing in terms of service patterns and is brought forward for Comparison with **Bundle 2**
- Higher overall Rail boardings and highest in Transport User benefits
- Confirms that **Loopline Bridge** capacity should be weighted in favour of the Northern line
- Could be increased to 14 Northern line trains, and 2 each for Maynooth and PPT Corridors?

	Test 1		
Corridor	Connolly	Docklands	Loop-line Br.
Phoenix Park Tunnel	5	8	3
Northern Line	2	2	12
Maynooth Line	5	8	3
TOTAL	***12***	***18***	***18***

Bundle 2 vs Bundle 6 – Performance Summary Sheet

KPI	Bundle 2 - Full DART Expansion	Bundle 6 - PPT Expansion	Difference
Mode Share (PT)	22.20%	21.90%	-0.30%
PT Boardings	174,800	174,200	- 600
Rail	62,800	55,000	- 7,800
Bus	63,300	67,400	4,100
LRT	10,900	12,800	1,900
Metro	37,800	39,000	1,200
PT Transfers	34,000	35,100	1,100
Cap Ex Costs (€m)	3,506	1,896	- 1,610
O&M Costs (€m)	88	51	- 37
Transport User Benefits (€m)	5,500	3,820	- 1,680
Present Value of Costs (€m)	3,050	1,543	- 1,507
BCR	1.82	2.47	0.7

Comparison of Bundle 6 vs Bundle 2 - Cost Estimates

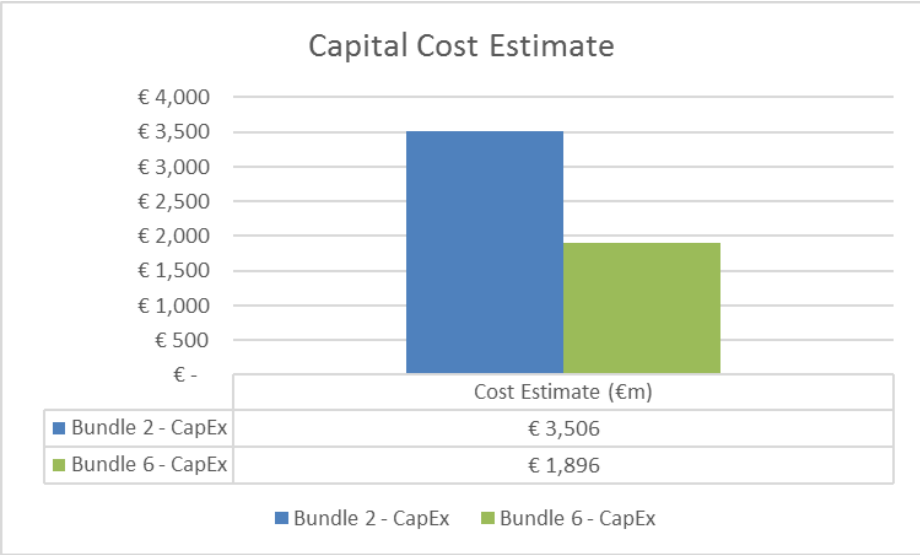
Bundle 6 Outline Cost Estimates:

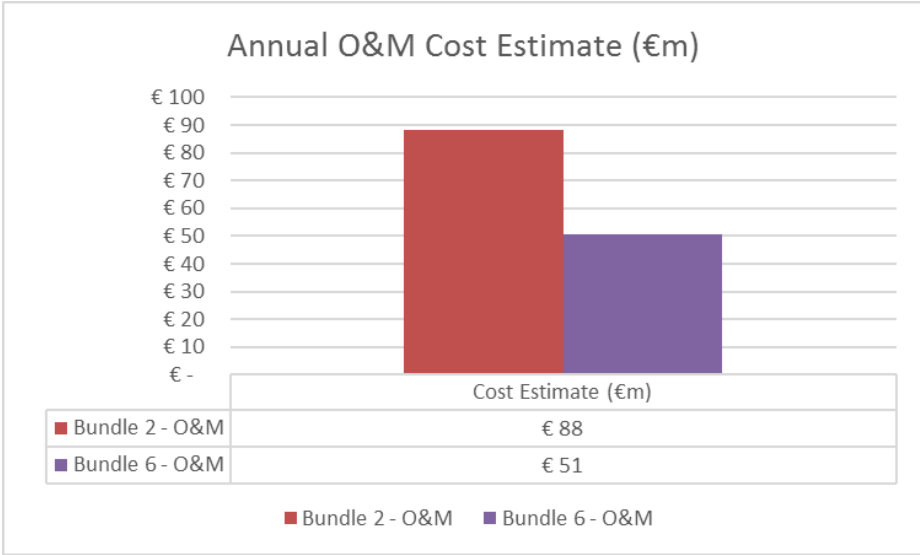
- DART Expansion Elements as per Bundle 2 - €720m
- KRP3 – 4-Tracking to Heuston - €92m

Jacobs 'Ball Park' Cost Estimates for additional Bundle 6 elements

- New Docklands Station – €100m
- PPT and Connolly Re-signalling - €50m
- Newcomen Canal Drop-Lock - €10m
- Connolly Station elements – €100m
- Glasnevin Station – €40m
- Cabra and Glasnevin Stations – €40m combined
- DART South Line Turnback - €75m

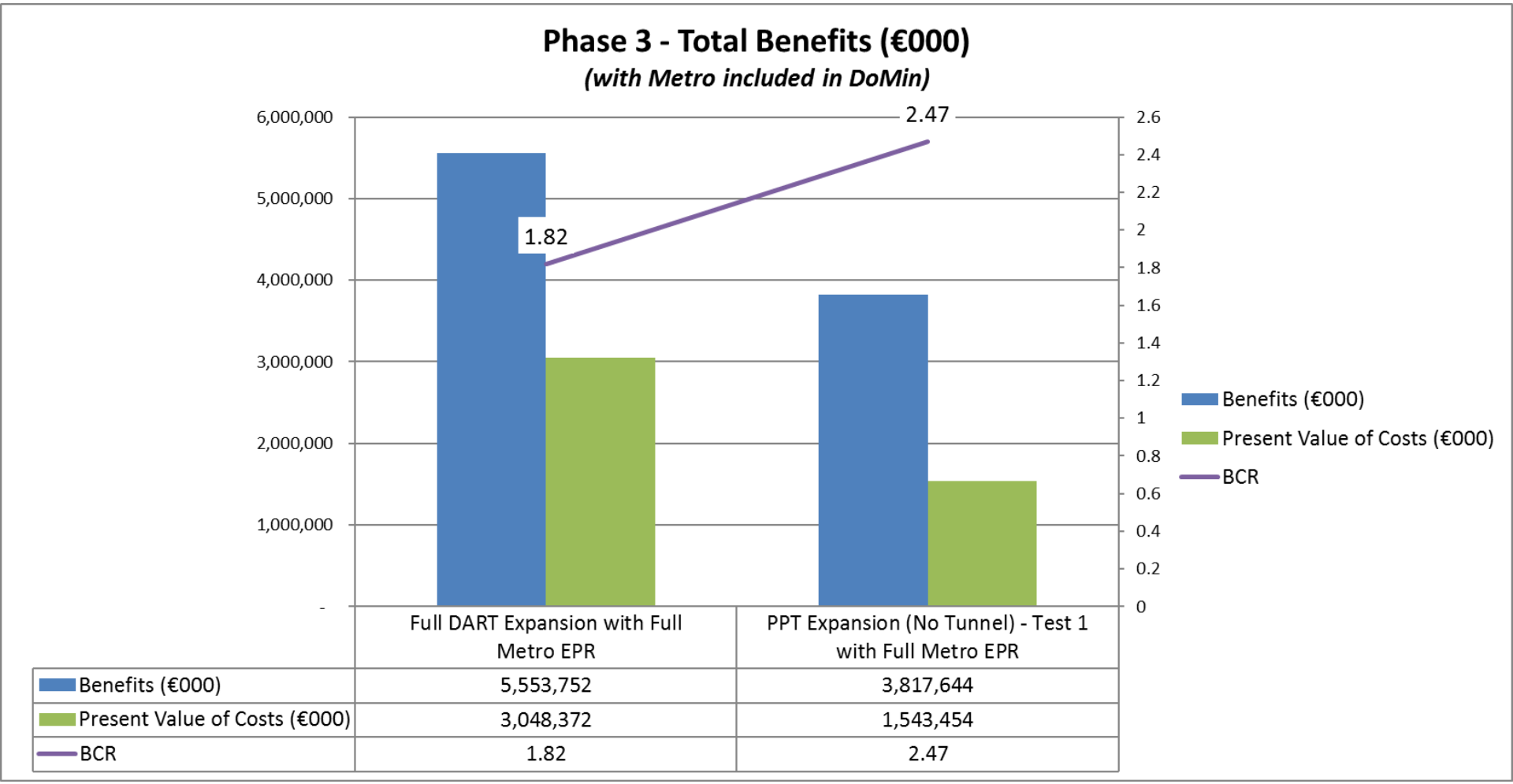
Comparison of Bundle 6 vs Bundle 2 - Cost Estimates





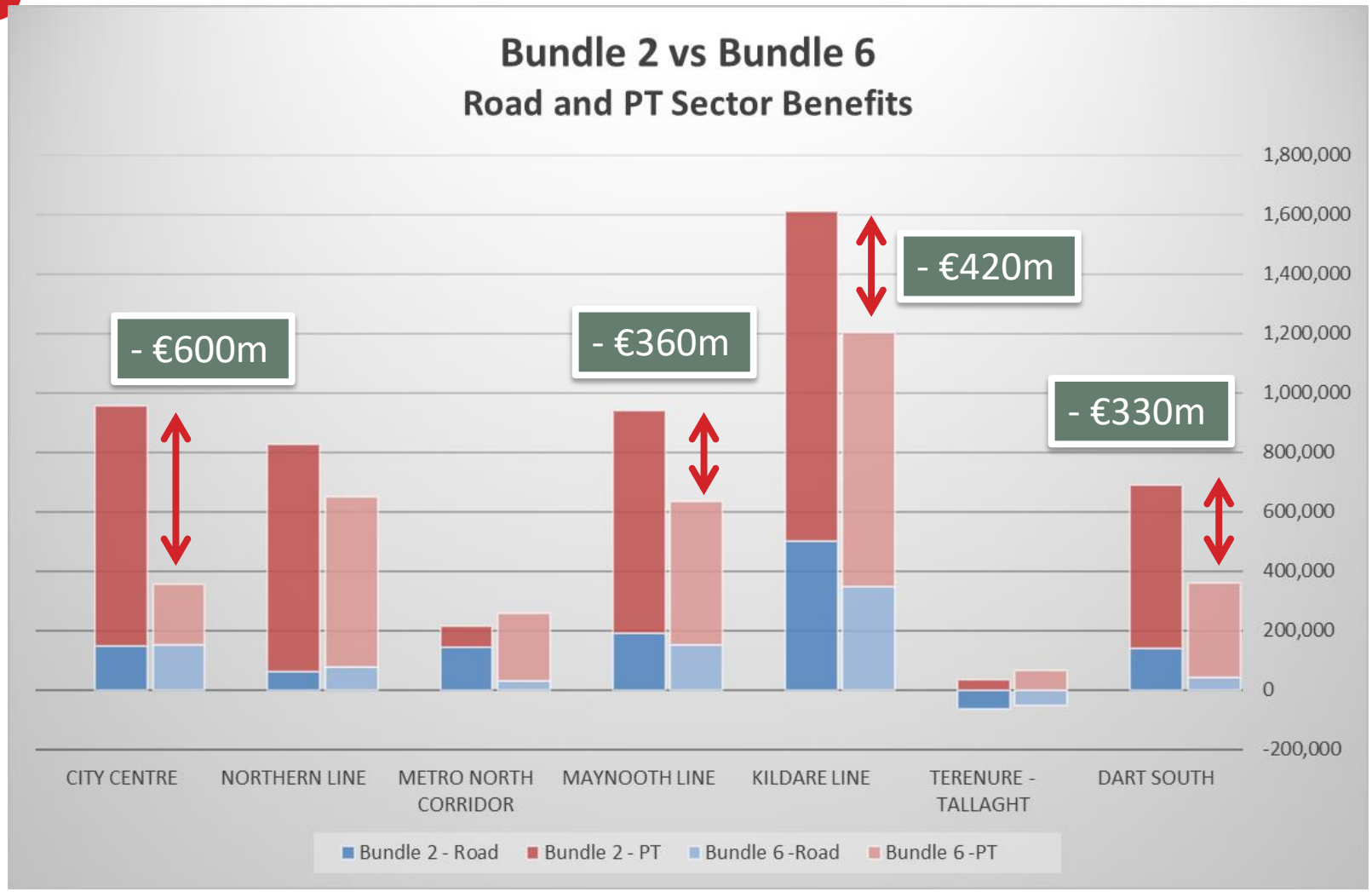
- The same Fleet Requirements are assumed in both options
  - 296 EMU's
  - Cost - €547.6m

