Light Rail Transit & Cyclists
A Guidance Note for Developers of Light Rail Transit
September 2013
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# Light Rail Transit & Cyclists

A Guidance Note for Developers of Light Rail Transit

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1.0 Introduction

1.1 Purpose of this Report

The Railway Procurement Agency has commissioned AECOM to prepare this report to provide guidance on the interaction of light rail transit and cyclists.

This report is intended to be used by the developers of light rail transit, as an aid to ensure the interaction with cyclists is given the appropriate level of consideration during all stages of scheme development. This report is likely to prove most useful at route selection stage – where the options for the provision of cyclist facilities along links are largest. It is not intended as a replacement for any part of the National Cycle Manual¹ which provides comprehensive guidance on the treatment of cyclists at junctions.

A separate note has been prepared to apply the methodology set out in this note to the new Luas Cross City in Dublin.

1.2 Approach

Our approach to the preparation of this report involved:

- A review of relevant literature was undertaken to understand the interaction. A summary of our understanding of the interaction is presented in Chapter 2;
- Proprietary products which propose to offer solutions to the issue were examined. Some conclusions on this review is presented in Chapter 2;
- Drawing heavily from the National Cycle Manual¹ and the Design Manual for Urban Roads and Streets² an approach to designing for the interaction between cyclists and light rail transit is presented in Chapter 3.

1.3 Background

Luas is the name of the light rail transit system serving Dublin. There are two main lines, which are known as the red and the green lines. An extension of the green line which will link to the red line is currently under construction.

The interaction of light rail transit and cyclists is topical in Dublin currently in the context of the rising volume of cyclists, the new Luas Cross City line, and planning policy seeking to promote more active and sustainable forms of transport.

The Department of Transport Tourism and Sport’s ‘Smarter Travel: A Sustainable Travel Future’³ policy document sets out the Governments desire to reduce the need to travel by the private motor vehicle. Some of the headline targets outlined in the document include increasing cycling as a mode of transport so that by 2020, 10% of all our trips will be by bicycle. This document and the National Cycle Policy Framework⁴ set out an ambition that walking cycling and public transport will be supported and provided to the extent that these will rise to 55% of total commuter journeys to work. Other relevant aspirations include:

- A culture of cycling will be developed to the extent that, by 2020, around 160,000 people will cycle for their daily commute, up from 35,000 in 2006.
- There is significant interest in making cycling a more popular travel option and the need for investment, including safe cycleways, secure parking facilities and public bike rental schemes, to support this mode is a recurring theme.

In conjunction with this and despite the downturn in the economy in the last few years, Luas passenger numbers have remained high with 29 million passengers carried in 2012.

From the above it is clear that, provision for the interaction between light rail transit (LRT) and cyclists is an important consideration. Facilitating public transport use, walking and cycling,
including provision for multi modal journeys, is a key component of an integrated transport policy. When designing an LRT scheme there are two main issues concerning cyclists:

- The opportunity to develop a positive provision for cyclists as part of an LRT system.
- The identification and amelioration of the risks posed to cyclists by the introduction of the LRT tracks and vehicles where LRT systems are introduced into an existing street network.

This report provides guidance for developers of LRT schemes on the potential impacts on cyclists associated with LRT, and the development of mitigation measures to minimise these impacts.

1.4 Light Rail Transit

LRT systems can range from segregated rail systems to street running trams operating in a mixed traffic environment. There are three types of on-street running and the level of interaction with other road users varies depending on the type of on-street running:

(i) Tram only streets: Other road users are not permitted to use the street;

(ii) Tram Lanes: Dedicated lanes are provided for the LRT, in some cases there can be a level difference between the tram lane and the adjacent traffic lanes, while in other cases road marking is the sole delineator of the tram lane;

(iii) Shared running: The LRT shares the traffic lane with all other traffic;

At present, two LRT lines are operational in Dublin which includes relatively minor proportions of shared running.

Luas Cross City (LCC) is the next stage of the development of the light rail network in Dublin. The LCC route, which is approximately 8km in length, will offer an end to end journey time of just 24 minutes and is expected to attract an additional 10.5 million passenger journeys on Luas each year. In addition it will link the existing Red and Green Luas Lines and facilitate greater permeability of the city centre by high quality public transport. The implementation of Luas Cross City will serve to further consolidate the performance of Luas and enhance considerably the options for public transport users in the capital.

