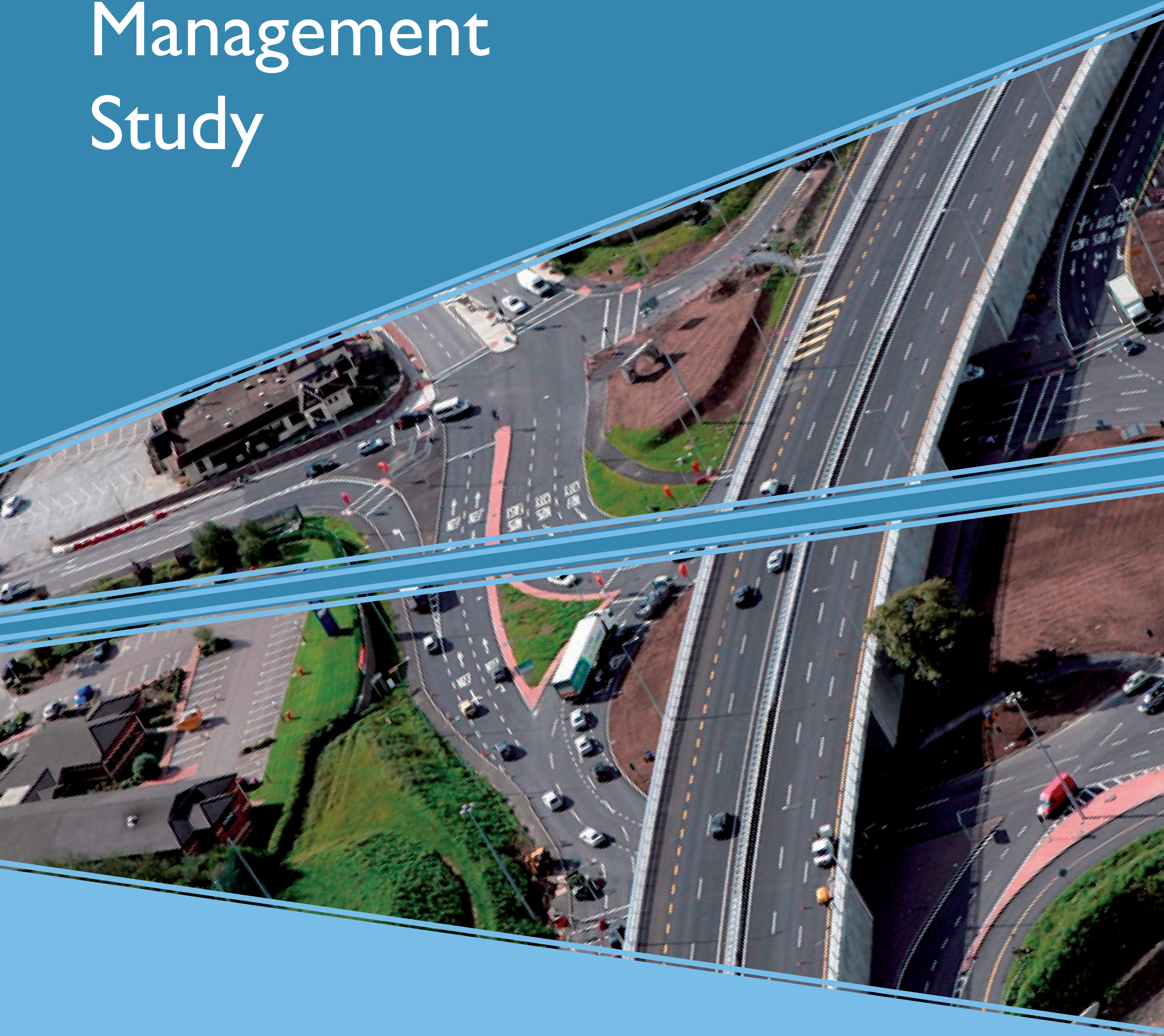
NRA
An tÚdarás um Bóithre Náisiúnta
National Roads Authority

February 2011

National Roads Traffic Management Study



Final Report

AECOM Roughan & O'Donovan Goodbody Economic Consultants

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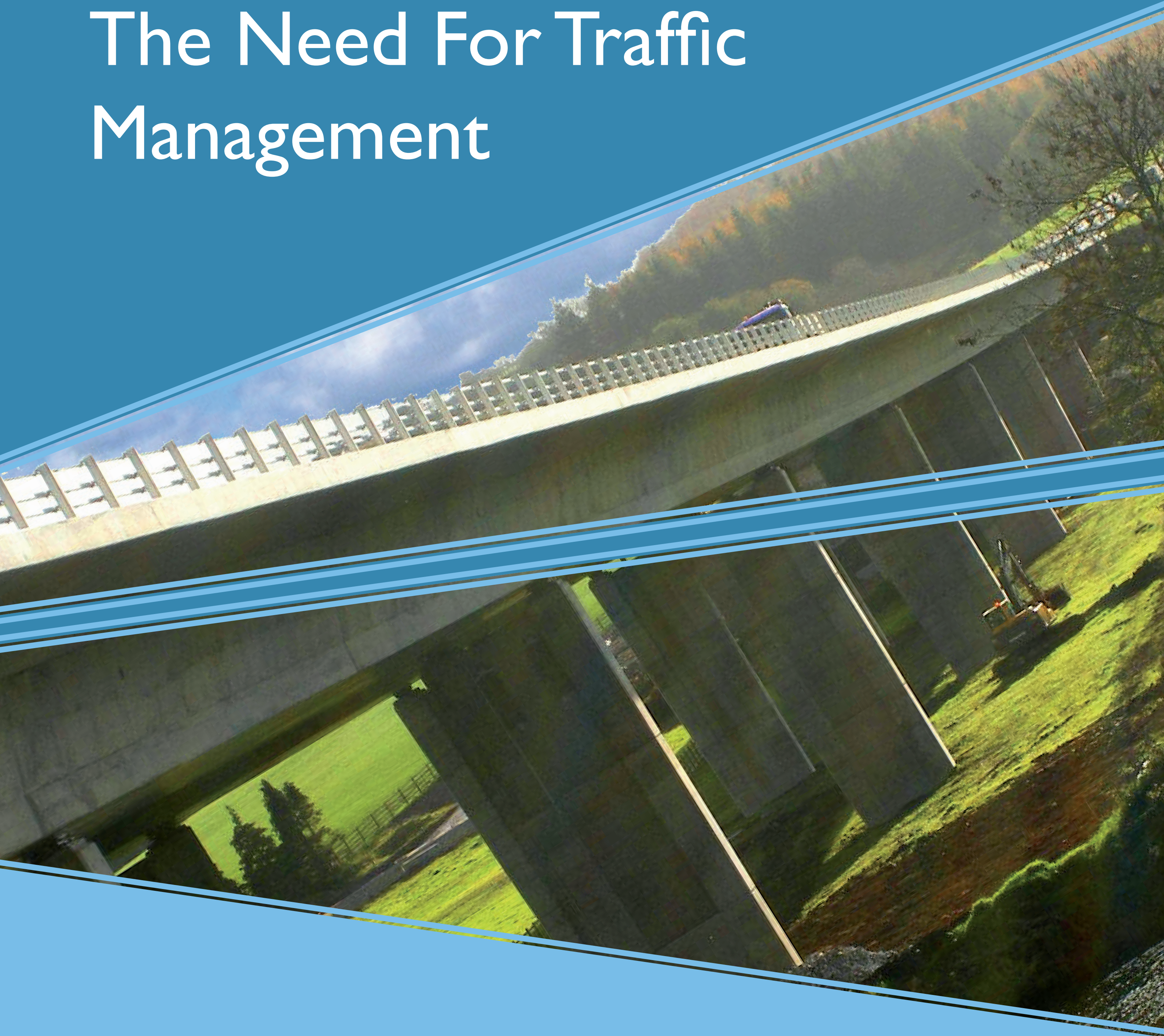
The Need For Traffic Management



Section A

AECOM
Roughan & O'Donovan
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Section A The Need for Traffic Management

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Chapter 1 Introduction

1.1 National Roads and Travel Demand

At a national level, vehicle kilometres increased by approximately 40% between 2000 and 2008. Table 1-1 sets out the trend in car and goods traffic volumes on a national basis over this period, and shows that total car and goods vehicle kilometres grew at an average rate of approximately 4.8 per cent per annum over the period 2000-2007. Goods vehicle kilometres were particularly strong with an average annual growth rate of 10 per cent over the same period. The data highlights a break in the trend in 2008, with reduced rate of growth of 1.8 per cent. This is largely due to a reduction in goods vehicle kilometres.

Table 1-1 Trends in Transport Demand (million vehicle kilometres)

Year	Cars (mvkm)	% Change	Goods (mvkm)	% Change	Total (mvkm)	% Change
2000	23,532		4,075		27,607	
2001	24,664	4.81	4,577	12.32	29,241	5.92
2002	25,142	1.94	5,048	10.29	30,190	3.25
2003	26,036	3.56	5,562	10.18	31,598	4.66
2004	26,913	3.37	6,116	9.96	33,029	4.53
2005	27,972	3.93	6,670	9.06	34,642	4.88
2006	29,015	3.73	7,409	11.08	36,424	5.14
2007	30,349	4.60	7,891	6.51	38,240	4.99
2008	31,173	2.72	7,745	-1.85	38,918	1.77

Source: CSO

Conventional forecasts of national traffic volumes (in vehicle kilometres) can be made by using the forecasts of vehicle numbers combined with assumptions about average annual use levels. Notwithstanding this, Smarter Travel[1] has set a target that "*the total kilometres travelled by the car fleet in 2020 will not increase significantly from current (2009) levels*." The exact mechanics of delivering on that objective remain to be developed but it is likely that a major portion of that target will be attributable to mode transfer in the urban areas.

In terms of longer distance strategic traffic associated with the national road network, the outcome of the Smarter Travel interventions are more difficult to assess. Many of the pre-requisites to achieving the Smarter Travel objectives are long-term in nature, such as the target to successfully integrate land use and transport planning. Table 1-2 sets out the forecasts, excluding Smarter Travel impacts, which are based on an assumption that average kilometres per car remains static, but that goods vehicles increase at a rate of 1.3 per cent per annum. It then sets out the 2025 forecasts which assume, in accordance with the Smarter Travel target, that overall car vehicle kilometres will by 2020 be the same as current levels but allowing that goods vehicles travel will continue to grow.

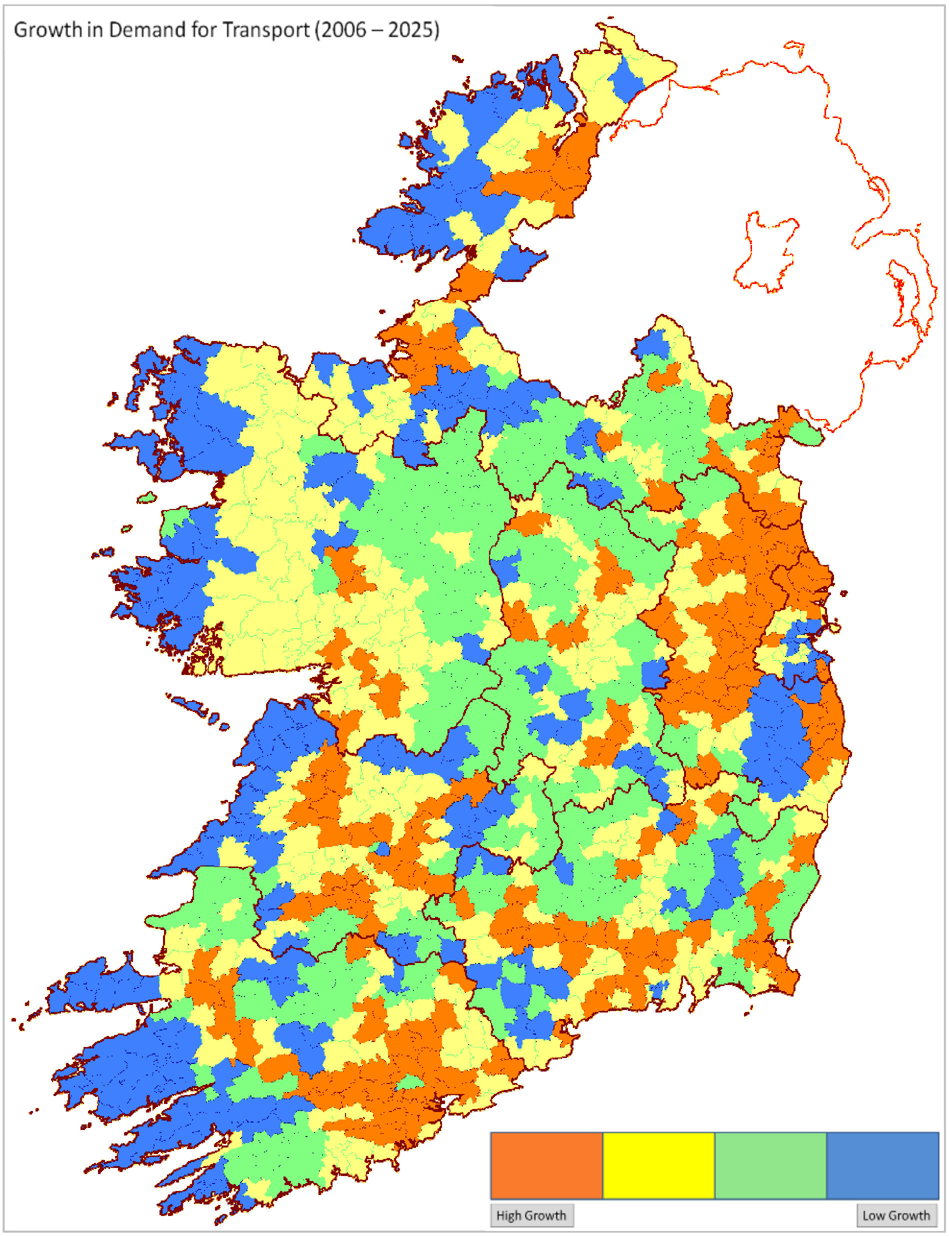
Table 1-2 Forecasts of National Traffic Volumes

Year	Cars (mvkm)	% Change	Goods (mvkm)	% Change	Total (mvkm)	% Change
2009	30,247		6,557		36,803	
2025 *(Without Smarter Travel)*	39,455	30.4	10,961	67.2	50,415	37.0
2025 *(With Smarter Travel)*	30,247	0	10,961	67.2	41,208	12.0

The analysis suggests that there would be a net decline in traffic volumes in 2009 and 2010 of some 7 per cent before growth resumes through 2011 (although this may be delayed slightly with any further downgrading of economic growth forecasts). The bulk of the decline in traffic is due to a substantial reduction in goods vehicle traffic, which fell by a cumulative 17 per cent up to the end of 2010.

The forecasts suggest, however, that traffic volumes will return to their peak level of 39,000mvkm by 2013/2014. Looking to the longer term and excluding the Smarter Travel initiatives, traffic volume growth rates of approximately 2.5 per cent per annum are forecast up to 2017, with a reduced growth rate thereafter. Examining these forecasts at a more disaggregate level using the National Traffic Model, Figure 1-1 shows that much of the future growth will materialise in those areas located on the periphery of our major towns and cities, where traffic congestion has traditionally been a significant barrier to the movement of people and goods.

Figure 1-1 Forecast Growth in Transport Demand (2006 – 2025)

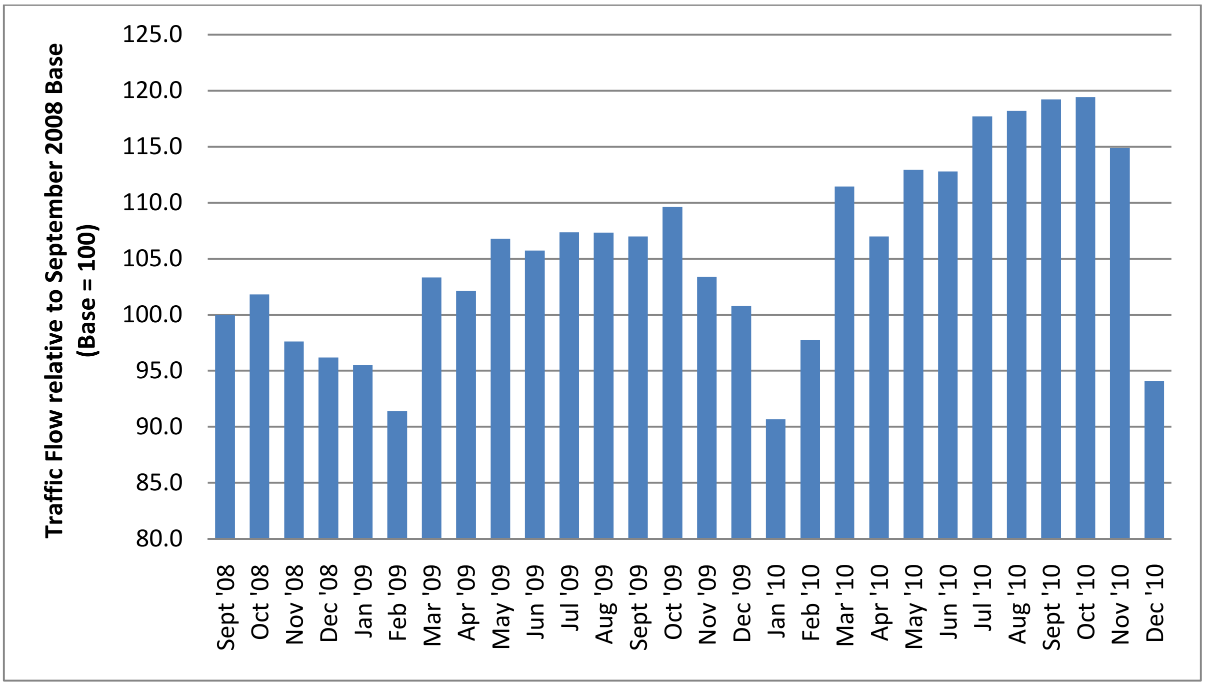


Source: National Traffic Model

These forecasts therefore provide an indication of how transport demand will grow in response to future growth in population and employment. Obviously, the exact level of growth will depend on the level of economic growth that materialises, and hence the requirement for periodic reviews of such forecasts.

It has long been acknowledged that the provision of additional road capacity can lead to growth in traffic demand that exceeds background expectations, mainly as a result of the induced traffic effects of such infrastructure. Examining the M50 over the period from 2008 to 2010, Figure 1-2 shows that there has been constant and consistent growth in monthly traffic volumes, with increases of up to 20% recorded over a 2-year period. This is in contrast to traffic volumes across much of the rural road network, where reductions of up to 20% have been recorded in individual areas since 2008. This conclusion suggests that the additional road capacity on strategically important routes remains under threat despite the economic slowdown, and that such growth will likely accelerate as the economy returns to growth.

Figure 1-2 Observed Traffic Growth on the M50 (Junction 6-7)



Application and delivery of the Smarter Travel objectives over the next decade is intended to alter these growth rates. Nevertheless, given the long-term nature of many of those initiatives, it is likely to take some time before their impacts on road traffic becomes apparent. Therefore, the only feasible scenario is that there will be continued growth in car vehicles kilometres initially, prior to a reduction in car vehicle kilometres as the impacts of the Smarter Travel proposals are fully implemented.

1.2 Responding to Travel Demand

Over the period since the publication of the National Road Needs Study in 1998, the increase in inter-urban travel demand by road has been supported through the construction of a number of major road projects, which include:

- The major inter-urbans (MIU's), connecting Dublin with the Regional Cities;
- Other major improvements on non-MIU corridors serving Dublin;
- The completion and subsequent upgrade of the M50 and its key junctions;
- The provision of the Dublin Port Tunnel;
- The advancement of the Atlantic Corridor; and
- Further investment in National Secondary Roads

This response to growth in travel demand nationally has been significantly different from the responses in those urban areas where growth has been managed through provision of public transport enhancements, quality bus corridors, traffic management, intelligent transport systems and fiscal measures such as parking charges and workplace parking levies. The approach to traffic management in urban areas reflects the understanding that provision of additional capacity can only be appropriate up to a certain level, beyond which capacity enhancements bring significant financial and environmental cost.

The National Roads Authority has recognised that much of the national road network (particularly those parts of the network which are located within or close to major towns and cities) has been upgraded to the point where future capacity enhancements will be extremely costly and disruptive, and hence these have reached the point whereby growth must now be managed using control and fiscal techniques that to date have focused on urban roads.

The National Roads Authority has therefore undertaken this Traffic Management Study in order to understand the implications of future traffic growth, identify network deficiencies and to examine management requirements across the network which will secure the ability of the network to cater for growth up to 2025. The Study is based on the National Traffic Model, produced by the National Roads Authority in 2008, and uses transport growth forecasts which account for recent economic events and form the basis for current long term forecasts in transport demand.

1.3 The Traffic Management Study Final Report

This report presents the results of the National Roads Traffic Management Study, demonstrating the various analytical and feasibility studies that have informed the development of the options, and presenting strategy alternatives for a number of key geographical areas. The report is divided into a number of sections as follows:

Section A: The Need for Traffic Management

Section A provides the context for the current study. It outlines the data sources available to the Authority in embarking on the study, and describes the development of the National Traffic Model which has played a key role in the study. This Section also provides a comprehensive review of existing transport demand nationally, describing how these demands materialise as traffic on the National Road Network. The discussion also sets out future challenges that will arise as a result of further growth in travel demand, and identifies a number of key areas where Traffic Management initiatives might initially focus. Finally, Section A explores the specific objectives of the study, formulating these into a series of clear statements which will guide the development of options and the appraisal of alternatives.

Section B: Traffic Management through Control Measures

Section B focuses primarily on the feasibility of employing *control* measures to manage traffic flow on the National Road Network. Traffic control measures broadly describe those measures which seek to manage traffic flow through regulatory mechanisms. Examples include traffic signals, speed limits and vehicle restrictions, and are intended to directly control traffic flow to achieve desired outcomes. Section B outlines the engineering and analytical studies that have been undertaken to understand the appropriateness or otherwise of such measures, leading to a set of conclusions for each regarding where and how they can be best employed. These conclusions are supported by further discussion on the interoperability of different technologies at a single site, and play a key role in defining the strategy options in the various geographical areas.

Section C: Traffic Management through Demand Management

Section C sets out the range of measures which can be employed to address the *demand* side of transport planning. Demand Management measures achieve this by encouraging users to change travel mode, travel during different times of the day, travel to destinations which have a lower impact on the transport network, or decide that no trip is necessary. Such measures also seek to ensure that local and regional planning is undertaken in such a way that the demand for transport infrastructure can be minimised. The measures set out in Section C are distinct from fiscal measures which can often achieve a similar outcome, albeit using a fundamentally different approach. There is a close relationship between the Demand Management measures outlined in this report and those contained in the Smarter Travel document, which has a number of objectives that are consistent with the Traffic Management Study.

Section D: Traffic Management through Fiscal Measures

In Section D, the discussion focuses on options for *fiscal* management of the National Road Network. Section D examines various forms of road user charging (satellite based or more conventional electronic or 'hard' tolling), and concludes on the most appropriate forms of charging in Ireland. The discussion identifies appropriate levels of charge for urban areas and inter-urban movements based on a combination of economic principles of congestion, and through an understanding of willingness-to-pay by road users. HGV road user charging options are also discussed, and the basis for satellite systems for HGV tolling is examined. Section D concludes with the development of the most appropriate road user charging strategy that can achieve the objectives of the current study, whilst accounting for the financial costs that can be accrued for different solutions.

Section E: The Development of the Strategy

Section E of the report presents the process of strategy development, outlining the identification of measures that are to be considered as part of alternative strategies for key geographical areas. The report outlines the basis for alternative strategies, and the appraisal of alternatives against criteria defined in Section A. Proposed measures are set out in outline only, with the exact form and extent of measures to be further dictated through the preliminary design and subsequent planning processes

Chapter 2 Objectives of the Traffic Management Study

2.1 Requirements of the Study

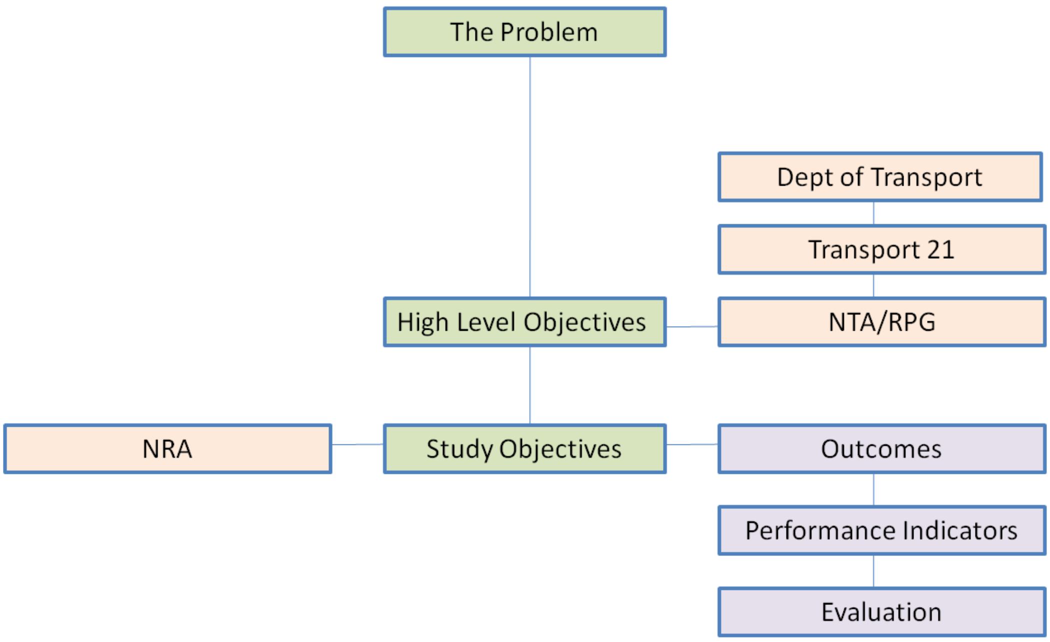
The study brief for the National Roads Traffic Management Study outlined the need to prepare a robust strategy which could:

- Sustain the contribution of the national road network to economic competitiveness;
- Sustain the transport efficiency and effectiveness of the national road network;
- Promote allocative efficiency in demand for road space;
- Reduce congestion;
- Reduce emissions;
- Manage traffic so as to maximise available capacity, level of service (LOS) and journey reliability;
- Support the operation of public transport using national roads; and
- Provide scalable and evolvable solutions.

The above represents a set of initial objectives which guide the interpretation of the study requirements amongst the project team as well as key stakeholders. Nevertheless, these objectives remain at a high level, and require further refinement before they can guide the specific direction of the study, and provide a framework for evaluation.

The setting of objectives for a study of this nature requires an understanding of the form and function of objectives within the overall project framework. Given the importance of this current study, and the potential significance of the strategies that will emerge from it, objectives have been based on a robust derivation of national and regional policy objectives. Figure 2-1 shows how study objectives are derived based on this approach.

Figure 2-1 Summary of process for objective setting



2.2 The Problem

The National Roads Authority is charged with the procurement and management of the national road network, and to ensure that the primary functions of that network can be protected. It is widely accepted that national roads are an important driver of economic growth and competitiveness, supporting balanced regional development, and ensuring access to jobs, businesses and education, as well as securing connections between various communities and markets.

Roadspace, for the most part, operates in a free market where demand for roadspace is met on a first-come first-served basis. There are limited current interventions on national roads which allocate roadspace to those who need it most, apart perhaps from the Dublin Port Tunnel where capacity is specifically reserved for freight movement. The subsequent behaviour of users leads to significant market externalities, where additional trips on the network lead to congestion and environmental impacts imposed on other users. This leads to inefficiencies in the demand for roadspace, particularly under congested conditions.

The purpose of the current study is therefore to address such inefficiencies by ensuring a more optimised allocation of road capacity such that the maximum potential benefit can be derived from the provision of such roads.

Many of the objectives set out for the study relate directly to the requirement of national roads to maintain their role of providing strategic connectivity between urban areas and key import/export markets.

Strategic Traffic describes those categories of traffic which generate broader strategic benefit to the economy. Such traffic predominantly comprises business travel and freight which facilitates and supports economic growth in the Hubs and Gateways, outlined in the National Spatial Strategy. High volumes of commuter traffic which contribute to localised congestion on national roads therefore inhibit the ability of those roads to fulfil this strategic function.

The Traffic Management Study will therefore seek to secure the ability of the national road network to provide fast, reliable and safe strategic connectivity through a series of measures which support the allocation of roadspace to those who will derive most value from it.

2.3 Objectives of the Traffic Management Study

The study objectives are defined below using five criteria which correspond with the NRA and Department of Transport Project Appraisal Frameworks. Categorisation of the study objectives in this way allows evaluation of the strategy under the published guidance, with the results of that evaluation feeding into the Project Appraisal, as set out in Chapter 24.

Figure 2-2 Objectives of the National Roads Traffic Management Study

Economic

- To improve the allocative efficiency of the national road network through the active allocation of demand for roadspace to those categories of user who maximise benefit and minimise adverse impact, particularly in congested areas;
- To reduce the economic impact of delay that results from incidents on the national road network through effective incident management
- To address excessive reliance on national roads as a means of supporting commuting traffic
- To maximise the capacity of congested areas of the road network through effective management solutions

Environmental

- To encourage the use of public transport on national roads through facilitating a reduction in travel times and an increase in reliability
- Contribute to reductions in CO_2 emissions, air pollution and noise

Accessibility and Social Inclusion

- To maintain and improve opportunities for access to business, employment, education, health and recreation where appropriate on national roads

Integration

- To promote an understanding of the requirements for integrated land use and transport planning policies in developing areas alongside or nearby national roads
- To encourage the use of public transport on national roads through supporting network integration

Safety

- To reduce knock-on safety risks that result from incidents on the national road network as a result of congestion and diversions to inappropriate routes
- To reduce the frequency and severity of accidents on National Roads

Chapter 3 Baseline Assessment

3.1 Overview

An assessment of existing and future transport demand and resulting conditions on the road network has been undertaken to inform the National Roads Traffic Management Study. The assessment aims to provide the basis for understanding the scale and location of measures that will be necessary to support each of the identified objectives, by addressing the following:

- How has the current network evolved and what are the plans for future investment?
- What are the key economic drivers of the network? What are the main sources of travel demand on the network and where is the highest demand?
- What level of connectivity and capacity does the network offer in responding to the needs and demands of users?
- What contribution does the national road network make to CO_2 emissions?
- What are the current applications of Intelligent Transport Systems technology on the network and what are the plans for future expansion?
- Where are the main safety concerns on the network and how can the Traffic Management Study address these?

The Baseline Assessment has optimised data from the National Traffic Model, the Census of Journey to Work and the National Road Accident Database.

3.2 Development of the Road Network

Ireland's current national road network developed from the older hierarchal system of Main, County, and Rural roads which were established by the Roads Traffic Act 1925. Main roads were further designated as Trunk, Arterial, and Link Roads, which followed the traditional routes between population centres. This system lasted until the current hierarchy of National Primary and Secondary Routes were introduced in 1977 under the provisions of the Local Government Act (Roads and Motorways Act) 1975. This led to a major increase in new road building along planned routes.

The NRA was formed by the Roads Act 1993 "to secure the provision of a safe and efficient network of national roads." It was set up as an agency which could coordinate local authorities and with necessary technical expertise to oversee the implementation of a national roads programme. The NRA has also coordinated standardisation of road design across the country, management of ongoing programmes of data collection, publication of standards, and provision of supporting research. Through this, the road planning process has been brought into line with EU practice, with greater consultation and appraisal at route selection stage.

The national road network has seen extensive redevelopment in recent years through implementation of the National Development Plan[2] (NDP). The 2000-2006 NDP proposed significant improvements to the national road network as follows:

- Upgrade of the five major inter-urban routes (MIUs) from Dublin to the border, Galway, Cork, Limerick and Waterford to motorway/high-quality dual carriageway standard;
- A programme of major improvements on other national primary routes;
- Completion of the M50 motorway and the Dublin Port Tunnel; and

- Improvement of national secondary routes of particular importance to economic development.

The 2007-2013 NDP has also set out challenging objectives for upgrade of the road network which are being implemented through the Transport 21 capital investment framework. Almost €18 billion is to be invested in the national roads component of the transport plan. Proposals for investment include:

- Completion by 2010 of the major inter-urban routes linking Dublin with Belfast, Cork, Galway, Limerick and Waterford;
- The upgrade of the M50 by 2010 including barrier free tolling (2008);
- Improvement of road links between the main National Spatial Strategy[3] (NSS) Gateways;
- Ongoing development of the Atlantic Road Corridor from Letterkenny through Sligo, Galway, Limerick, Cork and Waterford;
- Continued upgrading of road links to Northern Ireland;
- Targeted improvements of a number of key national secondary routes;
- Improvement and maintenance of the non-national road network; and
- Investment in strategic non-national roads which will complement the national roads investment.

Further projects, such as the Leinster Orbital Route and the Dublin Eastern Bypass are at Feasibility Stage, and are not currently included in any investment plan for National Road Infrastructure.

By the start of 2009, there were 5,415km of national road in Ireland, consisting of 2,739km of National Primary and 2,676km of National Secondary Routes. At that same time, 478km of new road were under construction.

Ongoing development of the road network under Transport21[4] focuses predominantly on the provision of improved strategic connectivity between hubs and gateways as envisaged in the National Spatial Strategy. Future capacity enhancement in urban areas is expected to be limited, and such needs are instead being addressed through the delivery of significant public transport infrastructure in addition to ongoing provision of local road infrastructure by Local Authorities. As such, it is unlikely that the road infrastructure as set out in Transport21 would fully address current difficulties on the road network in the vicinity of the major cities.

3.3 Existing Management of the National Road Network

3.3.1 Development Management

Capacity of the national road network remains under significant pressure in the fringes of major urban areas, where local trips comprise a significant proportion of the volume of traffic carried. Relative to local road networks, National Roads are typically built to high standards at significant cost, and the provision of capacity for non-essential local traffic movements is not a cost effective means of catering for such demand. In preparing a Local Area Plan, however, or when proposing a material contravention of a development plan, there is currently no obligation to consult with the NRA in advance of the public consultation process. Such a situation exists despite the potential for such processes to have a significant impact on adjoining roads.

The NRA can make submissions on planning applications, and can appeal decisions to An Bord Pleanála. Nevertheless, applications can, and are, granted against the advice of the NRA, and this can lead to notable cumulative impacts on the strategic road network.

3.3.2 Intelligent Transport Systems (ITS)

ITS provides an invaluable proactive management tool to maximise the current capacity of the road network which is increasingly important for meeting growing demand with fewer new road building projects. Investment in ITS to date has concentrated on four key routes and their immediate subsidiary links:

- M1 Dublin to Dundalk;
- M50 Dublin Orbital;
- M11 (N11) Dublin to Rosslare; and
- M7 Dublin to Limerick.

Existing ITS deployment on these routes includes Variable Message Signs (VMS) for traffic management and travel information provision, CCTV for traffic monitoring, Automatic Incident Detection (AID), In-Pavement traffic and congestion monitoring, Automatic Vehicle Classification and Weather Monitoring Equipment. A new traffic monitoring system for all National Roads is currently being procured and is expected to be operational by 2012.

3.3.3 Dissemination of Information

"*NRA Traffic*" is the web based service provided by the NRA for pre-trip and on trip traveller information. The site has the following functions which provides different benefits and impacts to the traveller.

- **Current live eye view cameras** which provide the user with the ability to view for themselves the level of congestion on the network;
- **VMS legend displays** allows the user to see those messages currently displayed which may impact on their journey;
- **Weather station data monitoring** sites which include road surface, temperature and wind speed information and may be particularly relevant when approaching icy conditions;
- **Travel time information** for key routes including the M1 Northbound between (Dublin Port Tunnel to Lissenhall) and M1 Southbound between (Balbriggan and the Dublin Port Tunnel) can allow users to check for freeflow conditions or gauge their travel times and potentially alter their departure time; and
- **Up to date road works and event information** which allows users to view any potential disruptions to their trip.

Whilst the website covers the full road network, the majority of the information is focused on the M1 and M50. The website also includes information for VMS situated within the Dublin City Region and used for the Dublin Port Tunnel, and provides traveller information for the end user despite different authority control. Real-Time and On-Trip services allow for updates for key routes to be sent via mobile phone messages which can be signed up for via the website thus developing the website into an online trip advice service.

3.3.4 Incident Management

The management of incidents on the National Road Network remains the responsibility of An Garda Siochana through the usual channels of dealing with emergencies (other than in specific areas such as the Dublin Port Tunnel). Although VMS infrastructure does exist on key corridors, there is no established procedure for early transmission of messages to warn motorists of incidents ahead. Such warnings are more commonly issued through radio stations which pass on messages from motorists, often with a significant lag time.

More recently, a pilot project has been developed in Co. Cork to manage incidents on major roads. The scheme attempts to generate pre-rehearsed responses by An Garda Siochana to manage closures of identified stretches of road, and is supported by a handbook which specifies diversion routes and associated signage for particular closures

3.4 National Travel Patterns

3.4.1 The Concept of Trip Density

In order to understand existing traffic demands, an exercise has been undertaken to show demand density (i.e. trips per square km) for 2006 (the year for which most recent census data is available). This information has been extracted from the National Traffic Model (2006), and is mapped thematically below for arriving and departing trips during the morning peak period. Those areas shaded in darker red represent 'zones' which generate higher volumes of traffic per square km during the morning peak period. Origins and destinations are shown separately.

Figure 3-1: Origin Trip Density (2006)

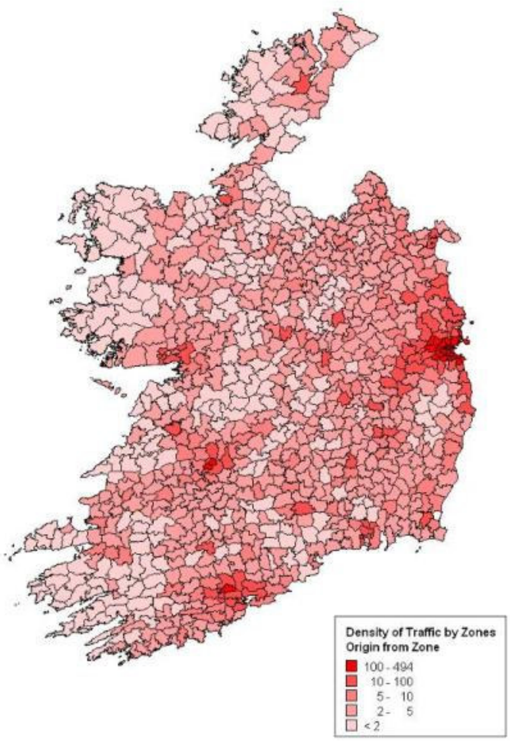
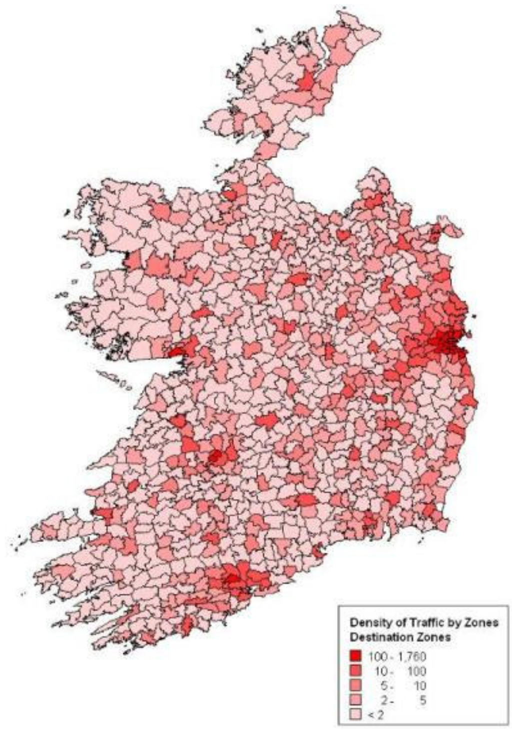


Figure 3-2: Destination Trip Density (2006)



The plots demonstrate a definite pattern of trip concentration in the vicinity of the major urban areas and along the major road corridors. Nevertheless, the pattern of destinations is more focused on urban settlements, as the models reflect the current patterns of commuting from regional towns and suburbs into city centres.

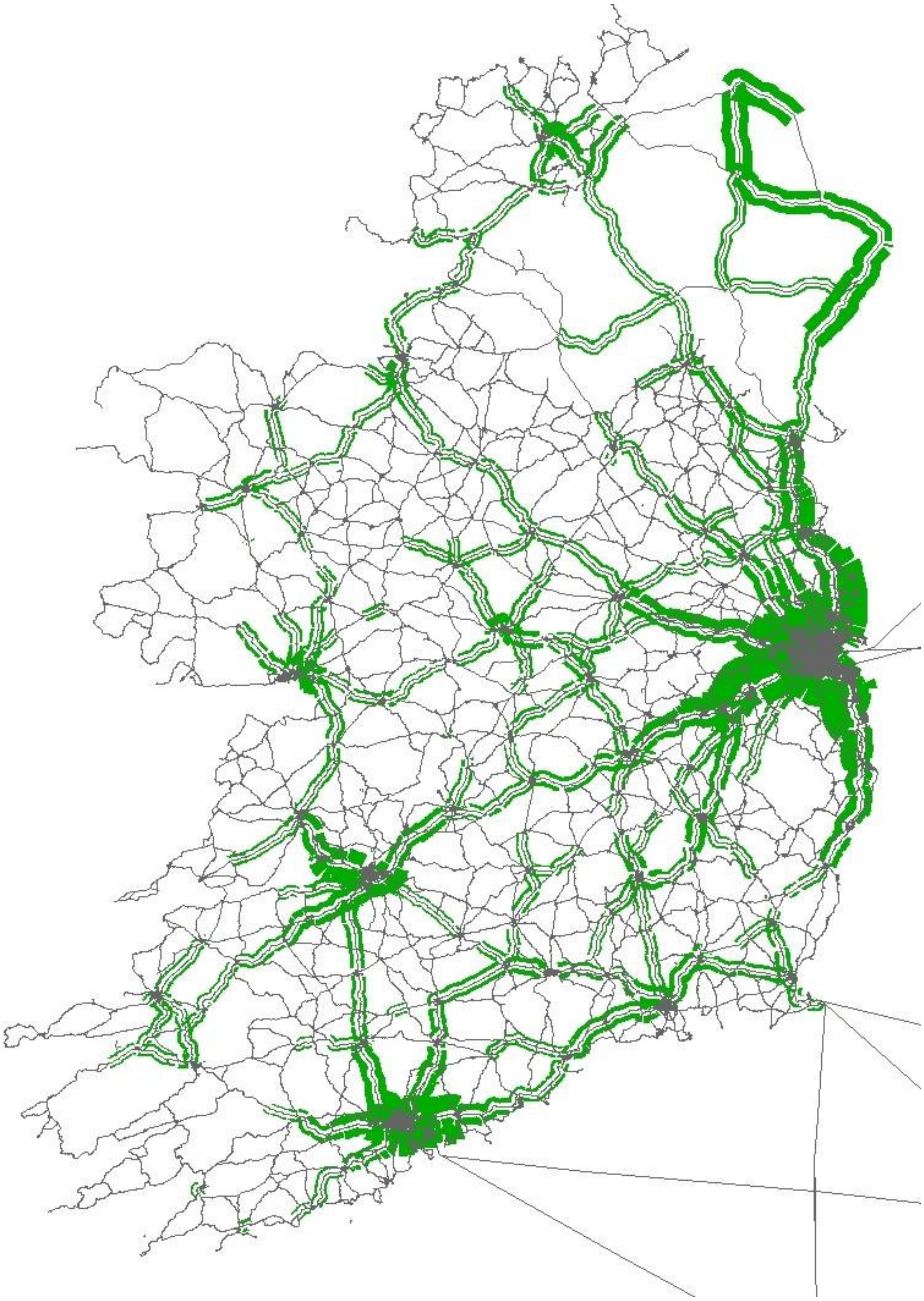
Of particular note is the high geographical spread of destinations in Dublin and Cork which suggests a high focus of employment areas around the edges of the urban areas. These areas rely heavily on orbital transport infrastructure to respond to commuter demand which can lead to travel patterns that are difficult to facilitate through provision of public transport.

3.4.2 The Concept of Transport Need

It is also possible to understand the relative role of different roads in supporting economic activity. Gravity modeling techniques have been used to generate a series of 'desire lines' between various zones as a function of the economic value of each zone (number of jobs) and the distance between them. This is referred to as 'Transport Need'

Plotting Transport Need shows a clear dominance along the key Inter Urbans, with the routes from Dublin to Belfast, Limerick and Cork showing significant importance. Within the Mid East Region, the corridors between Dublin and Athlone, Longford, Carlow and Arklow are particularly highlighted. Further afield, the corridor from Waterford to Cork, Limerick and Galway shows a strong result, which reflects much of the alignment of the Atlantic Corridor. This output represents an important consideration in the planning of future roads.

Figure 3-3: Assessment of Transport Need (2006)



3.4.3 The Level of Car Use

Information on existing travel patterns is available from SARTRE (Social Attitudes to Road Traffic Risk in Europe). The SARTRE project studies the opinions and reported behaviours of car drivers throughout Europe. The project is based on a survey of a representative sample of drivers within each EU country.

Figures 3-4 and 3-5 below demonstrate that Ireland generates significant levels of car travel per person in comparison to our EU neighbours. The graphs suggest that there may be a strong potential for significant change in existing travel behaviour.

Figure 3-4: Average kilometres driven by a car driver in 2004

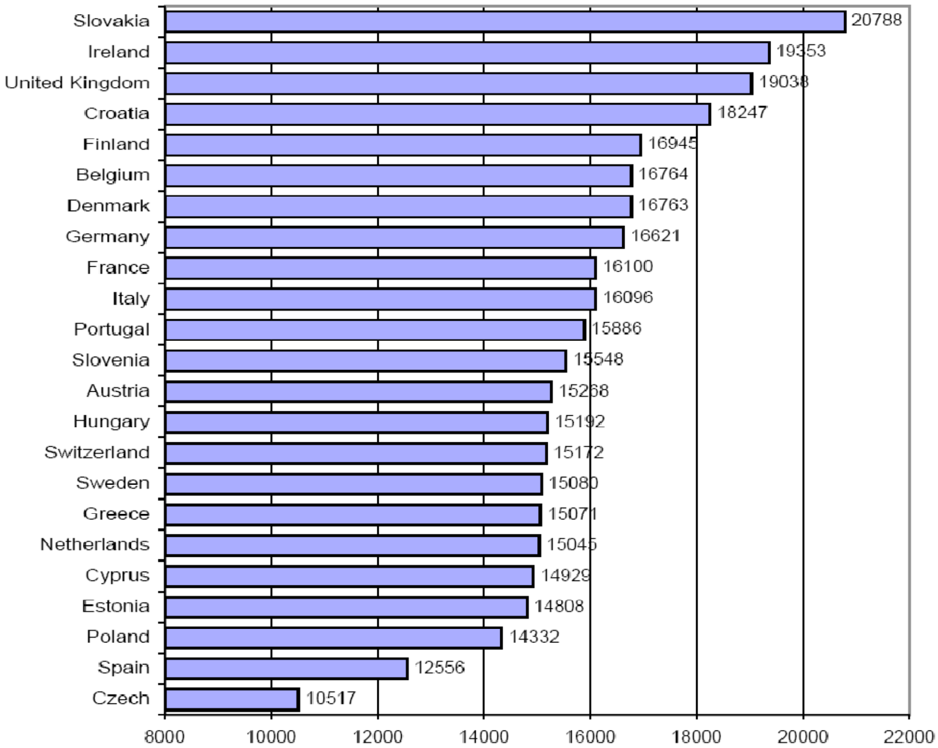
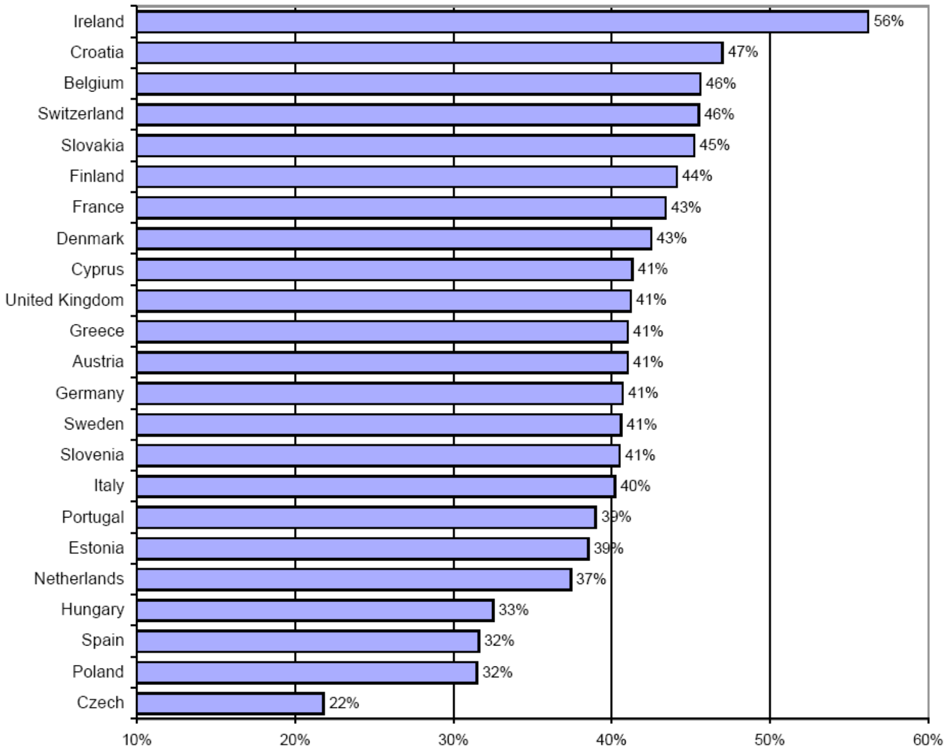


Figure 3-5: More than 15 000 kilometres driven in the last 12 months



3.4.4 The Movement of Freight

Transport of freight generates major demand on the road network especially in Ireland where 99% of all freight is transported by road. It is important therefore to consider the basis of this demand in more detail.

In 2009, 148 million tonnes of goods were transported by road in Ireland. In terms of kilometres travelled, a total of 1,580 million vehicle kilometres were completed in 2009. This demand clearly has a significant impact on the national road network.

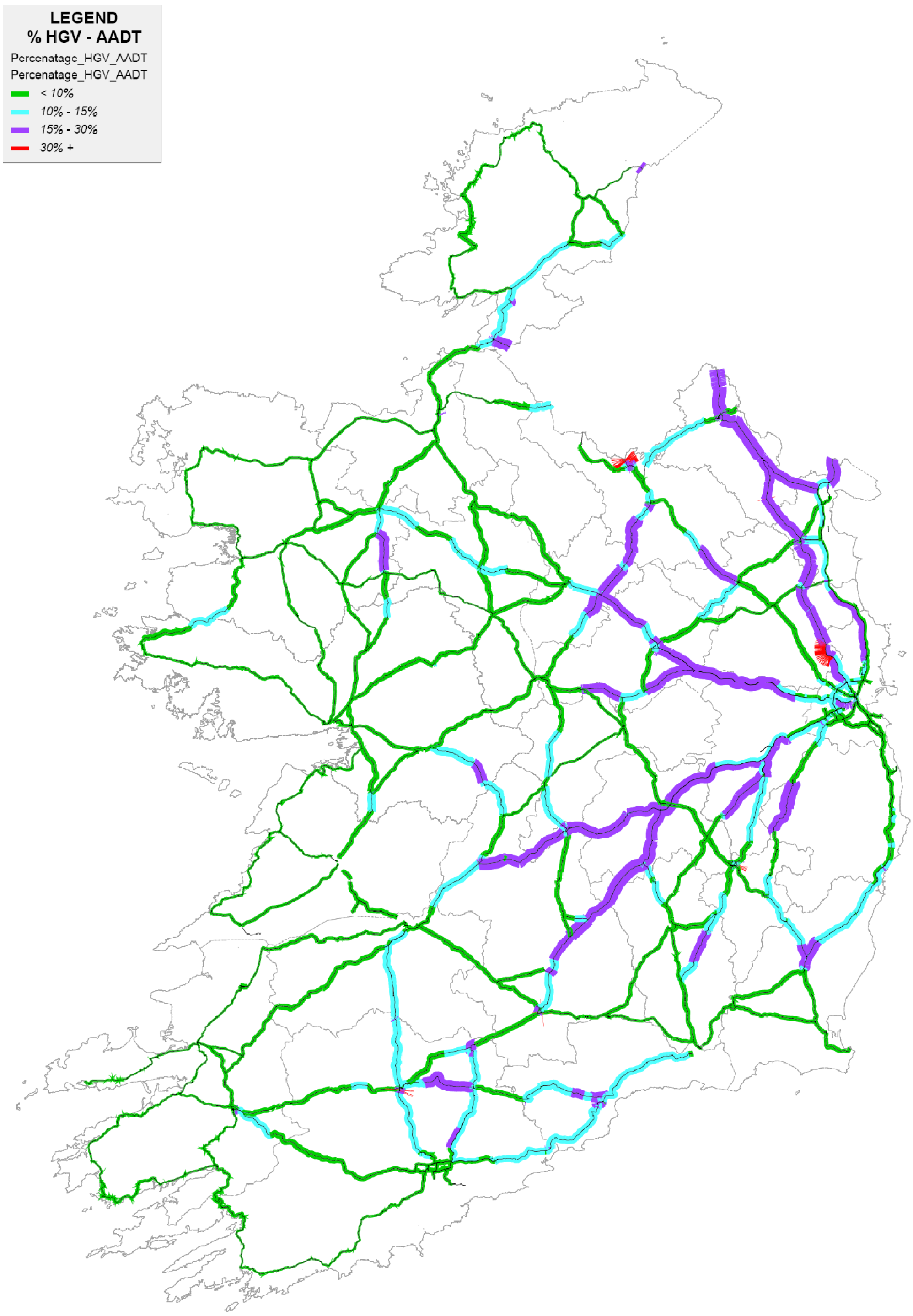
The size of freight vehicles on our roads is also increasing. In 2009 there were 87,556 goods vehicles with an unladen weight of 2 tonnes or greater. Of the total weight of goods carried, 46 million tonnes of 'Quarry products, metal ores and peat' was carried which makes up the highest weight of commodities transported. This category, however, represented just 4% of total vehicle kilometres travelled. In terms of distance travelled, the 'Foodstuff' category consumed the highest distance travelled at 267 million vehicle kilometres.

In identifying the importance of national roads to freight movement, it is useful to examine the proportion of freight vehicles using key roads as a function of total traffic movement. Figure 3-6 below highlights the proportion of HGVs on the national network in 2006. HGVs are defined as goods vehicles with three or more axles (OGV1 and OGV2).

As illustrated, a number of interurban routes display typical values of 10-15% HGVs. It is clear, however, that routes on the approach to Dublin experience the highest proportion of HGVs, with a large proportion of those routes experiencing between 15-30% HGVs such as the M1, N2, M4, M7, M8, N9 and N81. The dominance of HGVs on Dublin routes reflects the importance of Dublin Port in handling 50% of all Ireland's imports and exports and two thirds of containerised trade to and from Ireland. Trade levels through the Port reached a record high of almost 31 million tonnes in 2007. Although this decreased to 26.5 million tonnes in 2009, total throughput recovered to 28.1 million tonnes in 2010.

Analysis of HGV activity highlights a high proportion of HGV's on the National Secondary Road Network connecting the Midlands with the North East and Northern Ireland via Monaghan, and also from Dundalk to Northern Ireland via Monaghan. This suggests that Monaghan is located in a strategically important 'crossroads' on the National Road Network

Figure 3-6: Proportion of HGV vehicles on the National Road Network in 2006



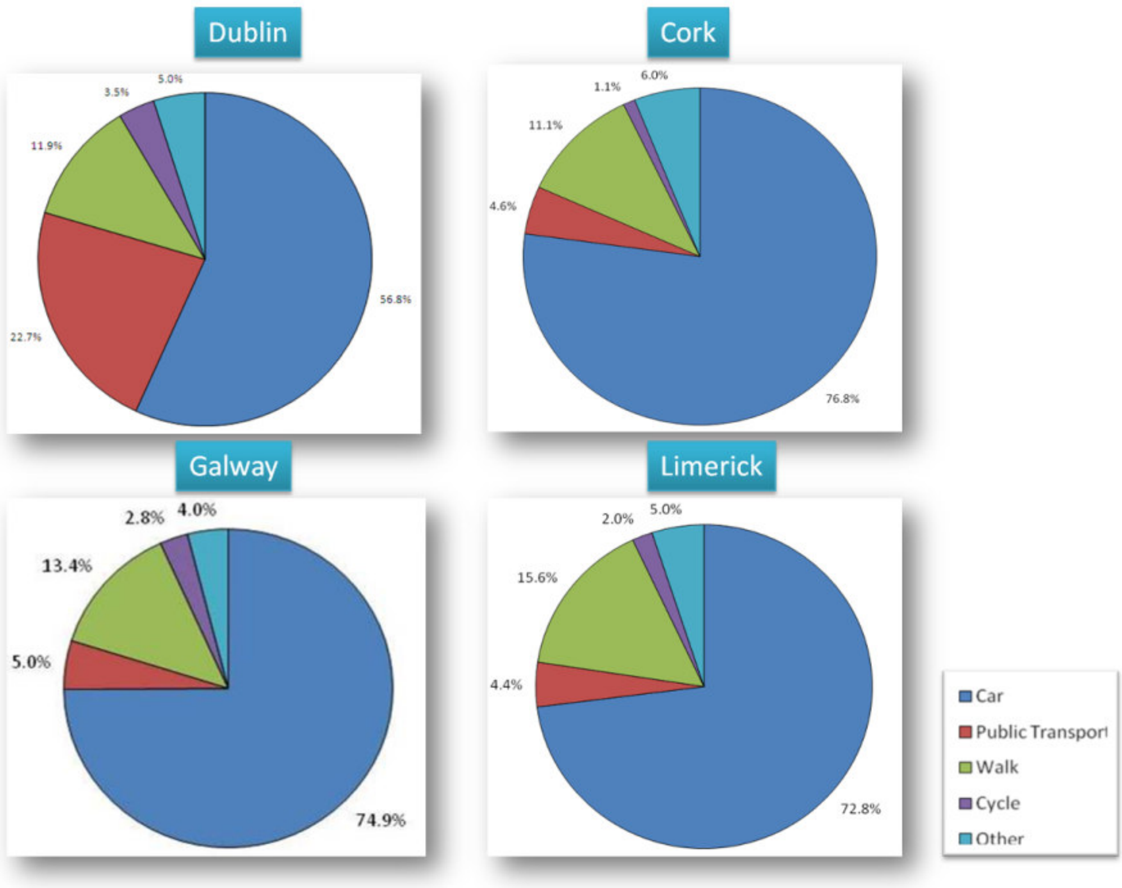
3.5 Regional Travel Patterns

For the majority of urban centres, commuting demand is a direct response to the level of employment activity within that centre. Nevertheless, through an examination of the catchment of each urban centre, a clearer picture of commuting demand can be established which can highlight those locations where longer-distance commuting is a significant element of that commuting activity which takes place. A series of interrogations of the POWCAR database have been undertaken in order to establish such patterns and are reported here.

3.5.1 Mode Share

Figure 3-7 below outlines existing share of travel modes in a number of major cities. The data highlights that Dublin retains the highest share for public transport trips at 22.7%. In contrast, travel in other cities is reasonably consistent at between 4% and 5% public transport use, and in the region of 75% car use. This dominance of car use is surprising in Cork, where higher levels of public transport are provided. Walking and cycling in Dublin, Galway and Limerick account for in the region of 15% to 17% of trips, whilst this figure is closer to 12% in Cork.

Figure 3-7: Mode Share for Key Cities (2006)

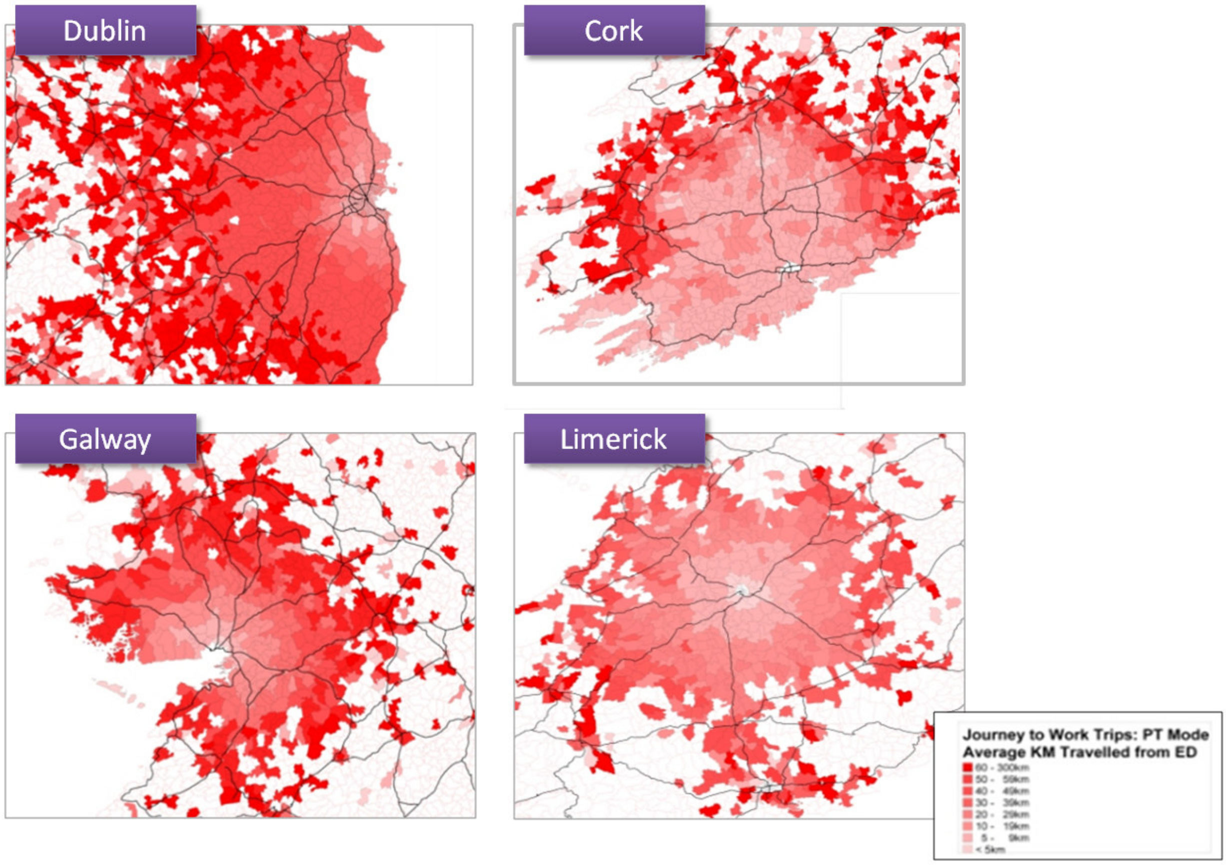


3.5.2 Commuting Footprint

The Commuting Footprint of a city defines the area from within which commuting trips are attracted to that city on a regular basis. Although in theory the commuting footprint of a city comprises the full country, some interesting patterns can be derived from the census, showing the dominant areas which generate trips to each city. The figure below shows the pattern of commuting into each of the 4 major cities. It demonstrates a strong commuting footprint for

Dublin, but also highlights quite large footprints for Cork and Galway. Although not supporting the same population, commuters are nevertheless prepared to travel long distances into the regional cities.

Figure 3-8: Commuting Footprint for Key Cities (2006)



3.6 Growth in Travel Demand

Projections for traffic growth in Ireland are currently based on the TRL 2003 Study, Future Traffic Forecasts 2002-2040. The forecasts are based on estimates of vehicle kilometres travelled in 2001, which were developed from a programme of manual and automatic traffic counts across the national and non-national road network. Forecast growth in Gross Domestic Product was then used to forecast the number of LGVs and HGVs that will travel the road network in the future. The forecasts also accounted for adult population size, the level of car ownership and Gross National Product. Analysis of these variables has resulted in the specification of traffic growth rates for national and non-national roads by each vehicle type.

In developing the National Traffic Model, further forecasts were prepared based on demographic and economic forecasts by region. The model has estimated that by 2025 the number of trips on the national road network will increase by up to 50%. This growth is higher than the anticipated increase in population and/or employment growth and therefore reflects the increased mobility that will occur as a result of the increases in car ownership over that period. In developing the 2025 National Traffic Model, the forecasting incorporates completion of the following major schemes:

- Upgrade of selected National Roads (low flow routes, < 5000 AADT) to modified single carriageways;
- Upgrade of selected National Roads (medium flow routes, >5000 AADT) to normal single carriageways;
- Development/Upgrade of selected National Roads to motorway or dual carriageway standard; and
- Development of new roads, such as the Leinster Orbital Route and key inter-urban routes.

Incorporating anticipated traffic growth, and the proposed infrastructural improvements previously highlighted, key outputs from the model are summarised in Table 3-1.

Table 3-1: National Impacts of Future Traffic Growth (Medium Growth Scenario)

Scenario	Total Trips	Network Time	Network Dist	Avg Speed
	(VEH)	*(HOURS)*	*(MILLION KM)*	***(KM/H)***
2006 AM Peak	347674	153906	7.02	**45.6**
2006 Inter Peak	248726	114989	5.66	**49.3**
2025 AM Peak	436737	194428	9.24	**47.5**
2025 Inter Peak	**292255**	**128814**	**6.97**	**54.1**

Source: National Traffic Model

Average Network Speed of vehicles is expected to experience a marginal change between 2006 and 2025 as a result of the provision of additional road capacity, in particular along the key interurban routes where significant capacity deficiencies were observed in 2006. Interpeak average speeds experience the greatest increase, from 49.3km/h in 2006 to 54.1km/h in 2025.

Average trip length is calculated as a function of total trips and total network distance. This shows a minor increase in trip length over the assessment period, rising from 20.2km in the 2006 AM Peak to 21.1km in 2025. Similarly, during the interpeak period there is a slight increase as trip length increases from 22.7km in 2006 interpeak to 23.8km in 2025. This increase is in response to the improved accessibility between development centres, and reflects the increase in travel demand that will result from such improvements.

Notwithstanding this, it is recognised that much of the improvement associated with future infrastructure provision is away from the urban areas, and there is continued erosion in levels of service in the fringe of established urban areas. Table 3-2 highlights key statistics for the main urban areas, and shows that there will be a deterioration in level of service in these locations, particularly in Dublin and Cork.

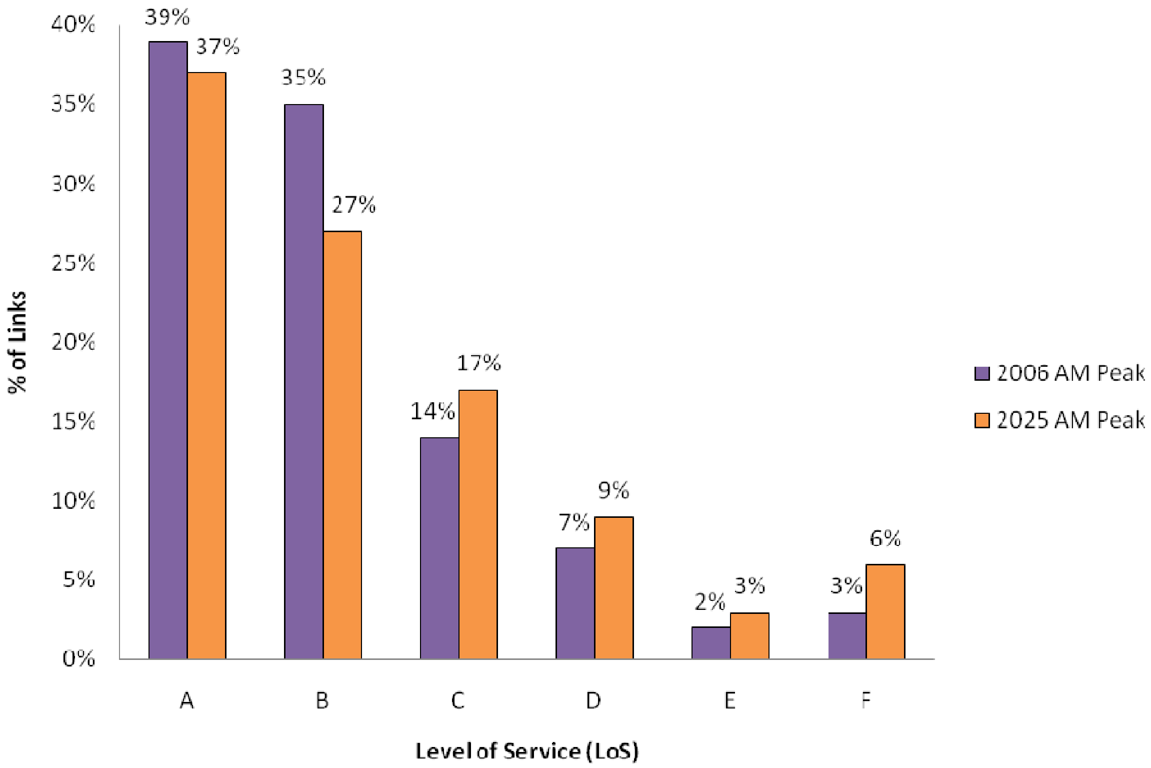
Table 3-2: Regional Impacts of Future Traffic Growth

Region	2006		2025	
	Total Trips	**Avg Speed**	Total Trips	**Avg Speed**
Dublin	158044	**36.3kph**	214558	**29.6kph**
Cork	63453	**49.2kph**	100148	**45.4kph**
Galway	29768	**54.4kph**	59015	**52.7kph**
Limerick	29358	**52.4kph**	51255	**52.1kph**

Source: National Traffic Model

Figure 3-9 below summarises the expected variation in LOS on the full national road network between 2006-2025. There is a 10% reduction in the number of routes with a LOS A and B, and a corresponding increase in the number of routes with a LOS C and worse, the majority of which are in urban areas. Note in particular the doubling in the number of roads experiencing LOS F.

Figure 3-9: Expected variation in Level of Service from 2006 to 2025



3.7 External Impacts of Traffic Growth

3.7.1 Economic Impacts

As the number of vehicles using the national road network increases the level of service for all vehicles will decrease. In other words, adding additional vehicles to the national road network increases journey times for all users. This imposes a real cost on road users and the economy as a whole. This cost should be taken into account when determining the "optimum" level of investment in roads, and the optimum level of road usage.

The cost imposed on a road user by extra congestion will be the sum of any extra vehicle operating costs and the value of the extra time their journey takes. The value of time is considered to be lowest where people are travelling for leisure purposes. If the time taken for a leisure journey increases, this will not impose any significant costs, or reductions in enjoyment, on a leisure traveller. This value of time is higher where a traveller is undertaking a journey to commute to work, and is reflective of the additional disutility associated with commuting travel. In addition, extra commuting time will potentially reduce working time, which has a subsequent economic cost. The value of time is highest of all where an individual is travelling for business purposes. In this case if a journey time is increased the traveller is prevented from carrying out other work for their employer, and imposes a direct cost on the individual's employer. This cost will be at least equal to the cost of the employer of the employees working time, i.e. wages, payroll tax and associated overheads.

Based on statistics from the National Traffic Model the net economic cost of congestion on the National Road Network was approximately €1.16bn in 2006, this is forecast to grow to €2.08bn by 2025, if management of the network remains 'business as usual'.

3.7.2 Journey Time Reliability

As congestion increases, journey times increase and the predictability of journey times decreases resulting in an additional cost to road users and the economy as a whole. Although official guidance on the costs and benefits of road investment does not yet take reliability of journey times into account, this is a real cost of additional road use that should be taken into account when determining the ideal level of usage for the national road network. In addition, from a user perspective, reductions in journey time reliability can increase operating costs - particularly for freight operators where the scheduling of vehicle journeys is impacted by journey time reliability and any decreases in reliability may result in less tonne kilometres per vehicle over time.

3.7.3 Environmental Impacts

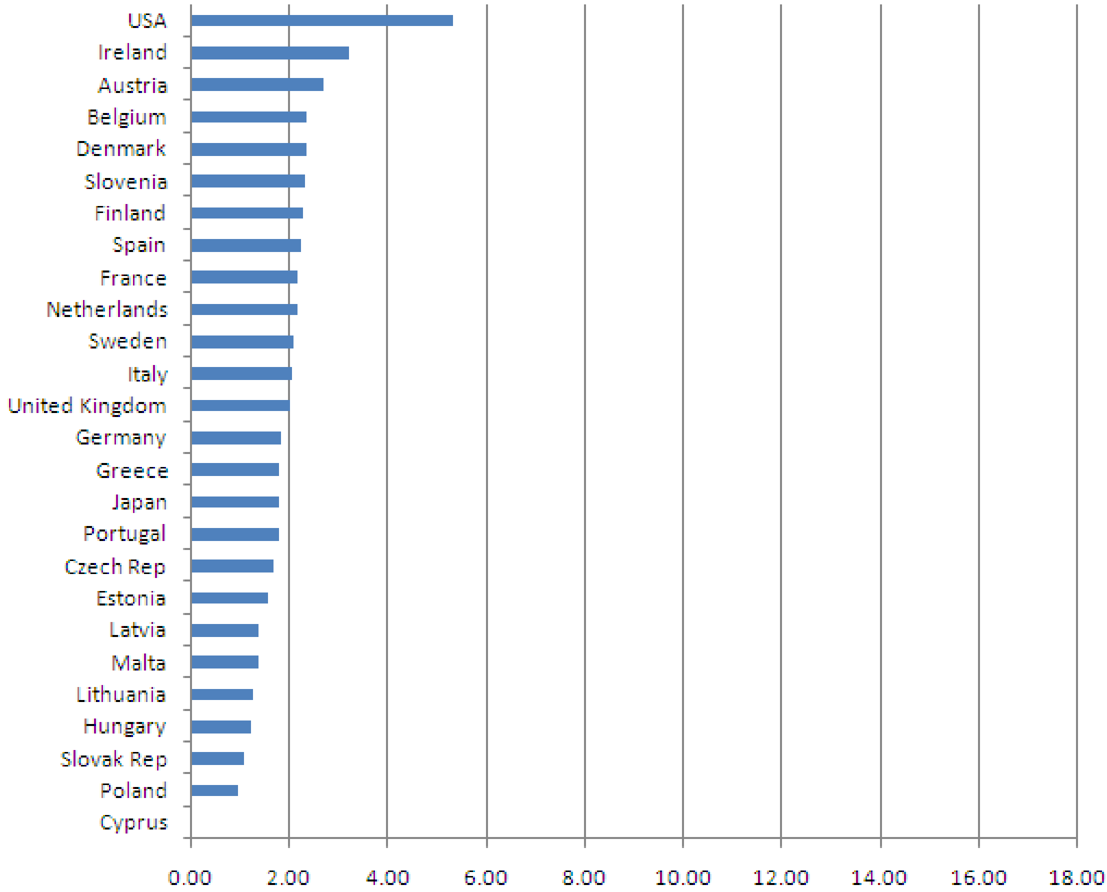
A further external cost of road use is the environmental damage from operating motor vehicles. These costs are imposed on the environment as a whole as opposed to the operator of the vehicle. A set of parameters have been developed by the Department of Transport which place a monetary value on some of these impacts. These parameters are normally used to measure the benefits of investment in transport infrastructure that reduces the level of road use, and hence the level of emissions from road vehicles. However these values are equally valid as a measure of the environmental costs of additional road use. The environmental impacts identified are:

- Air quality;
- CO_2;
- Noise and vibration;
- Landscape and visual quality;
- Biodiversity;
- Cultural heritage;
- Land use; and,
- Water resources.

Based on statistics from the National Traffic Model the economic cost of emissions on the National Road Network was approximately €530m in 2006, and is forecast to grow to €820m by 2025.

Figure 3-10 below compares 2006 road transport emissions from EU countries, the US and Japan per capita. As demonstrated below, Ireland has one of the highest emissions per capita from road transport. This highlights our per-capita dependence on non-renewable energy for transport as well as our over reliance on the car for short trips, a major generator of CO2 emissions.

Figure 3-10: Annual CO2 emissions per capita 2007



Source: Transport Indicators 2007, UN Economic Commission for Europe, Transport Division

3.7.4 Road Safety

Road accidents represent a significant external cost of transport. In 2009, 239 persons were killed on Irish roads, with over 9,700 persons injured. The cost to the economy in 2009 is conservatively estimated at over €1bn.

Nevertheless, despite an increase in population, as well as growing numbers of driver licence holders and registered vehicles, the annual number of fatalities has been declining since 1997 (in 2010 the number of persons killed reduced to 212 from the 2009 total of 239). Since 1997, the population has increased by 18 per cent, registered motor vehicles has increased by 71 per cent, number of driver licence holders (both full and provisional) has increased by 37 per cent, fuel consumption for road transport has increased by 45 per cent whereas the number of fatalities has decreased by 28.4 per cent. When compared with data from across Europe in 2006, Ireland ranked 12th among the EU 25 member states in terms of road fatalities.

3.8 The Role of the Traffic Management Study

In order to understand how the National Traffic Management Study can address the various issues presented by the Baseline Assessment, it is beneficial to draw relevant issues from the findings and compare them against the study objectives set out earlier, as presented in Table 3-3

Table 3-3: Summary of Baseline Issues

Economic	
Allocative efficiency	Dominance of commuting traffic on Dublin Radial routes, and on Ring Roads in Cork, Galway and Limerick. This dominance inhibits use by business and freight users during peak periods.
Incidents	Limited management of incidents away from existing and planned tunnels. Incidents can lead to significant delay and economic impact. There is only limited use of current ITS infrastructure in this regard. Recent incidents on the M50 and N11 support this conclusion.
Commuting	Planning of areas relies on provision of motorways, with often only nominal provision of public transport – particularly for retail and commercial uses outside the Dublin Area.
Capacity	Significant capacity deficiencies on National Roads in Dublin and Cork, with notable increase in congestion expected over the period to 2025.
Environmental	
Public Transport	Very low levels of public transport mode share in Cork, Galway and Limerick. Particular deficiency in Cork where commuter bus and rail services are provided.
Emissions	Continued growth in emissions due to traffic growth. Ireland has highest transport CO_2 emissions per capita in Europe.
Accessibility and Social Inclusion	
Access to Services	Accessibility is hampered by congestion on key locations on the road network which provide important roles in delivering longer distance connectivity.
Integration	
Promote Policies	Limited understanding of NRA policies by Local Authorities, and a poor record of cooperation in the preparation of Plans
Public Transport	Other than M3 at Blanchardstown, no specific provision for Public Transport using National Roads.
Safety	
Manage Incidents	Limited incident management away from existing or planned tunnels. Existing ITS provision is not used to its full potential.
Frequency/Severity	Significant progress made with reducing accidents, although accident clusters are evident on radial roads in Dublin and Cork.

Based on the above summary, a number of important conclusions can be drawn regarding how the Traffic Management Study can address the objectives set out under each heading:

Economic: Road capacity remains the key driver of economic considerations. Capacity deficiencies on national roads are most prevalent in the Dublin Area, followed by Cork City and Galway City, where strategic roads are heavily used as distributor roads. Issues are somewhat less notable in Waterford and Limerick, where deficiencies are more related to the local road network. Letterkenny has also been highlighted as a location where congestion on national roads is particularly notable. The use of management techniques to address congestion on strategic routes in these locations has been extremely limited, with interventions to date focusing on capacity increases – which have fuelled further growth in demand. This would suggest that roads in the Dublin, Cork and Galway would benefit from measures in the immediate term, followed by the other main cities as a subsequent phase of implementation.

Environmental Environmental issues are both national (in the case of emissions) and local (in the case of encouraging public transport). At a local level, it is evident that not all urban areas are achieving their full potential with regards to mode share for public transport trips. Although Dublin has a relatively strong level of public transport use, it is evident that there are areas, particularly outside the metropolitan area, where travel remains predominantly car based. Cork, on the other hand, exhibits quite a low mode share for public transport throughout most areas, despite the provision of urban bus and rail services. Galway and Limerick report slightly higher mode shares for public transport than Cork (although they are still some way behind Dublin), albeit with lower provision of services. It is concluded that the strategy should focus on how public transport mode share can be supported in Cork to reduce pressure on strategic routes, and in residual areas of Dublin where such potential has not yet been delivered.

Accessibility/Social Inclusion Whilst strategic accessibility has greatly improved through the upgrading of the national road network, a number of distinct bottlenecks have emerged on national roads which effectively inhibit the ability of the network to facilitate these connections during peak periods. Such bottlenecks are most evident on the ring roads of Cork and Galway where at-grade junctions lead to peak time congestion. A reduction in accessibility can isolate communities from employment opportunities, thereby reducing the level of social inclusion in those areas. It can also inhibit access to services in nearby areas (shops, schools community services etc). In fact, the severance impact of major road infrastructure can exacerbate such a situation. The traffic management strategy therefore seeks to address this by minimising the potential for future negative effects arising out of major road construction.

Integration The potential for public transport is highest in urban areas, but it is these areas where public transport is most hampered by congestion. As such, the need to deliver improved public transport facilities on national roads reflects those areas where congestion is most apparent. As outlined under the 'economy' heading, such focus should initially be on Dublin and Cork, although it is expected that Galway, Limerick and Waterford would benefit significantly from improved strategic public transport accessibility in the short term.

Safety — The impact of incidents on the National Road Network is most severe where capacity is at a premium. Again, this would suggest that the strategy should focus on Dublin, Cork and Galway. Nevertheless, there are elements of incident management that are non-geographic, and will form the basis of any strategy at a local level.

The discussion therefore highlights a number of distinct geographical areas where the Traffic Management Study will be required to address existing or future deficiencies through the various measures that are available. The most significant areas are discussed below:

3.8.1 Dublin – M50

In Dublin there are fundamental differences between the M50 and the key radial routes. The M50 supports a broad spectrum of journey purposes, and has a relatively flat flow profile across the day. As such, road capacity on the M50 is quite efficiently utilised, as is the case with many roads that are subject to tolling. The study is therefore likely to focus on management of traffic flow and response times to incidents in order to maximise safety and improve journey time reliability.

3.8.2 Dublin – Radial Routes

Many of the Dublin Radial Routes are defined as Major Inter-Urbans, connecting the capital with key regional towns and cities. Nevertheless, a number of such routes suffer from high levels of car use, particularly in those cases where rail services are of relatively low quality. The National Traffic Management Study will seek means of improving public transport use along the radial corridors, whilst employing measures to protect traffic conditions on the mainline carriageway. In addition, the study will examine measures to improve the dissemination of advance and real-time information to enable road users to make informed decisions regarding their journeys.

3.8.3 Cork Area

In the Cork Area, current problems relate specifically to the dominance of commuting traffic on National Roads, resulting from low public transport mode shares, and the pattern of developments which lead to high impacts on national roads. As such, the issues in Cork are relatively uniform across the full region, and hence it is possible to deliver Traffic Management solutions in Cork as a single package.

3.8.4 Galway Area

In Galway the strategic road network is still under development, and the existing Bóthar na dTreabh (N6) provides the function of a city bypass, but also has been subject to development of significant volumes of retail activity which hamper the ability of that road to achieve its primary function. There is therefore significant need to restore an appropriate level of safety and efficiency of the national road network in that area pending delivery of the Outer Bypass.

3.8.5 Limerick and Waterford

The strategic road network in Limerick and Waterford is well developed, and current traffic congestion is mainly confined to peak periods, with limited impact on national roads. The study in these areas will focus on future protection of the road network.

3.8.6 Letterkenny

Letterkenny continues to represent a significant bottleneck on routes into Donegal, and whilst the town does suffer from limited strategic routes, the traffic congestion is due in a large part to the proliferation of retail development along current national roads and the development of residential uses that rely heavily on use of cars for access to local services. Traffic modelling suggests that problems in Letterkenny will become critical over the lifetime of the study, and the National Traffic Management Study will therefore explore measures to restore strategic connections through this gateway

Chapter 4 Modelling Future Year Transport Demand

4.1 The National Traffic Model

The National Traffic Model was developed in 2008 on behalf of the National Roads Authority, with its primary function being to assist in the development and appraisal of national road infrastructure schemes. The National Traffic Model is currently used extensively by the NRA and several Regional Design Offices, and has provided the basis for a number of regional studies by Local Authorities. An overview of the model is provided in this chapter of the report.

Although the National Traffic Model (NTM) assignment uses VISUM, the model development has used a combination of processes using CUBE, EMME/3, and VISUM to assist in the matrix development and trip distribution modelling processes.

4.2 The Road Network

The National Traffic Model has been developed to a relatively high level of detail, covering all national Primary, Secondary and Regional Roads, in addition to a high number of local roads where it is considered that they provide some strategic function. This includes a reasonably high level of detail within urban areas to reflect traffic patterns on those strategic routes which pass through them. The model also includes all A-Roads in Northern Ireland.

Data for the road network has been sourced from the NAVTEQ database (2007), with local refinements as necessary to ensure that all key roads and junctions reflected layouts at that time. This requires a number of modifications to road classifications, junction arrangements, speed limits etc. A graphical representation of the road network is outlined in Figure 4-1

4.3 The Trip Matrix

The NTM Trip Matrix has been developed on the basis of in the region of 100 Roadside Interview Surveys undertaken between 2006 and 2007, with a further programme of volumetric counts and journey time surveys over that same period. In addition, the POWCAR dataset from 2006 was sourced and coded to a trip matrix for the modelled periods (AM Peak Period and Inter-Peak Period). Various adjustment factors were applied to POWCAR at County Level to account for missing records, undecipherable records or variable places of work.

The final matrix has been constructed to 874 zones (6 of these zones representing Northern Ireland), with zone size representing population density and the complexity of the road network in that area. A high level of detail has been required in urban areas to reflect the complex trip patters that occur along city ring roads in Dublin and Cork. The zone plan for the NTM is outlined below in Figure 4-2.