Comparison of Bundle 6 vs Bundle 2 - Economic Appraisal – BCR



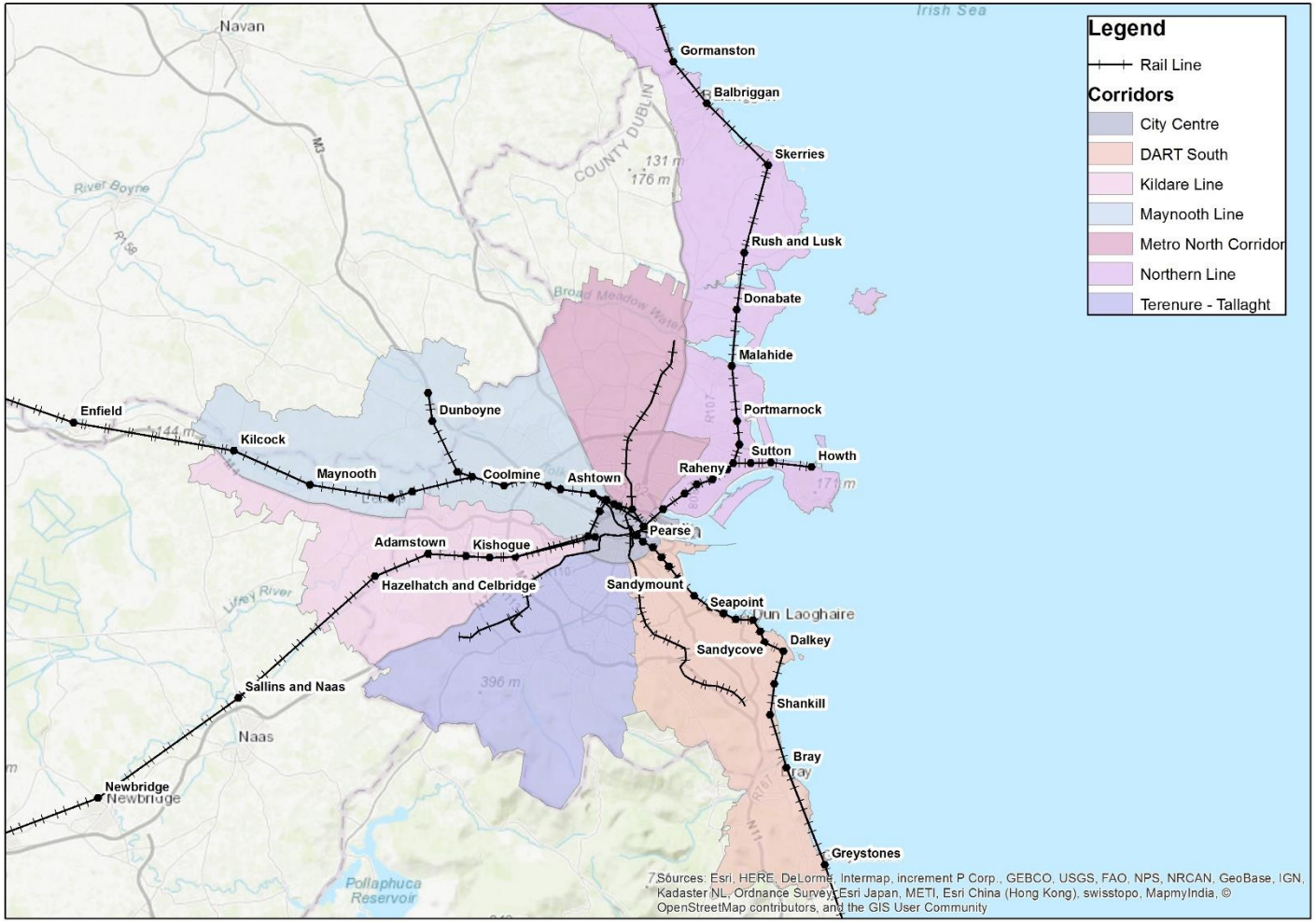
	Full DART Expansion with Full Metro EPR	PPT Expansion (No Tunnel) - Test 1 with Full Metro EPR
Benefits (€000)	5,553,752	3,817,644
Present Value of Costs (€000)	3,048,372	1,543,454
BCR	1.82	2.47

Comparison of Bundle 6 vs Bundle 2
- Economic Appraisal – Benefits

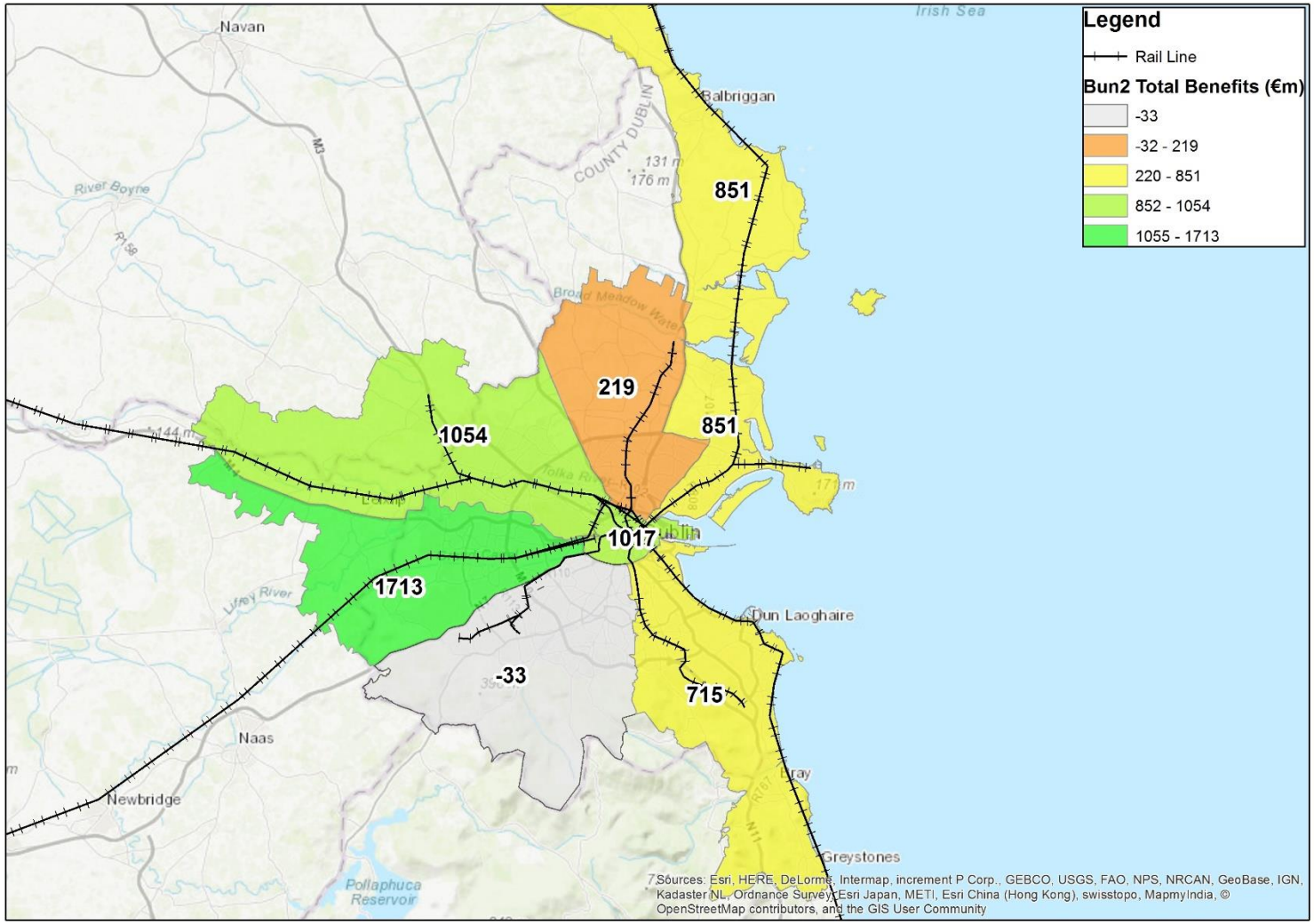


Sector System to align with Rail / Metro Corridors

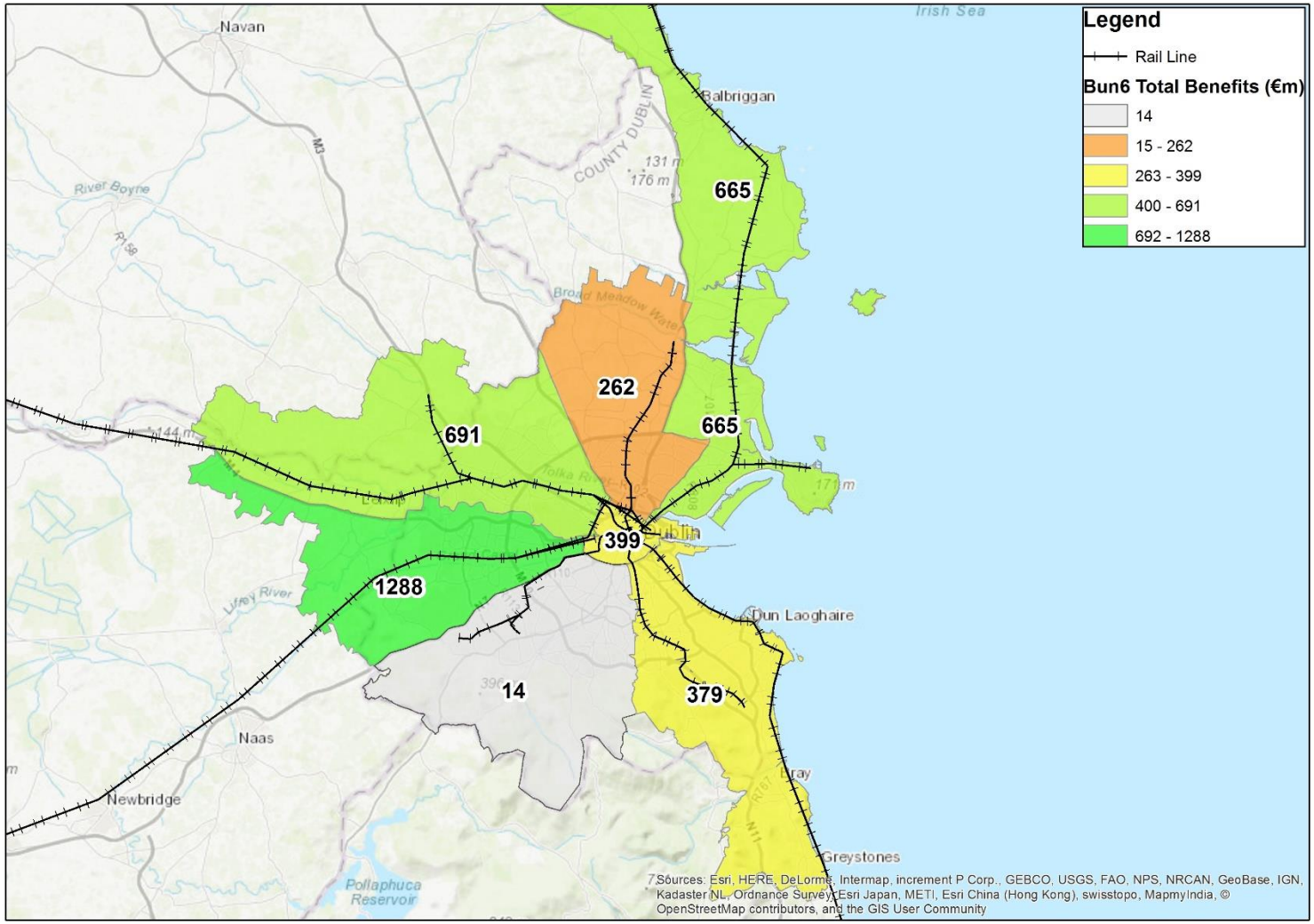
- **Corridor System** developed to align with the Rail / Metro and Luas Corridors
- Allows for geographical assessment of Bundle performance