The LCC route travels along some of the strategic traffic routes in the city centre and as such segregated tram lanes will not always be possible. As a result more significant proportions of shared running will be implemented as part of LCC. Increased shared running will have implications for cyclists, in terms of safety and continuity of routes. The Developers of LRT require cooperation from Local Authorities, Transport Agencies and other Public Transport Organisations to provide satisfactory design solutions.

1.5 The Rail Choice

On LRT systems two rail types are generally used, namely Vignole rail (T-rail) and grooved rail (also known as girder rail). Grooved rail was developed in the 1850’s to minimise the impact of tram systems on streets. Prior to the development of grooved rail, the installation of Vignole rail in a street created a serious impediment to the ordinary use of the street by other vehicles and indeed pedestrians. This impediment to the use of the street derived from the requirements to lay the rails proud of the adjacent road surface and to provide a gap between the rail head and the road pavement to facilitate the wheel flange of the LRT vehicle, known as the flangeway. The wheel rail interface for Vignole rail and grooved rail is shown in Figure 1.1 below:
The design of grooved rail provides for the wheel flange by creating a slot in the rail head. The benefit of the grooved rail design is that it allows for the road pavement surface to be installed flush with the side of the rail on both sides. In addition the profile of the rail head is flatter, when compared to Vignole rail, which allows the rail to be installed flush with the level of the road. The requirement for a flangeway when using Vignole rail causes significant difficulty for the structure of the road pavement and will lead to local failure around the rails when traversed by other road traffic.

Generally with on-street LRT systems there is a requirement for low radius curves as the route will follow the existing road layout. In such cases radii will not generally be reduced below 25m. In locations where low radius curves are required there is a need to cater for the movement of the wheel flange. When travelling around curves, and in particular, low radius curves, the bogie of the light rail vehicle (LRV) is pushed towards the external side of the curve (due to centrifugal forces) and there is potential for the back of the wheel flange to make contact with the back of groove (so called “rail keeper”). If the wheel flange were to make contact with the rail keeper, serious derailment risks would arise along with maintenance issues and noise generation. It is this requirement which determines the width of the slot / groove in the rail head. Similarly, if Vignole rail was installed on low radius curves the width of the flangeway would have to be increased to cater for the wheel flange.

The use of grooved rail also facilitates track crossings on LRT networks. Where two tracks meet, an opening is created at the crossing point of the rails, resulting in a lack of support for the wheel. With the use of grooved rail, the bottom of the groove can be lifted with ramps either side of the crossing point, so that the wheels can run supported on the flange rather than on the tread, as they normally do on grooved rail. This is not feasible with Vignole rails which would require additional iron works to facilitate rail crossings.

In summary, the use of grooved rail for shared on-street sections of LRT allows for better integration of the LRT system by catering for the use of the street by other road users. The presence of the groove can cause difficulty for cyclists, particularly when required to cross the rail at acute angles. However, the width and depth of the groove is far less than the flangeway required if Vignole rail were installed in a shared street environment.

1.5 The Challenge

Cyclists can experience difficulties in crossing tram lines where there is a risk of a bicycle wheel
becoming caught in the groove of the embedded rail. During the development of the LRT scheme this risk should be ameliorated through the use of the methodology outlined in Section 3 of this report.

1.6 RPA Awareness Campaigns

Prior to the commencement of Luas services in 2004 and regularly since then, RPA, and the Operator, have run a number of safety awareness campaigns, which focussed on the particular issues relating to cycling and Luas. A sample of one such poster campaign is presented in the Figure below.

The number of cyclists on Dublin’s streets has increased year on year since 2006. The installation of new cycle infrastructure, the Transport for Ireland’s Bike to Work scheme and the “Dublin Bikes” public bicycle hire scheme have all contributed to this increase in cycling within the city. RPA recognise that there are cyclists who may not be familiar with cycling in the environs of Luas and are launching additional further safety awareness campaigns which will advise cyclists where they can cycle and how to interact with Luas. This latest awareness campaign commenced in June 2013 and is covered by a variety of media including posters/billboards, newspapers, social media and radio.