Figure 4-1: National Traffic Model Road Network

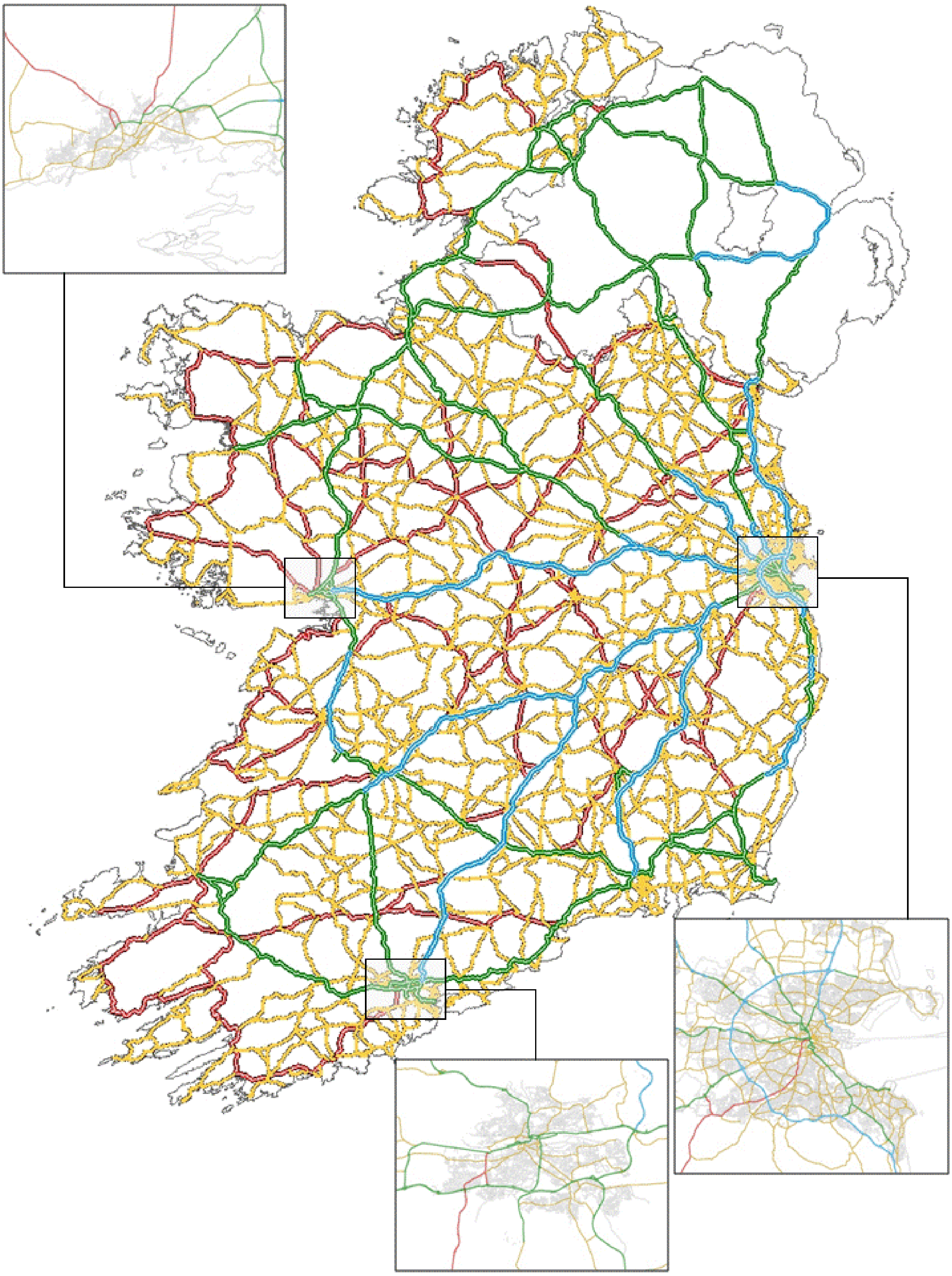
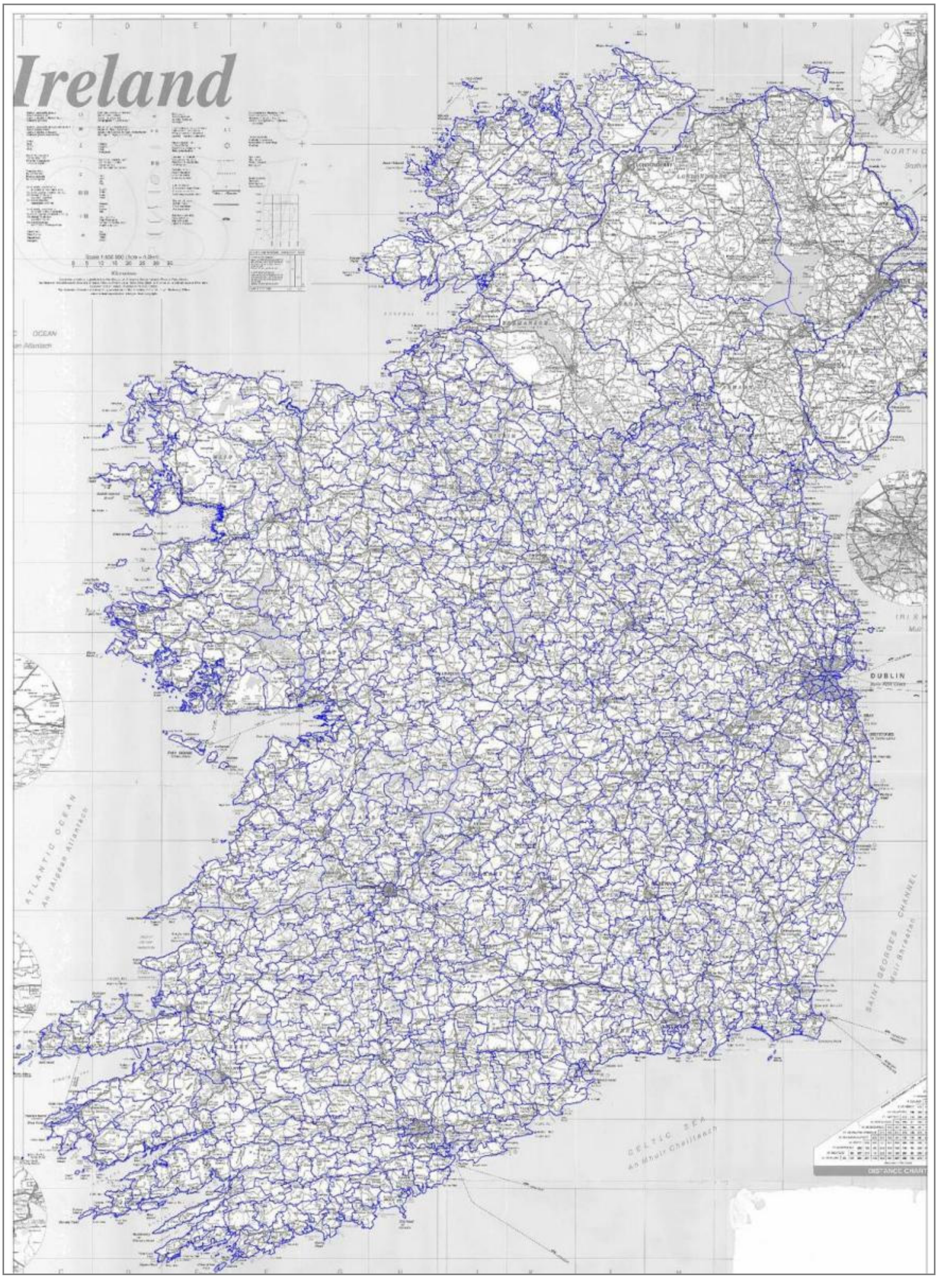


Figure 4-2: National Traffic Model Zone Structure



4.4 Future Year Traffic Forecasting

In order to develop future year forecasts for the National Traffic Model, it is recognised that a robust mechanism for 'growthing' current traffic volumes is necessary. In determining such growth forecasts, two questions are pertinent:

- What level of growth in traffic is anticipated with the model; and
- How will this growth be distributed amongst the main urban/rural areas.

In order to provide robust responses to these questions, a model of future demographic and economic patterns has been developed which allows growth to be assigned to each zone within the traffic model based on an understanding of population, job and car ownership increases in each zone. This was then translated into growth in vehicular trips, and this new set of trip ends redistributed using a Trip Attraction Generation Model (TAGM).

Population projections are central to this model as they are inputs to both jobs and car ownership forecasts. The projections are based on the natural increase in the population and net migration, but based around the F1M0 population projection issued by the CSO. The F1M0 projection assumes fertility rates remain at 2006 levels of 1.90 and zero net migration over the lifetime of the projections. This scenario has been adopted as the central scenario over the period to 2040, and is consistent with the medium growth forecasts published by the National Roads Authority in January 2011.

Car ownership forecasts at county level are based on an analysis of the varying historical trends in the rate of car ownership in each county over a number of different years. For each year selected, the counties were ranked in order according to their rates of car ownership. Three groups were defined – above average ownership, average ownership, and below average ownership. There was no significant movement of counties between the groups over each time interval. Thus, three different saturation levels were assumed, one for each group: 900 cars per 1,000 adults for counties with above average rates of car ownership, 850 cars per 1,000 adults for counties with average rates of car ownership, and 775 cars per 1,000 adults for counties with below average rates of car ownership.

Forecasts of the growth in jobs between 2010 and 2025 were derived from the 2006 jobs data and forecasts of changes to the numbers employed nationally. In developing Labour Force Projections, a number of assumptions were employed for future marriage rates, education participation rates and labour force participation rates. Employment projections are then derived from the Labour Force by applying unemployment rates. In preparing employment forecasts, it was assumed that the number of jobs located in each DED would increase in proportion to the increase in the aggregate employment projections. A further exercise was undertaken to ensure that the projections for DEDs are consistent with national jobs growth.

Using the increase in the numbers employed nationally to inflate the number of jobs in each period carries a number of implicit assumptions. The first is that jobs growth will continue to be located in areas of current employment. This is a significant assumption, as certain rural DEDs may have one significant employer and should such an employer cease to operate, the job numbers for this DED in 2025 are unlikely to reflect the true state of employment. However, without such an assumption it would be necessary to forecast future trends of workplace location, which are very difficult to predict. The use of the numbers employed at national level is warranted given that the numbers employed at regional or county level may not reflect the jobs in that area since a vast number of people travel outside their region or county for work.

The basis for the factors used in this growthing process was the change in the number of trips predicted by the direct demand equations used in the base year matrix development. These had originally been analysed using the observed trips from the various surveys.

4.5 Key Indicators

Using the future year 'reference' network, it is possible to understand the traffic conditions that will exist in the 2025 model, and benchmark these against the equivalent findings for the 2006 base year Model. This allows an understanding of the level of growth that will be expected, and how the proposed road improvements impact on average trip length. A high level understanding network efficiency can also be developed.

A series of Performance Indicators have been extracted from the VISUM models and are outlined below in Table 4-1 for the AM Peak and Inter Peak respectively.

Table 4-1: Key Results

Scenario	Total Trips Assigned (VEH)	Network Time (HOURS)	Network Dist (MILLION KM)	Avg Speed (KM/H)
2006 AM Peak	347674	161405	8.15	50.5
2006 Inter Peak	248727	140646	7.06	50.2
2025 AM Peak	541272	270914	13.01	48.0
2025 Inter Peak	370293	200480	10.64	53.1

The results suggest that the increase in trips that will occur during the AM Peak and Inter Peak will be to the order of 50% on 2006 levels. This is consistent with the car ownership increases that have been reported earlier in this report. It is noted that this growth is somewhat higher than the anticipated increase in population and/or employment growth and therefore reflects the increased mobility that will occur as a result of the increases in car ownership over that period. In reality, car use is likely to reduce close to major cities as a result of specific network management strategies and the delivery of additional public transport, whilst traffic growth in the more rural areas is likely to grow at a more significant rate.

Average trip length can be calculated as a function of total trips and total network distance. This shows a small increase in trip length over the assessment period, rising from 23.4km to 24.0km during the AM Peak, and from 28.4km to 28.7km during the Inter Peak. This increase is in response to the improved accessibility between development centres, and reflects the increase in travel demand that will result from such improvements.

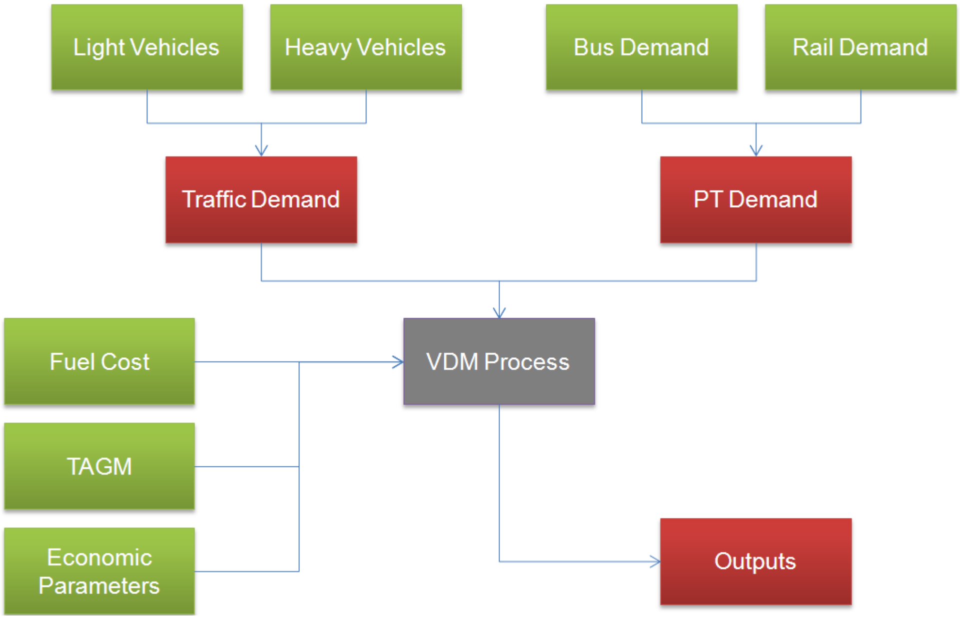
4.6 The National Transport Model

The National Traffic Model is currently in the process of being updated to incorporate Variable Demand effects arising out of transport infrastructure and policy interventions. The National Transport Model (NTPM) has been developed for a 2010 Base Year, with future forecast years of 2025 and 2040. It includes observed demand matrices for rail and inter-urban bus, in addition to the light vehicle and heavy vehicle matrices included in the National Traffic Model.

The NTPM will be the first strategic model which will allow the assessment of variable demand responses such as changes in trip rates and trip distribution effects. It will also include a function to reflect changes in the cost of fuel on transport demand.

The NTPM will be used as the basis of all future Strategic Planning exercised where Variable Demand responses are expected (as prescribed in Unit 5.3 of the NRA Project Appraisal Guidelines). It will also provide a facility for the development of Local Area Variable Demand Models (VDM) for scheme assessment and evaluation in those areas where such techniques are warranted.

Figure 4-3: The National Transport Model (NTPM)



Chapter 5 The Basis for Traffic Management

5.1 Overview

The investment of €13 billion in the national roads network in the decade 2001-2010 has transformed much of the national primary network. That period has seen the completion of motorways connecting Dublin with major regional towns and cities, the removal of a number of bottlenecks on national roads in the Greater Dublin Area, and a significant start made on the Atlantic Corridor.

The role of the NRA has evolved with this development of the network, with the management and operation of the network now demanding more resources than network improvements. This requires a continuous long-term understanding of transport demand and how future growth in demand will impact on the ability of the network to facilitate it. Where the network fails to perform within required tolerances, interventions are required to address existing or future deficiencies.

Whilst new road construction can remedy many such issues, such tends to be a costly solution, and not always the most appropriate intervention. Measures which seek to influence traffic behaviour on existing roads are described as 'Traffic Management' and typically comprise a series of policy, operational and engineering interventions which improve the efficiency of a network.

5.2 Supporting Policies

The Traffic Management concept is well established in many roads authorities internationally where a need to monitor and influence traffic behaviour has been identified. Considerable experience exists from across Europe, the USA, Asia and Australia on the use of management techniques to maximise capacity, improve safety, and reduce environmental impacts of transport demand. There therefore exists a considerable body of experience and evidence to support the investigation of traffic management proposals in Ireland. This evolution in the role of network managers is reflected in the Department of Transport Common Appraisal Framework[5] which describes Traffic Management as

> *"alternatives that represent those which seek to respond to transportation problems by maximising the value of existing infrastructure".*

Essentially, Traffic Management is the process of adjusting or adapting the use of the highway to meet specified objectives without resorting to substantial new road construction. Such an approach is inherent in the Smarter Travel policy document, which proposes measures to

- improve information for road users;
- prioritise road space for public transport;
- reduce fuel consumption and emissions; and
- optimise capacity for goods transport and business travel.

The Smarter Travel policy suggests that solutions are likely to include the deployment of incident management technologies on key road arteries with a view to limiting the development of traffic jams with their associated negative consequences for fuel consumption and emissions. As such, the development of Traffic Management interventions and policies has been recognised as an integral part of managing future traffic growth.

The report "*A Sustainable Future for Transport*[6]" prepared by the EU Directorate General for Energy and Transport in 2009 suggests that "*New infrastructure is costly and making optimal use of existing facilities can already achieve a lot with more limited resources….upgrading the existing infrastructure – also through intelligent transport systems – is in many cases the cheapest way to enhance the overall performance of the transport system*". This suggests recognition of the value of traffic management in supporting the function of transport networks.

5.3 Approaches to Traffic Management

In the early stages of this study it was recognised that Traffic Management objectives could be addressed through distinctly different approaches. Through an analysis of international experience, two key themes have emerged which are applicable to the current study:

5.3.1 Control Measures

Control refers to those measures which seek to actively manage and influence traffic flow through forcing particular behaviour. Measures can include

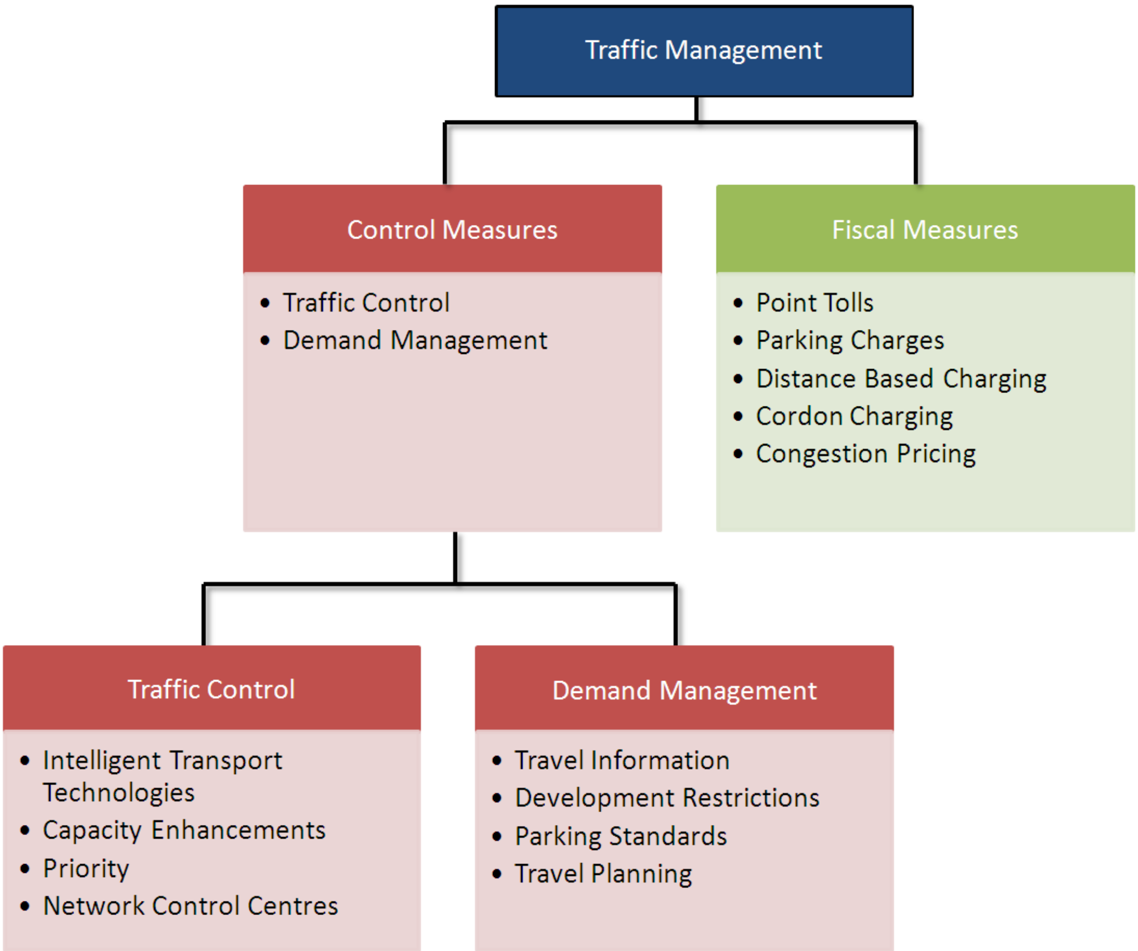
- Pre-trip measures, which influence the need to travel through the implementation of restrictions and obligations on development (excluding fiscal measures) – referred to as *Demand management* ; and
- Post-trip measures, which regulate the flow of traffic along major roads in an attempt to maximise efficiency – referred to in this study as *Traffic Control*.

In many cases, Traffic Control measures can generate quite notable benefits to those on the road network, but they do not always address the future growth in transport demand, and therefore tend to require supporting investment in infrastructure to realise their full potential. Demand Management measures can provide this additional support in addressing the growth in travel demand, but will achieve only limited success in the absence of strong restrictive policies which can sometimes be difficult to implement.

5.3.2 Fiscal Measures

Fiscal measures draw on economic theory to price for road use on the basis of the demands placed on it. They represent an extension to the concept of fuel taxes, which cannot discriminate between parts of the network which are congested or uncongested. The range of fiscal solutions is extensive, ranging from fuel taxation, parking charges, vehicle quotas, tolling, congestion charging and national road pricing.

Figure 5-1: The Traffic Management Toolkit

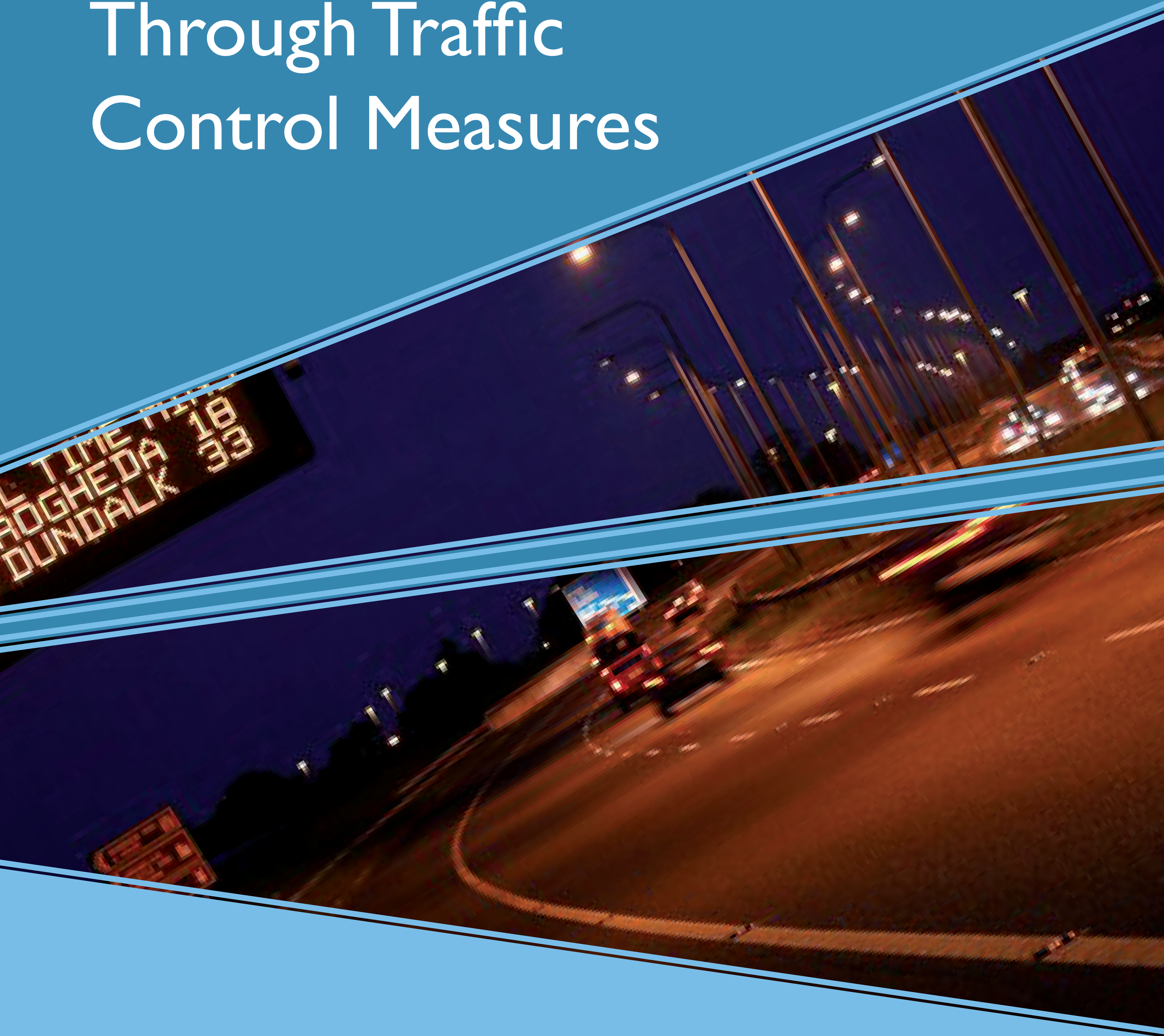


Sections B, C and D of this report will examine the scope and relevance of each of these categories of measures, drawing on international experience, feasibility studies and necessary analysis to conclude on their applicability. This analysis will support the presentation of a range of solutions in Section E to be considered for management of future growth on the national road network.

An tÚdarás um Bóithre Náisiúnta
National Roads Authority

February 2011

Traffic Management Through Traffic Control Measures



Section B

AECOM   Roughan & O'Donovan   Goodbody Economic Consultants

Section B Traffic Management through Traffic Control measures

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Chapter 6 Overview of Control Measures

6.1 Introduction

Traffic Control measures broadly describe those measures which seek to manage traffic flow through regulatory mechanisms, and which target traffic that has already made the decision to travel on the road network. The objectives of such control measures are to:

- Improve safety through managing traffic flow on high capacity roads;
- Improve travel time reliability through areas prone to congestion;
- Improve journey times by reducing traffic flow instability and making best use of existing roadspace;
- Providing reduced journey times or improved reliability for dedicated vehicle types (e.g. public transport vehicles, freight or high occupancy vehicles); and
- Reduce emissions by reducing energy use in transport streams.

This section of the report will provide an overview of the range of control measures that can be employed in order to meet these broad objectives. The discussion will be supported by feasibility studies for some selected major interventions to understand their appropriateness on the National Road network in Ireland.

6.2 Forms of Traffic Control

Broadly speaking, traffic control measures can be categorised under a number of headings, shown below in Figure 6-1. Each category is defined as follows:

- Intelligent Transport, which uses on-road technology to influence traffic flow in response to observed behaviour. Examples include ramp metering, variable speed limits, and incident detection;
- Capacity Enhancement, which increases road capacity within the existing boundaries, but supported by a management function. The most relevant examples are Hard Shoulder Running and reversible traffic lanes;
- Priority measures, which dedicate lanes to specific user types, such as public transport, freight, or high occupancy vehicles;
- Information sources provided pre-trip or during a trip which assist users in making appropriate responses to avoid congestion; and
- Network control through the use of national, regional or local control centres.

Figure 6-1 Summary of Traffic Control measures

6.3 The Report on Case Studies

A wealth of material has been gathered and reviewed by the Study Team reflecting the experience of transport authorities around the world and drawing upon the expertise of the study team and the client group. Table 6-1 outlines the examples that have been examined under the heading of *Traffic Control*.

Table 6-1: Case Studies of Traffic Control Measures

Category	Measure	Location
Intelligent Transport	Variable Speed Limits	M25, UK
	Ramp Metering	M3 and M27, UK
	Ramp Metering	Minnesota, USA
	Incident Detection	COMPANION, Italy and UK
	Incident Detection	MIDAS, UK
	Variable Speed Limits	Sweden
	Intelligent Road Studs	M8, Scotland
Capacity Enhancement	Hard Shoulder Running	M42, UK
	Reversible Lanes	I-64, USA
	Reversible Lanes	Tampa Expwy, USA
Priority	High Occupancy Vehicle Lane	I-64, USA
	High Occupancy Vehicle Lane	M62, UK
	High Occupancy Vehicle Lane	N6, Madrid
Information	Roadside Information	VMS, UK
	In-Vehicle Information	Own-Language Trials, Scotland
	In-Vehicle Information	RDS TMC, UK
	Internet	Truck Parking, Germany
Network Control	National Control Centre	NTCC, UK
	Regional Control Centre	Houston, USA
	Regional Control Centre	Florida, USA
	Regional Control Centre	Virginia, USA
	Regional Control Centre	Berlin, Germany

The Case Studies concluded that the above technologies were all broadly applicable for consideration as part of the current study. The main exception is with respect to High Occupancy Vehicle (HOV) Lanes, where experience has been mixed due to difficulties with under-utilisation and enforcement, leading to a recent trend of upgrading of these lanes to High Occupancy Toll (HOT) Lanes. HOV lanes were seen to provide limited benefit but with relatively high management cost – their upgrading to HOT lanes allows revenue collection to support the management requirements and allows more intensive use of the lanes.

Common across many case studies was the existence of network control centres which supported the network management requirements associated with traffic control measures. Drawing on examples from the UK, Europe and the USA it is apparent that integration and centralisation of control of the primary road network is important.

Studies in the USA have quantified the real benefit of Traffic Control Centres through travel time savings which are easily convertible into monetary benefits. The Houston TranStar Control Centre is believed to offer an annual benefit of $300 million through travel time and fuel cost savings compared with the annual operating cost of $23.2 million. Further benefits have included reduced incident clearance time (SMART SunGuide[7], Florida) and better control of planned events through better knowledge of the network.

Particular relevance has been attributed in the current study to the Intelligent Transport and Capacity Enhancement measures. Such measures have been seen to deliver quite promising results following recent deployment at high profile sites in the UK. It has been considered appropriate to examine these measures in further detail to understand the issues which will dictate the provision or otherwise of these measures on Irish roads. As such, a number of feasibility studies have been undertaken in order to investigate the following traffic control measures:

- Ramp Metering, which seeks to control traffic flow entering the mainline carriageway from slip roads such that flow disruption on the mainline carriageway can be minimised;
- Variable Speed Limits, which manage mainline speeds to suit the prevailing conditions, leading to improvements in flow conditions and road safety;
- Hard Shoulder Running, which facilitates use of the hard shoulder for provision of additional lane capacity during busy periods;
- Provision of lanes dedicated to public transport, freight or High Occupancy Vehicles such that higher-value road users can be protected from congestion, and mode transfer can be encouraged; and
- Reversible Lanes, which allows the direction of running lanes to be reversed to provide additional running capacity in the peak direction – whether this be for dedicated vehicle types or for all traffic.

The following chapters within this section examine the feasibility of each of the above measures on key roads. Each measure has been reviewed to determine its full potential, allowing the applicability of each measure to be considered in isolation for inclusion in an overall strategy.

Chapter 7 Traffic Control - Ramp Metering

7.1 Overview

In order to understand the role of Ramp Metering in the provision of traffic control, it is necessary to develop an understanding of the conditions within which Ramp Metering can offer benefits to traffic flow in a way that is consistent with the agreed objectives for this study.

In order to develop such an understanding, a feasibility study for Ramp Metering has been undertaken with a focus on the M50. The M50 provides a unique scenario for a national road in that it supports a significant number of variations in cross section and junction design along its length, ranging from 4+4 with full grade separation to 2+2 with partially grade separated junctions in its southern end. As such, the range of layouts at junctions will provide a useful insight into the typical situations that may be encountered nationally and hence the layouts which can benefit from such intervention.

7.2 Introduction to Ramp Metering

Ramp Metering may be defined as the installation of traffic signals on a grade separated junction on-ramp in order to regulate the flow of traffic joining a motorway or dual carriageway. The purpose of Ramp Metering is to prevent or delay the onset of flow breakdown on the main carriageway, maximising throughput whilst attempting to minimise disruption. Ramp Metering minimises congestion through the use of a systematic control mechanism, as follows:

- Traffic signals positioned on the on ramp are installed such that they use control loops on the mainline carriageway to assess flow conditions. This technology is used to monitor and manage the traffic flow on the on-ramp;
- Once a pre determined set of flow conditions are reached Ramp Metering is activated;
- The signals control the flow of additional traffic from an on ramp onto the motorway that, if left unregulated would contribute to or trigger the development of flow breakdown;
- The Ramp Metering control mechanism delivers an distribution of vehicles onto the main carriageway to reduce the potential for flow breakdown; and
- The control mechanism and associated infrastructure is designed in order to reduce or avoid congestion spillback to the adjacent urban traffic network or to other national routes.

It should be noted that in the case of strategically important routes such as the M50, Ramp Metering may also have the added benefit of deterring drivers from making short trips on the motorway, increasing the attractiveness of local roads as an alternative.

The potential disadvantage of Ramp Metering is the delay to on-ramp traffic arising from the use of traffic signals. This delay however is often offset by travel time savings once traffic has joined the mainline flow. It has been shown that Ramp Metering is not effective in periods of heavy congestion where the absolute capacity of the network has been exceeded.

7.3 Site Selection Criteria

There are a number of categories under which an assessment must be made prior to assessing the feasibility of implementing Ramp Metering at a particular site. These are:

- Traffic Conditions;

- Geometric Layout; and
- Existing Safety Conditions.

7.3.1 Traffic Conditions

In order for Ramp Metering to be affective, a road must experience significant delay which can directly or indirectly be attributable to traffic merging at an on ramp. It is necessary to consider traffic conditions relating to three separate elements of the road network prior to assessing site suitability. These are:

- Mainline traffic flow;
- On slip traffic flow; and
- Traffic flow on the adjacent local road network.

The first two of these elements are easily measurable whilst the last requires a detailed assessment of movements on the adjacent traffic network. This assessment should take into account both junction performance levels and queuing. As such for the purposes of preliminary assessment only conditions on the first two elements will be considered.

Table 7-1 below illustrates the maximum and minimum values acceptable in terms of delay, mainline flow and slip lane flow at any site where Ramp Metering may be considered. This table is taken from the UK Highways Agency, Ramp Metering Summary Report, and is based on experience gained on over 60 Ramp Metering sites in the UK.

Table 7-1: Ramp Metering Site Selection Criteria

Parameter	Minimum Value		Maximum Value	
	Ideal	Acceptable	Ideal	Acceptable
Annual delay at speeds below 50kph.	10000 Vehicle Hours Delay	100 Hours	No Maximum Value	
Downstream mainline flows per lane (vph)	1500	Appreciable based on local knowledge	No Maximum Value	
Slip road flows per lane (vph)	400	300	900	1250
Slip road flow as a percentage of downstream flow (%)	10	5	30	50

7.3.2 Geometric Layout

Sites where Ramp Metering is likely to be successfully implemented ideally consist of long, straight slip roads with long tapered or parallel merges. In the UK a large proportion of Ramp Metering sites consist of two lane slip roads merging onto three lane main carriageways. Ramp Metering is likely to provide a lower congestion mitigation benefit on sites with less suitable conditions such as locations where there are:

- Lane gain from slip road;
- Ghost Island;
- Curved on-slip.

These sites need additional design consideration to ensure that the best metering strategy can be applied.

There are no individual physical characteristics that rule out a site for selection completely with the main issue for consideration being the practicality of locating the stop line safely. If high approach speeds exist on the on ramp sufficient sight lines to the stop line and queue control area are required. It has been found through experience in the UK that sites which have the following characteristics can benefit greatly from Ramp Metering if the site is well designed and the correct metering strategy is applied:

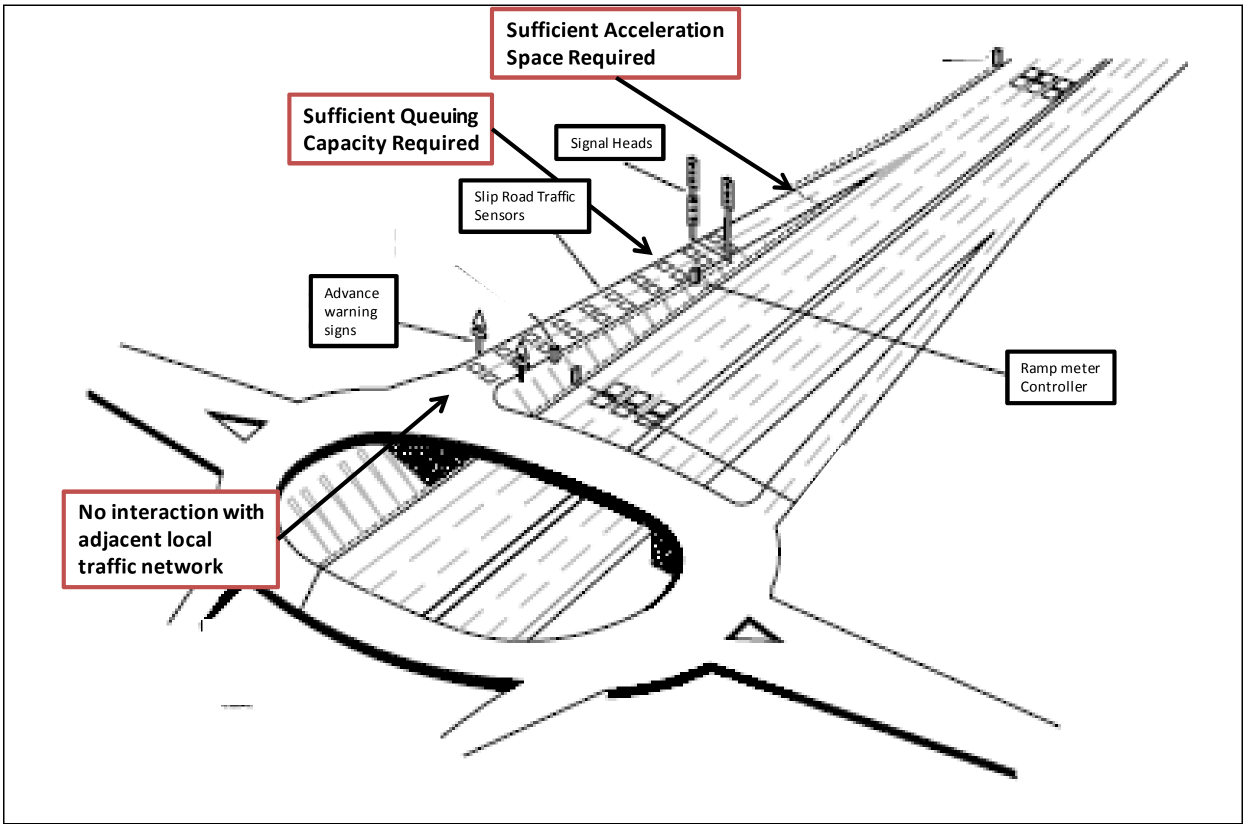
- Short or sub-standard merge areas;
- Where a bottleneck exists downstream on the main carriageway such as a bend or a gradient; and,
- For two lane on-slips which have been artificially reduced to one lane in an attempt to restrict joining traffic.

In the case of these characteristics occurring, they should be considered carefully and a judgement should be made as to whether they will affect the operation of the system, its ability to handle traffic flow or cause serious safety issues. Any of these characteristics must be noted and if the site is still considered suitable, be reconsidered when the scheme reaches the detailed design stage so that mitigation of any potential problems can form part of the early design.

As illustrated in Figure 7-1, at all times it should be borne in mind that when Ramp Metering is in operation, the slip road should satisfy two main requirements, as follows:

- There should be sufficient distance between the stop line and the main carriageway for vehicles to accelerate to the desired operational speed; and,
- It should be able to facilitate a sufficient number of vehicles such that, when queuing occurs, impact to movements on the adjacent local traffic network is minimised.

Figure 7-1: Preliminary Ramp Metering Design: Geometric Criteria



Assessment of the desired operational speed, queuing capacity requirements and stop line placement is part of the design process. These areas are defined in the design guidelines (MCH 2470 - Ramp Metering Technical Design Guidelines)[8]. These consider a number of factors at the site including, platoon size, number of HGVs, vehicle acceleration and gradient.

7.3.3 Existing Safety Conditions

The existing accident records for each proposed site should be considered in order to highlight areas where significant proportions of accidents occur. If feasible, the cause of each accident should be ascertained and particular attention should be paid to accidents caused due to merging traffic. All relevant accident records should then be considered once detailed design begins.

7.4 Site Selection

There are a total of 14 junctions on the M50. A preliminary feasibility assessment for implementing Ramp Metering on each junction was undertaken based on flow conditions.

7.4.1 Assessment of Flows

Tables 7-2 and 7-3 below illustrate the assessment of all northbound and southbound junctions on the M50 in accordance with the criteria set out above. Those deemed unsuitable for further assessment in overall terms will not be assessed geometrically.

Table 7-2 Assessment of M50 Northbound Slips

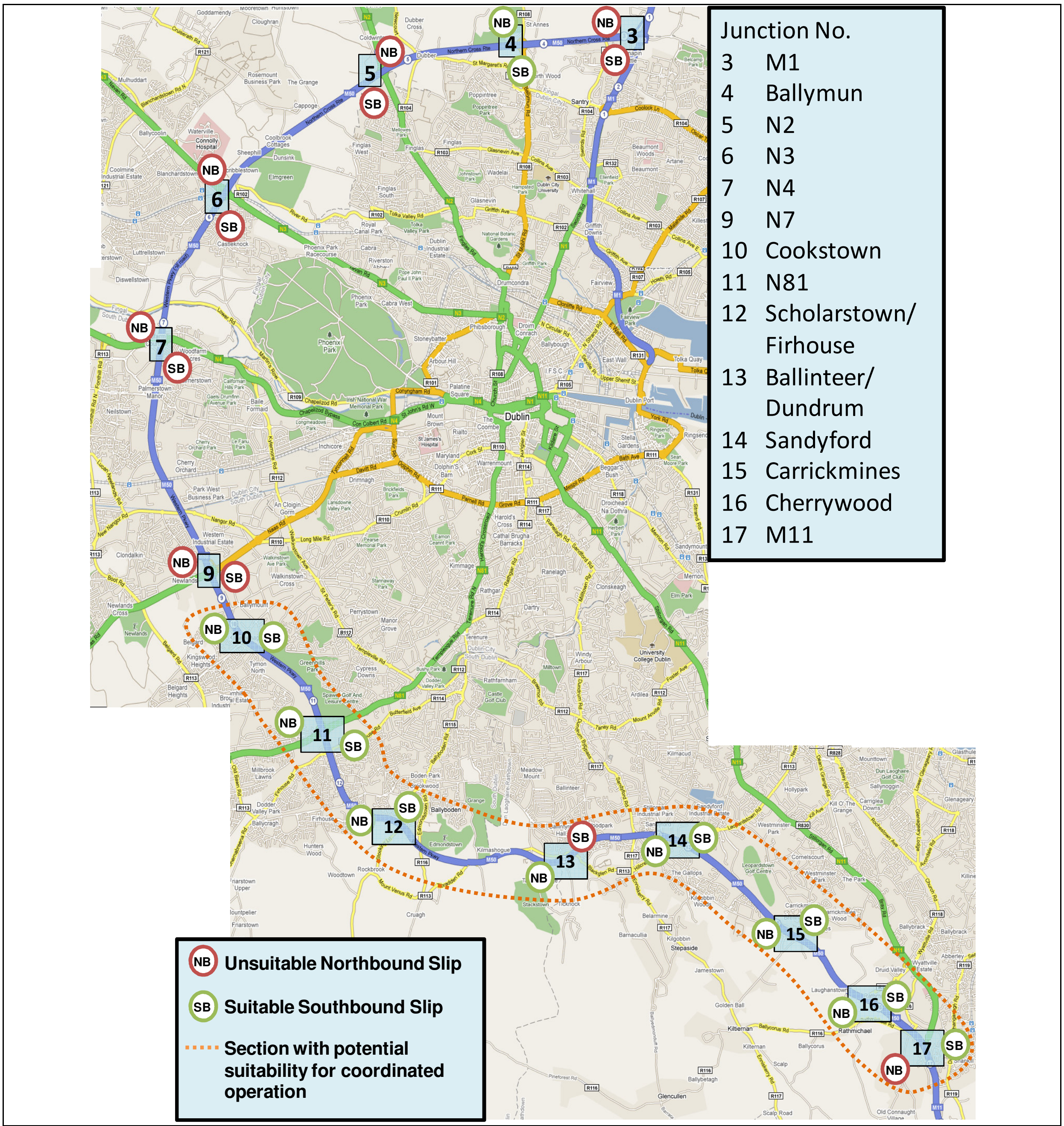
Junction		2016 Northbound								
		Slip	No. Of Lanes	Suitability	Main	Suitability	% Of DS	Suitability	Overall Suitability	Comment
3	M1	1822	2	Acceptable	2756	Ideal	40	Acceptable	Unsuitable	Freeflow
4	Ballymun	357	2	Unsuitable	4545	Ideal	7	Acceptable	Review	Aux Lane
5	N2	1018	2	Ideal	5836	Ideal	15	Ideal	Unsuitable	Freeflow & Low Flows
6	N3	1520	1	Unsuitable	5467	Ideal	22	Ideal	Unsuitable	Freeflow & Low Flows
7	N4	1615	1	Unsuitable	3942	Ideal	29	Ideal	Unsuitable	Freeflow & Low Flows
9	N7	831	2	Ideal	3036	Ideal	21	Ideal	Unsuitable	Freeflow & Low Flows
10	Cookstown	1122	1	Acceptable	4506	Ideal	20	Ideal	Review	Aux Lane
11	N81	1333	2	Ideal	3433	Ideal	28	Ideal	Review	Aux Lane
12	Scholarstown/ F	1244	1	Acceptable	2748	Ideal	31	Acceptable	Review	Aux Lane
13	Ballinteer/ Dund	869	2	Ideal	2012	Ideal	30	Acceptable	Review	Gradient Rev Rqd
14	Sandyford	-	0	No Slip	2011	Ideal		Not Suitable	Review	No Merge
	Leopardstown F	1038	2	Ideal	973	Review	52	Not Suitable	Review	
15	Carrickmines	263	1	Unsuitable	2161	Ideal	11	Ideal	Review	
16	Cherrywood	490	1	Ideal	2645	Ideal	16	Ideal	Review	
17	M11	-	0	No Slip	2772	Ideal		Not Suitable	Review	

Table 7-3 Assessment of M50 Southbound Slips

Junction		2016 Southbound								
		Slip	No. Of Lanes	Suitability	Main	Suitability	% Of	Suitability	Overall Suitability	Comment
3	M1	1000	2	Ideal	4469	Ideal	18	Ideal	Unsuitable	Freeflow & Low Flows
4	Ballymun	925	2	Ideal	4105	Ideal	18	Ideal	Review	Aux Lane
5	N2	1694	2	Ideal	4264	Ideal	28	Ideal	Unsuitable	Freeflow & Low Flows
6	N3	1950	2	Acceptable	5034	Ideal	28	Ideal	Unsuitable	Freeflow & Low Flows
7	N4	224	1	Unsuitable	5644	Ideal	4	Not Suitable	Review	Freeflow & Low Flows
9	N7	252	1	Unsuitable	4707	Ideal	5	Acceptable	Review	Freeflow & Low Flows
10	Cookstown	625	1	Ideal	3317	Ideal	16	Ideal	Review	Aux Lane
11	N81	691	1	Ideal	3178	Ideal	18	Ideal	Review	Aux Lane
12	Scholarstown/ F	1265	1	Unsuitable	3141	Ideal	29	Ideal	Review	
13	Ballinteer/ Dund	-	0	No Slip	3035	Ideal		Not Suitable	Unsuitable	No Merge
14	Sandyford	530	2	Unsuitable	1326	Ideal	29	Ideal	Review	
	Leopardstown F	-	0	No Slip	1856	Ideal		Not Suitable	Unsuitable	No Merge
15	Carrickmines	540	1	Ideal	1494	Ideal	27	Ideal	Review	
16	Cherrywood	???	1	Unsuitable	1270	Ideal		Not Suitable	Unsuitable	No Merge Figs
17	M11	655	2	Acceptable	1270	Ideal	34	Acceptable	Review	

Following the review of each suitable site consideration was given to whether the operation of Ramp Metering at number of these sites could be linked using a coordination algorithm. International experience suggests that this type of algorithm can further increase efficiencies of Ramp Metering installations.

Figure 7-2. M50 Junction Locations



7.4.2 Geometric Assessment

All of the junctions highlighted for review are suitable geometrically. It should be noted however that careful consideration is required at each location to review the potential impact on interchange traffic signals due to queuing traffic. At a number of locations, the impacts on existing free flow slips must also be understood. This review can only be undertaken with a significant level of confidence following a review of all as built drawings for the junctions that have recently been upgraded.

Analysis of accident records on Junctions 3 to 13 above would not be appropriate as they have just been constructed and as such historical records are obsolete. Accident statistics on Junctions 14 to 17 indicate that no accident black spots can be identified where accidents are directly associated with merging traffic. This is not surprising, as bottlenecks occurring as a result of merging traffic do not always remain at the merge point but propagate upstream back from the merge.

7.4.3 Site Selection Conclusions

A number of conclusions can be made based on the analysis above;

- A total of 9 out of the 14 junctions reviewed on the M50 were deemed suitable for further more detailed review;
- A total of 8 southbound and 8 northbound merges are suitable although the auxiliary lanes at these locations reduces the likelihood of a significant improvement in performance due to Ramp Metering; and
- A total of 14 merges that are suitable for Ramp Metering are in close proximity to each other south of the Red Cow Interchange.

7.5 Ramp Metering Algorithms

7.5.1 Overview

The fundamental philosophy of Ramp Metering is that it allows a corridor to maintain its optimal operation through controlling the quantity and rate of traffic entering the network. The on ramp signals are used to achieve this outcome, which has many potential advantages (Roess et al, 1998):

- Improvement of motorway mainline flow, due to access control and traffic diverting to other, less congested roads (such as parallel frontage roads);
- Metering smoothes out the traffic flow and breaks up platoons, allowing more efficient merging;
- Reduction of accidents, fuel consumption, emissions, and vehicle operating costs; and
- Network routings may be altered to achieve greater balance and efficiency.

Ramp Metering was first used in the United States in the early 60's, and has continually evolved in efficiency and effectiveness. Currently, there are a number of variations in the principals by which ramp meters control traffic flow and the mechanisms through which these principles are applied. Research worldwide has produced differing results following field testing of newly developed methods.

The majority of the methodologies associated with Ramp Metering were all developed to suit the needs of individual road and highway locations, and have then been adopted elsewhere with varying degrees of success. Prior to identifying the appropriate Ramp Metering methodologies and technologies to integrate into the Irish Road network, it is first necessary to study each of the wide range of Ramp Metering control mechanisms and principles.

7.5.2 Function of Algorithms

Ramp meter signals are set according to the current traffic conditions on the road. The original Ramp Metering controllers used pre-timed ramp meters which were based on achieving a predetermined optimal ramp flow based on historical flow patterns on both the ramp and the mainline road.

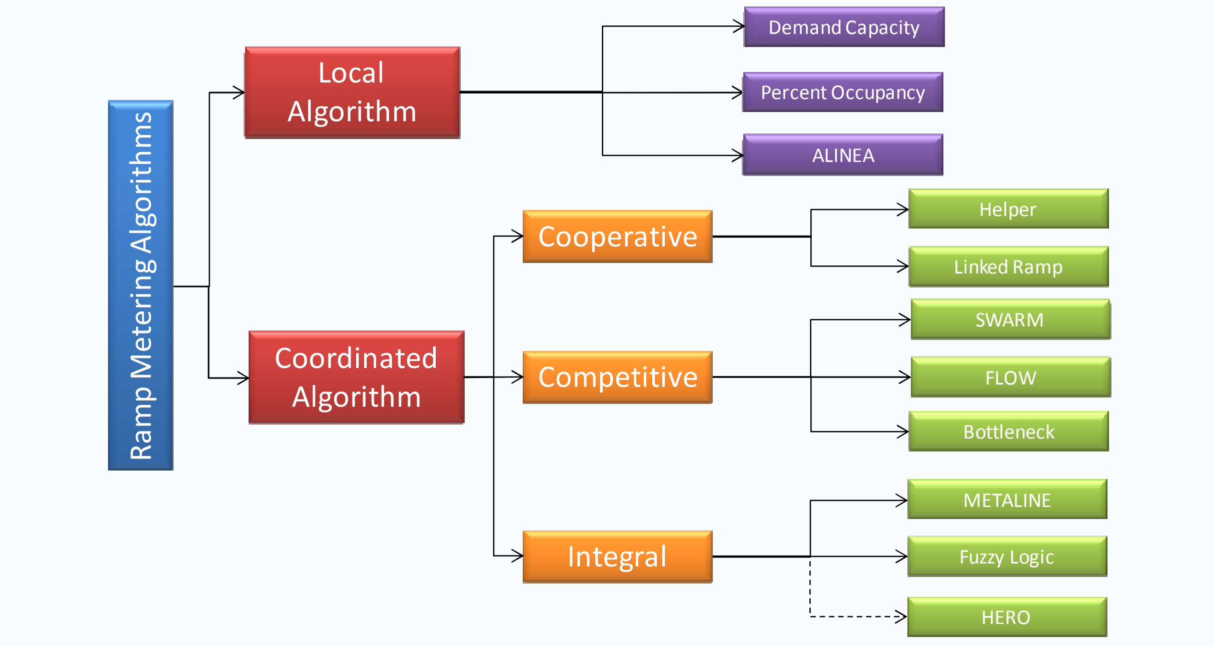
Modern Ramp Metering algorithms however, are traffic responsive. Detectors are installed both on the ramp and on the main road which measure traffic flow and calculate the speed and occupancy levels. This information is then used to calculate the optimum number of vehicles that should leave the ramp at any one time. In general, with a more congested carriageway, fewer vehicles are allowed to leave the ramp through reduction of green times on the ramp signals. The location of the detectors and the ramp green time calculation are both based on the particular Ramp Metering algorithm used.

Much research is currently being carried out worldwide to ascertain the most appropriate algorithms for controlling ramp meter signals. Zhang et al[9] outlined how given a clear set of control objectives and technologies, an ideal control methodology should possess the following properties;

- A good system model describing corridor operations and control; the model should be able to describe both the operations and control in the dual carriageway system accurately. It should capture major traffic flow phenomena that are critical to control design, such as criticality, shock waves, and drivers' response to controls;
- Sound theoretical foundation i.e., reasonable assumptions and objectives, rigorous problem formulation, efficient and accurate solution methods;
- Proactive and balanced i.e. prevent congestion rather than react to congestion, and avoid genration of spillback of queues or over-congestion concentrated in one particular part of the system;
- Accuracy and robustness; the control actions should be effective to achieve the control objective, and degrades gracefully when part of the system, such as input links, is down;
- Computational efficiency; Algorithms that are easy to program, run fast, and require moderate amount of memory;
- Flexibility and expandability; the algorithm should be easy to implement, modify and expand to account for more complex and perhaps more realistic situations encountered in the highway system;
- Ability to handle special situations, such as giving priority to high occupancy vehicles (HOV), control under bad weather, or incident conditions;
- Simplicity; Use the simplest logic structure possible to reconcile demands on realism and theoretical elegance.

An overview of Ramp Metering algorithm classifications are provided within Figure 7-3 below.

Figure 7-3: Overview of Ramp Metering Algorithm Classifications



7.6 Conclusions

Based on the completed analysis into the potential for introduction of Ramp Metering, the following conclusions can be drawn;

- There are a number of sites suitable for Ramp Metering on the M50;
- Ramp Metering could be introduced at suitable sites individually or as part of a scheme which uses a number of sites to collectively influence traffic flow;
- The adoption of a suitable Ramp Metering control algorithm may have considerable influence on the performance of an individual Ramp Metering site or group of sites; and
- Ramp Metering may be adopted on the M50 as a standalone capacity enhancement measure to address issues at specific locations or as part of an overall M50 strategy to work and interact with other measures.

Furthermore, the review of the M50 has highlighted a number of key requirements with respect to the applicability of Ramp Metering. These requirements are summarised as follows:

- Ramp Metering is most effective when the slip lane requires all vehicles to merge (i.e. it is not provided with a lane gain). With lane-gain junctions, benefits are less significant;
- Sites should broadly have mainline and slip road flows that are within the limits set out in the Highways Agency Advice Note
- Microsimulation models allow easy evaluation of Ramp Metering impacts, and such decisions are best based on analytical evidence; and
- Queuing on the slip road should not lead to congestion within an interchange, which will effect other movements through the interchange.

These conclusions suggest that M50 Ramp Metering would be restricted to those junctions along the M50 Southern Cross where no lane gain is present, and interchanges serve local roads only. Nevertheless, these conclusions do suggest that Ramp Metering may be appropriate at a number of locations on radial routes where congestion is exacerbated by merging activity.

Chapter 8 Traffic Control - Variable Speed Limits

8.1 Introduction

The use of mandatory Variable Speed Limits (VSL) is growing in popularity on motorway networks as a means of improving safety and improving traffic flow conditions. Typically such technologies are used on high capacity multi-lane roads where speed differentials between adjacent lanes can lead to sudden braking and an onset of shockwaves as a result of lane changing behaviour.

This chapter examines the role and function of VSL, and examines the case for deployment of such technology on the M50. The discussion also examines typical situations where VSL technologies should be considered, and how it can complement (or indeed compete with) Ramp Metering.

8.2 Review of Variable Speed Limits

Variable Speed Limits is not a new technology, it has been used for over 50 years to control speeds during adverse weather conditions, see image from the United States. Since the mid 90's it has become a common control strategy for motorways that suffer from routine and incident related congestion in and around peak periods. As a motorway approaches capacity, users experience "shockwaves" which increase the risk of rear-end type accidents. In congested environments this shockwave can propagate upstream from the incident and can last for sometime following the incident.

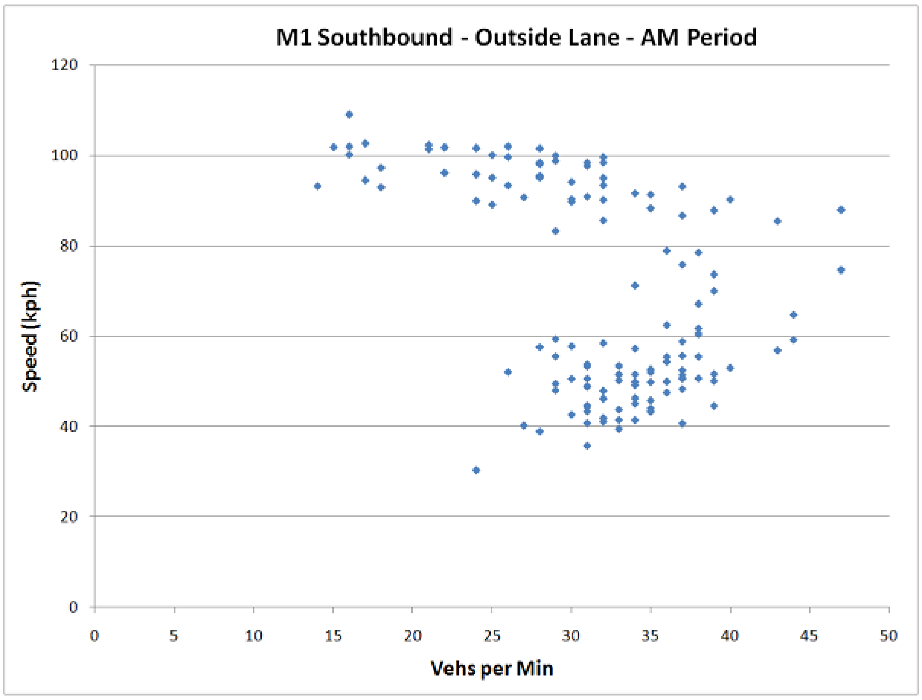
The principal of VSL is to reduce the speed variation during congested periods so traffic moves more smoothly with resultant improvements in driver behaviour (e.g. less frequent lane changes). The harmonising of traffic speeds reduces the severity of shockwaves, thereby reducing stop-start driving, which helps to delay the onset of flow breakdown and advances the recovery of traffic flow from congested conditions.

In 2007 the US Transportation Research Board (TRB) in cooperation with the Washington State Department set a challenge of explaining the concept of maximizing throughput to a sceptical audience, the following was the winning submission:

> ***Paul Haase of Sammamish, Washington**: If traffic slows down as they approach a congested area and all the drivers stay at a constant speed, traffic will get through the congested area faster. Imagine the highway as a funnel. Now, imagine the traffic which has to travel along the highway during a certain time as a container of rice. If you pour all the rice into the funnel at the same time, it gets congested at the bottom of the funnel and takes some time to work through the funnel. Now, if you slowly pour the rice into the funnel – keeping it at a steady pace – the rice moves through the funnel evenly and doesn't cause congestion. In fact, even though the rice is entering the funnel slower, all the rice gets through the funnel (to its destination) faster.*

It is sometimes argued that reducing vehicle speeds will reduce the throughput of a road. However, it is worth highlighting that for urban motorways, throughput is maximised for travel speeds of around 50 to 80 km/h. Figure 8-1 illustrates the relationship between traffic flow and speed for the M1 close to Dublin Airport. It shows that speeds reduce as traffic flow increases, but only until traffic reaches levels where traffic flows become unstable. Maximum traffic throughput occurs at vehicle speeds of approximately 60 to 70 km/h.

Figure 8-1 Speed Flow Curve on the M50, 2010



The total travel time of a journey is an important element for most road users; however the predictability and reliability of the journey may often be even more important. A more homogeneous distribution of speeds leads to better traffic flows and thus to more predictable journey times. VSL is in use in many countries around the world including the UK, Netherlands, Germany, Sweden, Finland and the United States and is considered to be an effective management tool.

In general, there are two different types of Variable Speed Limit systems in operation: variable and dynamic. Variable speed limits are activated through criteria such as the time of day, season, or defined weather conditions (rain/fog). These limits are usually set by each country at the national level. These are usually conveyed by fixed signing or through the "Rules of the Road".

- A few countries apply lower general speed limits for bad weather conditions. For example, in France, in case of rain or snow, the speed limit for motorways changes from 130 km/h to 110 km/h and on rural roads from 90 km/h to 80 km/h. In case of fog (visibility less than 50 meters), forward vision is reduced so reduced speed limits are particularly important. The speed limit on all types of roads is 50 km/h under fog conditions;
- Both Finland and Sweden apply different general speed limits in wintertime. In Finland, the speed limit on motorways changes from 120 km/h to 100 km/h and, on main rural roads, from 100 km/h to 80 km/h. These changes have been positively evaluated by recent research. Similarly, in Sweden the speed limits change respectively from 110 km/h to 90 km/h and from 90 km/h to 70 km/h; and
- In Ireland, UK, United States, Australia and several other countries, variable speed limits are applied in school zones at entering or exiting times.

Dynamic speed limits, on the other hand, are generally activated based on traffic volume or other criteria.

- In France, it is common to reduce the speed limit by 20 km/h on a temporary basis to improve air quality. This happens when the level of pollution is elevated due to high temperatures. The speed limit is then displayed either by variable message signs or announced through the media, but on these occasions the speed limit is not easily enforced, due to the fact that fixed speed limit signs remain visible.
- Dynamic speed limits are also used for speed control / regulation. When traffic flow and vehicle density increases, inter-vehicle time and distance decreases. In this event, the proposed speed (speed limit or recommended speed) needs to decrease to be compatible with the safe stopping of the vehicle (i.e. reasonable braking distance).
- In some countries (e.g. Germany, United Kingdom) matrix signs on motorways provide advisory or compulsory reduced speed limits when weather conditions are bad.
- Observations of traffic flows show that when traffic increases and nears maximum capacity, the flow is disturbed and the risk of accident increases. Usually, in these circumstances, a decrease in travel speed can lead to flow stability and a capacity gain (of at least a few percent) as well as a safety gain caused by and a reduction in incidents.
- Lowering the speed limit can also lead to a reduction of differences in speed between consecutive vehicles driving on the same lane, which in turn leads to a decrease in the risk of rear end collision. It also decreases the speed of the flow in the fast lane, and thus leads to a reduced interest in changing from the slow to the fast lane, which can disrupt flow and lead to an increase in incidents.
- Applying the same speed limit for all lanes emphasises this benefit. This option is used in many countries. However, in some countries (e.g. Italy, Luxembourg and Ireland) it is permitted to apply different speed limits for different lanes, although in Ireland differential speed limits are currently restricted in application to bus lanes.

Some international case studies are described below:

<u>**United Kingdom**</u>

M25 Controlled Motorway - Variable Speed Limit

The UK Highways Agency (HA) implemented a trial Controlled Motorway scheme on the M25 in 1995, which was later extended to other sections of the M25 in 2002. The M25 has traffic flows that are very close to the capacity of the motorway with congestion experienced throughout the day. Users experienced numerous traffic shockwaves leading to situations where the risk of shunt type accidents was relatively high. These perceived unsafe conditions and the unreliable journey time's led to higher user stress and a low level of satisfaction with this road.

The scheme includes the installation of variable speed limit signs over each lane on gantries at approximately 500m centres. These gantries contain enforcement cameras to increase compliance with the variable mandatory speed limits. Inductive loops imbedded in the carriageway constantly monitor traffic flow and speed conditions and when certain conditions occur the speed limit is altered automatically to suit the prevailing traffic conditions.

The benefits of the first phase of the M25 scheme are listed below based on the UK DfT, Controlled Motorways Summary Report [10].

Table 8-1: Summary of M25 VSL Benefits

Actual benefits reported		
Impact Assessments	Environment	Emissions reduced by between 2% and 8%, depending on the individual pollutant considered Weekday traffic noise adjacent to the scheme has been reduced by 0.7 decibels.
	Safety	Injury accidents reduced by 15%; 20% drop in the number of incidents (note that reductions of 40% have been reported for the Minnesota scheme); 5% reduction in drivers exceeding the 40 mph (64 kph) speed limit, which is now displayed as a mandatory limit
	Efficiency	Motorists were found to be more inclined to keep to their lane, as well as to keep to the inside lane and to maintain proper separation distances. Total throughputs during the 5- hour peak periods, between J15-16 has increased by 1.5% 9% reduction in amount of time flow on the anticlockwise carriageway is broken down and a 3% reduction in the number of flow breakdowns occurring 6% reduction in stop-start driving during peak periods
Technical Performance		System performed as anticipated and is being considered for rollout elsewhere on the Motorway network
User Acceptance		A survey of 1600 drivers noted that the scheme had resulted in improvements. Just under 60% thought the speed limits were appropriate for the conditions (only 25% disagreed), and 84% said they complied with the limits posted. Over two-thirds wanted the system extended to cover other areas of the M25 or to other congested parts of the motorway network.

M42 Active Traffic Management – 4 Lane Variable Mandatory Speed Limits
Following on from the experience on the M25 in London, the UK Highways Agency implemented an Active Traffic Management scheme on the M42 in Birmingham in 2006. The key features of this project were as follows:

- The use of variable mandatory speed limits;
- The dynamic use of the hard shoulder during periods of congestion or incidents;
- The provision of dedicated Emergency Refuge Areas for use when vehicles breakdown; and

- The installation of gantries with signals and Variable Message Signs (VMS).

As this scheme includes hard shoulder running as well as VSL, assessing the benefits of VSL requires analysis of the results for the short period between January 2006 and August 2006 when hard shoulder running was not in place but VSL had been implemented. The results from a 12 month review of the scheme are set out below[11].

Table 8-2 Summary of M43 VSL Benefits

Actual benefits reported		
Impact Assessments	Environment	Emissions reduced by between 3% and 10%, depending on the individual pollutant considered Weekday traffic noise adjacent to the scheme has been reduced by between 1.8 and 2.4 decibels.
	Safety	Limited Data Available: Personal Injury Accidents (PIAs) No VSL - 5.08 per month 3L – VSL - 3.17 per month (- 38%) 4L – VSL - 1.83 per month (- 64%) (includes hardshouler running) 94% or better speed limit compliance at 70mph (112 kph), 60mph (96 kph), 50mph (80kph) and 84% or better at the 40mph (64 kph) speed limit.
	Efficiency	The operation of the 4 Lane VSL has increased observed capacity of the motorway by an average of 7% (compared to No VSL) and 9% (compared to 3 Lane VSL). 4 Lane VSL has reduced journey times when compared with the other two scenarios.
Technical Performance		N/A
User Acceptance		In 2007, 30% of long distance users thought the M42 (with 4L – VSL) was better or much better than other UK motorways, compared to 16% recorded in 2003, before works had started.

Sweden

E6 Mölndal, Sweden – Traffic Controlled VSL

The Swedish Road Administration started to test VSL on motorways and other roads between 2004 and 2007. The speed limits are based on weather, traffic conditions and the presence of secondary traffic.

E6 through Mölndal is an example of application of VSL on an urban motorway with low posted speed limit. E6 Mölndal, which is situated on the Southern border of Gothenburg, has 90 kph as posted speed limit in normal free-flow conditions. Whilst the original motorway had two lanes in each direction, additional lanes were constructed in December 2002 by repainting and narrowing the lanes to 3.25m. At the same time, the posted speed limit was reduced to 70 kph. Variable speed limits were implemented two years later, firstly as advisory limits, and then as regulatory limits in February 2006. An aspect of the project was to identify the differences between advisory and regulated speed limits.

During operation of the system, the speed limit is reduced in steps from 90 kph to 70-50-30 kph. When dense traffic is detected (ca 950 v/h per lane) the speed limit is reduced to 70 kph to prevent the occurrence of sudden break-down of capacity. When a risk of queuing is detected (v<35 kph and 20% occupancy) the normal incident detection function is used for control. When queue formation is detected (v<15 kph) the speed limit is further reduced to 30 kph.

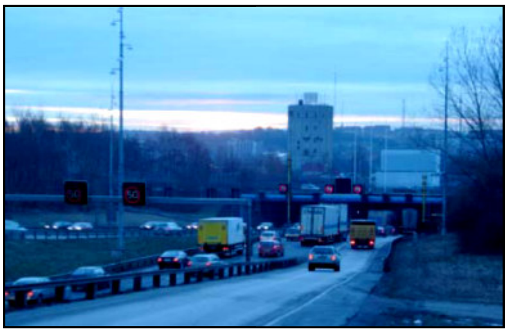


Table 8-3 E6 Mölndal, average speeds after implementation of VSL

	Post-study VSL (kph)	Difference compared to pre-study
90 kph, free flow	86.1	+7.0
70kph, dense traffic	72.1	+6.1
50 kph, risk of queue	71.2	+40.2
30 kph, queue formation	-	-

The results for the scheme indicate a substantial improvement in the driving behaviour in dense traffic conditions, with improvements in average speed of up to 40kph. Furthermore, injury accidents have been reduced by 20% when the advisory variable speed limits were implemented and 40% with regulatory variable speed limits. The number of accidents is however too small to draw any statistical conclusions. The fear that more accidents would occur as a result of the increased speed limit during free flow conditions (70 kph to 90 kph) seems to be unfounded.

Table 8-4 Summary of reported impacts of Swedish VSL

Actual benefits reported		
Impact Assessments	**Environment**	N/A
	Safety	• Limited Data Available: • 20% reduction of injury accidents with recommended speed limits • 40% reduction of injury accidents with controlled speed • Significant numbers exceeding speed limit.
	Efficiency	• The speed variation has been reduced and gaps between vehicles have been smoother. Sudden stops have probably been reduced to a great extent. Queue formations, where a 30kph limit should have been implemented, has not occurred; where as they did occur before VSL.
Technical Performance		• N/A
User Acceptance		• 70 % finds the system good: • "…the uneven traffic rhythm, the amount of stop-and-go traffic and the queue lengths are decreasing" • 50% are more attentive: • " it gives good information about what you can expect further on" • 30% state that their behavior has improved: • "… maintain longer distance to vehicle ahead" • "… more restrictive in overtaking other cars"

France

A7 Motorway, France – Seasonal VSL

ASF (Autoroute du Sud de la France – the company managing a French motorway network) conducted experiments, during the summer of 2004, with an innovative traffic control system on the A7 motorway, one of Europe's busiest interurban routes. On this north/south corridor linking northern France with Spain and Portugal as well as the Riviera, traffic flows increase during the holiday period from a daily average of 75 000 vehicles to around 110 000 vehicles. During the summer of 2004, ASF tested a new traffic management system to control speed, based on a range of ITS technologies.

An algorithm was designed to give advance warnings of congestion based on historical traffic flow data obtained from inductive loops buried in the carriageway. When the algorithm detects an anticipated risk of "traffic flow destabilisation", an alarm signal is transferred in real time to the control centres, where traffic operators check the validity of the signal and activate the system to inform the road users of the traffic conditions.

Road users are informed in real time of the current speed limit through motorway information being broadcast via radio (on stations designated for traffic information purpose), by mandatory speed limit pictograms (70, 90 or 110 km/h) mounted on overhead gantries, and with Variable Message Signs (VMS) located every 10 km. At the same time, the average speed of vehicles is calculated. If the calculated speed is higher than the current mandatory limit on the section, a VMS displays the vehicle's licence plate number and warns the driver to slow down.

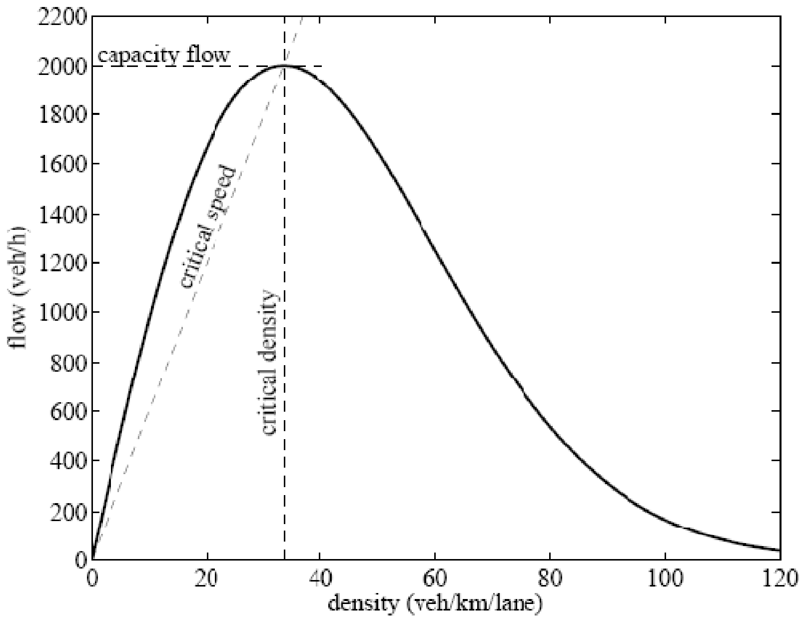
Initial evaluations showed that 75% of drivers drove within the speed limits. Roadside surveys also suggested that the system was widely supported by the motorists who faced less congestion and fewer accidents during their journey. Ongoing studies seem to indicate favourable trends in terms of traffic capacity and delay in the occurrence of congestion.

In summary, VSL has proved to be an effective traffic management tool for congested motorway systems in France. The motorways where VSL has been introduced operate more efficiently, with a resulting higher capacity, and injury accidents reduced by between 15 and 40%.

8.3 Variable Speed Limit Theory

In order to explain current VSL theories in detail it is first necessary to explain how traffic behaves under varying flow and density conditions. Figure 8-2 below illustrates a typical fundamental diagram.

Figure 8-2 Fundamental Flow Diagram



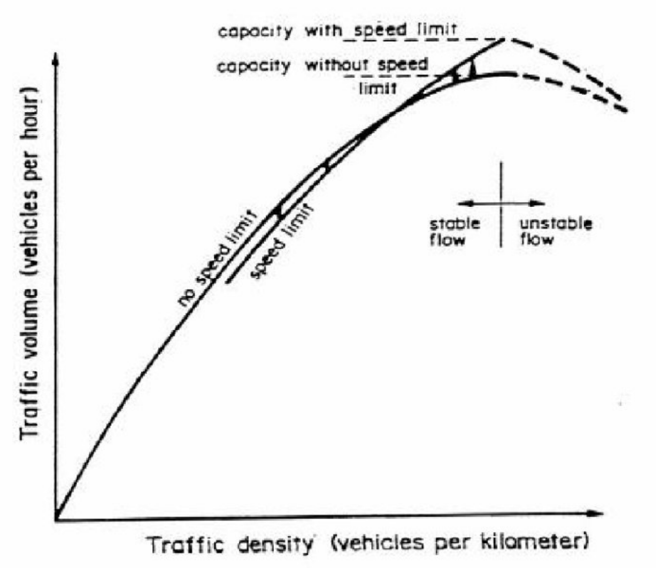
Source: University of Crete, 2007[12]

The diagram above represents the traffic behaviour on a homogeneous motorway. The diagram shows that when the density is low, drivers travel at speeds close to the maximum allowed speed and the relationship between flow and density is approximately linear. At higher densities, drivers reduce their speed until at a certain density called the 'critical density'; the capacity of the motorway is reached. When the density increases above the critical density, flow breakdown leads to inefficient operation and a net reduction in the carrying capacity of the road.

The relationship is, however, not always constant. Various data-driven investigations demonstrated that the capacity flow may vary considerably from day to day without any obvious reason. These variations were found to be more pronounced under different weather and lighting conditions. In contrast, the critical density (at which capacity flow occurs) was found to be less sensitive with respect to different weather conditions while no related results are known for the critical speed (Papageorgiou 2007)[13].

Papageorgiou[12] outlined how a number of studies had indicated that whilst different site conditions can alter the fundamental diagram for a particular area, the introduction of a Variable Speed Limit can impact on the shape of the curve outlined in figure 8-2. Studies have indicated that at higher flows, the introduction of VSL can facilitate higher flows and speeds. This alteration is indicated in Figure 8-3 below;

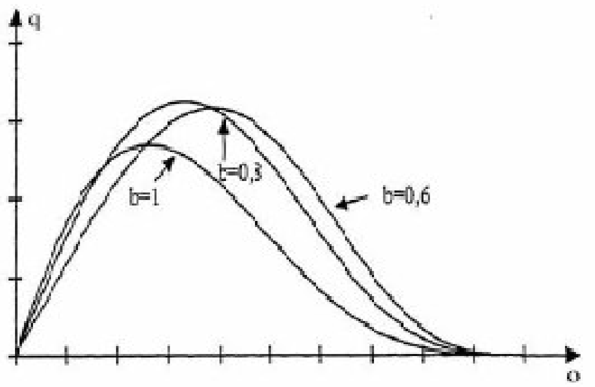
Figure 8-3 Alteration to Fundamental Flow Diagram due to VSL



Source: University of Crete, 2007[14]

Further studies have indicated that as the speed limit changes so does the shape of the curve. This means that a relationship can be produced to represent each step down in speed. Figure 8-4 illustrates possible changes as a result of changing speed limits.

Figure 8-4 Changes in Fundamental Flow Diagram associated with each varied speed limit



Source: University of Crete, 2007[15]

In Figure 8-4, b is the ratio of the speed (with applied VSL) to the free speed (without VSL), and, by convention, b = 1 corresponds to the no-VSL case. This demonstrates that as speed is reduced the levels of flow and occupancy may increase prior to flow breakdown occurring. It should be noted that the optimum speed reduction varies depending on location, time of day and variables impacting on driving conditions such as weather and light availability.

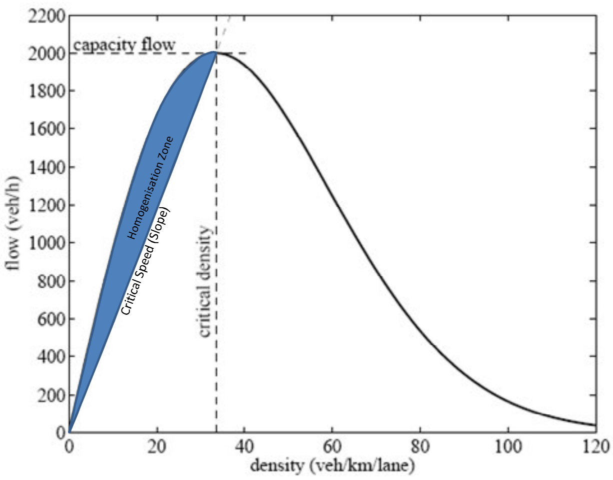
8.4 Variable Speed Limit Mechanisms

There are two theories on the use of dynamic speed limits. The first emphasizes the "homogenisation effect" whilst the second is more focused on preventing traffic breakdown by reducing the flow by means of speed limits.

8.4.1 Homogenisation VSL

The basic idea of homogenisation is that speed limits can reduce the speed (and/or density) differences, by which more stable (and safer) flow can be achieved. The homogenising approach typically uses speed limits that are above the critical speed i.e., the speed that corresponds to the maximum flow (see Figure 8-5).

Figure 8-5 Area in which Homogenised VSL typically operates



Source: University of Crete, 2007[16]

These speed limits do not limit the traffic flow, but only slightly reduce the average speed whilst slightly increasing the density. In general, homogenisation results in a more stable and safer traffic flow, but no significant improvement of traffic volume is expected or measured (Van den Hoogen, 1994)[17]. In theory this approach can increase the time to breakdown (Smulders, 1990)[18] but it cannot suppress or resolve shock waves. An extended overview of speed limit systems that aim at reducing speed differentials is given by Wilkie[19] (1997). It should be noted that whilst Wilkie[15] recommended placing VSLS upstream of reduced-flow locations, Van den Hoogen[13] concluded that speed control using Variable Speed Limits is not suitable to solve congestion at bottlenecks.

8.4.2 Traffic Breakdown Prevention VSL

This approach focuses more on preventing densities which are too high for a downstream bottleneck, and may allow speed limits that are lower than the critical speed in order to limit the inflow to these areas (Hegyi, 2004)[20]. Bottlenecks often cause areas of congestion or waves of dense traffic; in some cases these waves may move upstream becoming shockwaves. These waves can often be found to move upstream at approximately 15 km/h. Whether the congested area is stationary or moving, it is likely that every vehicle that enters the corridor upstream of the wave will have to pass through the congested area, this increases travel time and creates conditions which are less safe than usual.

In sections upstream of a shock wave, speed limits are imposed and consequently the inflow of the jammed area is reduced. When the inflow of the jammed area is smaller than its outflow, the jam will eventually dissolve. In other words, the speed limits create a low density wave (with a density lower than in the uncontrolled situation) that propagates downstream. This low-density wave meets the shock wave and compensates its high density. As a result, the shock wave is reduced or eliminated.

Although in general speed limits and therefore speeds are initially lower by resolving the flow breakdown which occurs at bottlenecks, an overall higher flow can be achieved in contrast to the homogenisation approach.

A disadvantage of this system is that although the approach reduces the shock wave it may do so in some cases at the cost of creating new shock waves upstream of the sections controlled by speed limits. However, if the speed limits are optimised properly, they will never create a shock wave that gives rise to delays that are higher than in the uncontrolled case.

The variability of aggregate traffic flow behaviour in the critical occupancy area, which was seen to occur even on days with similar weather and traffic demand characteristics, renders many currently operational VSL control strategies sensitive to the choice of the utilized flow and speed thresholds. In fact, due to the variability of traffic flow behaviour, any choice of flow/speed thresholds may turn out, on different days, to be either aggressive or conservative with the risk of "too-early" or "too-late" activation.

Of course, an occupancy-based control strategy requires a considerable amount of calibration when identifying the critical occupancy of each motorway location for VSL activation. This calibration must take account of changes in critical occupancy associated with a number of variables including adverse weather conditions, HGV proportions, incidents etc.

Methods to calculate critical occupancy in real-time are currently are being developed. These methods which adaptively estimate critical occupancy based on continuous traffic measurements to inform VSL systems are also used for Ramp Metering purposes and have been shown to be quite accurate. This adaptive approach employs a slope estimator for the flow-occupancy diagram and uses the slope estimation to eventually come up with critical occupancy estimates. The same approach – appropriately modified – could be used by a VSL control scheme utilising only the slope estimation module of the ramp metering algorithm. Some encouraging preliminary testing results for a potential VSL control strategy based on real-time slope estimation indicate pertinent decision making for VSL switching (not "too early", not "too late"), virtually without a need for calibration.

The reason why a slope-based decision procedure does not require a tedious threshold calibration for different sites, different weather conditions, etc. is that, whatever the site, weather, and further (stochastic) conditions, when the real traffic flow approaches the critical occupancy (or flow capacity) area, the slope of the flow-occupancy diagram will approach zero; thus the specification of thresholds for the slope appears easier and more general than the specification of thresholds for the absolute values of the traffic flow variables.

8.5 Optimum Conditions for Variable Speed Limits

In order for VSL to be adopted as an efficient means of reducing overall travel time on any network, suitable causes of congestion i.e. a 'Capacity Drop' must be identified following which, other flow and geometric conditions that determine if the traffic control can be applied successfully must also be examined. These conditions include the potential for:

- Sufficient Flow Limitation;

And the presence of both;

- Metastable flow (Metastability); and

- Sufficient length of the speed controlled motorway.

8.5.1 Capacity Drop

In order for VSL to be effective a 'Capacity Drop' must be present. Capacity drop is the phenomenon that occurs when the outflow of a traffic jam is significantly lower than the maximum achievable flow at the same location. Studies have identified that even a small drop in the outflow can have a big effect on the total time spent in congested networks.

This is usually initially caused due to the presence of a bottleneck or geometric constraint such as a tight bend or steep gradient. It should be noted that the capacity drop resulting from a shock wave on a motorway stretch is different from a capacity drop resulting from a fixed bottleneck, such as an on-ramp (Kerner and Rheborn, 1996)[21]. Capacity drop at fixed bottlenecks has been identified as a decrease in flow ranging up to 15 %. Since the capacity drop is not observed in all cases, traffic data from the bottleneck that is to be controlled has to be studied carefully. A capacity drop from a shock wave however has been observed to be in the order of 20% to 30%.

In order to assess the achievable improvement at any congested location, the capacity drop has to be estimated. The capacity drop is estimated by comparing outflow of a shock wave with the maximum flow of freely flowing traffic. The time and location for the outflow measurement of the shock wave have to be such that there are no on-ramps or off-ramps between the shock wave and the measurement point; otherwise the entering or exiting traffic could bias the estimation. Furthermore, the traffic should be in homogeneous free flow, to be sure that the flow drop is not caused by a downstream bottleneck, and that we are not measuring a transient state.

8.5.2 Sufficient flow limitation

A precondition for eliminating congestion is that the net outflow of the congested area should be positive. In other words, the traffic control measures should be able to limit the inflow to the congested area to a level that is less than the outflow of the area.

To effectively eliminate the shock wave using VSL, the minimum value of the speed limit should result in a flow that is lower than the outflow of a congested area; otherwise the density will not decrease even when the speed limit is set to its minimum value. In The Netherlands for example the lowest dynamic speed limit is 50 km/h, and the flow at this speed on a dual carriageway has been observed as 2900 veh/h at this speed. If the estimated outflow is greater than the inflow at the minimum permitted dynamic speed then flow limitation is deemed sufficient and VSL is a viable option for reducing congestion.

8.5.3 Metastability

Kerner and Rheborn (1996) categorised traffic flows on roads as being in one of three states, as follows:

- **Stable:** any disturbance (no matter how large) will vanish without intervention, usually observed at lower flows and densities;
- **Metastable:** small disturbances will vanish, but large disturbances will create a shock wave;
- **Unstable:** any disturbance, even those small in nature, will trigger a shock wave. Usually observed at higher flows and densities.

If speed limits are to be varied to dissolve shock waves, the traffic flow must be in the metastable state, because in the stable state there is not much to control, and in the unstable state any speed limit change will initiate a new shock wave. Hegyi (2004) outlined how a condition may be deemed metastable if the traffic demand is between the reduced outflow associated with a shock wave and the capacity of the motorway.

In the metastable state, the speed limits have the potential (if the change of the speed limit values is sufficiently small) to limit the flow without creating large disturbances. This means that a short unstable shock wave can be converted into a longer but stable disturbance.

8.5.4 Sufficient length of the speed controlled motorway

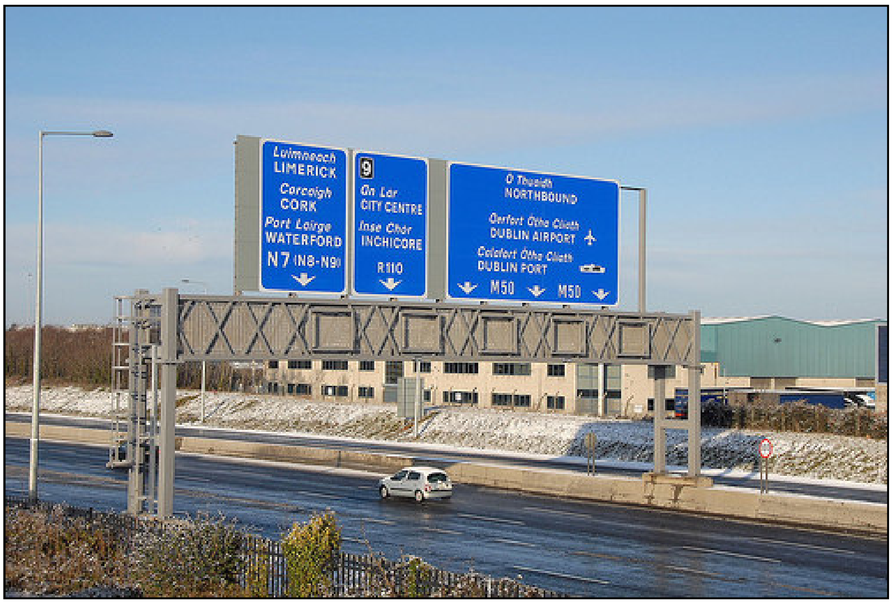
In a VSL system, there should be enough speed limits (enough length) to suppress a typical shock wave without causing a new shock wave. When a speed limit becomes active to limit the inflow of a downstream shock wave, it will cause an increasing density in the upstream segment. To prevent this density from becoming too high and causing instability, a second speed limit should become active that limits the inflow to this segment, and so on. This process continues until the shock wave is resolved and the speed limits can be released gradually. In this way the unstable shock wave is redistributed in a longer but smaller (in density) and stable wave. The necessary length of the speed controlled area depends on the number of excess vehicles (compared to capacity flow) in the shock wave.