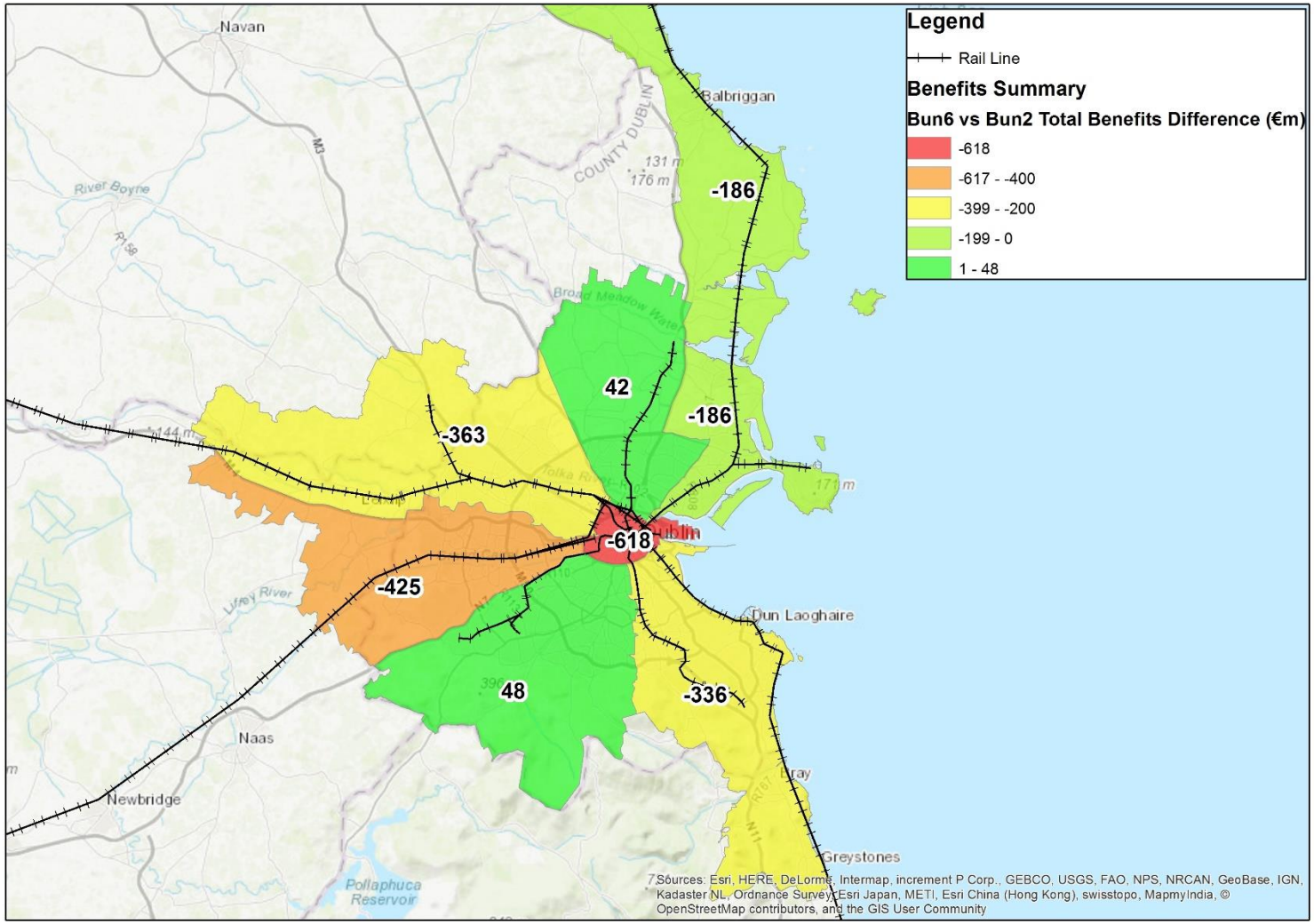
Comparison of Bundle 6 vs Bundle 2
- Economic Appraisal – Bundle 2 Benefits



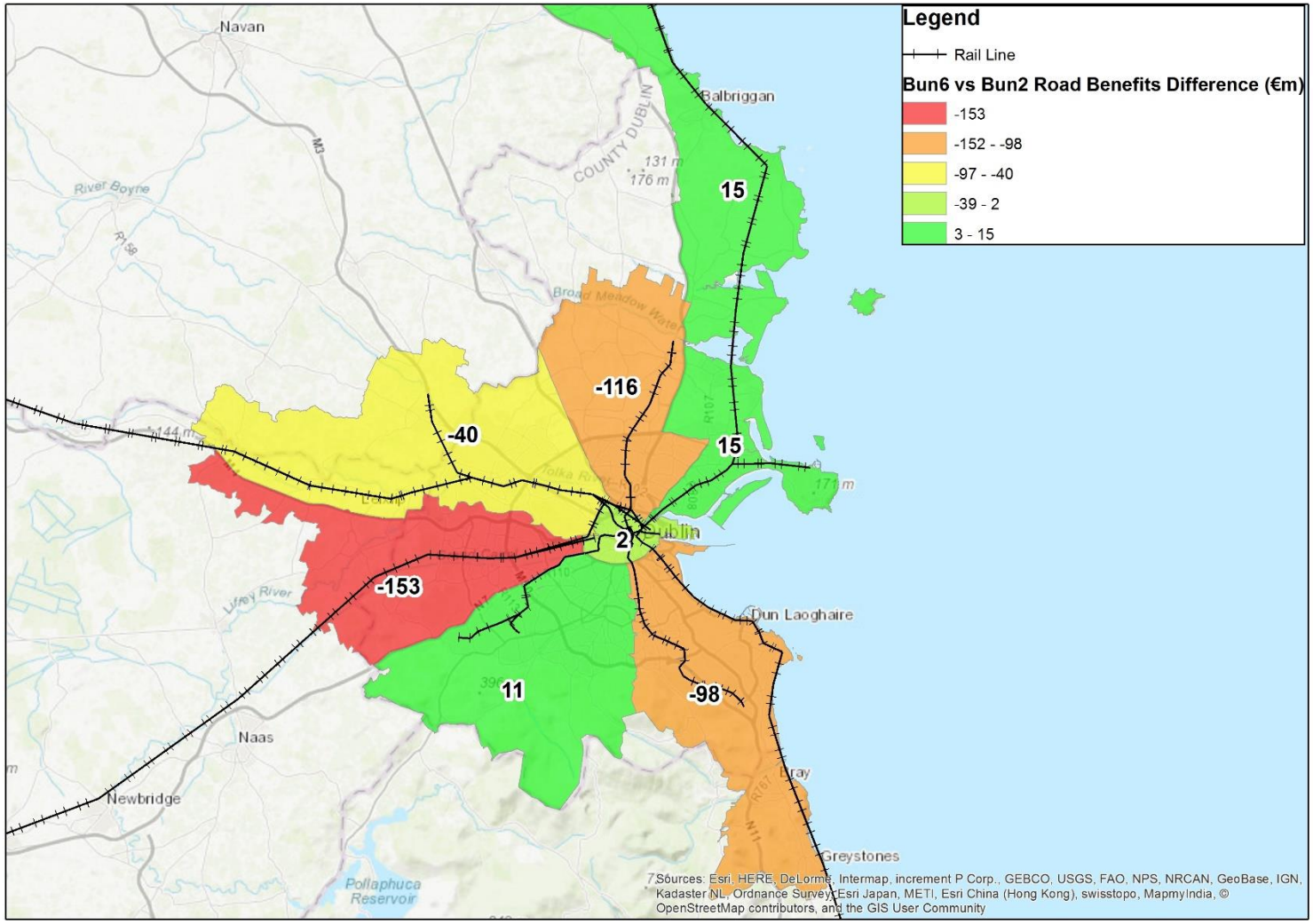
Comparison of Bundle 6 vs Bundle 2
- Economic Appraisal – Bundle 6 Benefits



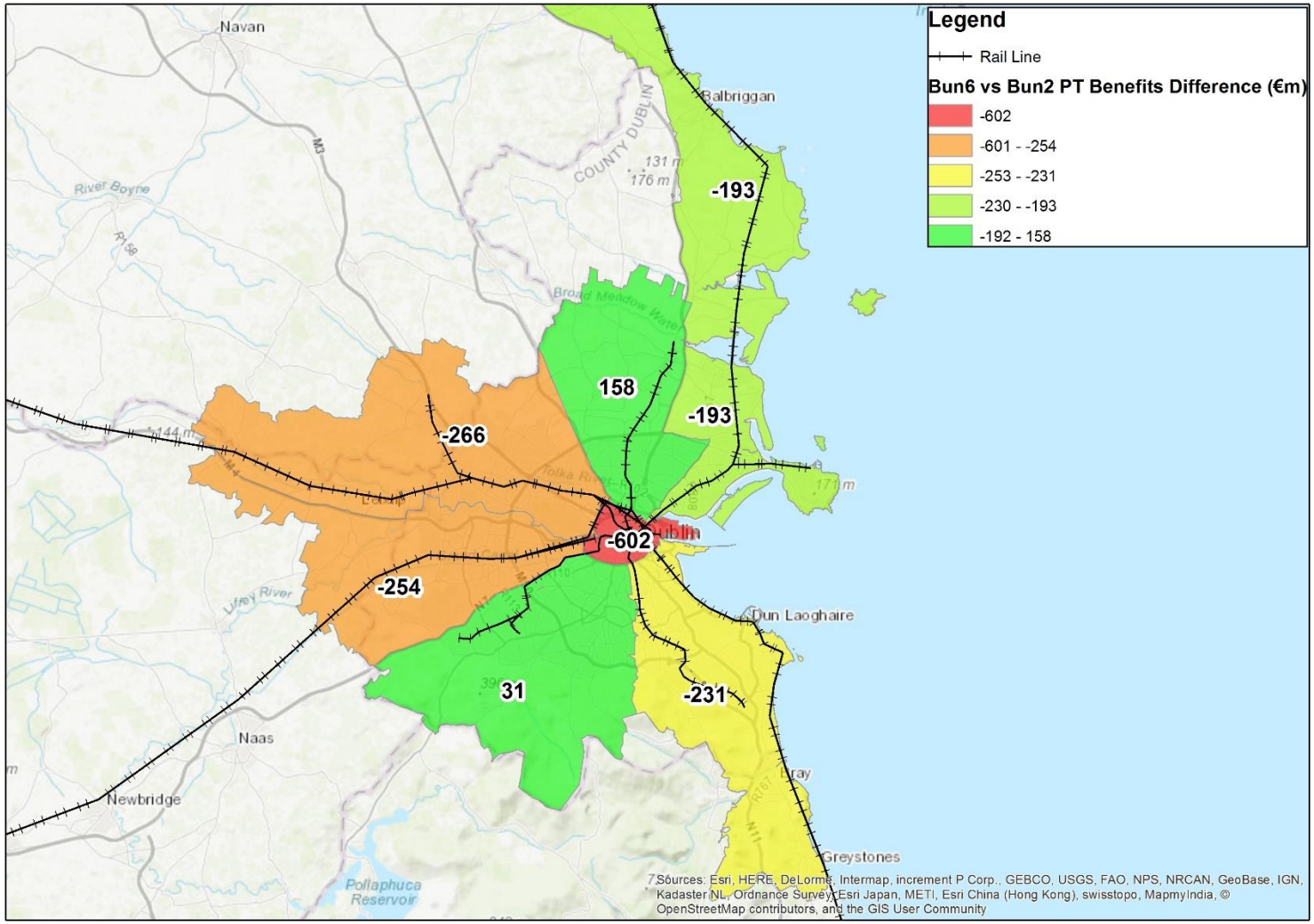
Comparison of Bundle 6 vs Bundle 2
- Economic Appraisal – Total Benefits Difference



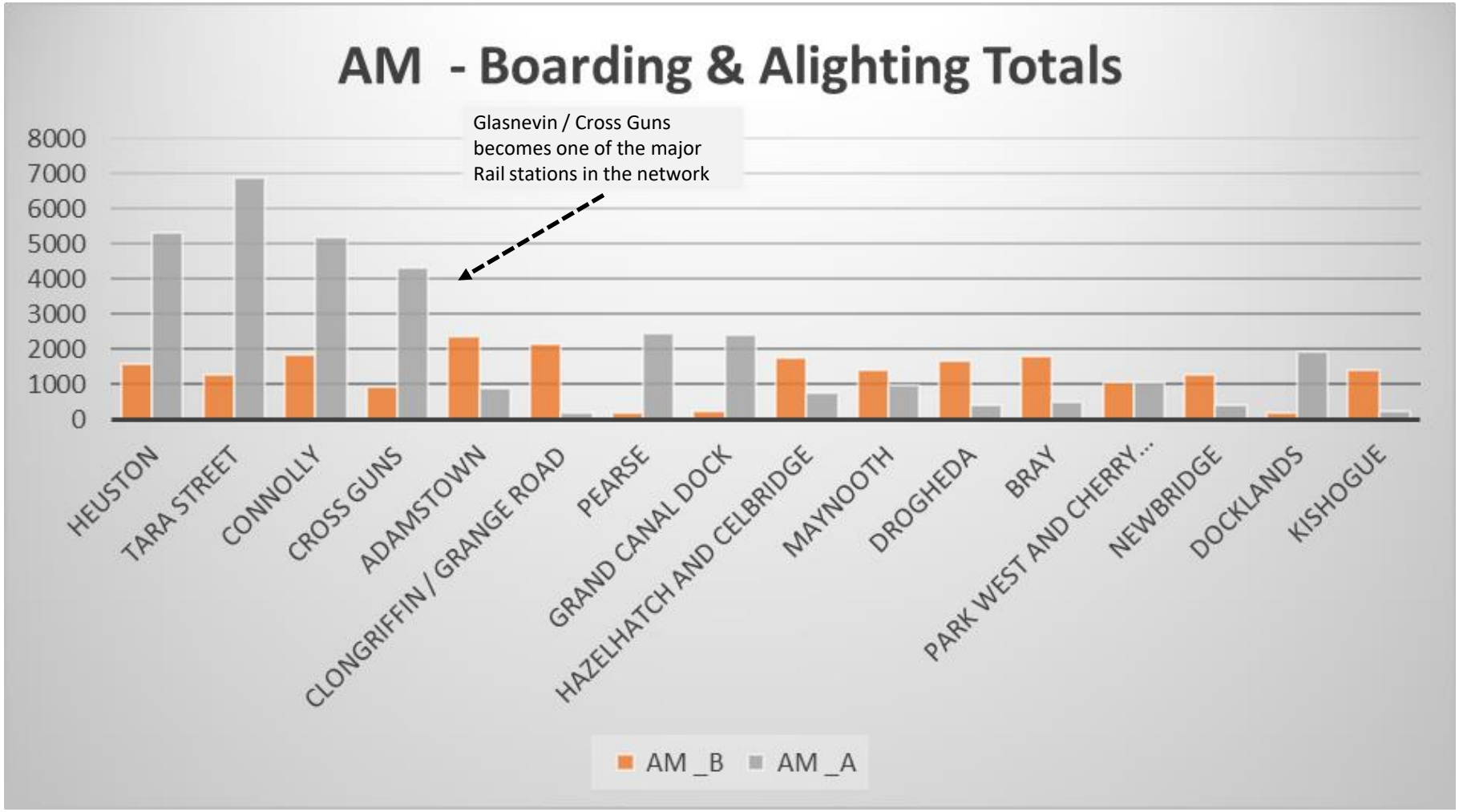
Comparison of Bundle 6 vs Bundle 2
- Economic Appraisal – Road Benefits Difference



Comparison of Bundle 6 vs Bundle 2
- Economic Appraisal – PT Benefits Difference



Bundle 6 – PPT Expansion
- Key Station Boardings



Key Station Analysis – Bundle 6

What are the **transfer** levels at key stations in the network?