Further information in relation to the provision of bicycle parking at stops, and advice on cycle safety is set out at the following website links:

http://www.luas.ie/cycle-and-ride/
http://www.luas.ie/improving-luas-cycle-ride-facilities.html

![Be Safe - Be Seen](Image)

Figure 1.2 Example of cycle safety awareness campaign
2.0 Understanding the Interaction

2.1 Introduction

In many cities throughout the world, cyclist and LRT systems co exist without significant difficulty. Street running tramways can be designed to create and maintain a safe environment for cycling. The factors that contribute to the success of both LRT and cycle networks are often complementary. For example, reducing motor traffic volumes in urban areas as a consequence of the introduction of a new LRT system can also result in benefits for cyclists in terms of enhanced comfort and safety. Similarly several light rail schemes in Europe demonstrate the complementary nature of cycling and LRT where it is common for a significant number of passengers to arrive at the LRT stop by bicycle.

In considering the provision of cycle facilities cognisance must be taken of recent changes in road traffic regulations (S.I.No.332/2012–Road Traffic (Traffic and Parking) (Amendment) (No. 2) Regulations 2012) whereby cyclists are no longer required to use cycle lanes / tracks where they are provided. The removal of this requirement to use cycle facilities puts a greater onus on designers to develop high quality, safe cycle facilities which cater for the needs of cyclists particularly in areas where use of other parts of the road is discouraged or prohibited. This is key to ensuring the most efficient use of available road space.

Where interaction between cyclists and LRT is anticipated to occur in proximity to high demand cycle routes (which might be defined as the primary or secondary network in the strategic cycle network of a city) the provision of segregated facilities may be appropriate. This facility can provide sufficient width to cater for the volume of cyclists using the facility whilst also addressing the crossing locations at the appropriate angles.

Figure 2.1: Melbourne Swanston Street

Integrating cyclists into the LRT route is an option where the volume of cyclists is consistent with single file one way cycling and crossing of the light rail tracks can be undertaken at the appropriate angles. The photo below shows how cyclists are integrated with the light rail system in Brussels.
Aligning cycle lanes and tram tracks to achieve a crossing angle of more than 45° (preferably at 90°) will minimise the risk of cycle wheels being deflected on contact with the rails. Crossing angles between tram tracks and the path followed by cycle wheels should be as close to 90° as possible in all traffic conditions and for all cyclist manoeuvres.

Where street widths are insufficient to provide dedicated cycle operating space and the remaining space does not offer acceptable levels of comfort and safety, alternative routes should be provided for cyclists. A quality of service assessment should be undertaken to identify the most suitable alternative route for cyclists. The alternative route should be appropriately signed to attract cycle users and the prohibited routes for cyclists should also be clearly identified. The developers of LRT must also consider junction treatments such as the provision of advanced stop lines, hook turns, dedicated cycle signals, landscape treatments and cycle route diversions. The National Cycle Manual\(^1\) provides guidance on the assessment of quality of service and junction treatments.
2.2 Proprietary Products

2.2.1 VeloSTRAIL

VeloSTRAIL is a product that produces a flat surface in the vicinity of the tram rail through the use of rubber mats. The rubber in the vicinity of the inner rail edges compresses only as the wheel flange passes over it. In this way the open groove is eliminated.

![Figure 2.4: VeloSTRAIL with Vignole Rail](image)

The suppliers of the VeloSTRAIL matting recommend that it is not to be used on the typical grooved rail construction but only with the standard vignole rail (T-rail). The product would appear to be mostly used at crossings locations and in relatively short lengths.

To assist in the preparation of this report the suppliers were contacted to request details of examples of the successful operation of the product at busy city centre locations. Information requested included traffic loadings (including % HGV and bus content), and the replacement and maintenance requirements. This correspondence suggests that evidence of its satisfactory deployment in heavily trafficked locations with high proportions of buses, may not be available at this stage.

Subject to the provision of further evidence the product may be an acceptable solution, however, at this stage there does not seem to be sufficient evidence to supports its wide scale deployment particularly in architecturally sensitive locations such as College Green.

![Figure 2.5: VeloSTRAIL at Oberndorf/Austria](image)
2.2.2 Flange Filler - Rubber Inserts
Inserting rubber inserts into the grooved rail has been trialed in a number of locations such as Cologne (Germany), Zurich and Basel (Switzerland). Often it would be desirable to use the inserts on curves where the loading can be particularly acute. These trials as reported\(^6\) concluded this was not a satisfactory solution as the inserts did not withstand the loadings placed on them.