8.6 Required Infrastructure

The equipment or infrastructure required to implement VSL typically consists of the following items:

- A Variable Speed Sign mounted on gantries over each lane of the motorway. These can display mandatory speed limits and also lane control information. These signs are either LED or fibre optic signs and must be in accordance with Road Traffic (Traffic Signs - Periodic Special Speed Limits) Regulations 2005 [SI No 756 2005];
- VSL processor and associated algorithms, which decide what the appropriate speed limit should be at any given time;
- Inductive loops in the carriageway (or Non-Intrusive Detectors such as Microwave Radar or Video Imaging etc) to measure speed, flow and occupancy data. This is used by the above VSL algorithms in the roadside cabinet to identify when the flow and speed relationship indicates likely flow breakdown. The system then selects an appropriate reduced speed limit designed to optimise the overall flow of traffic on the road.
- Enforcement cameras located over each lane linked to the VSL signage/processor constantly monitoring speed; and
- Gantries, typically at 500m centres, to support the VMS signage and enforcement cameras.

Figure 8-6 Existing Gantries on M50, which can accommodate VSL signage



When the VSL outstation identifies a requirement to reduce speed, the speed limit is reset. The Highway Agency in the UK states that checks and balances must be in place to ensure that signal settings are consistent and appropriate for the geometry of the road in question.

To increase effectiveness of the system, a high level of compliance with speed limits is required. For this reason enforcement cameras are generally required, until recently this consisted of cameras located in the gantries above the traffic lane (as shown in the figure above), however this has the disadvantage that motorists only have to comply with the limit directly within the detection zone to avoid conviction. More recently the use of Automatic Number Plate Recognition (ANPR) technology in conjunction with digital cameras requires motorists to comply with limits between camera installations, which would increase the effectiveness of VSL. A similar ANPR system has been used on the A1, north of Newry.

Under the Roads Traffic Bill 2009; any electronic apparatus (including a camera) capable of providing a permanent visual record of a speeding offence may be used as evidence in relation to such offences. This equipment however must have gained prior approval by any Garda ranked not below Chief Superintendant or the chief executive officer of the National Roads Authority.

8.7 Existing Traffic Flows

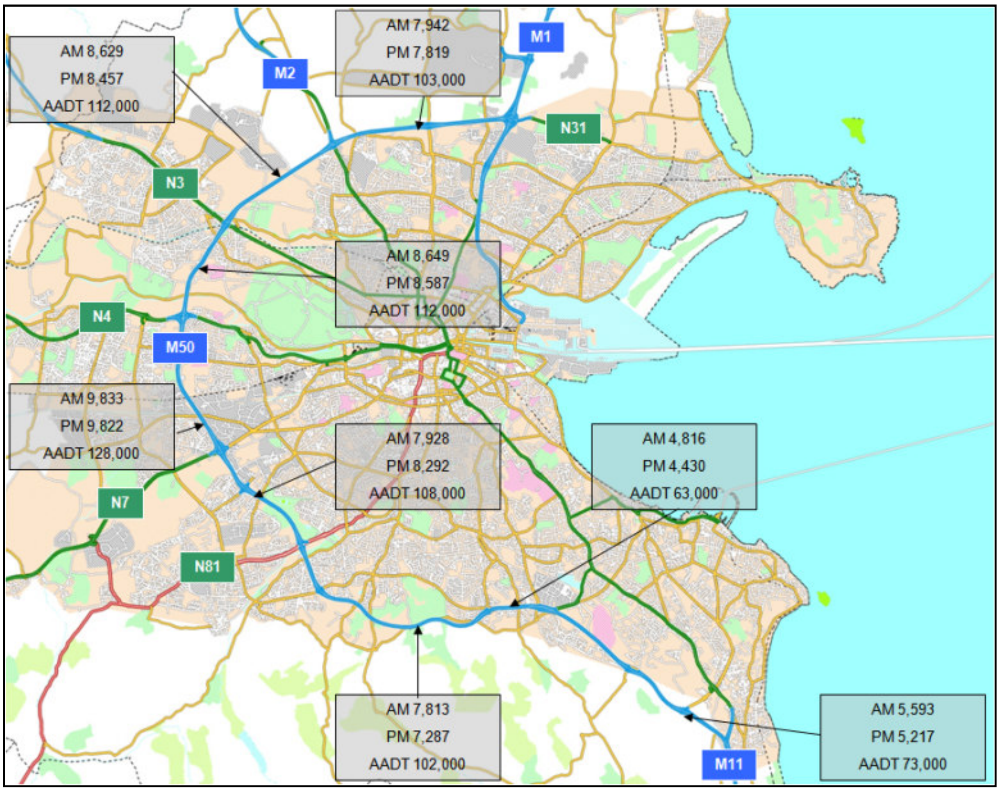
In order to evaluate potential benefits of VSL on the M50, a series of traffic surveys were undertaken at various points around the M50. The surveys were carried out between the 19th and 21st of January 2010, between 07.00 and 19.00. The results of these surveys are indicated in Figure 8-7 below. The main points that can be drawn from this survey are as follows:

- The M50 is carrying significant traffic volumes along its full length, with the busiest

section, between the N7 and N4 interchanges carrying an AADT of over 120,000 PCU's (Passenger Car Units);
- The AM peak occurs between 08.00 and 09.00 on a Wednesday with two-way flows ranging from 4,816pcu's to 9,833 pcu's, with the lower flows occurring to the south of the N7 and the higher flows to the north of that interchange. Of note is that there is little variation between traffic flows either side of the peak hour, therefore there is effectively a prolonged peak period during the morning;
- The PM peak hour varies between 16.00 and 18.00; however in general there is little difference in traffic flows between both of these hours; and
- The Heavy Goods Vehicle (HGV) content ranges from approximately 5% to over 10% per day, with substantial variations throughout the day.

It is clear that the M50 is easily the most heavily trafficked road in Ireland and is busy throughout the day. While the upgraded road is clearly operating significantly better, minor incidents can quickly result in significant congestion developing which can have a large geographical knock-on effect throughout the wider road network.

Figure 8-7 Traffic Flows on the M50, Dublin; January 2010 (Passenger Car Units)



8.8 Road Safety Data

Road safety records for the period 2001 – 2006 (inclusive) have been provided by the RSA. It is acknowledged that ideally a 3 year period following completion of the upgrade works should be used for assessment of the safety implications of M50 upgrade; however this information will not be available for at least another 3 years (works only complete in 2010).

8.8.1 M50 Construction Works

The M50 South Eastern Motorway between Leopardstown and the M11 opened to traffic in June

2005. Accident records for this section are therefore only for the period between June 2005 and December 2006.

It is acknowledged that the accident information outlined in this report generally relates to the pre-upgrade period and therefore does not relate to the M50 scheme that is recently completed. It is clear that the upgraded road may have fewer accidents than that recorded in the pre-construction period, particularly of the type that would be impacted by VSL. The reasons for this are as follows:

- The upgraded road clearly has significantly higher capacity, thus less queuing and as a result fewer rear end shunts;
- Many sections of the upgraded road have longer acceleration lanes, or auxiliary lanes linking two interchanges; thus there is less weaving movements. Again thus could result in smoother traffic flow and again less accidents; and
- Replacement of certain existing signalised interchanges with free-flow interchanges significantly reduces the incidence of queuing, thus the number of rear-end type shunts is reduced.

As limited post-construction accident information is available this report may be over estimating the accident rate for the upgraded M50 and alternative information sources may need to be obtained. This will be discussed later in this report.

The Annual Average Daily Traffic figures outlined in the following (Accidents) section relates to 2003, which was the median year for the accident records.

8.8.2 M1 Interchange to N3 Interchanges

This section of the M50 carried an Average Daily Traffic Flow (AADT) of between 65,000 and 85,000 vehicles (approximately 8% HGV content) in 2003 and runs to a distance of approximately 10km. A total of 39 personal injury accidents (PIAs) occurred on this section of the M50 between 2001 and 2006, a 6 year period. The severity rate, (percentage of fatal and serious injury accidents), is estimated at 0.15 or 15%. Table 8-5 below provides details of the relevant accidents identified.

Table 8-5 PIAs between M1 and N3 Interchanges – 2001/06

M1 Interchange to N3 Interchange	
No of PIAs	39
PIAs Rate per Month	0.54
PIAs Rate per KM	3.9
Fatal	4
Serious	2
Minor	33
Primary Collision type:	Rear End, Straight

It is noted that the N2 north of the interchange was recently upgraded from a single carriageway to a High Quality Dual Carriageway. The construction work took place between May 2004 and May 2006, therefore the construction works may have had an impact on the M50 traffic movements during the assessment period.

The information suggests that approximately 60% of accidents on this section were of the "rear end, straight type" which is the type that would be reduced by the implementation of a VSL system.

8.8.3 N3 Interchange to N7 Interchanges

This section of the M50 carried the heaviest traffic flows in 2003, with AADT's of up to 93,000 vehicles, and also included the toll plaza, which was subsequently removed in 2008 and replaced with a new barrier-free tolling system. This section runs to a distance of approximately 8km. A total of 56 PIAs occurred on this section of road in the 6 year assessment period, with a severity rate(percentage of fatal and serious injury accidents) of approximately 11%. Table 8-6 below provides details of the relevant accidents identified.

Table 8-6 PIAs between N3 and N7 Interchanges – 2001/06

N3 Interchange to N7 Interchange	
No of Accidents	56
PIAs Rate per Month	0.77
PIAs Rate per KM	7
Fatal	3
Serious	3
Minor	50
Primary Collision type:	Rear End, Straight

Note that the section from the N4 to the N7 excludes the period after March 2006, as construction works on the upgrade had started. Approximately two thirds of all PIA's involve rear end type collisions, which are associated with queuing events and variation in speeds.

8.8.4 Naas Road Interchange (N7) to Balinteer Interchange (R117)

This section of the M50 carried an AADT of approximately 72,000 vehicles and runs to a distance of approximately 11.5km. A total of 32 PIAs occurred on this section of road in the 6 year assessment period. The severity rate (percentage of fatal and serious injury accidents) on this section is low at just 3%.

Table 8-7 PIAs between N7 and R117 Interchanges – 2001/06

N7 Interchange to R117 Interchange	
No of Accidents	32
PIAs Rate per Month	0.44
PIAs Rate per KM	2.8
Fatal	0
Serious	1
Minor	31
Primary Collision type:	Rear End, Straight

Most of the accidents again involved rear end type shunts, however unlike the other sections these were associated with queues at interchanges, particularly the N81, rather than the mainline carriageway. This may be related to the ongoing construction works after the Ballinteer Interchange, where the motorway was not completed until 2004/2005.

8.8.5 Ballinteer Interchange (R117) to Shankill Interchange (M11)

This section of the M50 opened between November 2004 and June 2005. As a result the time period for assessment is very short. In this period only one or two minor injury (one may have been on the adjoining green routes but was poorly defined in the data) accidents occurred. As a result it is not possible to draw any conclusions for this section.

8.8.6 Overall Accident Rates

The number of vehicle kilometres travelled on each section of the M50 is relevant to understanding the prevailing accident rate. Using data for 2004, an accident rate per million vehicle kilometres was calculated as follows:

Accident Rate = Accidents / Exposure = [Accident (106)] / [AADT(365)(Length)(Years)].

The results are detailed in Table 8-8 below.

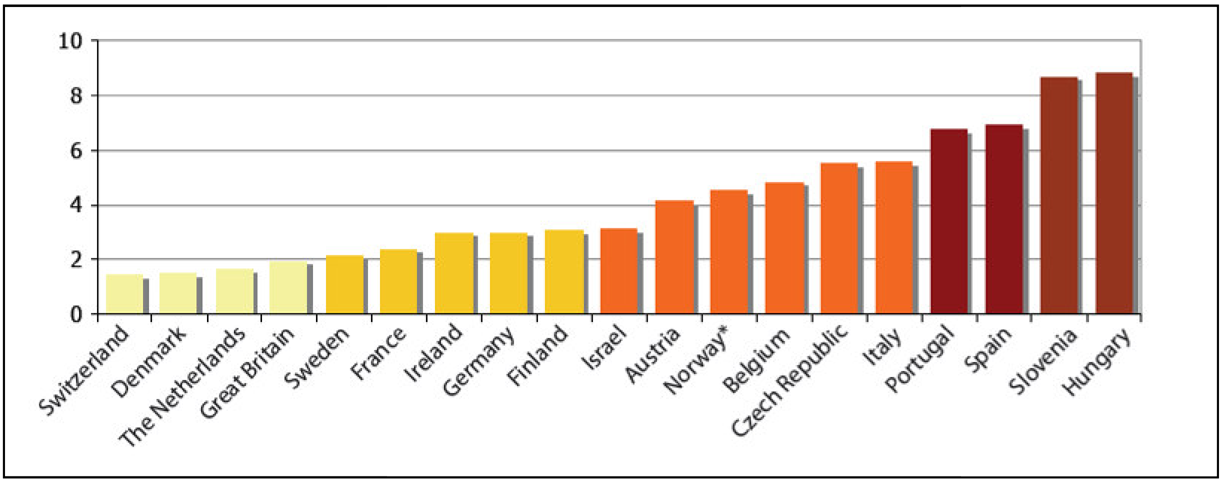
Table 8-8 Accident rates on M50 – 2001/06

Accident Categorisation 2001 - 2006	
Total PIAs	127
Fatal	7
Serious	6
Minor	114
Severity Rate	10%
PIAs rate per 10^6 Veh. KM	
M1 – N3	0.02
N3 – N7	0.04
N7 – R11	0.02
Overall M50	0.02
Fatal Rate per 10^9 Veh. KM	
Overall M50	1.2

The rates indicated above are broadly consistent with those indicated in the NRA PAG, Appendix 6 – National Parameter Value Sheet[22] (2008) document [0.037]. In general the M50 appears to be operating with a relatively low level of Personal Injury Accidents. In addition the severity rate would also appear to be lower than that normal expected in Ireland. The fatality rate of 1.2 per 10^9 vehicle km is slightly lower than the National figures for Motorways. The fatal accident rate for motorways in Ireland is approximately 1.9 (per 10^9 Vehkm).

This finding, along with international evidence presented below in figure 8-8 would suggest that the fatality rate on the M50 is relatively low and in line with the lowest rates in Europe.

Figure 8-8 Number of Deaths on Motorways per billion vehicle-km in 2006 – Road Safety Performance Index 2008 (European Transport Safety Council)



8.8.7 Accident Causation

The primary collision type for each accident is recorded in the RSA database. The principal categories are identified in Table 8-9 below.

Table 8-9 Primary Collision Types on M50 – 2001/06

Primary Collision Type		
Rear End	76	64%
Single Vehicle	13	10%
Angle, Both Straight	13	10%
Pedestrian	2	1%
Other (Not Specified)	23	18%

The results clearly indicate that the majority of accidents recorded on the M50 during the period in question are rear end collisions. Significantly, a high proportion of these accidents involved multiple vehicles indicating that speeds and inadequate headways may be a factor.

Nevertheless, the principal difficulty when examining accident numbers and rates is the level of under-reporting accidents. Reporting rates of accidents increase with increasing accident severity, and hence it is reasonable to assume the need for a larger adjustment factor for minor injury accidents compared with serious injury accidents. Inconsistencies and a lack of clarity in many cases make it difficult to compare the underreporting rate of injury accidents for different countries.

It is estimated, on the basis of evidence from a variety of countries and sources, that the rate of road accident reporting in Ireland for serious injury accidents could be anywhere between 50% and 75%. The reporting rate of minor injury accidents could be as low as 25%. Therefore there is a large margin for error in applying any corrective factor to minor injury accident totals. Table 8-10 shows the estimates of reporting rates in Ireland as well as the relevant adjustment factor.

Table 8-10 Summary of Accident Reporting Rates in Ireland (Source: UCC)

Accident Severity	Reporting Rate	
	Reporting Rate	**Adjustment Factor**
Fatal	100%	1.00
Serious	75%	1.33
Minor	50%	2.00

Table 8-11 indicates the adjusted accident rate, taking under reporting into account and also indicates estimates of injury accidents for various durations on the M50, prior to the upgrade works.

Table 8-11 Adjusted Accident Rate on M50 – 2001/06

Accident Categorisation 2001 - 2006	
Fatal	7
Serious	8
Minor	228
Total	**243**
Yearly Rate	40.5/PIA/Yr.
Monthly Rate	3.4/PIA/Mt.
Weekly Rate	0.8/PIA/Wk.

8.9 Recent Road Safety Data

In the not too distant past the M50 was renowned for being a very slow and congested orbital route around Dublin City, regularly coming to a complete stand-still due to accidents or other incidents. The congestion at the various signal controlled exits and also the Toll Plaza resulted in a motorway with a very low average speed, particularly during peak periods. With the upgrade works fully completed in 2010, most of these delays have been much reduced if not eliminated.

Nevertheless, incidents are still occurring with significant delays resulting. On the 13th November 2009, a truck jack-knifed between the Finglas and Blanchardstown exits on the southbound route around 12.30pm. A number of people were hospitalised with minor injuries and the southbound lanes of the motorway were closed for up to two and half hours while emergency services cleared the road. This had significant impacts on traffic movements throughout the City and continued to cause delays into the evening on the M50. While these events have become rarer they will start to increase again as traffic volumes increase and the road approaches capacity.

As has been noted earlier the accident information available at present is for the period before the upgrade of the road and does not relate to the completed scheme. This updated information will not be available for some time yet. For this reason AECOM have obtained incident records for the M50 for a 4 month period which will be used to estimate the number of incidents that impact on the flow of traffic on the upgraded M50 (note that some sections were not fully completed during this period). Table 8-12 below summarises the incident information.

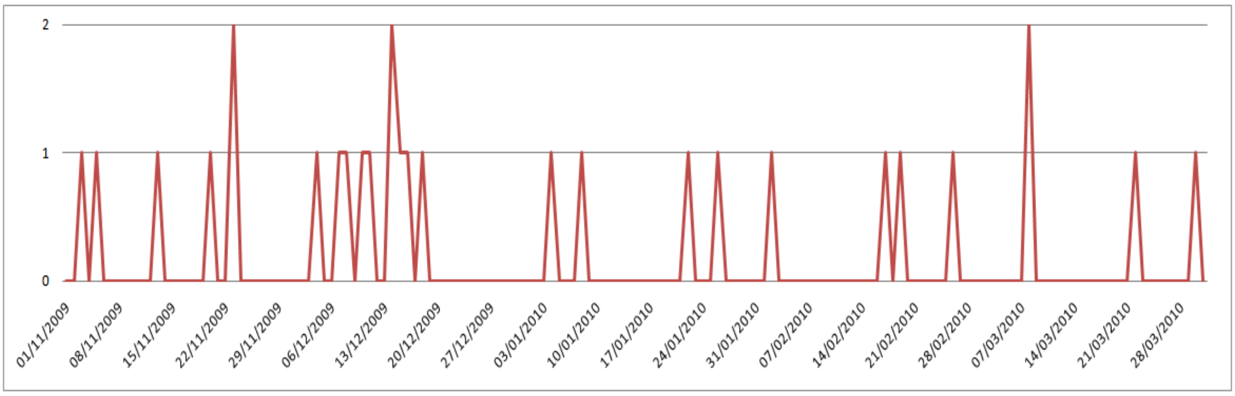
Table 8-12 Incidents on M50 – November 2009 to March 2010

Date	Direction	Location	Incident Type	Description	Additional Information	Start	End	Duration
03/11/09	S/B	After J11	Accident	Right L. Blocked	1 out of 3 Affected	07:30		
05/11/09	S/B	After J12	Congestion	All Lanes Affected	-	07:22		
13/11/09	S/B	After J5	Accident	Right L. Blocked	1 out of 2 Affected	12:33	14:27	01:54
20/11/09	S/B	After J4	Accident	Right L. Blocked	1 out of 2 Affected	17:49	18:39	00:54
23/11/09	S/B	After J11	Fire	-	Nothing Affected	16:35		
23/11/09	S/B	After J10	Accident	Right L. Blocked	1 out of 3 Affected	17:11	18:47	01:36
04/12/09	N/B	After J4	Accident	Right L. Blocked	1 out of 2 Affected	18:14		
07/12/09	N/B	After J4	Breakdown	Right L. Blocked	1 out of 2 Affected	16:23		
08/12/09	N/B	After J4	Accident	Left L. Blocked	1 out of 2 Affected	18:21		
10/12/09	N/B	After J4	Accident	Right L. Blocked	1 out of 2 Affected	18:15	18:34	00:19
11/12/09	N/B	After J10	Accident	Centre L. Blocked	1 out of 3 Affected	17:58		
14/12/09	S/B	At J6	Breakdown	Left L. Blocked	1 out of 2 Affected	16:24	17:43	01:19
14/12/09	N/B	After West Link	Accident	All L. Affected	1 Lane Open	18:35		
15/12/09	N/B	After West Link	Accident	Right L. Blocked	1 out of 2 Affected	10:33		
16/12/09	S/B	After J3	Accident	Right L. Blocked	1 out of 2 Affected	08:03	08:23	00:20
18/12/09	S/B	After J4	Accident	Right L. Blocked	1 out of 2 Affected	08:21	09:17	00:56
04/01/10	S/B	After J4	Breakdown	Left L. Blocked	1 out of 2 Affected	09:58		
08/01/10	N/B	After J5	Fire	-	Nothing Affected	11:33		
22/01/10	S/B	After J3	Breakdown	Left Sh. Blocked	Nothing Affected	07:00	07:17	00:17
26/01/10	N/B	After J6	Accident	Right L. Blocked	1 out of 2 Affected	08:20		
02/02/10	S/B	After J12	Accident	Left L. Blocked	1 out of 2 Affected	10:33		
17/02/10	N/B	After J7	Breakdown	Left L. Blocked	1 out of 3 Affected	11:25		
19/02/10	S/B	After J5	Accident	Left L. Blocked	1 out of 2 Affected	16:52		
26/02/10	N/B	At West Link	Breakdown	Centre L. Blocked	1 out of 4 Affected	16:38		
08/03/10	S/B	After J7	Accident	Centre L. Blocked	1 out of 4 Affected	08:51		
08/03/10	N/B	After J4	Accident	One Lane Open	All lanes affected	14:27		
22/03/10	S/B	After J6	Accident	Left L. Blocked	1 out of 2 Affected	16:01	16:43	00:42
30/03/10	S/B	-	Accident	Right L. Blocked	1 out 0f 2 Affected	10:10		

(Source: M50 Concession Ltd)

Using the data for the five complete months available the number of incidents is estimated at approximately 6 per month or approximately 1.3 incidents per week (see Figure 8-9 below). Importantly 5 of these incidents were significant with delays of up to 2 hours experienced. It is noted that works that were underway on the M50 until Christmas. For this reason it was decided to exclude the period before Christmas and use the subsequent 3 months of data (when most on-line works were complete) for estimating the number of incidence that are likely to occur on this motorway. As a result it is estimated that the number of incidents is expected to be approximately 1 per week or approximately 48 per year over the length of the M50.

Figure 8-9 Daily Incidents on the M50 by Date – Nov. 2009 to March 2010



A longer timeframe would be required to draw any substantive conclusions in regard to locations where incidents occurred, however Figure 8-10 indicates general locations of incidents on the M50. This suggests that the vast majority of incidents occurred north of Junction 7, which is the most heavily trafficked section of this corridor. It is our understanding that some works were underway on this section at this time; however it is felt that this was not sufficient alone to explain the pattern identified.

Figure 8-10 Approximate Locations of Incidents on M50 by Month – Jan. 2010 to March 2010

8.10 Calculation of Incident Rates

Table 8-13 below summarises estimates for incident rates (which includes Injury Accidents) and PIA rates for the M50 based on the information that is available at present. It is noted that the estimated PIA rate is based on information obtained for the period before the construction works started; therefore it is likely that this is an overestimate for the current road layout. In this regard one would expect a bigger difference between the number of incidents and the number of PIA accidents (currently PIA's approximately 80% of the incident rate, compared with a normal injury accident rate of approximately 21%).

Table 8-13 Estimated Accident Rates for M50

Category	Estimated Incident Rates	Estimated PIA Rate
PIA by Class		
Fatal	**-**	**1/Yr.**
Serious	**-**	**1.33/Yr.**
Minor	**-**	**38/Yr.**
Incident/Accident Rates		
Yearly Rate	**48/Yr.**	**40.5/Yr.**
Monthly Rate	**4/Mt.**	**3.4/Mt.**
Weekly Rate	**1/Wk**	**0.8/Wk**

AECOM has attempted to generate accident rates for the various cross-sections of the M50, i.e. 4x4, 3x3 and 2x2 Lane sections. However in researching this topic we were not able to obtain sufficient information to carry out this assessment. Some publications indicate that there is insufficient information available to distinguish between the various cross-sections, particularly between 3x3 and 4x4 sections. It is also noted that the COBA 11 Accident rates for Motorways does not distinguish between 2x2 and 3x3 cross-sections, giving the same rate for each.

In effect, this suggests that as traffic volumes increase on the M50 due to the increased capacity available following the upgrade, accidents will increase in line with the increase in vehicle km that will result. Such will further highlight the need for effective flow management.

8.11 Impact of Introducing Variable Speed Limits

The review of VSL has indicated that VSL can reduce Injury accidents by between 15 and 40%. Of particular note is that the 4x4 lane sections of the M42 say their accident rate reduced by more than 60%, which is assumed, is a result of the reduced weaving taking place at interchanges. It is most likely that much of this additional reduction resulted from the use of the hard shoulder rather than the VSL alone.

As we have already noted the M50 operates with a similar accident rate to UK Motorways therefore it seems reasonable to suggest that the impact of VSL will be similar. As there is no definitive figure for the impact of introducing VSL it is suggested that calculations are made on an upper and lower figure of 40% and 15% respectively.

Table 8-14 Estimates PIA Rate for the M50 with and without VSL

Category	Personal Injury Accident Rate		
	No VSL	**VSL (-15%)**	**VSL (-40%)**
PIA by Class			
Fatal	**1/Yr.**	**0.85/Yr.**	**0.6/Yr.**
Serious	**1.33/Yr.**	**1.1/Yr.**	**0.8/Yr.**
Minor	**38/Yr**	**32/Yr**	**23/Yr**
Accident Rates			
Yearly Rate	**40.5/Yr.**	**34.4/Yr.**	**24.3/Yr.**
Monthly Rate	**3.4/Mt.**	**2.9/Mt.**	**2.0/Yr.**
Weekly Rate	**0.8/Wk.**	**0.7/Wk.**	**0.5/Wk.**

Note that the above data excludes damage-only incidents, which include breakdowns, engine fires etc. VSL is unlikely to impact on those occurrences, but can manage the response of other road users to the resulting disruption that they cause.

In order to take into account the fact that a significant proportion of incidents are not accident related and a result of break downs etc, we have split the incidents into "Non Accident" and "Accident" related in the following table and only applied the reduction as a result of VSL to those involving accidents. Table 8-15 indicates the results of this assessment.

Table 8-15 Estimated Rates of Incidents on the M50 with and without VSL

Category	Incident Rate						
	No VSL	**VSL (-15%)**			**VSL (-40%)**		
		Non Accident	**Accident**	**Total**	**Non Accident**	**Accident**	**Total**
Yearly Rate (/Yr.)	**48**	19	25	**44**	19	17	**36**
Monthly Rate (/Mt.)	**4**	1.6	2.0	**3.6**	1.6	1.4	**3.0**
Weekly Rate (/Wk.)	**1**	0.4	0.5	**0.9**	0.4	0.4	**0.8**

8.12 Impact of Delays due to Incidents

This section sets out the modelling procedure developed to assess the impact of single or multiple lane closures on motorway capacity. This impact has been measured in terms of increased delay (hours) experienced on the network. The 4.6km (approx.) four-lane southbound section of the M50 between the N4 and N7 junctions was chosen as the study area for this model.

A 2010 Base Scenario VISSIM Microsimulation model was developed and observed flows assigned to the network. In order to simulate the effects of an incident on the mainline, a series of temporary blockages were located within the network. Lanes were blocked within the simulation at an assigned time and for a given duration. All other vehicles are required to use the remaining available lanes diverting around the blockage. The simulation examined 1, 2 and 4 lane closures for periods of 15, 30, 45 and 60 minutes.

The model was run for a four hour period; the study hour and following three hours. Total delay on the network was recorded for each scenario inclusive of delay experienced by vehicles waiting to enter the network. In addition to the 2010 base year flows an uplift of 20% was applied to these volumes to reflect the impacts of future traffic growth on the network. Table 8-16 summarises the impact of incidents on network performance during the AM peak period.

Table 8-16 Total Network Delay (Hours)

1 Lane Closure					
	Base	**15 Min.**	**30 Min.**	**45 Min.**	**60 Min.**
2010 Flows	34.5	36.0	37.3	38.8	40.1
2010 + 20% Uplift	63.4	66.5	69.8	72.7	75.4
2 Lane Closure					
2010 Flows	34.5	57.9	119.7	244.7	378.8
2010 + 20% Uplift	63.4	210.0	709.4	1,370.4	2,246.5
4 Lane Closure					
2010 Flows	34.5	589.0	2,377.0	5,182.4	8,844.6
2010 + 20% Uplift	63.4	1,615.8	4,859.7	7,284.6	14,089.5

The delay reductions as a result of introducing VSL on the M50 has then been calculated using the following assumptions:

- Fatal or Serious Accidents make up 6% of all accidents each year and result in delays of 60 minutes or more (on average) and will result in a 4 lane closure;
- All other accidents result in delays of approximately 30 minutes and will result in a 2 lane closure;
- Annual number of incidents includes accidents and breakdowns (40% of total). It has been assumed that breakdowns will last on average 15 minutes and result in 1 lane closure; and
- A growth rate has not been applied to accident rates, however a growth rate has been applied to the number of incidents as these will increase in proportion to traffic (i.e. +20%).

Table 8-17 Estimated Incident Rate and potential impact of introducing VSL on the M50

Delays	Base	-15%	-40%	Lane Impact
60 minutes	2.4	2.1	1.5	4 Closed
30 Minutes	27.5	25.3	21.6	2 Closed
15 Minutes	20	18.2	15.4	1 Closed
Annual Incidents	49.9	45.6	38.4	-

Table 8-18 indicates an estimate of the total annual delay as a result of delays on the M50. This table also indicates the impact of VSL, using the 15% and 40% reduction in accidents as described in this report. From this it is estimated that the introduction of VSL will reduce delays by between 9,961 and 26,561 hours per annum on the basis of 2010 traffic flows. This excludes the economic saving associated with the reduction in accidents.

Table 8-18 Estimated Annual Delay With and Without VSL

			Base		-15%		-40%	
Length of Closure	Traffic Flow Scenario	Delay per incident (Hrs)	Incidents (No./ Annum)	Estimated Annual Delay	Incidents (No./ Annum)	Estimated Annual Delay	Incidents (No./ Annum)	Estimated Annual Delay
60-min.	2010	8,810.1	2.43	21,408.5	2.07	18,197.3	1.46	12,845.1
	2010+20%	14,026.1	2.43	34,083.4	2.07	28,970.9	1.46	20,450.1
30 Min.	2010	85.2	27.52	2,344.3	25.29	2,154.6	21.58	1,838.2
	2010+20%	646.0	27.52	17,775.1	25.29	16,336.1	21.58	13,937.9
15 Min.	2010	1.5	19.96	30.0	18.24	27.4	15.36	23.0
	2010+20%	3.1	19.96	61.9	18.24	56.53	15.36	47.6
Total Annual Delay (Hrs/annum)				75,703.2		65,742.7		49,141.9
Difference from Base (Hrs/annum)				**-**		**9,960.5**		**26,561.3**

It is noted that fatal and serious accidents are likely to result in significant road closures of over 1-hour duration, however for this report it was felt that the impact of delays beyond 60 minutes is very difficult to predict as vehicles will divert to alternative routes around or through the City and thus the queues will not continue to build-up over the closure period. However this redistribution of traffic off the M50 is likely to result in significant increased congestion on other corridors which also has not been included in this assessment. For this reason it is likely that the above assessment is an underestimate of the impacts of introducing VSL on the M50.

Chapter 9 Hard Shoulder Running

9.1 Introduction

This chapter of the report assesses the feasibility of implementing Hard Shoulder Running on motorways in Ireland and examines the M50 motorway in Dublin as a specific case study. In particular, the study examines the comparative case for adopting Hard Shoulder Running with the use of the existing median to provide an additional lane.

Hard Shoulder Running involves the adaption of the hard shoulder for use as a traffic lane. Implementation of Hard Shoulder Running affords road authorities the opportunity to increase road capacity for significantly less capital expenditure than the more usual practice of widening to provide additional lanes. This study has examined the potential implementation of Hard Shoulder Running on the M50, which may provide an opportunity for the National Roads Authority to increase capacity on sections of this route, and realise significant savings over widening to provide additional lanes.

Hard Shoulder Running schemes can be either temporary to cater for increased traffic flows during peak periods or can be permanently operational. The operation of the schemes is managed by driver information displays mounted on overhead gantries, which display lane closures, varying speed limits, etc. A number of other measures must be put in place to allow for the operation of Hard Shoulder Running including the provision of Emergency Refuge Areas (ERAs) to cater for breakdowns and other emergencies.

There are currently no Hard Shoulder Running Schemes in operation in Ireland, although there are a number of dual carriageways that operate without the provision of a hard shoulder (mainly in urban/suburban areas). In order to inform the current study, a review of international practice was undertaken to investigate the use of Hard Shoulder Running on motorways across Europe. The standards for the implementation of Hard Shoulder Running were reviewed for the following countries:

- The UK;
- France;
- The Netherlands;
- Germany;
- Switzerland; and
- Italy.

Various configurations of Hard Shoulder Running schemes have been assessed and a cost estimate was developed to compare the cost of implementing Hard Shoulder Running to motorway widening.

9.2 Lane Widths

The most important consideration for the assessment of the viability of implementing Hard Shoulder Running is the width of the existing carriageway and associated lane widths, and the required minimum widths for trafficable lanes. The NRA DMRB requires minimum lane widths of 3.5m on motorways and minimum hard shoulder widths of 2.5m on Type A motorways, reducing to 2m in difficult situations. Earlier practice in Ireland was to provide a 3m wide hard shoulder, and these are present on motorways schemes designed prior to the adoption of the NRA DMRB in 2000. Various international standards have been reviewed to determine practice in other countries.

UK

The Highways Agency *'Managed Motorways implementation guidance - Hard Shoulder Running' (Interim Advice Note 111/09)*[23] document states that a minimum hard shoulder lane width of between 3.4m and 3.6m should be provided. This width is also dependent on the outer hard strip detail which should be a min. of 0.1m subject to drainage arrangements.

The only case in the UK where Hard Shoulder Running is currently in operation is in Birmingham on the M42 between Junctions 3A and 7, which was the UK Pilot scheme for Hard Shoulder Running. Lane widths here vary between 3.2m and 3.7m for all traffic lanes including the hard shoulder. According to the Highways Agency a departure is required for Hard Shoulder Running lanes which are less than 3.4m wide. The typical carriageway cross section for Hard Shoulder Running outlined in the Highway Agency Guidelines is shown in Table 9-1 below.

Table 9-1 Typical carriageway cross section for Hard Shoulder Running in UK

Dimension	Lane Type					
	Hardstrip	Hard Shoulder	Lane 1	Lane 2	Lane 3	Hardstrip
Lane Width (m)	0.6min	3.4	3.5	3.5	3.2	0.9

France

A project was undertaken in Paris to assess the feasibility of introducing Hard Shoulder Running on a permanent basis to ease congestion. The project is outlined in the document *'Gestion dynamique des voies: 2 projets francais pour réduire la congestion*[24] prepared by SETRA the Ministry of Transport France in 2007 for the '*Congrès de la route' in PARIS*. The Hard Shoulder Running scheme was implemented on the A4-A86 motorway which was originally a four lane carriageway in each direction.

The hard shoulder is utilised during peak periods to provide a fifth running lane, with access controlled using dynamic barriers to open/close the lane. The width of the lanes was reduced from the standard 3.5m to 3.0m or 3.2m. As a result of narrowing the lanes, the motorway has a reduced permanent speed limit of 90km/hr (hard shoulder open or closed). The lane widths of the Hard Shoulder Running Scheme are outlined in Table 9-2 below.

Table 9-2 Typical carriageway cross section for Hard Shoulder Running on A4-A86 Paris

Dimension	Lane Type						
	Hardstrip	Hard Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Hardstrip
Lane Width (m)	0.3	3.0	3.2	3.2	3.0	3.0	0.27

The Netherlands

The Netherlands currently has the largest number of Hard Shoulder Running Schemes in operation (17). These Hard Shoulder Running schemes are either permanent or temporary (during peak periods). A number of documents were reviewed regarding Hard Shoulder Running in the Netherlands. The document *'Ontwerp en Inrich Spitsstroken, Plusstroken en Bufferstroken', Advies voor de spoedwetprojecten*[25] was published by the Dutch Ministry of Transport in 2005.

This document outlines standards for emergency widening projects including Hard Shoulder Running to help reduce congestion.

The lane widths proposed for a 120 / 100 km/hr Hard Shoulder Running scheme are outlined in Table 9-3 below. The berm is a strip of land that helps to provide visual clearance; it also facilitates roadside equipment such as safety barriers and traffic signs depending on the width available. The speed limit is reduced from 120km/hr to 100km/hr or 90km/hr when Hard Shoulder Running is in operation.

Table 9-3 Typical carriageway cross section for Hard Shoulder Running in The Netherlands

Dimension	**Lane Type**							
	Berm	Hardstrip	Hard Shoulder	Lane 1	Lane 2	Lane 3	Hardstrip	Berm
Lane Width (m)	0.65	0.45	3.35	3.4	3.4	3.15	0.55	0.6

Germany
The cross-sections manual for motorways in Germany, *'RAS'*[26], was published in 1996. According to this standard, lane widths on motorways are to be 3.75m in width with a hard shoulder of 2.5m. Hard Shoulder Running lane widths are to be a minimum of 3.5m. There are currently six Hard Shoulder Running schemes in operation throughout Germany. Table 9-4 below shows a typical allocation of widths for a Hard Shoulder Running Scheme in Bavaria at Hessen. Another example of Hard Shoulder Running in Germany is A3 Offenbach – Obertshausen to A5 Bad Homburg – Frankfurt where three 3.75m lanes + 2.5m hard shoulder were converted to four 3.5m lanes. The speed limit is reduced from 120km/hr to 100km/hr when these Hard Shoulder Running schemes are in operation.

Table 9-4 Typical carriageway cross section for Hard Shoulder Running in Germany

Dimension	**Lane Type**					
	Hardstrip	Hard Shoulder	Lane 1	Lane 2	Lane 3	Hardstrip
Lane Width (m)	0.25	3.75	3.75	3.5	3.5	0.5

Switzerland
The report *'Conversion de la bande d'arret d'urgence en voie de circulation - ASTRA 15 002'*[27] was published by the Swiss Federal Roads Office (FEDRO/OFROU/ASTRA) in 2007 to detail the requirements when converting hard shoulders for use as running lanes. Table 9-5 below shows a typical cross section for Hard Shoulder Running in Switzerland. As a result of lane widths being narrowed to allow for Hard Shoulder Running, the speed limit on a 100km/hr road is permanently reduced to 80km/hr. This is further reduced when Hard Shoulder Running is in operation.

Table 9-5 Typical carriageway cross section for Hard Shoulder Running in Switzerland

Dimension	Lane Type					
	Hardstrip	Hard Shoulder	Lane 1	Lane 2	Lane 3	Hardstrip
Lane Width (m)	0.5	3.3	3.25	3.1	3.1	1.0

Italy
Hard Shoulder Running has not been implemented in Italy to date. However, the typical lane widths on motorways are tabulated below for reference:

Table 9-6 Typical motorway carriageway cross section in Italy

Dimension	Lane Type					
	Hardstrip	Hard Shoulder	Lane 1	Lane 2	Lane 3	Hardstrip
Lane Width (m)	-	1.75	3.75	3.75	3.75	0.5

Having reviewed international practice, it appears that there is scope for reducing lane widths below the 3.5m minimum currently used in Ireland, particularly in the overtaking lane. During recent roadworks on the M50, lane widths were regularly reduced to 3.25m, albeit with a temporary speed restriction of 60km/hr. Conformance with this temporary speed limit was low, with travel speeds of the order of 80km/hr through the works being more typical. Higher travel speeds were regularly observed in the overtaking lane. This may, in fact, have been a contributory factor to the higher accident rates through those work areas as noted in chapter 8.

It is recommended that the 3.5m standard be adopted as a desirable minimum for schemes in Ireland where the cross section is adapted to permit Hard Shoulder Running, with reductions below this width considered on a case by case basis in constrained conditions and accompanied by some significant reductions in speed limits.

It is noted that the left hand lanes should be wider where practicable to accommodate larger vehicles. However, in tightly constrained environments, it may be more prudent to distribute the available road space evenly. Minimum hard strips of 0.5m should be provided on both sides of the carriageway, as are currently used on Types 2 and 3 Dual Carriageways in Ireland.

Hard Shoulder Running should only be permitted where it is clearly demonstrable that adequate standards of forward visibility can be achieved in all lanes on the reconfigured cross section. Depending on the speed limit proposed on the section of motorway, lower forward visibility standards than those currently provided may be acceptable.

9.3 Emergency Refuge Areas

In the absence of hard shoulders, alternative provision is desirable to provide safe refuge for emergency situations, such as breakdowns, so as to reduce the risk of lane blockage giving rise to severe congestion. It is insufficient to rely on VMS to advise approaching drivers of incidents ahead, as there is typically a delay between the incident and the VMS warnings appearing, at which stage the breakdown will have already caused severe congestion due to forced weaving at slow speeds at the incident location. The most practical means of making provision for such emergencies is to construct pull in areas at regular intervals along motorways where Hard Shoulder Running is in operation. There are various issues associated with such facilities, not least the risk that they would be used as rest areas. A review of international practice has indicated the following:

The UK

The Highway Agency 'Managed Motorways implementation guidance – *Hard Shoulder Running (Interim Advice Note 111/09)*[16] states that inter-junction emergency refuge areas need to have a desired spacing of 800m, a maximum spacing of 1,000m and a minimum spacing of 600m. The average frequency must be not greater than 800m. They are to be co-located with gantries and located downstream of the gantry. If it is impractical to locate the ERA downstream of the gantry, it may be located upstream of the gantry. An Emergency Refuge Area must not be located less than 800m upstream of the Exit Datum Point at a junction and always upstream of the 800m gantry sign to prevent it from being confused with an off-slip. ERAs are not to be provided within a junction, as an increased number of conflicts would arise between mainline traffic, traffic exiting the ERA, and merging traffic from the on-ramp. In addition, the need for ERA's at junctions is diminished, as the junction itself provides an opportunity to exit the motorway.

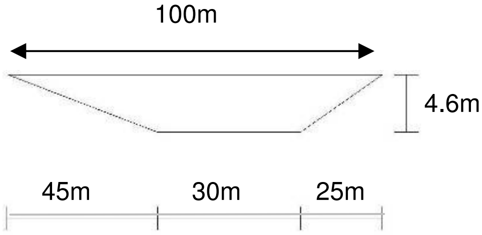


Figure 9-1: ERA's in UK

Emergency Refuge Areas should be 4.6m in width. This may be reduced to a minimum of 4m if the cost of construction is prohibitively expensive. The Highways Agency Project Manager for the Birmingham Box Active Management Scheme (M42, M6, M40, M5), Managed Motorway Hard Shoulder Running advised that emergency refuge areas should be between 80m – 100m in length which includes sufficient entry and exit tapers. The recommended dimensions of an ERA are shown on Figure 9-1.

France

Emergency Refuge Areas were not included as part of the Hard Shoulder Running Scheme in Paris. Instead, a lane closure is enacted if a vehicle breaks down on the carriageway. ERAs are however used on motorways in France where hard shoulders are not present. These are designed in accordance with *'National Instruction on technical design requirements for rural motorways'*[28] published by the French Roads and Motorways Engineering Department. The recommended dimensions of an ERA are shown on Figure 9-2. ERAs are provided along the motorways at 1km intervals.

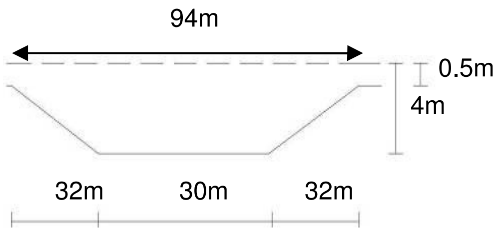


Figure 9-2: ERA's in France

Germany

Germany does not include Emergency Refuge Areas as part of Hard Shoulder Running Schemes. It is unclear why the provision is not required, however it is noted that the lane widths adopted are significantly wider than in other jurisdictions, affording other traffic more scope to pass broken down vehicles.

The Netherlands

The Dutch Ministry of Transport published the document *'Ontwerp en Inrich Spitsstroken, Plusstroken en Bufferstroken'* in 2005 to provide standards for the implementation of Hard Shoulder Running Schemes. The recommended dimensions of an ERA are shown on Figure

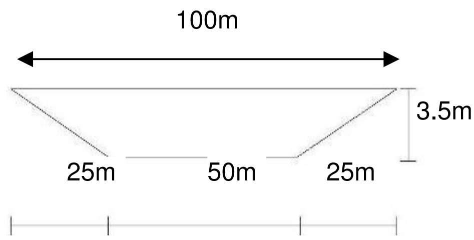


Figure 9-3: ERA's in Netherlands

9-3. ERAs are provided along the motorways at 1km intervals.

Switzerland

The standard design for emergency refuge areas are outlined in *'Conversion de la bande d'arret d'urgence en voie de circulation - ASTRA 15 002'*, published by the Swiss Federal Roads Office (FEDRO/OFROU/ASTRA) in 2007 to detail the requirements when converting hard shoulders for use as running lanes. The recommended design of an ERA is shown on Figure 9-4. ERAs should be no more than 1km apart. They should be 500-800m apart when there are long ramps, high volumes of traffic/HGVs, poor visibility or special operating requirements.

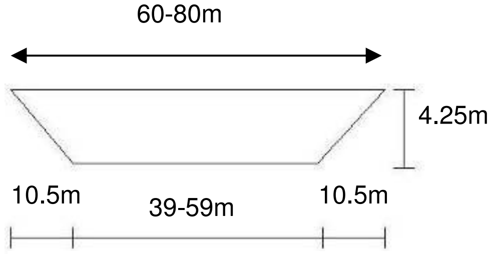


Figure 9-4: ERA's in Switzerland

Italy

A number of Italian suburban motorways use a hard shoulder of 1.75m. This is not sufficient in the case of a vehicle making an emergency stop. As a result, ERAs are provided along the motorway at 1km intervals. The ERAs are designed in accordance with *'Norme funzionalie geometriche per la costruzione delle strade'*[29], an Italian Ministry of Infrastructure and Transport document which outlines the geometric standards for road construction in Italy.

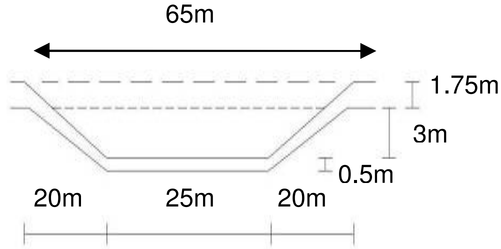


Figure 9-5: ERA's in Italy

Proposals for Emergency Refuge Areas in Ireland

Hard standing areas for maintenance are currently being provided at all new gantry locations as part of the M50 Upgrade Scheme. These are 2.5m x 8m in dimension. It is possible that some of these may be further developed to serve as an emergence refuge area. The Stopping Sight Distance for the ERA should be provided in accordance with DMRB standards for the associated Hard Shoulder Running speed limit. There is a concern that if ERAs are too large, they will be used for non-emergency purposes (parking lay-bys). An exercise was therefore carried out to investigate the requirements for an ERA from first principles using $v^2 = u^2 + 2as$, where:

v= final velocity (m/s)
u= initial velocity (m/s)
a= acceleration (m/s^2)
s= distance (m)

Length of Entry Taper:

It is assumed that a vehicle will have reduced its speed from 100kph to at least 50kph on the approach to an Emergency Refuge Area. The DMRB design standards assume an average deceleration rate of 2.45m/s^2 to account for wet conditions. However, during the recent preparation of the '*UK Manual for Streets*'[30], a detailed assessment, including first principles modelling and a study of international practice identified that this is excessively conservative and that a rate of deceleration of 4.41m/s2 is more realistic, and that this can be achieved even in wet weather conditions. This value has therefore been adopted in the analysis below. Taking these assumptions into consideration the length of entry taper required for an ERA is as follows:

v = 0kph (0m/s)
u = 50kph (13.89m/s)
a = -4.41m/s^2
s = Required length of Entry Taper in metres

$0^2 = 13.89^2 + 2*-4.41*s$
$s = 22m$

Based on the above, an entry taper length of 25m is considered appropriate.

Length of Exit Taper:
It is reasonable to assume that a driver will not attempt to rejoin the main traffic flow until a suitable gap appears. Given that ERAs are provided for use in an emergency situation only, it is also reasonable to assume that provision of a full length auxiliary lane for acceleration would be excessive. For the purposes of this assessment, provision is made for a vehicle to reach 50kph before joining the mainline traffic. The vehicle may then accelerate to full running speed (assumed to be 100kph) in the nearside / Hard Shoulder Running lane. The desk study has indicated that the approximate rate of acceleration for a standard vehicle is 2.315m/s^2, based on most vehicles managing 0-100kph in 12seconds.

A similar exercise was undertaken to calculate the required length of an exit taper, which suggests 42m is a required length to allow vehicles reach 50km/hr. An exit taper of 45m is therefore proposed.

Conclusion
From the above calculations it is recommended that the dimensions of an ERA should be as shown on Figure 9-6. A rest area of 30m in length will cater for all regular size vehicles on the network, as well as an emergency rescue vehicle. A width of 4.6m is considered appropriate and is in line with international practice. This would be located outside the 0.5m rubbing strip provided within the cross section, which would form an additional buffer.

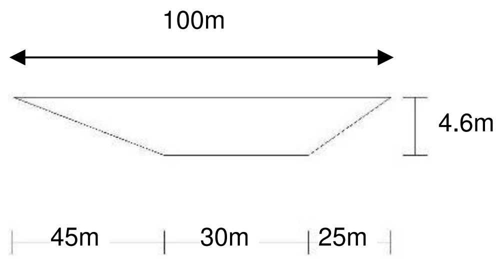


Figure 9-6: ERA's in Ireland

The proposed provision is identical to that used in the UK, and is similar to practice in other European countries.

9.4 Variable Message Signage (VMS) Gantries

Variable Message Signage (VMS) gantries are used to display messages to drivers advising them how to progress on the roadway ahead. Such signage can display, for example, symbols indicating lane closures and speed limit advice. In the absence of a hard shoulder, it is necessary to have the facility to close lane for emergency circumstances, and other exceptional circumstances and the gantries provide a means of effecting such closures. Gantries are likely to be required in any event for Advanced Directional Signage, and can therefore perform a dual function, like those currently being constructed on Dublin's M50 motorway, as part of the Upgrade scheme.

The UK
The Highway Agency recommends that gantries be co-located with ERAs. The Highway Agency *Managed Motorways implementation guidance - Hard Shoulder Running (Interim Advice Note 111/09)*[16] states that inter-junction gantries need to have a desired spacing of 800m, a maximum spacing of 1000m and a minimum spacing of 600m. A Departure from Standard Submission is required for signal gantry positions not in accordance with this spacing. A number of officials in the Highway Agency stated that intervisibility is the key factor when deciding distances between

gantries. As a result, it is not recommended that a specific distance be strictly adhered to.

France
The spacing for VMS signage gantries on the A4-A86 Hard Shoulder Running project was 500m-700m. An aspect of Hard Shoulder Running in France that is not used elsewhere is the use of moveable safety barriers. These barriers form a lane reduction taper closing off the majority of the auxiliary lane when Hard Shoulder Running is not in operation. These devices are installed at several key locations (e.g. at on ramps) so that drivers can see them from any point on the route and are dissuaded from using the hard shoulder lane.

The Netherlands
The maximum spacing between VMS signage gantries in The Netherlands is approximately 700m.

Germany
VMS signage gantries are spaced every 800-1000m as part of Hard Shoulder Running schemes in Germany.

Switzerland
VMS signage gantries are required as part of Hard Shoulder Running schemes. However, The Swiss Federal Road Office document for Hard Shoulder Running, *'Conversion de la bande d'arret d'urgence en voie de circulation - ASTRA 15 002'*, does not give details of the spacing for VMS signage gantries.

Proposals in Ireland
VMS signage gantries are currently being located at a spacing as low as 500m as part of the M50 Upgrade Contract. It is suggested that an average spacing of 750m, subject to intervisibility being achieved, would be reasonable along Hard Shoulder Running schemes in Ireland, which is consistent with international practice. Typically, VMS gantries are located coincident with Advance Directional Signage requirements, and these often dictate the spacing of the gantries.

International experience suggests that variable speed limits are used to maximise throughput on managed motorways. In applying such a solution, it should be confirmed that the requisite forward visibility is achievable in all lanes of the managed motorway for the maximum speed limit proposed.

9.5 Emergency Access

Emergency vehicles typically use the hard shoulder to access the scene of an incident on a motorway. Should Hard Shoulder Running be implemented on Irish motorways, this facility will no longer be available and access to the scene of an incident will have to be provided by other means. Several options are available to cater for such situations.

The practice in the UK is for emergency service vehicles to join the motorway at the next junction downstream and to drive up the hard shoulder lane to the scene of the incident if the mainline is impassable (note that under such conditions the mainline is unlikely to be flowing and hence such a routing involves somewhat less risk). If the distance between junctions is significant, alternative access routes are generally provided. This is a requirement of TD9 of the DMRB, which requires an alternative access for every 5km gap between junctions, where the AADT exceeds 50,000 (which would be expected where Hard Shoulder Running is being considered).

Based on the foregoing, access should be available to the mainline at a maximum spacing of about 2.5km for a typical motorway around or near a city, where Hard Shoulder Running would be most attractive. If it is impractical for an emergency service vehicle to access the road from the next access point downstream, VMS could be used to advise blocked vehicles behind the incident to move to the left or right to provide a clear channel for the emergency services. This should be possible in go slow conditions, given the overall carriageway width available with a minimum of 3 lanes. Even if very narrow lane widths of 3.0m were used, this would still leave sufficient room for an emergency vehicle to pass. Such a system is employed on the M42 scheme in the UK.

The exact arrangements would have to be assessed for each particular situation and an emergency access strategy formulated on a case by case basis.

9.6 Case Study – Hard Shoulder Running on the M50

A case study was carried out to assess the feasibility of implementing Hard Shoulder Running on the M50. For the purpose of this assessment separate sections were considered in turn as outlined below.

1) M1 Turnapin Junction to Scholarstown Junction;
2) Southern Cross Route (Scholarstown – Sandyford); and
3) South Eastern Motorway (Sandyford – Shankill).

9.6.1 M1 to Scholarstown

The upgrade of the M50 between the M1 (J3) and Scholarstown Junction (J12) is now complete. Details of the carriageway following completion of the upgrade are given below.

- 3 Lanes Each Carriageway (3.5m wide);
- Auxiliary Lanes Between Junctions (3.5m wide);
- 2.5m Hard Shoulders;
- 1.0m min. offside Hard Strips; and
- Total Width Available = 17.5m.

The existing width of carriageway will be insufficient to cater for 5 x 3.5m Lanes + Hard Strips (18.5m total). As a result, widening of the carriageway would be required which is not generally feasible due to constraints, including bridges between junctions. It would be feasible to provide 5 x 3.3m Lanes + 2 x 0.5m Hard Strips as an alternative. This is only a slight reduction from the established desirable standard.

A possible Hard Shoulder Running scheme (existing and proposed carriageway dimensions) is shown below in cross section for a section of M50 between the N4 and N7 Junctions in Figures 9-7 and 9-8.

Figure 9-7 M50 N4-N7 Existing (Cross Section)

Figure 9-8 M50 N4-N7 Proposed (Cross Section)

There are difficulties in providing Hard Shoulder Running through the junctions for this section of the M50. This is particularly the case where on ramps/off ramps merge and diverge with the mainline carriageway as the carriageway width is fully utilised at these locations and there is no hard shoulder available. More detailed studies would be required to establish how best to accommodate an additional lane through these junctions. There would be a requirement to reconfigure the merging and diverging arrangements, which vary from junction to junction. A further option would be to manage the Hard Shoulder Running lanes as additional auxiliary lanes between the junctions and to carry three lanes only through, although this is likely to simply duplicate the auxiliary lanes provided as part of the widening.

9.6.2 Scholarstown to Sandyford

The upgrade of the M50 between Scholarstown (J12) and Sandyford Junction (J14) is now complete. Details of the carriageway following completion of the upgrade are given below.

- 3 Lanes Each Carriageway (3.5m wide)
- No Auxiliary Lanes
- 2.0m Hard Shoulders (Constrained Area)
- 1.0m min. offside Hard Strips
- Total Width Available = 13.5m

This section of the M50 is particularly constrained in its current configuration, with substantial retaining walls along sections of the route (such as adjacent to College Road) and the cross section of the widened motorway has the hard shoulder reduced to the minimum permissible (2.0m). The verges (2.0m each side) act as service conduits (10 no. ducts in 4 circuits each for ITS infrastructure) and also accommodate manholes and gantry bases and are therefore not suitable for carriageway widening, without further land being required.

The existing width of carriageway will be insufficient to cater for 4 x 3.5m Lanes + 2 x 0.5m Hard Strips. There would be particular difficulty in providing an additional lane between Scholarstown and Ballinteer Junction (J13). This available width is 1.5m short of the desirable requirement of 15.0m for Hard Shoulder Running. Lane widths of 3.0m and 3.25m could be required which are considerably below the desirable standard (or those widths currently provided). A possible Hard Shoulder Running scheme between the Scholarstown and Sandyford Junctions with reduced lane widths is shown on Figure 9-9 and 9-10 below.

Figure 9-9 M50 Southern Cross Motorway Existing (Cross Section)

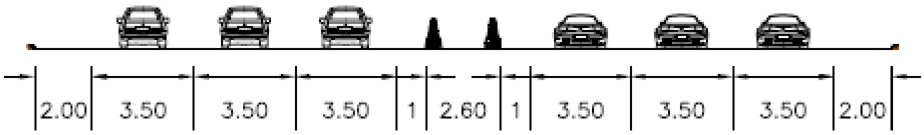
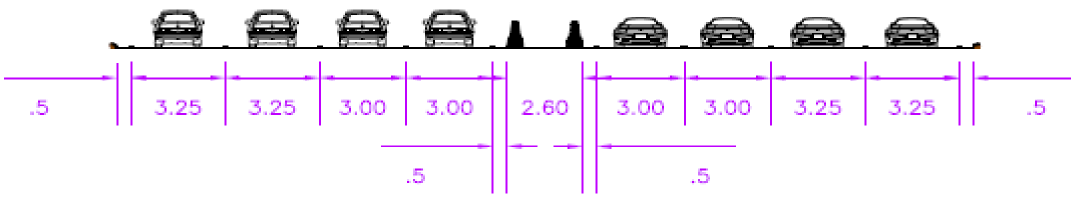


Figure 9-10 M50 Southern Cross Motorway Proposed (Cross Section)



9.6.3 Sandyford to M11

The M50 between Sandyford (J14) and Shankill Junction (J17) is not included in the current M50 Upgrade Scheme. Details of the carriageway for this section of motorway are given below.

- 2 Lanes Each Carriageway (3.75m wide)
- No Auxiliary Lanes
- 3.0m Hard Shoulders (Older Design Standard)
- 1.0m offside Hard Strips
- Total Width Available = 11.5m

The width of carriageway is sufficient for the implementation of Hard Shoulder Running without further carriageway widening being required. This is based on the fact that each carriageway will be sufficient to cater for 3 x 3.5m Lanes + 2 x 0.5m Hard Strips. The existing and Hard Shoulder Running carriageway dimensions are shown in Table 9-7 and Figures 9-11, 9-12 and 9-13 respectively.

Table 9-7 Existing and suggested Hard Shoulder Running carriageway dimensions

Dimensions for carriageway options (in metres)							
	Hardstrip	Hard Shoulder	Lane 1	Lane 2	Lane 3	Hardstrip	Total
Existing	-	3.0	3.75	3.75	-	1.0	11.5m
Suggested	0.5	3.5	3.5	3.5	-	0.5	11.5m

Figure 9-11 M50 South Eastern Motorway Existing (Cross Section)

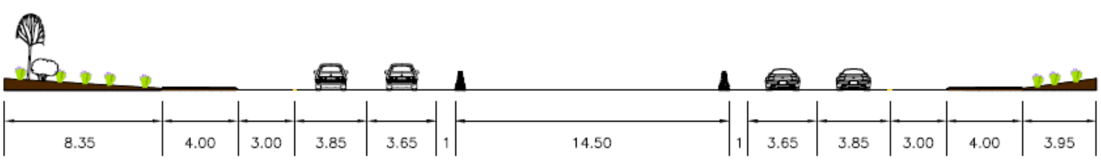
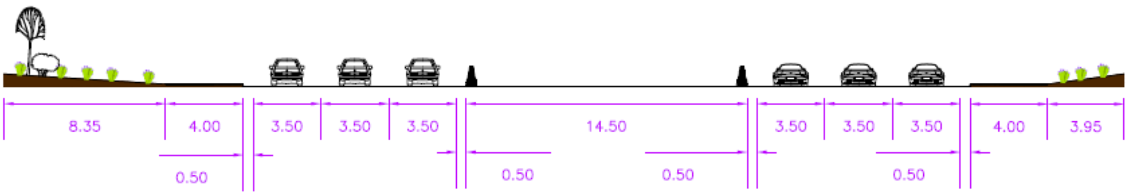


Figure 9-12 M50 South Eastern Motorway Proposed (Cross Section)



Plan layouts of possible Hard Shoulder Running layouts for this section of the M50 are shown below in figures 9-13 and 9-14.

Figure 9-13 M50 South Eastern Motorway Existing (Plan)

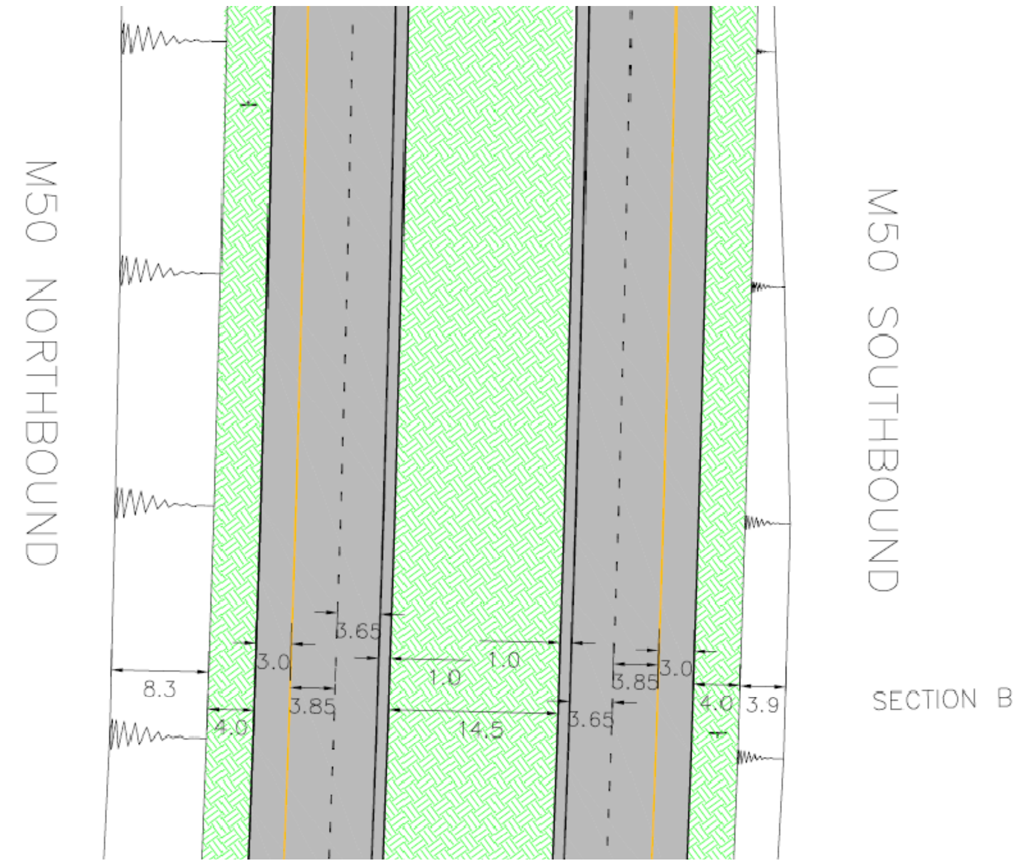
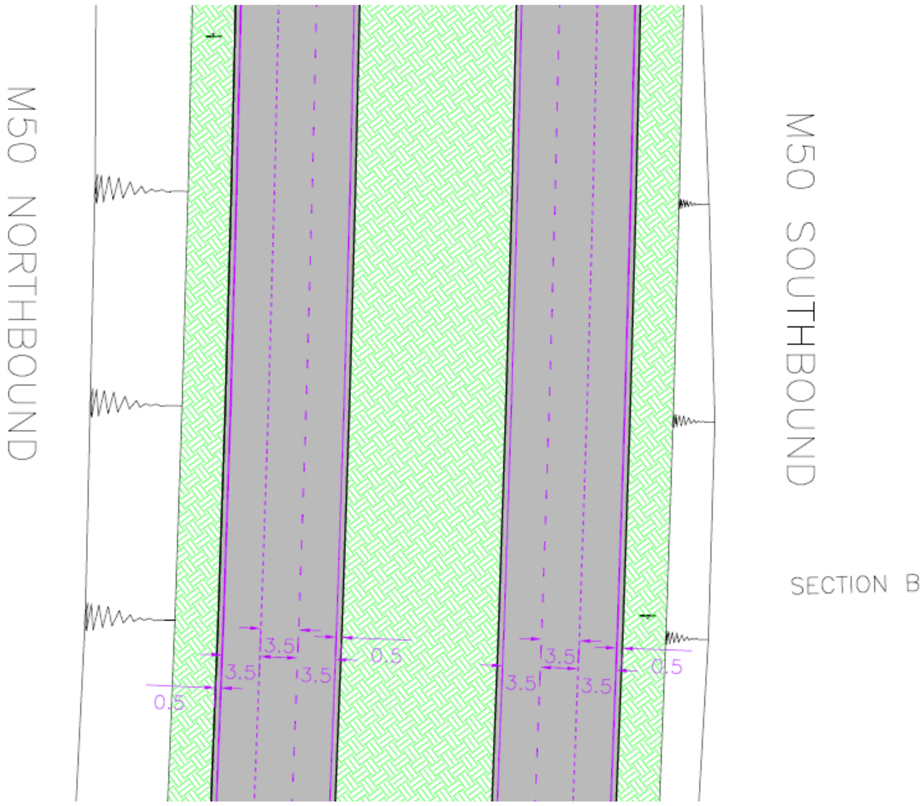


Figure 9-14 M50 South Eastern Motorway Suggested (Plan)



Hard Shoulder Running is therefore a particularly attractive option for enhancing capacity along the South Eastern Motorway section of the M50, as no carriageway widening would be required. This section of the M50 was constructed with Porous Asphalt surface course, on which it is difficult to successfully remove road markings. It is therefore likely that a new surface course might be required to accommodate the lane lines being shifted. The existing surface course would be planed and the new surface laid in its place so as to avoid impacting on road levels. This could be undertaken with temporary lane closures at night, if one lane running were acceptable, otherwise, contra-flow running arrangements would be required, with temporary crossovers provided at the ends of each work area.

The implementation of Hard Shoulder Running would not preclude the addition of a median lane in the future.

9.7 Alternative to Hard Shoulder Running on M50 – Motorway Widening

An alternative option to Hard Shoulder Running for the M50 South Eastern Motorway and other motorways with wide grassed medians would be to widen the carriageway into the median to provide an extra traffic lane. In the case of the M50 South Eastern Motorway, the carriageway would be widened by 2.5m into the median and the redistribution of lane widths would also be required. Other motorway schemes would potentially require greater intrusions into the median, if less generous carriageway cross sections are currently provided.

Civil works required would include the removal and relocation of the central reserve concrete barrier and renewed drainage facilities. Additional signage gantries would also be required to ensure driver understanding of lane destinations. Under this scenario, the existing hard shoulder would be retained and emergency refuge areas would not therefore be required. The resulting carriageway cross section for the case study scheme – the M50 South Eastern Motorway - is shown in Table 9-8 along with the existing and Hard Shoulder Running Proposal carriageway dimensions.

Table 9-8 Existing, Hard Shoulder Running and Median Widening carriageway dimensions

Dimensions for carriageway options (in metres)							
	Hardstrip	Hard Shoulder	Lane 1	Lane 2	Lane 3	Hardstrip	**Total**
Existing	-	3.0	3.75	3.75	-	1.0	**11.5m**
Suggested	0.5	3.5	3.5	3.5	-	0.5	**11.5m**
Median Widening	-	2.5	3.5	3.5	3.5	1.0	**14.0m**

9.8 Scheme Costs

A significant drawback associated with Hard Shoulder Running is that it entails operating costs that do not arise in the case of simple motorway widening, certainly not to the same extent. Limited data is available on the out-turn cost of Hard Shoulder Running schemes, other than recent pilot projects in the UK. The costs associated with such pilot schemes can be greater than for schemes that have been informed by previous pilot studies.

The available data suggests that Hard Shoulder Running might cost approximately 2.2 times more than median widening in the case of the South Eastern Motorway if implemented as a standalone pilot project, taking account of operating costs over a 30 year period. The operating costs account for approximately 80% of the total project cost. Gantries are included in both proposals at a spacing of 750m.

The comparison assumes that the M50 will not itself in future be managed. If such a managed motorway project were implemented, much of the system infrastructure required to control the Hard Shoulder Running scheme would already be in place. The Hard Shoulder Running project could then take advantage of the pre-existing system infrastructure, which would remove a significant percentage of the cost differential.

In conclusion, it appears that Hard Shoulder Running would be an expensive proposition as a standalone scheme but could provide an attractive economical alternative to motorway widening in the context of an overall managed motorway scheme. It is concluded that where provision for traditional widening has been made, then such an approach to providing additional capacity is likely to represent the most economic approach to capacity enhancement

9.9 Conclusion

Hard Shoulder Running has been identified as most easily delivered on older sections of motorway with wider (3.0m) hard shoulders at low capital cost (provision of additional lane approx. 2.5 times as expensive). Nevertheless, operating costs of such a scheme are high. As such, it is concluded that the case for Hard Shoulder Running might be strongest in those areas where the alternative means of increasing lane capacity requires widening outside the motorway boundary with necessary acquisition of land.

Chapter 10 Traffic Control - Dedicated Lanes

10.1 Introduction

A further form of traffic control is achievable through the allocation of roadspace to particular vehicle types. Such measures can comprise the allocation of a single lane within the carriageway to dedicated vehicle classes (as in the case of bus lanes), or the restriction of the use of a road to nominated types of vehicle (bus, taxi and/or Luas). In the case of the Dublin Port Tunnel, roadspace is allocated to public transport and freight vehicles, with other vehicle classes permitted but through payment of a toll.

This section of the report examines the case for Dedicated Lanes on the National Road Network in order to support the strategy objectives. Various forms of dedicated lanes are outlined, and a series of principles are outlined which can guide the identification as to the form of dedicated lanes that can be used in specific circumstances.

10.2 Types of Dedicated Lanes

In allocating roadspace to vehicles classes, it is useful to refer back to the development of the study objectives, which define a hierarchy of road users. In that hierarchy, freight and public transport were deemed to be the highest priority users of the road network, followed by business travellers. Commuting and leisure were deemed to be of lesser strategic economic value, although this does not discount the value that is allocated to them.

The allocation of roadspace follows this rationale by developing mechanisms to distinguish between such classes of user. Whereas freight and public transport can be defined by their vehicle type, business travellers can be catered for through the provision of services for which only higher value-of-time users would be prepared to pay. In other words, roadspace can be reserved for high value-of-time users (i.e. business travellers) through the collection of a toll for such roadspace, although in practice this can be somewhat crude due to the variability in value of time across all users.

A number of options for allocating roadspace are outlined in Table 10-1.

Table 10-1 Forms of Dedicated Lanes on National Roads

	Public Transport	Freight	Car with >1 occupants	Car with 1 occupant *TOLLED*	Car (regardless of occupancy) *TOLLED*
Public Transport Lanes	✓				
Freight Lanes		✓			
Public Transport/Freight (PTF) Lanes	✓	✓			
Public Transport/Freight Toll (PTFT) Lanes	✓	✓			✓
High Occupancy Vehicle (HOV) Lanes	✓		✓		
High Occupancy Toll (HOT) Lanes	✓		✓	✓	

The table shows a gradually increasing quantum of allocation to a dedicated lane, which ultimately depends on the anticipated demand that might arise from each user category. Insufficient demand in a dedicated lane may lead to excessive reduction in capacity for residual users, generating resulting congestion and a net reduction in benefit. On the other hand, excessive demand will reduce the benefit of the lane itself, leading to 'switchback' to other lanes.

10.3 Principles for Dedicated Lanes

It is therefore appropriate that the use of Dedicated Lanes is based on a series of simple principles which will allow such a measure to generate benefits. Such principles are outlined below:

- The lane should be neither under-utilised or over-utilised. An anticipated traffic flow of between 1200 and 1600 PCU's per hour should be targeted, and a minimum speed should be achievable (in the region of 80% of the free-flow running speed);
- They should only be considered where there is periodic congestion on the mainline that leads to delays to high-value road users;
- The lane should be located on a length of road where significant weaving might not be expected. Where the Dedicated Lane is positioned adjacent to the 'fast lane', it should be provided on a stretch of road where high levels of demand by weaving into and out of the lane are not expected at locations along the length of the lane;
- That the positioning of a Dedicated Lane adjacent to the 'slow lane' should only be provided where there are long sections of road between junctions. This will avoid excessive weaving across the lane by other traffic attempting to merge/diverge at junctions;

- Where tolling is employed, there would ideally be a function to adjust the toll level such that the level of service within the lane can be maintained, and the cost of toll collection is adequately considered;
- For Dedicated Lanes which offer an incentive to High Occupancy Vehicles, that appropriate enforcement measures are considered (through network patrols) to ensure that this facility is not abused; and
- Dedicated Lanes can offer significant benefit where they are implemented within an existing Hard Shoulder – particularly where the hard shoulder is not suited to general Hard Shoulder Running due to downstream constraints.

Following the principles set out above, it is possible to generate significant benefit from Dedicated Lanes through the provision of priority to higher value users, although any increase in delay to other road users requires evaluation to ensure that these benefits are real.

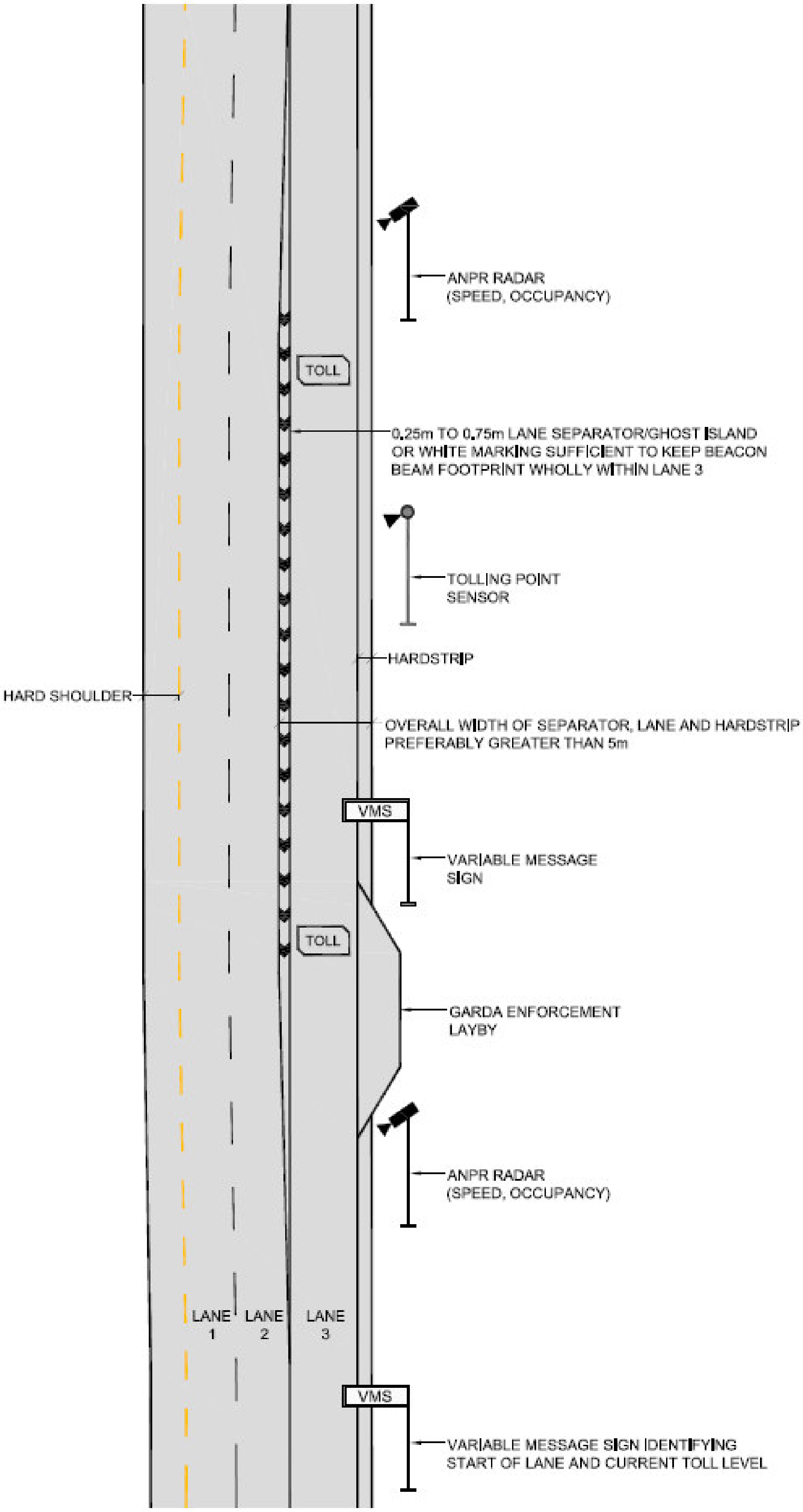
10.4 Design of Dedicated Lanes

An indicative design for an offside dedicated lane is illustrated in Figure 10-1. The figure shows an arrangement for a lane where tolling is also employed, but is typical of any offside dedicated lane where some level of enclosure is necessary.

ANPR and TAG technologies are used to enforce the function of the lane whilst also being used to automatically charge the lane users in the case of tolled facilities. VMS technology will be central to informing potential users of current toll level in an arrangement where levels may vary at different times or under different flow conditions.

Enforcement can either be via mobile network patrols, or using lay-bys. It is noted that the inclusion of lay-bys, although indicated, is not essential and in certain conditions might not be possible due to space constraints.

Figure 10-1 Sample Design of Dedicated Lane



10.5 Identification of Sites

10.5.1 Assessment of Routes

The selection of sites for Dedicated Lanes has been based on an assessment of existing traffic flows on key National Primary Routes. This assessment examines the existing traffic composition, and hence the level of traffic flow that might use a Dedicated Lane at each site. The assessment also examines the impact of a Dedicated Lane on other traffic (eg loss of a general lane). The addition of tolling is considered to increase overall use of the lane where it is considered that base demand would be insufficient.

The areas of focus for the Traffic Management Study have been highlighted in the Baseline Report, and the assessment of sites has initially focused on these areas. The results are outlined below.

Table 10-2 Site Assessment for Dedicated Lanes on National Roads

Link	Congestion Present	Total Vehs (AM)	HV Total (AM)	LV Total (AM)
M1 South of Lissenhall	Yes	3590	270	3320
M2 Ashbourne Bypass	No	1830	156	1674
M3 South of Navan	No	712	61	651
N4 East of Kilcock	No	1933	145	1788
N7 Kill	No	4015	301	3714
N11 South of Kilmacanogue	No	2745	151	2594
M50 from M1 to Ballymun	No	3029	351	2678
M50 from N2 to N3	No	4043	454	3589
M50 from N3 to N4	No	4127	490	3637
M50 from N7 to Ballymount	No	4215	226	3989
M50 from Firhouse to Ballinteer	No	3750	160	3590
Cork Ring Road west of Kinsale Rd	Yes	2735	181	2554

Examining the table, it is clear that in all cases, there is an insufficient quantum of heavy vehicle traffic to warrant the provision of a dedicated lane for buses and freight on the grounds of journey time benefits alone, where such would lead to an erosion of journey times for other users as a result of the reduction in residual lane capacity. This does not dictate against the use of freight lanes when there is a possibility of using the hard shoulder as a running lane.

10.5.2 Dedicated Lanes on the M50

On the M50, it is notable that the level of heavy vehicle traffic is at its highest; with close to 1000 PCU's in each direction (depending on the factor used for HGV's). There is therefore potential to introduce some form of dedicated lane which will cater for such users, but which might provide an additional service for some other traffic. This could be achieved either through the provision of access upon payment of a toll for light vehicles (although this would only be appropriate in the absence of a broader tolling strategy for the M50 as proposed later). South of the N7 junction, the level of heavy vehicle traffic drops substantially and the case for dedicated lanes reduces.

Note however, that traffic on the M50 is generally short-distance, and the use of dedicated lanes is only likely to be warranted for the small proportion of traffic that travel through multiple junctions. This further reduces the market for a Dedicated Lane on the M50.

Where a multi-point road pricing system for the M50 is adopted, it is not considered that any form of supplemental tolling would be achievable, and in such cases there is no case for dedicated lanes.

10.5.3 Dedicated Lanes on the Dublin Radials

Heavy vehicle flows on the radial routes are somewhat lower, although the potential for influencing public transport demand is significantly higher on these routes which are predominantly commuting corridors. Even so, heavy vehicles account for up to 300 vehicles per hour during the peak period, equivalent to up to about 600 PCU's on the N7 where such flows are highest.

It is therefore evident that the provision of dedicated lanes on these corridors will also be required to capture light vehicles. Whereas High Occupancy Vehicles could be permitted to use the lanes, the enforcement costs of such can be high. Alternatively, the lanes could be tolled with a capacity for between 1,200 and 1,500 light vehicles per hour.

The case for Dedicated Lanes on the Dublin Radials is further strengthened by the longer-distance nature of such traffic which tends to be travelling from the boundary of the metropolitan area into the M50 and beyond.

10.5.4 Dedicated Lanes in Cork

The Cork Southern Ring Road currently provides two running lanes, and the data presented above does not warrant the dedication of one such lane. Nevertheless, it is noted that the Cork Southern Ring Road currently has a hard shoulder west of the Kinsale Road Interchange, which experiences considerable congestion throughout much of the peak periods. Although flows remain low, there may be an opportunity to utilise the Hard Shoulder as a dedicated lane for Public Transport and Freight to maintain reliable journey times through the congested section for these users, with quite limited impact expected to other traffic. This would require some widening of the hard shoulder, possibly achieved through a narrowing of adjacent lanes.

This could support a broader strategy of developing the South Link Road as a public transport artery into the City Centre, with appropriate supporting measures along that corridor.

Chapter 11 Interoperability of Alternative Control Technologies

11.1 Context

In examining control strategies, it has become clear that in many of the case studies examined, multiple technologies have been employed at a single site, but without a clear understanding of the contribution of each technology to the outcomes. As part of the current consideration of options, consideration was therefore given to the impact of each individual measure to traffic management, and where alternative measures might complement or contradict each other.

11.2 Review of Alternative Measures

In this section, the detailed impacts of each of the three traffic management measures are examined in more detail. The discussion will be informed by microsimulation modelling to assist in the understanding of behavioural responses, and impacts on the traffic stream.

11.2.1 Ramp Metering

Although becoming relatively common as a traffic management measure, the implementation of Ramp Metering can take many forms, depending on the particular function that it is required to fulfil.

The role of Ramp Metering is most effective when it is used as a means to restrict traffic flows on slip roads entering high volume traffic streams, and such merging traffic is only permitted when sufficient gaps are detected in the mainline stream. Under high mainline flows and high slip road flows, Ramp Metering will provide little benefit. This reflects the findings of the literature review presented earlier.

Returning, however, to the discussion earlier of variability in traffic flows, it follows from the above findings that as the gaps between vehicles on the mainline reduce, the delays caused by Ramp Metering increase at a higher rate. It is therefore evident that the successful operation of Ramp Metering requires some variability in traffic flows, such that vehicles can be released during those periods when the traffic stream operates at a lower overall vehicle concentration, and that vehicles are held on the slip road during periods of higher vehicle concentration. The net result is an overall optimisation of network capacity, and a reduction in vehicle delay.

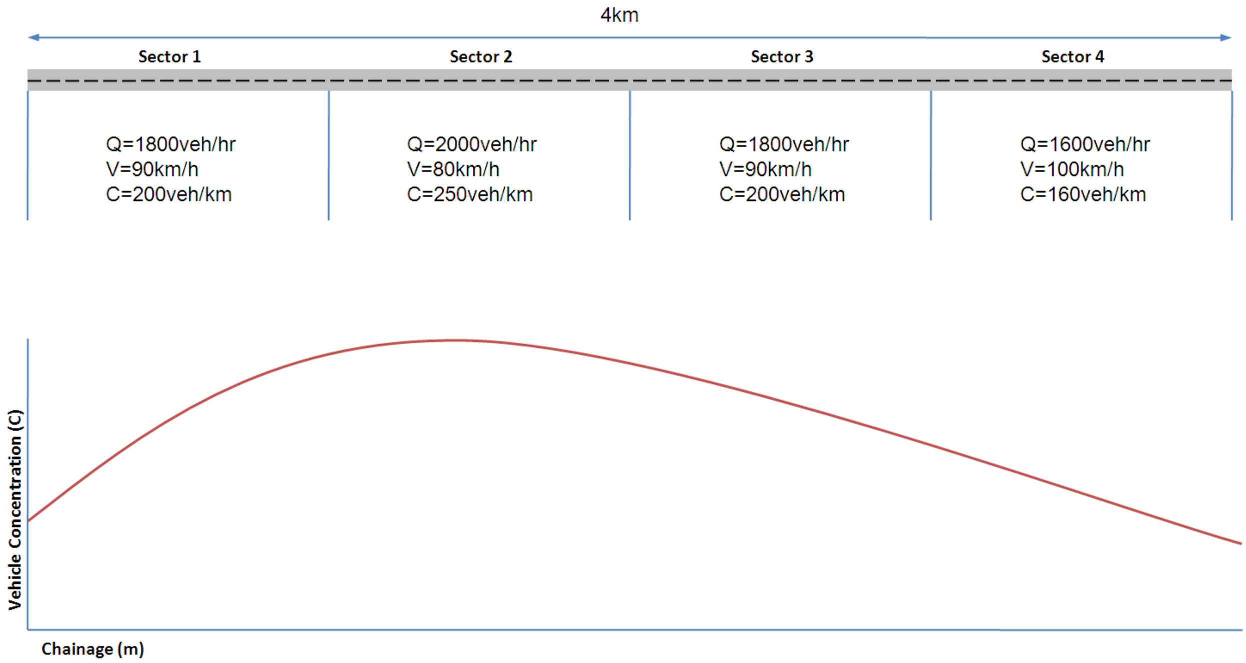
11.2.2 Variable Speed Limits

Whilst the installation of Variable Speed Limits has mostly been in response to a particular safety objective, it is noted that capacity objectives have been included in a number of installations. The discussion here will initially focus on these capacity considerations.