Glasnevin Stations

- Major transfer between Rail and Metro at Glasnevin

Transfer at Glasnevin

	Whitworth (Metro)	Glasnevin (Rail)	Other (Bus)
Whitworth (Metro)		382	175
Glasnevin (Rail)	2,603		140
Other (Bus)	926	101	

4,327

Heuston Stations

- Predominant transfer is between Rail and Luas at Heuston

Transfer at Heuston

	Heuston Rail	Heuston Luas	Heuston West	Other (Bus)
Heuston Rail		1,395	368	2,110
Heuston Luas	592		20	236
Heuston West	235	79		38
Other (Bus)	581	479	18	

6,150

Key Station Analysis– Bundle 6

What are the **transfer** levels at key stations in the network?

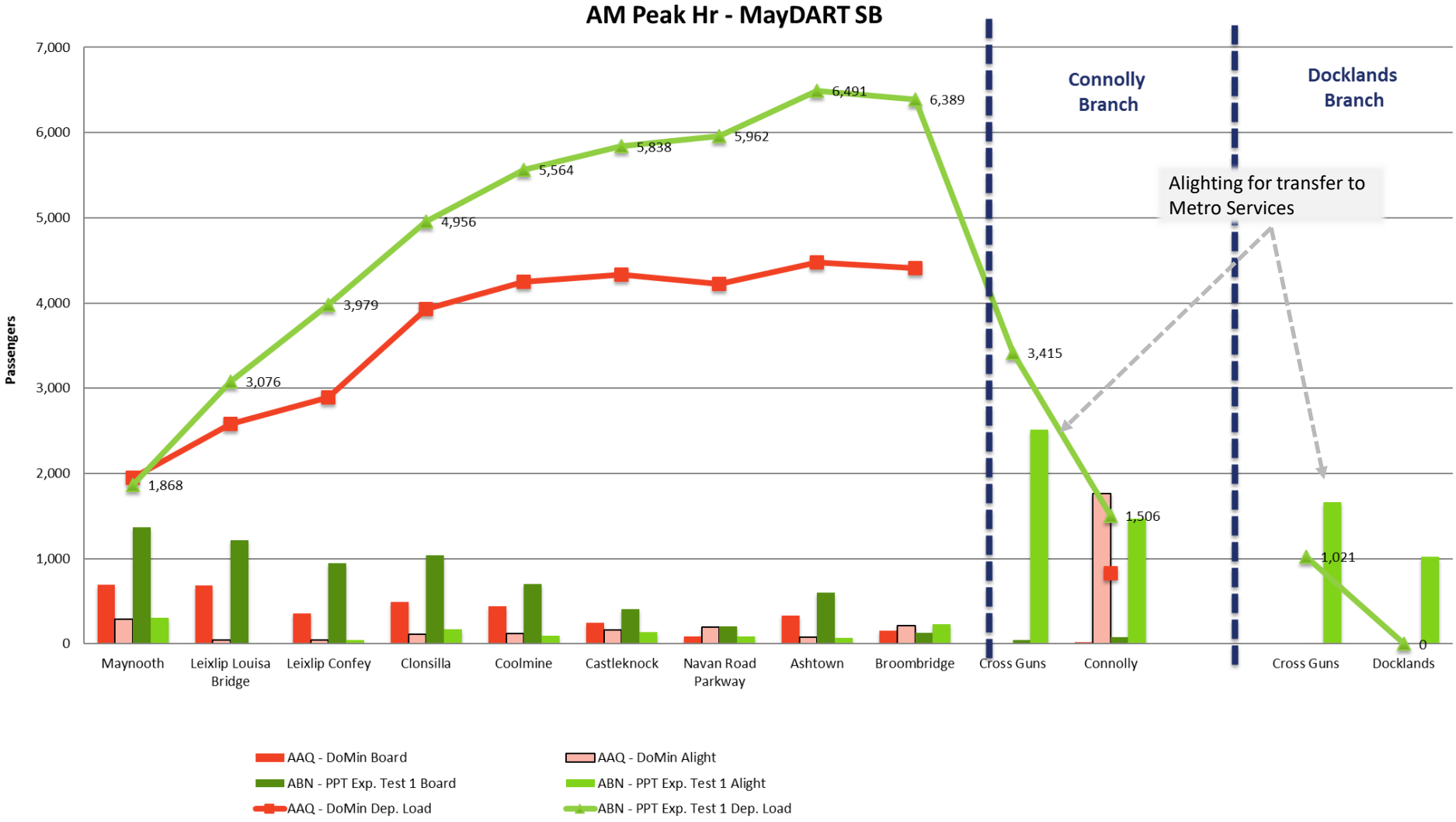
Docklands Stations

- Minimal Transfer at Docklands between Rail and Luas Red line

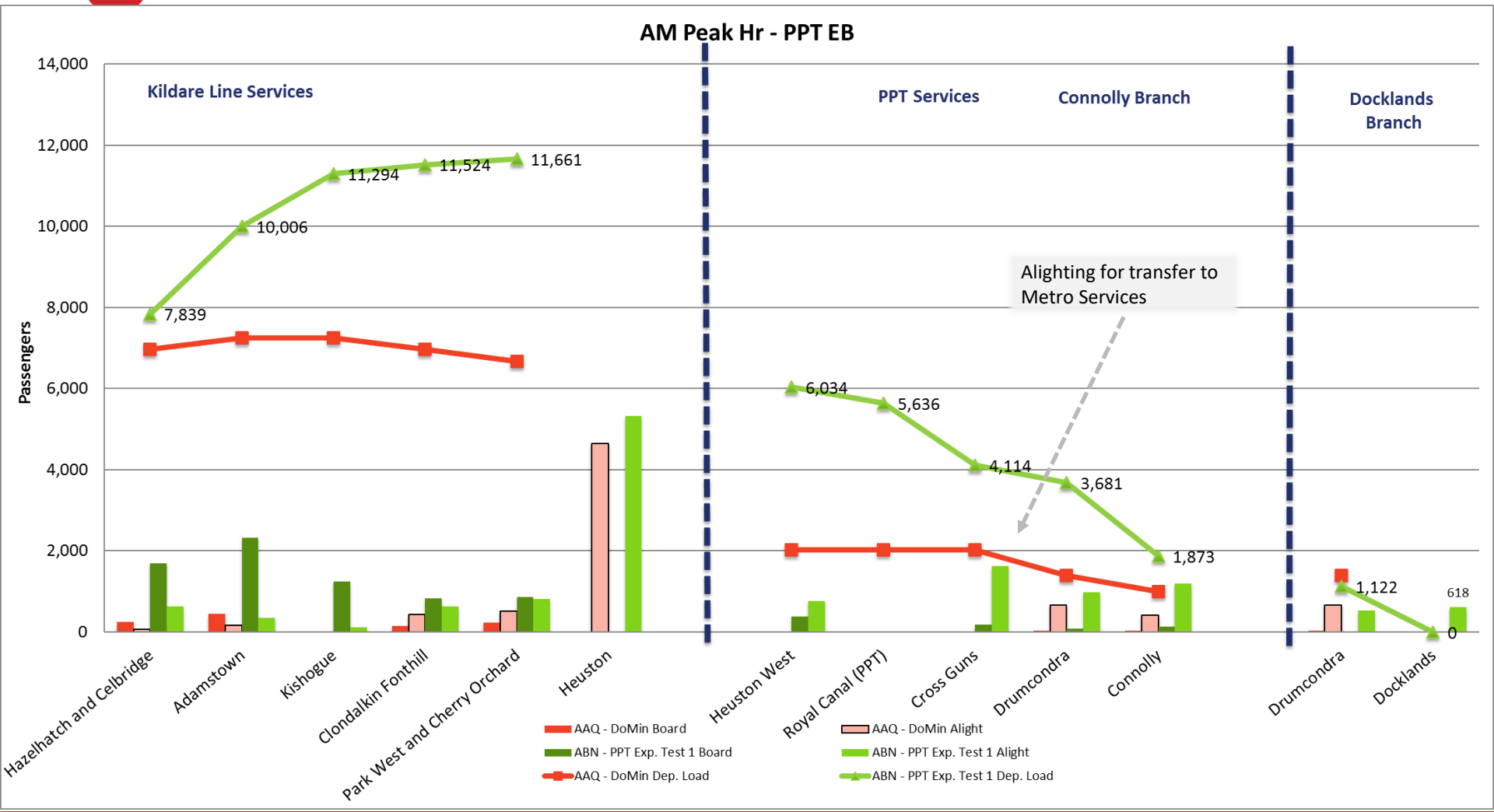
Docklands

	Docklands	Spencer Dock	Other (Bus)
Docklands		53	1
Spencer Dock	6		0
Other (Bus)	5	2	

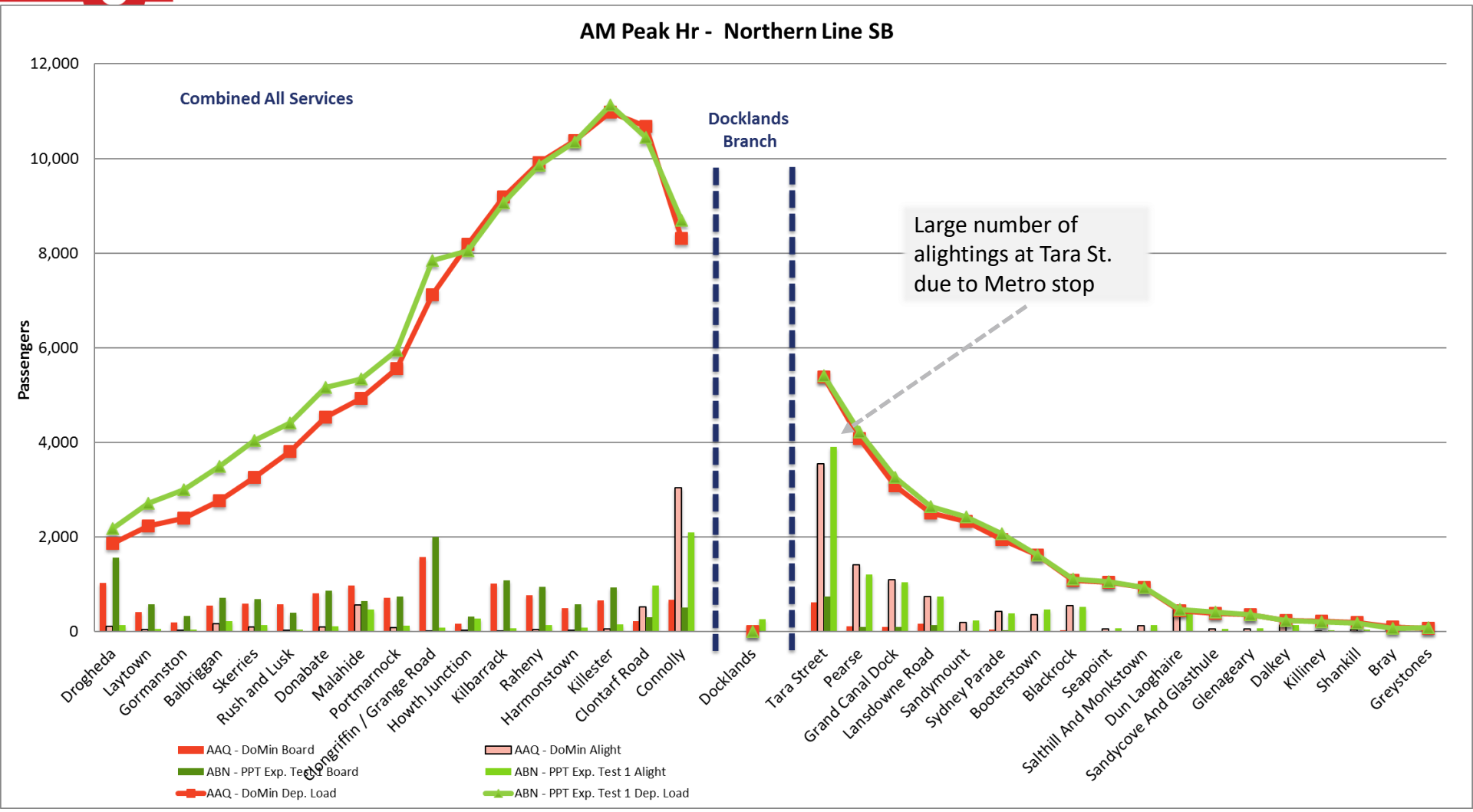
Bundle 6 – PPT Expansion - Line Profiles – Maynooth Line
(vs DoMin)