A report prepared for the National Transport Authority by Jacobs Consulting Engineers\(^7\) similarly concluded that the rubber inserts did not adhere well and required significant maintenance as the tram wheel wore down/ripped the material.

2.3 Opportunities

Provision for cyclists within the design of LRT schemes is an important outcome in the sustainable development of a transport system. Use of a bicycle to reach the LRT stop can increase the catchment area significantly beyond the size of the pedestrian catchment area. Safe routes to the LRT stops and secure and appropriate cycle parking can contribute to maximising combined cycle and LRT journeys. On this basis it can increase LRT patronage and the overall number of trips taken by sustainable modes.

High quality, secure cycle parking provision at LRT stops can encourage ‘bicycle park and ride’ and ride and bicycle combinations. These can offer convenient access, weather protection and should be well signed and lit. Where security cameras are used to view platforms, car parks and ticket machines, these should also cover cycle parking sites. Cycle parking lockers can be used for long stay (all day) parking. There are also 10 bicycle lockers and 35 bicycle racks located at Dundrum Cycle + Ride Facility and another 10 bicycle lockers at Windy Arbour Cycle + Ride Facility on the Luas Green Line.

*Figure 2.6: Example of long stay bicycle parking facilities at the Dundrum stop on the Luas Green Line – features include bicycle lockers, cover bicycle racks in a well lit high quality environment*
3.0 Approach to Designing for LRT/Cyclist Interaction

3.1 Introduction
In this section an approach is outlined, to the identification of design options, to manage the LRT/cyclist interaction. In many cases, the introduction of LRT provides the opportunity to reallocate road space in favour of public transport, cycling and walking, and to provide more direct or traffic free routes. Conversely LRT has the potential to introduce difficulties for cyclists where the alignment coincides with, or sever, existing formal cycle routes or other roads or paths used by cyclists. In summary the approach proposed involves the identification of the movement function, the place context, cycle network and options selection.

![Figure 3.1: Approach to Design](image)

3.2 Street Function
LRT routes generally travel along a wide range of streets serving different movement functions including arterial, link and local streets. Design Manual for Urban Roads and Streets (DMURS)\(^2\) illustrates how street/road hierarchies contained within other relevant documents are cross referenced with these different movement functions.

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<thead>
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<tr>
<td>Arterial</td>
<td>National</td>
<td>Primary Distributor</td>
<td>Distributor</td>
</tr>
<tr>
<td>Link</td>
<td>Regional (See Note 1)</td>
<td>District Distributor Local Collector (see Notes 1 and 2)</td>
<td>Local Collector</td>
</tr>
<tr>
<td>Local</td>
<td>Local</td>
<td>Access</td>
<td>Access</td>
</tr>
</tbody>
</table>

Note 1: Larger Regional/District Distributors may fall into the category of Arterial where they are the main links between major centres (i.e. towns) or have an orbital function.

Note 2: Local Distributors may fall into the category of Local Street where they are relatively short in
length and simply link a neighbourhood to the broad street network.

3.3 Cycle Network

Route selection for LRT systems should include assessments of the potential for impact on cyclists. Reference can be made to cycle route network proposals contained in walking and cycling strategies and local plans. Generally for urban cycle networks, a hierarchy of cycle route functions can be applied. This hierarchy can be used as an input to deciding the most appropriate form of treatment for the integration of cyclists and LRT systems. The following table provides a summary of the route functions and categorisation of a typical cycle network.

<table>
<thead>
<tr>
<th>NETWORK</th>
<th>ROUTE CATEGORY</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>Urban Cycle Network</td>
<td>Primary</td>
<td>Main cycle arteries that cross the urban area and carry most cycle traffic</td>
</tr>
<tr>
<td></td>
<td>Secondary</td>
<td>Link between primary cycle routes and local zones</td>
</tr>
<tr>
<td></td>
<td>Feeder</td>
<td>Cycle routes within local zones and/or connections from zones to the network levels above</td>
</tr>
</tbody>
</table>

3.4 LRT Provision

LRT systems can range from segregated rail systems to street running trams operating in a mixed traffic environment. There are three types of on-street running and the level of interaction with other road users varies depending on the type of on-street running:

(i) Tram only streets: Other road users are not permitted to use the street;

(ii) Tram Lanes: Dedicated lanes are provided for the LRT, in some cases there can be a level difference between the tram lane and the adjacent traffic lanes, while in other cases road marking is the sole delineator of the tram lane;

(iii) Shared running: The LRT shares the traffic lane with all other traffic;

3.5 Option Development

Consideration of cycle facilities should take cognisance of both the existing street function and the future scenario as a consequence of the LRT system i.e. tram only street, mixed traffic environment, reduced speed profile. The Guidelines for the Design of Railway Infrastructure & Rolling Stock (GDRIRS) recommend to avoid the risks from unauthorised parking of vehicles fouling the developed kinematic envelope, the width of the cycle track (between the kerb and the furthest edge of the road marking line) should not be greater than 1500mm and the edge of the road marking line nearest to the tram track should be at least 300mm from the developed kinematic envelope.

In identifying the appropriate provision of cycle facilities along any particular route the designer should apply the principles as set out in the National Cycle Manual. The guidance graph presented in Figure 3.2 provides a useful starting point.
Figure 3.2: Guidance on Cycle Provision (Source: National Cycle Manual)

Taking the proposed LRT provision as per Section 3.5 it is possible to identify the potential options for providing for cyclists:

**Tram lanes**

Tram lanes are dedicated lanes which are provided for the LRT, in some cases there can be a level difference between the tram lane and the adjacent traffic lanes, while in other cases road marking is the sole delineator of the tram lane. The provision of the cyclist facility between the vehicular traffic and the tram lane should be considered in conjunction with the proposed location of trams stops (the side of vehicle the doors discharge), the location of loading bays of kerbside parking.
Tram Lane Option 1 can be selected when the speed and volume of general traffic, as shown in Figure 10, indicate that the cycle facility should be segregated. This option is most suited for cycle facilities which are higher up the hierarchy of network provision. The cycle track should be provided on the opposite side to the side that the LRT doors open thus avoiding conflicts with passengers. Where the speed and volume of general traffic allow, the provision of a cycle lane (see Tram Lane Option 2) may be the most appropriate option.

For lightly trafficked roads where speeds are particularly low (see Tram Lane Option 3) the use of a shared traffic and cycle lane may be the most appropriate option.

In situations where the volume of traffic is high (and it is not possible to reduce the traffic volumes sufficiently) and the frequency of trams is such that an acceptable quality of service cannot be achieved, it is recommended that an alternative route is provided for cyclists (see Tram Lane Option 4). In these circumstances it is important that the quality of service that is provided on the alternative route is sufficiently attractive to ensure that cyclists will use the route. Care is required to ensure that desire lines are accommodated.
Shared running:

For shared running lanes the LRT shares the traffic lane with all other traffic. The provision of the cyclist facility between the vehicular traffic and the footpath should be considered in conjunction with the proposed location of tram stops, the location of loading bays and kerbside parking.

In circumstances where shared running is proposed and the cycle facility is intended to provide a high order function (primary/secondary) the provision of a cycle lane is appropriate (see Shared Street Option 1). Subject to the quality of service assessment, which will include an assessment of the junction treatments to ensure the crossing of the cyclist at 90 degrees, it may be possible to facilitate the cyclists within the tram lines (see Shared Street Option 2). Typically this can only be provided in circumstances where the volume of cyclists is such that only single file cycling will occur.

In situations where the volume of traffic is high (and it is not possible to reduce the traffic volumes sufficiently) and it is proposed to run the LRT on the same street it may not be appropriate to also accommodate cyclists (see Shared Street Option 3). This situation is unlikely to occur as the service levels delivered by the tram in these circumstances are unlikely to be acceptable. For shared streets it is not possible to prohibit cyclists only, but rather alternative routes should be provided with high levels of service such that are sufficiently attractive to cyclists.

3.6 Quality of Service Criteria

The National Cycle Manual provides guidance on the criteria that input into the Quality of Service assessment as follows:

1. Pavement Condition Index (PCI) is a measure of the physical integrity of the cycling surface. It is determined by comprehensive visual inspection as set down by the Department of Transport. The Manual suggests that in the absence of a formal PCI score, a locally derived marking system can be adopted.