The operation of VSL is based on the implementation of a speed limit that is appropriate to the running conditions. As such, gradual increases in traffic flow lead to gradual reductions in speed limits, to the point where the onset of congestion is unavoidable and flow breakdown occurs. The VSL installation works by examining traffic conditions in each 'sector' of a road over a prescribed length. The conditions in a sector are ascertained through measurement of speed and vehicle concentration within that sector, and traffic entering that sector is assigned an appropriate speed limit. Whereas in practically all cases, traffic will respond to prevailing conditions and reduce speed accordingly, the VSL approach seeks to control such speed changes more uniformly through the traffic stream, thereby leading to a lower potential for sudden braking and resulting turbulence in the traffic stream.

Consider a scenario comprising a 4km length of motorway, divided into 4 1km segments for the purpose of implementing a VSL system. This is outlined in Figure 11-1 below with typical data reported for speed, flow and concentration per lane. The illustration also shows the likely concentration of vehicles on the carriageway with a peak in concentration occurring at the location of highest traffic flow.

Figure 11-1 Typical speed, flow and concentration in VSL System



With a VSL system, Sector 2 would be identified as a location which might be most susceptible to flow breakdown. In such a situation, it would be beneficial to smoothen the concentration profile to achieve a relatively uniform concentration along the full length of the road. This would lower the vehicle concentration that is currently passing through Sector 2, dissolving it into the surrounding traffic stream.

The VSL system would detect high concentration in Sector 2, thereby reducing the speed limit of traffic entering this section. At the boundary between Section 1 and Section 2, vehicles would brake as they enter the reduced speed limit, thereby reducing the speed, and increasing the concentration of traffic as vehicles begin to cluster. Such behaviour would create a 'gap' ahead of the traffic stream entering Sector 2, as those passing through the boundary ahead of the activation of the speed reduction would not brake, and would proceed into the more congested section. Meanwhile, traffic in Sector 2 would be permitted to continue into Sector 3 at a higher speed, given the less congested conditions in Sector 3.

This therefore dissipates the 'bulge' in vehicle concentration by restricting following vehicles from entering it, and permitting vehicles at the front of this bulge to accelerate into less congested conditions. The net effect would be a flattening of the profile of vehicle concentration along the length of the road.

In effect, therefore, VSL facilitates a reduction in the variation that exists within the traffic stream, leading to laminar flow at higher speeds and higher vehicle concentrations. It is evident that the reduction in flow variability leads to a reduction in the probability of flow breakdown at higher mainline flows. As such, there are clearly demonstrable theoretical benefits of VSL under such conditions, although they do require careful attention to the algorithm used within the system.

Nevertheless, as discussed earlier, the occurrence of flow breakdown at these higher mainline flows would tend to be more catastrophic. In other words, the potential of the mainline to recover from such conditions would be quite limited given the limited residual variability that might exist within the traffic stream.

11.2.3 Hard Shoulder Running

The concept of HSR is relatively simple. In essence, the provision of a Hard Shoulder as a running lane provides a step-increase in mainline capacity. Nevertheless, the provision of Hard Shoulder Running can take different forms which impact on the nature of the capacity increase. These include:

- Provision of an additional lane through the full length of the scheme, maintaining existing junction configurations; or
- Provision of an additional lane between junctions only, acting as a lane gain/lane drop through each junction.

Whereas the first option provides a uniform increase in capacity along the full scheme, the second option only delivers capacity increases between junctions. This suggests that existing capacity is maintained on the section of motorway passing through each junction, and as such the benefits of such an approach are maximised when there are large entry/exit flows at such junctions, leading to notable reduction in through-flows at these locations.

11.2.4 Conclusions

The discussion set out above therefore leads to a number of pertinent conclusions regarding the function of each of the above measures in the development of any Traffic Management Study on major roads. These can be summarised as follows:

- Slip road flows can generate significant network delay as they merge into the mainline at relatively high levels of traffic flow. This level of delay increases rapidly with increasing slip road flows;

- Ramp Metering relies on the inherent variation in vehicle concentration in traffic streams to operate effectively. Allowing traffic to merge into a stream with variable gaps will lead to less delay than the same traffic merging into a stream with consistent gaps;
- Variable Speed Limits are intended to reduce this variability in traffic flow over a length of motorway. They achieve this through modification of the speed limit in various sections to dilute any localised build-up in vehicle concentration; and
- At moderate traffic flows, breakdown can occur where there is high variability in the traffic flow, although such breakdowns are likely to dissipate quickly. Where the variability in the traffic flow is low, breakdown will occur at higher flows but is unlikely to recover until there is a broader reduction in demand flows, such as at the end of the peak period.

The discussion therefore provides some clarity on the relative role of each of the systems in managing mainline traffic flows. A synopsis of each is provided below:

Ramp Metering	Ramp Metering provides an excellent means of allocating traffic from slip roads on the motorway at appropriate times, to coincide with gaps in the mainline traffic stream. Furthermore, such a system can restrict traffic from joining the mainline carriageway where such activity would lead to flow breakdown and resulting congestion, leading to overall increases in travel time. Where the mainline geometry provides a lane-gain merge (either as default or through the provision of Hard Shoulder Running), the benefits of Ramp Metering are significantly diluted, as it is less likely that merging traffic would lead to mainline traffic flows exceeding capacity. Nevertheless, in certain instances the weaving that occurs downstream of the merge may lead to the development of shockwaves. In such instances, however, this occurrence of flow breakdown is related more to mainline flow characteristics as opposed to any specific merging activity.
Variable Speed Limits	VSL generates a condition whereby the maximum capacity of the mainline is utilised, and there is little residual capability of the system to either accept additional traffic into the mainline, or indeed recover from any flow breakdown events. In this regard, it therefore follows that any system where VSL is maintaining high levels of traffic flow cannot operate successfully should there be additional traffic demand emerging from slip roads. The only instances where such could be accommodated are where increases in traffic flow from slip roads are compensated by flow reductions immediately upstream of the merge (ie traffic exiting at the same junction), or where increases in traffic flow are matched by increases in capacity (i.e. lane gain)

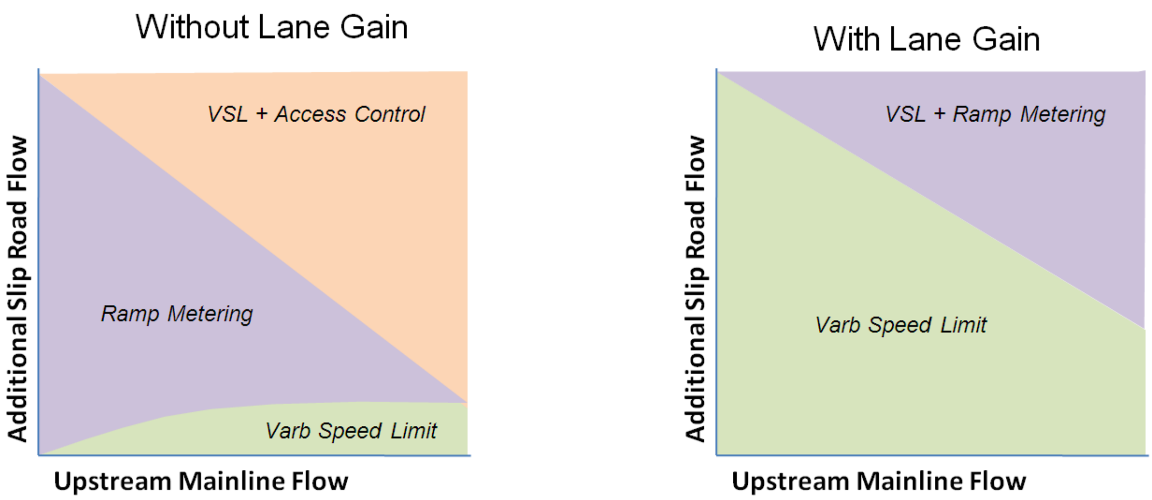
Where a system comprises a long length of carriageway where there are specific geometries or elements of user behaviour which can lead to random disruption of the traffic flow, VSL can provide a useful mechanism for restoring laminar flow by dissipating the bulge in vehicle concentration that results from the breakdown. Under such situations, there are no increases in mainline flow arising from slip roads, and this improves the ability of the system to repair itself.

It is therefore concluded that the provision of Ramp Metering and Variable Speed Limits can effectively conflict under certain conditions. In effect, VSL can create a set of conditions whereby the facilitation of further slip road traffic can generate flow breakdown. Likewise, Ramp Metering relies on variability in traffic demand which can be removed with the implementation of VSL, thereby exacerbating the potential for flow breakdown to occur.

As an additional mechanism for motorway management, the concept of Access Control can also be addressed. A variation on the Ramp Metering theme, Access Control defines a system which effectively restricts access to the motorway for specified vehicle types during periods of high traffic flow. Such a mechanism would be employed where it is envisaged that there is limited strategic value in permitting access which will lead to congestion on the mainline, and a net reduction in network performance. In reality, such a measure might operate by means of significant restriction on merging traffic flows, as opposed to complete closure of the interchange. It would be supported by advance signage to notify road users of the status of any interchange, highlighting alternative routes as appropriate.

Figure 11-2 outlines an attempt to correlate the different elements of the discussion above into a simple diagram outlining the applicability of the various technologies.

Figure 11-2 Summary of Applicability of Control Measures



In the first case (without the Lane Gain), VSL is the preferred management mechanism for roads with high mainline flows, but with quite low additional traffic flow arising from slip roads. VSL manages the traffic stream, implementing reduced speed limits where necessary to dissipate any flow disruption. Where slip road flows increase, Ramp Metering becomes more preferable due to the ability to match entry flows to gaps in the traffic stream. Under such circumstances, the VSL might be deactivated such that some variability in the traffic stream is retained. Nevertheless, the VSL could be retained as a mechanism to manage traffic in the event of downstream incidents. At very high mainline and slip road flows, the only means for avoiding flow breakdown is through the imposition of significant restrictions on the slip roads, although implementing such a measure might be impractical.

For lane-gain scenarios, VSL becomes quite a practical means for controlling the traffic stream. Slip road flows are accommodated by the additional lane capacity at each junction, and the VSL can be used to manage the weaving activity that occurs following the introduction of the additional lane. It is, of course, important to note that a lane-drop at the next junction may lead to squeezing into the residual lanes should there be an imbalance in entry/exit flows between the two junctions. In such cases, Ramp Metering could be considered at upstream junctions in addition to the VSL to manage the downstream demand.

Chapter 12 Conclusions – Control Measures

12.1 Introduction

Section B of this report has therefore provided a thorough understanding of the range, effectiveness and requirements of traffic control measures that can be considered as part of the National Traffic Management Study. Measures range from relatively high investment solutions (Hard Shoulder Running and National Control Centres) to quite low investment measures, including Ramp Metering and Driver Information Systems. In all cases, the experience in implementation of measures is strong, and perhaps with the exception of High Occupancy Vehicle Lanes, they continue to be deployed internationally on the basis of experience to date.

The evidence supporting the various case studies suggests that a number of these solutions can support the objectives of the current study, particularly those that relate to road safety, journey time reliability and environmental benefits. This chapter will examine the performance of each measure with a view to concluding on its relevance to the current study.

12.2 The Sifting Process

In order to inform the formulation of strategy options, it is necessary to sift through the potential traffic control measures to develop a list of possible solutions that should be examined as part of the Traffic Management Study. The sifting process is based on a high level understanding of the applicability of each potential measure being supported by the relevant feasibility studies where appropriate. This process considers:

- The rationale behind the measure, and whether that rationale is relevant to the current study and its objectives;
- Existing deployment of the measure in Ireland, our experience with this measure, and the impact of that measure on its environment;
- A review of the potential (claimed) benefits of the measure;
- An overview of the infrastructure that is necessary to support the measure, whether this be roadside infrastructure, or back-office systems;
- An understanding of case studies. The case studies also highlight why such a measure was adopted and, where available, the success of that measure meeting its required function;
- How applicable that measure might be in the Irish context, as informed by the Baseline Assessment;
- How the measure would support or conflict with each of the objectives outlined for the current study; and
- An understanding of risk in design, implementation and funding.

Following the sifting exercise, those options worthy of further consideration are taken forward, grouped into packages and assessed according to the priorities in each of the sub-areas identified in the baseline assessment. The overall process is illustrated in Figure 12-1 below.

Figure 12-1 Strategic Sifting Approach – Traffic Control Measures

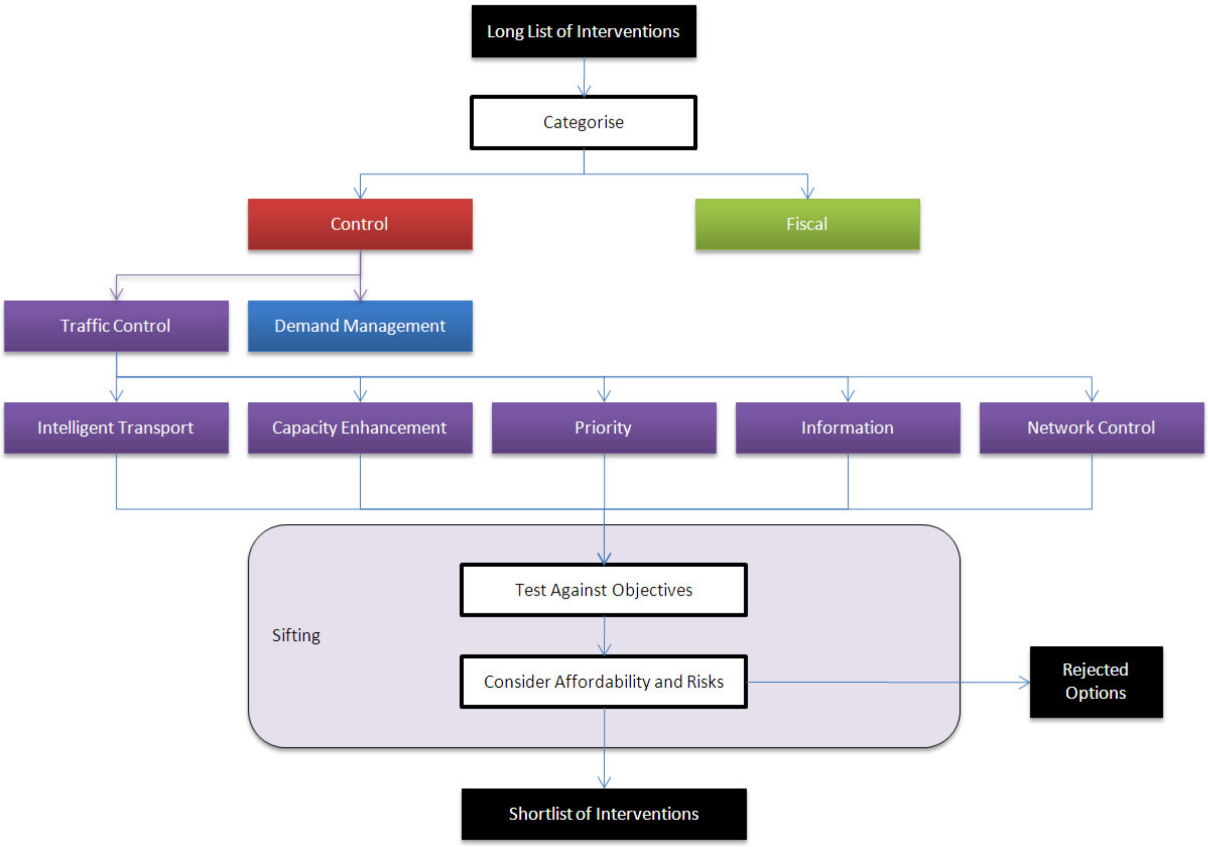


Figure 12-2 outlines the results of the sifting process which compares each measure against the objectives set out in Chapter 2 of this report. The analysis proposes that measures are either:

- Rejected, as they do little to support the objectives of the current study;
- Adopted, but subject to further study at specific sites to understand their applicability; or
- Adopted as a solution which strongly supports the study objectives.

The following findings are noted:

- The rejection of Intelligent Road Markings. Such a measure achieves little in itself as a traffic management measure, but could be used to support designs for other systems (such as Reversible Lanes) where variable road markings are required. They therefore may be retained but simply as a support to other measures;
- The conditional adoption of High Occupancy Vehicle Lanes, Public Transport Priority Lanes and Freight Lanes. This decision is made on the basis of recent experience in the USA, which points towards violation rates in the region of 30% where such lanes are not physically segregated. Studies on a number of roads in the Dublin Area suggest that the designation of lanes as either HOV, Public Transport or Freight might not allow the capacity of a lane to be fully utilised. Instead, the HOV and Freight Lane Concept might be combined, along with public transport lanes into the consideration of Public Transport Freight (PTF) Lanes. A HOV facility could be considered as an optional add-on to the PTF concept;
- The rejection of telephone as a means of disseminating traffic information. The use of

telephone represents a costly means of delivering information due to the requirement for one-on-one contact; and

- The rejection of Regional Control Centres. The National Road Network is relatively small in scale, and the geographical scope for implementing traffic control measures is more limited. It is feasible that future traffic management requirements can be incorporated into existing obligations associated with the Dublin Port Tunnel and other elements of major infrastructure. A National Control Centre is therefore seen as the most appropriate form of control.

Figure 12-2 Results of Sifting – Traffic Control Measures

Objectives	Access Control	Incident Detection	Variable Speed limits	Intelligent Road Markings	Reversible Lanes	Hard Shoulder Running	High Occupancy Vehicle Lanes	High Occupancy Toll Lanes	Public Transport Priority	Freight Lanes	Public Transport Freight Lanes (PTF)	Public Transport Freight Toll (PTFT)	Internet	Telephone	Roadside Information	In-Car Information	National Control Centres	Regional Control Centres	Network Patrols
	Intelligent Transport				Capacity		Priority						Information				Network Control		
Economy																			
Improve allocative efficiency	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					
Reduce the economic impact of delay through effective incident management		✓	✓										✓	✓	✓	✓	✓	✓	✓
Address excessive reliance on national roads as a means of supporting commuting traffic	✓								✓		✓	✓							
Maximise the capacity of congested areas through effective management solutions	✓		✓		✓	✓	✓	✓	×			✓	✓	✓			✓	✓	
Environmental																			
Encourage public transport on national roads	×		✓		✓	✓	✓	✓	✓		✓	✓	✓				✓	✓	
Contribute to reductions in CO2 emissions, air pollution and noise	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Accessibility																			
Maintain and improve opportunities for access			✓		✓	✓	✓	✓		✓	✓	✓							
Integration																			
Promote an understanding of integrated land use and transport planning policies																			
Encourage the use of public transport on national roads through supporting network integration									✓		✓	✓	✓	✓	✓				
Safety																			
Reduce knock-on safety risks that result from incidents	✓	✓	✓										✓	✓	✓	✓	✓	✓	✓
Reduce the frequency and severity of accidents on National Roads		✓	✓	✓	×	×				✓	✓	✓					✓	✓	✓
Adopt/Reject	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	×	✓

✓ Measure adopted as technically feasible and strongly supporting strategy

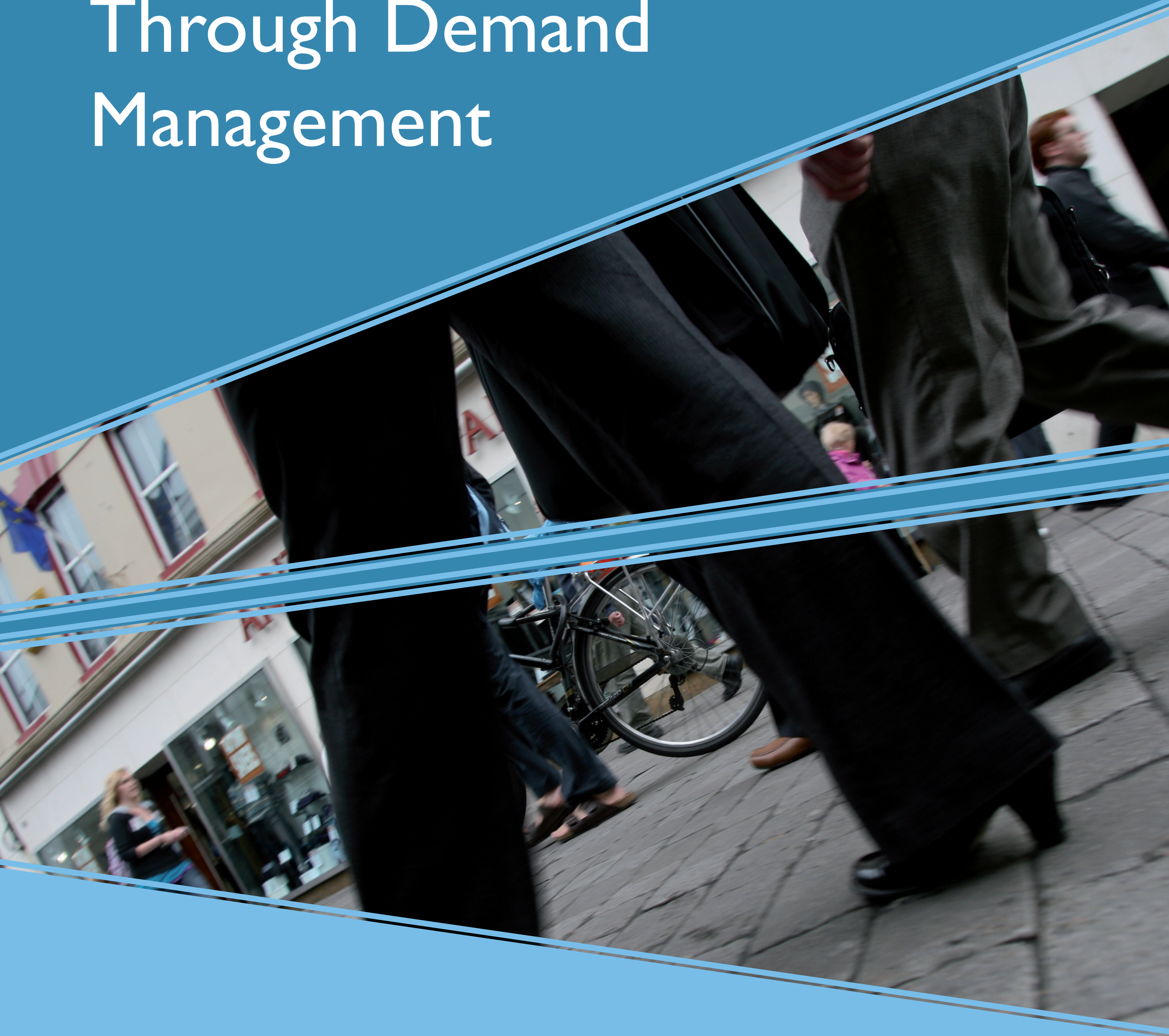
✓ Measure adopted but subject to further study of specific sites

× Measure rejected due to technical challenges or conflict with study objectives

NRA
An tÚdarás um Bóithre Náisiúnta
National Roads Authority

February 2011

Traffic Management Through Demand Management



Section C

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Section C Traffic Management through Demand Management

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Chapter 13 Overview of Demand Management Measures

13.1 Introduction

Demand Management describes those policies and strategies which seek to reduce unnecessary or inappropriate forms of transport demand. Measures achieve this by encouraging users to change travel mode, travel to destinations which have a lower impact on the transport network, reorganise their trip schedule, or decide that no trip is necessary.

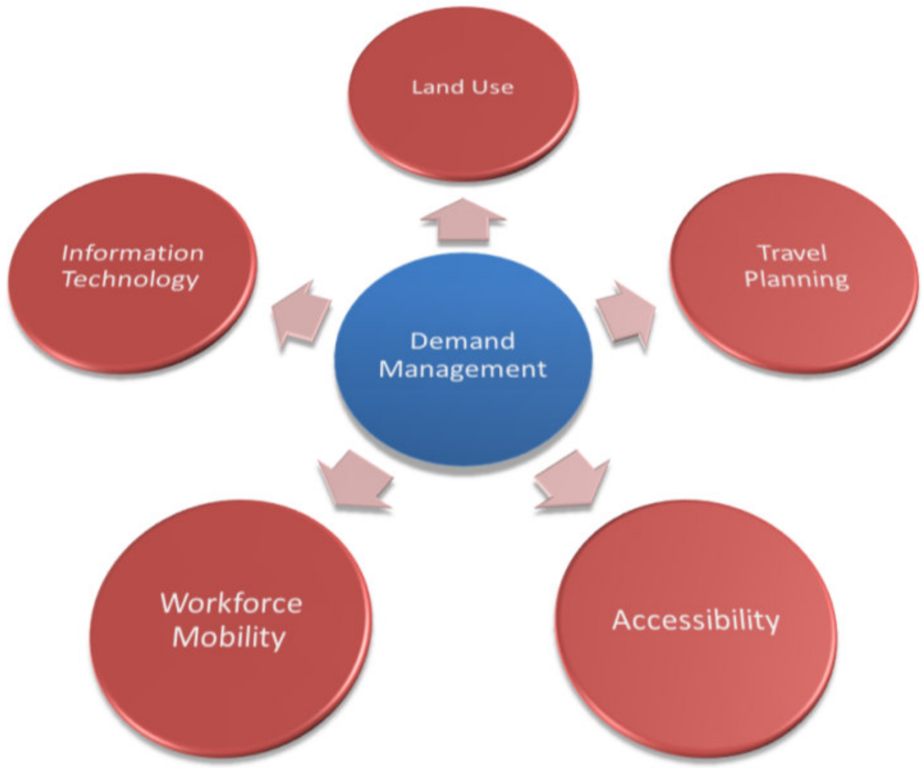
In this section of the report, we discuss the application of Demand Management measures to be considered as part of the National Roads Traffic Management Study. Note that the discussion of Demand Management measures here specifically excludes fiscal interventions, which are addressed in Section D.

13.2 Forms of Demand Management

Demand Management covers a broad range of interventions which have been employed over the past 40 years in an attempt to reduce the pressure placed on transport networks. An attempt has been made to categorise such measures as follows:

- Land Use Policies, which place specific requirements and restrictions on the location, mix, density and transport provision requirements for new development sites and areas;
- Travel Planning, which is based on a process of informing transport users of all available travel choices, and specifically markets sustainable modes to clusters of the population (e.g. major employers, residential clusters, hospitals or schools) ;
- Accessibility measures, which seek to rebalance the level of accessibility to destinations through restricting car parking availability, improving public transport, or providing improved options for walking and cycling;
- Workforce Mobility, which addresses the recent growth in the mobility of labour markets by facilitating those employees who wish to live close to their place of work; and
- Information technology, which reduces the need to travel through better communication networks and facilities.

Figure 13-1 Summary of Demand Management Measures



13.2.1 Land Use Policies

The use of Land Use Policies is perhaps the most powerful and common mechanism for influencing travel demand. At a national level, the National Spatial Strategy[3] (NSS) establishes a 20 year planning framework designed to deliver more balanced social, economic and physical development between regions. The strategy establishes a hierarchy of growth areas to guide future development which is reflected in subsequent regional and local planning documents. In support of the NSS, the Smarter Travel policy document highlights the importance of aligning transport and land use policies to reduce to need for travel. A number of commitments have been made in this regard, such as supporting the roll out of Land Use and Transport Strategies (LUTS) for identified NSS Gateways and Hubs.

At a regional and local level, the Regional Planning Guidelines, County Development Plans and Local Area Plans identify more specific development objectives. Arguably, the greatest opportunity for effective integration of transport and land use objectives lies within the development of Local Area Plans where more detailed plans for development are outlined.

In 2010, these various resources were further supported by the "Draft Planning Guidelines on Spatial Planning and National Roads"[31] developed by the DOEHLG. The guidance aims to ensure that roads and development planning and development management processes are appropriately and effectively aligned. The document provides guidelines to steer development to the most suitable locations to maximise the longevity of the national roads network, while also encouraging a shift towards more sustainable forms of travel and transport. Additional guidance is also set out in various documents published by the Dublin Transport Office (prior to its transition to the National Transport Authority in 2009) such as the Greater Dublin Area Travel Demand Management Study[32] (2004).

Each of these documents has a similar objective, namely the implementation of controls and requirements on development which will minimise long term transport impacts. Land Use Policies are best delivered through a plan-led approach to new development, which sets out development aspirations in a specific locality and which describe how transport demand will be managed in an appropriate manner. The roll out of such plans is therefore critical to ensuring the following is taken into account:

- Land use type, density and transport provision;
- Location of major land uses relative to transport infrastructure;
- Transport impact of alternative development strategies, thereby informing the development of a preferred strategy;
- Compliance with national and regional policy documents (e.g. County Development Plan, Regional Planning Guidelines and Spatial Planning Guidelines);
- Provision of local services that are necessary to minimise transport demand; and
- Transport infrastructure that is necessary to support residual transport demand.

The development of a set of 'measures' to be applied under the category of Land Use Policy is challenging, as each location will attract a different set of requirements. Instead, it is more common to set out a number of principles which should be adopted in the consideration of any land use. There may be potential to develop a checklist, or 'Transport Sustainability Audit' for new developments to ensure that key principles are incorporated into any development proposals – this will provide additional transparency of land use issues to developers and authorities, and would reflect many of the issues presented in the Spatial Planning Guidelines.

13.2.2 Travel Planning

Travel planning is a tried and tested tool to reduce dependency on car travel. These bespoke local measures are developed to influence travel behaviour and are generally more associated with behaviour and psychology than typical transport engineering approaches

Travel plans can be developed for workplaces, schools and households to identify the barriers to sustainable transport use and make these alternatives a more attractive option by raising awareness and improving access to information. Travel plans also provide various incentives to travel behaviour change such as discounted public transport tickets, reserved parking for car poolers or improved facilities for cyclists and pedestrians such as parking and shower facilities in the work place.

Travel planning is most effective when supported by area wide marketing and education campaigns which secure buy in to travel behaviour change at a local level. Ongoing marketing campaigns which raise the profile of sustainable travel, for example the 'Bus on Thursday' campaign run by Dublin Bus which offers all ticket holders on that day a range of offers from major City Centre department stores and shops. In addition, one off events such as 'In Town Without My Car' and 'National Bike Week' have been very effective in raising the profile of sustainable transport

Furthermore, targeted education for pedestrians and cyclists is aimed at resolving the poor perception of safety in relation to these modes. Cycle training for children now forms part of the school curriculum in Ireland and education campaigns have also been introduced to raise awareness among motorists about the needs of pedestrians and cyclists as well as bus drivers using shared bus/cycle lanes. Education campaigns also focus on the health as well as economic benefits of a shift to more sustainable travel modes. Travel Planning is best implemented in one of the following forms:

Workplace Travel Planning This is currently being rolled out by the NTA in the biggest 100

	companies in Ireland. An average reduction in car use of 18% has been achieved to date;
School Travel Planning	Following a number of successful Pilot Studies which commenced in 2002, this is now being implemented by An Taisce through the Green Flag Programme for schools. The average reduction in car use has been reported at 22%;
Personal Travel Planning	These Plans provide tailored travel information to participants on a one-to-one basis. To date, two such plans have been delivered in Ireland. The Midleton and Adamstown PTPs resulted in reductions in car use of between 12% and 41%; and
Area Based Travel Plans	There are, as yet, no specific examples of these plans in Ireland. However, based on experience of the UK Highways Agency Influencing Travel Behaviour (ITB) Programme, the plans may be used to address congestion hotspots on the National Road Network where there is a high level of trip generation from business parks, universities etc.

Travel planning at various levels, be it area based or individual workplaces, still forms one of the most effective soft measures in mobility management. Average reductions in car use as a result of workplace travel plans is 15%, with reductions of up to 30% for school travel plans and 15% for personalised travel plans.

13.2.3 Accessibility

Accessibility describes the ease by which travel is possible between an origin and destination. Accessibility is generally measured in terms of reliability, journey time, journey quality and the range of options that are available. Demand Management measures can be achieved through rebalancing accessibility to specific areas in order to influence the travel choices that individuals will make. Measures considered under demand management include:

- The setting of maximum parking standards to restrict the ability to travel by car to destinations where limited road capacity is available. Such a measure is evident in major towns and cities throughout Ireland, where there has been a transition in recent years from the use of minimum standards (which seek to ensure that parking will be available for the maximum anticipated demand) to maximum standards (which seek to limit demand due to capacity constraints on the road network);
- Investment in walking and cycling policies to reduce car dependency. Such policies can include frameworks for the delivery of infrastructure, supported by the development of guidance to support the design of good quality facilities. Significant research is still required to understand the factors which influence growth in pedestrian and cycle demand, which will in turn influence the future direction of such policies;
- Public transport regulatory reform and service enhancements, which offer a more customer-orientated approach to providing services. The establishment of the National Transport Authority has included a new framework for the delivery of future public transport services, and supporting the delivery of accessibility improvements through measures such as real time information, integrated ticketing, rolling stock/fleet enhancements and service quality improvements;
- Providing travel alternatives for those without access to a car through Car Sharing. The former ensures those without access to a car can gain access to a shared pool of cars at

a reasonable cost. Go Car, currently established in Cork and Dublin is a successful example of such a resource; and

- The provision of information to support travel choices which offer a greater level of network efficiency. Examples include journey planners, car sharing databases, and greenhouse gas calculators.

The Traffic Management Strategy objectives focus predominantly on the need to improve accessibility for high value road users – namely business users and freight traffic. Nevertheless, for many rural areas, road will remain the most relevant means of providing accessibility to population centres from surrounding population catchments of low density. The rebalancing of accessibility towards walking and cycling is most relevant to small towns, or localities within larger towns where transport infrastructure can lead to barriers to such activity. Public transport accessibility is most relevant to those wishing to access or move around the larger towns and cities, where facilitating all such demand by road is not feasible or economical.

13.2.4 Workforce Mobility

Recent years have seen a gradual increase in the mobility of labour markets, with employees now moving between employers on a more regular basis. As the transport network improves, employees have access to a greater range of employers. This leads to an increase in average commuting distances, made possible as a result of the higher commuting speeds.

Nevertheless, in order to support such mobility, a complementary strategy merits consideration which seeks to encourage relocation of employees closer to their place of work. Such has been significantly improved with the recent reduction in the stamp duty rates, and makes such relocation less of an economic burden for some.

13.2.5 Information Technology

Advances in Information Technology over the past 20 years have been significant, and continue to reduce the reliance on personal contact for business, shopping and leisure activities. Such advances have been key to reducing travel demand through a number of initiatives, including:

- Telecommuting, where employees use communication networks to work from home;
- Teleconferencing, where the need for travel is reduced through the holding of virtual meetings; and
- Internet shopping, where the only transport demand arises out of the delivery costs. Whilst it is accepted that delivery activity does lead to a transport demand, this is often timed to avoid peak traffic activity, and is undertaken using a smaller number of vehicle kilometres.

The use of Information Technology in reducing travel demand has been market-driven, with such reductions arising out of the ability of organisations to cut costs. Nevertheless, there is a growing body of research that suggests there is an appetite for a minimum level of travel within any population, and reducing travel demand through, for example, telecommuting, may lead to increased travel activity in other areas (e.g. off peak leisure trips).

13.3 Summary

The discussion has therefore highlighted that although Demand Management covers a relatively broad range of measures, that the experience in applying such measures is relatively good. The recent Smarter Travel policy document has strengthened the role of demand management in providing for future transport growth, and envisages that measures should be employed which will lead to zero net growth in private transport demand between 2009 and 2020. A summary of current Demand Management Initiatives in Ireland is outlined in Table 13-1.

Table 13-1: Examples of Existing Demand Management Measures

Category	Measure	Experience
Land Use	Planning Guidelines	IFPLUT Guidance (NTA)
	Planning Guidelines	Spatial Planning Guidelines (DOEHLG)
	Planning Guidelines	Development Plans
	Sustainability Audit	Common in road safety and appraisal, but not planning
Travel Planning	Workplace Plans	NTA Programme
	School Travel Plans	An Taisce Green Schools
	Personalised Plans	Adamstown, Midleton
	Area Plans	No Irish Experience
Accessibility	Parking Standards	Dublin City Maximum Parking Standards – rated by transport accessibility
	Walking & Cycling Policy	Galway City Walking & Cycling Strategy
	Public Transport Service Improvements	NTA Regulation
	Car Sharing	Go Car in Cork and Dublin
	Travel Information	Journey Planning information from NTA and other Private Operators
	Park & Ride	Pace (Co. Meath), Red Cow (Co Dublin), Black Ash (Co Cork)
Workforce Mobility	Stamp Duty Reform	Finance Bill, 2011
Information Technology	Telecommuting	Various private sector vpn suppliers
	Teleconferencing	Various private sector suppliers
	Internet Shopping	Dependant on broadband availability, although this is good in urban areas

Throughout the discussion presented here, a number of gaps have been identified which can support current and future efforts in this area. These are:

Planning Guidelines and Handbook

The 'Guidelines on Spatial Planning and National Roads' were published as a draft in 2010, and provide a discussion on sustainable planning principles. The Guidelines, which have been drafted by representatives from the Department of the Environment, Heritage and Local Government in consultation with local authorities, the Department of Transport and the National Roads Authority, will assist road and planning authorities, the National Roads Authority and providers of public transport in relation to their involvement in the overall planning process.

As a further development of these Guidelines, it is proposed that a supplementary advice note be prepared which sets out the typical processes for the development of sustainable area plans and road infrastructure. The note would draw on the principles set out in the Development Guidelines and provide more detailed information on the principles behind development management and the strategic function of national roads. The note would also introduce the concept of a 'Transport Sustainability Audit' to allow more informative screening of development proposals which may impact on national roads.

Area Wide Travel Planning

Travel Planning has, to date, been focused on individual organisations with large impacts on the transport network. Nevertheless, the delivery of Area-Wide travel planning can be extended to those locations where a large number of small and medium sized employers can lead to strong cumulative impacts on national roads. Initially, such locations might include Sandyford (Dublin), Little Island (Cork) and Ballybrit (Galway).

Park & Ride

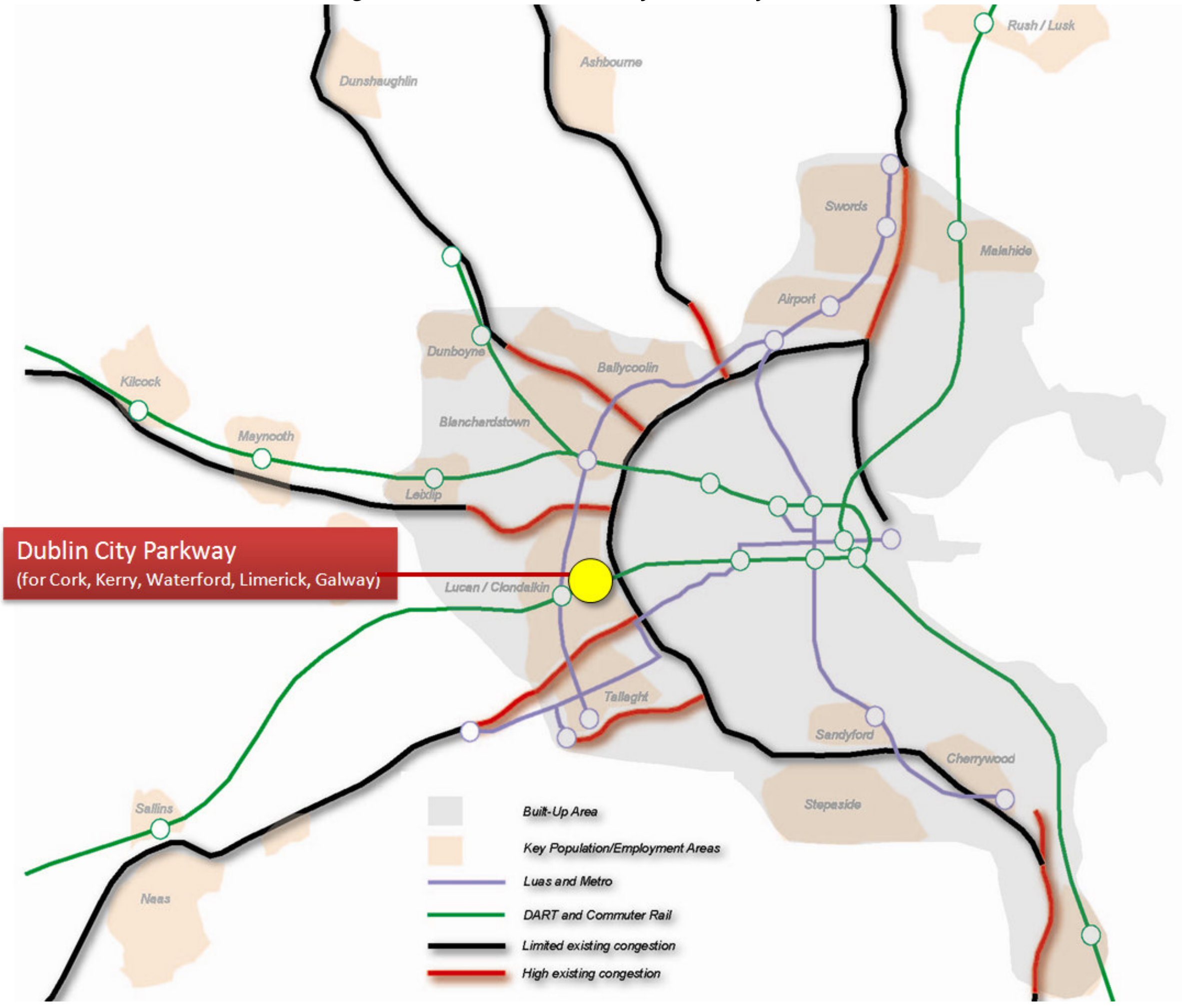
At present, the level of connectivity between the Inter-City Rail Network and the National Road network can be poor, with Inter-City travel focused on City Centres at the expense of many of the fringe communities and settlements located around them.

In recent years, the provision of Park & Ride capacity has been focused on the fringes of the major cities, with sites currently proposed or recently delivered at Dunboyne/Pace (Rail), Lissenhall (Metro), Adamstown (Rail), Dunkettle (Rail), Black Ash (Bus), Sandyford and Cherrywood (Luas) and the Red Cow (Luas). Nevertheless, all such sites focus on the needs of commuters, and have little impact on volumes of traffic using the Inter-Urban road network outside the fringes of the major cities.

At a more strategic level, it is worth considering the role of Park & Ride sites which focus on non-commuter movements, in an attempt to reduce the level of long-distance trips using the road network and their subsequent impact on city centre traffic at their destinations. This can be achieved through the definition of 'Parkway' sites which are specifically intended to facilitate those areas on the fringes of major Cities (most specifically Dublin) to make a more informed choice between rail and road. These sites are selected on the basis of access between road and railway networks, and would need to be supported by a review of rail services for those stations. Nevertheless, this needs to be balanced by the impact of an additional stop on inter-city movements, which can lead to an additional journey time of up to 7 minutes.

Examining the potential for such a facility, it is evident that the main railway spine emerging from the City travels from Heuston Station, and is in the process of being 4-tracked to improve reliability and journey times for Inter-City and Commuter services. The route crosses the M50 between junction 7 and 9, although it is relatively inaccessible from the strategic road network at this location. Access to the railway close to the M50 would maximise the potential for such a proposal – further investigation of the most likely site in this area, and the most appropriate means of access is warranted. This proposal is outlined below in Figure 13-1.

Figure 13-1 Dublin City Parkway Station



In the above example, potential passengers from across the Dublin Area could access outbound Inter-City services at the Parkway station to travel to Cork, Kerry, Mayo, Waterford, Galway and Limerick. It would be important that the level of rail services at the parkway station would be sufficient, and would be supported by good access from the motorway network. Most likely, the station would accommodate outbound services during the morning peak, with inbound services serving the station during the evening peak in order to avoid the station being used as a commuter Park & Ride for those wishing to travel into the city centre. Further discussions with Irish Rail are proposed in this regard.

Such an increased level of integration would contribute to a network-wide reduction in emissions resulting from transport. Although leading to a reduction in toll revenue on certain routes, this would be offset through the imposition of nominal car parking charges.

Monitoring and Evaluation

The potential strategies arising out of the National Traffic Management Study will lead to a number of impacts on traffic which will include:

- Reassignment of traffic to alternative routes;
- An increase in vehicular occupancy;

- Reassignment of travel demand to alternative travel modes (public transport, cycling etc);
- Re-timing of trips to avoid congested periods;
- The selection of alternative destinations, leading to a change in the distance travelled;
- Reductions in traffic congestion on National Roads; and
- A reduction in the quantum of trips made.

In order to determine the success or otherwise of both the National Roads Traffic Management proposals and the Smarter Travel initiative, there is an evident need to develop an improved understanding of existing travel demand in Ireland. In developing the National Traffic Model, and indeed the subsequent National Transport Model, the model development was somewhat constrained by the absence of a dataset describing aggregate national travel demand. Such datasets are typically established through national or regional household travel surveys, and can establish the following on the basis of each household:

- Number of trips made over a defined period;
- Trip length and journey purpose;
- Travel Mode used for each trip; and
- Other factors which may influence the decisions associated with travel.

The surveys would be used to develop and maintain a National Trip End Database, which could form the basis for subsequent monitoring of travel demand and travel behaviour by region. Such a model would also form an important input to determining environmental impacts of travel demand, which are currently assessed at aggregate level only.

Data for the UK indicate that leisure trips account for the majority of trips per person per annum (26.1 per cent in 2006), with shopping journeys and the journey to work coming in second and third place with 21.1 per cent and 18.8 per cent of total journeys respectively (Department for Transport, 2007). Whilst targeting the Journey to work can lead to strong localised benefits due to the level of congestion during that period, relatively smaller changes in behaviour in leisure/shopping activity can have quite large impacts on reducing the environmental impacts of travel.

Using a National Trip End Database, measurable targets could be developed which might include:

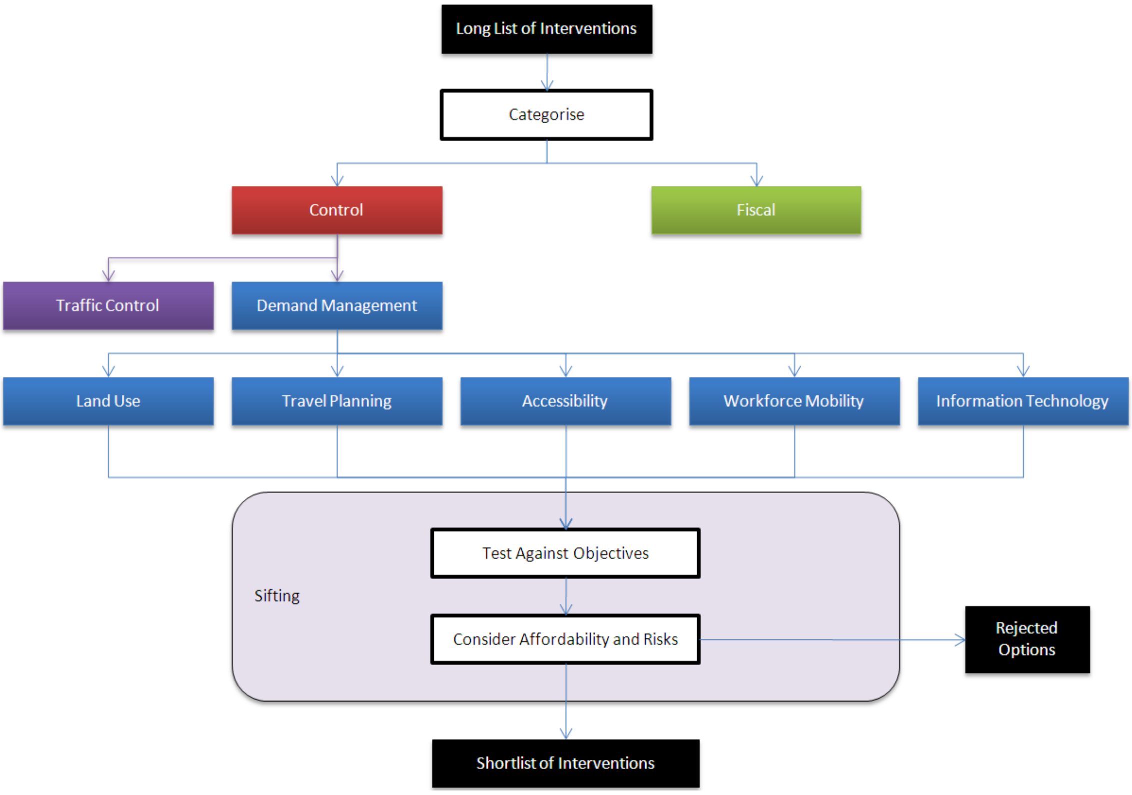
- The facilitation of an increase in mobility which exceeds the rate of increase in traffic demand;
- Maintaining or reducing average commuting distances in key locations; and
- Maintaining trip frequency by car at 2010 levels.

Regular updating of the National Trip End Database through an annual programme of surveys would support monitoring in this manner, and would allow more targeted monitoring of travel behaviour to inform the future implementation of plans and policies

13.4 Sifting of Measures

As with the Traffic Control measures in Section B of this report, the various Demand Management Measures have been run through the sifting process, shown in Figure 13-2 and 13-3 overleaf. The analysis shows that all measures offer strong support to the study objectives, and hence should be taken forward as part of the current study.

Figure 13-2 Strategic Sifting Approach – Demand Management Measures



In general, the sifting exercise shows that all measures offer strong support to the various study objectives, mainly under the economy, environment and accessibility criteria. Furthermore, measures outlined under the heading of Demand Management are typically low cost, and hence affordability is not likely to represent a barrier to implementation.

Figure 13-3 Results of Sifting – Demand Management Measures

Objectives	Land Use: Planning Policy Guidelines	Land Use: Framework Plans	Land Use: Sustainability Checklist	Travel Planning: Workplace Travel Plan	Travel Planning: School Travel Plan	Travel Planning: Personalised Travel Plan	Travel Planning: Area Travel Plan	Travel Planning: Monitoring & Evaluation	Accessibility: Parking Control	Accessibility: Walking and Cycling Strategies	Accessibility: Public Transport Improvements	Accessibility: Strategic Park & Ride	Accessibility: Travel Information	WM: Stamp Duty Reform	Technology: Telecommuting	Technology: Teleconferencing	Technology: Internet Shopping
Economy																	
Improve allocative efficiency	✓	✓	✓							✓	✓	✓					
Reduce the economic impact of delay through effective incident management																	
Address excessive reliance on national roads as a means of supporting commuting traffic	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Maximise the capacity of congested areas through effective management solutions				✓	✓	✓	✓		✓								
Environmental																	
Encourage public transport on national roads	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓				
Contribute to reductions in CO2 emissions, air pollution and noise	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Accessibility																	
Maintain and improve opportunities for access	✓	✓	✓					✓		✓	✓	✓	✓		✓	✓	✓
Integration																	
Promote an understanding of integrated land use and transport planning policies	✓	✓	✓					✓									
Encourage the use of public transport on national roads through supporting network integration								✓			✓	✓	✓				
Safety																	
Reduce knock-on safety risks that result from incidents																	
Reduce the frequency and severity of accidents on National Roads										✓							
Adopt/Reject	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

✓ Measure adopted as technically feasible and strongly supporting strategy

✓ Measure adopted but subject to further study

× Measure rejected due to technical challenges or conflict with study objectives

February 2011

Traffic Management Through Fiscal Measures

Section D

Section D Traffic Management through Fiscal Measures

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Chapter 14 Rationale for Fiscal Measures

14.1 Introduction

This section considers the underlying rationale for the application of fiscal measures in the context of the wider National Traffic Management Study. A review of international experience has highlighted a number of dominant considerations that are normally raised when considering such measures:

- The rationale for charging for road use and the extent to which they are justified by economic considerations;
- Which form or forms of charge (for example congestion charging, road pricing or fuel taxation) best achieves the benefits that economic theory suggests can be realised by the imposition of charges for road use ;
- Other policy issues relevant to the introduction of road pricing; and,
- The potential or need for road pricing to raise revenue for the Exchequer.

The Section draws together an examination on what might be a practical and useful form of fiscal measures that will meet the traffic management objectives on the National Road Network in Ireland.

14.2 Basis of Charging for Road Use

There exists a widely accepted view from economics that if a price was charged for road use equal to the full social cost , that this would lead to the optimum level of investment in roads. It would also lead to an optimal level of road use and allocation of road capacity between potential users. In this context a "price" for road use means any payment levied on road users including vehicle registration tax, fuel taxes, simple tolls or the latest road pricing systems.

In this context, social cost includes more than the cost of building and maintaining roads. These costs are borne by the public or private entity that provides the road and can potentially charge a price for road services. The full social costs also include the "external" costs that are imposed on third parties when a road is used. These "externalities" need to be included when assessing the full social cost of road use, which if fully priced determines the optimum level of investment in roads and the optimum level of road use. The full social costs of road use include:

- The costs of building, maintaining and operating the road infrastructure;
- The costs imposed on road users by congestion on roads. Each additional user of a road can add to congestion and so impose a cost on other road users;
- The costs imposed on road users by unreliability of journey times on roads. Each additional user of a road can add to this unreliability and so impose a cost on other road users; and
- The environmental costs of road use, including:
  - Emissions that reduce air quality;
  - Noise and vibration;
  - Landscape and visual quality;
  - Biodiversity;
  - Cultural Heritage;
  - Land Use;
  - Changes in greenhouse gas emissions;

- Water Resources; and
- Accidents

There is therefore a strong economic case for charging for road use such that the receipts from the charge or charges cover all of these costs. The resulting level of road use, and level of investment in road infrastructure or other transport modes, would represent the optimum allocation of the total resources of the economy where road user charging is based on the full social cost of road use.

14.3 Rationale for Road Pricing

Charges based on the full cost of providing roads can contribute to the environment in a number of ways. Firstly, charging will reduce road use and its environmental impacts. Secondly the remaining road users will be those users for whom the benefit derived from road use is greater than the cost to society of the road use, including the environmental costs. The environmental cost of this road use can therefore be considered to be justified. Finally, the funds raised through the charge or charges will include the full cost of the remaining environmental damage and can be applied to counteract this environmental damage.

Similarly, a charge or charges for road use will address the problem of congestion by reducing road use, and by ensuring that remaining road users gain a benefit from road use that outweighs the cost of the congestion they impose on other road users. In addition, the funds raised can be used to counteract, or compensate for, the congestion costs imposed on road users.

Finally, a charge for road use can raise revenue for the Exchequer. The economically optimal charge described above includes a contribution to the cost of building, operating and maintaining a road. In theory, the road system would be self financing if economically optimal charges for the use of roads were levied. However charging for road use can also be an attractive way of raising additional revenue for any purpose for the Exchequer. A good summary of the potential use of additional charges for road use as a source of revenue is set out in the recent McCarthy Report[33]:

"Road pricing can have a dual purpose as a revenue raising and demand management tool and both elements should be exploited. Moreover the introduction of pricing mechanisms should not be restricted to new infrastructure; rather a full analysis of all existing road routes (including bridges and tunnels) should be undertaken with a view to implementing a comprehensive and integrated nationwide road pricing system. The Group considers that this approach would represent a fundamental structural reform that would (a) provide a significant ongoing source of Exchequer revenues if introduced at a high enough level (b) broaden the revenue base away from the State's income and enterprise activity and (c) promote more rational economicay activity by road users, including promoting the use of public transport where appropriate".

Similar points were made in the report of the Commission on Taxation[34].

We propose restructuring the tax treatment of motor transport so that VRT on cars purchased is phased out over time, and tax on registration is replaced by a tax on motor usage. This would comprise (a) increased fuel charges (including the carbon tax on emissions) and (b) road pricing. We also support targeted measures aimed at reducing usage of environmentally-damaging cars, and recommend that consideration should be given to the introduction of a new VRT scrappage scheme in this context. We do not propose any further changes to motor tax."

The key point here is that charges for road use have the potential to be a useful source of revenue that does not affect incentives to work or engage in business activity, unlike typical taxes. The McCarthy Group also notes the economic efficiency arguments.

14.4 International Rationale for Road Pricing

Whereas our assessment has examined road user charging mechanisms in a number of cities as well as the rationale for their introduction, it is important at this stage to also provide an overview of *why* other cities around the world have introduced road pricing measures.

Table 14-1: Summary of International Rationale for Introduction of Road Pricing

Area	Reduce Congestion	Improve Air Quality	Sustain Economy	Improve Urban Environment	Raise Funds for Transport	Modify/ Replace Taxation Regime
Case Studies						
Singapore	✓					✓
Trondheim					✓	
San Diego	✓				✓	
Stockholm	✓			✓		
Germany HGV Tolling					✓	
Netherlands						✓
Other Cities						
London	✓	✓	✓			
Rome		✓		✓		
Shanghai	✓	✓				
Barcelona	✓			✓		

As demonstrated above, reduced congestion is the most common objective for the introduction of road pricing schemes. Where this objective is the key driver, tolling schemes tend to have variable tolls depending on time and distance as well as place. Reduced congestion as an objective is often supported by environmental objectives, based on air quality or wider environmental objectives.

14.5 Methods of Charging for Road Use

A charge for road use can take a number of forms including:

- A tax on fuel, which can be taken as a proxy for the intensity with which the tax payer uses the road network;
- A simple form of tolling where a charge is levied for use of a road based on the length of journey and the size of vehicle; and

- Full road pricing where the charge for road use varies according to the extent to which the road in question is congested. This usually consists of a set of tolls that vary according to the time of day and location on the network.

In theory the method of charging for road use adopted should strive to reflect the theoretically ideal price for road use referred to above (i.e. the total charge levied on a road user should reflect the costs arising from that road user's activity). The three types of cost arising from road use are:

- The cost of providing the road infrastructure;
- The environmental cost of road use, which includes emissions and other environmental impacts; and,
- The additional congestion imposed on other road users by a given piece of road use.

The extent to which the three forms of charge for road use can capture these different elements of the cost of road use is discussed over the remainder of this chapter.

14.5.1 Fuel Tax

A road user's use of fuel will increase with increases based on the distance travelled, the speed of travel and the weight of the vehicle used. Distance, speed and vehicle weight are also good measures of the extent to which the road users contributes to the degradation of the road system, so giving rise to a need to replace, renew and maintain roads. An appropriate level of fuel tax should therefore be a good way to charge road users for the infrastructure cost of their road use.

The environmental impact of road use, and in particular the emissions of CO_2 and other gases, are also broadly proportionate to the distance travelled, speed of travel and the size of vehicle. Environmental impacts also vary according to the type of engine used. Diesel vehicles emit significantly less CO_2 than petrol vehicles. As a result an appropriate tax on fuel, which differentiates between different types of fuel, is a good way to charge users for the environmental cost of their road use. A tax on fuel use may be less effective at capturing the other environmental impacts of road use. For example, the heavy slow moving traffic associated with road congestion may have significant negative environmental impacts in terms of visual impact and noise, without incurring very heavy fuel use.

The effect of road use on congestion depends on the time and place where the road use takes place. Where a stretch of road is operating below capacity adding additional users will not lead to congestion and will not reduce travel speeds for existing road users. In these circumstances road use has no congestion cost. To use current terminology there is no "Marginal External Cost of Congestion" (MECC) where a road user uses a piece of road that is operating below capacity. A tax on fuel will not vary according to the time when a vehicle is used or the place where it is used. Fuel taxes cannot therefore be used to charge road users for the congestion arising from their road use.

14.5.2 Road Tolls

A simple road toll, i.e. a charge for using a road that charges based on the type of vehicle using the road can be designed so as to reflect the cost of construction and maintenance of a road. It is therefore a good way to charge road users for the infrastructure cost of their road use.

Road Tolls of this type are less effective at recovering the environmental cost of a given piece of road use. Although the toll can increase for larger vehicles, it will not reflect the extent to which a road user has minimised the environmental impact of their road use by, for example moderating their speed or operating an efficient vehicle. A simple toll of this type will be less likely to reflect the environmental costs of road use than a fuel tax, and will not provide the same incentives to minimise environmental impacts as a fuel tax. Some of these issues have been tackled by the suite of 'Eurovignette' regulations which require tolling authorities to include for environmental costs as well as infrastructure costs in tolling for future schemes.

Where a given piece of road has a tendency to operate above its ideal capacity and so to be congested, this can be reflected in the toll. Tolls on roads that tend to be congested can be set higher than tolls on other roads. This reflects the higher congestion cost of using a road that has a tendency to be congested. A road toll can, therefore, partly reflect the congestion cost of road use, and provide incentives to use the road network in ways that reduce congestion. However this type of toll will not reflect the actual level of congestion being experienced when a road is used.

14.5.3 Road Pricing

Current technology allows for a form of charge for road use referred to as "road pricing". This refers to a system where a road user faces a charge determined by some or all of the following:

- The exact sections of road used;
- The type of vehicle (and emissions class if required);
- The time at which they are used or service level on the road; and
- The degree of congestion when the road was used;

Such road pricing is as at least as effective as a simple toll at reflecting the infrastructure and environmental emissions cost of road use and fully reflects the congestion cost of road use. By targeting congestion directly, such a charge can be effective at reducing the non-emissions environmental impacts of road use. These features of the different forms of road pricing are summarised in Table 14-2 below. The main conclusions from this are:

- A fuel tax set at the correct level is an effective way to charge road users for the infrastructure and environmental cost of their road use;
- Road pricing that takes account of the time of day or the level of congestion at the time a road is used is the only form of charging for road use that can accurately reflect the cost of the congestion that a road user imposes on other road users;
- This type of sophisticated road pricing can be structured to reasonably reflect the infrastructure and environment costs of a road users travel.

Table 14-2 Effectiveness of Different Forms of Road Pricing

	Costs of Road Use			
Form of Charge	**Infrastructure Cost**	**Environmental Cost - Emissions**	**Environmental Costs - Other**	**Congestion Imposed on other Road Users**
Fuel Tax	+++	+++	+	-
Road Toll	++	++	+	+
Road Pricing	++	++	+++	+++
Key: + Road price will reflect element of cost poorly				
++ Road price will reflect element of cost moderately well				
+++ Road price will reflect element of cost very well				

There are at least two ways of charging road users the full cost of their road use so as to secure the economic benefits described above. In theory the ideal system would be a sophisticated system of road pricing applied to all road use and designed so as to charge each user for the full costs of their road use. However there is little real world experience in implementing such a system and this should be considered an impractical approach. Alternatively, one could rely on fuel tax to recover the bulk of the infrastructure and environmental costs of road use. This would then be supplemented with charges on key, congested, sections of road which would recover congestion costs and additional environmental costs.

14.6 Other Issues in Introducing Road Pricing

A number of other economic and policy issues should be considered in relation to the introduction of road pricing. These include:

- The "user pays" and "polluter pays" principles;
- Equity issues that may arise from the introduction of some form of road pricing;
- The superiority of road pricing over other methods of traffic restraint; and,
- The problem of "second best".

The user pays and polluter pays principles are a central plank of environmental policy in the EU. It establishes that, where possible, the cost of use and of environmental damage should be borne by the persons or firms that caused the environmental damage. These principles underly the EU Directive requirements on tolls and user charges for heavy vehicles. This Directive allows the charge levied on heavy vehicles to be varied according to the level of emissions produced by the vehicle. The economic theory behind this principle is the same as that set out in this report. Unsurprisingly the type of road charge that would be suggested by economic theory, as described here, would be completely compatible with the user pays and polluter pays principles.

The introduction of charges could give rise to serious issues of social equity. A charge for the use of what is traditionally a public facility is usually considered in a similar way to a tax by the persons paying the charge. For example the widespread introduction of bin charges by local authorities was perceived as a tax by most of the public. There is a strong public expectation that taxes should be levied in a socially equitable way. In particular there is an expectation that the level of charge should take account of the payers ability to pay. There is also an expectation that low income should not exclude anyone from access to the service in question. In the case of bin charges, local authorities had to introduce special schemes to reduce or cancel bin charges for vulnerable groups such as the elderly and welfare recipients. Similar concerns could arise if widespread road charging were introduced. The cost based charges described here would not take any account of a traveller's ability to pay and this could be perceived as inequitable.

Road pricing has a number of advantages over other forms of traffic restraint. The maximum level of personal choice is preserved, and the amount of road use that results represents an optimum from the point of view of the economy as a whole. The introduction of a price serves as a way of prioritising access to the roads; the users that continue to use the roads are precisely those who value road use the most. This represents an efficient allocation of the right to use roads.

This discussion of the socially optimal level of pricing for road use assumes that a pricing regime is in place that levies a charge on all roads. In practice this would not be the case. If not all roads are subject to a charge, this may have a significant effect on the level of charges that would be best on those roads that do attract a charge. For example consider a case where a journey between two cities can be made on a newly constructed motorway standard road or on an older single carriageway that passes through a number of smaller towns. The type of charging suggested by economic theory would lead to a charge for using either of these roads, based on the relative cost of using both roads. One might expect the charge for use of the motorway to be higher reflecting the higher infrastructure cost of this type of road. This charging regime would lead to an optimum sharing of traffic between the two routes. If it is not possible to charge for use of the older road, the optimum level of charge for the new road may also change. The ideal level of charges from a theoretical point of view might be the equivalent of 5c/km for the motorway and 2c/km for the old single carriage road. This might lead to an optimum solution where, say, all HGVs and 70 per cent of motorists use the new motorway and 30 per cent of motorists use the older road. If it is not, in practice, possible to charge 2c/km for use of the old road, the optimum charge for the motorway will not necessarily be 5c/km. The charge for use of the motorway should be set at a level that lead to all HGVs and 70 per cent of motorists using the motorway, as in the theoretically optimum situation. This might involve setting a lower charge than 5c/km for the motorway.

14.7 Revenue Generation

As discussed above the ideal level of charge for road use would be sufficient to recover the infrastructure cost of roads and all of the "external" cost of road use. A road charge of this magnitude would by definition produce more revenue than is required to build, operate and maintain the road network.

However, any additional road charges will be introduced in an environment where motorists already make significant payments to the Exchequer. The magnitude of these is set out in the Table below.

Table 14-3: Total Government Revenue from Motor Related Taxation 2007

Revenue Element	2007 (€m)
VRT on Cars	1,376.4
VRT on Other Vehicles	956.73
Road Tax	29.7
Excise on Fuels	2,126.7
VAT on Motor Vehicles	663.0
VAT on Repairs	50.0
VAT on Fuels	525.0
Road Tolls (est)	49.0
Benefit in Kind (est.)	238.3
Total	**6,014.8**

Given the existence of significant existing revenues from road users it will be possible to introduce any additional charges for road use as either:

- Revenue neutral;
- Revenue raising with revenue hypothecated to transport; or,
- Revenue raising with revenue forming part of general Exchequer revenue.

Revenue neutrality could be achieved by lowering another form of tax on road users to compensate for any additional charges on road use.

Revenue raising with hypothecation would alternatively involve levying extra charges on road use, and ensuring that the additional revenue was applied to transport-related spending. This might make the extra charges more acceptable to the public, but would not represent an optimal way to decide on public spending. There is no reason to suppose that the amount raised by additional charges for road use would be equal to the optimal amount to spend on roads in any one year as:

- Charges would be designed to recover all costs of road use, not just the infrastructure costs that might be met out of public spending; and,
- Road spending already takes place and is funded out of general Exchequer revenues.

It is noted that the Infrastructure Investment Priorities 2010 – 2016 proposed expenditure of €1bn per annum of transport infrastructure over that period. There will be significant challenges to delivering such investment over that period given the current funding difficulties, and the revenue generated from the application of fiscal policies will offer support to this spending plan, in addition to facilitating the ongoing maintenance and operational needs of the existing road network. This is particularly relevant given the increasing cost of raising finance on the international markets.

14.8 Conclusions

The key conclusions from the discussion on road pricing are:

- Significant economic benefits can result from charging road users the full costs of their road use;
- These costs comprise the cost of providing the road infrastructure, the environmental costs of road use, and the congestion imposed on other road users;
- In theory a sophisticated system of road pricing applied to all roads would achieve the objective of charging all road users the full costs of their road use, however this is unlikely to be a practical approach; and
- The most practical approach to achieve an economically efficient system of road charging is to rely on fuel taxation to recover the infrastructure and environmental costs of road use, and to introduce charging on key sections of road to capture the bulk of congestion costs.

Chapter 15 International Practice in Road Pricing

15.1 Introduction

Successful road tolling mechanisms have been in place across the world for many centuries, ranging from manual based paper licensing and toll plazas to the more recent advancement to electronic and GPS tolling, the latter which is still evolving. This section examines a range of emerging road pricing technologies across the world, the rationale for their introduction and impact.

The areas chosen for review demonstrate a range of technology and rationale as summarised in the table below. The need to reduce congestion is the most common rationale applied to the introduction of road pricing, while the economic rationale of 'user pays' is also a key driver in influencing the development of road pricing. Tag and beacon and ANPR are common forms of road pricing technology although the flexibility offered by GPS based systems means it is likely to have a much larger role in road pricing internationally in the coming years.

It is important to note at this stage the main principles upon which road tolls are based are distance travelled, place, time, vehicle type and the level of congestion. This chapter will examine each of these areas, but will firstly examine typical tolling technologies that are available and which will guide the selection of an outline proposal.

Table 15-1: Summary of International Best Practice

Case Study	Rationale	Technology	Mechanism
Singapore ERP	Reduce congestion Vehicle taxation based on usage	ANPR GPS trials being carried out	Distance Time Place Congestion (assessed quarterly)
San Diego Express Lanes	Maximise HOV lane utility Reduce congestion Revenue for I-15 project	DSRC ANPR	Distance Time Place Congestion (real time)
Stockholm Congestion Charge	Reduce congestion Environmental improvements	ANPR	Time Place
HGV Tolls in Germany	Recovering costs of HGV's to motorway network	GPS	Distance Time Place Congestion
Netherlands National Road Pricing	Equitable taxation of car use nationally	GPS	Distance Time Place Congestion

15.2 Tolling Technology

Tolling technologies vary considerably across different systems, ranging from basic systems (such as the Dublin HGV Permit system) to highly complex automated systems (such as that employed on the M50). A number of current technologies are discussed here.

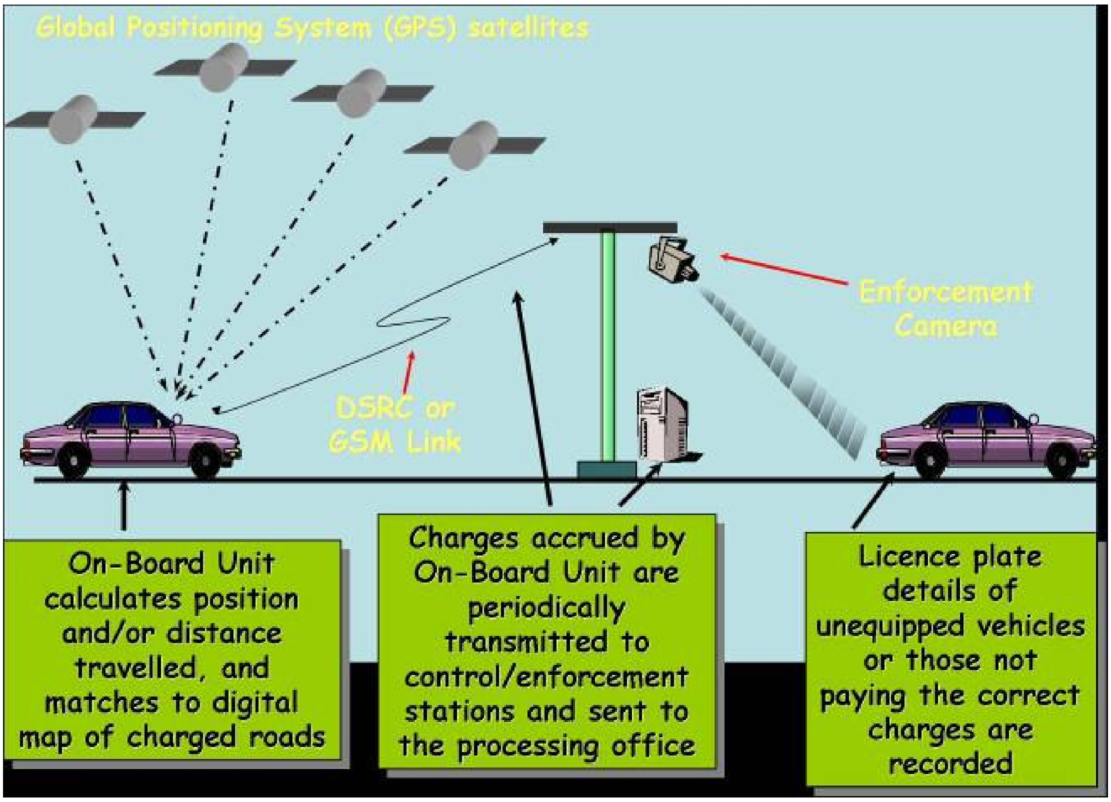
15.2.1 Dedicated Short-Range Communications (DSRC)
These systems need road-side equipment, typically mounted on a gantry, with electronic tags in the vehicles which may be read-only, read–write or smartcard-based. Read-only tags contain a fixed identification code which, when interrogated by a roadside reading device at the charging point, conveys this identity to the roadside system. The code relates to the identity of the vehicle or the identity of the users account. Read-only tags operate reliably only if used for single-lane operation at low speed and over a short range.

Read–write tags are a logical development of the read-only tag. They can receive data from the roadside and store this data directly on the tag or on a separate value-card (which may be interfaced to the tag whilst in the vehicle).The most flexible in-vehicle units (IVUs) are transponders (smart tags) that support smartcards. They are 'intelligent', having the capability to handle and process many kinds of data and (potentially) to be programmed to manage a number of different applications. Such a system requires a reliable, high-speed two-way data-communications link with the roadside and more complex on-board equipment, replacing some of the processing requirements traditionally handled by the roadside equipment.

For many years, DSRC-based systems have been preferred, due to their simplicity of operation, potential for supporting additional services for vehicle users and, most importantly, because they are easy for users to understand – you pass a point and you pay.

15.2.2 Wide Area Communications-based
Wide-area systems are a more recent innovation in charging and tolling technology – also widely known by the term MPS (mobile positioning systems). They use two technologies adapted from other applications; namely, GNSS (Global Navigation Satellite System) whose satellites enable suitably equipped vehicles to calculate their location accurately; and a two-way communications link (e.g. GSM) based upon cellular radio. These systems were tested in the German trials in 1995–96 in parallel with an EPSRC-funded trial in Newcastle during the same period and Hong Kong 1998–99 (Blythe 1999). They are designed (like DSRC systems) not to disrupt the flow of multi-lane traffic on motorways. Moreover, because in urban areas 'virtual' toll-points can be established (and changed, as necessary), these wide-area systems will reduce the amount and environmental intrusion of roadside infrastructure required, in comparison to DSRC systems.

Figure 15-1: GNSS based Road Pricing

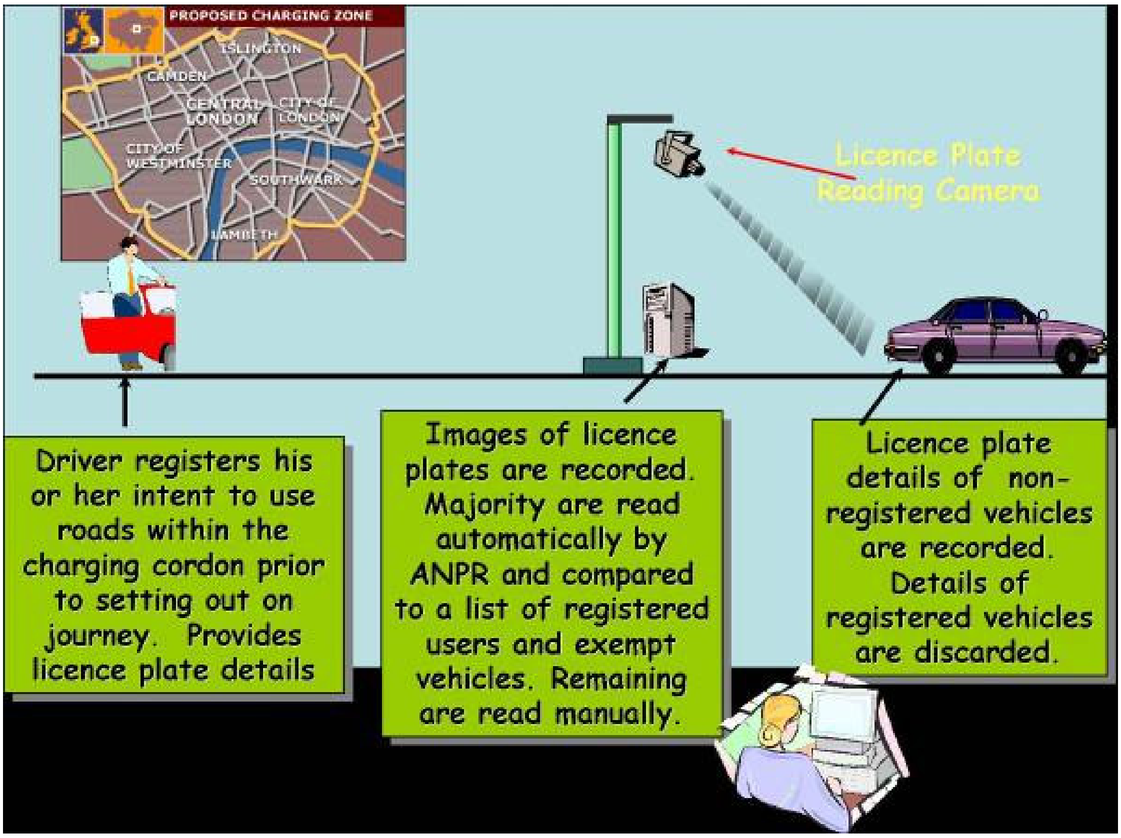


The in-vehicle unit (IVU) contains a GNSS receiver and the transponder must have a record of the locations of all charging points. At a pricing cordon, the system will deduct the appropriate charge from the credit-units stored in its account. It can use GSM to inform the central system, once a limit has been reached on the on-board account, enabling it to initiate the clearing process and allowing a range of credit-transfer options. GSM can also reload a smartcard and update the IVU with information on the charging tariff and locations of the 'virtual' pricing sites as well as providing an enforcement function. Such a solution lends itself to distance-based and zone-based charging as well. Such a system has been proposed on German motorways (Charpentier & Fremont[35] 2003, Ruidisch[36] 2003, Kossak[37] 2004).

15.2.3 Automatic Number Plate Recognition (ANPR)

Video-based systems rely on the accurate 'reading' of vehicles' licence plates as the primary means of identifying, charging and enforcing vehicles in a congestion charging scheme. Automatic number plate recognition systems process the video images taken by a camera at the roadside or on a gantry, locate the number plate in the image and convert this into the appropriate alphabetic/numeric characters, without any human intervention. The big advantage is that it removes the need for any in-vehicle equipment. Moreover, it solves the 'occasional user' problem, whereby those who rarely use a particular charging scheme do not have the necessary in-vehicle equipment to pay the charges automatically. ANPR is a variation on the automatic account identification system, which also relies on the vehicle's number plate as its unique identifier.

Figure 15-2: ANPR Road User Charging



The increasing use of video cameras for road traffic monitoring has given an incentive to improve camera technology, including optical processing, to provide a wider contrast range and give clear images, even when the licence-plates are in heavy shadow or surrounded by bright headlights in direct alignment with the camera. Unresolved problems with ANPR, however, still include:

- number plates of many and different shapes and sizes;
- number plates which are not retro-reflective;
- difficulties for accurate reading in poor weather, due to dirt/rain/snow;
- non-standardised fonts;
- similarities between some letters/numbers (Os being read as Ds, for example); and
- insufficient control of ambient light at camera positions

15.3 Singapore Electronic Road Pricing

15.3.1 Overview

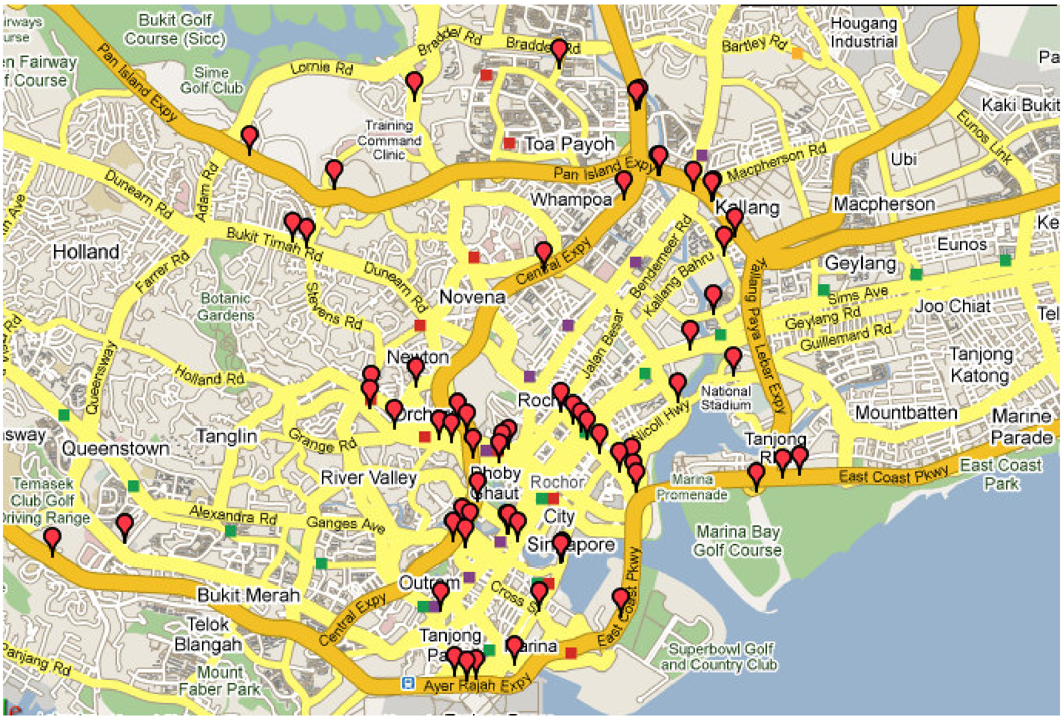
Singapore has a long history of road pricing, dating back to 1975 with the introduction of the Area Licensing Scheme. This original scheme was based on paper licenses displayed on each vehicle which were checked at strategic points on the road network. This manual method of road pricing was gradually replaced in the mid-1990's by Electronic Road Pricing (ERP) making Singapore the first city in the world to introduce electronic road toll collection. The ERP was implemented by the Land Transport Authority (LTA) in 1998 after successfully stress testing the system for a period of 9 months.

The original ALS scheme was introduced against a background of rapidly rising car ownership and congestion in the central area. The aim of the scheme was to cut congestion by reducing the number of cars entering the central area in the peak period by 25-30%.

15.3.2 Technology

The ERP consists of over 80 ERP gantries on all roads linking into the Singapore CBD as well as on major expressways, as illustrated in Figure 15-3. New gantries can easily be constructed where congestion becomes a problem. Traffic conditions are reviewed on a quarterly basis, after which rates may be adjusted to minimise congestion. Road pricing is part of a package of demand management measures put in place by the LTA, which includes increasing the costs of car ownership, restraining car ownership and improvements to the public transport network.

Figure 15-3: Gantry locations for Singapore's ERP



The supporting technology for the Singapore ERP is ANPR based and is made up of three major components, as follows:

- **On-Board Unit (OBU):** The ERP system uses a dedicated short-range radio communication system to deduct ERP charges from CashCards. These are inserted in the OBU's of vehicles before each journey. Each time vehicles pass through a gantry when the system is in operation, the ERP charges will be automatically deducted. These were produced specifically for the ERP system but were developed and marketed for multiple additional purposes. Different OBU's were developed for the various vehicle types. It is compulsory for all Singapore registered vehicles to be fitted with an OBU, which costs $150(€90), in order to use the toll roads;

- **On road equipment:** This includes all equipment on roadside gantries such as the antennae, vehicle detectors and cameras. All these are linked to a controller at each site. Data collected is transmitted back to the Control Centre continuously;

- **Control Centre:** with various servers, monitoring systems as well as a master-clock to ensure that the timing at all the ERP gantries are synchronised. All the financial transactions are processed here, before being sent to the banks for settlement. In addition, violation images are processed at the Control Centre, and letters are printed and sent out from here to all the offenders.

Prior to launching the scheme, a section of an unopened stretch of expressway with 12 sets of ERP gantries was converted into a test site. Using a fleet of 250 vehicles, each with a prototype OBU or transponder fitted, about 4.8 million trips or ERP transactions were clocked before the technology was seen as fit for purpose. After the success of this trial, the OBU's went into mass production and construction of the gantry equipment was permitted to commence.

The LTA has completed a series of field tests spanning over a year to determine the reliability of a GNSS based infrastructure which could operate without gantries. The system trials were completed in December 2007 and while details of how the system will be used to price the network have still to be agreed, Singapore is poised to be one of the first cities in the world to use a GPS based road pricing system. It will rely on GPS-enabled OBU's to track where drivers go, as well as the distance they clock. This system will determine quickly when and where congestion is occurring, and levy charges accordingly.

15.3.3 Business Model

As previously highlighted, the Singapore ERP has evolved from paper licensing through to ERP, and now GPS options are being investigated to develop a road pricing mechanism for all roads on the island. The current system is operated by a consortium including Philips Singapore Pty Ltd, Mitsubishi Heavy Industries Ltd, Miyoshi Electronic Corporation and CSE Global Ltd.

Implementation of the ERP system, including in-vehicle technology and installation, cost approximately S$200m (€120m). Annual revenue from the program is $50 million (€30m), which compares with the S$16 million (€9m) annual operation costs.

Figure 15-4: Singapore CBD Sample Costs

Eu Tong Sen Street after Outram Road (3)	
0700-0800	$0.00
0800-0805	$1.00
0805-0830	$2.00
0830-0900	$2.50
0900-0925	$2.00
0925-0930	$1.50
0930-0955	$1.00
0955-1000	$0.50
1000-1200	$0.00
1200-1205	$0.50
1205-1400	$1.00
1400-1405	$1.50
1405-1455	$2.00
1455-1500	$1.50
1500-1730	$1.00
1730-1800	$1.50
1800-1805	$2.30
1805-1825	$3.00
1825-1830	$2.50
1830-1855	$2.00
1855-1900	$1.50
1900-1955	$1.00
1955-2000	$0.50
2000-2230	$0.00

Emphasising the role of ERP as a vehicle taxation tool based on usage, the Singapore Government has progressively reduced vehicle taxation. As 24% of the total vehicle population of 850,000 pays the ERP charge daily, the majority of vehicle owners can expect to benefit in tax savings if they use alternative modes to travel in the peak periods.

The charge passing through a gantry depends on the location, time and level of congestion on the road (for that quarter), the peak hour being the most expensive. As an example, a trip from Woodlands to the CBD (a distance of approximately 15km) will cost approximately $15 (€7.25) during the peak period while the same trip during lunchtime will cost about S$2 (€0.95). Foreign-registered cars using the priced roads, during the ERP operating hours, could choose to either rent an OBU or pay a daily flat fee of $5 when leaving Singapore.

Motorists who pass through an operational ERP gantry without a properly-inserted CashCard in the OBU, or one with insufficient monetary value in the CashCard to pay the ERP charges, will receive a letter within a few days of the violation requesting them to pay the outstanding ERP charge plus an administrative fee of $10, within two weeks from the date of the letter. The administrative fee is reduced to $8 if payment is made electronically via the internet, the post office and ATM's.