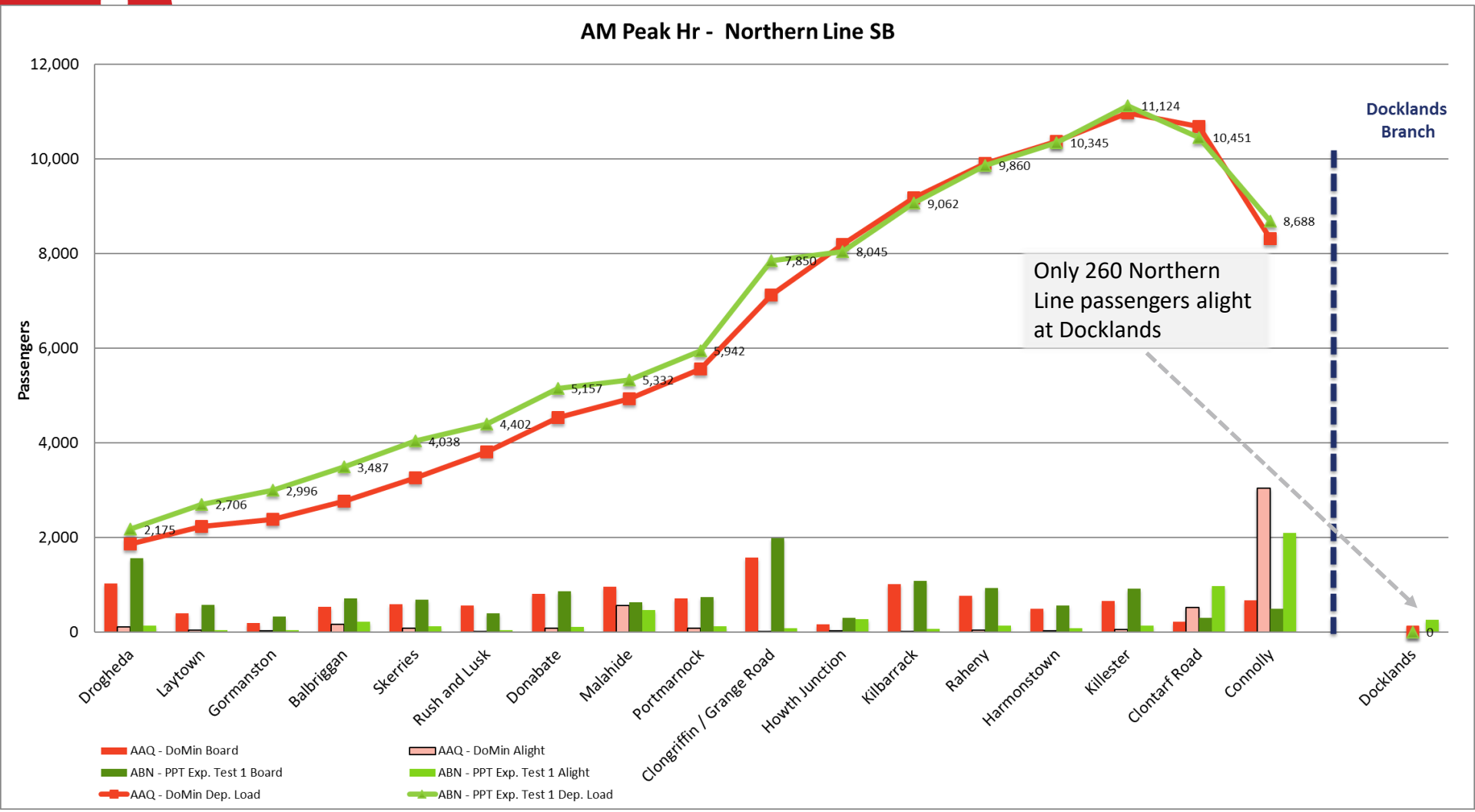
Bundle 6 – PPT Expansion - Line Profiles – Kildare Line
(vs DoMin)



Bundle 6 – PPT Expansion - Line Profiles – Northern Line
(vs DoMin)



Bundle 6 – PPT Expansion - Line Profiles – Northern Line
(vs DoMin)



Appendix I - DART Expansion Project
– Sensitivity Tests
– Model Outputs Summary

SYSTRA

Model Outputs Summary

- The following KPI's have been extracted from the model for each scenario:
  - Mode Share
  - Boardings
  - Transfers
  - Costs
    - Capital
    - O&M
    - PVC
  - Transport User Benefits
  - BCR

DART Expansion – Bundle 6 KPI Summary

KPI	Bundle 6 - PPT Expansion Core Original	Bundle 6 - PPT Expansion with Kylemore Station	Bundle 6 - Irish Rail Suggestions
AM Mode Share (PT)	22.4%	21.9%	21.7%
24Hr Mode Share (PT)	12.8%	12.5%	12.5%
AM PT Boardings	181,400	181,600	180,900
Rail	56,300	57,100	57,800
Bus	69,400	68,100	67,300
LRT	11,600	11,700	11,600
Metro	44,100	44,700	44,200
24Hr PT Boardings	1,143,300	1,144,300	1,141,300
Rail	344,700	353,200	353,800
Bus	429,800	416,700	415,100
LRT	83,900	84,500	84,300
Metro	284,900	289,900	288,100
PT Transfers	36,900	36,300	36,000
Cap Ex Costs (€m)	2,225	2,197	1,863
O&M Costs (€m)	49	49	49
Transport User Benefits without Externals(€m)	4,491	4,914	4,181
Present Value of Costs (€m)	1,613	1,680	1,648
BCR	2.78	2.92	2.54

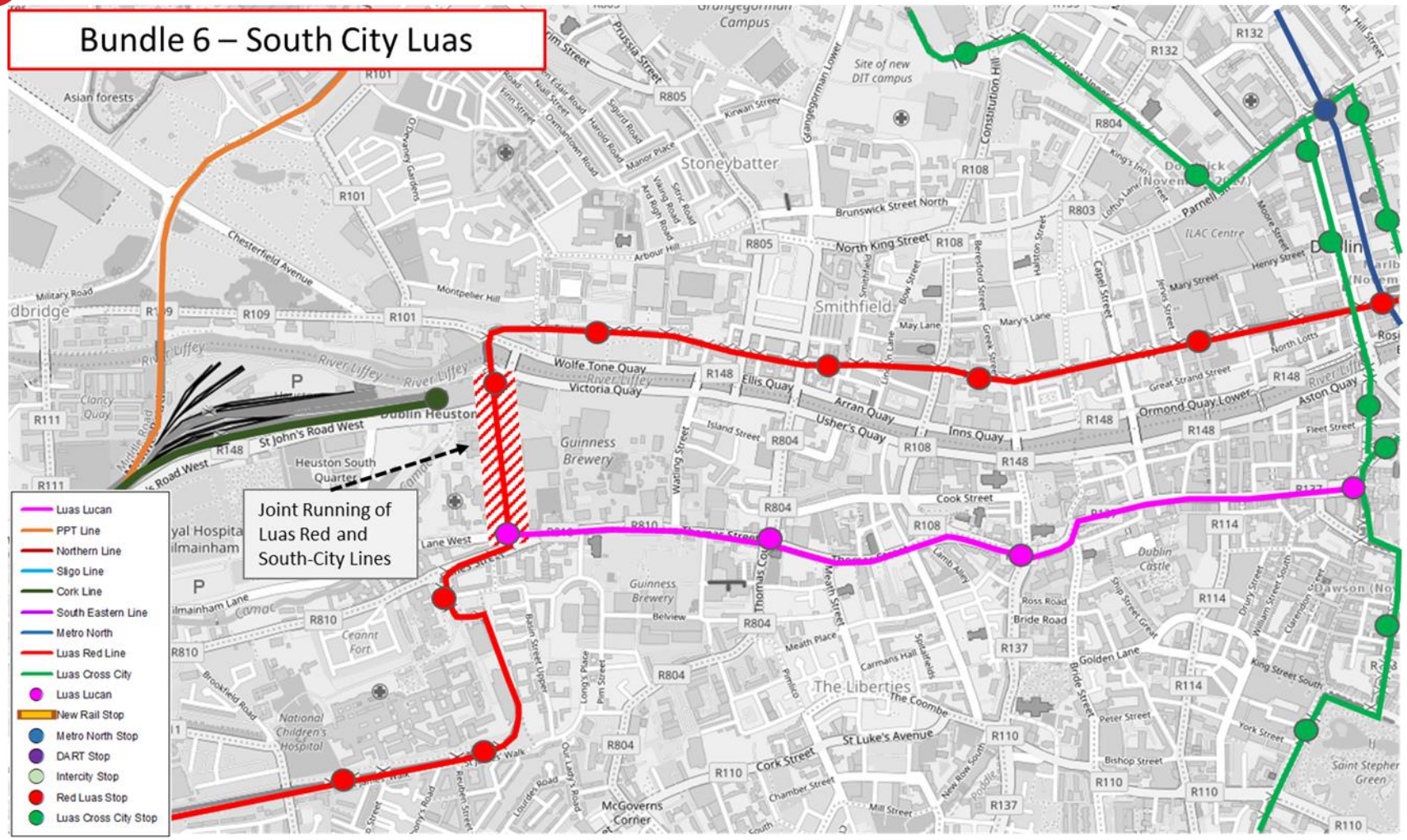
DART Expansion – Final Modelling - Sensitivity Tests

- **Sensitivity Tests**
  - Network Adjustments (South-City Luas)
  - Land-use Adjustments (80% Growth test)
  - Model Parameter Adjustment
    - 5 minute interchange penalty

- **Other Tests**
  - Heuston Turnback Transfer Sensitivity
  - Christchurch Station Removal

DART Expansion – Final Modelling

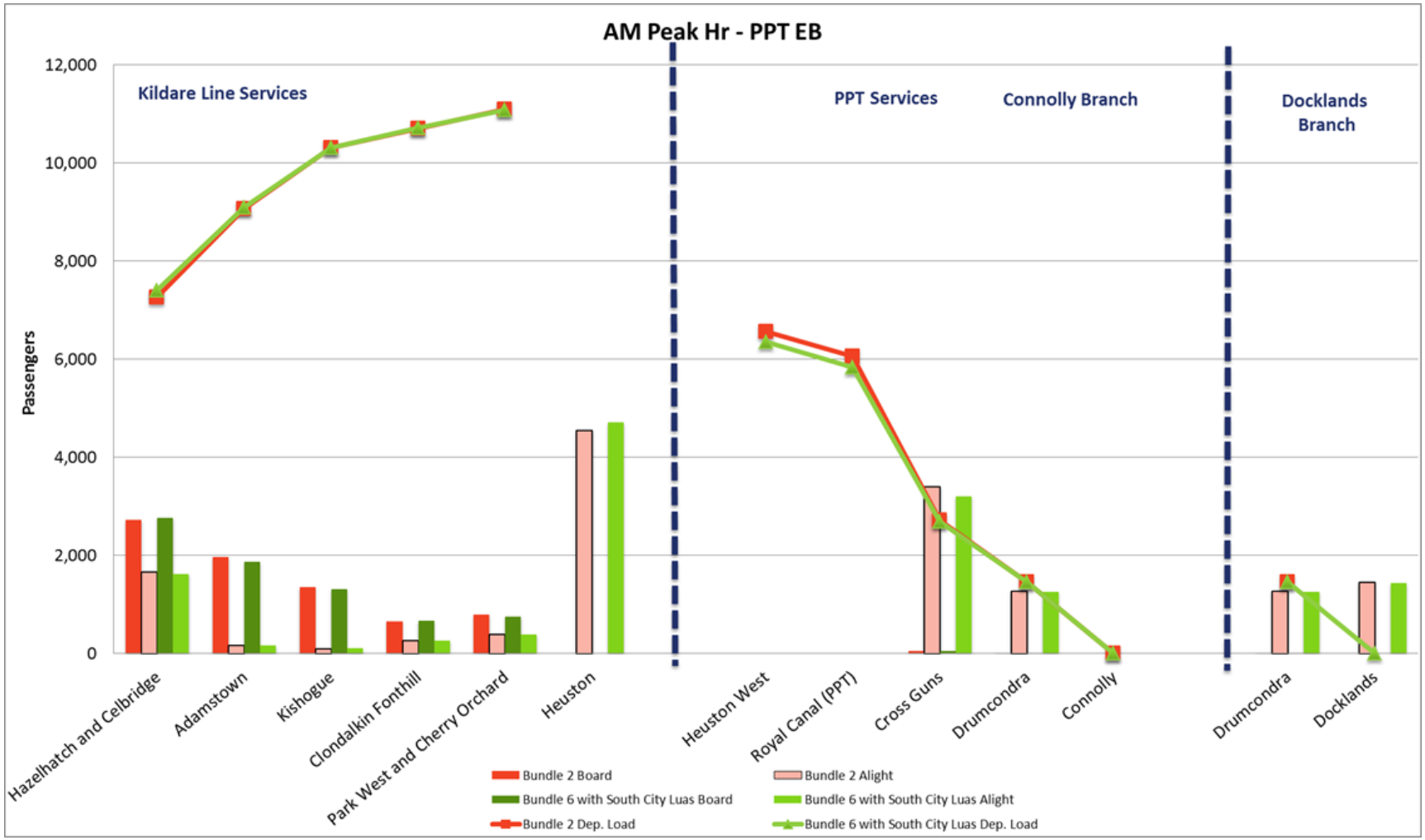
- Sensitivity Tests : Network Adjustments (South-City Luas)