2. Number of adjacent cyclists describes the capacity two abreast and/or overtaking. "2+1" accommodates two abreast plus one overtaking.
3. Number of conflicts is a measure of the potential interruptions to a cyclist per 100m and may include bus stops, side roads, driveways, entrances, junctions, pedestrians crossings, parking and loading etc.

4. Junction time delay is a measure of the actual time delay at junctions as a percentage of the overall journey time, assuming journey speed of 15km/hr.

5. HGV influence is a measure of the number of HGVs and buses adjacent to cyclist as a percentage of the total traffic during peak hours.

Targets for the appropriate Quality of Service can be selected on the basis outlined in the following Table. There are two facets to the QoS that require to be considered separately.

1. In terms of conflicts, level of comfort, junction time delays and pavement quality a minimum Quality of Service Level B should be provided on all cycle routes, regardless of the volume of demand; and

2. The width factor depends on the peak volume of cyclist demand. Above 500 cyclists per hour it is desirable to provide Width Level A+/A, with 2+1 conditions for social cycling and passing. Where the peak volume is less than 500 cyclists per hour, Level A/B will provide sufficient capacity with room for overtaking by faster cyclists.

<table>
<thead>
<tr>
<th>ROUTE TYPE</th>
<th>PRIMARY/NATIONAL</th>
<th>PRIMARY</th>
<th>SECONDARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle Volume (3 hr peak period)</td>
<td>n/a</td>
<td>200-1000</td>
<td>100-500</td>
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<tr>
<td>Target QoS Width Factor</td>
<td>A+</td>
<td>A+/A</td>
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<td>Target QoS Other Factors</td>
<td>2+1</td>
<td>2+1</td>
<td>1+1</td>
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<table>
<thead>
<tr>
<th>ROUTE TYPE</th>
<th>PRIMARY/NATIONAL</th>
<th>PRIMARY</th>
<th>SECONDARY</th>
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<tbody>
<tr>
<td>Cycle Volume (3 hr peak period)</td>
<td>n/a</td>
<td>200-1000</td>
<td>100-500</td>
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<tr>
<td>Target QoS Width Factor</td>
<td>A+</td>
<td>A+/A</td>
<td>A/B</td>
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<tr>
<td>Target QoS Other Factors</td>
<td>2+1</td>
<td>2+1</td>
<td>1+1</td>
</tr>
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3.7 Option Selection Framework

In broad terms the options available to LRT designers can be summarised in the following table. The option ultimately selected requires the consideration of the potential impact on other activates being undertaken along the street such as loading, boarding and alighting/boarding of bus services. An option selection framework is presented on the following page.
<table>
<thead>
<tr>
<th>STREET FUNCTION</th>
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<td>Shared Running</td>
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<td>Light Rail Transit and Cyclists</td>
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3.8 Conclusions

Many cities throughout the world have demonstrated that cycling and LRT systems can co-exist successfully. In many cases, the introduction of LRT provides the opportunity to reallocate road space in favour of public transport, cycling and walking, and to provide more direct or traffic free routes.

This guidance note has proposed an approach to the design of cycle facilities in conjunction with LRT schemes. The initial step in the proposed approach involves the identification of the street function. Guidance on the categorisation of street functions is provided in the Design Manual for Urban Roads and Streets (DMURS)².

The next step is to identify the classification of the street within the cycle network for the City. Guidance on the preparation of cycle networks is contained in the National Cycle Manual¹.

The LRT provision is the next input into the assessment. LRT systems can range from segregated rail systems to street running trams operating in a mixed traffic environment. There are three types of on-street running and the level of interaction with other road users varies depending on the type of on-street running.

A matrix of options has been proposed based on these three inputs. The option ultimately selected requires the consideration of impact on other activates, being undertaken along the street, such as loading, boarding and alighting from bus services etc.
4.0 List of Relevant Literature Reviewed

1. "National Cycle Manual" published by the National Transport Authority (June 2011) available at www.cyclemanual.ie


3. "Smarter Travel: A Sustainable Travel Future" published by the Department of Transport Tourism and Sport (February 2009) available at www.transport.ie


9. "Edinburgh Tram Cycle Integration Study" Published by The City of Edinburgh Council (July 2009) not available online


12. "Light Rapid Transit and Cyclists Guidelines for Planning and Design" Published by CTC (August 1998) not available online