When ERP was introduced, it was actually cheaper per kilometre than the previous Area Licensing Scheme. This formed an important basis to the publicity and marketing campaign prior to launch of the scheme. Publicity commenced one year before the launch of the ERP. The LTA fitted 98% of vehicles with transponders free of charge and all vehicle owners were sent brochures, detailing the ERP system, how it works and the differences between that and the then working ALS/RPS. Advertisements were also placed on all national media outlets. After the ERP was launched, a free trial period was permitted to allow customers to adjust to the system, test their OBU's and to experience the ERP charging process. This helped boost drivers' familiarity with and confidence in the system.

15.3.4 Impact of Road Pricing

The LTA have reported that traffic volumes reduced in the Singapore City area by 10-15% after the introduction of the ERP system compared to the ALS scheme. This was in spite of the road pricing charge being lower per kilometre. The major difference is that the ERP charge is applicable to each trip, while the ALS charge allowed multiple entries for that day. The ERP therefore reduced multiple trips into the CBD, estimated to be about 23% of trips that entered the CBD under the ALS. Average speeds increased by 20% and traffic within the restricted area itself decreased by approximately 13%. In addition, an increase in public transport patronage and car pooling was observed and the peak period gradually eased and spread into the off-peak hours.

15.3.5 Issues Experienced

Roll out of the ERP was not without issues and criticism. Road users have highlighted the problems the ERP has created in dispersing traffic to other non-tolled roads. The LTA have responded to this by introducing an increased number of gantries and introducing local traffic management measures. This reaction has led residents to coin phrase 'chasing the jam' for ERP.

There were also issues with regards driver's privacy. However, being an active system, there was no necessity for the central computer system to keep track of vehicle movements since all charges were deducted from the inserted smart-card at the point of use. Records of such transactions were kept in the memory chip of the smart-card that belonged to the individual. The authorities took action to assure the public that all records of transactions required to secure payments from the banks were erased from the central computer system once this was done – typically within 24 hours.

15.4 Road Tolling in Norway

15.4.1 Overview

Road tolling has been in place in Norway for over 70 years with the introduction of tolls as a tool for raising revenue for bridge, tunnel and roads projects. From 1930 to 1980, almost 5% of the total annual road budget came from road toll revenues. However, with the introduction of the Bergen Tolled Ring Road in 1986, revenues from toll roads were set to play a much greater role in financing infrastructure schemes.

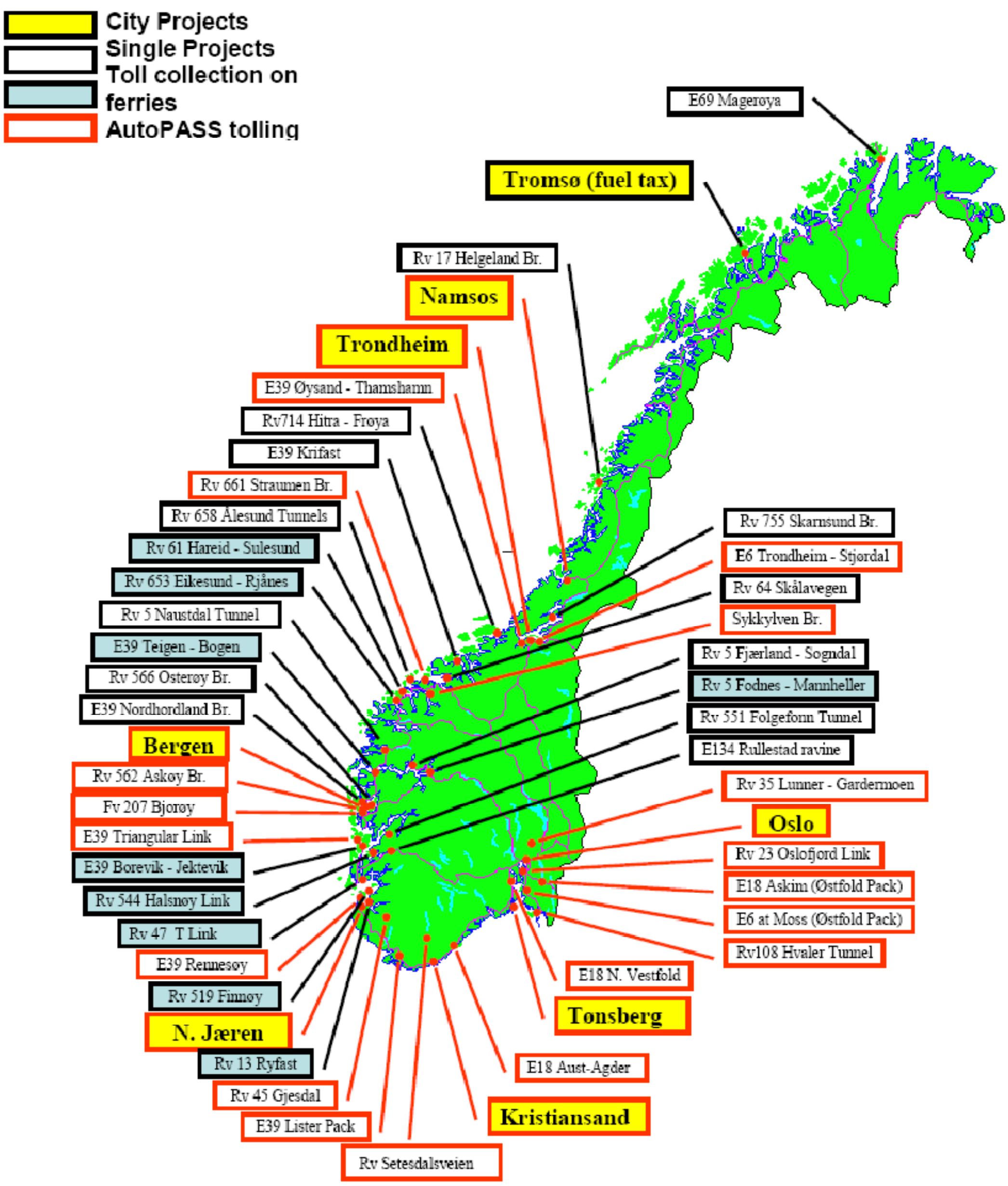
Facing increasing congestion, traffic accidents and pollution, in 1983 the City of Bergen put in place a radical transport and land use masterplan for the city which included new roads, priority for public transport, car parking, pedestrianisation, cycling networks and more open spaces. Due to a significant shortfall in funds to deliver the plan, the City Council pursued tolling of the city's ring road to raise funds to deliver the project.

Three years later toll stations were placed on the main access routes to Bergen's city centre. Vehicles were tolled a flat rates throughout the days with tolls for HGV's double that of passenger cars. Prepaid tickets and monthly, bi- annual and annual permits could also be purchased at discounted rates. The toll scheme was set up for an initial period of 15 years only to pay for proposed infrastructure, however in 2004 when this period had expired an additional city plan was proposed for funding, this time concentrating more on public transport development.

Expected revenue from the toll scheme was double that originally predicted, almost 70% of income went towards the cost of implementing the city plan while the system had an operating cost of 20% of total revenue.

Based on the success of the Bergen toll scheme, many other cities in Norway followed suit and today there are approximately 45 toll roads across Norway ranging from city toll roads to inter urban motorway tolls. In 2005, almost €350m or 35% of the total annual road construction budget came from toll fees collected from road users.

Figure 15-5: Road toll schemes in Norway



The rationale for road tolling in Norway is the financing of transport infrastructure schemes. In 2006, almost 30% of transport funding came from toll roads. Congestion reduction was not an objective of the tolls reflected in the low traffic reduction of less than 5%, mainly due to the modest tolls which were kept low to ensure public acceptance. Increasingly road pricing is being viewed by the population as a mechanism for reducing congestion rather than a 'tax'.

Nevertheless, tolls in Norway are still based on a flat toll throughout the day.

As more toll roads in Norway reach the end of the 15-20 year tolling period it is likely that the retention of tolls as a congestion charging mechanism will be established although this will require an increase in tolls and variable tolls throughout the day. To reflect this, the Norwegian Traffic Act has been amended to form a legal base for future road pricing incorporating the following principles:

- Road pricing shall be cost based charging for use of roads;
- The main objective of road pricing is to regulate traffic;
- Implementing a road pricing system shall be based on local initiative;
- Revenues should be ear marked for local transport;
- Road pricing and toll financing should not be used in the same area; and
- A road pricing scheme has no time limitation.

15.4.2 Technology and Operations

Although most of the original toll schemes in Norway operated through manual payment at toll plazas, toll roads are now operated through Electronic Toll Collection. Norway is a pioneer in ETC and introduced the world's first electronic toll plaza at Alesund in 1987.

In 1988, the Norwegian Public Roads Administration introduced a publicly owned organisation called AutoPASS to manage the roll out of DSRC based technology on all toll roads in Norway. Interoperable OBU's, similar to those used in Singapore, were placed in over one million cars in Norway, approximately one third of the national car fleet at the time.

Approximately 35 of the existing 45 toll roads schemes in Norway are now part of the AutoPass tag system which as well as offering electronic payment options also offer a manual payment option (although this is usually not manned). The schemes not included in the AutoPASS system are those where charges are based on vehicle occupancy, something the DSRC technology is not capable of reading.

15.4.3 Business Model

The organisational framework of Norwegian toll roads is unique and can be described as a bottom-up approach where each toll project is based on a local initiative established by local stakeholders. The initiative is usually taken by the business community, local authorities or even individuals. Based on this initiative, a toll company is founded and organised as a limited liability company. The company must be jointly owned by the local authority within which the project lies and must be organised as a non-profit enterprise. The toll company works to promote the scheme and gain political acceptance of the proposal. With this support, the scheme is then presented to the Norwegian Public Roads Administration which is the national body responsible for planning, building and operating road projects financed by toll revenue and for planning and building the toll collections systems.

After Government approval, the Administration has responsibility for technical and economic feasibility studies. The toll company seeks private funding for the project which made available to the NPRA through loan capital for implementation of the project. This loan is paid off during the 15 year toll period. Once constructed, the collection of tolls is usually outsourced to commercial tolling companies, however the tolling company remains responsible for the collection of tolls and remains the contracting party with the NPRA. Ownership of the road during the collection period remains with the NPRA and the role of the toll company is to raise the funds and help repay them. If revenues from the project are higher than anticipated the toll collection period will finish earlier and the toll company dissolved.

15.4.4 Impact of Road Pricing

As previously highlighted, road pricing in Norway did not have a significant impact on congestion reduction due to the low level of charges introduced. Nevertheless, revenues have been instrumental in financing road projects as well as sustainable transport improvements in major cities. Other impacts of tolling are not clearly documented.

15.4.5 Issues Experienced

Despite the extent of road tolling in Norway, public acceptability is still an issue although the NPRA highlights that the direct relationship between toll revenues and infrastructure investment is an important tool in securing public support. Further criticism has been levied on the NRPA due to that fact that because many tolling schemes are locally driven, the national trunk roads have suffered from a lack of investment and as a result, the NRPA is increasingly turning to PPP methods of financing upgraded trunk roads.

15.5 Interstate 15 Express Lanes, San Diego, USA

15.5.1 Overview

Express Lanes on the Interstate-15 in San Diego provide an example of innovative traffic management measures which could be adopted on busy sections of the Irish road network. The I-15 Express Lanes were originally introduced as High Occupancy Vehicle (HOV) Lanes but with low demand for the lanes during peak hours, single occupant vehicles (SOVs) were permitted to use the lanes but for a fee. The HOV lanes were upgraded to HOT (High Occupancy Tolls) lanes in 1998 and since then the lanes have expanded from 13km to 26km with plans to further develop the network to 32km by 2012. The lanes route carpools, vanpools, buses and motorcycles south during the morning commute, 5:45 - 11 a.m., and north during the afternoon commute, noon - 7 p.m.

Figure 15-6: HOV lanes on I-15, San Diego

The I-15 Express Lanes have been developed by the San Diego Association of Governments

(SANDAG) and the California Department of Transportation (Caltrans). Their innovative plan for the Express Lanes is due to be completed in 2012 with the development of a dedicated Bus Rapid Transit (BRT) corridor within the Express Lanes, 5 BRT stations and supporting Park and Ride facilities as well as three traffic lanes and additional access points. The total cost for the freeway improvements including the public transport element of the I-15 Express Lanes is estimated at $1.3 billion (€1bn).

15.5.2 Technology and Operations

The I-15 Express Lanes became part of the FasTrak electronic toll collection system in 1998. FasTrak allows solo drivers to travel on the lanes for a fee but not at the expense of carpoolers or public transport users. FasTrak and discount pricing work to control the number of customers using the Express Lanes, ensuring room for carpoolers and bus riders and free-flowing lanes.

The tolling technology is DSRC based with a FasTrak transponder affixed inside each car requesting to use the express lanes and gantries over each entry communicate to deduct the designated toll at that time from the charge card. As the car approaches the I-15 Express Lane, and electronic sign indicates the toll amount for that time which depends on demand in the lane. Tolls for the HOT lanes are updated every six minutes to account for the level of traffic using them.

I-15 Express Lanes in San Diego, CA

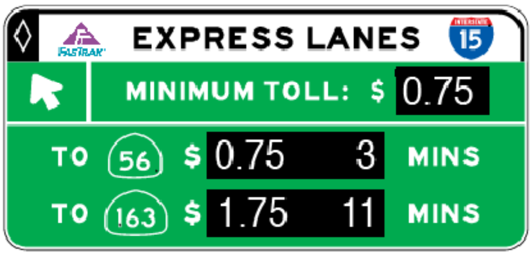
The same transponder can be used on other California Toll roads that are part of the FasTrak system. Full roll-out of the I-15 Express Lanes in 2012 will also incorporate an upgrade of existing technology such that SOV (Single Occupancy Vehicle) users of the Express Lanes will be charged based on distance as well as time of travel.

Operation of the reversible Express Lanes begins at 5 a.m. with visual inspections of the lanes for debris and to make sure all safety devices to prevent wrong-way traffic are working properly. Variable message signs indicate the lanes are opened to southbound traffic at 5:45 a.m. At 11 a.m. the lanes are reversed through variable message signing, activating safety devices and visually checking the lanes. A similar procedure opens and closes the lanes to northbound traffic from noon - 7 p.m.

Access points have been built into the I-15 Express Lanes at one-mile stretches to give emergency vehicles access to the lanes. The Express Lanes are also opened to all traffic if an accident blocks two or more of the main lanes for more than two hours.

15.5.3 Business Model

The rationale behind the I-15 Express Lanes was to maximise the efficiency of HOV lanes and to generate revenue for the I-15 BRT corridor.



Although SOV are permitted to use the lanes in the peak hour, this is never at the expense of carpool or public transport users, maintaining the original objectives of the lanes. Tolls to use the lanes depend on the time of day and extent of congestion within the lanes; these generally vary from 75 cents to $4.00 (or 12 cents to 50 cents per mile) on a typical day. During very congested periods, the toll can be as high as $8.00. Pricing is based on maintaining a Level of Service "C" for the HOT facility.

On average, approximately 75% of weekday traffic using the priced HOV lanes travels for free (vehicles with two or more occupants qualify as carpools). The remaining drive-alone commuters are FasTrak customers who pay the toll.

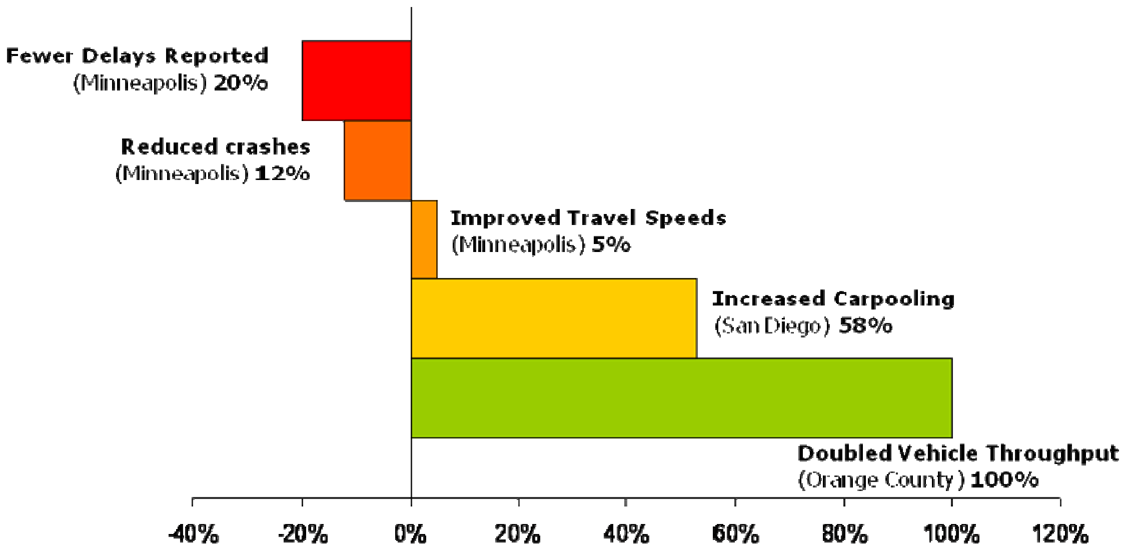
Throughout the USA, enforcement is generally undertaken by network patrols – the technology for automatic enforcement of vehicle occupancy is not yet suitable for full implementation. Users who travel with the required number of occupants in the vehicle are simply required to turn the transponder off.

In 2006 gross revenue from tolls generated by the I-15 Express Lanes exceeded $17m since the program's inception in 1998. Over $7.5m has been used to subsidize the Commuter Express Bus service in the I-15 corridor. The main expenditures include HOV enforcement, maintenance and operation of the electronic toll collection (ETC) system and Customer Service Centre.

15.5.4 Impact of the Express Lanes

Research done by SANDAG into the effectiveness of HOT lanes across the United States, found that the lanes were quite effective in reducing delays and accidents, improving travel speeds and increasing carpooling. A summary of the findings is illustrated below.

Figure 15-7: Impact of HOT lanes



In San Diego, I-15 is the fastest growing freeway in Southern California. The volume of traffic along the route has generally tripled in the past decade, with traffic volumes on the route now as high as 300,000 vehicles per day. Travellers in the general purpose lanes at peak times regularly experience delays ranging from 30 to 45 minutes. Traffic in the corridor is expected to increase to 380,000 vehicles by 2020.

I-15 Express Lanes encourage ridesharing by providing an alternate route around congestion. Motorists using the Express Lanes generally cut commuting times by about 10-15 minutes, while at the same time helping to relieve congestion in the main lanes.

SANDAG conducts periodic outreach to measure public response to the value pricing concept. These efforts have revealed broad support for managed/HOT lanes through the years. While average incomes of I-15 FasTrak patron households are well above the area median income, equity has not been perceived as a major obstacle to implementing pricing on HOT lanes in the San Diego region.

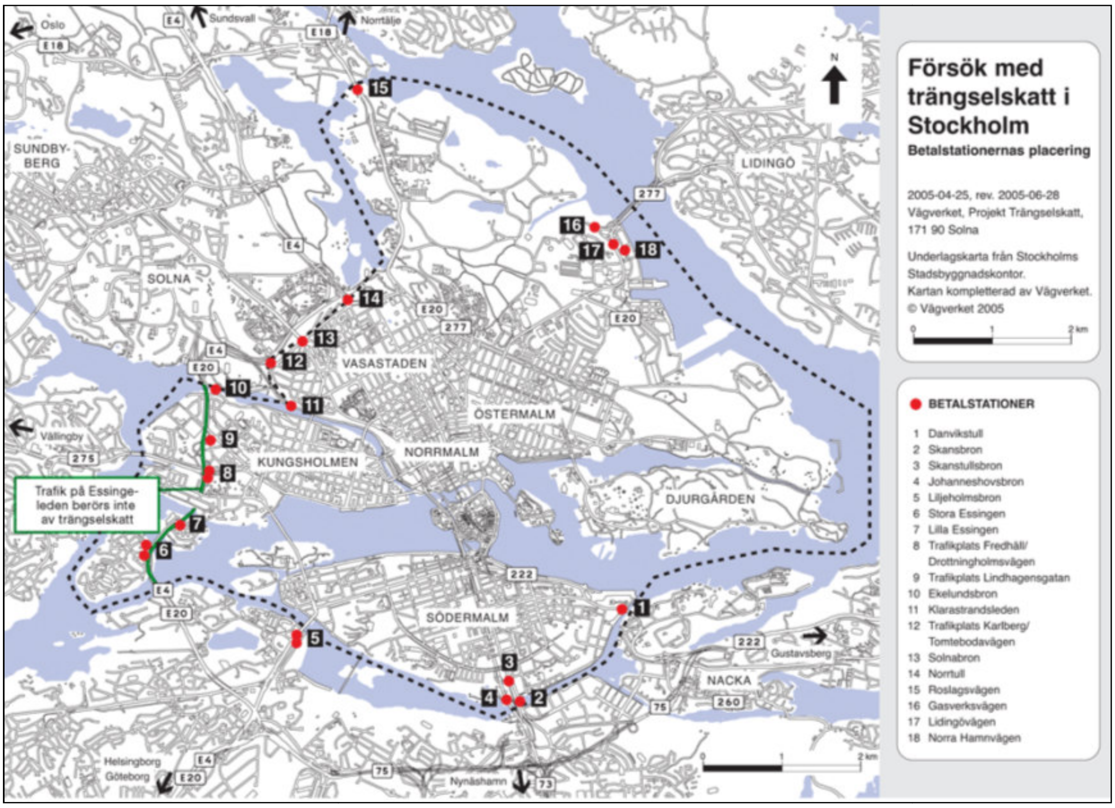
15.6 Stockholm City Congestion Charge

15.6.1 Overview

The Stockholm Congestion Charge was trialled for a period of 6 months from January to July in 2006. Following a city referendum in September 2006, the Swedish government declared that the Stockholm congestion charge was to be introduced permanently during the first half of 2007. The main objectives of the scheme were to reduce congestion, increase accessibility and improve the environment. Subsidiary objectives were to improve the flow of traffic on the busiest roads, reduce emissions, improve the perceived quality of the city environment and provide resources for more public transport.

The Stockholm Congestion Charge is a time and place based charge at 18 entry and exit points to the city, as illustrated below. Vehicles are registered automatically through ANPR and a toll is deducted from the on-board electronic unit.

Figure 15-8: Congestion charging points around Stockholm City



Improvements to public transport and Park and Ride was a major component of introducing road pricing with 197 new buses introduced and 16 new bus routes. This ensured an effective and fast alternative to car travel during the peak hours from the municipalities surrounding Stockholm into the inner city. In addition, existing underground and commuter train line services were also improved. A further 2800 new park-and-ride spaces were built in the region bringing the total Park and Ride spaces to 13800.

15.6.2 Technology and Operations

The Vägverket (Swedish Road Administration) is the body responsible for the administration of the charge and its systems and IBM was responsible for solution design, development and operation.

IBM built the on-demand solution using wireless Radio Frequency Identification (RFID) technology supplied by Norwegian company Q-Free, a supplier of technology for road charging systems. The system is ANPR based, using an OBU and road side technology in combination with an operational system provided and run by IBM.

Payment is via a number of channels including by direct debit triggered by the recognition of the on-board electronic tag that is loaned to drivers. Q-Free cameras can also detect and record car number plate images using ANPR software to identify those vehicles without tags, and are also used to verify tag readings and provide evidence to support the enforcement of non-payers. Over 400,000 drivers in Stockholm have equipped their cars with a transponder for easy payment and can pay automatically by Autogiro directly from their bank account.

15.6.3 Business Model

The cost of the toll varies according to the time of day and vehicle size. A maximum charge is levied during the AM and PM peaks. Although tolls are levied on entering and exit of the cordon points there is a maximum charge of SEK 60 (€6.44). The amount to pay depends on the time of the day the driver enters or exits the congestion tax area. The tax may be paid online, over the telephone, or alternatively at most convenience stores in the City. The tax is not paid on Saturdays, Sundays, public holidays or the day before public holidays, nor during the night time period (18:30–06:29).

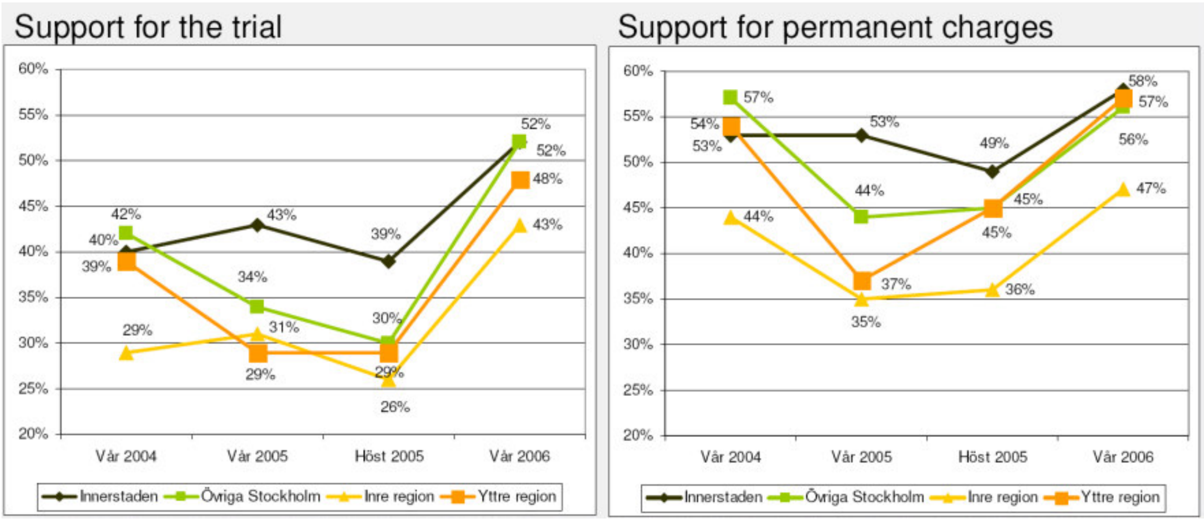
Time of day	Tax	In other currencies[1]
00:00 – 06:29	0 SEK	
06:30 – 06:59	10 SEK	1.06 EUR, 1.64 USD
07:00 – 07:29	15 SEK	1.59 EUR, 2.46 USD
07:30 – 08:29	20 SEK	2.11 EUR, 3.28 USD
08:30 – 08:59	15 SEK	
09:00 – 15:29	10 SEK	
15:30 – 15:59	15 SEK	
16:00 – 17:29	20 SEK	
17:30 – 17:59	15 SEK	
18:00 – 18:29	10 SEK	
18:30 – 23:59	0 SEK	

A bill is sent to the vehicle owner at the end of each month, with the tax decisions for the preceding month's control point passages. The bill must be paid before the end of the next month. The vehicle owner is responsible for the payment of the tax, even if the bill does not arrive.

If the charge is not paid within five days, a reminder is posted to the driver with an additional charge of 70 SEK (€7.50). If the tax along with the reminder fee is still unpaid within 30 days after the reminder bill was sent, the case is forwarded to the Swedish Enforcement Administration which adds an additional fee of at least 600 SEK (€46), and the vehicle owner will be noted in the Enforcement Register unless payment is made.

Although support for a congestion charging trial was as low as 26% in some regions of Stockholm, full support for introduction of the tax increased significantly after the trial was completed. This is demonstrated below across four regions of Stockholm, where on average support for the congestion charging trial went from 37% to 48% for full implementation of the scheme. Successful implementation of the trial was therefore an imperative factor in gaining public support for the project.

Figure 15-9: Public support for the Stockholm congestion charge



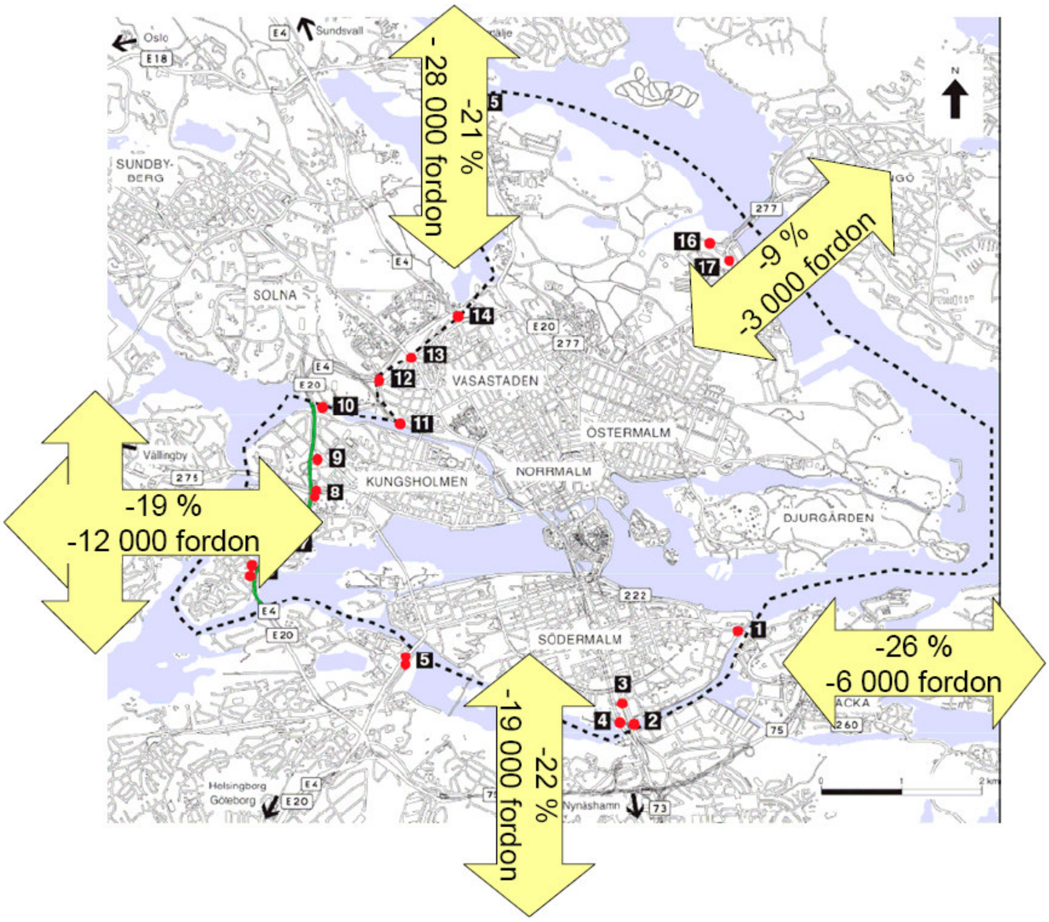
Source: Review of Stockholm Congestion Charge, WSP

15.6.4 Impact of the Toll

An evaluation of the impact of the congestion charge during the six month trial was carried out incorporating traffic impact, public transport impact, environmental impact and road safety impact among others.

Traffic reductions in Stockholm in the peak hour reduced more than expected and were seen further out of the city than expected. Over a 24 hour period congestion reduced by 22%, equivalent to 100,000 trips over the charge cordon. The decline was greatest in the AM and PM peaks when charges were highest. Figure 15-10 below summarises the traffic reduction throughout the day across the congestion cordon.

Figure 15-10: Change in traffic flows over charge cordon from 6.30am to 6.30pm



Reduced traffic flows improved accessibility to the city centre significantly with queue times falling by one-third during the morning peak period and by a half during the PM peak period. Accessibility by public transport also increased with improved service reliability on bus services. During the trial period, public transport patronage increased by 6%. It is estimated that the congestion charge is most likely responsible for 4.5% of this increase with the remaining due to an increase in fuel charges and other external factors.

After the six month trial of congestion charging, there was a reduction in emissions of both carbon dioxide and particles. Reductions in carbon dioxide have been estimated as proportionate to the decline in vehicle kilometres travelled, which means that the effect of traffic on exhaust emissions fell by 2-3% in Stockholm County and about 14% within the city. The number of cars qualifying for a 'green' exemption to the congestion tax has tripled since introduction of the tax in 2007.

Hugosson and Eliasson (2006) estimate that the congestion-tax system yields an annual cost-benefit surplus of about SEK 760 million (€73m) after deducting operating costs. On this basis it would take four years to pay back the congestion-tax system's investment costs in the form of social-economic benefits. The congestion tax is still cost-benefit positive, even when the cost of the investment is taken into account.

The cost-benefit surplus of the congestion tax is found, for example, in shorter travel times (worth SEK 600 million per year), increased road safety (SEK 125 million per year); and health and environmental effects (SEK 90 million per year). Revenues from the congestion tax are calculated at SEK 550 million per year (after the system's operation costs have been deducted). A summary of the costs and benefits of the congestion tax is highlighted below.

Figure 15-11: Costs and benefits summary of Stockholm Congestion Charge

Shorter, more reliable travel times	590 mkr/year
Paid congestion charges	-760 mkr/year
Health and environment	90 mkr/year
Traffic safety	120 mkr/year
Revenues from congestion charges	760 mkr/year
Other revenues/costs	190 mkr/year
Maintenance and running costs	-220 mkr/year
Net benefit	760 mkr/year
Investment and running costs 2006	-2000 mkr
Shadow prices etc.	-1100 mkr
Total initial cost	-3100 mkr
Payback time: 4 years.	

Source: Hugosson and Eliasson (2006), The Stockholm congestion – charging trial 2006: Overview of effects, ETC Conference 2007.

15.6.5 Issues Experienced

ANPR has it shortcomings. In Stockholm number plates from Finland and Lithuania have a similar format compared to Swedish number plates and created some difficulties in administration. Because the system cannot read the difference between plates from different countries Swedish car owners have sometimes been falsely charged. Stolen and forged plates have also caused false payment.

15.7 Netherlands: National Road Pricing

15.7.1 Overview

A distance based road pricing scheme was, until 2010, under development in the Netherlands. The road charge was to be variable by distance, but also place and time to permit control of traffic congestion. Vehicle emissions classification was to be taken into account, and the existing car tax system phased out.

The proposal was based on the concept that distance based road pricing, replacing road tax, is a fairer means of charging for road use. The social cost of travel by car, including environmental impacts and wear and tear on the network, increases with distance travelled; the cost to the motorist should be similarly proportional. Kilometre based road pricing more realistically exposes the motorist to the true cost of their travel. It can encourage behavioural change, encouraging network users to consider their journey more carefully.

The Dutch system proposed OBU's based on satellite technology to monitor a driver's activity. Potential benefits of the system included:

- Charges more accurately reflect the true cost of motoring
- Encourage modal shift to sustainable travel
- Reduced congestion

- Improved network efficiency
- Reduced vehicle emissions through modal shift and free flowing traffic
- Encourage clean vehicle choice.

Cost estimates were obtained for the Dutch system to equip eight million vehicles with the necessary equipment in 2006. The average capital price estimate for the system was between €2.0 billion and €2.5 billion. The operating costs for the system were estimated at the same time as being in the range €500 million to €1 billion per year. The Dutch government aimed for operational costs to be at most 5% of the revenue collected.

The Dutch government also conducted a cost benefit analysis of a number of different forms of the road pricing system; for 25 out of 31 variants a positive benefit was calculated. A charge varying with place/time and emissions as well as distance produced a more positive benefit to cost ratio.

A road pricing scheme of this kind is most applicable when considering large scale road pricing across all roads; it could be applied to a more localised area but this would introduce boundary effects and may lead to increased complication within the system, and hence higher management costs. Planning for the Dutch scheme had been ongoing for several years; it was originally scheduled for implementation in 2012. Prior to its suspension in 2010, the latest target date for full operation was 2016, suggesting that an Irish scheme would take several years to plan and implement. However the Irish vehicle fleet is smaller and lessons learned from other current schemes could be used to minimise the development period.

The implementation of a similar scheme in Ireland would require a new system to be delivered with development costs likely to be very high. However there should be no technical or legislative barriers in Ireland which have not been dealt with in the Netherlands.

15.8 Conclusions

As demonstrated above, there is a significant level of experience of various road tolling methods around the world which provide useful guidance for future development of tolling in Ireland. The most common form of technology currently being applied is ANPR/DSRC, with the use of GNSS or GPS based systems mainly restricted to truck tolling across mainland Europe (see chapter 20).

It should be noted that many of the above case studies are based on well established systems - they have demonstrated successful implementation and continue to generate significant revenue. These schemes, in addition to the failed road tolling projects, provide some insight into factors which can be considered as important factors in the successful implementation of road tolling, these factors are summarised as follows:

- Providing a clear indication of how revenues are to be invested;
- Early participation of stakeholders;
- A clear logic for charging, and the benefits that it will bring;
- Facilitating a trial period for the technology and allowing the public to benefit from this; and
- The need to evaluate effects of the scheme early and continuously to inform further development of the scheme

Chapter 16 Irish Experience in Road Pricing

16.1 Overview

At present road tolling in Ireland is more focussed on financing and infrastructure costs and users willingness to pay, rather than the pricing of transport externalities. Toll charges are determined in accordance with the procedures contained in the Roads Act, 1993, as amended by the Planning and Development Act, 2000, which provide for public consultation on a tolling proposal brought forward by the NRA. This is a separate procedure from the motorway and environmental assessment process and has been used to establish tolls at the following locations:

- M1 Drogheda Bypass (PPP with tolling rights);
- M3 Eurolink (PPP with tolling rights);
- M4 Eurolink (Kilcock to Kinnegad) (PPP with tolling rights);
- M6 Motorway (Ballinsloe to Galway) (PPP with tolling rights);
- M7/M8 CRG Portlaoise (PPP with tolling rights);
- M8 Directroute Fermoy Bypass (PPP with tolling rights);
- Limerick Tunnel (PPP with tolling rights);
- N25 Waterford City Bypass (PPP with tolling rights);
- M50 Barrier-free Tolling (Junction 6 to 7) (tolling operation only – no O&M obligations with revenue collected on behalf of NRA);
- M50 Dublin Port Tunnel (O&M contract with tolling but revenue collected on behalf of NRA).
- East Link toll bridge – which is not part of the national network and not managed by the NRA.

With the exception of the barrier free tolling on the M50, all toll roads are using conventional tolling plazas with barriers. All toll plazas facilitate eToll, which is the national interoperable electronic tolling scheme which operates on all toll lanes on Irish toll plazas. The system was introduced in June 2007 and operates using an electronic tag, which is placed inside the vehicle, and is detected each time the vehicle passes through the plaza. The toll is then automatically debited from the customer's account. The electronic tolling system automatically recognises the correct toll for the class of vehicle.

Prior to introduction of the system, a range of different incompatible schemes were operated at the inconvenience of road users. eToll therefore provided a single method of payment for all toll roads in Ireland. At present, ten different operators supply tags, eight of which are the actual concessionaires for roads schemes. These providers use the eToll Interoperability system which means a driver will only need one tag for tolling facilities in Ireland. The terms and conditions for purchase and use of the tags vary between each operator with tags available for either purchase (approx €30) or lease. Accounts can be settled through any of the following mechanisms:

- **Bill account - Post-paid:** Allows the customer to set up an account with a tag supplier to pay the toll charges incurred during that month at the end of the month. Customers can choose a variety of payment options including direct debit, credit card and debit card.
- **Bill account - Pre-paid:** Allows the customer to set up an account with a tag supplier where they pre-load / pre-pay onto their account in advance. Customers can choose a variety of payment options including direct debit, credit card and debit card. Customers'

accounts are then automatically 'topped-up' when their account reaches a specified minimum level.

- **Cash account - Pre-paid:** Allows the customer to 'top up' their tag with credit in advance using cash payments through certain retail outlets.

A review of the various tolling locations on the national road network is provided through this chapter of the report.

16.2 M50 Dublin Ring Road

16.2.1 Background

A single-point toll was in operation at the West Link Bridge on the M50 between Junctions 6 and 7 from year of opening in 1989. A traditional toll plaza and barrier system was operated by National Toll Roads (NTR) at a location just north of the bridge crossing of the River Liffey, which formed a natural barrier with few suitable or convenient alternative bypass routes for traffic wishing to avoid the toll. Electronic tag tolling was introduced under the "EazyPass" system by NTR for use at both the West Link and East Link Bridges in Dublin. This paved the way for wider introduction of electronic tag tolling systems by other operators in Ireland over the past decade as additional toll roads were completed and led to the availability of several alternative but compatible systems.

In 2006 the Government bought out the West Link Toll concession from the private operators, and subsequently introduced barrier-free fully electronic tolling in August 2008. This was the first such installation in Ireland and its' success has opened possibilities for much wider application of similar systems in a greatly expanded toll road network.

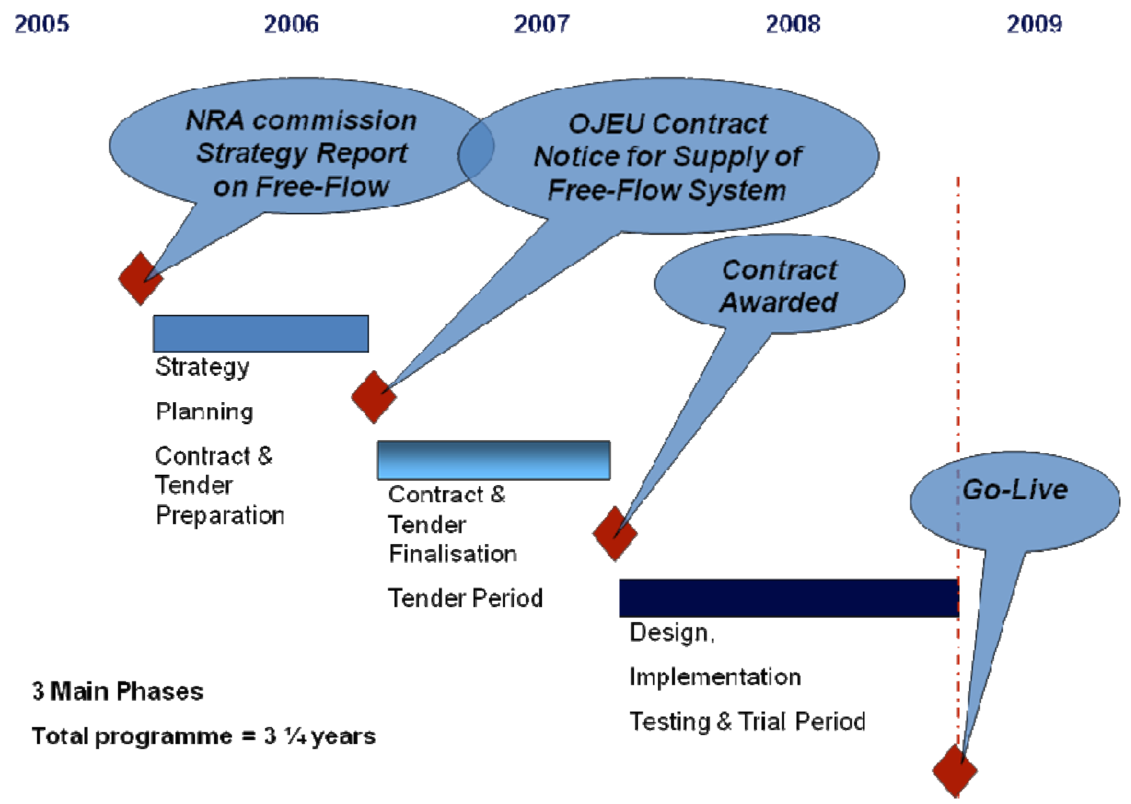
As part of the M50 upgrade, barrier-free tolling, known as e-Flow, was launched at the existing toll plaza site in August 2008. The new tolling system was developed and is being operated by BetEire Flow, a consortium comprising of two French companies (Sanef and CSSI). All revenues collected from new tolling scheme go directly to the NRA and that this revenue has been used to support the following schemes/operations:

- a "buy-out" of the existing West Link plaza (circa €50m indexed per year);
- M50 upgrade project;
- New M50 operation and maintenance costs; and
- Toll collection operation and maintenance costs.

16.2.2 Project Delivery

The e-Flow project took 3 years to deliver, with an approximate implementation budget of €25m. Figure 16-1 below summarises the three year delivery of the project.

Figure 16-1: Summary of three year delivery programme



16.2.3 Business Model

Development of the Business Model was a critical task in terms of project scheduling. This incorporated the rules and procedures for each of the following:

- Account types;
- Payment channels and triggers;
- Customer terms and conditions;
- Privacy policies and data protection policies; and
- Enforcement policies.

16.2.4 Technology

Another important work stream was the supply, operation and maintenance contract for the actual tolling system. The tolling system architecture is divided into four subsystems:

- **Video Audit System:** The Video Audit System consists of a video system which reads number plates in real time and records the data. With this information and connection through the National Vehicle Registration file the owners name and address is ascertained and thus a tolling charge maybe delivered to the individual. This system is mainly used by unregistered customers.
- **On Board Unit:** An OBU also known as a Tag, communicates through a sequence of commands and responses between a tag and a beacon. The tag is located a customer's car and the RSE beacons at the toll plaza detect the tag. This transaction is sent to the back-office for processing and assigning to the customer account (registered customers). This tag system has an additional benefit of interoperability with all tags and that the M50 eFlow tags are usable on all other toll plazas.
- **Central Computer System:** The central database holds important and highly confidential information relating to customers car registration plates and banking details. Information

for registered users is kept on file, while unregistered user information is stored for 13 months; and

- **Road Side Equipment**: The Road Side Equipment used by the electronic toll collection system records trips on the M50 by detecting an electronic tag, and recording a photograph of the vehicle's number plate.

Figure 16-2: M50 tolling system structure

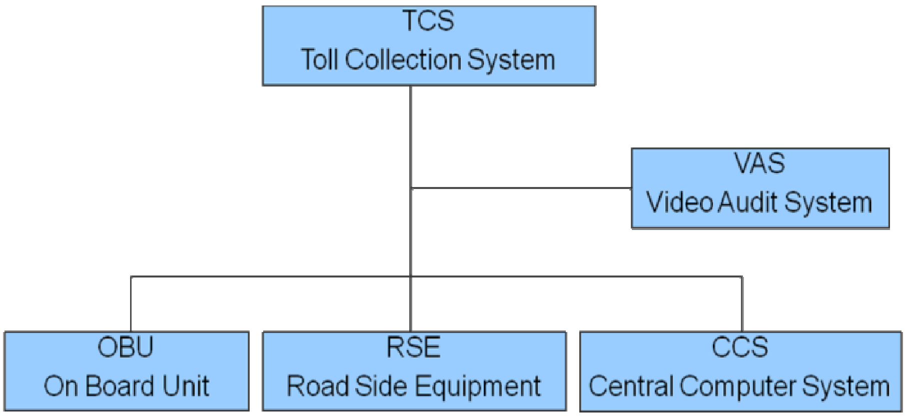
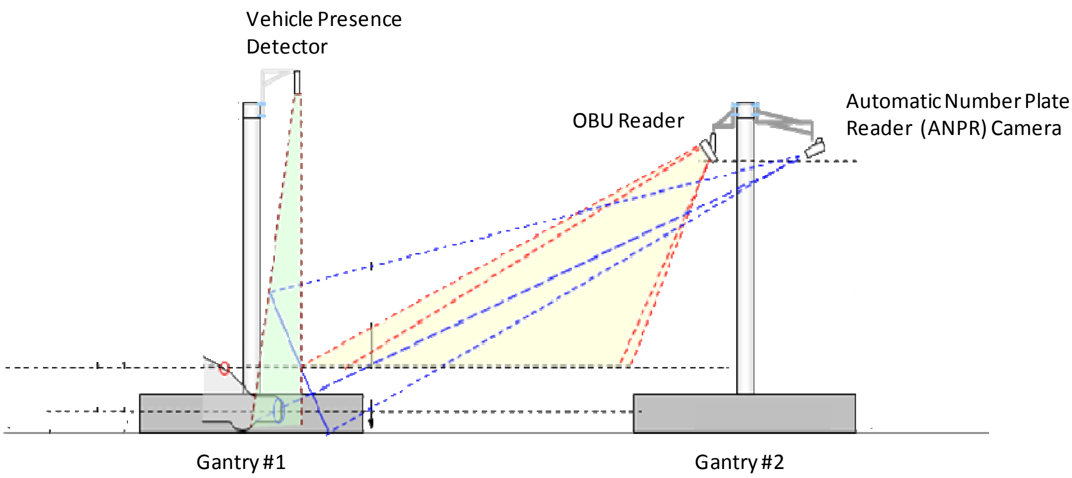


Figure 16-3 below shows the layout of the roadside equipment. The first gantry detects the vehicle (supports 4 lasers and 1 VAS camera) and the second has detectors and cameras (supports 13 beacons, 9 VES cameras and 6 VAS cameras) to identify the car registration plate.

Figure 16-3: eFlow equipment



16.2.5 Project Impact

Because the e-Flow project was delivered simultaneous to the overall M50 upgrade, it is difficult to decipher the exact impact of the project. However, it is generally accepted that with removal of the old Westlink toll plaza, the capacity on the M50 increased greatly with the elimination of the need for stopping or slowing down. This has resulted in decreased journey times and reduced emissions.

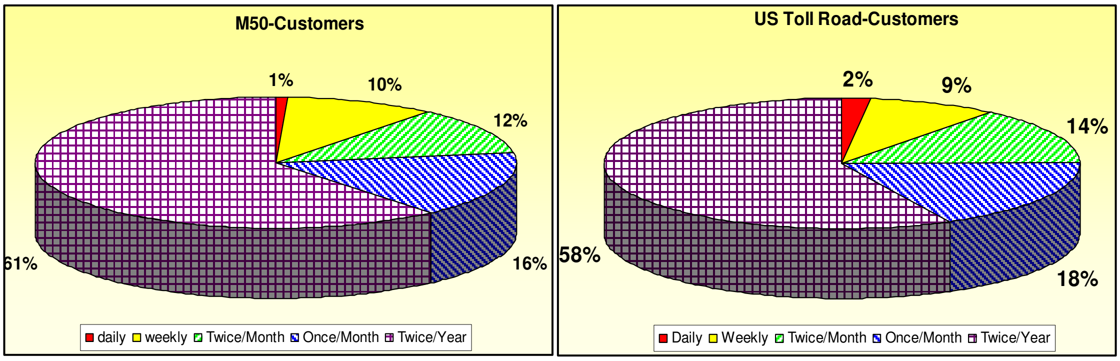
Traffic volumes through the toll are close to 100,000 vehicles per day (including weekends) with 75% of customers registered with e-Flow or another tag provider and 25% unregistered. The total M50 toll revenues for 2009 were in the region of €97 million (including penalty charges). Currently the registered (tag & video – pay electronically) customer base includes 580,000 vehicles with the unregistered customer base approximately 1,600,000 vehicles.

Table 16-1: Breakdown of current eFlow customers

Frequency	% of customers	% of trips
Daily	1%	14%
Weekly	10%	48%
Twice/Month	12%	16%
Once/Month	16%	11%
Twice/Year	61%	11%

"Regular" customers account for 11% of customer base but make 60% of all trips and "Irregular" customers account for 60% of the customer base but make 10% of all trips on the motorways. Irregular customers outnumber regular customers by over five to one however, trips by regular customers outnumber trips by irregular customers by at least five to one on the M50. The main challenge therefore is to manage high volumes of irregular users and ensure these customers are registered to reduce operation costs. As demonstrated below, experience from US toll roads presents a similar challenge.

Figure 16-4: M50 customer database compared to similar US toll road



The central customer services centre receives an average of over 300,000 contacts per month which excludes retail contact. Telephone calls average up to 80,000 per month, and represent the most costly form of customer contact.

16.2.6 Summary of M50 Tolling

The move to barrier free tolling on the M50 was a major step forward for the NRA; however it has been achieved at a price to the NRA in terms of paying to operate the new system and to buy out the previous concession. The question is whether the price of investing in new barrier-free tolling is a price worth paying. The general move towards barrier-free tolling internationally suggests that most road authorities are now starting to value the benefits while recognising the challenges (in particular potentially higher costs during the early years and higher levels of evasion).

Maintaining the traditional barrier system on the M50 would have had lower operating costs as well as slightly lower revenues. However, this does not take into account the cost saving associated with reduced journey times, improved journey time variability and environmental improvements from the introduction of free-flow tolling. Nor does it take into account the resulting ability to significantly increase traffic using the route and thereby growing revenues by eliminating the bottleneck on the road.

The global operating costs for the new barrier-free tolling system was expected to be in the region of 15% - 30% of the total revenue collected during the initial years of operation. Actual costs are in the lower part of this range, at close to 20% of revenue. Notwithstanding this, it is difficult to compare collection costs as a percentage of revenue across different systems, as such a measure relates directly to the fee being charged. Also, the cost of managing the system is biased by the provision of a back-office and business structure that supports only a single toll point – as the number of electronic toll points increases the proportional cost can reduce dramatically.

The main factor driving operating costs on the M50 is the level of customer engagement, and such will reduce as users become more familiar with the system, the level of registered users increase, and as the roadside equipment is subject to further fine tuning.

16.3 M8 Fermoy Bypass

The Fermoy Bypass was completed in 2006 and formed a preliminary phase of development of the Cork-Dublin inter-urban route. The route was designed and constructed by Direct Route who also maintain the route and take responsibility for toll collection along the route and carry the risk of any cost over runs. The concession period is for 30 years from the date of contract signing in 2004 after which period Direct Route should return the route to NRA with a further 10 year life before any structural investment would be required.

The scheme includes 17.5km of motorway with 3 interchanges and a 450m long viaduct spanning the Blackwater Valley. A toll plaza for the route is located approximately 25km north of the Dunkettle Interchange at the N8/N25 junction, and applies a charge of €1.90 for cars and up to €6.00 for the largest commercial vehicles. The plaza accommodates both electronic and manual payment through machines and staffed toll cabins. There is an express lane for cars fitted with e-toll transponders.

16.4 M1 Drogheda Bypass (Gormanstown to Monasterboice)

The M1 Drogheda Bypass tolled motorway opened in June 2003. The PPP project here includes the operation and maintenance of existing motorway with an approximate length of 42km and the operation and maintenance of a toll plaza at Dardistown 6km south of Drogheda. The PPP was awarded to Celtic Roads Group for a 30 year period.

The car toll on the M1 is currently set at €1.90 for a motorway length of approximately 14km between Junction 7 at Drogheda South (Gormanstown) to Junction 10 at Drogheda North (Mell). Toll plazas at Junction 9 on the Donore Road in Drogheda ensure a closed toll bypass of the town. The distance based toll rate is 13.6 cent/km, which is relatively high compared to other toll roads in Ireland. The toll for large trucks (>4 axles) is €6.10, equivalent to 44 cent/km.

16.5 M4 Kilcock - Enfield - Kinnegad Motorway

The project involved the construction of 39 km of motorway from Kinnegad to Kilcock and is an extension of the Kilcock-Maynooth-Leixlip motorway on the N4/N6 Sligo/Galway to Dublin route. The Motorway by-passes the towns of Enfield and Kinnegad, includes 39km of motorway, 19 overbridges, 7 underbridges, and 3 underpasses, The PPP contract was awarded in March 2003 to the EuroLink Consortium. The Authority's payments to EuroLink are fixed and consist of payments of €146m over the period of the construction as well as €6m during the period of operation.

Tolls on the M4 are slightly higher than for other schemes, at €2.90 for cars, and can be paid by cash, credit cards, and electronic toll collection tags. Road users can also purchase EuroLink pre-paid cards for 20 journeys at a discount of 10%, i.e. 20 journeys for the price of 18. Customers can buy and top-up pre-paid cards at EuroLink's commercial office using cash or credit cards.

16.6 East Link Toll Bridge

The East-Link toll bridge is owned by Dublin City Council and was built and is operated by National Toll Roads (NTR) plc. The lifting bridge links North Wall to Ringsend, and is the most easterly bridge on the Liffey, before it opens out into Dublin Port and Dublin Bay. The Bridge which opened in October 1984 was the first PPP in Ireland. An average of 22,000 vehicles use the East Link on a daily basis and the bridge is raised up to three times per day to allow river traffic to pass.

16.7 M50 Dublin Port Tunnel

The Dublin Port Tunnel opened in December 2006 and relieves surface road congestion in Dublin city centre by diverting heavy goods vehicles (HGV's) from Dublin Port directly onto the motorway network. The tunnel is free for trucks and buses, but a time variable toll is charged for private cars and other traffic for traffic management purposes.

Following a tender process in 2005, the NRA selected Transroute International, part of France's Groupe Egis, to operate the tunnel for a period of five years with an optional renewal of two years. The service contract provides for operation, maintenance, safety, traffic management and toll collection.

A toll plaza operates at the southern tunnel portal with toll collection from cars and light commercial vehicles, paid in cash or electronically. HGV's use a toll-free lane. A toll of €10 (peak) and €3 (off-peak) is levied on cars and light commercial vehicles. Peak is defined as 6 am to 10 am southbound and 4pm to 7 pm northbound, except Saturdays, Sundays and public holidays.

16.8 M7/M18 Limerick Tunnel

The Limerick Tunnel Project is Phase II of the Limerick South Ring road project connecting the Dublin Road, N7 to the Ennis Road - N18. The project was completed in 2010 at a cost of €500m. Direct Route (Limerick) Ltd. signed a Public Private Partnership (PPP) agreement with the National Roads Authority (NRA) in the August 2006 for the construction, operation and maintenance of the Tunnel. A single point toll plaza is located on the northern section of the route just south of Meelick Bridge. DirectRoute are responsible for collection of tolls for a period of approximately 31 years after opening of the project in 2010.

16.9 N25 Waterford Bypass

The Waterford Bypass includes approximately 23 km of dual carriageway and 14 km of single carriageway. Concessionaire for the road scheme is Celtic Roads Group who is responsible for the design, build, maintenance and operation of the scheme including tolls. The toll on the N25 Waterford Bypass is set at €1.90 for cars and €4.80 for vehicles with 2/3 axles. The toll plaza is located to the southwest of the River Suir Bridge, between the Western Link junction and the Grannagh junction.

16.10 M3 Clonee to Kells

This project lies on the Monaghan to Dublin route and comprises a 50 km stretch of motorway/dual carriageway, and 11 km of single carriageway. The scheme also involved construction of a further 24 km of link road and the widening/realignment of other roads. The PPP Contract was awarded to the Eurolink Consortium in 2007. Toll locations for the scheme are located between the Dunshauglin and Pace Interchanges, and on the Navan Bypass and is operated by Eurolink, with each location applying a charge of €1.30.

16.11 M7/M8 Portlaoise to Cullahill

The M7/M8 scheme lies at the connection of the M7 Limerick Road and M8 Cork Road, immediately southwest of Portlaoise. A PPP contract was awarded for the 40km scheme in June 2007 to the Celtic Roads Group (Portlaoise) Limited consortium which comprises BAM PPP bv, Iridium Concesiones de Infraestructuras S.A. and NTR plc. The scheme opened in May 2010 and has a single toll point to the east of the M7/M8 junction.

16.12 M6 Ballinasloe to Galway

In April 2007 the PPP contract for the last section on the M6 was awarded to N6 (Concession) Limited which comprises FCC Construction S.A. and Itinere Infraestructuras, and PJ Hegarty & Sons. The scheme opened to traffic in December 2009.

16.13 Conclusion

In conclusion, existing road tolls in Ireland largely result from the decision to use the PPP mechanism as a tool to finance the relatively rapid delivery of the new motorway network over the past decade. Although this provides little guidance on moving forward, the existing schemes:

- Provide evidence of willingness to pay;
- Provide technologies which would be suitable for road user charging; and
- Suggest the need to integrate existing tolls with new congestion-related charges (particularly from the user point of view in avoiding the need to engage with multiple payment processes).

With regard to future technology, the current ANPR and video technology deployed at the M50 are likely to present a basis for more widespread deployment. As road users on the motorway network get accustomed to the new toll roads around the country it is likely that the uptake of electronic tags will also increase as their market. Experience gained through the development of e-Flow is likely to be highly valuable in developing future systems. In understanding the current level of acceptance of tolling as a means of funding infrastructure in Ireland, it is worth noting that:

- In 2009 approximately 30 million toll trips with a value of €85 million was paid for by electronic means;
- Globally this represents approximately 50% of all trips on Irish toll roads; and
- In 2007, prior to full interoperability, approximately 29% of all trips were ETC.

Chapter 17 Potential Forms of Fiscal Measures in Ireland

17.1 Overview

The implementation of fiscal measures to support traffic management are intended rationalise the demand for transport infrastructure based on user need. Nevertheless, the implementation of fiscal measures can also attract a financial cost, both for construction of the initial infrastructure, and for the operation of the processes. They also require a reasonable level of simplicity to ensure that charges are transparent – this conflicts with the economic theory on user pricing which requires quite complex charge-calculating algorithms.

It is for this reason that a number of approaches exist for road user charging, with each solution tailored to meet the specific needs of a particular location. In this chapter, we investigate the various mechanisms available to charge for road use in Ireland, and discuss which approaches might offer the most appropriate solution.

17.2 Forms of Fiscal Measures

Broadly speaking, fiscal measures comprise:

- Road Pricing based on Global Navigation Satellite Systems (GNSS), which apply a charge for road use based on time, distance and the level of congestion;
- Tolling, whether this is applied as single point tolling, multi point tolling, or access charges; and
- Destination charges such as parking charges or workplace levies, where charges are levied for the duration of stay.

Examining the evidence, there is a general consistency regarding where and how each of these measures have been implemented in recent years. A useful summary is outlined below in Table 17-1.

Table 17-1: Experience with Fiscal Measures

Frequency	Applications	Comments
Destination Charges	Most City Centres	Mainly confined to urban centres in an attempt to reduce congestion and generate revenue
Access Charges	London, Stockholm	Mainly confined to urban centres in an attempt to reduce congestion
Road Pricing based on GNSS	Quite common across Europe for tolling of goods vehicles on major inter-urban roads	No successful application to date for road pricing of private cars
Single Point Tolling	12 locations in Ireland and numerous examples internationally in urban and rural areas	Can be implemented as cash/barrier tolls or as electronic open road tolling. Requires high value payment at one location.

Multi-Point Tolling	Portugal, South Africa, Melbourne	Emerging popularity as a form of distance-based charging on strategic roads

17.2.1 Destination Charges
Examining the above measures, it becomes clear that each measure has a defined function. On National Roads, parking charges or workplace levies have limited scope, as they mainly relate to managing access to City Centres. Although their application in the city centres can have an impact on the national road network as a result of traffic switching travel mode, such impact would occur on the radial routes only. The impact on orbital routes would be less pronounced, as traffic demand associated with the many out of town retail and commercial developments would be impacted to a lesser degree.

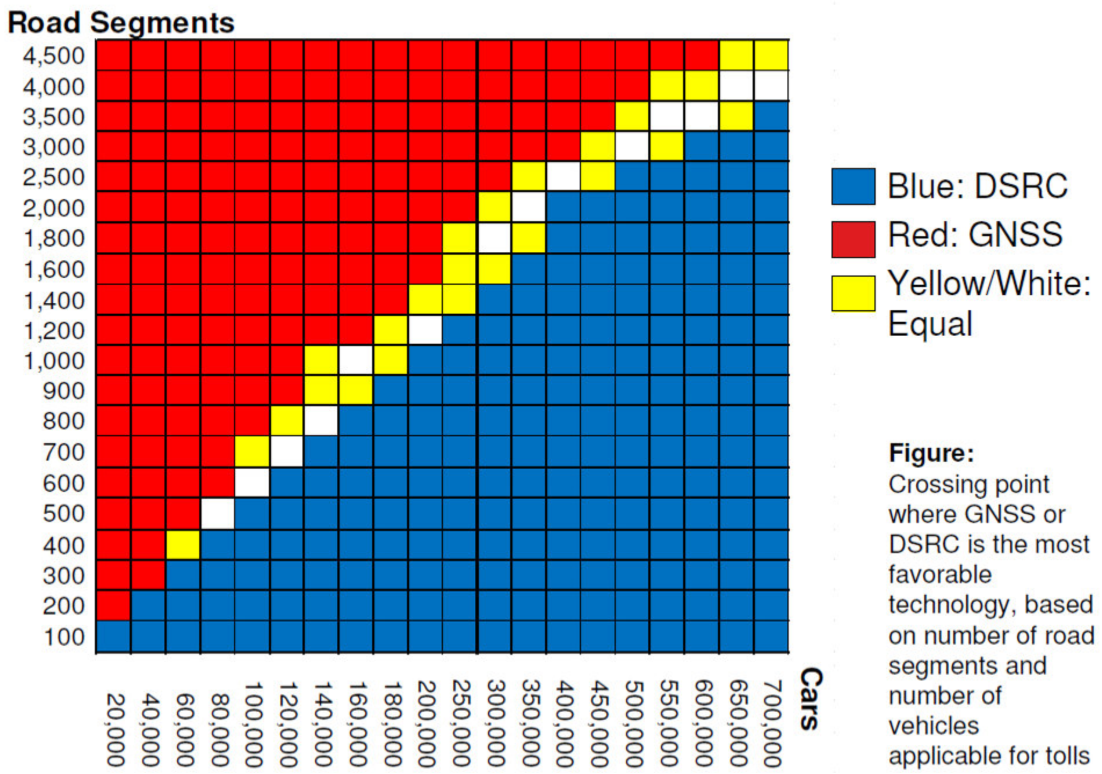
17.2.2 Access Charges
Access charges also typically apply to manage traffic into and out of city centres. Whilst the size of the cordon for access charging could be widened in order to capture orbital routes (such as the M50), this would lead to a higher level of complexity and cost in providing the numerous entry/exit points. Furthermore, the application of a single charge for journeys irrespective of the distance travelled is not in keeping with the objectives of fiscal measures which are built on polluter pays principles. As such, it is appropriate that the application of such a system is confined to small areas of city centres as a means of restraining traffic from entering those parts of the network.

The experience of Access Charging also suggests that these systems can attract a significant operating cost. In 2009/10 the London System required an operating cost of £154m for the collection of £312m in revenue. This suggests a cost of £4 for every toll collected, and is clearly a significant cost that is only implementable as a result of the high charge to road users. In Stockholm the operating cost is significantly less, mainly as a result of the automation of many of the billing processes.

17.2.3 Road Pricing Based on GNSS
Although satellite based road pricing for all vehicles is based on sound economic theory, it has yet to be implemented on anything beyond a user trial. In considering the role for GNSS systems in road pricing, Figure 17-1 shows how distance based charging is defined by the complexity of a network, and the density of traffic using that network. In areas where the extent of road infrastructure is quite high, and with low relative vehicle numbers, GNSS based systems are more appropriate means of applying distance based charging. GNSS based systems operate using in-vehicle technology which tracks the vehicle, and applies charges based on the time of travel, distance travelled and level of congestion. The system relies to a lesser extent on roadside equipment other than that used for enforcement.

Given the ability of a GNSS based system to charge on all roads, it can be difficult to define boundaries for a system other than at international crossings, where the road network is typically more controlled. This would suggest that GNSS based systems might be difficult to develop without progressing to systems with full national coverage (as was the intention in Holland). Whilst this has been done internationally, it has been restricted to HGV's.

Figure 17-1: Application of Alternative Road Pricing Technologies



This Dutch experience to date highlights the myriad of challenges in successfully bringing a project of this scale into the delivery phase (not to mention mobilisation and successful operation) and suggests that an Irish national scheme could take several years to plan and implement. We note that there remains no international experience in successful implementation of full road user charging of this nature.

Progress in the US in this area is something which should be tracked as some US States (including Minnesota and Oregon)[38] are said to be leading the way in terms of operating and trialling tolling and road user charging based on congestion pricing on the network and as a "vehicle miles tax" (VMT). It is interesting to note that the main driver in the US is the need to generate sustainable revenues for funding infrastructure, which differs in many ways from the economic language used in Europe (i.e. "*the internalisation of external costs*") to promote the same solutions. This difference may be because US analysis has identified a worrying shortfall in fuel taxes as well as a heightened focus on global climate change and the need to reduce carbon footprints.

17.2.4 Single Point and Multi-Point Tolling

Referring again to Figure 17-1, it can be seen that regions having a high volume of traffic using a limited number of roads are most suitable for conventional point-tolling. Point tolling uses physical gantries that apply charges to traffic passing them, and hence relies on the ability to capture high proportions of traffic at a single location. Nevertheless, it is difficult with such a system to impose charging on all roads due to the level of infrastructure that would need to be employed.

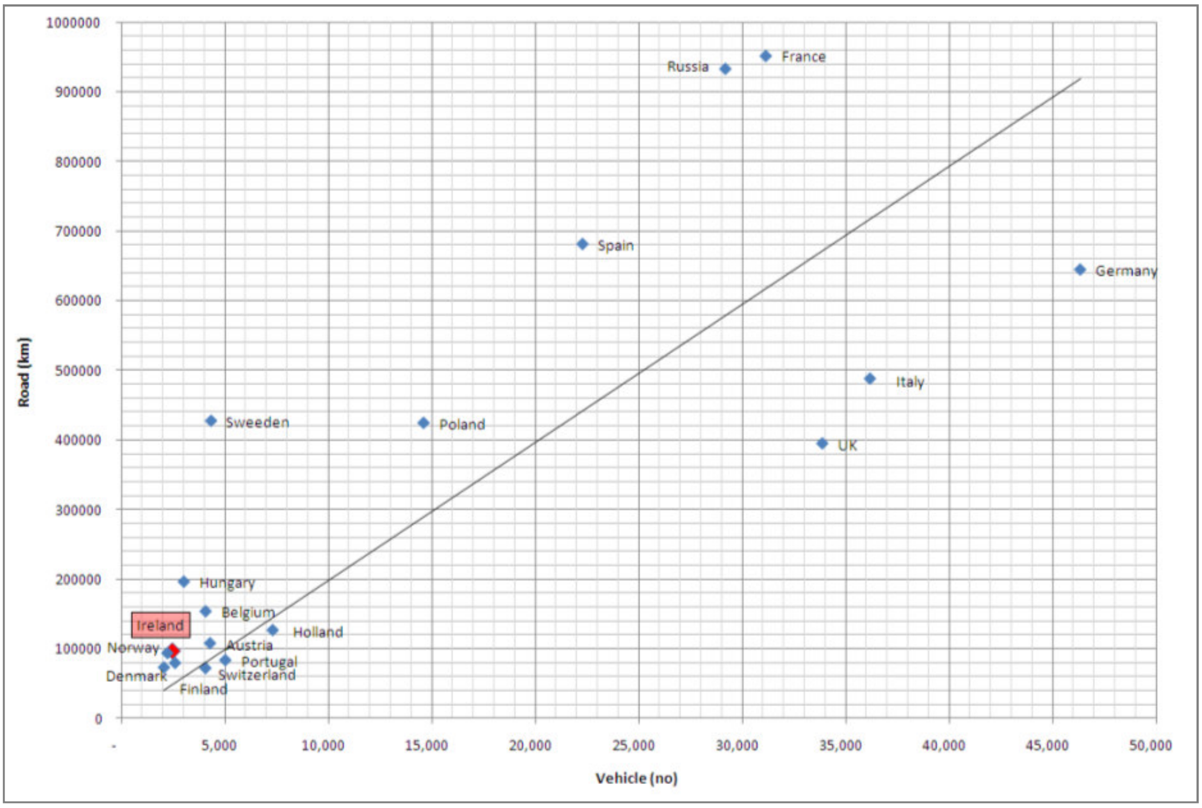
As such, the conventional and / or barrier-free systems are required to apply low but frequent tolls such that diversion rates can be minimised and hence the system can approximate a true use-based charging mechanism. In Singapore, the approach is based on tolling a selection of the more important roads which cater for a large proportion of traffic movements, but acknowledges that there remains a number of 'holes' in the system where users may not be charged.

17.3 Pricing of Roads in Ireland

In considering the most appropriate form of charging for Ireland, two key issues are relevant:

Firstly, Ireland has one of the lowest population densities in Europe, and has a level of car ownership which remains below the EU average. Figure 17-2 below plots the ratio of car ownership to network density across a number of countries, showing a broad picture of those areas which are suited to DSRC versus GNSS approaches to tolling.

Figure 17-2: Vehicle Density in Europe



Note: all units expressed in thousands

This suggests that the Irish Road network lies in the red area of the graph shown in figure 17-1, and hence the form of charging in Ireland would be most appropriate as a GNSS system. It is noted that on the basis of this comparison, DSRC tolling systems could represent a realistic option for the UK.

Secondly, however, it is noted that the majority of traffic in Ireland uses a small number of major roads, leading to geographically small areas of high demand and resulting deterioration in levels of service. In essence, if road pricing were to examine a 'subset' of roads classed as National Roads where congestion is a risk – the resulting subset would comprise a small length of road network, with a high traffic demand – essentially lying in the blue area of the graph.

It is worth recapping on the reasons for GNSS based charging, particularly in comparison to the application of fuel duty which offers a good proxy of road user charging based on the level of use.

The main argument is the inability of fuel taxation to differentiate between those areas of high and low congestion on the network, and hence the estimation of externalities. In Ireland, however, analysis of existing and future traffic demand using the National Traffic Model has suggested that congestion over the period to 2025 on the National Road Network will be relatively confined to a small number of metropolitan areas – namely Dublin, Cork, and Galway, with some localised congestion through smaller towns and cities on the remainder of the National Road Network. Accepting that fuel taxation is a relatively low cost method for collecting road user charges, it follows that GNSS pricing methods are very unlikely to offer much added benefit in any location away from these localities.

This situation may well change if the trend towards electric vehicles accelerates, as such would lead to a growing reduction in the revenue that can be collected through fuel taxation.

Finally, having concluded that Access Charges and Parking Charges can offer limited contribution to management of National Roads, it is therefore concluded that fiscal policies in urban areas can be achieved through one of the following means:

- The application of GNSS based road pricing on a regional level, with defined boundaries around the edge of the metropolitan areas. This is likely, however, to be an equally costly solution to the national system, as it would require the same level of basic infrastructure (i.e. financial systems and customer support, but with perhaps a lower number of enforcement sites); or
- The use of DSRC systems on a selection of roads. Unlike existing tolling infrastructure in Ireland, the use of DSRC as a road pricing mechanism would require a system of frequent, but lower value, tolls. This would represent a proxy of the pay-by-distance charging that is supported by the economic theories.

The main issue restricting the use of the GNSS systems is risk –the capital cost for the Dutch system was estimated at up to €2.5bn, with an operating cost of up to €1bn per annum, and was suspended in 2009. Further work would be required to fully understand the cost of implementing and managing such a system as there are no existing systems upon which estimates can be made. In addition, the management of such a system which only operates in one part of a network would be difficult.

The consideration of DSRC is therefore substantially more attractive. In this context a DSRC system would move away from the concept of single-point tolls, which traditionally seek to recoup a single high-value fee at one location in return for access to infrastructure. Single point tolling has worked well in urban areas but normally only at tunnels or bridge crossings where alternative routes are relatively long and the cost of the infrastructure is high. On urban motorways, the use of Single Point tolls is more difficult due to the shorter distances between junctions and the consequential ability of users to divert away from short stretches of road in order to avoid the toll at that point. In order to combat this effect, authorities either:

- Develop a closed system, where the payment is calculated on the basis of a recording at both the entry and exit point (closed system); or
- Develop an open system, where the toll is collected on the basis of a number of individual low-value payments at specific locations along the journey (Multi-Point).

Both these systems will be examined as a means of providing a fiscal solution for the Dublin and Cork Areas where significant investment in infrastructure has been made over the past 15 years, but where congestion remains a significant problem on the National Road Network.

17.4 Form of Pricing

Prior to examining the preferred form of tolling, an initial assumption is made that toll schemes would be applied to high quality national roads which offer considerable value to the user. At this stage, no consideration will be given to distance-based pricing of local roads within urban areas.

17.4.1 Dublin Area

The area of the road network within the Greater Dublin Area that is under consideration for fiscal solutions is outlined below in figure 17-3, and covers the Dublin metropolitan area in addition to major surrounding towns. National roads in this area comprises almost 150km of road network with close to 150 access points, supporting some 1.19m vehicle movements per day in 2010.

Figure 17-3: Greater Dublin Area Road Pricing Zone

Closed Tolling System

A closed tolling system would require tolling points at each on-slip and off-slip, with each tolling point comprising a DSRC/ANPR gantry with a supporting vehicle detection gantry. In order to maximise the accuracy of reads, a third gantry supporting additional ANPR equipment would be required.

It is possible to examine the financial case for such a system, assuming a series of per-km charges. Charges of between 5c/km and 20c/km are assumed to reflect a reasonable range of charges that might be applicable, above which excessive levels of diversion would be expected to occur. A collection cost of 50c/transaction is assumed to be appropriate based on current experience with the M50 toll (although with efficiencies the cost of collection would be substantially less). This collection cost covers the overheads associated with front and back office infrastructure, customer support and system management. The results of an assessment are outlined in Table 17-2.

Table 17-2: Financial Assessment of Closed Toll System in GDA

Charge/km	Weekday Collection Cost	Weekday Revenue
5c	€0.6m	€0.86m
10c	€0.6m	€1.71m
15c	€0.6m	€2.57m
20c	€0.6m	€3.42m

Analysis of traffic impacts suggests that any toll rate above 15c/km will start to erode the benefits of the infrastructure itself, and hence would require supporting infrastructure to manage toll avoidance effects. At a charge of 10c/km, the resulting revenue would be in the order of €1.1m per weekday, with the costs of collection being up to 35% of net revenue. By imposing requirements for pre-registration of vehicles, these costs can be significantly reduced.

The implementation cost of a closed toll system are likely to be to the order of €45m for the roadside equipment, assuming €300k per site for the costs of gantries, communications and supporting equipment.

Nevertheless, a closed system requires complete protection of the road infrastructure compatible with that normally provided on motorways. In Dublin, much of the network remains accessible from private access points, and these cannot be managed in a closed system. As such, a closed system, although worthy of consideration, will be difficult to implement pending full upgrading of the road network to motorway status, and hence should be retained as a medium term objective

Multi-Point Tolling System

A Multi-Point system can overcome these deficiencies as an interim solution. For a Multi-Point system, the complexity of infrastructure can be significantly reduced, with charges applied at a smaller number of locations spread across the network, but equating to an average charge of 10c/km for traffic movements. Individual tolls would be kept low to reduce the level of toll avoidance at particular sites. Our analysis suggests that the cost of collection as a proportion of revenue for a multi-point system will be less than for the closed system, but again with scope for significant cost reductions through improving registration and other processes.

The implementation of a multi-point toll system in the Dublin Area will be examined later in this section of the report, but as an interim measure pending future consideration of cordon pricing on the GDA motorway network.

17.4.2 Cork Area

The geography of the Cork Area is fundamentally different to that in Dublin. The level of protection of the road network is limited, and congestion is limited to a small number of locations located between Dunkettle and the Bandon Road roundabout on the N25. Examining traffic patterns in Cork City, it is clear that a large proportion of traffic on the South Ring Road uses the Jack Lynch Tunnel, and the implementation of fiscal measures at that location would impact on a high proportion of traffic movements. The implementation of fiscal measures in the form of a closed system would not be possible under the current configuration, although such may become more feasible following future upgrades to the South Ring Road.

17.5 Conclusion

In conclusion, full road pricing is a theoretically attractive model for road pricing. In addition, the technology to implement it in practice does already exist. However, there are a number of reasons why implementing such a system should be considered over the longer term rather than the shorter term including:

- There would be considerable political and legal challenges to implementing such a system. It is worth noting that the Dutch system has failed to secure final approval from the Dutch Government;
- There are no robust and proven technological solutions in full and widespread operation today. There are charging systems for HGVs but these are not national and obviously not for the full fleet of vehicles. Also as noted above, the delivery date for the Dutch system has already slipped back a number of times; and
- Other more deliverable options for 'road pricing' exist which would realise valuable revenue and assist in the management of traffic and congestion on the network in the shorter term, for example extending tolling on the M50 and the MIUs.

Delaying any decision to introduce full satellite-based road pricing would allow Ireland to benefit from improvements in the technology which will be realised as other jurisdictions make progress with deploying national charging systems. Instead, it is considered that a smaller scale electronic tolling system may provide a more cost effective solution in the Dublin and Cork Areas.

Examining an electronic tolling system, it is concluded that a closed tolling system that applies a rate of 10c/km on major roads in the Dublin Area can offer a viable long term mechanism for road pricing in the Dublin Area. Nevertheless, the network is not yet ready to accept such a system, and a lower scale multi-point tolling system represents a more attractive option. In Cork, a single point toll on the Jack Lynch Tunnel will influence a high proportion of traffic on the South Ring Road, although there may be scope for multi-point tolling or a closed system.

Chapter 18 Consideration of Multi-Point Tolling

18.1 Establishing a Distance-Based Charge for Urban Areas

18.1.1 Overview

In September 2008, the barrier tolls at the Westlink tolling facility on the M50 were replaced with a barrier-free tolling system. Although a number of payment options were made available to users, the new toll scheme was designed to offer lower tolling charges for vehicles using the more efficient technology - in this case OBUs (or Tags) in vehicles detected using DSRC. The new system arrangements give rise to a number of observations:

- Firstly, as only a single tolling point is in place, the charges are not directly related to use. In particular, a large number of users that use the M50 but do not pass through the toll facility are not subject to tolling. In addition, short distance users on this section of the M50 pay as much as long distance users. This raises the question as to whether a more distance based tolling structure would be more equitable, and also more effective for managing demand on the Motorway.
- Secondly, it is noted that toll charges are fixed throughout the 24 hours, although traffic volumes and thus journey times vary on the M50 by time of day. A time of day variable charge might thus have advantages in encouraging increased off-peak use of the motorway.
- Thirdly, the structure of charges by type of vehicle which broadly relates to the cost of the infrastructure (and of using the infrastructure) within the confines of what is affordable and acceptable, which is the traditional philosophy underpinning tolling schemes (i.e. to fund the infrastructure) is only one of many that could be introduced. These charging structures may not adequately reflect the principles that charges should reflect congestion costs and / or environmental costs.
- Finally, there is no guarantee that the toll charges are set at a level that reflect congestion costs. Thus, there could be a case for significantly increasing or reducing the toll charge levels.

As such, the M50 toll is currently set as an infrastructure charge, and offers little in the way of management of traffic through fiscal measures. Our analysis suggests that there is significant toll avoidance occurring through the Lucan/Strawberry Beds area as a result of the application of a single high-value toll on this relatively short section of motorway.

18.1.2 Economic Principles

Tolling charges may be set to maximise economic welfare, to maximise revenue, or to achieve a mix of revenue and welfare aims. For publicly owned toll roads, the emphasis is always likely to be largely on tolls that contribute to economic welfare. It is on this basis that the prescription that tolls should reflect congestion costs arises. Economic theorising about toll charges is easier to undertake in what are called first best scenarios, which assumes that all roads are to be subject to the same tolling regime. This is obviously not the case in respect of the M50, where alternative routes are not tolled.

18.1.3 Setting Optimum Prices

Economic theory suggests that traffic on roads may be expanded to the point where the marginal social benefit (MSB) of the last journey equals the marginal social cost of making it (MSC). The marginal social cost reflects the cost that is imposed on road users and society at large by an additional trip. It thus includes the cost to the individual making the trip plus, the costs imposed on other road users by that trip and the external costs imposed on society as a whole.

It should be noted that prices for road travel should be set in relation to the costs of travel and not the benefits of travel to users. It is commonplace to hear arguments that freight traffic should be favoured with low tolls because of the importance of trade to the Irish economy. However, at the margin, the benefits to the Irish economy are reflected in the road user's Willingness to Pay (WTP). To set prices below MSC for such users would be to incur a loss to society as a whole as the marginal benefits would be less than the marginal costs. The only adjustment to this rule is where there are marginal external benefits (MEB) i.e. benefits that arise to non road users.

In the past, economists took the view that MEB was likely to be small; however, recent research has concluded that MEB may be significant in some instances. MEB includes:

- Agglomeration effects;
- Increased competition in the economy;
- Increased output of firms; and
- Tax benefits arising from increased labour supply.

Research has indicated that agglomeration effects are the major element of MEB, particularly in urban areas. Such effects are likely to occur because of use of the M50, as it is both a major commuting route and also connects a number of large business districts.

In setting optimum tolls, the difference between the marginal social cost and the trip maker's own costs is usually referred to as the marginal external cost of congestion (MECC). Where MEB is insignificant this collapses to the usual rule that tolls should reflect the marginal external cost of congestion, which represent the full external costs imposed on other road users. In principle, this would include emissions, vehicle operating costs, the costs of operating and maintaining the infrastructure, and the risk of accident costs. With regard to emissions, recent analysis has indicated that emissions amount to less than 0.8 cents per kilometre for cars at speeds of 60 to 70 kph (€120 per annum based on an annual mileage of 15,000km at these speeds). Nevertheless, emissions costs are sensitive to vehicle speed changes at very low traffic speeds. This implies that the marginal social cost associated with emissions will be low except in congested conditions. Similar remarks apply to marginal vehicle operating costs, which are dominated by fuel costs, which are again insensitive to speed, except at very low speeds.

With regard to infrastructure and accident costs, UK research indicates that these elements are typically only some 12 per cent of time congestion costs. This suggests that toll charges should be set to reflect the marginal external cost of congestion (as measured by time delay) less the marginal external benefits. As there is likely to be some marginal external benefits associated with the M50, tolls on the M50 should be set somewhat below the marginal external cost of congestion.

Using the above rule, are there any insights that can be drawn with regard to the other features of M50 tolling? The first and obvious comment is that some users are not charged at all. This represents an economic sub-optimum. That is, if asked to pay a toll equivalent to the benefit derived from the use of the M50, some drivers would not use the M50. That is the value to them of using the M50 would not exceed the costs that they impose on other road users. Thus, there are clear advantages from an economic welfare point of view of applying toll charges to all users, as the roadspace would then be occupied by those who derive most value from it (including business users and freight).

A second point is that benefits arising from use of roads in urban areas could vary on different parts of the route. This is because traffic volumes and more particularly, volume-capacity ratios differ. Tolls should be ideally differentiated by link, where estimated volume and volume/ capacity ratios are shown to vary. Where volumes are low, this could indicate a very low toll charge i.e. perhaps one not worth collecting.

Thirdly, (MECC-MEB) varies by time of day. Lower values occur at off-peak hours and this argues strongly for a time of day variation in pricing.

As such, an optimum tolling structure would involve extension of tolls to all users and the differentiation of tolls by vehicle type, road link and time of day where the MECC varies with these elements.

Furthermore, the relative tolls for different vehicle types should broadly reflect their relative MECCs. Passenger Car Unit (PCU) factors reflect the impact of different vehicle types on road capacity and thus reflect their impact on congestion. The PCU factor for cars is obviously unity, while those for goods vehicles are usually in the range of 1 to 2.5, depending on vehicle size and the level of congestion. The US Highway Capacity Manual suggests an average factor for truck of 1.5 for roads with good gradient characteristics. More recent research indicates that this should be increased to 2.5 for congested road conditions. Currently, the toll rates in Ireland for HGV's are between twice and three times those for cars. Thus, the rates are thus slightly higher, but nevertheless reasonably well aligned with the relative MECCs.

18.1.4 Calculating a Distance-Based Charge

Based on an analysis of single-lane speed flow relationships for the M50, it has been possible to estimate the MECC at current and anticipated traffic volumes. With regard to the assumptions, the Value of Time (VoT) is the mandated value for project appraisal updated to 2008 prices. That is, they are average values for the country as a whole: relevant road users would probably have a higher value than this.

Table 18-1: Inputs for MECC Calculation

Variable	Value	Source
VOT work time (€ per hour) 2008 prices VOT non-work time (€ per hour)	33.6 8.3	DOT value updated
Cars: proportion work journeys (%) Trucks: proportion work journeys (%)	10 100	Assumption
Vehicle occupancy cars Vehicle occupancy trucks	1.3 1.1	COBA default
Car proportion in traffic flow LGV proportion in traffic flow Truck proportion in traffic flow	80 8 12	Traffic counts/COBA defaults
PCU factors Car LGV Trucks	 1 1 2	International literature
Current peak hour speeds (kph)	65	Baseline Report
Current maximum hourly traffic volumes	3,600	NRA Traffic counters

Based on these inputs the MECC can be calculated for current traffic volumes as follows:

- Cars/:LGVs : 6 cents per kilometre
- Trucks: 11 cents per kilometre

The implied toll rates for the M50 are set out in Table 18-2 and refer to the MECC for a journey the full length of the M50. The analysis suggests a MECC based toll of €2.10 for cars, €2.10 for LGV's and €4.2 for trucks. The value for cars is the same as the current toll (€2.10 versus €2.00), but the value for LGVs and HGV's are lower than existing tolls.