SYSTRA

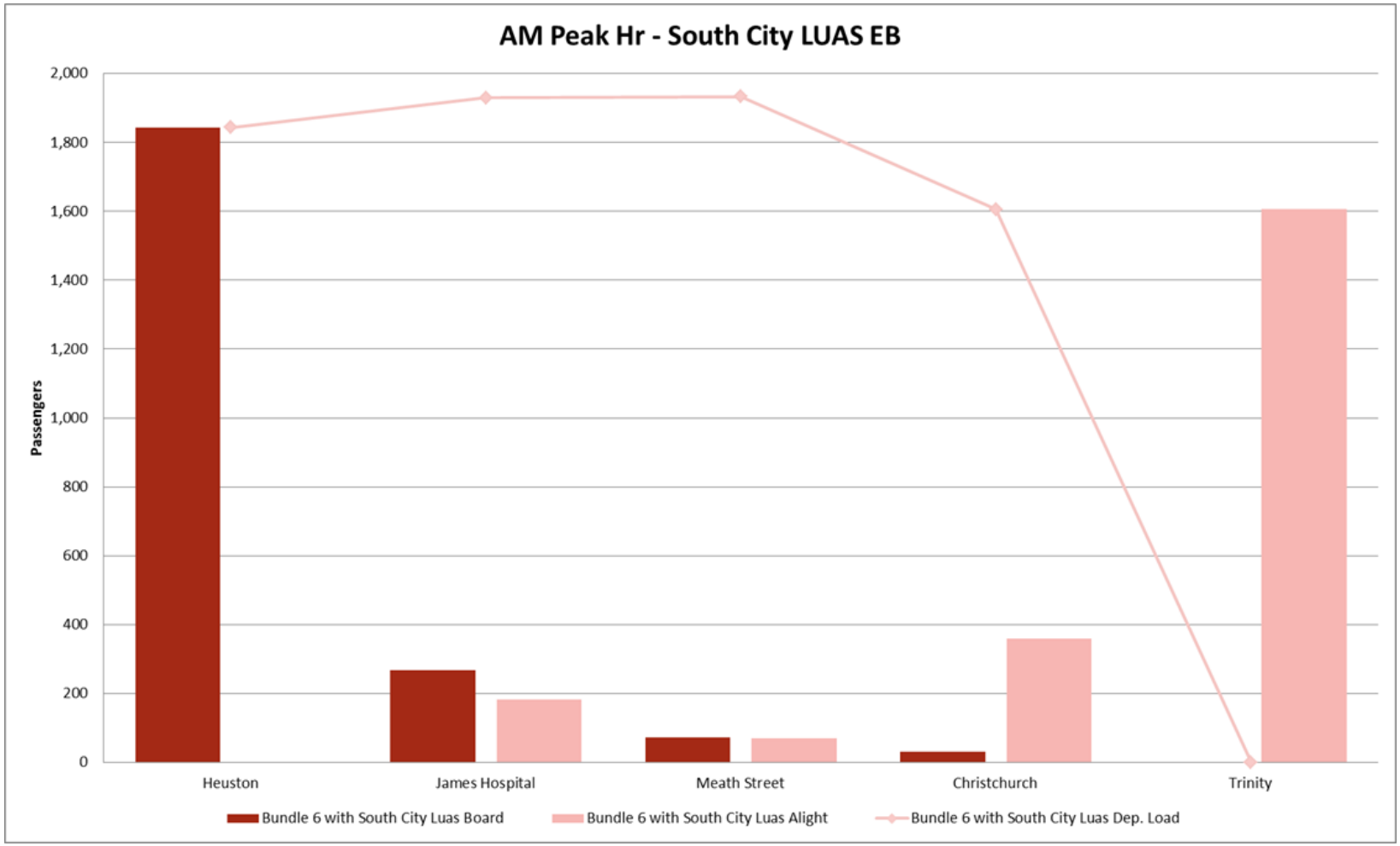
DART Expansion – Final Modelling

- Sensitivity Tests : Network Adjustments (South-City Luas)



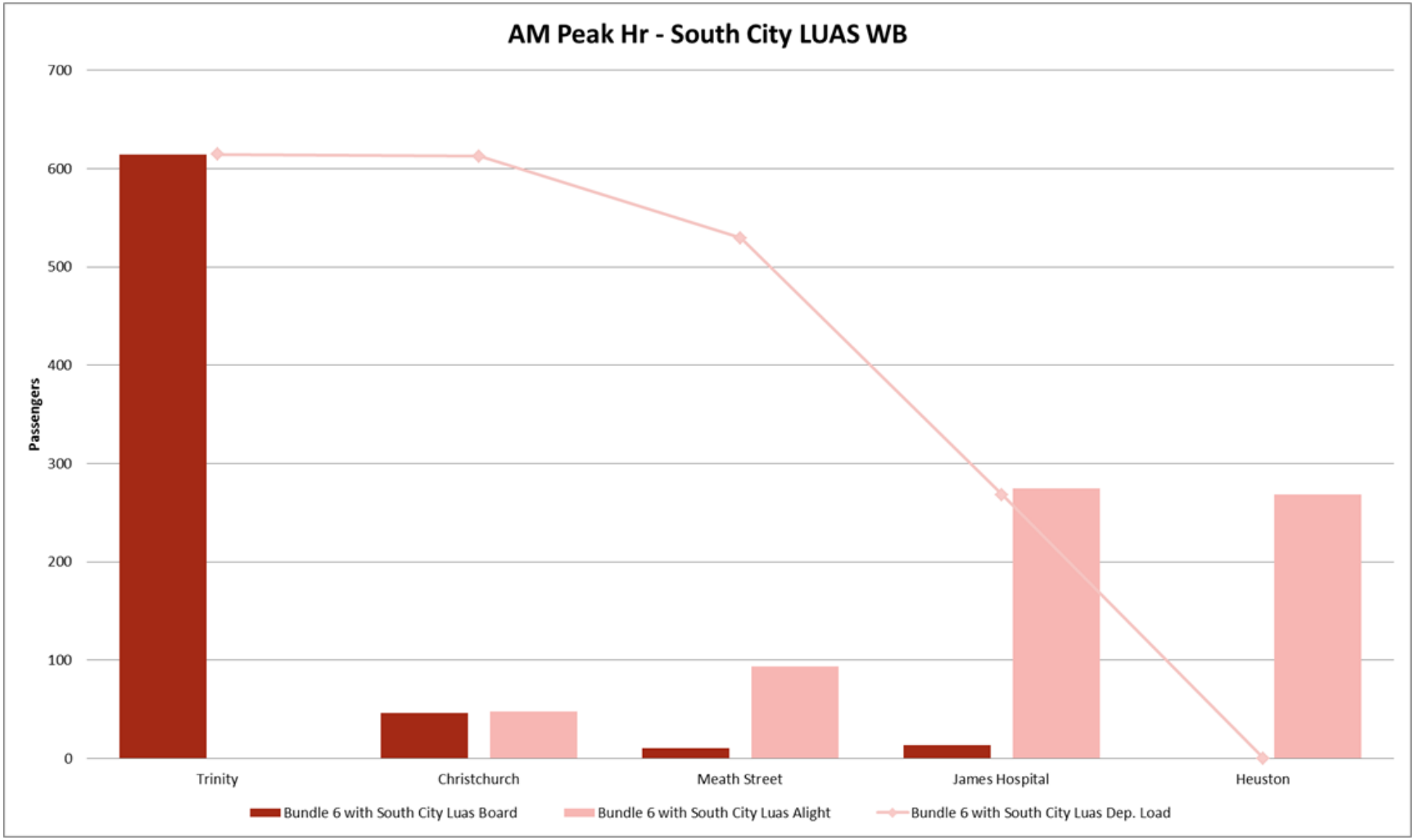
DART Expansion – Final Modelling

- Sensitivity Tests : Network Adjustments (South-City Luas)



DART Expansion – Final Modelling

- Sensitivity Tests : Network Adjustments (South-City Luas)



DART Expansion – Final Modelling

- Sensitivity Tests : Network Adjustments (South-City Luas)

KPI	Bundle 6 - PPT Expansion	Bundle 6 - PPT Expansion with South City Luas
AM Mode Share (PT)	21.9%	21.9%
24Hr Mode Share (PT)	12.5%	12.6%
AM PT Boardings	181,600	181,400
Rail	57,100	57,100
Bus	68,100	66,500
LRT	11,700	13,700
Metro	44,700	44,200
24Hr PT Boardings	1,144,300	1,147,400
Rail	353,200	352,400
Bus	416,700	409,100
LRT	84,500	96,700
Metro	289,900	289,200
PT Transfers	36,300	36,800
Cap Ex Costs (€m)	2,197	2,356
O&M Costs (€m)	49	57
Transport User Benefits without Externals(€m)	4,914	4,959
Present Value of Costs (€m)	1,680	1,854
BCR	2.92	2.67

DART Expansion – Final Modelling
- Sensitivity Tests : Land-use adjustments (80% Growth)

- Test for scenario where less growth is envisaged for the region
- Applied a 20% reduction to growth between 2011 and 2035

- Re-run of Options with reduced demand:
  - Do Minimum
  - Bundle 2
  - Bundle 6

DART Expansion – Final Modelling

- Sensitivity Tests : Land-use adjustments (80% Growth)

KPI	Bundle 2 – Full Dart Expansion	Bundle 2 – Full Dart Expansion with reduced remand	Bundle 6 - PPT Expansion	Bundle 6 – PPT Expansion with reduced demand
AM Mode Share (PT)	22.0%	21.1%	21.9%	21.0%
24Hr Mode Share (PT)	12.7%	12.3%	12.5%	12.1%
AM PT Boardings	179,500	169,000	181,600	170,600
Rail	63,600	59,500	57,100	53,400
Bus	63,200	60,000	68,100	64,700
LRT	10,100	9,700	11,700	11,100
Metro	42,700	39,800	44,700	41,400
24Hr PT Boardings	1,137,800	1,080,400	1,144,300	1,081,000
Rail	394,900	371,900	353,200	329,800
Bus	389,300	373,400	416,700	398,600
LRT	74,000	71,100	84,500	80,300
Metro	279,600	264,000	289,900	272,200
PT Transfers	35,400	33,600	36,300	34,100
Cap Ex Costs (€m)	3,947	3,947	2,197	2,197
O&M Costs (€m)	85	85	49	49
Transport User Benefits without Externals(€m)	6,518	6,539	4,914	4,793
Present Value of Costs (€m)	2,964	2,964	1,680	1,680
BCR	2.20	2.21	2.92	2.85

DART Expansion – Final Modelling
- Sensitivity Tests : 5min Rail Interchange Penalty

- Transfer Penalty (To/From Rail) adjusted to account for improved interchange opportunities in the future transport network
  - Same adjustment as applied in NMN Modelling
- Re-run of Options with Parameter Change:
  - Do Minimum
  - Bundle 2
  - Bundle 6

Before

	DART	RAIL	LUAS	URBAN BUS	OTHER BUS	BRT	METRO
DART	15	15	15	15	15	15	15
RAIL	15	15	15	15	15	15	15
LUAS	15	15	5	5	5	5	5
URBAN BUS	15	15	5	15	5	5	5
OTHER BUS	15	15	5	5	5	5	5
BRT	15	15	5	5	5	5	5
METRO	15	15	5	5	5	5	5

After

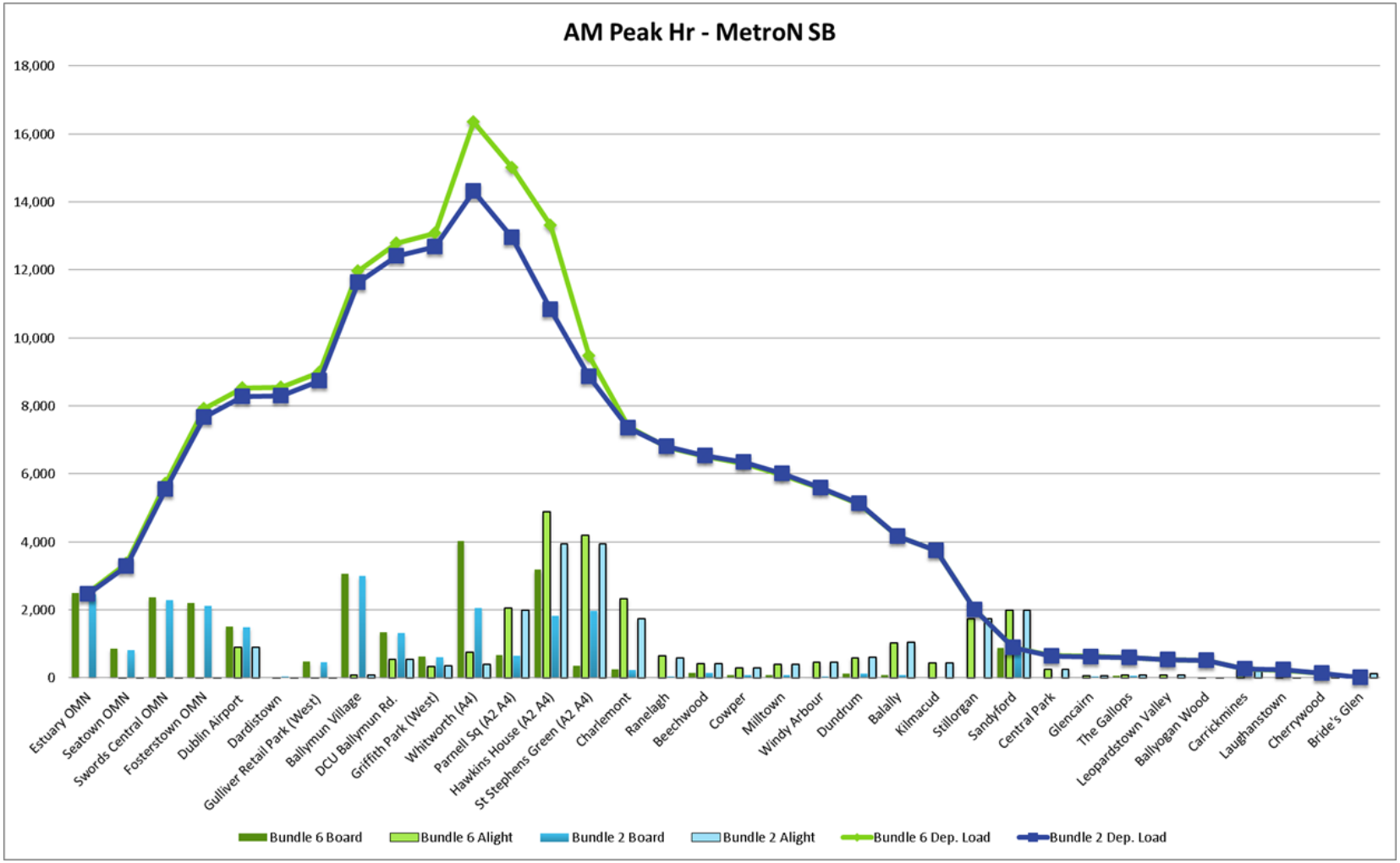
	DART	RAIL	LUAS	URBAN BUS	OTHER BUS	BRT	METRO
DART	15	5	15	15	15	15	15
RAIL	5	5	5	5	5	5	5
LUAS	15	5	5	5	5	5	5
URBAN BUS	15	5	5	15	5	5	5
OTHER BUS	15	5	5	5	5	5	5
BRT	15	5	5	5	5	5	5
METRO	15	5	5	5	5	5	5

DART Expansion – Final Modelling

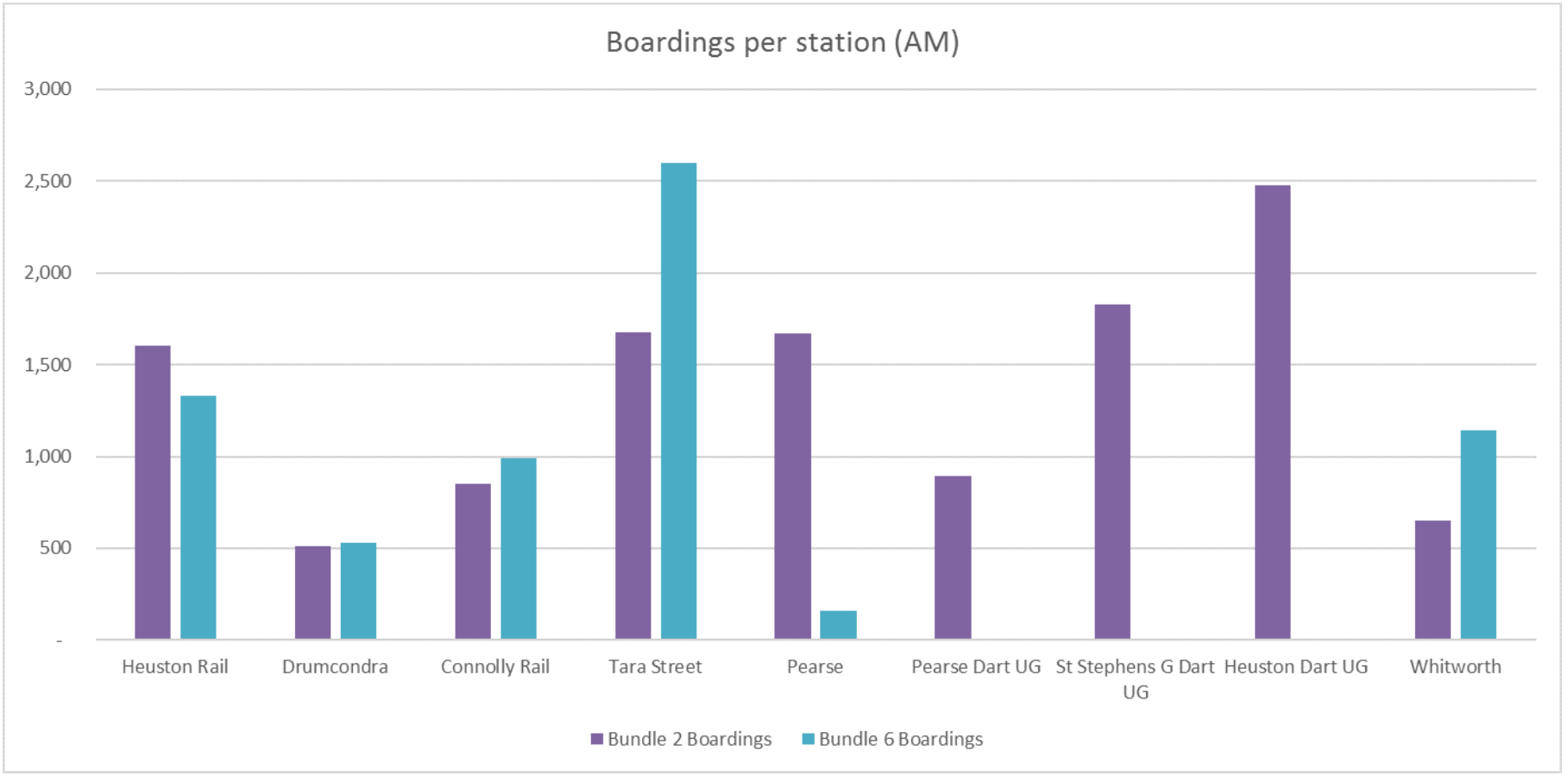
- Sensitivity Tests : 5min Rail Interchange Penalty

KPI	Bundle 2 – Full Dart Expansion	Bundle 2 – Full Dart Expansion with 5min rail interchange penalty	Bundle 6 - PPT Expansion	Bundle 6 – PPT Expansion with 5min rail interchange penalty
AM Mode Share (PT)	22.0%	22.3%	21.9%	22.1%
24Hr Mode Share (PT)	12.7%	13.0%	12.5%	12.7%
AM PT Boardings	179,500	192,600	181,600	192,800
Rail	63,600	72,800	57,100	65,800
Bus	63,200	64,500	68,100	68,500
LRT	10,100	10,600	11,700	11,900
Metro	42,700	44,700	44,700	46,600
24Hr PT Boardings	1,137,800	1,212,100	1,144,300	1,207,100
Rail	394,900	452,400	353,200	403,500
Bus	389,300	392,700	416,700	416,400
LRT	74,000	76,200	84,500	86,000
Metro	279,600	290,900	289,900	301,200
PT Transfers	35,400	44,300	36,300	43,800
Cap Ex Costs (€m)	3,947	3,947	2,197	2,197
O&M Costs (€m)	85	85	49	49
Transport User Benefits without Externals(€m)	6,518	7,389	4,914	5,279
Present Value of Costs (€m)	2,964	2,964	1,680	1,680
BCR	2.20	2.49	2.92	3.14

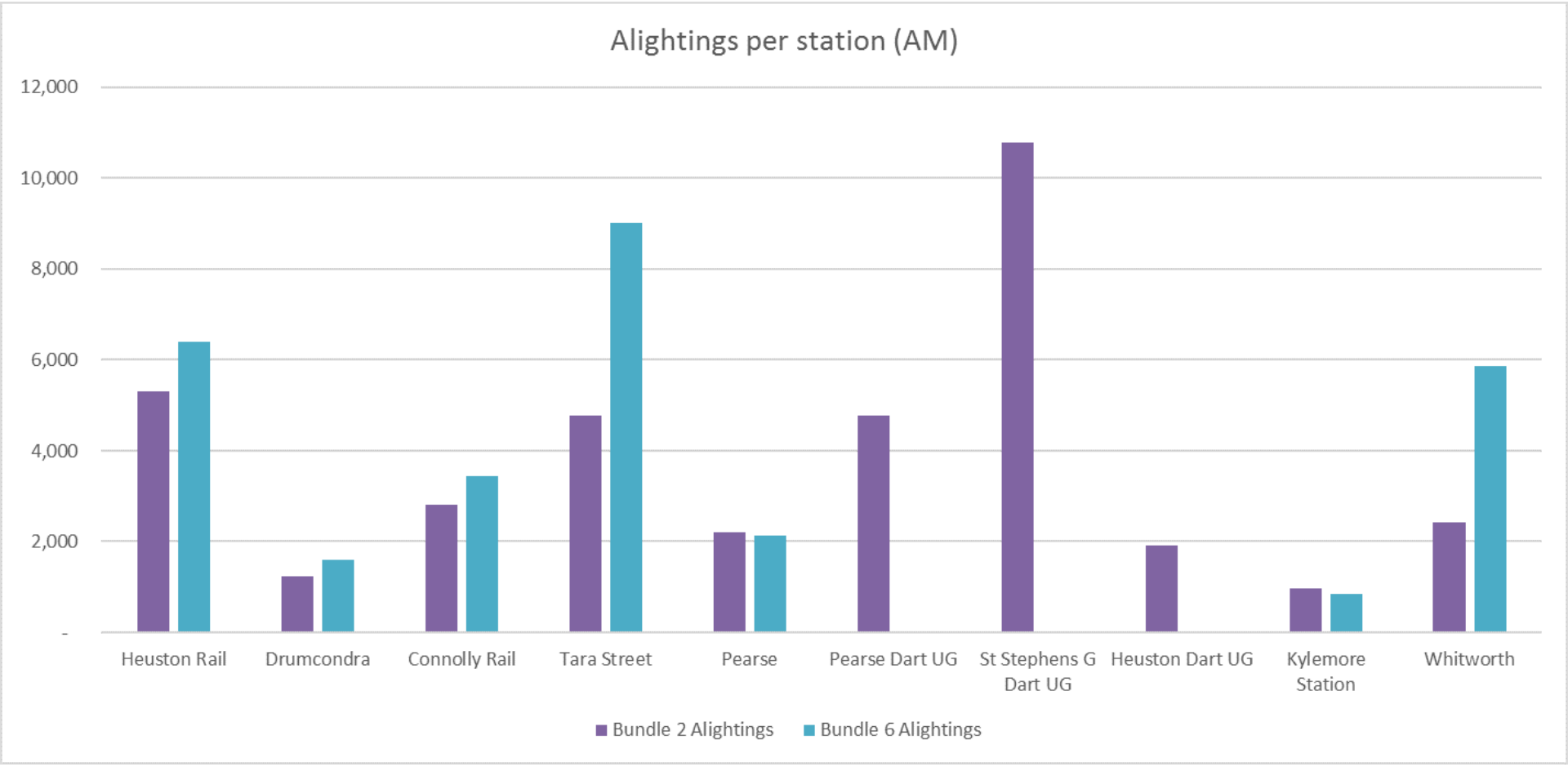
Bundle 2 vs Bundle 6
- Metro Profile



Bundle 2 vs 6 – Boardings (AM)



Bundle 2 vs 6 – Alightings (AM)



Bundle 2 Full DART Expansion – Transfers (AM)

Transfer at Whitworth - Bundle 2

	Whitworth (Metro)	Withworth (Rail)	Other (Bus)
Whitworth (Metro)		334	133
Withworth (Rail)	1,762		110
Other (Bus)	777	146	

3,262

Transfer at Tara St - Bundle 2

	Tara Street (Metro)	Tara Street (Rail)	Other (Bus)
Tara Street (Metro)		825	1,841
Tara Street (Rail)	1,088		974
Other (Bus)	2,416	572	

7,716

Transfer at Heuston Station - Bundle 2

	Heuston Rail	Heuston Luas	Heuston Dart UG	Heuston West	Other (Bus)
Heuston Rail		1,200	1,937	0	1,249
Heuston Luas	429		156	0	206
Heuston Dart UG	719	352		0	86
Heuston West	0	0	0		0
Other (Bus)	346	334	150	0	

7,164

Bundle 6 PPT DART Expansion – Transfers (AM)

Transfer at Whitworth - Bundle 6

	Whitworth (Metro)	Whitworth (Rail)	Other (Bus)
Whitworth (Metro)		804	155
Whitworth (Rail)	4,647		304
Other (Bus)	819	187	

6,916

Transfer at Tara St - Bundle 6

	Tara Street (Metro)	Tara Street (Rail)	Other (Bus)
Tara Street (Metro)		1,254	1,984
Tara Street (Rail)	2,586		1,893
Other (Bus)	2,559	947	

11,224

Transfer at Heuston Station - Bundle 6

	Heuston Rail	Heuston Luas	Heuston Dart UG	Heuston West	Other (Bus)
Heuston Rail		2,053	0	0	2,645
Heuston Luas	616		0	0	193
Heuston Dart UG	0	0		0	0
Heuston West	0	0	0		0
Other (Bus)	518	390	0	0	

6,415

SYSTRA

Key Station Analysis – Bundle 2 vs 6 – AM Peak

What are the **transfer** levels at key stations in the network?