Table 18-2: Charges for M50 (€) based on MECC estimates

Traffic Level	Cars/LGVS	Trucks
Current	2.1	4.1
Future	6.2	12.4

Whereas current tolls are in line with existing charges for the full length of the M50, in the future, optimum toll rates will be determined by the volume of traffic and the nature of speed flow relationships. Typical speed flow relationships indicate that a sharp rise in toll rates may be justified as M50 traffic grows.

18.1.5 The Ratio of Car and Truck Tolls

Earlier it was suggested that the current relative tolls for cars and trucks are close to their relative MECCs. The analysis of second best pricing rules suggests that tolls on trucks should be somewhat lower than is currently the case. It is generally held that truck traffic is more sensitive to toll rates than car traffic. This implies that if tolls are to be raised above MECC, then the proportionate increase should be lower for trucks rather than cars. As such, where there is a revenue target to be met, this should be achieved by raising tolls on cars proportionately more than on trucks.

18.2 Establishing a Distance-Based Charge for Rural Areas

18.2.1 Overview

In order to illustrate the potential application of a national distance-based tolling system, the M7/M8 route between Dublin and Cork has been used as a case study. The overall distance from the M50/N7 Red Cow Junction in Dublin to the N25/M8 Dunkettle Junction in Cork is 242 km. As previously highlighted in Section 4, there are existing tolls on the route at Fermoy Bypass (€1.90) and on the M7/M8 Portlaoise to Cullahill Scheme (€1.90). These combined tolls amount to a toll of €3.80 for a combined tolled length of 46km of the overall Cork / Dublin route. Nevertheless, 196km of the route remains untolled.

18.2.2 Analysis of Willingness to Pay

An assessment has been carried out to determine the distance based toll that could potentially be introduced on the M8. A model was developed for the task which firstly looked at the generalised cost calculation for both the tolled route and the most direct non tolled route between Cork and Dublin. The generalised cost was considered to primarily be a function of the in vehicle time (or journey time), the value of time (depending on trip purpose) and the toll fare charge. Vehicle fuel charges were excluded as the variance between the route lengths was not hugely significant. Similarly other externalities such as pollution and congestion were excluded in the interests of simplicity and the expected insignificance of the variance between the relevant routes.

Once the generalised cost was calculated a binary logit function was carried out to establish the probability of motorists selecting the tolled route. The exercise was carried out for both commuter and working trip purposes to understand the effect of this variation on route selection. Once this was completed it quickly became clear the introduction of a Route Quality Factor (to account for the preference by users to travel on higher quality roads) and interchange penalty (to account for the effect of physically coming off the motorway onto a lower quality road) to the generalised cost was required to reflect the tendency of motorists to stick to the more direct route. Following several iterations a Route Quality Factor of 0.8 and an interchange penalty of €3 were selected.

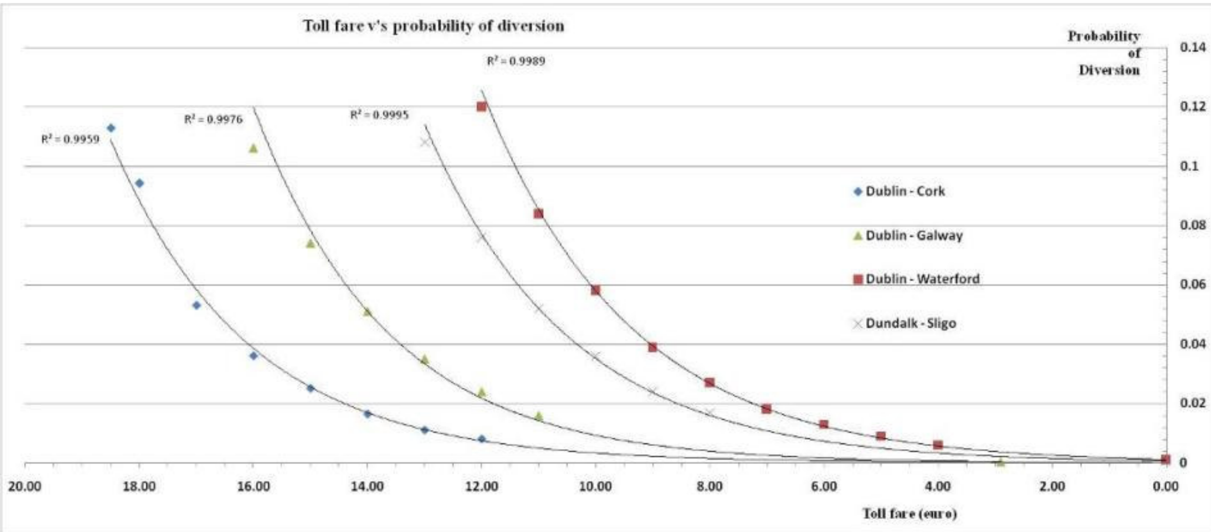
At the time of the analysis, the only toll charge on the Cork to Dublin route was €1.90 at Fermoy. The model indicates a very high probability that a motorist undertaking this journey will pay the toll to continue on the most direct route. Interestingly the model indicates if the toll were increased to €18.50 a reduction of traffic flows in the order of 11% could be expected. Reducing this charge to €10 would not be expected to generate a significant reduction in the traffic flows on the main route.

Test 2 involved a journey from Dublin to Waterford. This route is not currently tolled. The model indicates a charge of €4 would not be expected to generate a significant reduction in the traffic flows on the main route. The charge would need to increase to €12 to cause 10% of traffic to move away from the main route.

Test 3 involved a journey from Dublin to Galway. Currently the toll charge on this route is €4.70. The model indicates a charge of €9 would not be expected to generate a significant reduction in the traffic flows on the main route. If a toll of €16 where introduced a reduction of traffic flows in the order of 10% could be expected

Finally, test 4 involved a journey from Dundalk to Sligo. Currently this route is not tolled and involves a lengthy journey through Monaghan, Clones, and Enniskillen. A direct route would deliver motorists with a potential average speed of 110kph - a toll of €16 would reduce flows to the order of 10%. A €9 charge would not be expected to generate any significant reduction in the traffic flows on the main route.

Figure 18-1: Behavioural Response to Tolls on Inter-Urban Routes



It is accepted that these exercises are indicative only, and are undertaken simply to understand the likely behavioural response based on fixed demand. It is likely that tolls at this level would lead to a reduced level of trip making activity, or transfer to bus or rail (indeed, this is the general objective of charging – namely that users are encouraged to consider the value of their trip before deciding to travel).

18.2.3 Route Costs

The existing cost per km of motorway was established for the M1, M4 and M8 motorways. This cost relates to the section of motorway that can only be travelled by paying the toll i.e. sections of motorway that can be travelled without paying the toll have been excluded.

Table 18-3: Potential Inter-Urban Route Costs

Route	Length of toll section (km)	Existing Charge (Euro)	Existing Cost Rate (euro per km)	Corridor Length (km)	Suggested Cost (Euro)	Suggested Cost Rate (euro per km)
M4	31.193	2.90	0.09	218	9	0.04
M8	17.3	1.90	0.11	254	10	0.04
N9	**-**	-	-	164	4	0.024

The above table demonstrates that by moving from a point to a distance based tolling system the actual cost (km per euro) is reduced. The analysis suggests that a distance based charge of less than 5c per km might be the lower limit for distance based tolling on inter-urban roads where an alternative, parallel route exists.

18.2.4 Conclusion

The analysis gives some useful outputs for discussion. The graphical representation of the outputs above gives an indication of anticipated effects of changes to tolling fares. The r^2 value indicates the trend line fitted represents a good fit to the data. However the model is particularly sensitive to changes in average journey speed as this feeds directly into the generalised cost of the particular journeys.

Whilst the technology and legal requirements to establish a distance based tolling system between major centres of population on the major inter-urban network is achievable in the medium term, it is noted that the traffic flows along these major routes would be key to establish the economic justification for deploying significant technology to cover long distance corridors.

Furthermore, current DSRC and Video based Open-Road Tolling systems can be expensive to operate if a full scale system (e.g. backoffice and customer management operation) is established to support a relatively small number of toll points and the high proportion of occasional users who are not incentivised to register and use the more efficient options. Although in progressing to multi-point systems it is likely that significant efficiencies can be achieved, it is likely that the cost of collection would remain in the region of €0.25 to €0.50 per transaction (allowing for the higher costs associated with non-tag users). As such, the collection of tolls is constrained by the need to collect higher individual tolls at each point, although this conflicts to some extent with the objectives of the Traffic Management Study. In the case of the M8, there are in the region of 30 road links making up the journey from Dublin to Cork, suggesting an average of €0.30 per link to generate a €10 end to end toll. This would likely be a costly approach to tolling, and hence unfeasible for a DSRC / Video based system.

Instead, it is likely that any inter-urban tolling might be best achieved through the provision of a small number of individual toll charges (€1.30 is a useful benchmark as it corresponds with the current M3 tolls), at those locations where environmental impacts are not likely to be significant. Nevertheless, such would be likely implemented as an infrastructure charge, given the ability of fuel taxation to capture the MECC associated with travel in uncongested areas.

18.3 Distance Based Charging through Multi Point Tolling

Chapter 17 has highlighted that Multi-Point Tolling can prove wholly appropriate for tolling subsets of the road network where the extent of the road network is limited, and where those sections of road carry a substantial volume of traffic. Given the concentration of traffic demand in a small number of congested urban areas, the discussion concluded that a national road pricing system using satellite technology is not warranted. Instead, fuel duties set at an appropriate level provide a successful means of capturing distance-based charges in rural and/or uncongested areas, with focused road pricing using DSRC / Video systems being most appropriate in the congested locations (albeit on national roads only).

Nevertheless, an assessment of the Major Inter-Urban routes has highlighted that although road users would be willing to pay €10 and above for an inter-urban trip on a high quality road, that the cost of collection of such a fee using DSRC link-based tolling between each junction could be prohibitive on the basis of current technology. As such, the following role can be identified for Multi-Point Tolling;

- It should focus on the areas of highest demand, where there is existing or forecast congestion over the appraisal period;
- It should be designed such that the cost of the toll collection can be minimised (through reduction in the number of toll points and efficiencies in the cost of collection);
- The toll level should be set at a nominal level which will not lead to significant levels of inappropriate diversion away from the main route (i.e. it should continue to offer value from the use of the infrastructure); and
- Consideration should be given to proxy multi-point tolling, where tolls are spaced at reasonable distances along a corridor, but may not necessarily capture each individual road link along that corridor.

These guidelines have been used to identify a strategy for Road User Charging in the Greater Dublin Area.

Chapter 19 Road User Charging Options in Ireland

19.1 Introduction

This Chapter examines the most likely configuration of Multi-Point Tolling in the Greater Dublin Area. The discussion examines the M50 and the Dublin Radial Routes as separate entities, developing a possible tolling strategy for each which considers toll levels, cost of collection, diversion and resulting traffic and environmental impacts. The final tolling strategy is presented as an amalgamation of the preferred strategy for each area.

19.2 The M50 Dublin Ring

19.2.1 Existing Conditions

The M50 has, in recent years, undergone a significant upgrade and supports a strong level of growth in traffic demand since 2008. The upgrade was completed in 3 phases, with Phase 2 being the last section completed in 2010.

The data for understanding the existing conditions is based on traffic counts and journey time observations undertaken in January 2010 which account for the upgrade between the N81 and N3, but with works still in place along much of the remaining sections. Data from the 2010 traffic counts are outlined below.

Table 19-1: M50 Traffic Flows (January 2010)

Junction No's	Junction Names	Abbreviation
J3 – J4	M1 to Ballymun	M1 – BMN
J4 – J5	Ballymun to N2	BMN – N2
J5 – J6	N2 – N3	N2 – N3
J6 – J7	N3 – N4	N3 – N4
J7 – J9	N4 – N7	N4 – N7
J9 – J10	N7 to Ballymount	N7 – BMT
J10 – J11	Ballymount to N81	BMT – N81
J11 – J12	N81 to Firhouse	N81 – FIH
J12 – J13	Firhouse to Ballinteer	FIH – BAT
J13 – J13	Ballinteer to Sandyford	BAT – SAF
J13 – J15	Sandyford to Leopardstown	SAF – LEP
J15 – J16	Leopardstown to Carrickmines	LEP – CAM
J16 – J17	Carrickmines to Cherrywood	CAM - CHW

Figure 19-1: 2010 AM Peak Traffic Flows on the M50 (northbound)

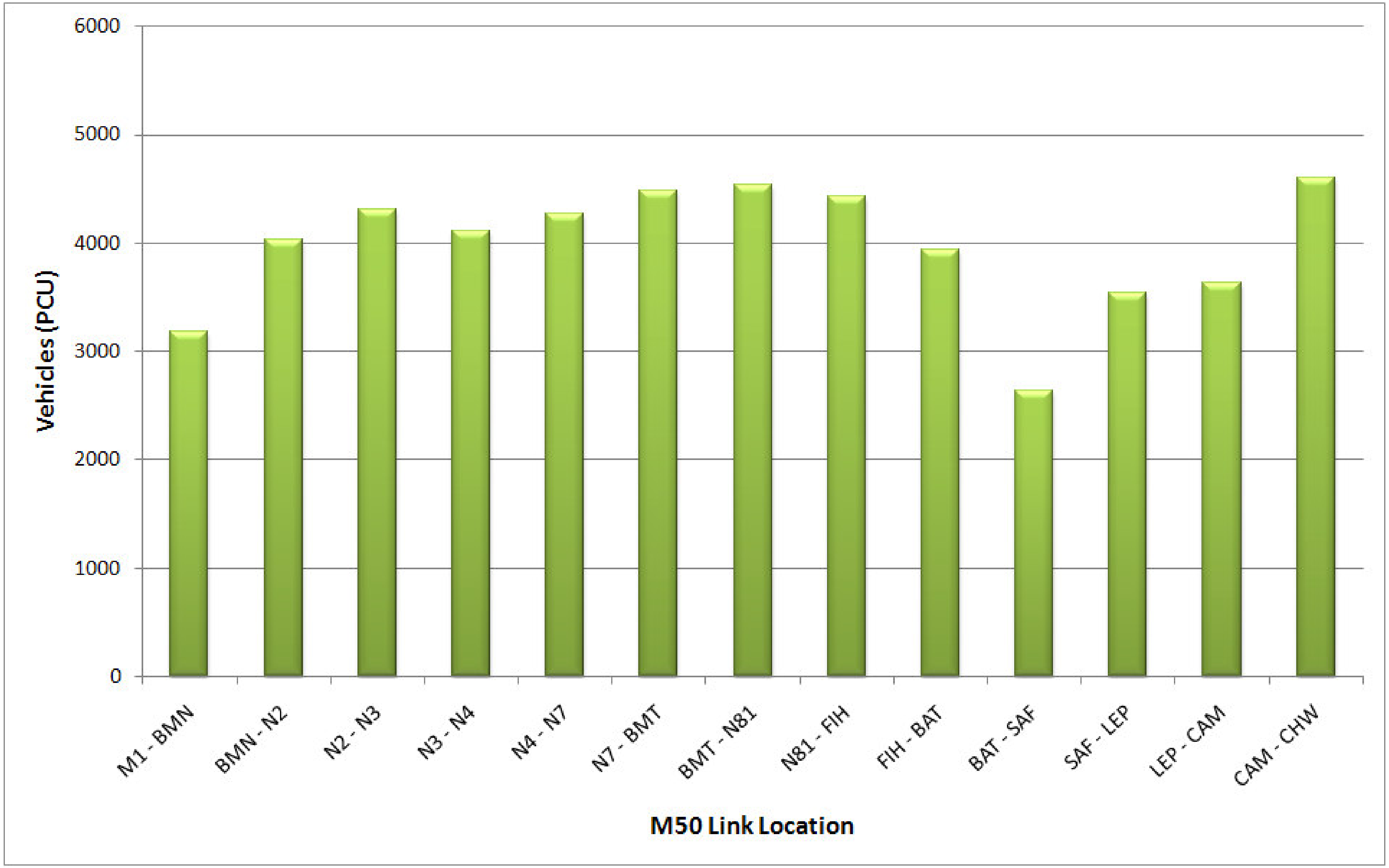


Figure 19-2: 2010 AM Peak Traffic Flows on the M50 (southbound)

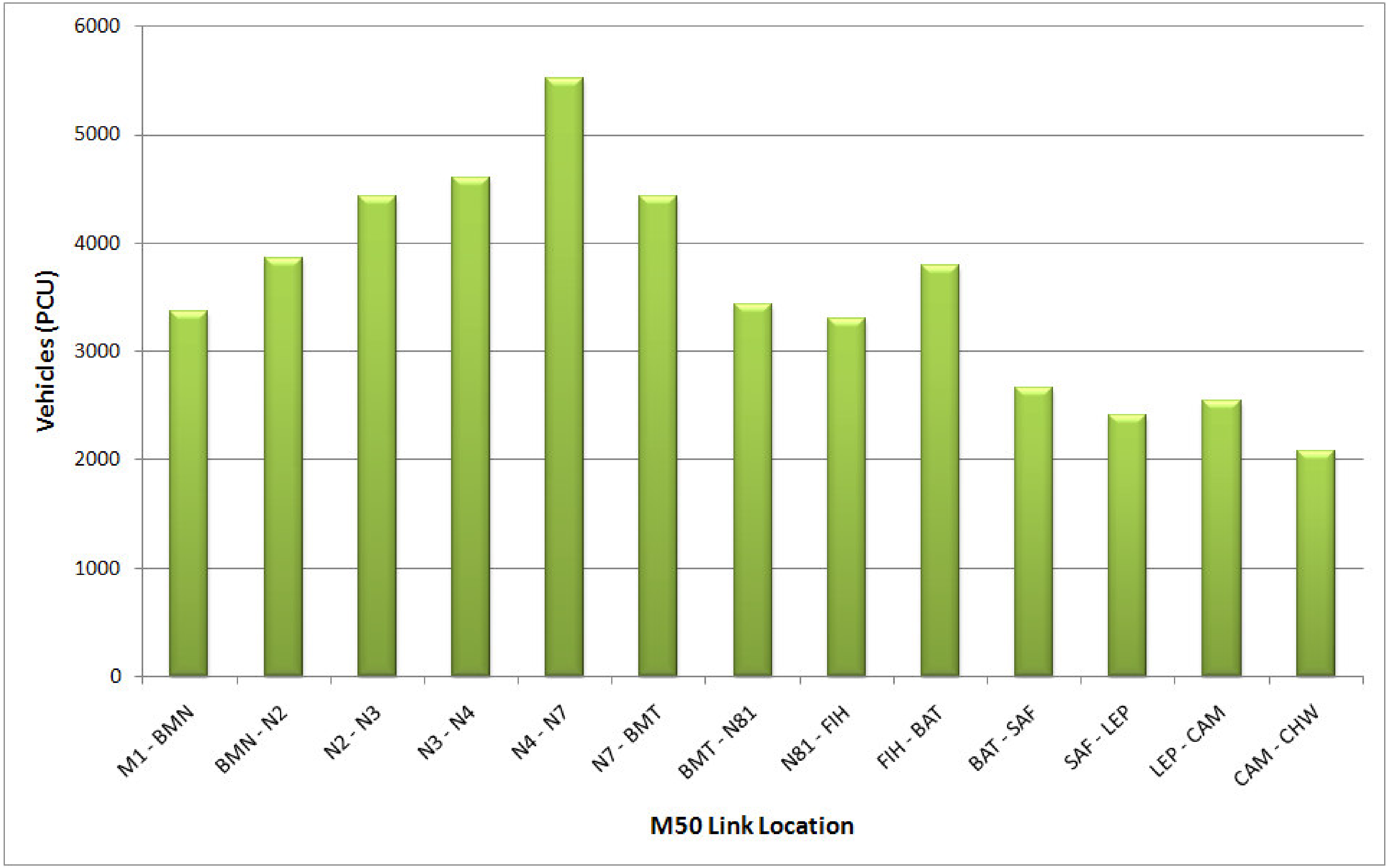
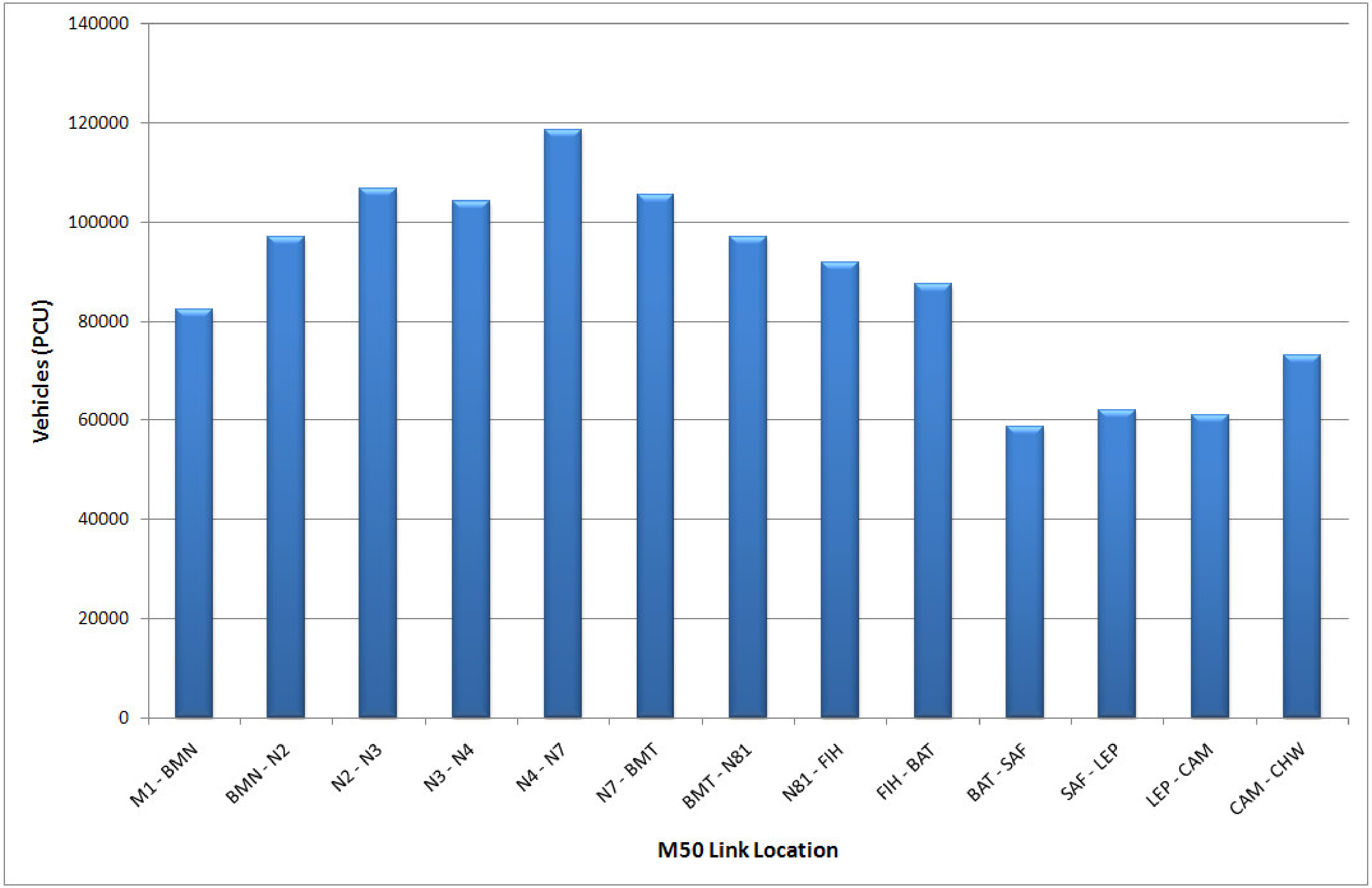
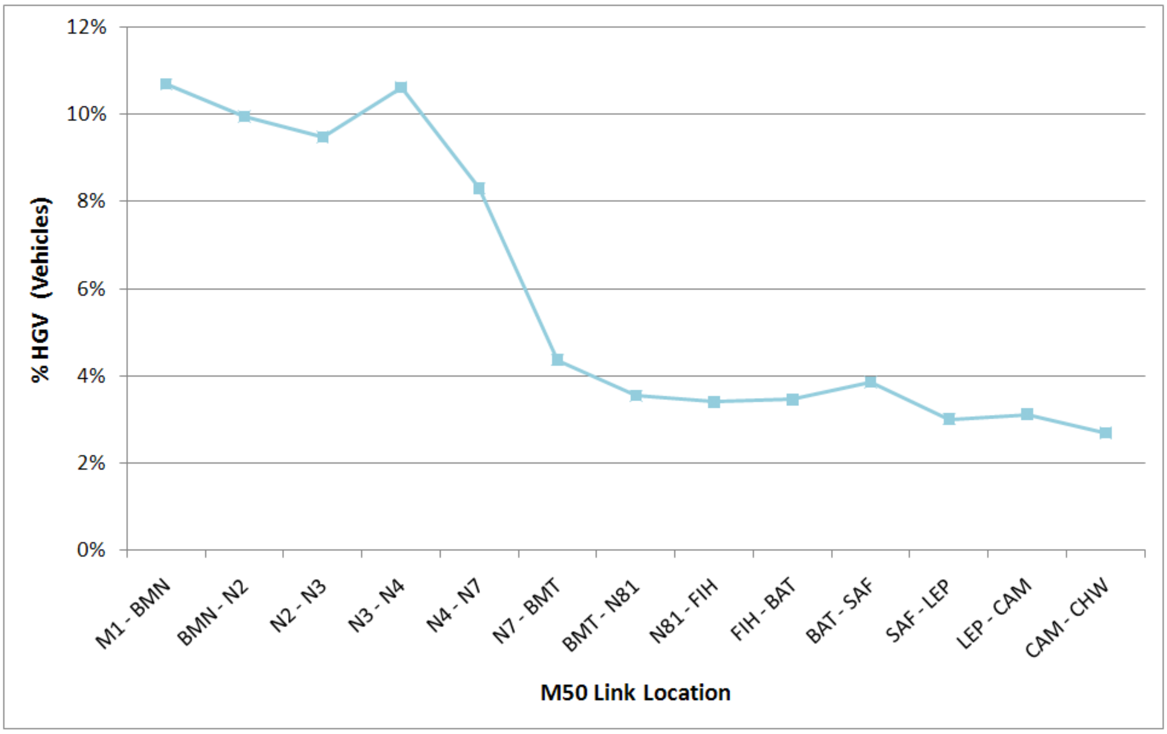


Figure 19-3: 2010 (AADT) Traffic Flows on the M50 (Two Way)



The proportion of HGV's has also been calculated and is outlined in Figure 19-4 below. The proportion of HGV activity is highest between the M1 and N4, decreasing substantially on the southern sections.

Figure 19-4: 2010 HGV% along each section of the M50



19.2.2 Traffic Modelling

An AM Peak SATURN assignment model has been developed to reflect demand as observed in 2010 throughout the M50 and along the major radial routes. The M50 Traffic Model has been developed to understand the implications of road user charging proposals on the M50 and key radial routes feeding into it. It has been based on the traffic data collected in January 2010, and is therefore a 2010 Base Year Model of the Greater Dublin Area, but with a specific focus on the national primary roads.

In order to represent the impacts of tolling, the model is based on a number of user classes, and with income segmentation applied to commuting traffic. The starting point for the income segmentation has been an analysis of the income effects on value of time. Suitable VoT values were calculated based on the earnings of the average person at work (~€45,000). Using this as a starting point and assuming direct proportionality of VOTs with net income for leisure and commuting purposes and gross income for work purpose, yielded the following income related values.

Table 19-2: Value of Time Calculations based on Income

Net Income per household	Gross Income per household	VoT Leisure (Market Prices)	VoT Commuting (Market Prices)	VoT Work (Market Prices)
€ 24,041	€ 24,041	€ 5.37	€ 5.91	€ 11.00
€ 31,633	€ 34,726	€ 6.70	€ 7.37	€ 15.89
€ 34,892	€ 40,068	€ 7.37	€ 8.11	€ 18.33
€ 39,833	€ 46,747	€ 8.20	€ 9.02	€ 21.39
€ 43,485	€ 53,425	€ 9.04	€ 9.94	€ 24.44
€ 47,024	€ 60,103	€ 9.87	€ 10.86	€ 27.50
€ 54,306	€ 73,459	€ 11.54	€ 12.69	€ 33.61
€ 61,871	€ 86,815	€ 13.20	€ 14.52	€ 39.72
€ 69,451	€ 100,171	€ 14.87	€ 16.36	€ 45.83
€ 88,422	€ 133,562	€ 19.04	€ 20.94	€ 61.11
€ 103,481	€ 160,274	€ 22.37	€ 24.61	€ 73.33
€ 118,553	€ 186,986	€ 25.71	€ 28.28	€ 85.56

The information above was utilised in conjunction with the POWCAR household income data to ascertain a suitable VoT for each user class in the model. It was found that for car users the Average Gross Household Income in the POWCAR dataset was €68,935. The data in Table 19-2 was then interpolated for the various VoT to ascertain the average VoT for each user class.

Table 19-3: VoT for each user class used in the 2010 Model

Trip Type	Outline	Value of Time (PCU)
HGV	Developed based on average income per household in POWCAR (assuming 1 HGV=3 PCU). Based on **Work VoT**.	€ 10.52
Home Based Work	Developed based on average income per household in POWCAR. Based on **Work VoT**.	€ 31.55
Commute Income 1	Developed based on average income in income band 1 per household in POWCAR. Based on **Commuting VoT**.	€ 9.95
Commute Income 2	Developed based on average income in income band 2 per household in POWCAR. Based on **Commuting VoT**.	€ 13.66
Commute Income 3	Developed based on average income in income band 3 per household in POWCAR. Based on **Commuting VoT**.	€ 16.27
Commute Income 4	Developed based on average income in income band 4 per household in POWCAR. Based on **Commuting VoT**.	€ 21.49
Other	Developed based on average income in income per household in POWCAR. Based on **Leisure VoT**.	€ 14.88
Business	Developed based on average income per household in POWCAR. Based on **Work VoT**.	€ 31.55

Before any analysis, the M50 Traffic Model was utilised to understand the patterns of existing traffic that use the M50, highlighting those junction to junction movements that are most highly used. This information is summarised below in Figure 19-5. The dominance of movement to and from the M1 is noted, particularly from the N3, N4 and N7, which places considerable pressure on the Northern Cross.

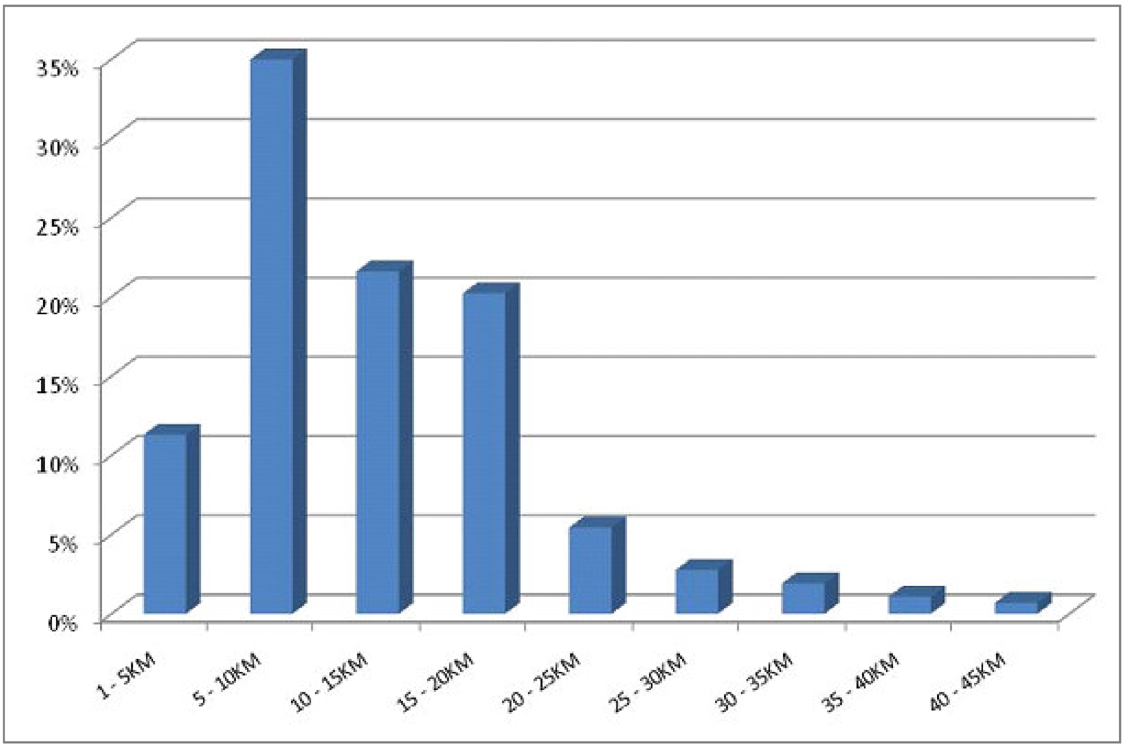
Also evident, however, is the relatively large number of short distance trips along the Southern Cross in the vicinity of Ballinteer, Sandyford and Carrickmines. The provision of alternative routes to the M50 is poor in these areas as a result of the significant topographical constraints. Consequently, the M50 supports a higher local distributor function in comparison to the northern sections.

Figure 19-5: AM Peak Traffic Movements between Interchanges (PCU)

	M1	BMN	N2	N3	N4	N7	BMT	N81	FIH	BAT	LEP	CAM	CHW	N11
M1		611	678	703	314	612	273	94	32	24	4	39	19	45
BMN	675		221	175	133	438	148	29	18	4	2	5	1	14
N2	514	428		181	344	595	253	91	25	30	3	43	25	28
N3	1056	501	335		198	287	115	37	14	21	2	19	6	14
N4	392	229	268	299		556	619	274	66	78	19	176	51	158
N7	346	189	255	301	487		539	460	105	151	19	146	110	141
BMT	186	26	35	74	156	99		102	98	67	33	117	38	137
N81	91	61	52	123	217	377	205		11	252	108	207	197	354
FIH	61	31	31	79	161	198	104	217		263	58	284	129	147
BAT	38	19	34	78	195	230	86	200	97		162	27	24	24
LEP	48	34	37	104	152	280	83	218	81	201		1041	17	52
CAM	22	17	18	41	40	93	29	85	35	145	42		348	400
CHW	26	22	10	47	58	183	53	76	2	125	47	44		0
N11	29	25	28	73	94	242	66	151	27	259	1039	759	320	

The M50 Traffic Model was also interrogated to calculate the distribution of trip length for all movements using the M50 corridor. Figure 19-6 presents a distribution of distance travelled on the M50 during the AM Peak.

Figure 19-6: Distribution of Trip Length on the M50 during the AM Peak Hour

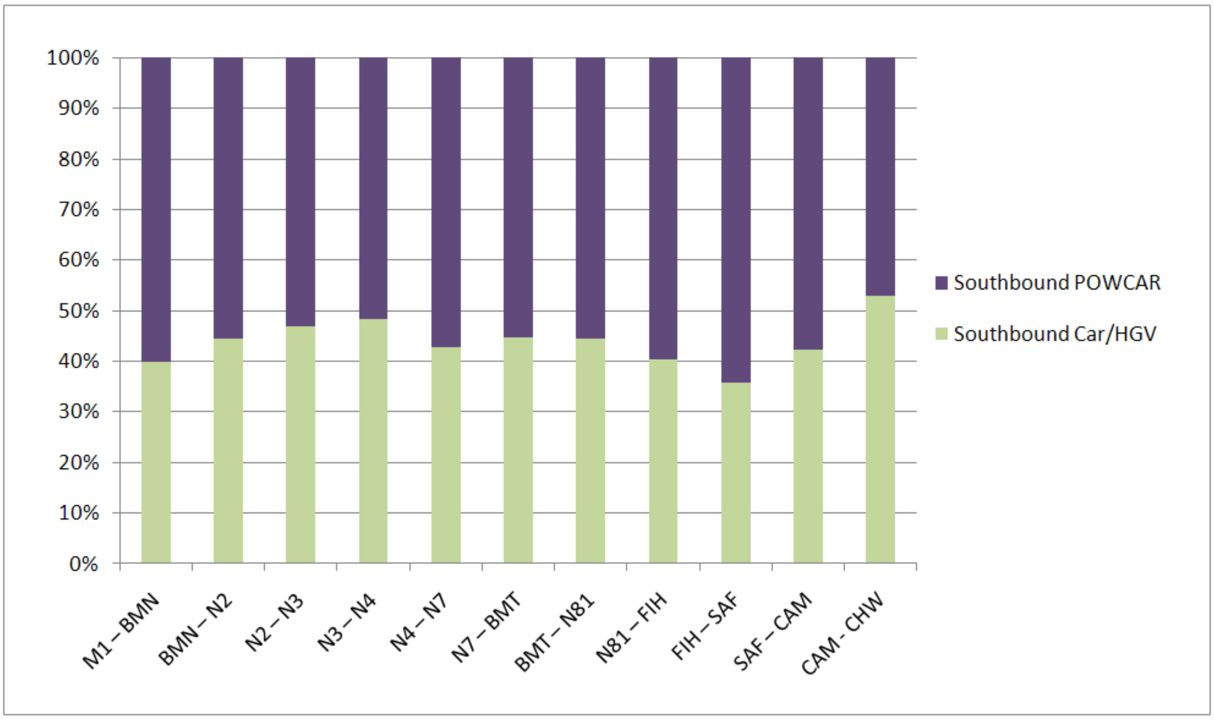


This analysis highlights the high level of short distance trips on the M50, with some 45% of trips travelling 10km or less. This equates to a total distance of between 1 and 2 junctions. Less than 10% of trips on the M50 travel distances greater than 20km, which equates to approximately half the length of the scheme, or the approximate distance from the M1 to the N7.

Traffic composition provides a useful indicator of the function of the M50. Using the Model, traffic composition using the M50 during the AM Peak Period is outlined below in Figure 19-7 and 19-8. The results demonstrate that the section of the M50 from the N7 to the M11 provides a strong commuting function during the morning peak period. Commuting traffic (POWCAR) represents up to 70% of traffic volumes, as compared to approximately 55% on sections of the Northern Cross.

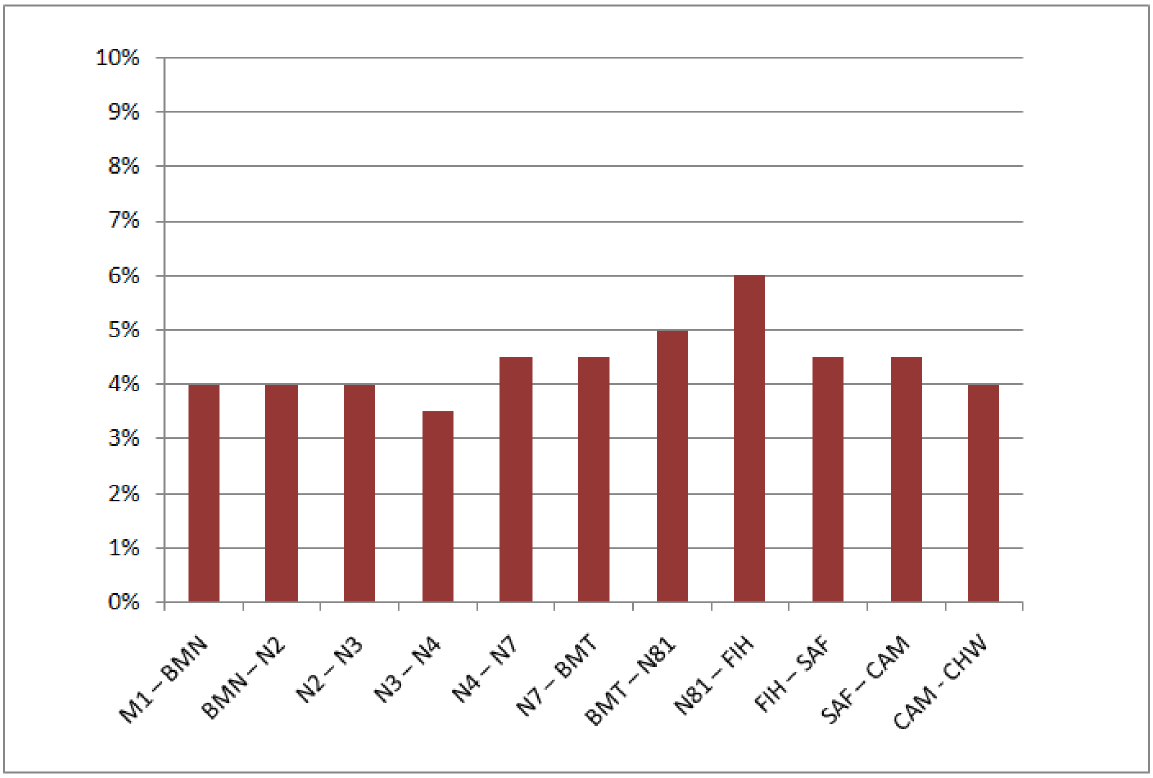
Figure 19-7: M50 Traffic Composition (Northbound AM Peak)

Figure 19-8: M50 Traffic Composition (Southbound AM Peak)



As an additional assessment, the proportion of AM Peak commuting trips as compared to the 24-hour total traffic flow provides a further indication of the dependence of the road as a commuting route, with lower proportions suggesting that the corridor provides other important non-commuting functions throughout the day. The relative proportion for each section of the M50 is outlined below.

Figure 19-9: M50 Weekday AM Peak Commuting Proportion (2-way)



The results highlight the strong commuting dependence on the M50 between Ballymount and Carrickmines, with a particular dominance of commuting in the vicinity of the N81 and Firhouse interchanges.

19.2.3 Future Year (2025) Conditions

A number of forecast scenarios are available to project traffic models into future years. The NRA have recently derived a set of high, medium and low growth forecasts for use in scheme appraisal, with the high growth scenario being roughly consistent with the population projections set out in the Regional Planning Guidelines. A comparison of growth between the NRA and that used in the National Transport Authority transport models is outlined below.

Table 19-4: Comparison of Future Forecast Population

Dublin	2008	2010	2016	2022	2025
NTA	**1,217,800**	**1,256,900**	**1,361,200**	**1,464,200**	
NRA High Growth		1,274,997	1,434,249	1,583,184	1,640,590
NRA Medium Growth		1,193,771	1,245,557	1,307,870	1,334,665
NRA Low Growth		1,193,653	1,215,804	1,235,852	1,253,746
Dublin & Mid East					
NTA	**1,732,300**	**1,796,900**	**1,955,800**	**2,103,900**	
NRA High Growth		1,819,213	2,068,343	2,294,079	2,383,814
NRA Medium Growth		1,717,872	1,830,833	1,944,650	1,994,358
NRA Low Growth		1,715,284	1,790,448	1,854,447	1,895,385

The NTA forecasts for the Dublin region roughly equate to the NRA high growth forecasts for 2016, but lying roughly mid-way between medium and high for 2022. On this basis, it was considered that the growth used in the NTA transport model might reflect a reasonable, but perhaps slightly optimistic view of population by 2025. Traffic growth over the period to 2025 in the M50 Traffic Model is outlined below in Table 19-5.

Table 19-5: Segmented Matrix Totals

Matrix Segment	2010 AECOM	2025 AECOM	% Difference
HGV	20,730	30,887	49.0%
Home Based Work	2,735	3,708	35.6%
HometoWork Income 1	1,786	2,251	26.0%
HometoWork Income 2	24,441	31,174	27.5%
HometoWork Income 3	66,154	88,109	33.2%
HometoWork Income 4	88,135	117,987	33.9%
Other	11,487	15,175	32.1%
NonHomeBasedWork	19,251	26,902	39.7%
TOTAL	**234,719**	**316,193**	34.7%

The forecast traffic flows on the M50 are shown in Figures 19-11 to 19-14. The data shows the future expected traffic flows, how this compares with base year traffic flows, and an indication of flows per lane to highlight any potential capacity pressures. The data shows that a number of links exceed the upper capacity limit of 1,800 vehicles per lane by 2025.

Note that this excludes the effect of induced demand which is likely to materialise as a result of land use and journey planning responses to the recent upgrades – such increases have already occurred with traffic growth of some 15% over the period from 2008 to early 2011.

Figure 19-11: 2010 AM Peak and AADT Traffic Flows on the M50

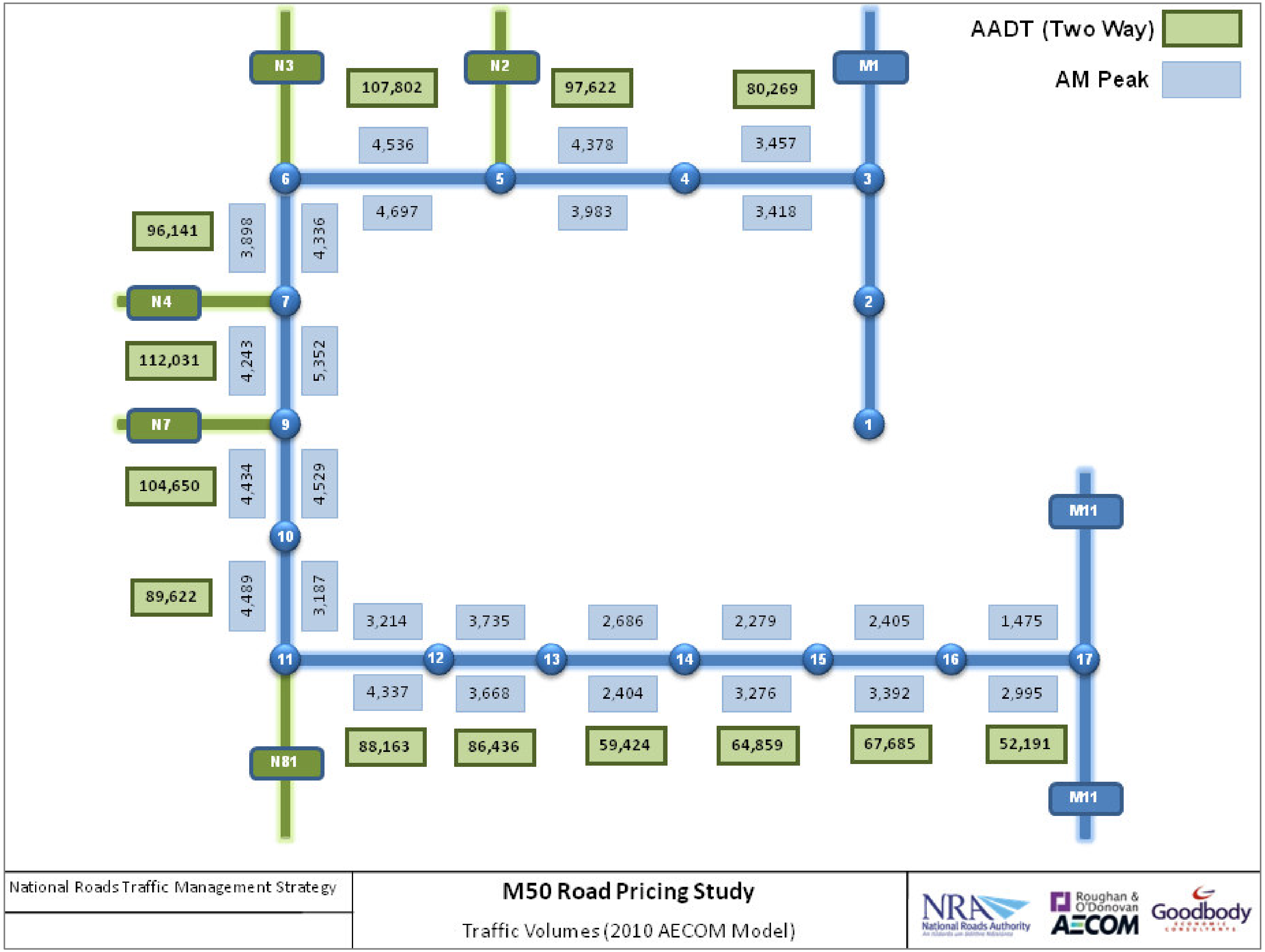


Figure 19-12: 2025 AM Peak and AADT Traffic Flows on the M50

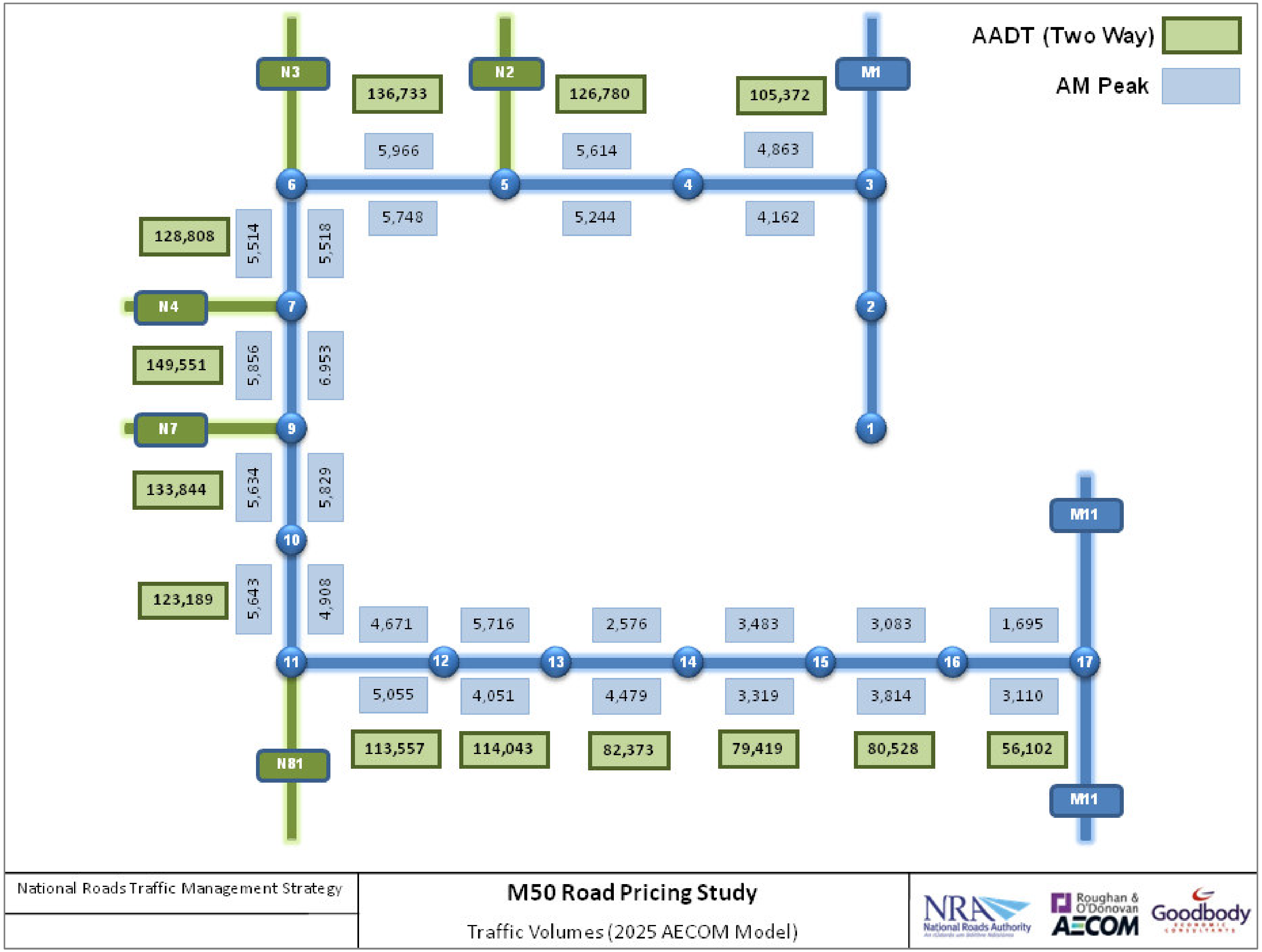


Figure 19-13: Northbound M50 Traffic Flows per lane

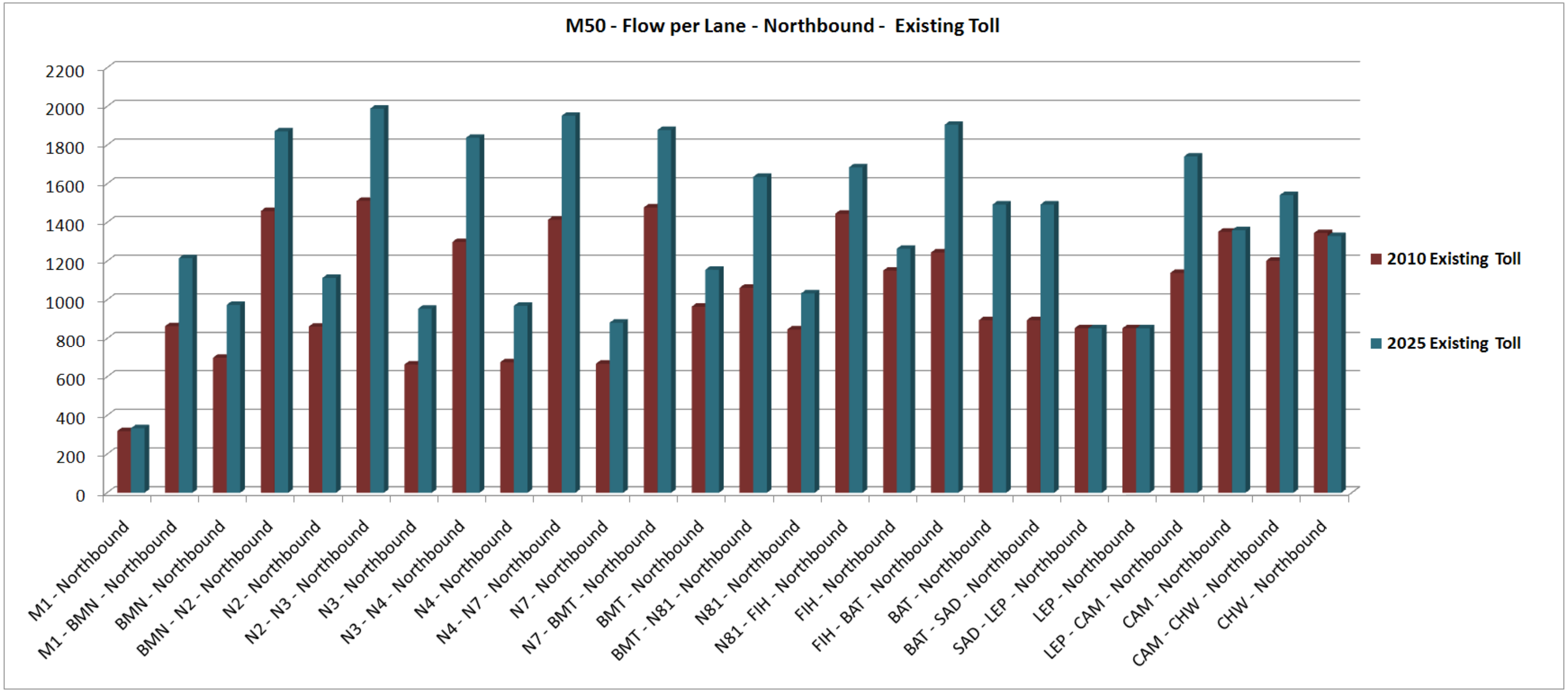
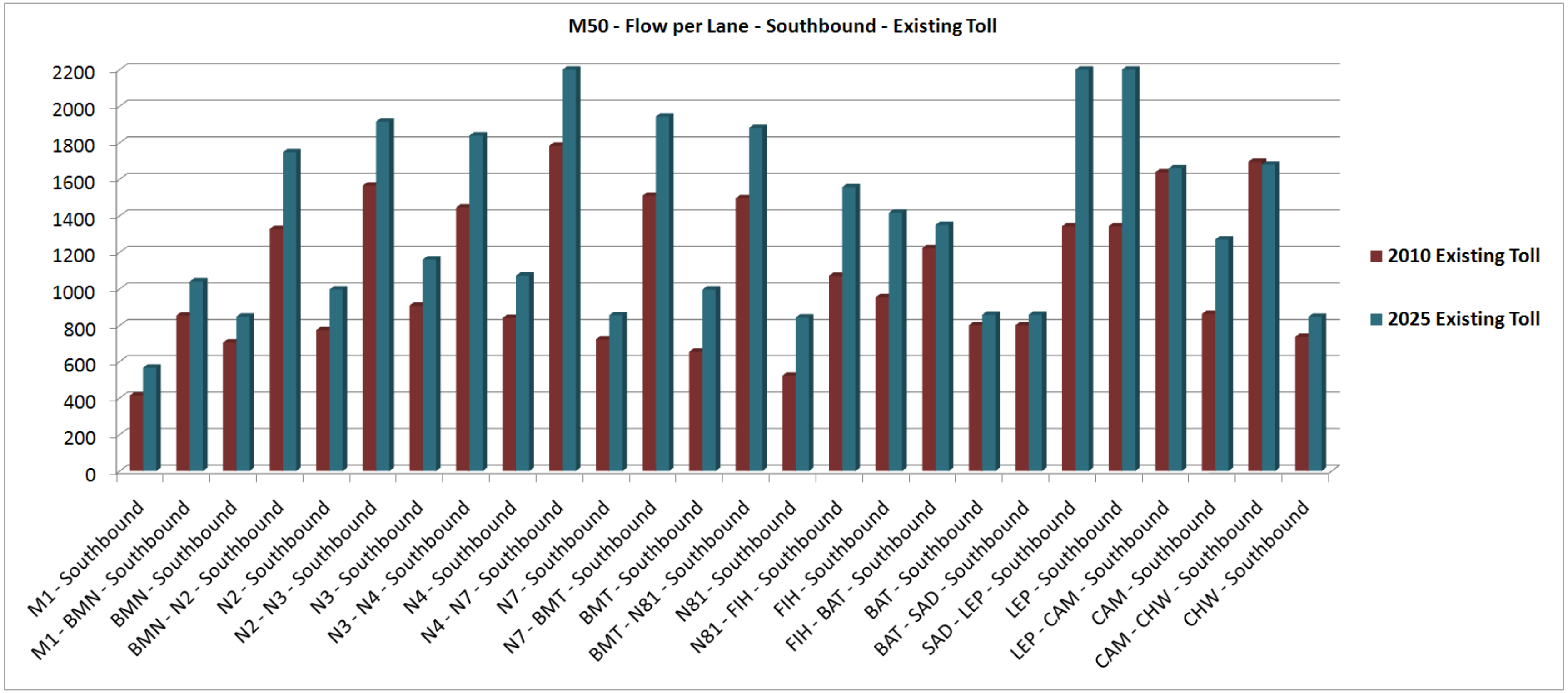


Figure 19-14: Southbound M50 Traffic Flows per lane



19.2.4 Options for Multi-Point Tolling

The range of multi-point tolling options on the M50 hinges on the number of toll points that can be implemented, which in turn defines the appropriate level of charge at each. Broadly speaking, the assessment seeks to apply a rate which would equate to a charge of about €5 for the use of the full length of the 40km road, although as set out earlier, the number of users would use the full length is extremely low. This suggests a rate of about 12c per km, which would incorporate a MECC charge of about 6c/km, plus an infrastructure charge as is currently collected at the existing toll point. Options are set out in Table 19-6 below.

Variations on this charge are also tested, up to a maximum of €7.80 for the full length of the M50.

The analysis in this section of the report will establish a maximum allowable avoidance rate, which defines the proportion of users that are displaced to other routes following the implementation of a toll. The assessment will then outline the cost of toll collection at each point, defining the minimum toll rate that is appropriate to generate a positive return. Both these parameters will allow us to define the links where implementation of a toll point is feasible within a multi-point tolling scenario. The alternative strategies will be appraised and compared to identify the most feasible based on the following elements:

- Annual Revenue (extrapolation of Peak Period Revenue);
- Capital and Operating Costs;
- Cost of Delay through interrogation of network statistics;
- Level of Diversion (compared to do-minimum) by link of M50;
- Performance of Mainline (although this will be less relevant for the base year);
- High level discussion of other impacts of diversion (e.g. any sensitive areas?)

All appraisal is initially based on the 2010 traffic model which has been calibrated/validated to 2010 levels of traffic demand. The 2025 future model is used to assess the preferred scenarios that emerge from the initial appraisal.

Table 19-6: Tolling Scenarios for Testing

Scenarios	Approach	M1-BMN	BMN-N2	N2-N3	N3-N4	N4-N7	BMT-N81	FIH-BAT	BAT-SAF	SAF-CAM	CAM-CHW
0	*Existing*				*€2.33*						
1					*€2.00*						
2	*Distance Based*	*50c*	*50c*	*50c*	*50c*	*50c*	*50c*	*50c*	*50c*	*50c*	*50c*
3	*Revenue Maximising*		*€1*	*€1*	*€1*	*€1*		*€1*			
3a	*Revenue Maximisation (a)*	*€1*		*€1*	*€1*	*€1*		*€1*			
3b	*Revenue Maximisation (b)*		*€1*		*€1*	*€1*		*€1*		*€1*	
3c	*Revenue Maximisation (c)*		*€1.16*		*€1.16*	*€1.16*		*€1.16*		*€1.16*	
4	*Market Maximising*	*€1*			*€1*		*€1*	*€1*			*€1*
5	*Variation 1*		*€1*		*€1*		*€1*	*€1*		*€1*	
6	*Variation 2*	*€1*		*€1*	*€1*		*€1*	*€1*			
7	*Variation 3*	*€1.25*			*€1.25*			*€1.25*		*€1.25*	
8	*Differential Pricing*	*€1*			*€1.50*		*€1*	*€1.50*			
9	*Differential Pricing*			*€1.50*	*€1.50*	*€1*		*€1*			
10	*Differential Pricing*	*75c*		*75c*	*€1*	*75c*		*€1*		*75c*	
11			*€1.67*		*€1.67*			*€1.67*			
11a		*€1.74*	*Toll added BMN West Slips*		*€1.74*			*€1.74*			
12			*€1.25*		*€1.25*	*€1.25*		*€1.25*			
12a		*€1.25*	*Toll added BMN West Slips*		*€1.25*	*€1.25*		*€1.25*			
12b		*€1.16*	*Toll added BMN West Slips*		*€1.16*	*€1.16*		*€1.16*			
12c		*€1.16*	*Toll added BMN West Slips*		*€1.16*	*€1.16*		*€1.16*		*€1.16*	
12d		*€1.45*	*Toll added BMN West Slips*		*€1.45*	*€1.45*		*€1.45*			
12e		*€1.16*	*Toll added BMN West Slips*		*€1.16*	*€1.16*		*€1.16*	*Toll added SAF West Slips*	*€1.16*	
12f		*€1.16*	*Toll added BMN West Slips*		*€1.16*	*€1.16*		*€1.16*		*Toll added CAM West Slips*	*€1.16*
13			*€1.00*		*€1.00*	*€1.00*		*€1.00*			
14					*€2.57*	*€2.57*					
14a			*€2.57*		*€2.57*						
14b					*€2.57*		*€2.57*				
15			*€2.57*		*€2.57*			*€2.57*			

19.2.5 Preliminary Appraisal

The scenarios above were input into the M50 Traffic Model and the outputs used as the basis for the appraisal. Each scenario was appraised based on a number of outputs as per below.

- Overall Network Performance Indicators – Travel Time and Travel Distance
- Diversion off/on to the M50 – Assessment of suitability of alternative routes
- Revenue Generation
- Traffic Flows - Lane Capacity along each Link
- Environmental Impacts

Each scenario was appraised in terms of the above outputs and a decision was made on each scenario to bring it forward for further testing. The results of this preliminary appraisal are given in Table 19-7 below.

Note that costs are based on pro-rata of the existing M50 system – they do not include efficiencies associated with multi-point tolling which can be significant. As such, the analysis is purely for the purpose of comparison at this stage.

Table 19-7: Appraisal of Tolling Scenarios

Scenario		0	1	2	3	3a	3b	3c	4	5	6	7	8	9	10	11	11a	12	12a	12b	12c	12d	12e	12f	13	14	14a	14b	15
Network Statistics																													
Total Travel Time	**% Difference from Existing**	100%	99.8%	100%	100.6%	100.5 %	100.2%	100.6%	100.3%	100.2%	100.5%	100.3%	100.5%	101.4%	100.2%	100.7%	100.8 %	100.7%	100.7%	100.4%	100.5%	101.2%	100.6 %	100.7%	100.2%	101.7%	101.7%	101.2%	102.6 %
Travel Distance		100%	100%	99.6%	99.5%	99.5%	99.6%	99.5%	99.6%	99.6%	99.5%	99.7%	99.5%	99.5%	99.5%	99.6%	99.6%	99.5%	99.5%	99.5%	99.5%	99.4%	99.5%	99.5%	99.6%	99.7%	99.9%	99.6%	99.5%
Diversion																													
Mainline Only – Max diversion from a link			0.18%	26.8%	32.4%	28.9%	25.0%	29.6%	25.6%	30.3%	29.0%	35.7%	29.7%	30.5%	22.9%	39.5%	37.2%	31.7%	27.2%	24.3%	33.8%	34.1%	29.7%	31.8%	25.0%	55.8%	60.7%	44.3%	62.1%
Annual Revenue (€Million)																													
Based on extrapolation of AM Peak Revenue			€83.4	€145.1	€159.8	€157.9	€153.3	€169.3	€138.1	€141.3	€150.7	€133.0	€146.4	€160.9	€156.1	€145.2	€152.4	€154.8	€159.6	€152.2	€169.8	€172.8	€173.2	€173.2	€133.6	€131.9	€123.6	€138.5	€166.0
Annual Operating Costs (€Million)																													
Based on number of journeys along tollable sections		€38.3	€38.3	€80.8	€81.1	€80.3	€78.6	€70.0	€72.7	€73.9	€77.6	€61.6	€64.8	€70.1	€80.7	€56.7	€60.0	€68.8	€70.0	€71.8	€75.9	€66.8	€77.0	€77.0	€70.4	€45.9	€44.1	€47.3	€49.4
Total Capital Costs (€Million)																													
Total initial costs for implementing additional tolls		€0.0	€0.0	€53.2	€37.2	€37.2	€37.2	€37.2	€37.2	€37.2	€37.2	€34.0	€34.0	€34.0	€40.4	€30.7	€34.0	€34.0	€34.0	€34.0	€37.2	€34.0	€37.2	€37.2	€34.0	€27.5	€27.5	€27.5	€30.7
Traffic Flow																													
Total Flow through Toll Locations (PCU)		105256	114263	795207	437806	432472	419975	399842	378425	387122	412975	291606	309999	347011	505594	238234	240011	339386	349720	359418	400979	326418	409039	409155	366078	140650	131800	147713	177018
No. Toll Locations (Incl Slip Lane Tolls)		1	1	10	5	5	5	5	5	5	5	4	4	4	6	3	4	4	5	5	6	5	7	7	4	2	2	2	3
Toll Cost for entire M50 (excl Slip Tolls)		€2.33	€2.00	€5.00	€5.00	€5.00	€5.00	€5.80	€5.00	€5.00	€5.00	€5.00	€5.00	€5.00	€5.00	€5.01	€5.22	€5.00	€5.00	€4.64	€5.80	€5.80	€5.80	€5.80	€4.00	€5.14	€5.14	€5.14	€7.71
Appraisal																													
Scenario carried forward for further testing?		-	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO
Rational for inclusion/exclusion in further testing			Low Revenue	Low Revenue Excessive Toll Locations high collection cost, High Capital Costs, High Operational Costs	Environmental Impacts, High cost of toll collection, High Operational Costs	High levels of Diversion, Environmental Impacts, High Operational Costs	High levels of Diversion, Environmental Impacts	High levels of Diversion, Environmental Impacts	Low Revenue	Low Revenue	High levels of Diversion, Environmental Impacts	Low Revenue	Low Revenue	High levels of Diversion, Environmental Impacts	Low Revenue, Excessive Toll Locations high collection cost, High Capital Costs, High Operational Costs	Low Revenue, High levels of Diversion	High levels of Diversion	High levels of Diversion, Environmental Impacts	High levels of Diversion, Environmental Impacts	Limited Diversion, Limited Environmental, Significant Revenue	Limited Diversion, Limited Environmental, Significant Revenue	Limited Diversion, Limited Environmental, Significant Revenue	Limited Diversion, Limited Environmental, Significant Revenue	Limited Diversion, Limited Environmental, Significant Revenue	Low Revenue	Low Revenue, High levels of Diversion	Low Revenue, High levels of Diversion	High levels of Diversion	High levels of Diversion

19.2.6 Further Testing of Options

The five scenarios brought forward from the initial appraisal above were subjected to further testing under the following headings;

- Diversion;
- Environmental Impacts.
- Toll Costs for users;
- Toll Collection Costs;
- Net Revenue over an 8 year period;
- Marketability of the scenario

A multi criteria appraisal was undertaken based on the outputs above to ascertain the optimum fiscal scenario for the M50.

19.2.7 Toll Collection Costs

The cost of collecting tolls can be split into Capital and Operating Costs. An exercise was undertaken in conjunction with the NRA and Bet Eire Flow Ltd to calculate the cost of toll collection per journey for each of the scenarios tested.

Table 19-8: Capital Costs

	12b	12c	12d	12e	12f
Capital Cost	24,800,000	27,650,000	24,800,000	27,650,000	27,650,000
Year 1 Mobilisation Cost	6,050,000	6,050,000	6,050,000	6,050,000	6,050,000
Capital Contingency Costs (12.5%)	3,100,000	3,456,250	3,100,000	3,456,250	3,456,250
Total Capital Cost	**33,950,000**	**37,156,250**	**33,950,000**	**37,156,250**	**37,156,250**

As can be seen from Table 19-8 above the capital cost associated with the introduction of additional toll points is dependent on the number of additional toll points. The difference in capital costs for each scenario is minimal with Scenarios 12c, 12e and 12f being most expensive.

Table 19-9 outlines operating cost estimates, and suggests that the annual operating costs are approximately double the capital costs highlighting the importance of efficiency in the collection of toll revenue. The operation costs we calculated based on tollable journeys (i.e. a journey may include none or all tolls). Based on this Scenario 12d has the lowest annual operation cost.

Note again that these are extreme upper estimates, and do not account for the significant cost efficiencies that can be gained as a result of extending the current system. Further study is necessary to fully understand the actual operating cost of the final scheme.

Table 19-9: Operating Costs

	12b	12c	12d	12e	12f
Total Tollable Journeys	89,854,750	100,244,750	81,604,500	102,260,000	102,288,750
Variable and Outlay Costs	39,868,553	44,478,596	36,207,917	45,372,762	45,385,518
Fixed Costs	8,470,000	8,470,000	8,470,000	8,470,000	8,470,000
Rates	7,000,000	7,000,000	7,000,000	7,000,000	7,000,000
Rates Contingency Costs (7% of add revenue)	7,117,884	5,637,167	5,853,121	5,884,317	5,887,843
Base Enforcement Costs	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000
Additional Enforcement Costs	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Consultancy Fees	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Marketing / Advertising	300,000	300,000	300,000	300,000	300,000
Operating Contingency Costs	1,000,000	2,000,000	1,000,000	2,000,000	2,000,000
Total Operating Costs	**71,756,437**	**75,885,763**	**66,831,038**	**77,027,079**	**77,043,361**

19.2.8 Net Revenue over 8 years

In calculating the net revenue of a tolling system it is common practice to spread the initial capital costs over a number of years, in this case 8 years, in order to provide a reasonable estimation of future net revenue.

The annual revenue for years 1 – 8 has been calculated by interpolating traffic flows from the 2010 and 2025 models and calculating revenue for each year based on toll levels in each scenario. The costs include the operation and capital costs set out in Table 19-9 above, spread out over years 1 – 8. Operating cost efficiencies are estimated at a 10% reduction in Year 2 following by 2% reduction each year thereafter. This excludes the savings that would be associated with the restructuring of the back office to facilitate a multi-point system.

Table 19-10: Net Revenue

	12b	12c	12d	12e	12f
Net Revenue (Years 1 – 8 Inclusive) (€ Million)	€687.4	€787.2	€918.3	€804.6	€802.4

19.2.9 Option Appraisal

A summary of the multi criteria appraisal of the preferred scenarios is given in Table 19-11 below.

Table 19-11: Multi Criteria Appraisal of Tolling Scenarios

Scenario	12b	12c	12d	12e	12f
Maximum Diversion off M50 Mainline (2025)	-19%	-27%	-25%	-26%	-26%
Appraisal Score	***10***	***2.5***	***7.5***	***5***	***5***
Environment impacts of diversion	Neutral	Moderate Negative	Moderate Negative	Moderate Negative	Moderate Negative
Appraisal Score	***10***	***7.5***	***7.5***	***7.5***	***7.5***
CO_2 Emissions (kg) - % Increase from Existing	-0.5%	-0.6%	-0.5%	-0.6%	-0.5%
Appraisal Score	***5***	***5***	***5***	***5***	***5***
Toll Cost for entire M50 (In line with Economic Recommendations – MECC)	€4.64	€5.80	€5.80	€5.80	€5.80
Appraisal Score	***10***	***5***	***5***	***5***	***5***
Net Revenue Over 8 Year Period (€Millions)	€687.4	€787.2	€918.3	€804.6	€802.4
Appraisal Score	***0***	***5***	***10***	***5***	***5***
TOTAL	**35**	**25**	**35**	**27.5**	**27.5**

The summary suggests that Scenarios 12b and 12d represent the more preferable options for Multi-Point Tolling on the M50. In the Base Year, diversion rates are modelled at less than 25%, although with the inclusion of Route Quality Factors, it is anticipated that this would be an over-estimate of diversion, it is a useful criteria for comparing options. Furthermore, diversion rates would reduce as the level of tag use increases due to the lower unit cost for road users.

Most notable are the environmental benefits resulting from the toll schemes – the reduction in emissions result from a significant reduction in traffic through the Lucan and Strawberry Beds areas which currently result from the relatively high single point toll of €2 to €3 for cars at the Westlink. As this toll reduces, further users are attracted to the scheme, with positive impacts outweighing negative impacts elsewhere.

The key differential between Scenario 12b and 12d is the net revenue, with significantly higher returns for 12d. Although subject to further analysis, it is likely that Scenario 12d represents the most favourable approach to tolling on the M50.

19.2.10Proposed Charges

Translating the standard €1.45 charge form the above analysis into a final charging structure for the M50 will require consideration of vehicle classes, payment mechanisms (e.g. tag, video registered and unregistered) in addition to other variables such as different charges by time of day.

In the assessment of the current proposals, all work has been undertaken on the basis of Passenger Car Units (PCU's). Larger vehicles can be expressed as multiples of a PCU (in our analysis we have assumed the largest vehicle size to be equal to 2 PCU's). In this way, a single toll can be applied to all vehicles if the traffic demand is expressed in PCU's.

Examining data from the M50, The payment of tolls was equivalent to €2.33 per PCU in 2010 with the current rates of registration. This equates to a 16.5% uplift on the basis tag rate of €2.00. Assuming that the average PCU charge will be €1.45 with the new system, this suggests a basic tag rate of €1.24.

The consumer price index is currently running at a rate of approximately 2% per annum. Given that the system proposed here is unlikely to be in operation until late 2012 (2.5 years from mid-1010), a basic toll rate of €1.30 is suggested for tag users at each toll point. Further study is required to understand whether this charge could also be applied for video-registered users, and what additional levy might be more appropriate for unregistered users to reflect the higher costs of processing those transactions.

A summary of the final proposals and its impacts on current traffic flows is provided in Figures 19-15 to 19-17.

Figure 19-15: Toll Cost and Locations for Emerging Preferred Strategy (cost for Tag Users)

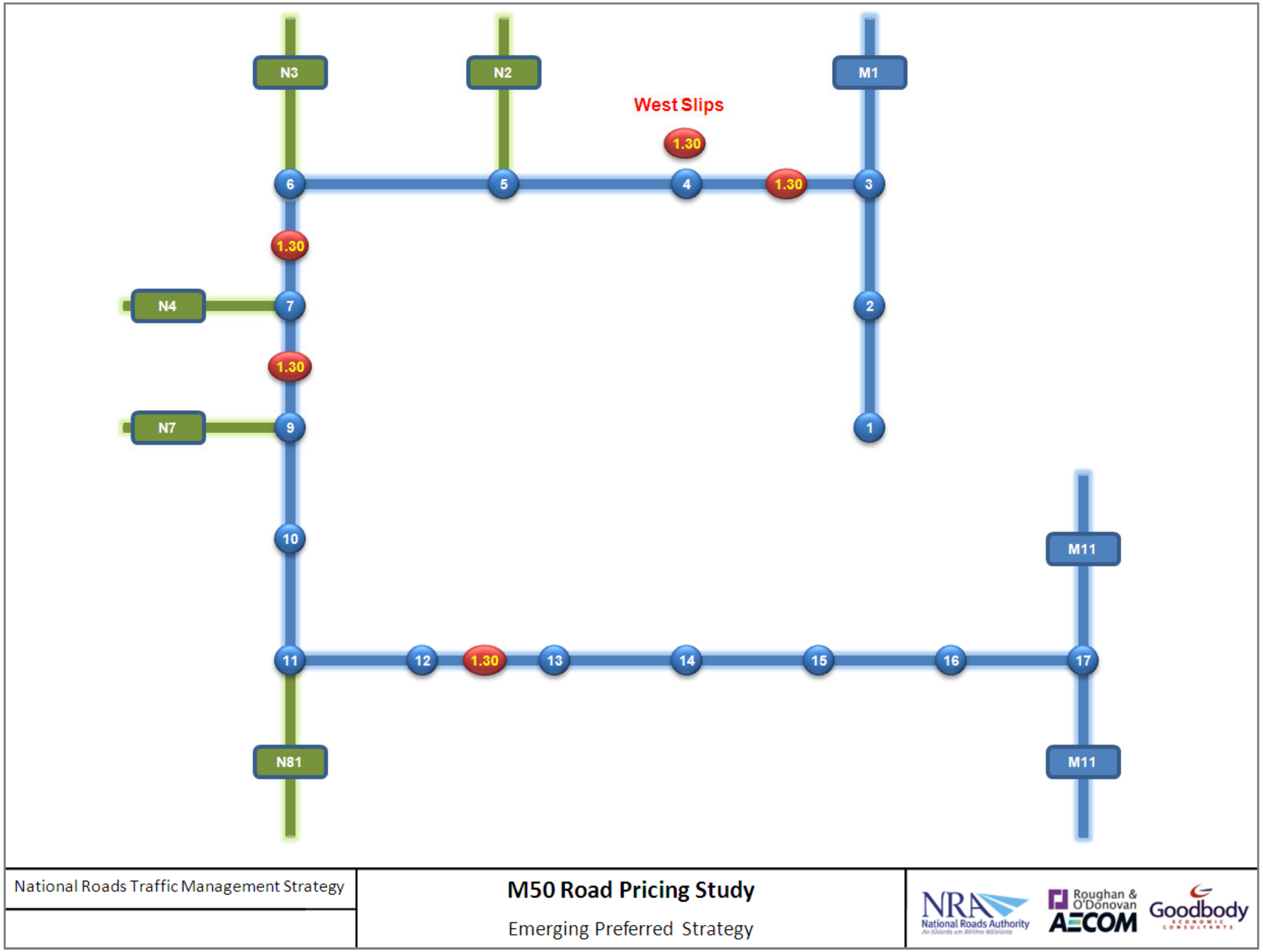


Figure 19-16: Traffic Flows (Passenger Car Units) per Lane for Existing and Proposed Toll Scenarios in 2010 and 2025 - Southbound

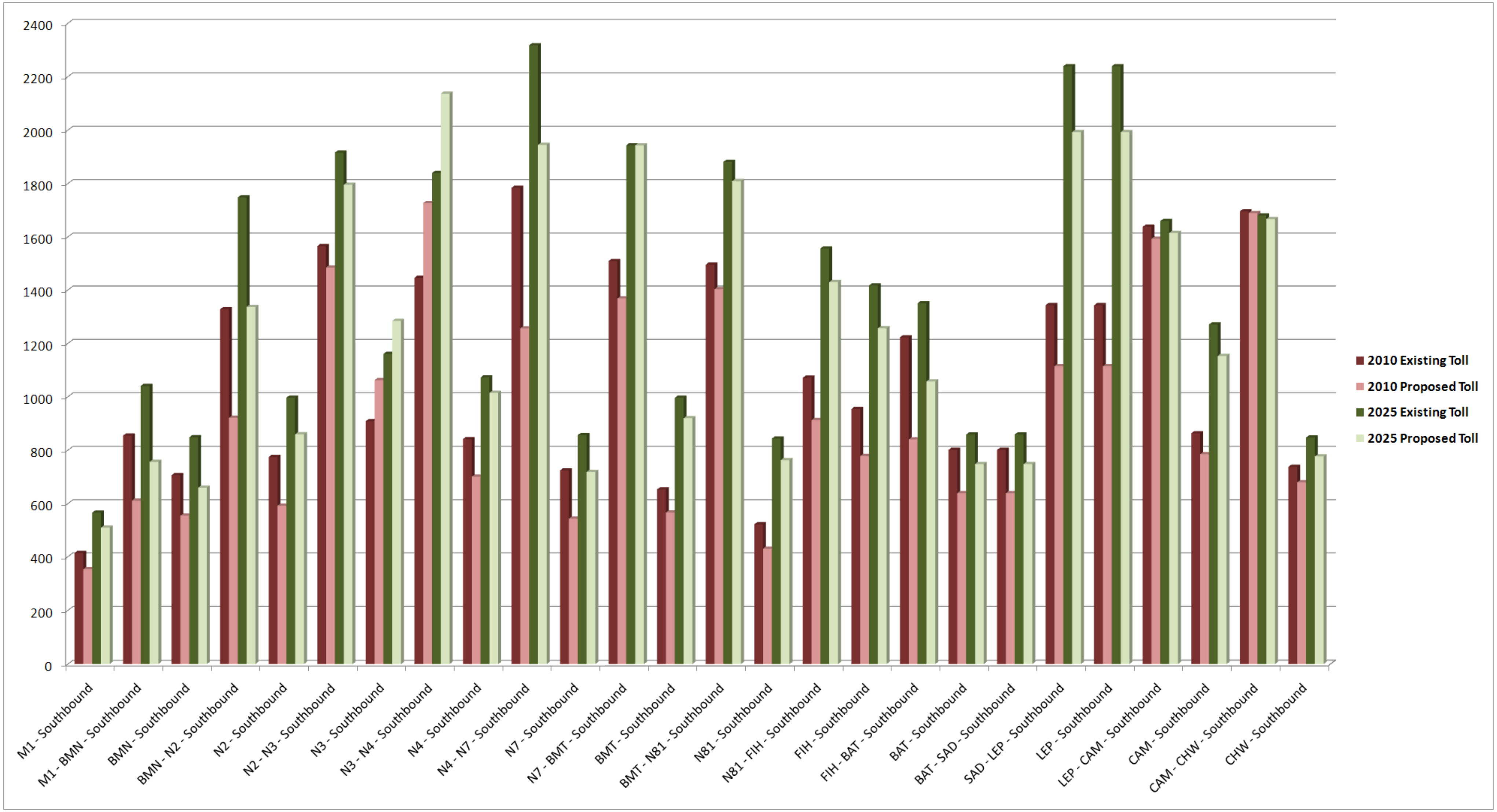
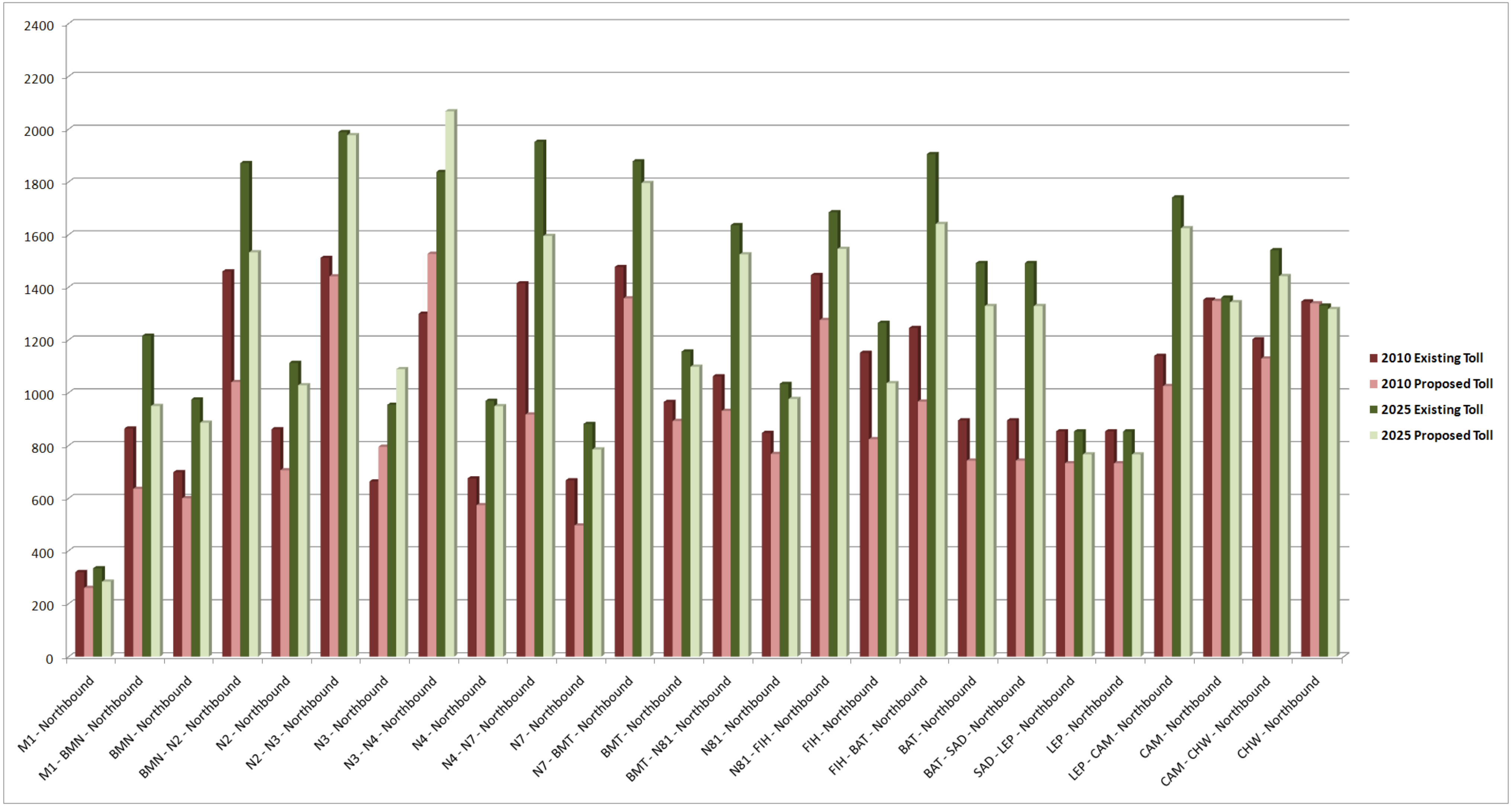


Figure 19-17: Traffic Flows (Passenger Car Units) per Lane for Existing and Proposed Toll Scenarios in 2010 and 2025 - Northbound



19.3 Greater Dublin Area (Dublin Radial Routes)

19.3.1 Existing Conditions

The key National radial routes connecting Dublin to the surrounding region and in many cases also forming the wider national interurban road linkages are reviewed in this section. In summary these key National radials are as follows:

- N1/M1 The Dublin to Belfast route (continues as the A1 in Northern Ireland)
- N2/M2 The Dublin to Derry route (continues as the A5 in Northern Ireland)
- N3/M3 The Dublin to Ballyshannon route (part of the route in Northern Ireland via the A405/A46)
- N4/M4 Dublin to Sligo route (also connects to M6/N6 Galway route at Kinnegad)
- N7/M7 Dublin to Limerick route (also connects with the M9/N9 route to Waterford at Kilcullen, and the N8/M8 route to Cork at Portlaoise)
- N81 Dublin to Tullow route (connects with N80 Carlow-Enniscorthy route south of Tullow)
- N11/M11 Dublin to Wexford route (also connects with the N25 Cork-Waterford-Rosslare route at Wexford)

19.3.2 Existing Traffic Volumes

In order to develop a full picture of traffic flows on the Dublin Radial Routes, reference has been made to the M50 Traffic Model, which models the Greater Dublin Area (GDA). Average AM Peak Hour (07:00 – 09:00) traffic flows statistics were extracted from the 2010 Traffic Model, and are outlined below in Figures 19-18 to 19-20.