Glasnevin Stations

- **Major transfer between Rail and Metro at Glasnevin**

Transfer at Whitworth - Bundle 6

	Whitworth (Metro)	Glasnevin (Rail)	Other (Bus)
Whitworth (Metro)		406	248
Glasnevin (Rail)	3,076		141
Other (Bus)	1,028	104	

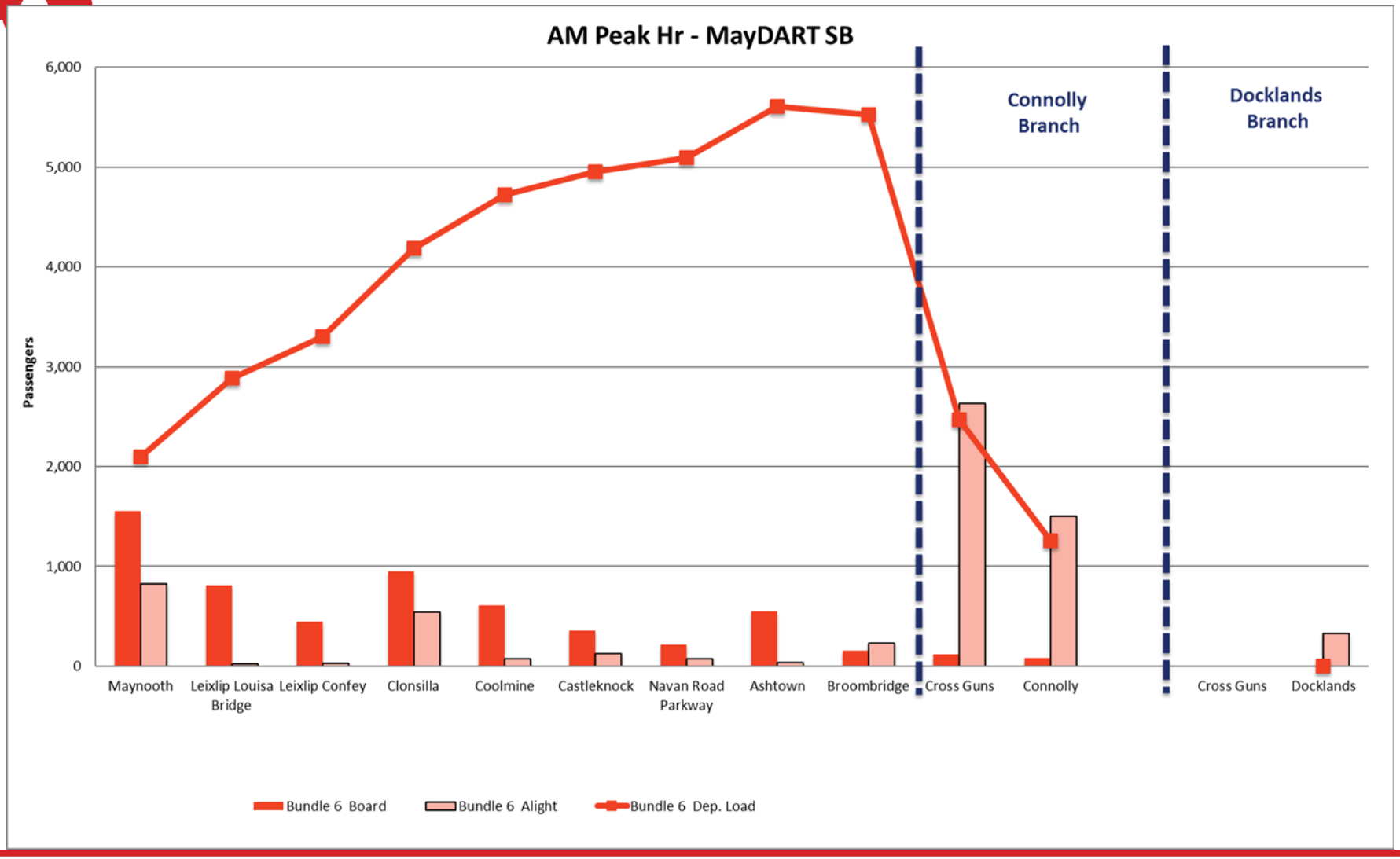
5,004

Transfer at Whitworth - Bundle 2

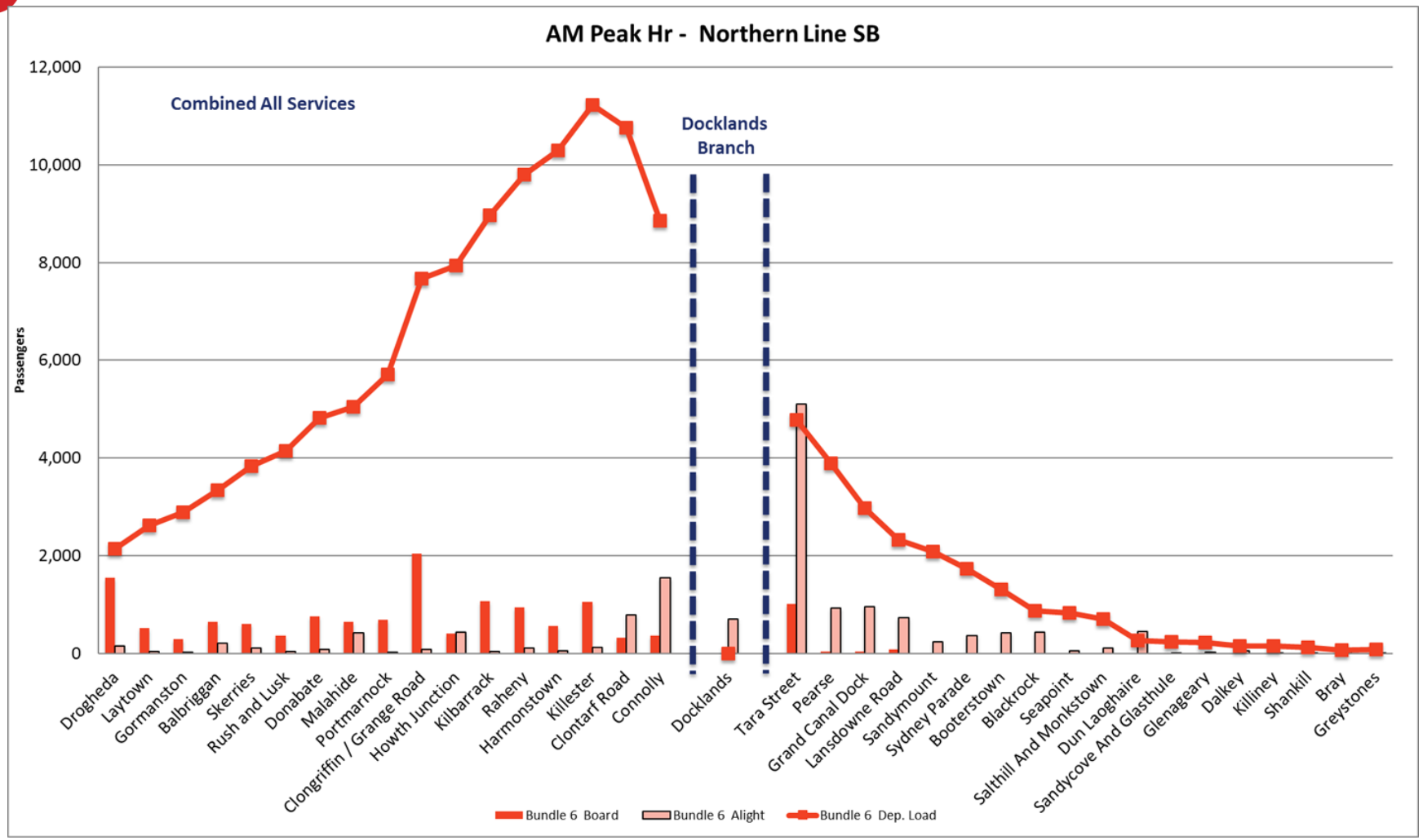
	Whitworth (Metro)	Glasnevin (Rail)	Other (Bus)
Whitworth (Metro)		189	208
Glasnevin (Rail)	1,080		37
Other (Bus)	933	62	

2,510

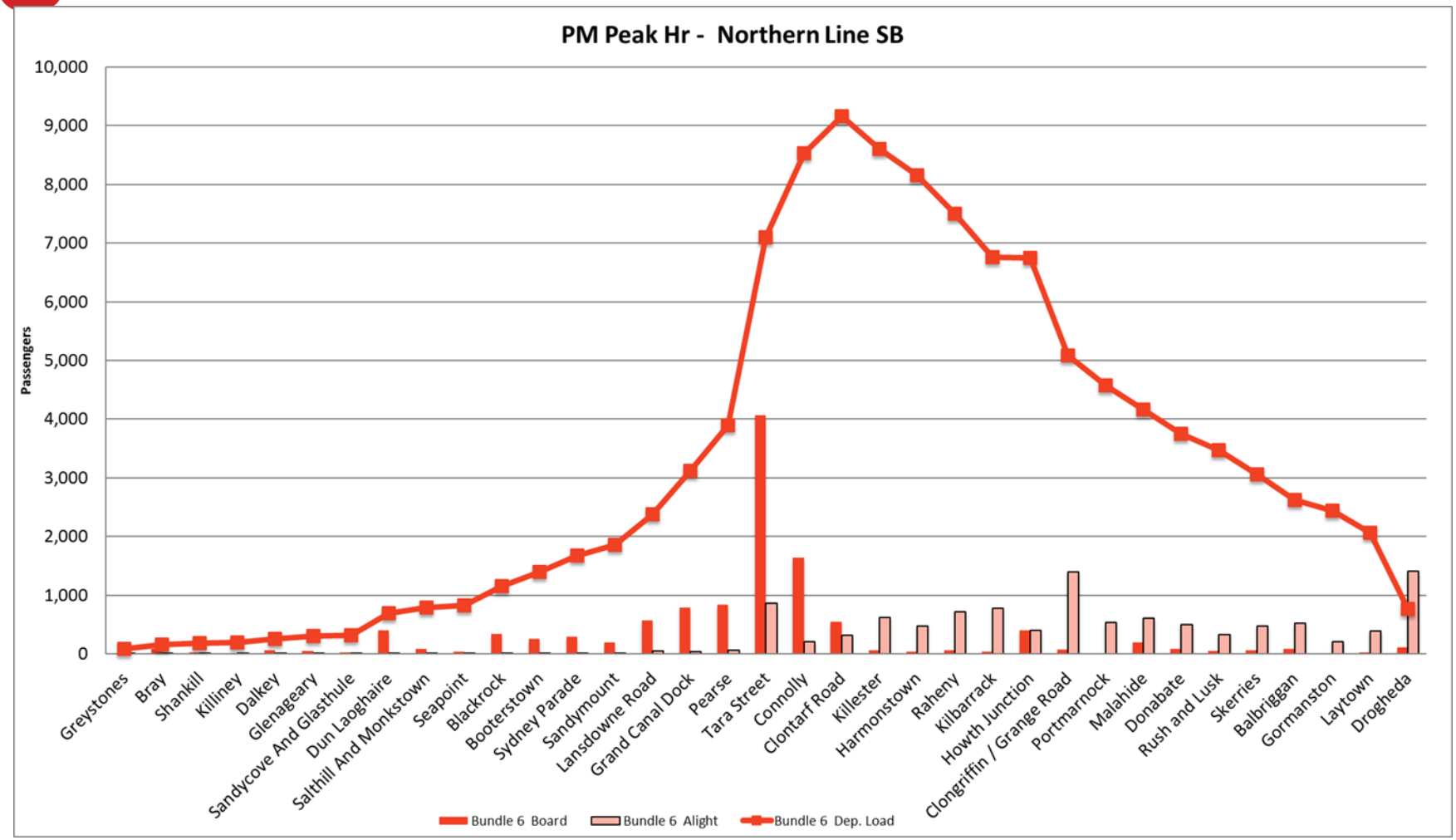
Line Flows – Bundle 6
Maynooth Line Inbound



Line Flows – Bundle 6
Northern Line SB



Line Flows – Bundle 6
Northern Line NB



Line Flows – Bundle 6
Phoenix Park Tunnel EB