Figure 19-18: 2010 AM Peak Traffic Flow - Dublin Radials

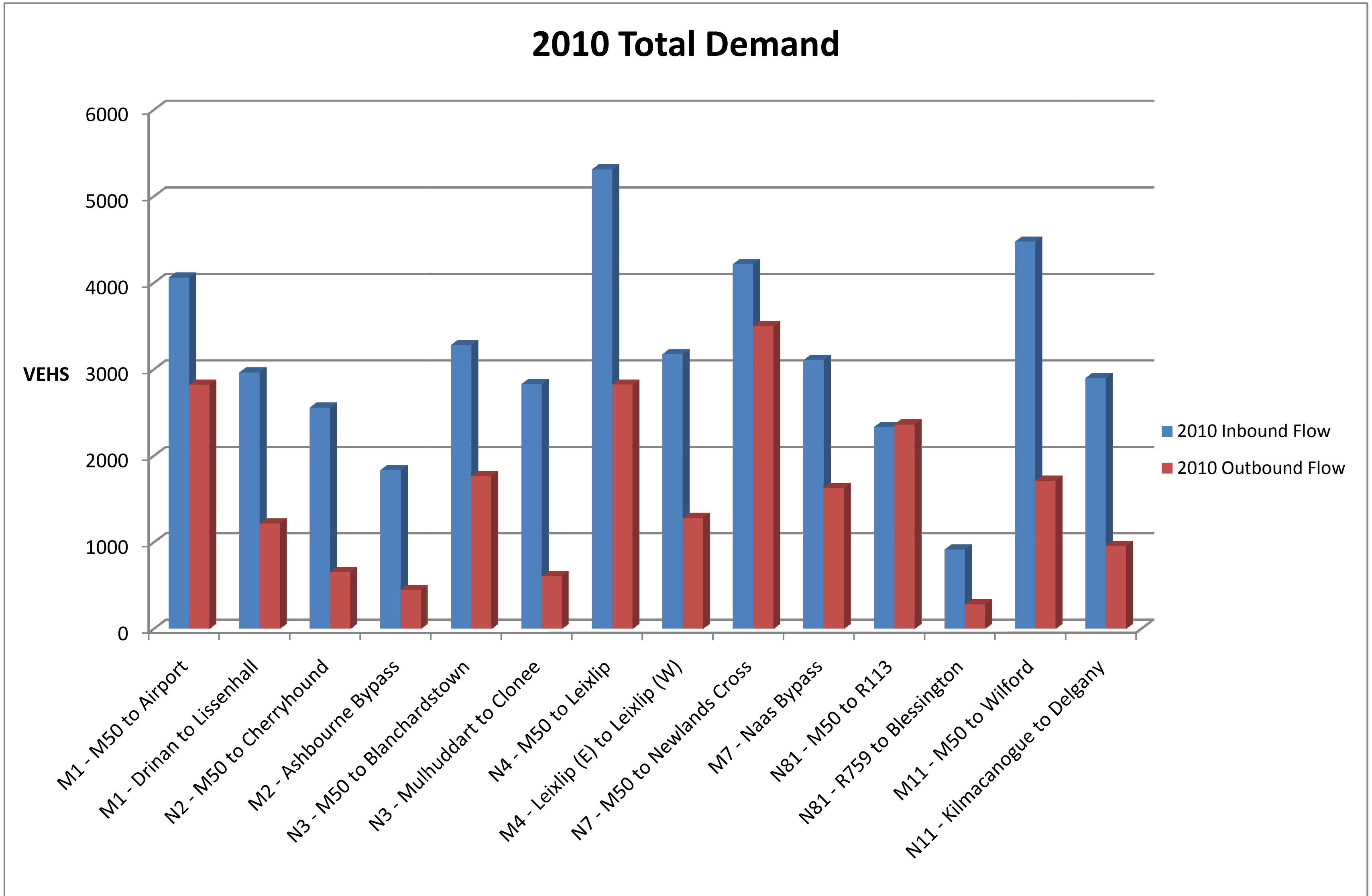


Figure 19-19: 2010 AM Peak Traffic Flow\Lane - Dublin Radials

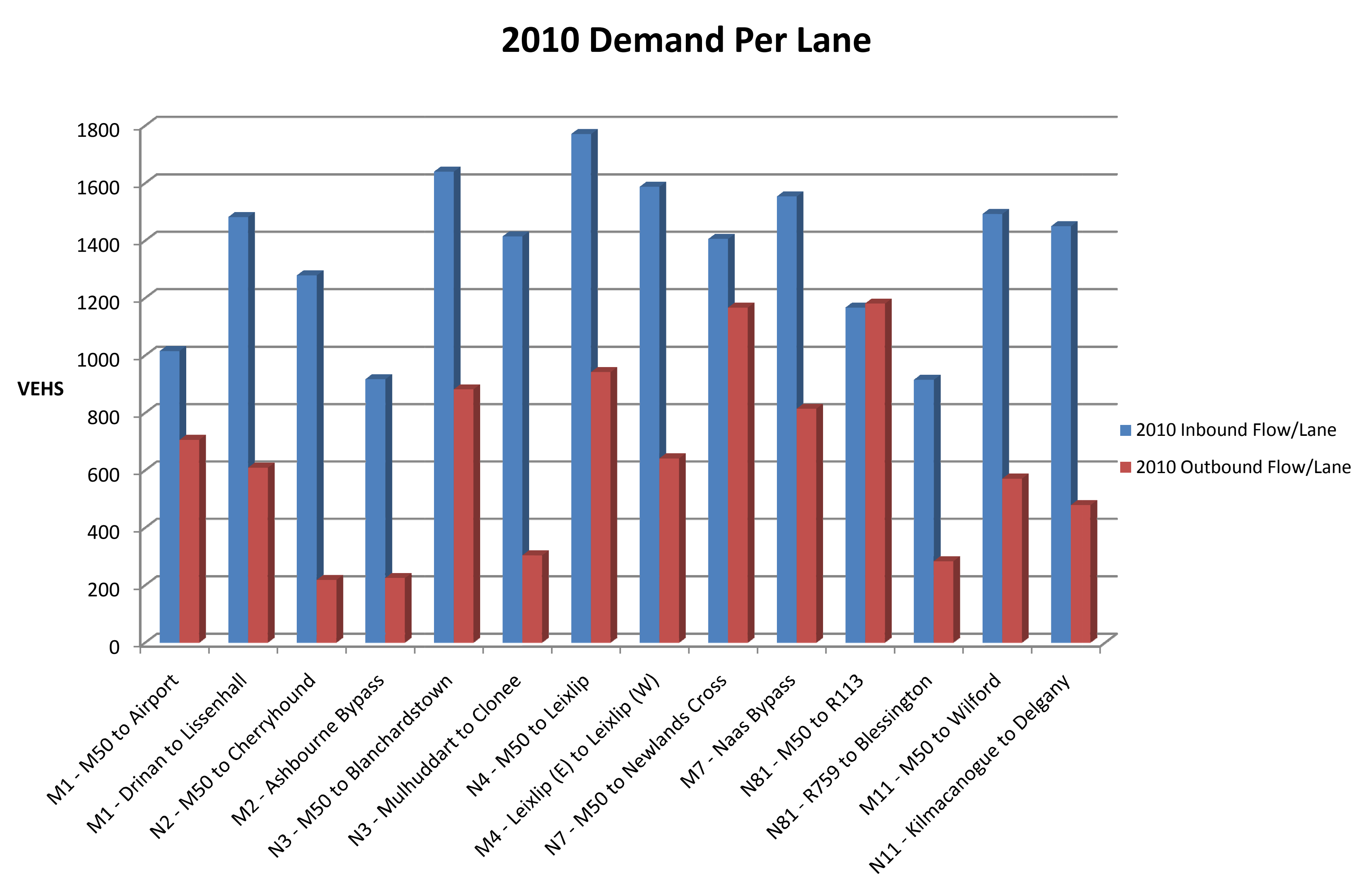
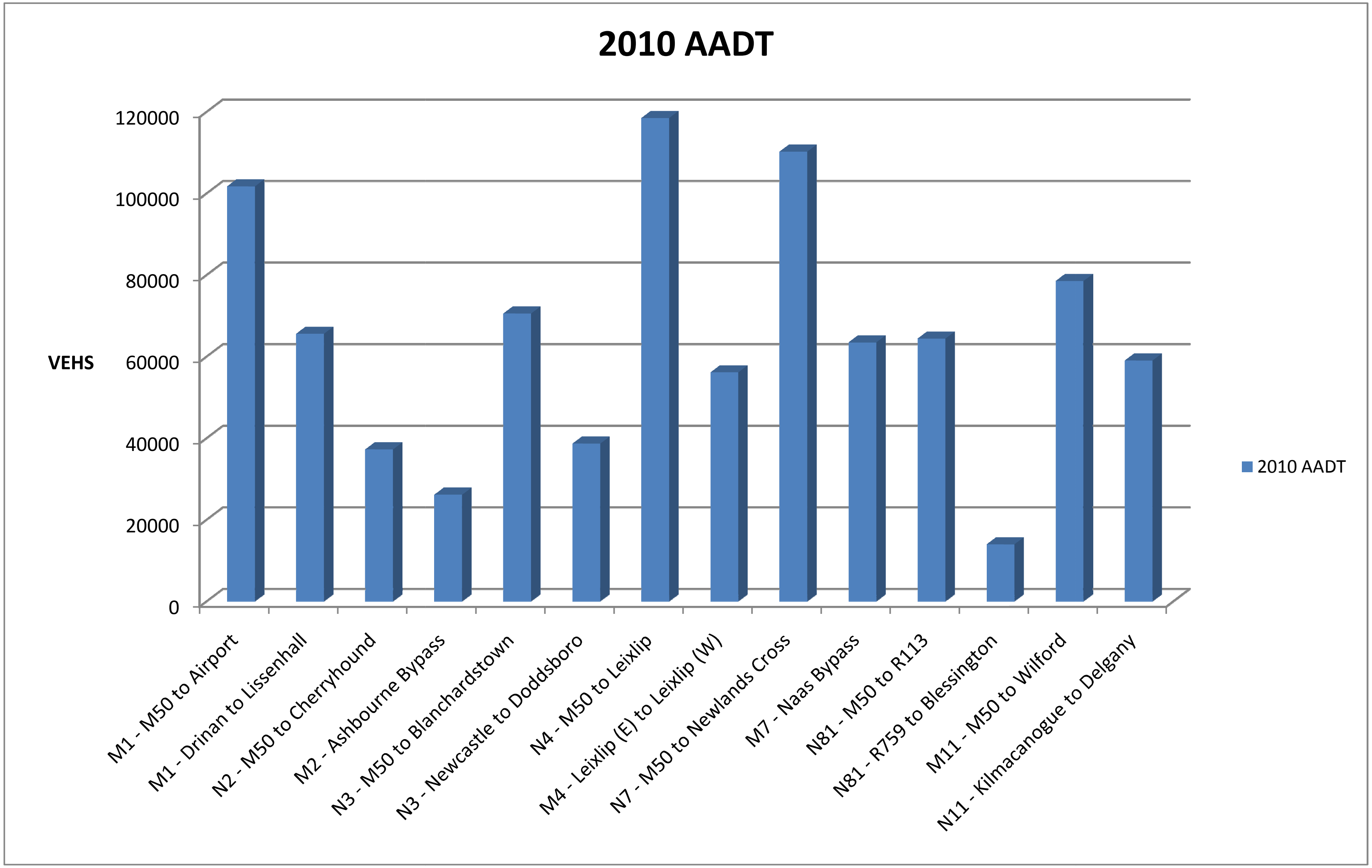


Figure 19-20: 2010 AADT – Dublin Radials



19.3.3 Network Performance

Level of Service (LOS) provides a good measure of effectiveness of the national road network. The 2010 DRRM has been used to determine the LOS on the Dublin Radial Routes to highlight areas where intervention may be required through the Traffic Management Study.

The output from the NTM is presented in the form of 'Actual Flows' on all links throughout the country. When compared against Link Capacities that have been defined during the development of the model, the identification of the Volume/Capacity (V/C) Ratio is possible. The V/C value is output directly from the VISUM programme, expressed as a percentage.

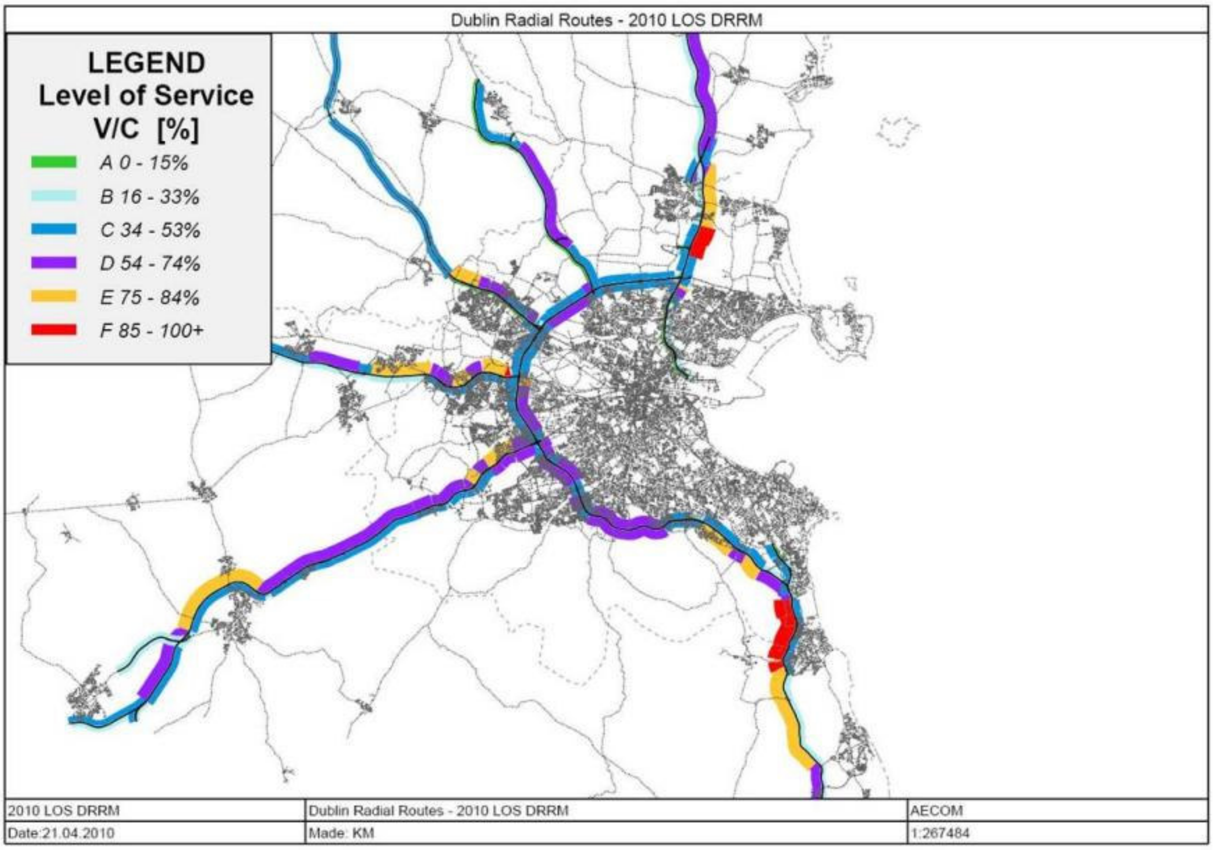
The nearest standard output that VISUM produces that equates to LOS is this V\C Ratio. In order to translate the V/C ratio to LOS a conversion spreadsheet was developed that considered the range of flows and in particular the thresholds in terms of traffic levels at which a particular LOS changed. The result of this analysis produced a spreadsheet table which has produced a range of V/C ratios applicable to the six specified LOS's. The output from this exercise is outlined below in Table 19-12.

Table 19-12: Conversion from V/C% to Level of Service

Level of Service	**V/C (%)**	
	Minimum	***Maximum***
LOS A	0	**15**
LOS B	16	**33**
LOS C	34	**53**
LOS D	54	**74**
LOS E	75	**84**
LOS F	**85**	**100+**

Figure 19-21 highlights 2010 LOS in the Greater Dublin Area (GDA) where much of the network is operating at LOS D or less. The M1, N4 and N11 approaches to the M50 experiences a LOS of F. This low LOS reflects the experience of many users in this area, where traffic congestion occurs from 07:00 until 10:00.

Figure 19-21: 2010 AM Peak Level of Service



19.3.5 Existing Traffic Composition

Traffic composition provides a useful indicator of the function of the Dublin Radial Routes. The National Traffic Model comprises 3 user classes for the AM Peak Period as follows:

- Heavy Vehicles;
- Commuting Trips (POWCAR); and
- Other Trips (Light)

Traffic composition during the AM Peak Period for the Base year (2006) is outlined below in Figure 19-22 and 19-23 for the inbound and outbound movements respectively.

Figure 19-22: Dublin Radial Routes Traffic Composition (Inbound AM Peak)

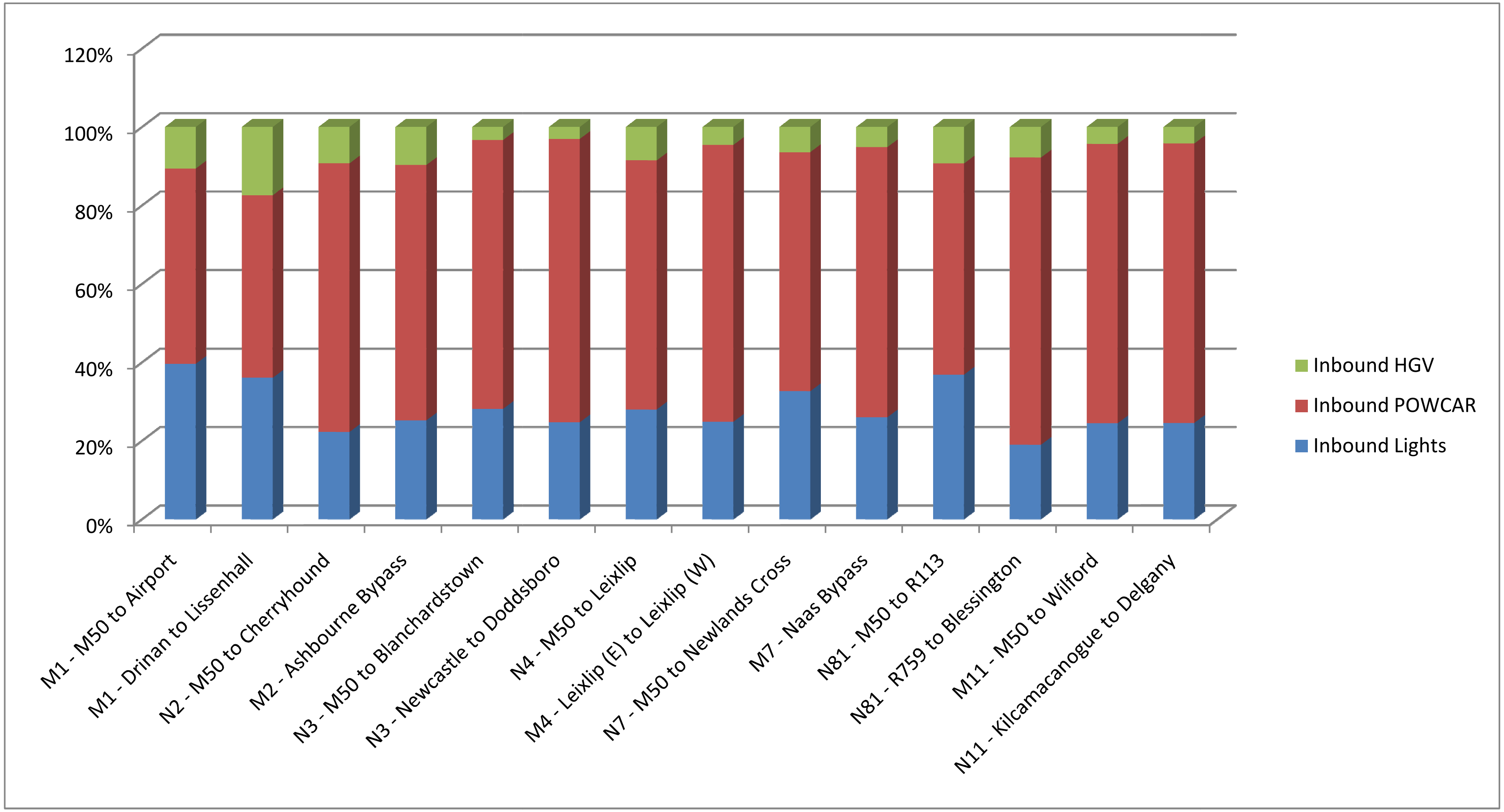
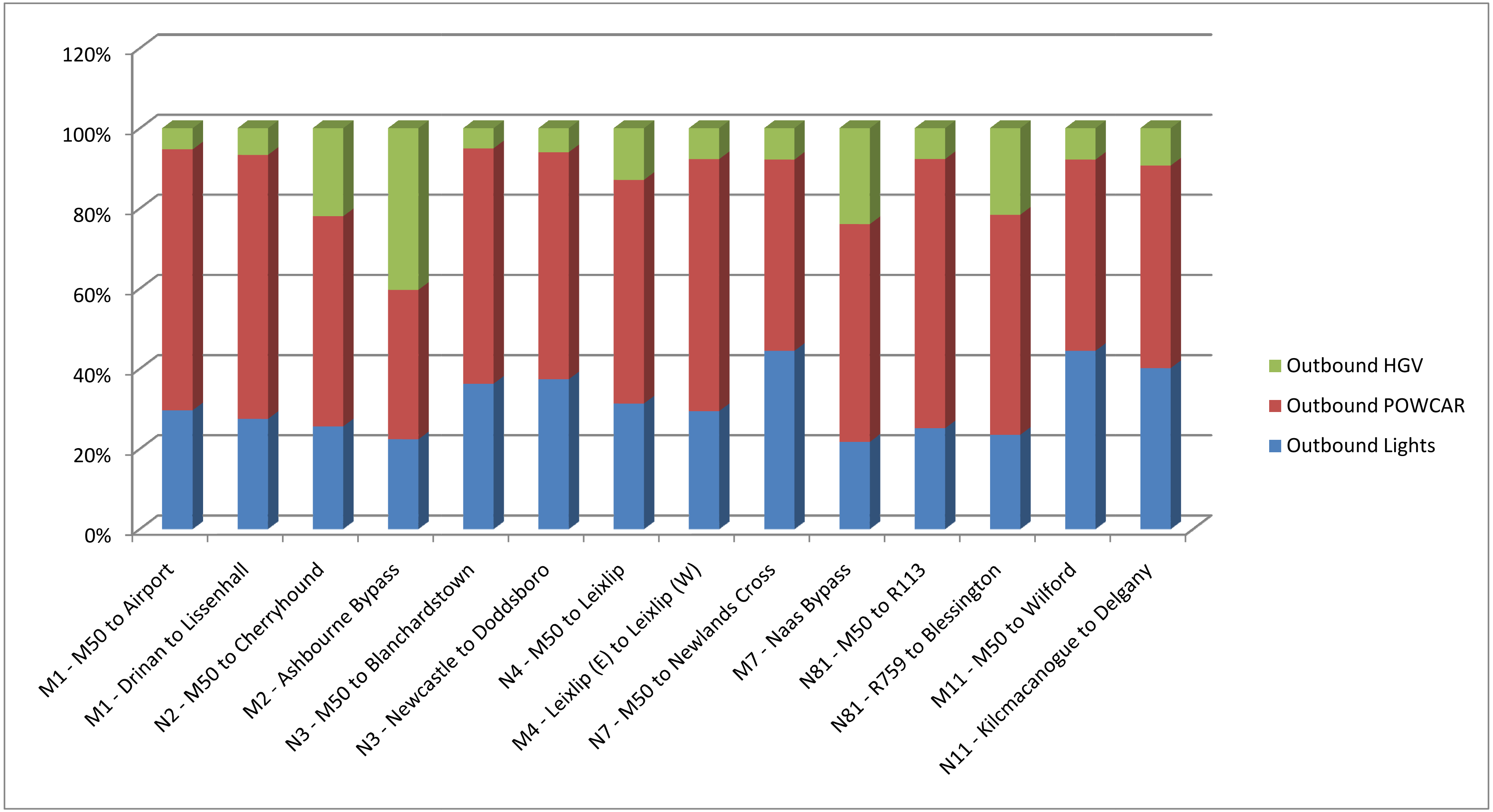


Figure 19-23: Dublin Radial Routes Traffic Composition (Outbound AM Peak)

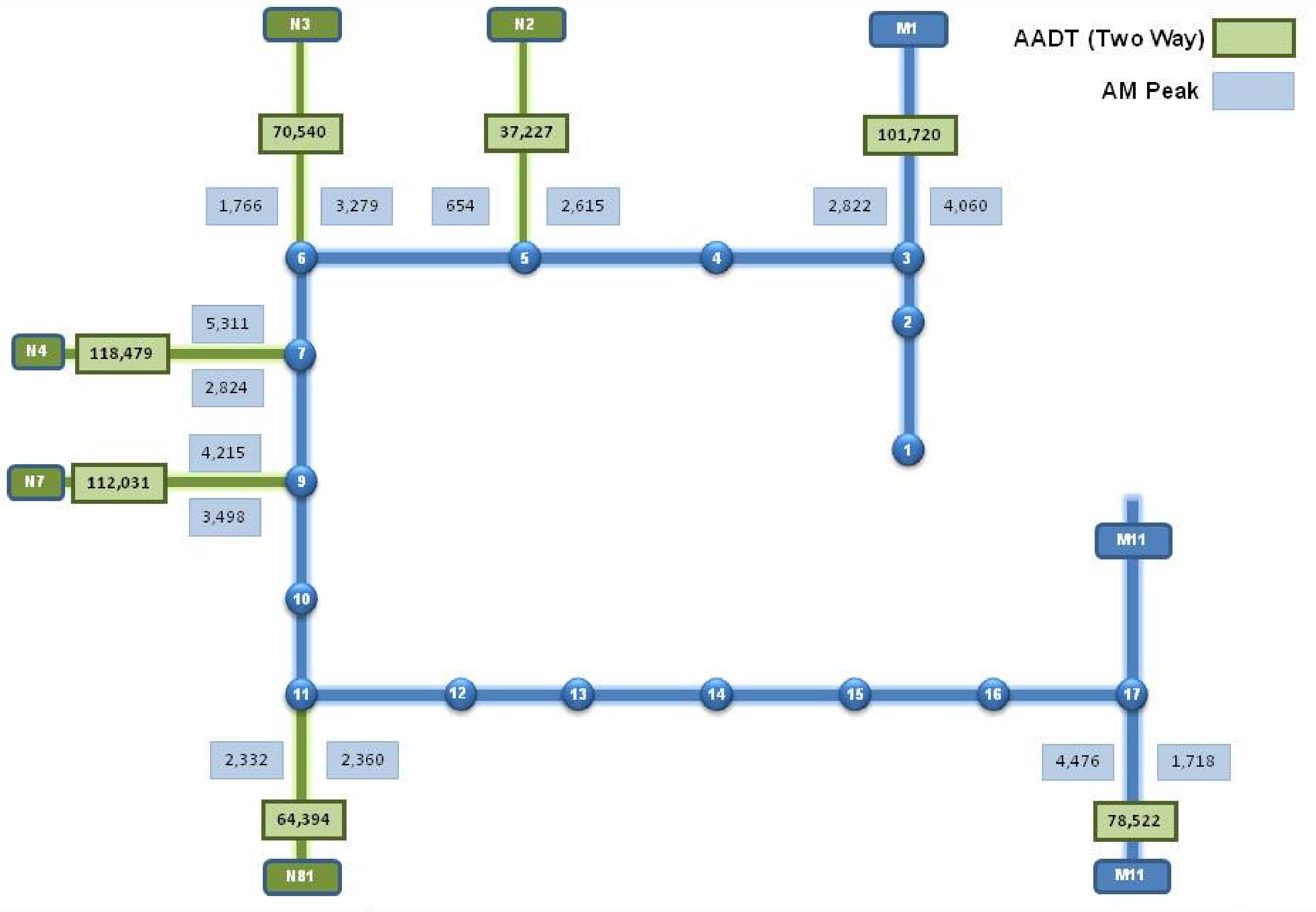


The results demonstrate the high level of commuting traffic (POWCAR) on all radial routes, which can account for up to 70% of the total traffic volume on inbound radial routes during those peak periods. Peak period HGV proportions are highest on the N2 where HGV traffic can account for over 25% of the total northbound traffic during the AM Peak.

19.3.6 Future Year Conditions

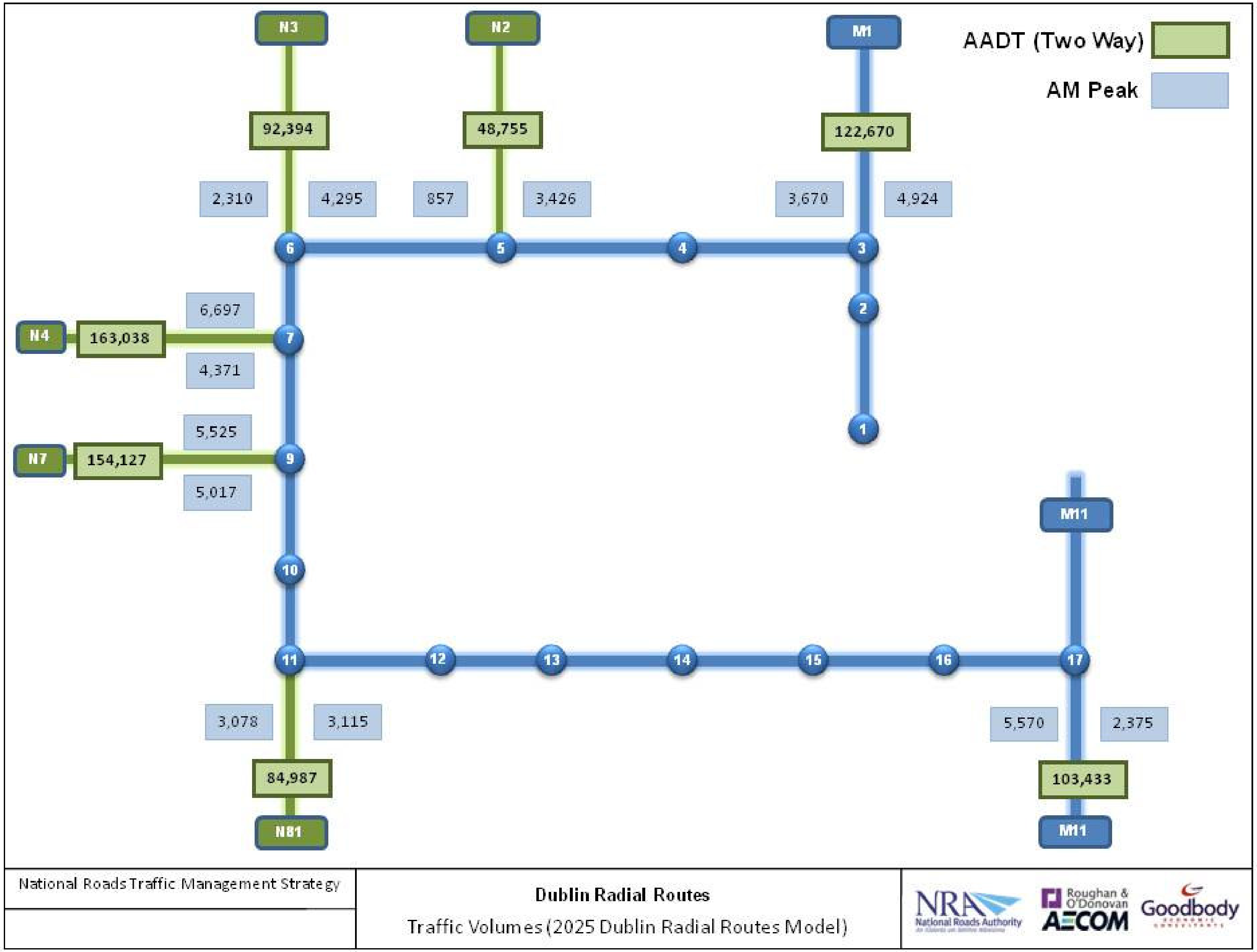
Future year traffic conditions have been based on national demographic and economic forecasts developed as part of the National Traffic Model. The implications of this growth on the Dublin Area for the 'High' growth scenario are shown overleaf.

Figure 19-24: 2010 Traffic Volumes – Dublin Radials



National Roads Traffic Management Strategy	**Dublin Radial Routes** Traffic Volumes (2010 Dublin Radial Routes Model)	NRA National Roads Authority / Roughan & O'Donovan AECOM / Goodbody

Figure 19-25: 2025 Traffic Volumes – Dublin Radials (High Growth)



19.3.7 Options for Multi-Point Tolling

In identifying tolling options on the Dublin Radial Routes, the same guiding principles applied as in the M50 work. These cover the need to approximate distance based charging through the strategic positioning of toll points, but the need to ensure that collection costs are adequately covered without leading to excessive diversion.

In examining the Dublin Area, it is evident that all existing toll locations on National Roads are located well outside the boundary of the built-up area. The recently introduced M3 toll at Pace best approximates the concept of a nominal toll which captures commuters travelling into the city area, but which is set at a low value (€1.30 such that it should not generate excessive diversion).

The provision of multi-point tolling has therefore examined how additional low-value tolls could be located on the key approaches into the built-up area of the city, but in such a way that they can complement the proposed tolling structure for the M50. The following criteria dictated the selection of tolling locations:

- Tolls to be introduced on network prior to traffic entering built up area;
- Toll charge to cost €1.30 in line with tolls proposed for M50 Multi-Point Tolling;
- Diversion should not lead to potentially significant environmental impact on sensitive areas; and
- Tolled charge to equate to exiting average toll rate of approximate 10c/km or less (i.e. for €1.30 toll, Total Carriageway > 13km);

The locations that were selected for initial consideration are outlined in Table 19-13 below.

Table 19-13: Proposed Single Point Toll Locations

Toll Location	Total Carriageway Provided (km)	Nominal Toll Charge (€)	Cost per/km (c/km)
M1: North of Lissenhall	26.8	1.30	0.05
N2: Ashbourne Bypass	15.9	1.30	0.08
N4: South of Leixlip	23.1	1.30	0.06
M7: Naas Bypass	26.3	1.30	0.05
N11: South of Kilmacanogue	10.3	1.30	0.13

Table 19-13 above shows that all proposed toll locations satisfy the criteria outlined above with the exception of the N11, which has a slightly higher cost/km than average. This is mainly as a result of the closer junction spacing along this corridor. These sites are taken forward as the basis for assessment, but would be subject to more detailed scrutiny at implementation stage.

Using the generalised cost and stochastic function, the diversion rates at the proposed toll locations were assessed. Table 19-14 indicates the forecast levels of diversion.

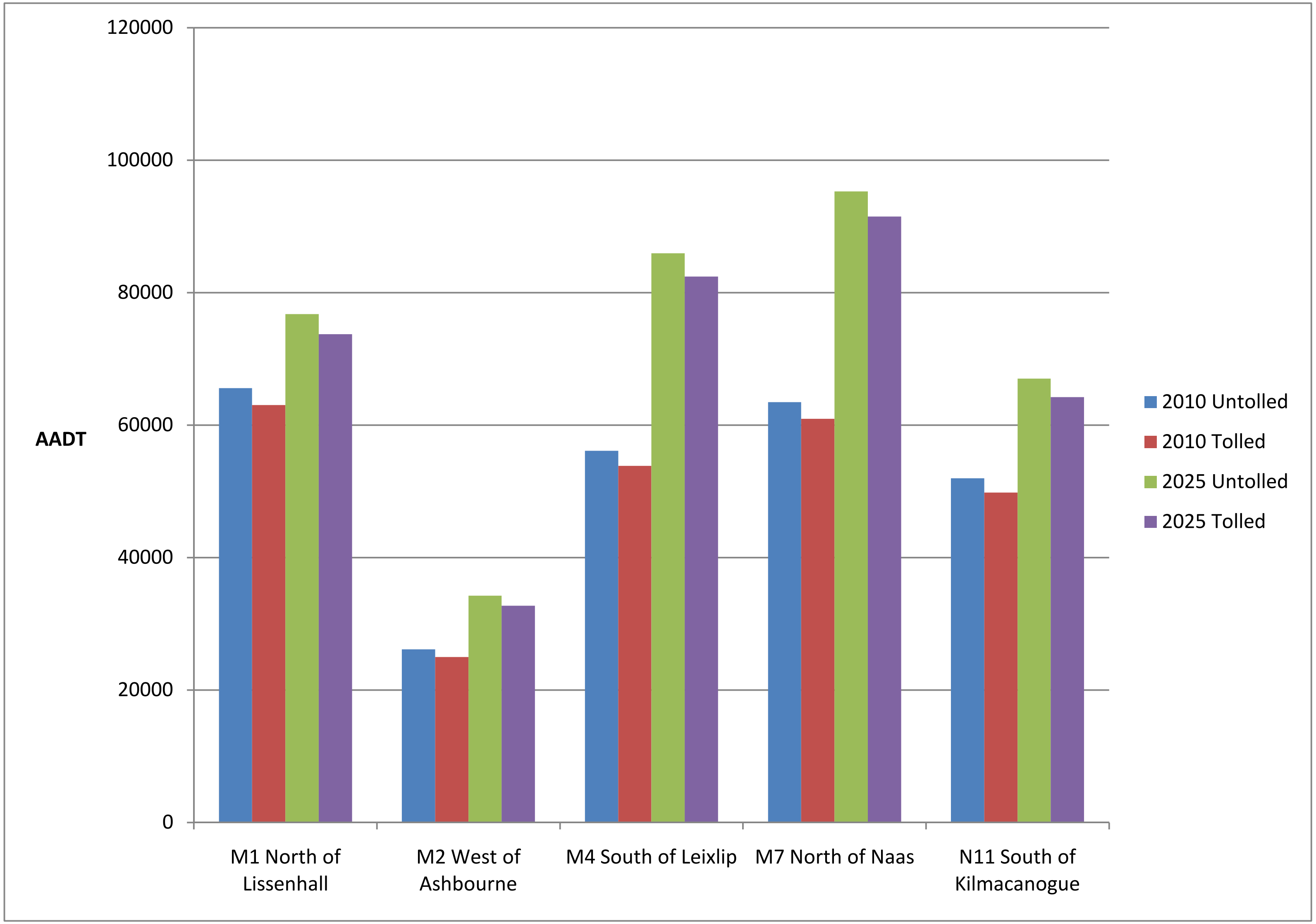
Table 19-14: Forecast Levels of Diversion (Light & Heavy Vehicles)

Route	Tolled Length (km)	Alternative Route Length (km)	Light Vehicle Diversion	Heavy Vehicle Diversion
M1	16.1	16.8	4.32%	0.61%
M2	13.4	13.4	13.78%	4.50%
M4	6.2	8.6	6.43%	0.75%
M7	7.5	8.5	9.76%	1.61%
N11	3.2	8.3	13.24%	1.60%

The assessment used average journey times which do not account for the reduced quality and junction delays associated with using the alternative route, therefore the generalised cost of using the alternative route may be underestimated and lead to a high estimate of diversion rates.

The lower diversion rate for heavy vehicles reflects the higher value of time associated with this type of road user. The results shows that the introduction of a toll on the radials entering the built-up area could lead to the diversion of up to 14% of traffic onto the local road network. Figure 19-26 illustrates the forecast tolled and untolled AADT at the possible single point toll locations.

Figure 19-26: Tolled and Untolled AADT at Possible Single Point Toll Locations



19.4 The Cork Area

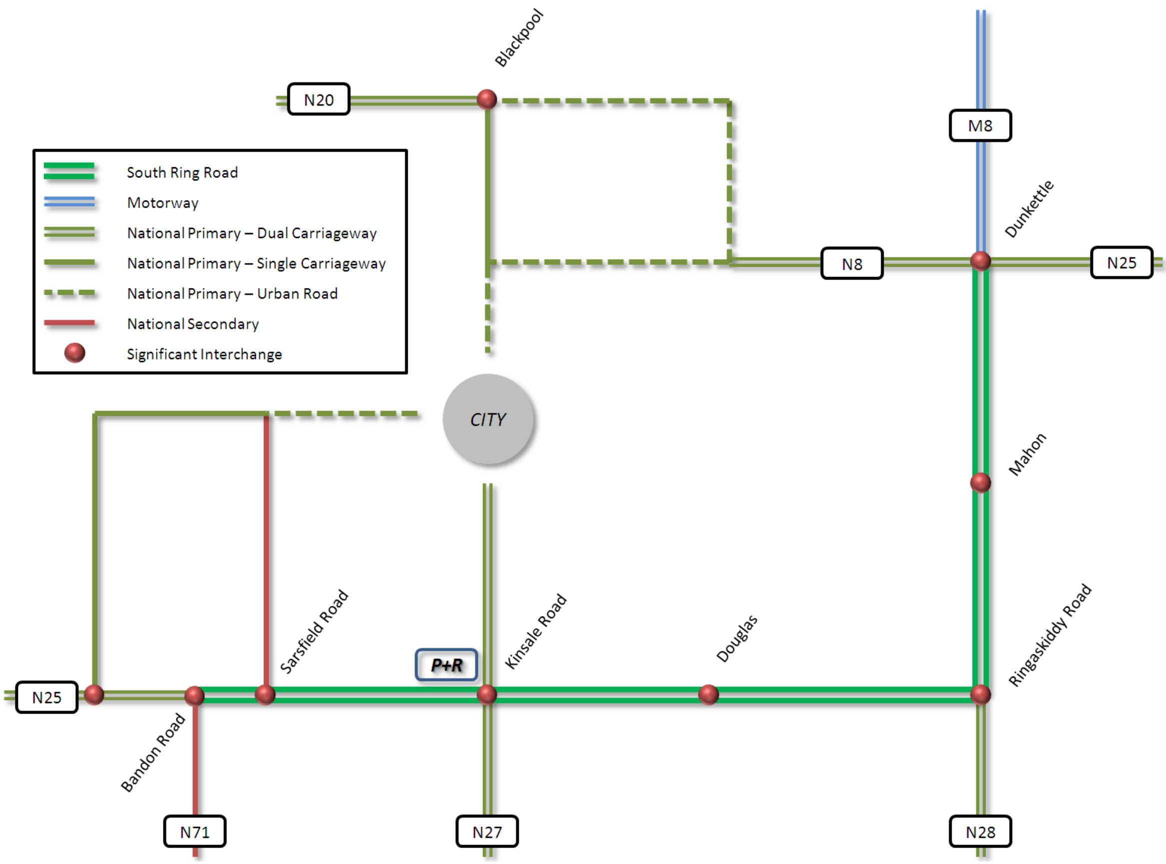
19.4.1 Overview

Cork has been identified in the baseline assessment as an area where the national road network remains under significant pressure. Although the N25 South Ring Road provides a crucial strategic connection into West Cork and Kerry, it has attracted significant development pressures and generated an enormous increase in travel demand as a result of the benefit that it offers.

As set out in the discussions earlier, it is evident that the external costs generated by users of the road outweigh the benefit afforded to all individual users, thereby suggesting that the current pattern of use is inefficient.

The radial routes leading into Cork carry relatively low traffic volumes when compared to Dublin, although these do serve to feed traffic into the South Ring Road, thereby exacerbating the problems outlined above.

Figure 19-27: The Strategic Road Network in Cork



19.4.2 Road User Charging Options in Cork

Examining charging options on the road network in Cork, it is evident that options will be restrained as a result of the relatively open access to the road network, with a high level of at-grade junctions, particularly on the western end. Nevertheless, a scheme has been prepared to upgrade these junctions to grade-separated interchanges which will reduce the difficulties encountered along this route.

It is expected that the delivery of grade separation at Dunkettle, Bandon and Sarsfield junctions will reduce, but not fully alleviate traffic congestion on the local road network in the vicinity of the N25. More relevant to the current study, however, is the effect that they are likely to have in pushing additional unsustainable traffic growth, leading to the emergence of eventual bottlenecks at Douglas and through the Jack Lynch Tunnel – which it will not be possible to address through capacity improvements. User charging would be a key measure to manage this future growth.

A SATURN model has been developed for the Cork Southern Ring Road based on traffic surveys from 2010 to understand the pattern of flows along this corridor. The model suggests that the Jack Lynch tunnel is the focal point of traffic on the Cork Southern Ring, feeding traffic across the river between Dunkettle and the various interchanges located to the south. Focusing on the Jack Lynch Tunnel for user charging would achieve a number of effects:

- It would influence a high proportion of users, leading to travel demand reductions along the full corridor;
- It would act as an infrastructure charge to reflect the significant investment made in the tunnel; and
- It would lead to manageable diversion impacts, as there are no parallel alternative routes that would suffer excessively as a result of a nominal charge.

The Jack Lynch tunnel also carries the highest traffic flow along the Southern Ring Road, and hence would offer the greatest operating cost efficiencies for a toll facility.

As the remaining junctions are upgraded, the provision of additional toll points may be warranted, although this would likely require a reduction on the tunnel charge to offset the new charges elsewhere on the corridor. As in Dublin, a closed system of charging will become a possibility as the network is improved, and will apply a distance based charge to all users of the infrastructure of between 10c and 15c per km.

19.5 National Multi-Point Tolling

19.5.1 Overview

It has been identified that a proxy form of Road Pricing can be delivered through the introduction of multi-point tolling on national Roads. Nevertheless, the discussion thus far has focused on the provision of tolls in the Greater Dublin Area, and has not considered the ability to deliver road pricing through the introduction of a number of single-point tolls at key locations on the network.

In identifying locations for potential new tolling points it is necessary to set out some criteria which could be used in establishing suitable locations. The following criteria are relevant:

- Annual average daily traffic (AADT) gives an indication of the potential volumes of traffic that might be expected to use the new tolling point. AADT can be used to establish the parts of the network which are currently highly utilised and could support the strongest business case for the provision of new tolling points.
- The standard of road provided can be influential in generating general acceptance of the tolling location. Motorway standard roads are currently provided at all tolling points within the national road network. It would seem logical therefore that this would be the minimum standard of road provision required for new tolling points.
- The potential for diversion of traffic away from the tolled section of road is an important consideration in the selection of new locations. If an alternative route exists, offering comparable journey times, the capture rate of the new tolling location will be reduced. In

addition traffic diverting from the tolled sections may have effects on the un-tolled road as these will often pass through populated areas.

- The location of existing toll points is a consideration in examining the potential for new locations. To ensure general equity it would seem sensible to ensure the major interurban journeys are comparable in terms of the number of toll points provided or the charge per unit distance travelled.
- New toll points can act as a demand management measure by influencing the time, the mode or desire to undertake a journey. They can play an important role in sustainable transport planning particularly in Cities where alternative options are available.

Considering the above criteria, a number of locations have been identified as suitable for further consideration. These locations are outlined below in Table 19-15 and Figure 19-28.

Table 19-15: Potential National Toll Locations

Route	Toll Location	Nominal Charge (€)	AADT (Vehs)	Daily Revenue (€)
M1	Dundalk Bypass	1.80	19,100	34,380
N20	Croom Limerick	1.80	12,300	22,140
N20	Cork Mallow	1.80	16,800	30,240
N18	Ennis Bypass	1.80	9,000	16,200
N9	Carlow Bypass	1.80	9,000	16,200
N17/N18	Tuam Bypass	1.80	11,100	19,980
N11	Arklow Bypass	1.80	18,000	32,400
Total Daily				*171,540*
Annual				**€62m***

** This excludes the costs associated with collection*

Figure 19-28: Potential Future Toll Locations (excludes Dublin Area)

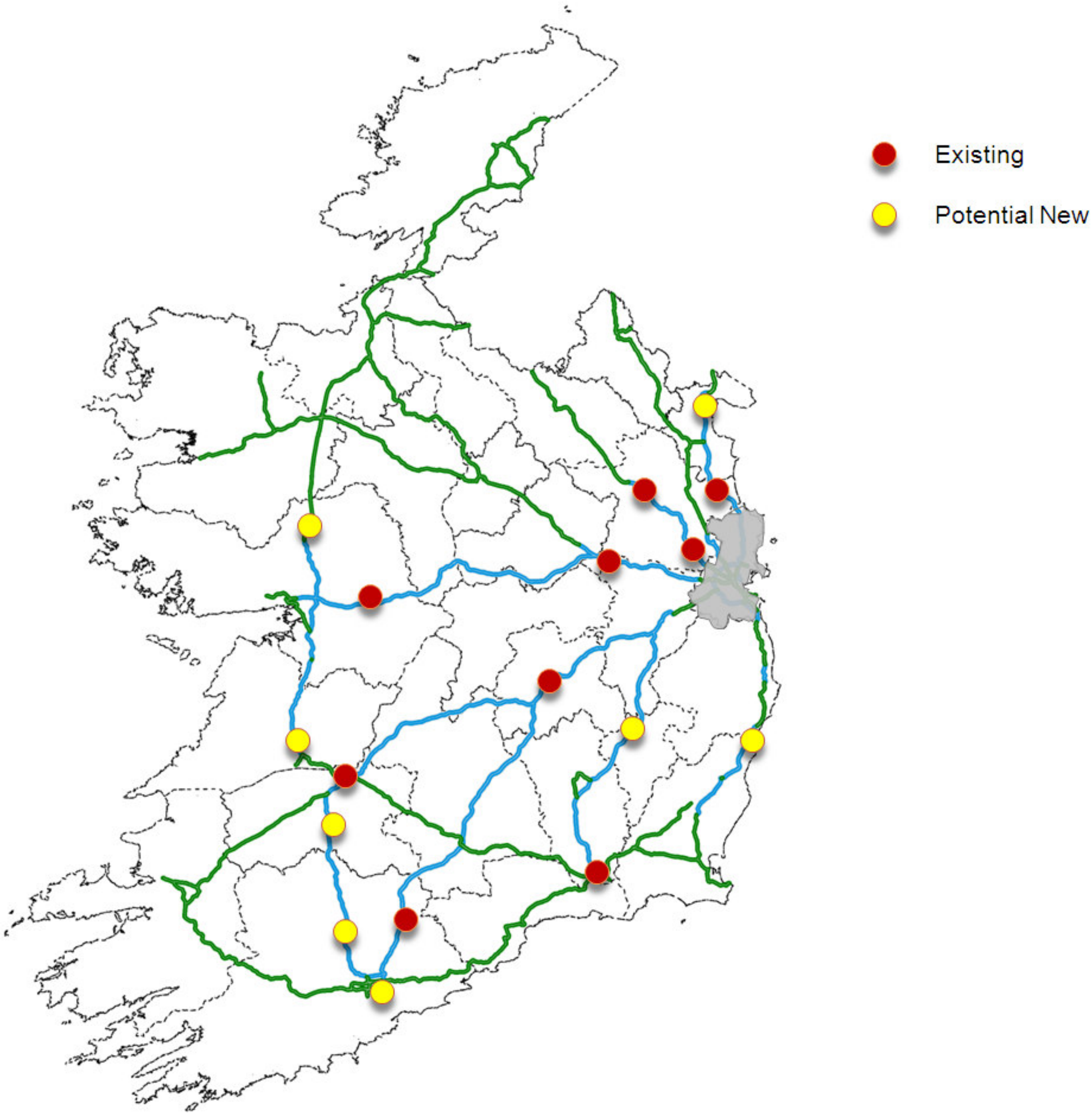


Figure 19-28 shows that with the additional tolling points, that road tolling locations become more evenly distributed across the country, with the exception perhaps of the northwest where road quality is generally of lower standard (although a number of schemes are currently at development stage which will address this deficiency). Such tolls would predominantly apply to long distance inter-urban movements which represent a high proportion of users on the new inter-urban network, and would generate additional net revenue to the order of €50m per annum.

It is accepted, however, that such charges would be predominantly on the basis of an infrastructure charge to fund ongoing maintenance and future investment, as MECC would be covered by fuel taxation in uncongested areas.

Chapter 20 Road Pricing for Goods Vehicles

20.1 Introduction

The concept of HGV Road Pricing is a growing solution for managing goods traffic and has been successfully delivered in a number of countries throughout Europe. For the most part, the proposal to charge for use of National Roads by HGV's on a distance charge has resulted from the considerable volumes of foreign-registered vehicles using transit routes through countries, including Germany, Slovakia and France. In such cases, road pricing is employed as a means of capturing user costs from those who are not liable for fixed costs such as national road taxes, vehicle duty etc. HGV Road Pricing remains under consideration in the UK (potentially including Northern Ireland), and such would have a notable impact on Irish vehicles that transit the UK en route to continental Europe.

20.2 HGV Tolling in Germany

20.2.1 Overview

In 2005 Germany introduced an electronic heavy goods vehicle tolling system covering its entire motorway network (approximately 12,000 km of motorways, more than 2,200 motorway junctions and more than 250 interchanges). The rationale behind introduction of the toll included:

- Mobilise additional funds for improving transport infrastructure;
- Recuperate the infrastructure costs from those who impose them in an optimum way;
- Provide an incentive for a more economic use of transport capacities in the field of road haulage;
- Provide an incentive to purchase cleaner vehicles or upgrade older vehicles;
- Fairer competition between the road and rail modes.

The toll is levied on heavy goods vehicles using Germany's federal motorways. The toll is a distance-based charge but also takes account of place and time of vehicle travel. All vehicles exclusively intended for road haulage whose maximum permissible weight is 12 tonnes or more are subject to the road toll. The charge per kilometre varies according to the number of axles and the vehicle's emission category. For the purpose of the toll, there are two axle classes and 3 emission categories as demonstrated below.

Table 20-1: German HGV Road Tolls

Emission Category	3 axles or fewer (toll in €/km)	4 or more axles (toll in €/km)
A	0.09	0.10
B	0.11	0.12
C	0.13	0.14

20.2.2 Technology and Operations

Automatic HGV tolling in Germany is based on GNSS satellite positioning and an On Board Unit which recognises the road network section the vehicle is travelling in. The OBU calculates the toll due in accordance with the declared number of axles and the emission class concerned. This data is then transmitted to the control office where the bill is prepared. Before the start of each journey, drivers must enter the correct number of axles into the OBU while all subsequent steps in the tolling process are then carried out automatically.

No roadside infrastructure is therefore required in order to levy the charges although there are toll gantries on the motorways exclusively for enforcement purposes. The automatic tolling system is flexible in that it is capable of varying the tolls according to place but also according to the time of day. Since the introduction of the tolling scheme the tolling network has been updated to include new sections and new junctions simply by way of data transfer via the mobile communications network (GSM) - without any technical problems or inconvenience to road users. The HGV toll is levied through any of the following mechanisms:

- Automatically via an on-board unit; or
- via a booking on the Internet; or
- via a booking at a point of payment terminal.

Road users wishing to use automatic tolling or book on the Internet must first register as users with the operator - Toll Collect GmbH. Prior registration with Toll Collect is also required for fast-track booking at the point of payment terminals. Registration is free. The advantage of automatic tolling is that the system recognises the individual motorway sections and calculates the toll for them. Drivers do not have to interrupt their journey if they want to change their route.

Enforcement of toll payment is the responsibility of the Federal Office for Goods Transport with the support of Toll Collect. The system of checks comprises the following elements:

- automatic checks at 300 control points;
- stationary checks carried out by network patrols at control points;
- mobile checks carried out by network patrols using 280 control vehicles; and
- checks carried out at the haulier's premises.

Checks are carried out at all times of the day or night on all sections of motorway, and on a random basis covering the whole network. The level of violations is reported as less than 2 per cent which by international experience is considered effective.

20.2.3 Business Model

Introduction of the HGV toll in Germany was subject to the so called “Eurovignette” Directive which lays down common principles for tolls and user charges for heavy goods vehicles. The tolls have to be based on the actual costs caused by the use of the motorway and relate to the costs for the construction, operation and upgrading of the motorway network.

In 2005, gross toll revenue from the system was €2.86 billion, with collection costs currently estimated at 20% of revenue. HGV tolls are thus making a significant contribution to the funding of transport infrastructure in Germany with a large proportion of the revenue invested in the road network. In keeping with the Government's integrated transport policy, some revenue is also being used to upgrade railway infrastructure and waterways. This will make it possible to continue ongoing projects, remove bottlenecks at congested junctions and on busy routes and make a contribution to the preservation and modernization of the existing road, rail and waterway networks.

20.3 Other Relevant Examples

Similar systems have been put in place in a number of other Member States of the EU. Slovakia and Switzerland have satellite based tolling for trucks, while Austria and Czech Republic have DSRC based systems. A number of other countries including Poland, France, Austria, Denmark and Finland are all currently planning for satellite based truck systems (in addition to Holland). In HGV tolling, satellite systems are typically applicable in preference to DSRC where the length of roadway is high in proportion to the number of vehicles (i.e. where the transaction cost per user would be high).

The Slovakian system is an interesting example of a different approach to that applied in Germany. HGVs are charged for motorway use and for using sections of alternative non-motorway routes. Some 80,000 OBU's have been issued. This has two interesting effects:

- It eliminates an incentive for HGVs to divert from motorways to alternative routes. This type of diversion can have undesirable consequences in the form of road congestion and road damage; and,
- The system avoids a technical problem in a system that only charges for motorway use. Where a system is only meant to charge for motorway use it can in practice be difficult to distinguish whether a HGV is using a motorway or a nearby secondary road that may be running in parallel.

20.4 Potential to Apply HGV Road Pricing in Ireland

HGVs are already charged a significant amount for their road use, as they are subject to vehicle taxes, excise duties on fuels, and vehicle tolls on those parts of the motorway network that have been recently upgraded. Introducing this type of road charging on National Roads with the objective of generating *additional* revenues would be challenging as:

- There would be significant stakeholder pressure to reduce the other fiscal burdens on HGVs to compensate for this new charge; and,
- There would be a significant risk of vehicle diversion onto non national (i.e. "free") roads.

However this type of road charging for HGV's could be a valuable part of a Traffic Management Study if it were extended to cover all roads, and not just restricted to particular road classes. If such charges were introduced, with suitable compensations for HGVs in the form of reductions in other costs such as tolls and taxation, they could be used to:

- Attract HGVs away from inappropriate use of local roads;
- Incentivise HGVs to use the road network at certain times of day; and
- To automatically charge HGVs for entering urban areas at certain times.

In addition, there is a general push towards the introduction of user charges in this sphere by the European Commission and there is another draft HGV charging directive[39] in 'the pipeline', which promotes the concept of distance-based tolling. This new directive will likely direct Member States implementing toll schemes to provide for the inclusion of an environmental charge (e.g. to compensate for air and noise pollution) in addition to an infrastructure usage charge. It is also likely that this directive will impose restrictions with respect to charging structures which, for example, may limit our ability to introduce discounts for regular users as well as introducing new EU approval procedures for new tolling schemes in Ireland.

The current draft HGV directive also promotes electronic barrier-free tolling commenting that *"the use of electronic tolling is essential to avoid disruption to the free-flow of traffic and to preventing adverse effects on the local environment caused by queues at toll barriers*".

Using 2006 information for goods vehicles greater than 2 tonnes, road pricing is likely to generate to the order of €100m per annum, assuming a distance charge of 5c on uncongested roads, with a higher charge on congested or unsuitable routes. Operating costs for HGV systems in Europe are typically less than 10% of revenue, albeit at much higher revenues than would be expected with an Irish system. Nevertheless, costs could be reduced substantially if the system were to use many of the business tools already set up for the existing M50 toll.

Therefore, it is likely that, at best, the introduction of a HGV Road Pricing Strategy would be revenue neutral, with the income from a distance-based charge being offset by reductions in other forms of taxation. Nevertheless, the environmental and safety benefits could be significant as HGV's are attracted back onto the most suitable routes.

Chapter 21 Conclusions – Fiscal Measures

21.1 General

The discussion provided throughout this section of the report has therefore addressed a number of forms of fiscal intervention, ranging from city centre charges through parking or cordon charging, to the various mechanisms possible for charging on national roads.

The evaluation undertaken has supported a number of distinct findings relative to the application of fiscal measures:

- That urban parking charges or cordon charging will have some impact on demand on national roads in the fringes of the urban areas. Nevertheless, in the absence of stronger planning controls, such measures do have some influence in displacing car-based development to edge of city sites. As such, those measures do not fully control the level of car reliance that major road infrastructure can generate;

- That national road pricing using GNSS technology would be a very appropriate form of charging on the basis of the existing level of vehicle density in Ireland. Nevertheless, such an approach to user charging would offer limited benefit over fuel taxation throughout much of the network, where the network is uncongested and where high quality roads offer an attractive alternative to less appropriate roads;

- In the case of goods vehicles, network efficiency is sub-optimal along many inter-urban corridors, as drivers do currently avoid tolled routes. This leads to higher environmental and infrastructure cost on inappropriate routes. A national GNSS based road pricing system for goods vehicles would reduce environmental impacts of goods transport by providing more attractive pricing for use of more appropriate infrastructure; and

- Road pricing is most appropriate in the congested areas of Dublin and Cork, but using DSRC and ANPR technology, as is currently in use on the M50. Whilst distance based charging represents an attractive medium term solution for the road network in the Greater Dublin Area, further upgrade works are required on the N7, N3 and N11 to facilitate this. In the interim, a multi-point tolling system on the M50 and main radial routes will provide an effective proxy of distance based charging which will meet the objectives of the current Study.

21.2 Sifting

All fiscal measures have been subject to the sifting process to understand those measures which should be carried forward for inclusion in subsequent strategies. The sifting proposes that measures are either:

- Rejected, as they do little to support the objectives of the current study;
- Adopted, but subject to further study at specific sites to understand their applicability; or
- Adopted as a solution which strongly supports the study objectives.

Figure 21-1 Strategic Sifting Approach – Fiscal Measures

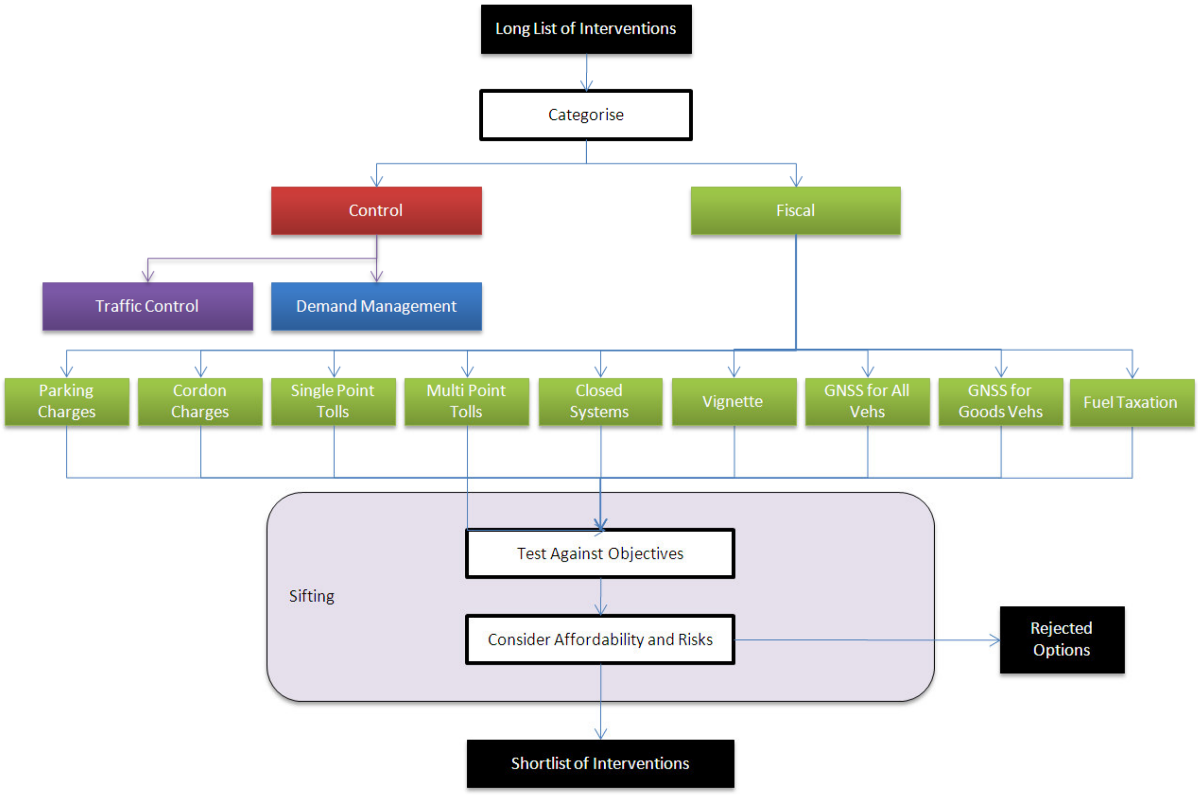


Figure 21-2 overleaf summarises the results of the sifting process. This concludes that the following measures should be carried forward:

- Multi-Point Tolling using DSRC technology (for application in the Greater Dublin Area);
- A Single Point Toll using DSRC technology (for application in Cork);
- Distance-based road pricing on national roads in the Greater Dublin Area using a closed system as a medium-term objective;
- GNSS based road pricing technology for goods vehicles as a medium term objective but subject to further investigation; and
- Fuel taxation as the preferred means of charging for road use by non-goods vehicles outside the major cities.

Note that although GNSS road pricing performs well against the objectives, it does not perform that much better than DSRC tolling systems when addressing congestion or allocative efficiency on national roads in urban areas. As such, it is dismissed on the grounds of cost in comparison to comparable technologies.

Figure 21-2 Results of Sifting – Fiscal Measures

Objectives	Urban		Regional				National		
	Parking Charges	Cordon Charges	Single Point Tolls	Multi-Point Tolls	Closed Systems	Vignette	GNSS Road Pricing (all vehicles)	GNSS Road Pricing (goods vehicles)	Fuel Taxation
Economy									
Improve allocative efficiency			✓	✓	✓		✓	✓	
Reduce the economic impact of delay through effective incident management									
Address excessive reliance on national roads as a means of supporting commuting traffic			✓	✓	✓		✓		✓
Maximise the capacity of congested areas through effective management solutions			✓	✓	✓		✓		
Environmental									
Encourage public transport on national roads	✓	✓	✓	✓	✓		✓	✓	✓
Contribute to reductions in CO2 emissions, air pollution and noise	✓	✓	✓	✓	✓		✓	✓	✓
Accessibility									
Maintain and improve opportunities for access			✓	✓	✓		✓		
Integration									
Promote an understanding of integrated land use and transport planning policies									
Encourage the use of public transport on national roads through supporting network integration									
Safety									
Reduce knock-on safety risks that result from incidents									
Reduce the frequency and severity of accidents on National Roads									
Adopt/Reject	×	×	✓	✓	✓	×	×	✓	✓

- ✓ Measure adopted as technically feasible and strongly supporting strategy
- ✓ Measure adopted but subject to further study
- × Measure rejected due to technical challenges or conflict with study objectives

NRA
An tÚdarás um Bóithre Náisiúnta
National Roads Authority

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Proposals for Traffic Management

Section E

AECOM Roughan & O'Donovan Goodbody Economic Consultants

Section E Proposals for Traffic Management

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Chapter 22 Overview of the Strategy Development Process

22.1 Overview

In seeking to develop a strategy to protect and manage transport infrastructure through future years of traffic growth, it is evident that the range of alternatives is significant, and that some form of systematic formulation of options is necessary to allow the development of a shortlist of alternatives.

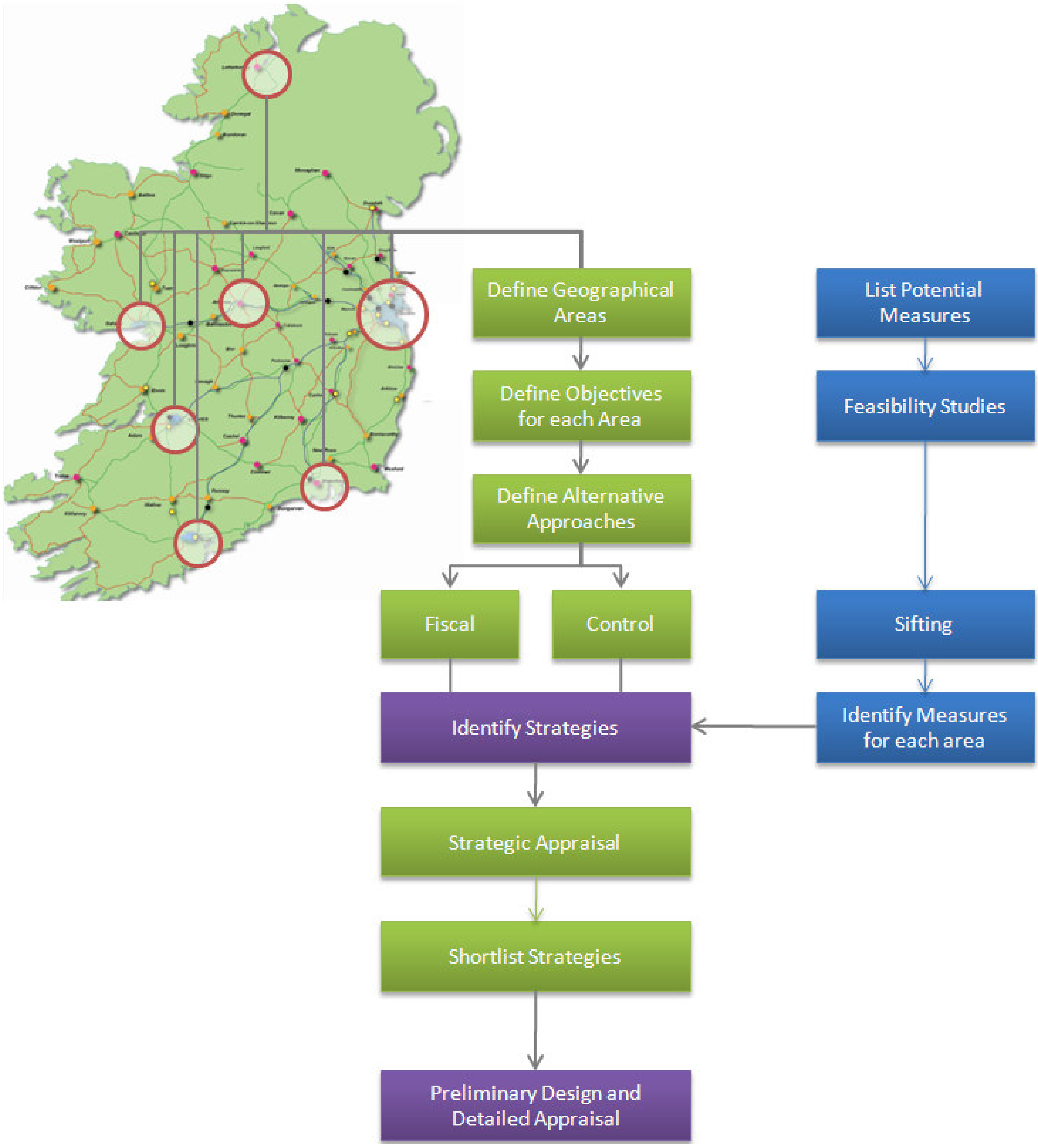
Based on the feasibility work undertaken in this report, a good understanding of the role and function of a range of the more prominent potential measures has been developed. This, combined with the review of case studies allows an informed progression through the strategy development process.

22.2 Structure of the Strategy Development Process

The development of the strategy alternatives for the Traffic Management Study therefore requires a number of layers, with each layer requiring a more detailed level of scheme appraisal to understand the role of each measure, and how can it fit within a potential overall strategy.

The Strategy Development Process is outlined below in Figure 22-1. On the leftmost column, the process of understanding the baseline, defining the key geographical areas, and setting specific objectives for those areas is outlined – this has been covered in Section A of this report. The rightmost column deals with the selection of measures and identification of those which can form part of a strategy. The definition of measures and feasibility studies, in addition to the initial sifting has been covered in Sections B, C and D of this report.

Figure 22-1: Strategy Development and Appraisal Process



The sifting exercise (informed by the various feasibility studies) has led to the definition of a total of 18 measures which are to be considered for implementation in each of the geographical areas defined. The development of individual strategy options pulls together measures in response to the defined set of objectives for each area.

In doing this, a clear approach to the definition of strategies is required in order to limit the number of potential strategy options, but also to allow each alternative to follow a clear 'concept'. For the current study, it became evident at an early stage that the consideration of fiscal measures (tolling or road user charging) would give rise to an additional layer of solutions.

The baseline assessment outlined the widely accepted result from economics that if a price was charged for all road use equal to the full social cost of road use that this would lead to the optimum level of investment in roads. It would also lead to an optimal level of allocation of roadspace between potential users. In this context a "price" for road use means any payment levied on road users including vehicle registration tax, fuel taxes, simple tolls or the latest road pricing systems.

In Section D of this report, various forms of fiscal intervention were discussed in detail. The discussion proposed that the development of multi-point tolling on National Roads should be considered as a proxy for distance-based charging, at intervals and payment rates which would allow levels of diversion onto less suitable roads to be managed effectively. It is expected that such proposals would have a notable impact on traffic demand over the future years of traffic growth – it would manage large-scale demand responses to additional transport infrastructure, and would reserve roadspace for those higher value users (freight, public transport and business trips) who are more prepared to pay for the benefits that it provides. A strategy option that is built on a series of fiscal measures would therefore differ substantially from that which would emerge from a strategy restricted to control measures.

In the absence of any fiscal proposals, the use of only control measures would achieve little in the way of addressing existing or future demands, and would necessitate more of a *restrict and control* approach. Such an approach would acknowledge the inability to manage demand through pricing, and would seek more direct means of reallocating road capacity to higher value users, whilst attempting to maximise road capacity for other users. Such an approach is common in urban areas of cities, where road capacity is allocated to buses (bus lanes) or freight (dedicated routes such as Dublin Port Tunnel), and traffic control systems attempt to maximise residual road capacity for other traffic. In such situations, however, it is clear that the level of demand can never be fully provided - hence the recent considerations of cordon charging for urban areas (such as that in London or Stockholm) to manage such demand.

22.3 Approaches to Option Development

On the basis of the discussion outlined above, alternative approaches to strategy development have been defined. The concepts are based on the level of fiscal intervention that is introduced, as this has the ability to set the context for the overall tone of the proposals:

Fiscal Approach: An approach which is founded on a basic system which prices road use on the basis of cost externalities (mainly distance and level of congestion). Having established the fiscal measures, other supporting control strategies are then examined which will support residual management requirements;

Control Approach: An approach which seeks to restrict access to the road network in order to maintain a basic level of service, whilst releasing small amounts of additional capacity from existing infrastructure. The Control Approach also attempts to provide, insofar as is possible, acceptable levels of travel time reliability and road safety to those users on the network.

In developing individual traffic management strategies, the fiscal approach will be based on multi-point tolling throughout the Greater Dublin Area, supported by a single point toll on the Jack Lynch Tunnel in Cork. The deployment of additional tolls on the inter-urban corridors away from these locations is not specifically considered, as they lie outside the key areas to be addressed as part of the detailed proposals.

Chapter 23 Definition of Options

23.1 Introduction

The development of the strategies for each of the geographical areas is outlined in this section of the report. The following discussion is provided for each area:

- An overview of the existing road network and its development;
- A discussion of existing conditions, expanding on the discussion in the chapter 3;
- An outline of the key deficiencies in that area of relevance to the Traffic Management Study, and hence the areas which the strategy will be required to address;
- The fiscal, control and combined strategies for that area; and
- A summary of the strategy appraisal process.

For each geographical area, the discussion presented here outlines the basis for Traffic Management, and the measures to be considered as part of the subsequent appraisal process.

23.2 The M50 Dublin Ring Road

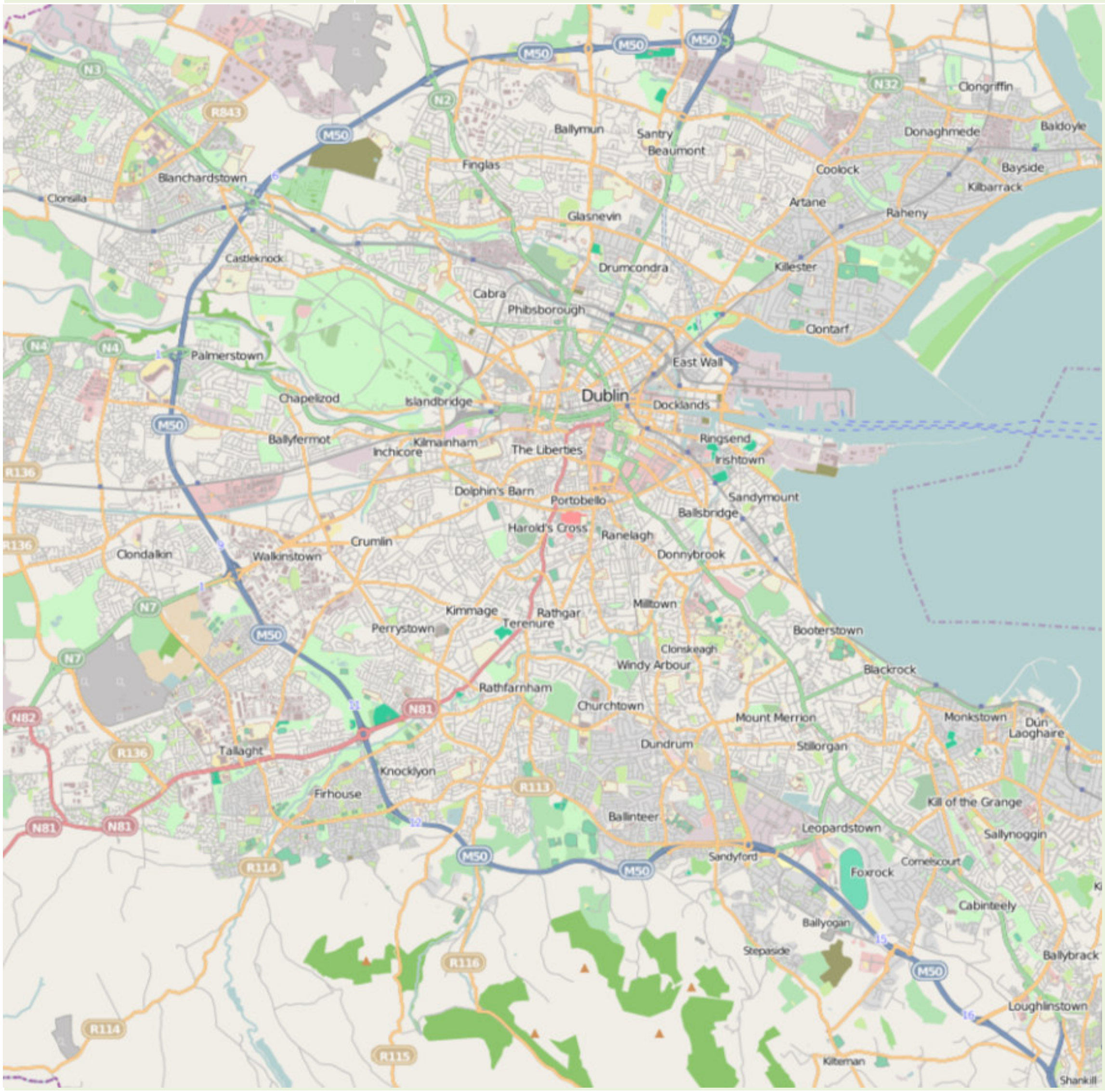
The analysis undertaken in the Baseline Analysis and as part of the investigation of fiscal measures in Section D of this report suggests that there are a small number of dominant issues which influence Traffic Management needs for the M50. These are:

- The high dependency on the route for commuting trips;
- The impact of a large number of short distance movements on the overall ability of the M50 to function as a strategic connection;
- The level of incidents that are commonly associated with congested conditions;
- The significant delay that can result from incidents; and
- The threat of large increases in traffic demand due to land-use responses to additional road capacity.

As such, Traffic Management proposals for the M50 will seek to influence longer term travel patterns (and land-use patterns) which lead to an excessive level of short-distance trips, but will also seek to deploy measures to manage the traffic stream to improve general safety and running capacity for residual users.

A summary of the Strategy Development Process for the M50 is provided over the following pages.

Area	**M50, Dublin**
Details	National Primary road, 42km in length connecting Dublin Port with the M1 and orbiting the City as far as the M11. Construction commenced in 1987 with most recent upgrade completed in 2010.



Key Features	Motorway standard, constructed in five sections (South Eastern Motorway, Southern Cross, Western Parkway, Northern Cross and Dublin Port Tunnel. Recently upgraded between Junction 3 and Junction 14 to provide increased lane capacity and freeflow junctions. Existing toll between Junctions 6 and 7 with toll price varied by vehicle type and by payment method.
Function	Operates as a strategic orbital route of the City, and provides access to Dublin Port via the Dublin Port Tunnel. Dependency on M50 as a distributor road has risen, leading to a high level of short distance inter-junction movements.

Area	**M50, Dublin**
Key Deficiencies	• The high dependency on the route for commuting trips; • The impact of a large number of short distance movements of the overall ability of the M50 to function as a strategic connection; • The level of incidents that are commonly associated with congested conditions; • The significant delay that can result from incidents; and • The threat of large increases in traffic demand due to land-use responses to additional road capacity.
Existing Measures	• Freeflow tolling point between Junction 7 and 8 (eFlow). • Network patrols to deal with incidents • Control Centre (at Dublin Port Tunnel) • Variable Message signing, although use is limited • Some coverage on *NRA Traffic* website
Area Objectives	• Examine means for adjusting the existing toll point, moving to a system of more frequent but lower cost tolls. • Reduce the quantity of incidents on the M50, thereby improving the reliability along the corridor thus preserving its strategic function. • Minimise response times to incidents through early detection and rapid management of responses. • As congestion increases, identify areas where access is to be managed in order to maintain an adequate level of service on the mainline carriageway. • As congestion increases, identify means of prioritising freight and public transport vehicles, with a facility for high-value users (business users) to avail of improved reliability at a cost. • Support with relevant national policies and travel initiatives
Analytical tools	A traffic model of the M50 has been developed and validated for a 2010 Base Year, and 2025 Future Year. Demand has been further segmented by trip purpose and by income band to enable responses to fiscal strategies to be understood.
Traffic Conditions	Existing traffic flows expected to increase substantially over the period to 2025, with AADT of 150,000 expected. Expected to lead to substantial pressure on road capacity and adjacent junctions. Some means of managing such traffic volumes will become necessary.

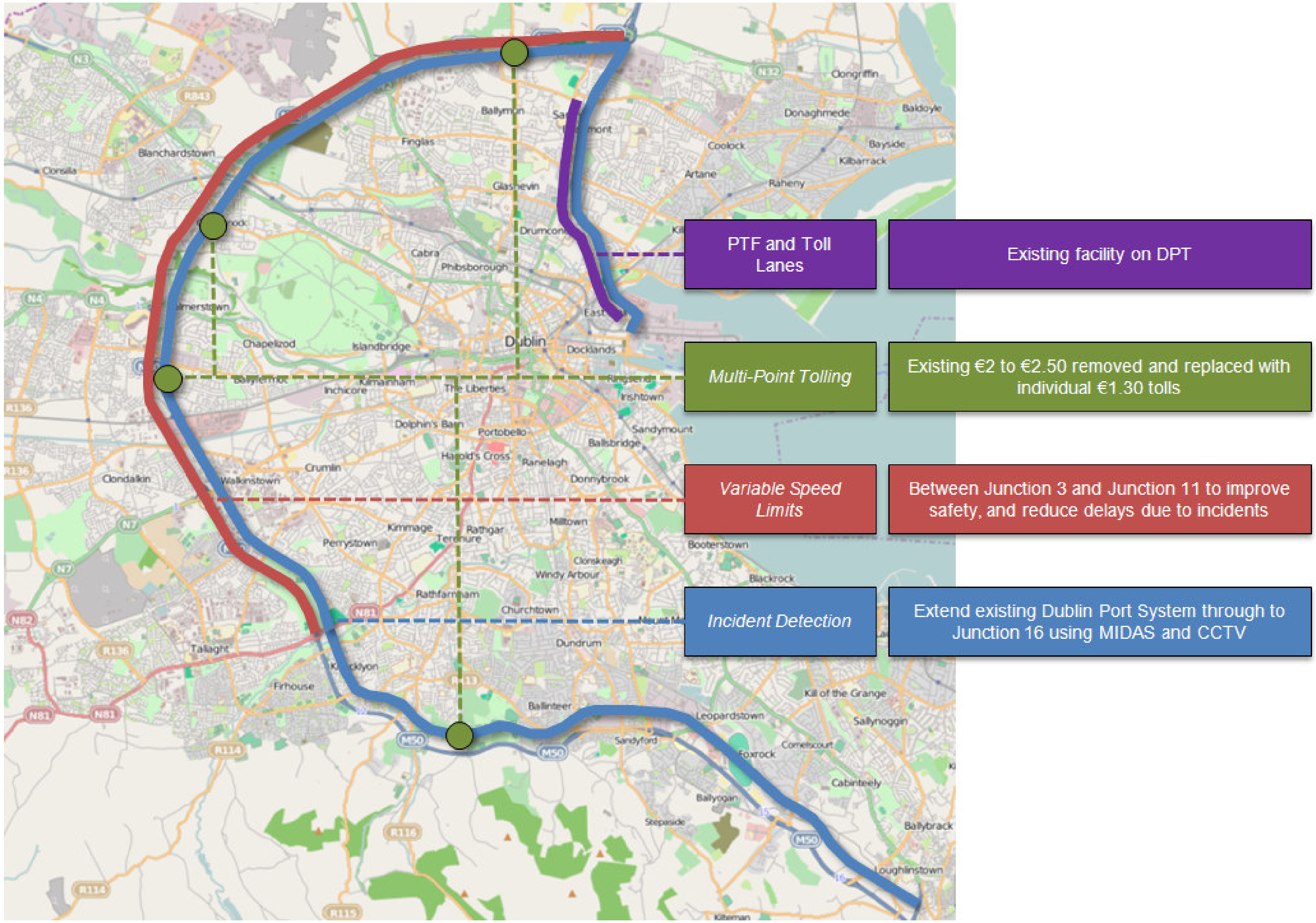
Assessment of Measures *(Adopt✓ or Reject ×)*			
Fiscal	Single Point Tolls	Existing single point toll does little to support objectives – leads to diversion between N3 and N4 with limited impact elsewhere on M50	×
	Distance Based Tolling	Strongly supports objectives and to be examined using multi-point or closed system	✓
	Toll by Time	There is some potential to reduce off-peak tolls	✓
	Toll by Congestion	Would be difficult to achieve	×
	Toll by Vehicle Type	Maintain existing mechanism, but examine opportunities to simplify, and incorporate reduction in HGV tolls	✓
	Analysis of tolling options and resulting impacts suggests that the objectives of the study can be best met through the development of a multi-point tolling system which charges a lower individual toll at each point. This achieves the objectives of a distance based system, but can be delivered as an expansion of the existing freeflow tolling operation.		
ITS	Access Control	Only feasible at a small number of individual sites, mainly along South Eastern motorway. Will likely only be necessary in absence of fiscal measures.	✓
	Incident Detection	Can lead to strong benefits. Existing DPT system could be extended through full M50	✓
	Variable Speed Limits	Good safety benefits at higher flows	✓
	It is proposed that Incident Detection and Variable Speed Limits form part of the management of the M50 in the short to medium term. Access control will be required if fiscal measures cannot be delivered.		
Capacity	Reversible Lanes	No real potential on M50	×
	Hard Shoulder Running	Not technically feasible other than on South Eastern motorway, but poor business case	×
	There are no practical means of increasing capacity between Junction 1 and Junction 14. Whilst Hard Shoulder Running can be delivered beyond Junction 14, it is concluded that median widening would be a preferable medium-term solution.		
Priority	High Occupancy Lanes	Limited potential as a stand alone measure	×
	High Occupancy Toll Lanes	Could be implemented in areas where there are no background tolls	✓
	Public Transport Lanes	Limited public transport demand along M50, and hence would cater for small number of users to detriment of others	×

	Freight lanes	Provides benefits to HGV's but would lead to net increase in congestion at current levels of HGV activity.	×
	Public Transport Freight Lanes	Caters for higher number of users, but may need VSL to function properly. HGV and freight are low proportion of M50 traffic and hence may still lead to net increase in congestion. May become necessary where congestion is unavoidable (i.e. where there is no background fiscal strategy) to maintain strategic function.	✓
	Public Transport Freight Toll Lanes	Maximises lane efficiency, but could only be implemented in areas where there are no background tolls	✓
	The concept of Public Transport Freight (PTF) or Public Transport Freight Toll (PTFT) Lanes has been suggested as the most appropriate means of delivering priority. This might best be achieved through reallocation of the fast lane, but only under conditions where variable speed limits are activated. A facility for tolled use by other vehicles could be allowed in situations where there are no background tolls. This may be a part-time measure only.		
Information	Internet	Low cost measure with good benefits	✓
	Roadside Information	Adopt to supplement other systems only	✓
	In-Car Systems	Will become available soon	✓
	Adopted measures will be delivered regionally or nationally, and are not specific to the M50.		
Demand Management	Various (see Section D)	All should be progressed at national/regional level to manage existing demand and future growth	✓
	Land Use Proposals apply to new development lands, with Accessibility and Travel Planning providing benefit for existing uses.		
Control	National Control Centre	Will be required to support traffic control measures – good foundation already provided in Dublin Port Tunnel Control Centre	✓
	Network Patrols	Existing arrangements could be extended	✓
	National Control Centre will initially locate in the Dublin Port Tunnel, and control of M50 could represent an initial phase of the rollout of the centre.		

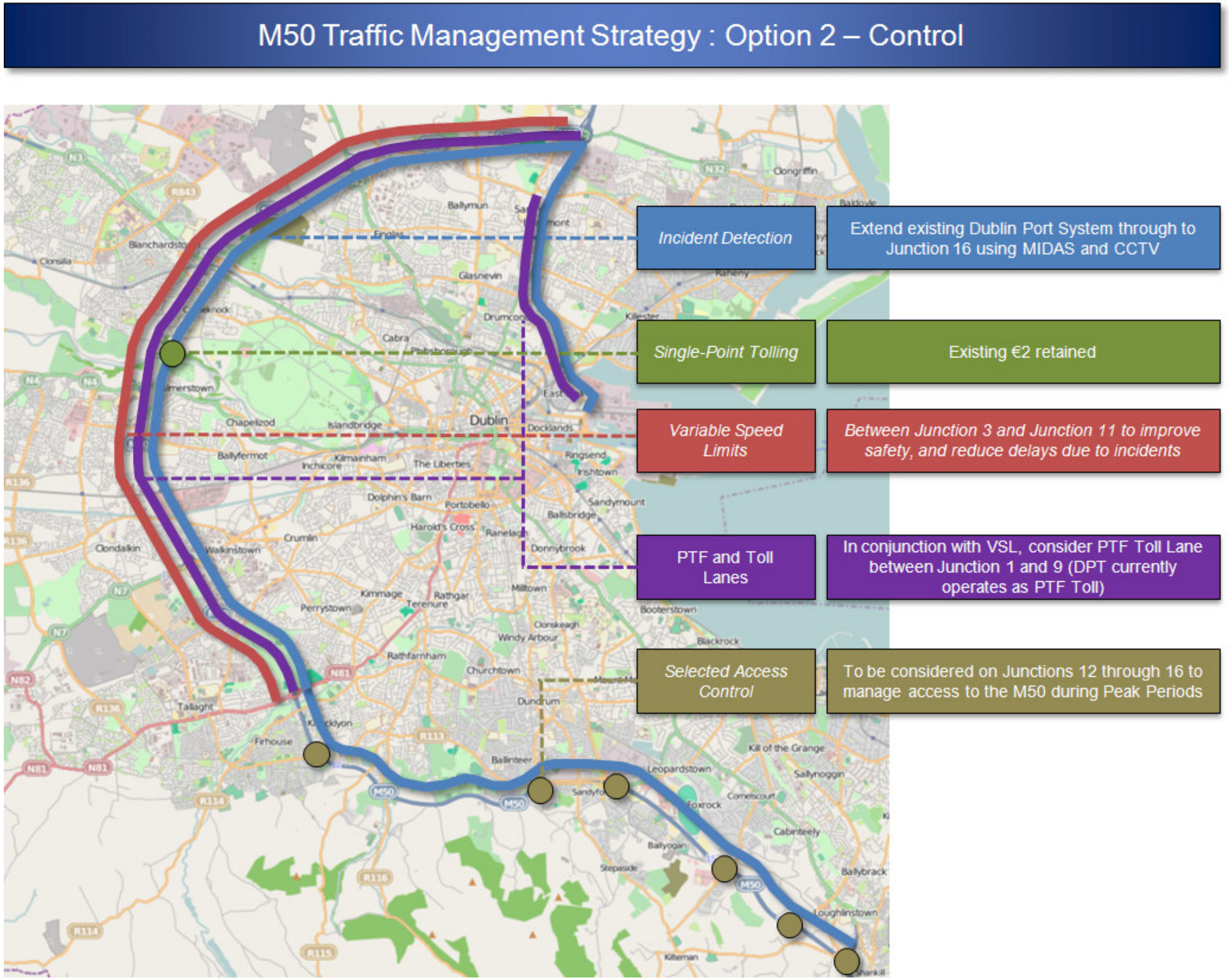
The Strategy alternatives for the M50 are outlined overleaf, and describe the two main approaches to traffic management on the M50 corridor. It is evident that in the absence of any additional fiscal intervention, that measures to restrict access and measures to prioritise more important traffic movements will become necessary. Key measures include:

- Variable Speed Limits through the busiest section of the M50, between Junction 1 (Dublin Port) to Junction 11 (N81) to improve safety and reduce the delay arising from incidents. This would be supported by incident detection and response services along the full M50 corridor;
- A fiscal strategy which will see the delivery of a total of 4 toll points along the M50, each applying a charge in the region of €1.30 for registered users. This will replace the existing toll point which currently charges between €2.00 and €2.50 for registered users;
- A Public Transport Freight Toll (PTFT) facility currently exists between Junction 1 and 2 (i.e. the Dublin Port Tunnel). Where no fiscal strategy is implemented, it would become necessary to examine the extension of a PTFT facility along the M50 as far as Junction 11 (N81). This lane would allow free passage for public transport and freight, with other users permitted to use the lane upon payment of a toll. The PTFT lane would continue to be subject to the existing M50 toll located at the West Link bridge; and
- In the absence of fiscal interventions, access control will be necessary along the M50 south of Junction 11 (N81) to manage interaction with mainline traffic volumes.

M50 Traffic Management Strategy : Option 1 – Fiscal



M50 Traffic Management Strategy : Option 2 – Control



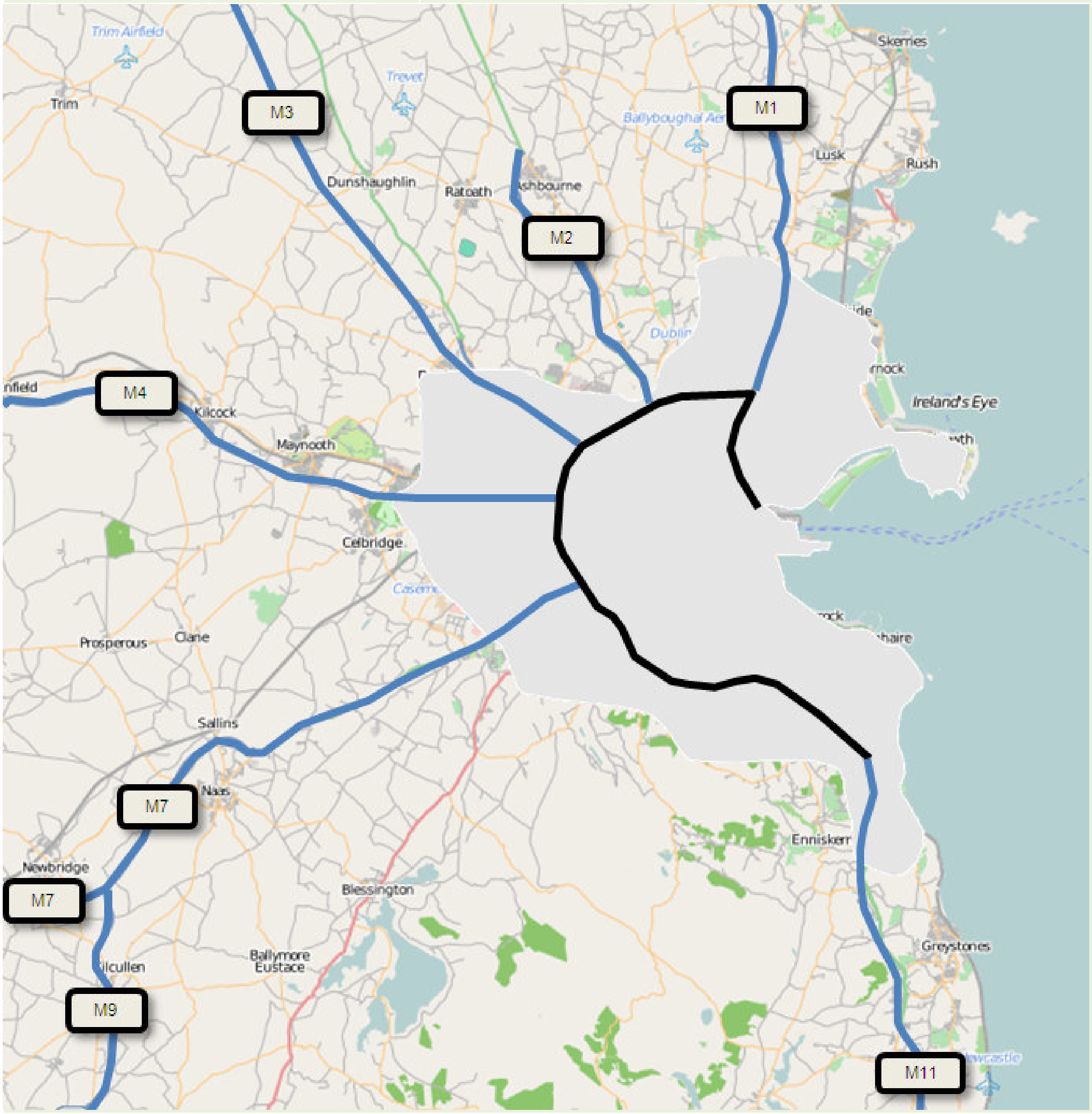
23.3 The Dublin Radial Routes

Although spread throughout a large geographical area, the Dublin Radial Routes all provide relatively similar functions, namely providing strategic connectivity between different regions via the M50, and providing for car-based commuting into the City. Although the scale of deficiencies ranges considerably amongst the different routes, a number of common issues are prevalent:

- The congestion on the approach to the M50, exacerbated by high volumes of merging traffic;
- The limited provision for public transport;
- The significant reduction in strategic accessibility during commuter peak periods;
- The level of incidents that are commonly associated with congested conditions;
- The significant delay that can result from incidents; and
- The risk of larger than planned increases in traffic demand due to inappropriate land-use responses to additional road capacity.

The N81, N32 and N31, while National Roads, offer more in the way of local or regional importance, and have grown to provide a local distributor function. These routes are not of the same strategic importance as the other radial routes, and are therefore not specifically considered in this report. Nevertheless, these routes may benefit from local initiatives on traffic management, and in such situations these should be consistent with the Traffic Management Study.

Area	**Dublin Radial Routes**
Details	System of routes providing access to the Dublin Area, converging onto the M50. National Primary Routes designated M1 to M11 as one travels anticlockwise around the M50.



Key Features	Combination of motorway and Dual Carriageway. Full grade separation on all dual sections, with the exception of the N3 at Blanchardstown and N7 at Newlands Cross. Recent major widening projects completed on N4 and N7, with more limited widening on M1.
Function	Provide strategic connectivity into Dublin City. Also facilitate longer distance movements through the City Area via the M50 and internationally via Dublin Port Tunnel and Dublin Airport via M1. Cater for high commuting volumes during the peak periods.

Area	Dublin Radial Routes
Key Deficiencies	• The high dependency on the routes for commuting trips; • Congestion on approach to the M50, exacerbated by high volumes of merging traffic; • Limited provision for public transport; • Significant reductions in strategic accessibility during commuter peak periods; and • The risk of larger than planned increases in traffic demand due to inappropriate land-use responses to additional road capacity
Existing Measures	• Some pubic transport priority on N3 at Clonee. • Single point toll on M3 at Pace (€1.30 for cars) • Variable Message signing, although use is limited • Some coverage on *NRA Traffic* website
Area Objectives	• Manage future traffic growth by encouraging alternative travel choices, either by fiscal or control measures. • Understand how best to allocate future capacity increases that can be delivered; • Support with relevant national policies and travel initiatives
Analytical tools	The 2006 National Traffic Model, updated to represent a 2010 Base Year using additional traffic volumes from the M50 and Dublin Radials. Future growth forecasts based on NRA Growth forecasting methodology.
Traffic Conditions	At present flows on a number of Dublin Radial at the intersection with the M50 are between 70,000 and 110,000 AADT, with the highest traffic flows on the M1, N7 and N4. Transport demand is forecast to grow by up to 40% on the Dublin Radials over the period 2010 to 2025 as a result of further population and employment growth in the region, and this increase in traffic will exacerbate existing capacity issues along the routes. Induced land use responses will exacerbate this growth. The Dublin Radials carry high levels of commuting traffic which can account for up to 70% of traffic during the AM Peak Period. The proportion of HGV traffic varies by route, with highest daily proportion of 10% on the N2, reducing to 4% on the N11. Although the volume of HGV traffic on the N2 is relatively high, this is partly a result of traffic avoiding M1 tolls at Drogheda.

Assessment of Measures *(Adopt✓ or Reject ×)*			
Fiscal	Single Point Tolls	Potential for single point tolls as an extension of M50 system, but will require low toll cost to limit diversion potential	✓
	Distance Based Tolling	Strongly supports objectives and to be examined using multi-point system, although this can migrate to closed system as remaining routes are upgraded	✓
	Toll by Time	Potential to consider different charge by time of day	✓
	Toll by Congestion	Would be difficult to achieve	×
	Toll by Vehicle Type	Maintain existing approach, but examine reduction in level of HGV tolls	✓
	Traffic studies suggest that there are a limited number of locations where tolling would be feasible on the Dublin Radials. Even so, any toll level would need to be kept quite low to manage diversion impacts. There does exist potential to introduce nominal tolls on key approaches to the M50 as an extension of the multi-point tolling concept described above. This will lead to a good approximation of distance based charging.		
ITS	Access Control	Will become necessary to manage high volumes of merging traffic on approach to M50.	✓
	Incident Detection	Can lead to strong benefits, although may be best achieved through CCTV as a means of mobilising response	✓
	Variable Speed Limits	Good safety benefits at higher flows	✓
	As traffic flows increase, access control will become more necessary on the radials to protect the capacity of the mainline carriageway. Where any tolling of the mainline takes place, it is preferable to ensure that those being required to pay a toll would not be subject to such restrictions. Incident Detection and Variable Speed Limits are adopted in principal, but will only be applicable on the most heavily trafficked routes, and will be extensions of the M50 system.		
Capacity	Reversible Lanes	May be potential for reversible lanes in conjunction with PTFT lanes on radials where there are long radial movements (N3, N7 and M11), but only in the absence of other fiscal measures.	✓
	Hard Shoulder Running	Although technically feasible, operation costs lead to poor business case in comparison to median widening	×
	Many radials have a provision for future widening using the central median. Nevertheless, although longer term objectives do exist for widening, it will be necessary to consider how that capacity is utilised to support strategic objectives relating to national development and spatial planning.		

Priority	High Occupancy Lanes	Limited potential as a stand alone measure, as it would need to deliver a significant increase in vehicle occupancy	×
	High Occupancy Toll Lanes	Could only be implemented in areas where there are no background tolls	✓
	Public Transport Lanes	Would support radial public transport connections, and should be considered	✓
	Freight lanes	Relatively low proportion of freight on radial routes travelling in peak direction suggests that designation of freight lanes would lead to net increase in congestion.	×
	Public Transport Freight Lanes	Responds to higher public transport flows and HGV proportions on radial routes, but may need VSL to function properly. May become necessary where congestion is unavoidable (i.e. where there is no background fiscal strategy)	✓
	Public Transport Freight Toll Lanes	Maximises lane efficiency, but could only be implemented in areas where there are no background tolls	✓
	The higher levels of freight and public transport on the radial routes make the concept of Public Transport and Freight lanes more feasible, potentially making use of opportunities for median widening. In absence of other fiscal measures, use could also be made available for high occupancy vehicles, or by single occupant cars upon payment of a toll.		
Information	Internet	Low cost measure with good benefits	✓
	Roadside Information	Adopt to supplement other systems only	✓
	In-Car Systems	Will become available soon	✓
	Adopted measures will be delivered regionally or nationally, and are not specific to this area.		
Demand Management	Various (see Section D)	All should be progressed at national/regional level to manage existing demand and future growth	✓
	Land Use Proposals apply to new development lands, with Accessibility and Travel Planning providing benefit for existing uses.		
Control	National Control Centre	Will be required to support traffic control measures – good foundation already provided in Dublin Port Tunnel Control Centre	✓
	Network Patrols	Existing arrangements could be extended	✓
	Control Centre will initially locate in the Dublin Port Tunnel. Control of Dublin Radials will represent one phase of the rollout of the centre.		

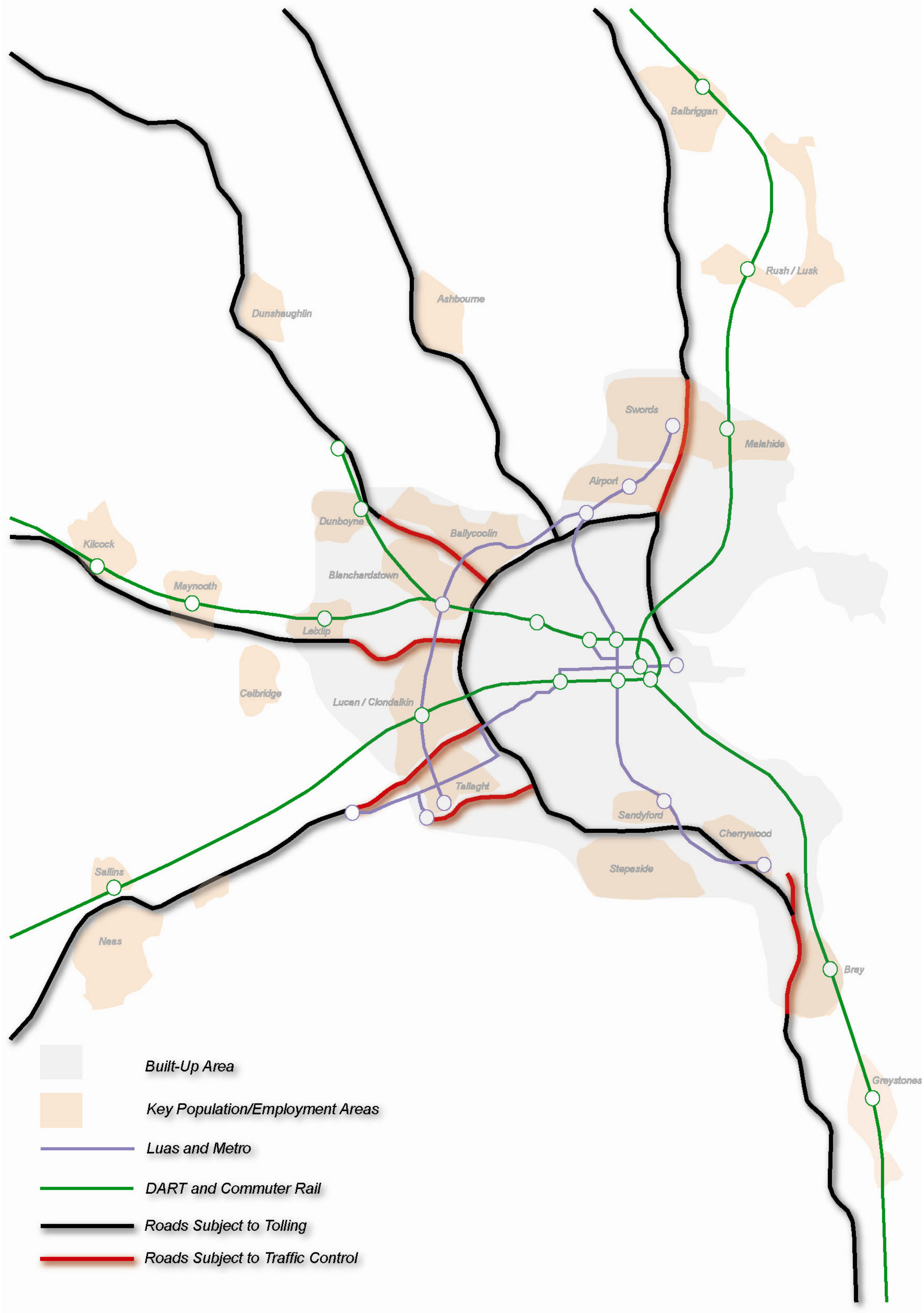
The nature of traffic management proposals for the Dublin Radials is therefore quite different to that proposed on the M50. The study acknowledges the substantial peak period congestion that already exists, and focuses instead on how future capacity enhancements should be allocated to different users.

The main challenge on the Dublin Radials is the variable layout and designation of each road. Roads are a combination of National Primary and National Secondary, have grade separated and at-grade junctions, and are classed both as dual carriageway or motorway. As such, whilst the difficulties associated with each corridor may be quite similar, the means of addressing the issues will vary considerably.

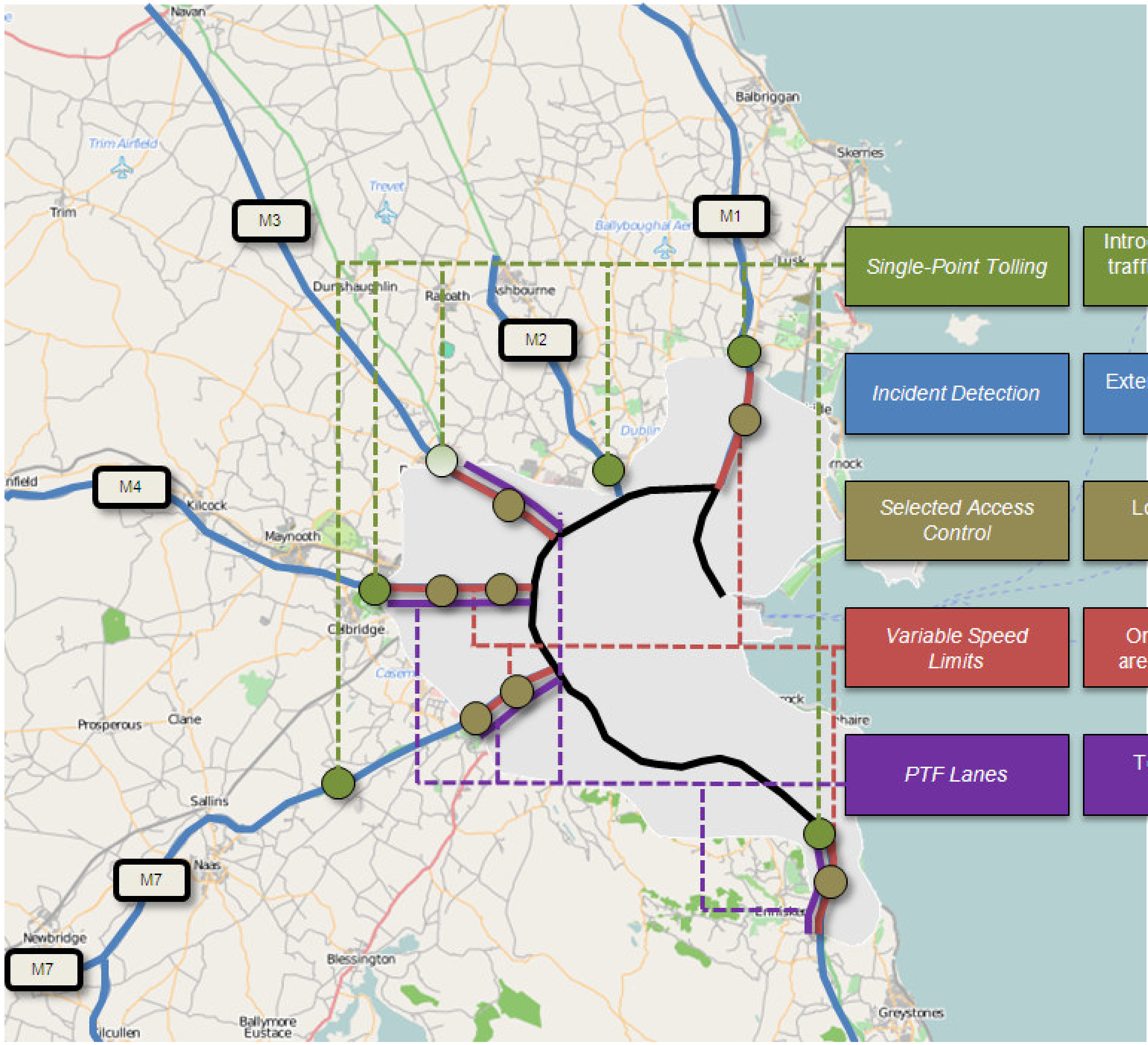
In defining the strategy, it has become useful to define two different levels of road type in the Dublin Area. The M1, M2 and M11 are of motorway standard, providing a high capacity connection with the M50. Nevertheless, these roads do suffer from variable levels of congestion on the approach to the M50, with the extent of congestion closely reflecting the extent of the built-up area of Dublin City. On the N3, N4, N7 and N81, access is less controlled, although congestion problems are similar, again loosely reflecting the boundary of the built-up area. This is illustrated schematically in Figure 23-1 overleaf.

The Traffic Management Study will therefore seek to deal with the congested areas within the built-up area through management of demand and of access to national roads, with supporting measures to address the demands that arise from traffic travelling into these congested sections from outside the built-up area.

Figure 23-1: Radial Routes and the Built-Up Area



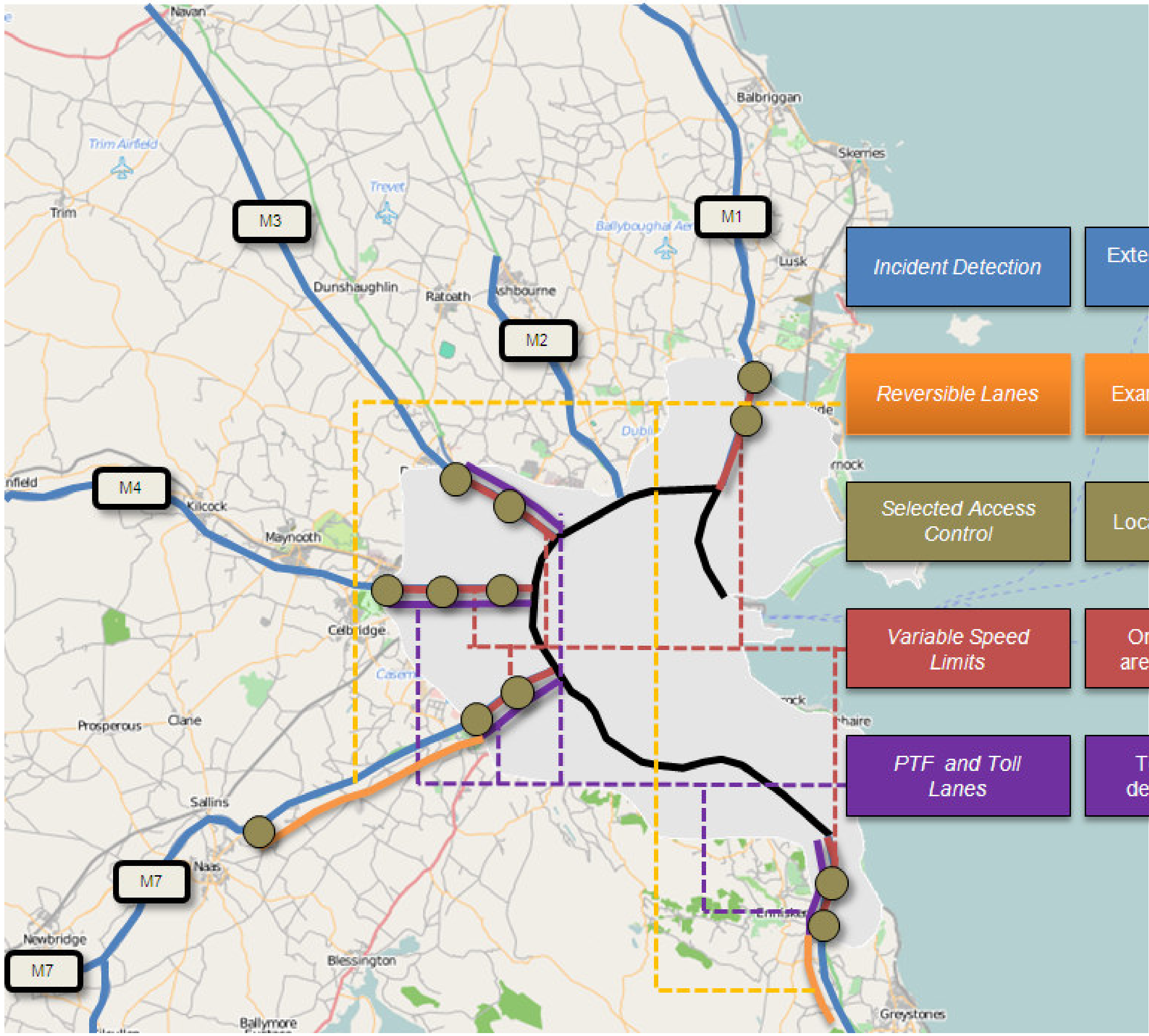
GDA Traffic Management Strategy : Option 1 – Fiscal



Single-Point Tolling	Introduction of €1.30 charge on radial routes for traffic entering built-up area. M3 toll remains at €1.30
Incident Detection	Extend M50 system onto Radials within Built-up Area
Selected Access Control	Located on major junctions within untolled sections of built-up area.
Variable Speed Limits	On approaches to the M50 through built-up area, where full grade separation is provided
PTF Lanes	To be examined on radials with sufficient demand

Note: With the exception of the M3 toll at Pace, all proposed tolls are in addition to those currently in place on the M1, M3, M4 and M50 within Greater Dublin Area

GDA Traffic Management Strategy : Option 2 – Control



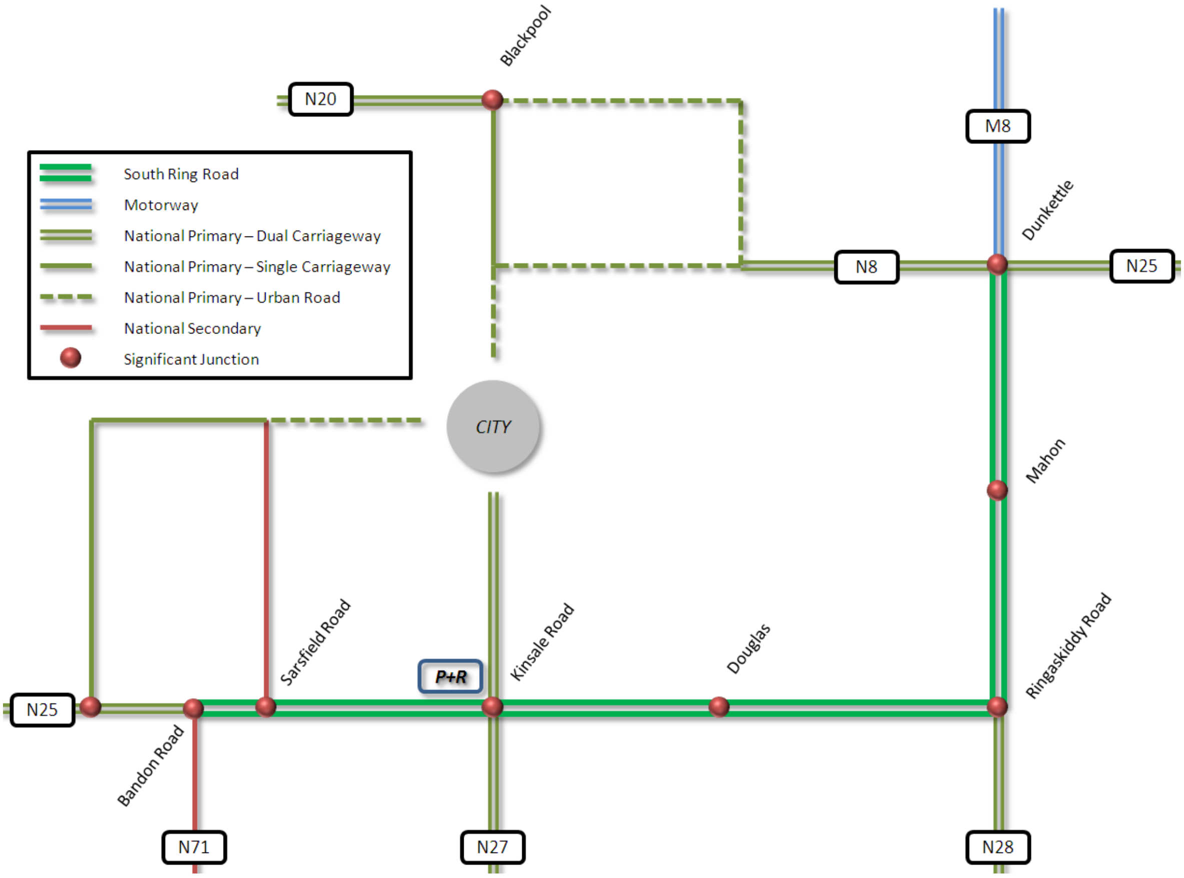
Incident Detection	Extend M50 system onto Radials within Built-up Area
Reversible Lanes	Examine on long corridors with limited weaving
Selected Access Control	Located on major junctions within built-up area
Variable Speed Limits	On approaches to the M50 through built-up area, where full grade separation is provided
PTF and Toll Lanes	To be examined on radials with sufficient demand, potentially also as reversible lanes

Note: Existing tolls retained on M1, M3, M4 and M50 within Greater Dublin Area with this approach

23.4 The Cork Area

The study has identified the Cork Southern Ring Road (N25) as a key corridor within the Cork Area, and the focus of many of the difficulties within that region. The N25 South Ring Road, including the Jack Lynch Tunnel, links the N8, N28, N27, N71 and N22, and as a result plays an important role in providing for strategic connectivity for the region.

Figure 23-2: The Strategic Road Network in Cork



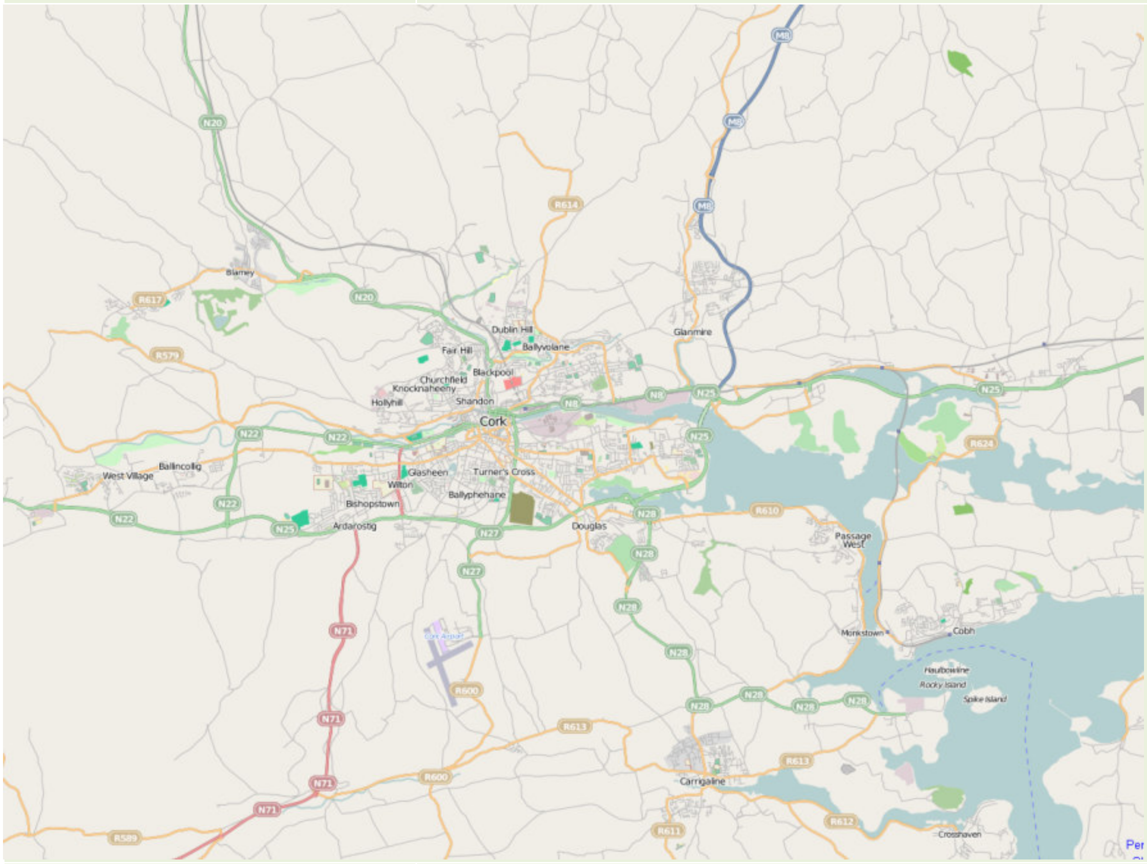
Nevertheless, although junctions at Mahon, the N27 and N28 are grade separated, the volume of merging traffic is substantial, and merging can lead to complete flow breakdown in peak periods. Furthermore, existing signalised at grade roundabouts at Bandon Road and Sarsfield Road experience significant queuing and delay.

The Traffic Management Study will focus on the Cork Southern Ring Road in an effort to influence traffic demands across the Cork Area, and control likely rates of future growth in non-essential movements. Key issues to be addressed are therefore:

- The significant delay at Dunkettle Interchange and through Jack Lynch Tunnel;
- The interaction between merging and diverging traffic at several interchanges which reduces the N25 mainline performance;
- The high dependency on the N25 for commuting trips;
- The specific provision for public transport on the N27 South Link Road;
- The level of incidents that result from congested conditions, and the knock-on delays that they cause; and
- The threat of large increases in traffic demand due to land-use responses to additional

road capacity.

The National Roads Authority is currently examining designs for upgrading the Dunkettle Interchange to a full freeflow junction. Work undertaken to date has suggested that in the absence of any supporting measures, that the Jack Lynch Tunnel will quickly exceed capacity when this bottleneck is released. This will be further exacerbated by the upgrading of the Bandon Road and Sarsfield Road roundabouts which will facilitate significant increases in traffic flow along the South Ring Road.

Area	**Cork Area**
Details	Strategically important node in the national network, with a number of National Primary Routes converging at the Dunkettle Interchange and along the South Ring Road. N20 to Limerick terminates in Blackpool and is more remote from remainder of strategic network.
	
Key Features	National Primary Roads are all Motorway or Dual Carriageway into the City Boundary. N71 to Bandon is a National Secondary Road. Full grade separation on all dual carriageway sections, with exception of two at-grade roundabouts on South Ring Road at Bandon and Sarsfield which cause considerable congestion.
Function	South Ring Road, Dunkettle Interchange and Jack Lynch Tunnel provide crucial strategic link between M8, N22, N28, N25, N27 and N71. Significant commuter demand during peak periods leads to long delays on the Ring Road.

Area	Cork Area
Key Deficiencies	• Strategic impact of congestion on South Ring Road between Dunkettle and the N71; • Isolation of the N20 from other strategic routes; • Limited provision for public transport; • High reliance on cars for commuting trips; • The threat of large increases in traffic demand that may arise following removal of current bottlenecks; and • Limited real-time information on network performance or incident detection
Existing Measures	• Park & Ride at Black Ash. • Traffic Management associated with Jack Lynch Tunnel
Area Objectives	• Manage future traffic growth by encouraging alternative travel choices, either by fiscal or control measures; • Address existing car reliance through support for public transport; • Identify means of protecting strategic accessibility for high value road users; • Support with relevant national policies and travel initiatives.
Analytical tools	Existing data available from Cork Northern Ring Road SATURN Model, and from existing PARAMICS models of the South Ring Road. CASP Model is becoming available in the short term.
Traffic Conditions	Whilst the radial routes leading into Cork City are typical of commuter routes in that they exhibit defined increases in traffic flows during the AM and PM peak periods, the N25 South Ring Road supports high traffic flows throughout the day. On the N25, daily two- way traffic volumes range from 36,000 to 78,000, with the highest volumes measured on the section between the Kinsale Road (N27) and the Dunkettle Interchange (M8). Although junctions at Mahon, the N27 and N28 are grade separated, the volume of merging traffic is substantial, and merging can lead to complete flow breakdown in peak periods. Furthermore, existing signalised at grade roundabouts at Bandon Road and Sarsfield Road experience significant queuing and delay. Future upgrades to the remaining at-grade interchanges will exacerbate this situation by facilitating higher volumes of traffic onto the South Ring Road. On the radial routes, traffic congestion is generated predominantly as a result of the junctions at the end of these routes as they approach the city centre, or at junctions onto the South Ring Road.

<table>
<tr><th colspan="3">Assessment of Measures (Adopt✓ or Reject ✗)</th><th></th></tr>
<tr><td>Fiscal</td><td>Single Point Tolls</td><td>Good potential for single point tolls at key locations, to protect capacity for high value users</td><td>✓</td></tr>
<tr><td></td><td>Distance Based Tolling</td><td>Would be difficult to achieve throughout much of the network in its current form, although may be possible in the future as junctions are upgraded and access is consolidated</td><td>✗</td></tr>
<tr><td></td><td>Toll by Time</td><td>Good potential to consider different charge by time of day, especially given current levels of congestion during the peak periods</td><td>✓</td></tr>
<tr><td></td><td>Toll by Congestion</td><td>Would be difficult to achieve</td><td>✗</td></tr>
<tr><td></td><td>Toll by Vehicle Type</td><td>Tolling proposals would incorporate different charges for light vehicles and HGV's</td><td>✓</td></tr>
<tr><td></td><td colspan="3">Traffic analysis indicates that the Jack Lynch Tunnel supports a significant volume of traffic using the South Ring Road and many of the radial routes. The introduction of a single point toll at this location would reduce much of the non-essential traffic from the South Ring Road, thereby leading to a significant improvement in traffic conditions. It would also allow future growth to be managed such that further capacity increases would not be eroded prematurely.</td></tr>
<tr><td>ITS</td><td>Access Control</td><td>Will be necessary on South Ring Road between N27 and M8 to maintain good level of service on the mainline where fiscal strategies are not adopted.</td><td>✓</td></tr>
<tr><td></td><td>Incident Detection</td><td>Implementation on the busy South Ring Road can lead to strong benefits, and could be achieved through extension of existing system in Jack Lynch Tunnel or Dublin Port Tunnel</td><td>✓</td></tr>
<tr><td></td><td>Variable Speed Limits</td><td>Good safety benefits at higher flows. Most appropriate on South Ring Road between M8 and N27, with future extension to N71 following junction upgrades.</td><td>✓</td></tr>
<tr><td></td><td colspan="3">Capacity increases on the mainline of the South Ring Road are extremely difficult, and flows will require management to enable an acceptable level of service to be maintained on the mainline. Whereas Incident Detection and Variable Speed Limits will potentially bring significant benefit to the operation of the South Ring Road, it is likely that Access Control will instead be necessary should there be no fiscal measures introduced.</td></tr>
<tr><td>Capacity</td><td>Reversible Lanes</td><td>There may be potential for introducing reversible lanes on the South City Link Road, in order to improve public transport access from the Black Ash Park & Ride into the City Centre during peak periods. The lower speed of this road makes such a proposal possible, but perhaps as a Public Transport facility only.</td><td>✓</td></tr>
<tr><td></td><td>Hard Shoulder Running</td><td>Limited provision for hard shoulder running due to limited provision of Hard Shoulder along the</td><td>✗</td></tr>
</table>

		South Ring Road. Elsewhere, traffic volumes do not warrant the use of hard shoulders to increase mainline capacity.	
	The potential for capacity increases is therefore limited. The use of reversible lanes for public transport vehicles could be introduced as part of the development of a strong public transport link from the south city to compliment proposals contained in the Cork Area Transport Strategy.		
Priority	High Occupancy Lanes	Limited potential due to difficulty in providing additional lanes, and impact of reallocating and existing lane.	×
	High Occupancy Toll Lanes	Limited potential due to difficulty in providing additional lanes, and impact of reallocating an existing lane.	×
	Public Transport Lanes	May be feasible as part of a proposal to introduce reversible lanes (see above)	✓
	Freight lanes	Implementation on the South Ring Road would support strategic freight movement, although impacts on other road users may be excessive given the limited number of vehicles and difficulty in widening.	×
	Public Transport Freight Lanes	Could be considered as part of widening along sections of the South Ring Road, where congestion leads to significant delay to these users.	✓
	Public Transport Freight Toll Lanes	Could be considered as part of widening along sections of the South Ring Road, where congestion leads to significant delay to users.	✓
	The provision of priority would be focused along the South Ring Road where strategic connectivity is most inhibited by existing and future traffic congestion. Nevertheless, it is likely that any reallocation of roadspace would be based on the identification of additional lane capacity such that impacts on other users could be managed.		
Information	Internet	Low cost measure with good benefits	✓
	Roadside Information	Adopt to supplement other systems only	✓
	In-Car Systems	May become available in the medium term following trials in Dublin.	✓
	Adopted measures will be delivered regionally or nationally, and are not specific to this area.		
Demand Management	Various (see Section D)	All should be progressed at national/regional level to manage existing demand and future growth	✓
	Land Use Proposals apply to new development lands, with Accessibility and Travel Planning providing benefit for existing uses.		

Control	National Control Centre	Will be required to support traffic control measures – good foundation already provided in Dublin Port Tunnel Control Centre	✓
	Network Patrols	Existing arrangements could be extended	✓
	Control Centre will initially locate in the Dublin Port Tunnel. Control will represent one phase of the rollout of the centre.		

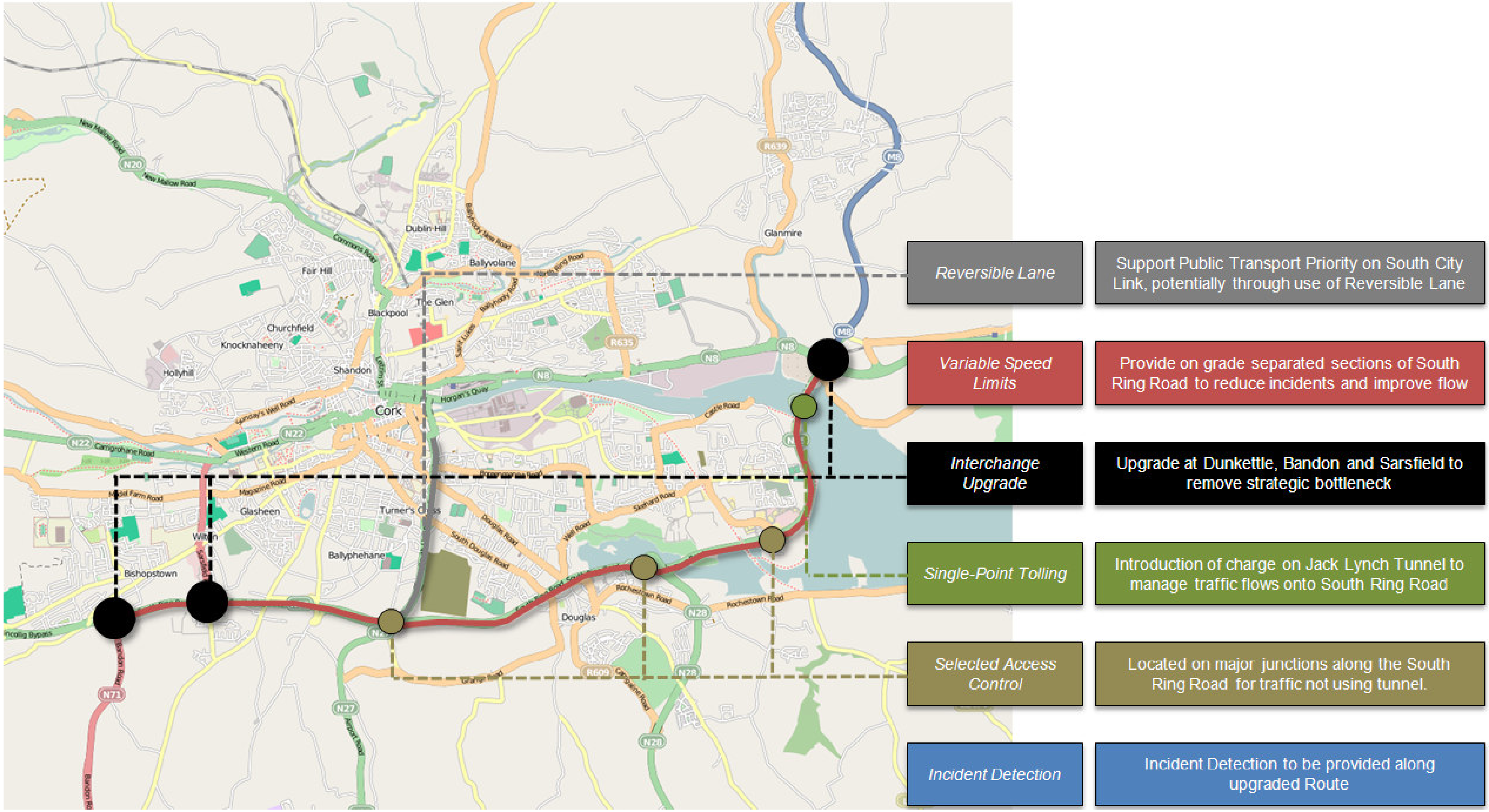
The development of strategy options in Cork therefore focuses strongly on the function of the South Ring Road between the N71 (Bandon Road) and the M8 (Dublin Road). Whereas traffic flows on the radials leading into the ring road are manageable with the existing road cross sections, it is the degree of traffic that subsequently turns onto the South Ring, and the level of overlapping demand which places excessive demand on this road. This is further exacerbated on the reliance on the Ring Road as a local distributor road, delivering commuters and shoppers into the various employment and retail destinations along it. These locations are not currently served by public transport which connects them with all main radials.

Significant improvements to conditions on the South Ring Road can be delivered through fiscal interventions. In such cases, it will become feasible to upgrade residual at-grade junctions, without any significant risk that resulting increases in traffic flows will congest the mainline carriageway of the N25. Without Fiscal measures, it will be necessary to provide some form of restraint through more limited upgrades such that some level of improvement to mainline traffic can be delivered, with further measures to support the flow of pubic transport and freight traffic through the Cork Area.

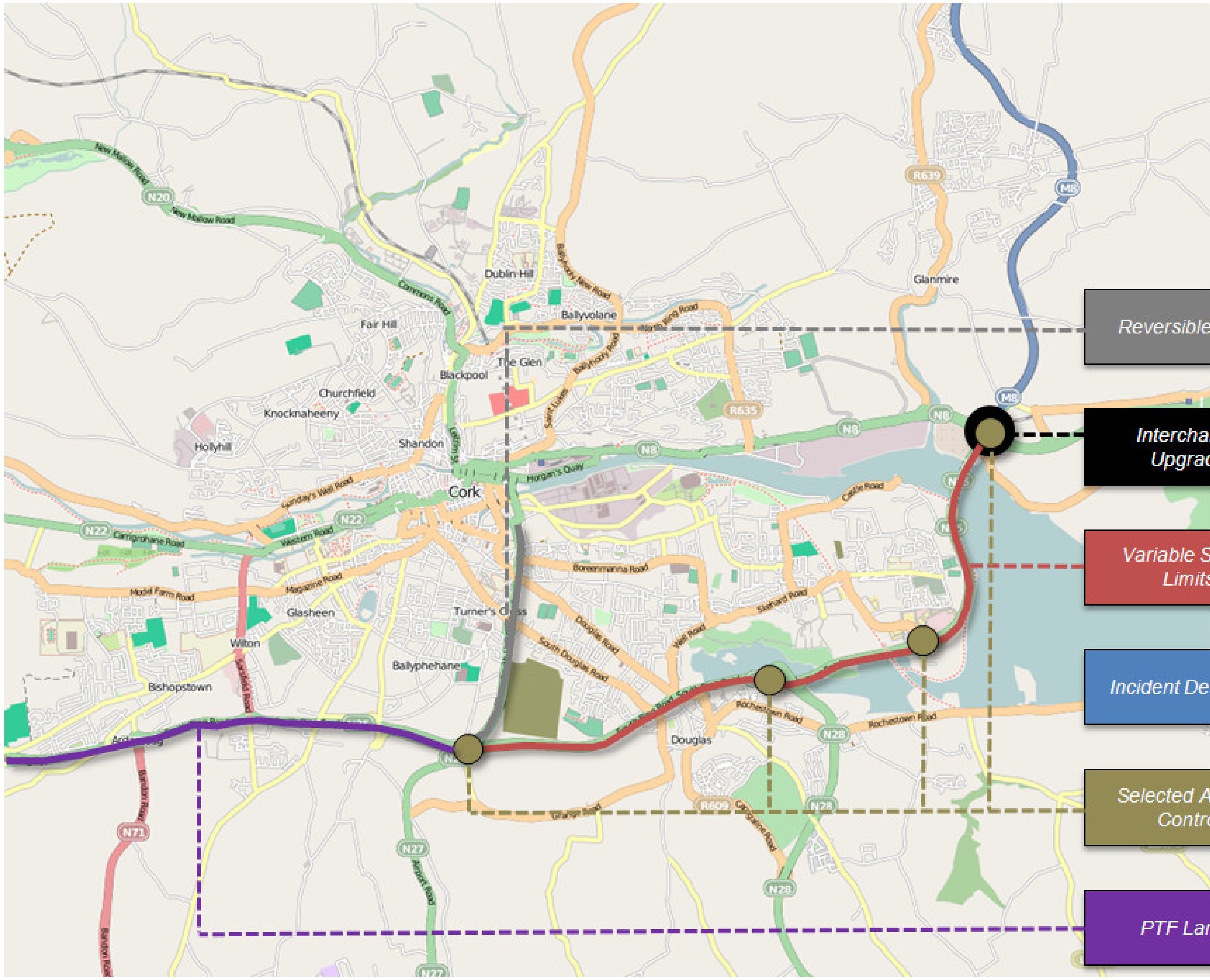
In all cases, the strategy is heavily constrained by the difficulty in providing additional lane capacity along the South Ring Road. This results from the inability to add traffic lanes through the Jack Lynch Tunnel, through the Douglas area, or through the grade separated Kinsale Road interchange.

The strategy will also seek to make best use of the existing South City Link Road, which provides a dual carriageway connection via the South Ring Road into the heart of the City Centre.

Cork Area Traffic Management Strategy : Option 1 – Fiscal



Cork Area Traffic Management Strategy : Option 2 – Control



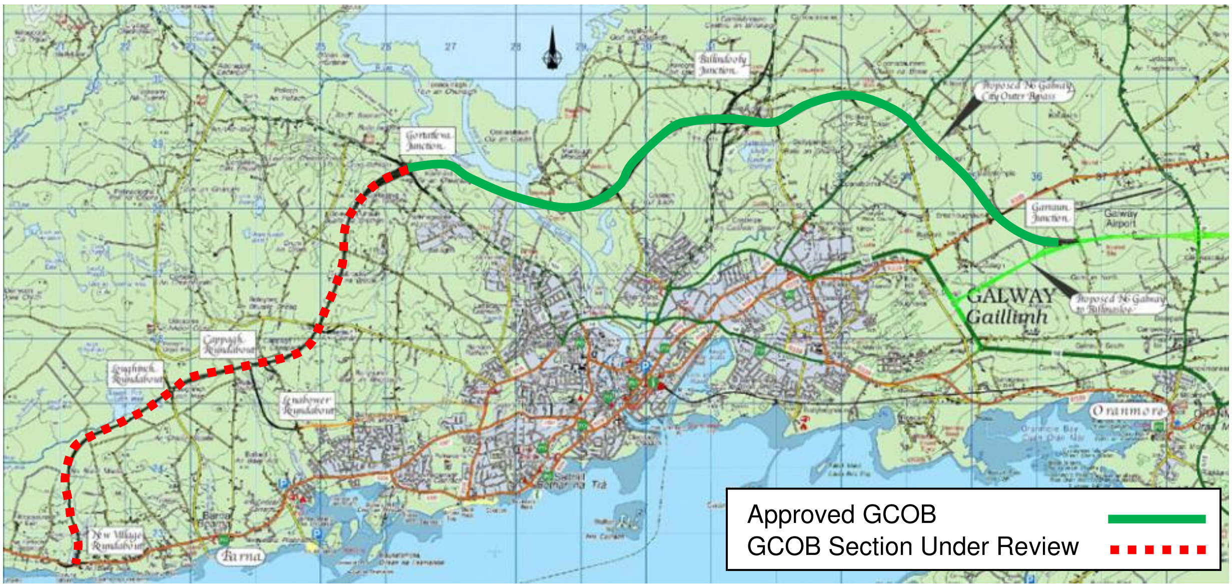
Reversible Lane	Support Public Transport Priority on South City Link, potentially through use of Reversible Lane
Interchange Upgrade	Upgrade at Dunkettle to remove strategic bottleneck
Variable Speed Limits	Provide on grade separated sections of South Ring Road to reduce incidents and improve flow
Incident Detection	Incident Detection to be provided along upgraded Route
Selected Access Control	Located on major junctions along the South Ring Road.
PTF Lanes	To be examined as part of widening on South Ring Road

23.5 Galway

23.5.1 Overview

The future proposals for Traffic management in Galway will depend heavily on the outcome of the current proceedings with respect to the Galway City Outer Bypass (GCOB). To date, planning permission has been received for the section from the N59 at Gortatleva to the Galway – Dublin M6 at Garraun. The route will be of dual carriageway standard. The remaining section of the route from the N59 to Barna on the west of the City, as highlighted below, is currently under review due to environmental constraints.

Figure 23-3: Proposed Galway City Outer Bypass



In the absence of the GCOB, the Galway Ring Road continues to provide connectivity between the major radial routes. Nevertheless, although constructed as a City Bypass, the existing Ring Road (Bóthar na dTreabh) has supported significant growth in retail and low-density employment uses which have been displaced from the City Centre by this infrastructure. This has led to significant erosion in the level of service provided by the ring road, leading to an inability to achieve its originally desired function.

The gateway status of Galway reflects its geographical location on the west coast, acting as a Regional City to support Counties Galway, Mayo and Clare. Many of the strategic routes to these areas pass through Galway City en route to major national and international markets, and hence rely on the provision of connectivity between those routes via a bypass of the City.

With a Galway City Outer Bypass, a significant level of route protection would be necessary to retain the function of such a route. Such would seek to restrict development in the vicinity of interchanges to those which support the regional economy and which rely on roads as a primary means of distribution of goods and services.

It is important to note, however, that the construction of the GCOB is some years away, and in its absence, the regional economy is likely to remain constrained, particularly for those areas to the north and west of the City who rely on a city bypass to access the midlands, south and east. As an alternative (or indeed interim) measure, the current Strategy has examined means of delivering such connectivity for strategic traffic movements.

23.5.2 Approach to Management

The Traffic Management Study objectives set out a clear hierarchy of road users and required functions of a National Primary Route. In the case of the Galway Ring Road, it is evident that significant interventions are necessary in order to provide for the needs of the road, whilst considering the range of existing users along that corridor.

The ring road comprises a mixture of single and dual carriageway connecting the N6 with the N59. Whilst the at-grade roundabouts represent a key capacity constraint, it is noted that these roundabouts also provide access to numerous retail and commercial developments along the corridor, and as such any capacity increase would require such access to be considered. Whilst subject to more detailed design studies, a Traffic Management Study for Galway is therefore likely to include a number of initiatives which may include:

- Major enhancements at up to six existing at-grade junctions to improve traffic flow, provide for pedestrian/cycle movement and improve traffic safety;
- Removal of direct accesses where possible to protect traffic flow;
- Provision of new link roads to improve access to new grade separated junctions;
- Provision for high-value road users (Freight/Public Transport etc); and
- Significant investment in Smarter Travel policies and infrastructure to reduce car demand.

It is envisaged that a Traffic Management Study could deliver significant benefit to Galway City as an interim measure pending construction of the GCOB. The existing layout of the Galway Ring Road lends itself to significant scope for improvement, although the appropriate management of development clusters will be a significant requirement to ensure that the benefits of such a strategy can be fully captured.

Fiscal measures have not been set out above as it is considered that such would be quite challenging to deliver given the nature of the existing road. It is expected, however, that fiscal proposals could form part of the management of the future Galway City Outer Bypass as part of a broader strategy to protect capacity on new outer ring roads (which might also include the Cork Northern Ring Road).

Galway City has already made significant progress in the delivery of Smarter Travel policies through its development of a Walking and Cycling Strategy, a Public Transport Strategy (which incorporates Bus Rapid Transit), and its shortlisting as an area for the award of funding under the DoT's Smarter Travel initiative. It is expected that there would be a strong synergy between the Traffic Management Study proposals and those set out within the various strategy documents with Galway City.

23.6 Limerick and Waterford

There are strong similarities with respect to Limerick and Waterford in the context of National Roads and Traffic Management. Both cities represent important nodes on the National Primary Road Network, and are defined as Gateways in the National Spatial Strategy. Likewise, access between National Roads has, until recently, required traffic to travel through the City Centre leading to significant congestion, and a poor level of accessibility to peripheral areas of the country requiring transit through these cities.

The opening of the Waterford Bypass, and the completion of the Limerick Southern Ring Road (Phase 2) has transformed both cities, ensuring a high level of strategic accessibility through them, and releasing further growth potential within the cities themselves. In both cases, the new bypass routes are tolled, which in additional to supporting the financial feasibility of the project will allow land-use responses to such road infrastructure to be managed.

Traffic Management in these cities will therefore be required to focus on those areas where tolls are not implemented, and where inappropriate land-use responses represent a real threat to the protection of future road capacity. These areas include the western end of the N25 Waterford Bypass, and the Limerick Southern Ring Road (Phase 1). The Traffic Management Study in these areas is therefore likely to focus on:

- Continuous monitoring of demand to identify growth and the basis for such growth;
- Management of development, to ensure that strategic sites can be reserved for those who bring economic benefit, but not at the expense of utilising excessive road capacity; and
- Other supporting demand management at a national level;

The case for more active management in Limerick and Waterford will require continuous review should traffic volumes increase to a point where strategic accessibility is under threat. Nevertheless, with appropriate development management and the adoption of Smarter Travel policies it is unlikely that such a situation might arise within the timescale for this study.

23.7 Letterkenny

The designation of Letterkenny as a Gateway in the National Spatial Strategy[2] reflects its location as an important access point into North West Donegal. The development of the A5 between Monaghan and Derry will provide a dramatic increase in connectivity into this part of the country, and in particular into the linked Gateway of Letterkenny-Derry. Nevertheless, Letterkenny itself remains the only Gateway which does not benefit from a town bypass, which continues to constrain access into the northwest.

Although the Letterkenny Relief Road has been proposed, it is likely that such a proposal is a number of years away. In the meantime, traffic congestion at the Ramelton Road (Station Road) roundabout leads to significant delays for traffic travelling through the town, and although diversion routes are possible to avoid the congestion, such roads are not appropriate for high traffic volumes.

It is proposed that some form of route protection strategy is examined to cater for traffic travelling through Letterkenny on the N14 and N56. Whilst this may lead to an upgrade at the Station Road Roundabout, such investment would require parallel investment in the implementation of Smarter Travel Policies which are required to reduce the high level of car dependency in this part of Donegal. Such proposals would likely include the consideration of mechanisms to reduce the impact of retail traffic on strategic routes through travel demand measures, redesign of accesses to national roads, and some capacity upgrades.

23.8 Other Locations

Examining the other Gateway towns and Cities, it is clear that although many are subject to periodic traffic congestion within town centres, that such congestion has limited impact on National Roads. Dundalk and the Midlands Gateway (Tullamore – Athlone – Mullingar) have both been provided with strategic bypass routes which function well in providing for inter-urban connections. Nevertheless, the future growth in these areas will need to be focused on a pattern of sustainable development which focuses on growing the existing town centre and surrounding built-up area. It will be crucial to avoid the onset of 'urban splatter' where isolated developments emerge at or near the new bypasses in an attempt to capture inappropriate levels of road capacity for particular development sites.

In Sligo, where the relief road travels through the town centre, development management will need to focus on protecting the capacity of that road to ensure that its strategic function can be maintained. In Sligo it is recognised that development responses will be more challenging to manage and the introduction of Traffic Management measures are likely to be required over a shorter time horizon.

23.9 Other Supporting Proposals

Whilst the measures outlined above refer to specific geographical areas, there are a further range of proposals that are applied at a national level and are necessary to support the strategy objectives. These are:

- The development of the National Control Centre at the Dublin Port Tunnel, with phased introduction of responsibilities over the next 5 to 10 years;
- Increasing the level of investment in network monitoring on inter-urban roads to include traffic flows, speeds, vehicle classification and weather;
- The development of a central source for collation of network information, and management of information to road users through internet, roadside information and traditional forms of broadcasting;
- The publication of a document to inform regional and local authorities of the basis for protection of the investment in the national road network, and how this might translate into supporting development policies;
- Working with local authorities and the National Transport Authority to identify means of addressing existing bottlenecks on national roads through promotion of Smarter Travel policies and programmes

Chapter 24 Strategy Appraisal

24.1 Guiding Documentation

The purpose of appraisal is to ensure that scarce public funds are allocated in an efficient manner by establishing the merits of a proposal using a consistent and comprehensive framework. Because proposals for public sector investment invariably exceed the resources available, choice and priority setting are therefore inescapable. Appraisals provide an assessment of whether a proposal is worthwhile and allow conclusions and recommendations to be clearly communicated. It is important to recognise that, as set out in the Project Management Guidelines, appraisal is an ongoing process through the life of a project

The requirements for the appraisal of any public sector investment have been set out in two key documents:

- "Guidance for the Appraisal and Management of Capital Expenditure Proposals in the Public Sector" [40], Department of Finance, 2005, and
- "Guidelines on a Common Appraisal Framework for Transport Projects and Programmes"[41], Department of Transport, 2009.

Following their publication, the NRA has produced the Project Appraisal Guidelines[42] which built on these documents and set out in more detail the requirements for appraisal through the life of a scheme. The key aspect here is the recognition that appraisal is an ongoing process and the level of detail that is possible, and indeed desirable, will alter as proposals become more clearly defined.

24.2 Stages of Appraisal

At this stage of the project, the identification of measures has been based on their ability to support the various objectives of the Traffic Management Study. Although in most cases the inclusion or otherwise of a measure has been based on a feasibility study of that particular measure, the conclusions of such feasibility studies are nonetheless preliminary in nature, and require further consideration of how various measures interact to support common objectives.

There is therefore a requirement for a strategic-level appraisal which addresses the ability of a package of measures to achieve desired outcomes, but taking into account the level of analysis that has been used to support their development. This step facilitates further fine-tuning of the strategies before they are taken forward to more detailed design studies and subsequent preliminary and detailed appraisal in accordance with the requirements of the Project Appraisal Guidelines.

Although the Project Appraisal Guidelines remain the primary reference for appraisal of projects or strategies, it is evident that the document has been prepared with specific relevance to the appraisal of a particular project or strategy that is defined in the Project Brief. The current project has developed a number of alternative mechanisms of addressing a particular need, and the strategic appraisal is required to assist in the development of a Project Brief.

Indeed, the Common Appraisal Framework outlines the concept of a 'Sketch' appraisal, which can precede the more detailed appraisal stages by adopting qualitative in addition to quantitative indicators in order to reduce the necessity to monetise all benefits at an early stage in the appraisal process. This process allows for consideration of:

- Management versus investment options;
- Scale of investment;
- Different technical solutions;
- Different standards;
- The timing and phasing of projects;
- Incremental options;
- Synergistic or complementary projects or packages of measures; and
- Strategic or consistent approaches

Australia adopts a similar approach to appraisal, setting out the concept of Rapid Economic Appraisal in the consideration of Strategic Fit[43]. This initial appraisal is used to inform the Project Brief and makes reference to order of magnitude estimations of quantitative costs and benefits, with reference to qualitative costs and benefits where appropriate.

In the UK, the DaSTS[44] programme used such an approach to support the identification of strategies which typically comprised packages of individual measures. The appraisal summarised each option on the basis of:

- Project Description;
- Cost and Likely Value for Money;
- Deliverability;
- Performance against Departmental Goals;
- Scale of Impact;
- Strategic Fit; and
- Quality of Evidence;

The criteria relating to Performance Against Goals allows disaggregation into key criteria which broadly reflect the appraisal criteria within our own guidelines. For the current project, it is considered appropriate that these criteria might reflect the project objectives.

In the current study, sources of information for use in the strategic appraisal are not confined to traffic modelling outputs, but include:

- Transport Model output;
- Case Study Evidence;
- Consultant's Estimate;
- NRA Information; and
- Other published material.

Although appraisal remains at a strategic level, it is nonetheless appropriate to retain the appraisal within the five key criteria outlined in all current appraisal documentation – namely environment, safety, economy, accessibility & social inclusion and integration. This ensures that the appraisal maintains a balanced view of the study objectives, which have also been structured under these main headings.

A further level of appraisal will then be undertaken at subsequent strategy formulation and design stage, and examines how the various design options perform against the more detailed requirements of the Project Appraisal Guidelines.

24.3 Appraisal Methodology

A strategic appraisal summary sheet has been produced which collates the findings of the strategic appraisal process, taking due account of the relative strength of evidence that is available to quantify the indicators at this stage.

Appraisal Summary Sheets have been prepared for the three priority areas outlined in this Strategy (i.e. M50, Dublin Radials and Cork) and are outlined over the following pages. These summarise the Appraisal of each area, by strategy, pulling together the impacts of individual measures and identifying how each strategy would support the objectives in the context of:

- The ability of each strategy, properly implemented, to support that objective;
- The risk that any strategy will act against other objectives;
- A qualitative assessment of the scale of impact that is achievable;
- How current systems support the implementation of that strategy; and
- Any significant technical risks associated with that strategy.

The results of the appraisal process for the three priority areas are summarised within a standard appraisal template below. Supporting information is outlined in Tables 24-1 to 24-3.

National Traffic Management Strategy

Strategic Appraisal

Project Details

Project Location	M50, Dublin
Project Title	Fiscal Strategy
Project Description	Introduction of multi-point tolling on M50 to replace existing toll point between N3 and N4. Provision of other supporting traffic management measures

Project Costs	Score	Comments
Likely Cost (€m)	medium	low capital cost, but higher operational costs
Risk Level	medium	proven individual technologies
Likely Revenue (Annual €m)	~ €50m	Net increase includes deduction for operating costs
Likely Return on Investment	medium	congestion relief, accident benefit and incident response

Project Risk		
Project Duration (months)	24	
Technical Risk	low	proven individual technologies
Timescale Risk	low	no major works required. Systems already in place
Public Acceptability	medium	will represent increase in toll for *some* users

Quality of Evidence		
Quality of Supporting Evidence	high	detailed M50 modelling undertaken
Key Risks	- Not all links on M50 will be tolled - may lead to localised congestion on untolled sections - Reduction in tag coverage would increase costs	

Strategic Fit

Economy

Improve allocative efficiency	
strong +	*Efficiency achieved through pricing - higher value users are more willing to pay*
Reduce the economic impact of delay through effective incident management	
strong +	Incident Detection and response proposed as extension to DPT system
Address excessive reliance on national roads as a means of supporting commuting traffic	
slight +	*Strategy imitates distance based charge which can encourage use of pubic transport*
Maximise the capacity of congested areas through effective management solutions	
slight +	Some additional capacity results from Variable Speed Limits

Environment

Encourage public transport on national roads	
slight +	*May become more cost effective to travel by public transport for longer distances*
Contribute to reductions in CO_2 emissions, air pollution and noise	
slight +	*Reduction in traffic through Lucan/Strawberry Beds due to reduction at existing toll point.*

Accessibility

Maintain and improve opportunities for access	
slight +	*Less congestion due to reduction in demand and reduction in inidents*

Integration

Promote an understanding of integrated land use and transport planning policies	
neutral	
Encourage the use of public transport on national roads by supporting network integration	
neutral	

Safety

Reduce knock-on safety risks that result from incidents	
strong +	Reduction in incidents due to VSL, with higher response times due to Incident Detection
Reduce the frequency and severity of accidents on National Roads	
strong +	Reduction in incidents due to VSL, with higher response times due to Incident Detection

Other Comments

Performs well against objectives, althrough tolling proposals will need to be explained well to ensure that the implications are understood. Some further proposals are required to address integration objectives such as a Park & Ride Strategy and Smart Travel awareness initiatives. Improved performance against environmental objectives could be achieved through consideration of variable tolls to manage peak demands.

National Traffic Management Strategy

Strategic Appraisal

Project Details

Project Location	M50, Dublin
Project Title	Control Strategy
Project Description	Use of Traffic Management Measures to provide information to road users, actively manage traffic flows, allocate lane capacity, meter demand and provide roadside services in order to maximise efficiency of the road network.

Project Costs

	Score	Comments
Likely Cost (€m)	medium	low capital cost, but higher operational costs
Risk Level	medium	proven individual technologies
Likely Revenue (Annual €m)	none	existing M50 toll retained
Likely Return on Investment	medium	mostly through accident benefits and incident response

Project Risk

Project Duration (months)	24	major programne with moderate timescales
Technical Risk	low	proven individual technologies
Timescale Risk	low	no major works required
Public Acceptability	medium	May be resistance to PTF Toll Lanes and Access Control

Quality of Evidence

Quality of Supporting Evidence	medium	Based on initial M50 feasibility studies
Key Risks	- May not adequately control demand responses to M50 widening - Local road impacts may reduce performance of Access Control	

Strategic Fit

Economy

Improve allocative efficiency	
slight +	*Allocation of lanes to Public Transport and Freight, plus provision for toll lanes*
Reduce the economic impact of delay through effective incident management	
strong +	Incident Detection and response proposed as extension to DPT system
Address excessive reliance on national roads as a means of supporting commuting traffic	
neutral	*Providing additional capacity through management is offset by PTF Lanes/Ramp Metering*
Maximise the capacity of congested areas through effective management solutions	
neutral	Some additional capacity results from Variable Speed Limits, but offset by PTF Toll Lanes

Environment

Encourage public transport on national roads	
slight +	*Allocation of lanes to Public Transport and Freight*
Contribute to reductions in CO_2 emissions, air pollution and noise	
neutral	*No major changes in demand patterns would be expected*

Accessibility

Maintain and improve opportunities for access	
slight +	*Less congestion will result from incidents due to VSL and Incident Detection*

Integration

Promote an understanding of integrated land use and transport planning policies	
neutral	
Encourage the use of public transport on national roads by supporting network integration	
neutral	

Safety

Reduce knock-on safety risks that result from incidents	
strong +	Reduction in incidents due to VSL, with higher response times due to Incident Detection
Reduce the frequency and severity of accidents on National Roads	
strong +	Reduction in incidents due to VSL, with higher response times due to Incident Detection

Other Comments

Quite a positive score at relatively low costs and makes good use of infrastructure already provided. The strategy does not fully address environmental objectives, nor does it address integration objectives. Some further proposals are therefore required in this regard such as a Park & Ride Strategy, Smart Travel awareness initiatives, and possible introduction of discount off-peak charges at the existing M50 toll point.

National Traffic Management Strategy

Strategic Appraisal

Project Details

Project Location	Greater Dublin Area
Project Title	Fiscal Strategy
Project Description	Implementation of low-value single point tolls on key approaches into built-up area, supported by other traffic management measures where appropriate.

Project Costs

Project Costs	*Score*	*Comments*
Likely Cost (€m)	medium	main cost is construction and operation of tolling infrastructure
Risk Level	medium	proven individual technologies
Likely Revenue (Annual €m)	~ €100m	Net increase includes deduction for operating costs
Likely Return on Investment	medium	congestion relief, accident benefit and incident response

Project Risk

Project Duration (months)	36	
Technical Risk	low	proven individual technologies
Timescale Risk	low	no major works required. Systems already in place
Public Acceptability	low	mainly due to introduction of new tolls

Quality of Evidence

Quality of Supporting Evidence	medium	uses National Model - further local analysis required
Key Risks	- Ability of eFlow system to manage significant expansion - Reduction in tag coverage would increase costs	

Strategic Fit

Economy

Improve allocative efficiency	
strong +	*Efficiency achieved through pricing - higher value users are more willing to pay*
Reduce the economic impact of delay through effective incident management	
strong +	*Incident Detection and response proposed*
Address excessive reliance on national roads as a means of supporting commuting traffic	
slight +	*Strategy imitates distance based charge which can encourage use of pubic transport*
Maximise the capacity of congested areas through effective management solutions	
neutral	*Some additional capacity results from Variable Speed Limits, although offset by PTF Lanes*

Environment

Encourage public transport on national roads	
strong +	*Provision of dedicated lanes for public transport/freight*
Contribute to reductions in CO_2 emissions, air pollution and noise	
slight +	*Reduction due to reduction in discretionary trips, with some increase due to diversion*

Accessibility

Maintain and improve opportunities for access	
slight +	*Less congestion due to reduction in demand and reduction in inidents*

Integration

Promote an understanding of integrated land use and transport planning policies	
neutral	
Encourage the use of public transport on national roads by supporting network integration	
slight +	*Connects into existing Park & Ride sites at Pace, Lissenhall, Sandyford, Red Cow*

Safety

Reduce knock-on safety risks that result from incidents	
strong +	*Reduction in incidents due to VSL, with higher response times due to Incident Detection*
Reduce the frequency and severity of accidents on National Roads	
strong +	*Reduction in incidents due to VSL, with higher response times due to Incident Detection*

Other Comments

Will lead to improvement in travel conditions due to reduction in demand and limited net increase in capacity. Effects of traffic diverting onto non-national roads will require close examination to identify adverse impacts, although charges would be set low to minimise such effects. Some further proposals are required such as Smart Travel awareness initiatives, and possible introduction of discount off-peak charges at proposed toll points.

National Traffic Management Strategy

Strategic Appraisal

Project Details

Project Location	Greater Dublin Area
Project Title	Control Strategy
Project Description	Use of Traffic Management Measures to provide information to road users, actively manage traffic flows, allocate lane capacity, meter demand and provide roadside services in order to maximise efficiency of the road network.

Project Costs	*Score*	*Comments*
Likely Cost (€m)	medium-high	reversible lanes and PTFT lanes attract higher construction and operational cost
Risk Level	medium	proven individual technologies
Likely Revenue (Annual €m)	none	
Likely Return on Investment	medium	mostly through accident benefits and incident response

Project Risk		
Project Duration (months)	36	could be delivered in stages over 3 years
Technical Risk	low	proven individual technologies
Timescale Risk	low	no major works required
Public Acceptability	medium	May be resistance to PTF and Toll Lanes

Quality of Evidence		
Quality of Supporting Evidence	medium	Based on initial feasibility studies
Key Risks	- Resistance to lane allocation may lead to erosion of project case if omitted	

Strategic Fit

Economy

Improve allocative efficiency	
slight +	*Allocation of lanes to Public Transport and Freight, plus provision for toll lanes*
Reduce the economic impact of delay through effective incident management	
strong +	*Incident Detection and response proposed as extension to DPT system*
Address excessive reliance on national roads as a means of supporting commuting traffic	
neutral	*Providing additional capacity through management is offset by PTF Lanes/Ramp Metering*
Maximise the capacity of congested areas through effective management solutions	
neutral	*Some additional capacity results from Variable Speed Limits, but offset by PTF Lanes*

Environment

Encourage public transport on national roads	
strong +	*Allocation of lanes to Public Transport and Freight*
Contribute to reductions in CO_2 emissions, air pollution and noise	
neutral	*No major changes in demand patterns would be expected*

Accessibility

Maintain and improve opportunities for access	
slight +	*Less congestion will result from incidents due to VSL and Incident Detection*

Integration

Promote an understanding of integrated land use and transport planning policies	
neutral	
Encourage the use of public transport on national roads by supporting network integration	
slight +	*Connects into existing Park & Ride sites at Pace, Lissenhall, Sandyford, Red Cow*

Safety

Reduce knock-on safety risks that result from incidents	
strong +	*Reduction in incidents due to VSL, with higher response times due to Incident Detection*
Reduce the frequency and severity of accidents on National Roads	
strong +	*Reduction in incidents due to VSL, with higher response times due to Incident Detection*

Other Comments

Strategy includes for provision of Public Transport/Freight and High Occupancy Toll Lanes along most corridors, and therefore would provide an accessible route into the Dublin Area for appropriate vehicle types, although the capacity effects of such proposals will require further consideration. The strategy does not fully address environmental objectives, nor does it address integration objectives. Some further proposals are therefore required in this regard such as a Park & Ride Strategy, Smart Travel awareness initiatives, and possible introduction of discount off-peak charges at the existing M50 toll point.

National Traffic Management Strategy

Strategic Appraisal

Project Details

Project Location	Cork Area
Project Title	Fiscal Strategy
Project Description	Implementation of single point toll in Jack Lynch Tunnel, supported by other traffic management measures where appropriate.

Project Costs	***Score***	***Comments***
Likely Cost (€m)	medium	requirement for additional toll infrastructure also attracts operating cost
Risk Level	medium	proven individual technologies
Likely Revenue (Annual €m)	~ €30m	Net increase includes deduction for operating costs
Likely Return on Investment	medium	congestion relief, accident benefit and incident response

Project Risk		
Project Duration (months)	36	phased introduction assumed
Technical Risk	low	proven individual technologies
Timescale Risk	low	no major works required. Systems already in place
Public Acceptability	low	mainly due to introduction of new toll

Quality of Evidence		
Quality of Supporting Evidence	medium	further local analysis required
Key Risks	- Development of the toll collection system - Financial implications of low tag penetration	

Strategic Fit

Economy

Improve allocative efficiency	
strong +	*Efficiency achieved through pricing - higher value users are more willing to pay*
Reduce the economic impact of delay through effective incident management	
strong +	*Incident Detection and response proposed*
Address excessive reliance on national roads as a means of supporting commuting traffic	
slight +	*Will lead to longer-term land use responses*
Maximise the capacity of congested areas through effective management solutions	
slight +	*Improvement in travel conditions results from a reduction in demand*

Environment

Encourage public transport on national roads	
strong +	*Public transport benefits from improved traffic conditions - lower relative costs to car users*
Contribute to reductions in CO_2 emissions, air pollution and noise	
neutral	*Reduction due to reduction in discretionary trips, with some increase due to diversion*

Accessibility

Maintain and improve opportunities for access	
slight +	*Less congestion due to reduction in demand and reduction in inidents*

Integration

Promote an understanding of integrated land use and transport planning policies	
neutral	
Encourage the use of public transport on national roads by supporting network integration	
neutral	*No defined Park & Ride Strategy exists at present*

Safety

Reduce knock-on safety risks that result from incidents	
strong +	*Reduction in incidents due to VSL, with higher response times due to Incident Detection*
Reduce the frequency and severity of accidents on National Roads	
strong +	*Reduction in incidents due to VSL, with higher response times due to Incident Detection*

Other Comments

Provides strong support to economic objectives, and possible removes the need to manually allocate road capacity to different user classes. Environmental impacts will require further analysis of adverse impacts due to traffic avoiding the toll - although toll will be set such that this activity will be manageable. Further consideration is also required on how integration objectives can be supported, possibly through the development of a Park & Ride Strategy, and further Smarter Travel initiatives.

National Traffic Management Strategy

Strategic Appraisal

Project Details

Project Location	Cork Area
Project Title	Control Strategy
Project Description	Traffic Management Measures to maximise existing capacity, improve safety and protect strategic function of National Roads, with a particular focus on the N25 Cork Ring Road.

Project Costs

Project Costs	*Score*	*Comments*
Likely Cost (€m)	low	age and ITS equipment attracts most cost - reduced expenditure on junction upgr
Risk Level	medium	proven individual technologies
Likely Revenue (Annual €m)	none	
Likely Return on Investment	medium	accident benefits, with some congestion benefits

Project Risk

Project Duration (months)	24	Limited lead-in time required
Technical Risk	low	proven individual technologies
Timescale Risk	low	will need to be coordinated with junction upgrades
Public Acceptability	high	PTF lanes potentially deliverable within existing curtilage

Quality of Evidence

Quality of Supporting Evidence	medium	requires more work on offline impacts
Key Risks	- Timing is dependant to some extent on junction upgrades	

Strategic Fit

Economy

Improve allocative efficiency	
slight +	*Allocation of lanes to Public Transport and Freight, but with only limited potential benefit in absence of fiscal measure*
Reduce the economic impact of delay through effective incident management	
strong +	*Incident Detection and response proposed as extension to DPT system*
Address excessive reliance on national roads as a means of supporting commuting traffic	
neutral	*No behavioural responses anticipated*
Maximise the capacity of congested areas through effective management solutions	
slight +	*Capacity improvements for public transport and freight only, with some broader benefits*

Environment

Encourage public transport on national roads	
strong +	*Allocation of lanes to Public Transport and Freight, plus reversible lane on South Link Road*
Contribute to reductions in CO_2 emissions, air pollution and noise	
neutral	

Accessibility

Maintain and improve opportunities for access	
slight +	*Public Transport and Freight accessibility improved. Some improvement to other users*

Integration

Promote an understanding of integrated land use and transport planning policies	
neutral	
Encourage the use of public transport on national roads by supporting network integration	
neutral	*No defined Park & Ride Strategy exists at present*

Safety

Reduce knock-on safety risks that result from incidents	
strong +	*Reduction in incidents due to VSL, with higher response times due to Incident Detection*
Reduce the frequency and severity of accidents on National Roads	
strong +	*Reduction in incidents due to VSL, with higher response times due to Incident Detection*

Other Comments

Strategy provides most benefit to public transport and freight, primarily due to introduction of PTF lanes along sections of N25. Eastern end of N25 likely to remain congested due to release of bottleneck at Dunkettle - this will impact on all road users. Ramp metering is therefore an important part of the strategy but is likely to attract some negative sentiment. Further upgrades at Bandon and Sarsfield Roundabouts would likely exacerbate this situation.

Table 24-1: Strategic Appraisal of M50 Traffic Management Study

Objective	Control Strategy		Fiscal Strategy	
Economy				
Improve allocative efficiency	Allocating lanes to Public Transport and Freight will potentially provide a more cost effective use of the available road space.	Slight Positive	Multiple single point tolls approximate to distance charging and will therefore lead to more efficient usage of network	Moderate Positive
Reduce the economic impact of delay through effective incident management	Incident detection will facilitate better incident management.	Moderate Positive	Incident detection will facilitate better incident management.	Moderate Positive
Address excessive reliance on national roads as a means of supporting commuting traffic	Allocating lanes to Public Transport will encourage a shift from car to PT.	Slight Positive	A reduction in traffic volumes will lead to increased patronage and improved traffic conditions for public transport.	Slight Positive
Maximise the capacity of congested areas through effective management solutions	Incident detection and Variable Speed Limits will reduce incidents and increase response times – leading to reduction in incident related congestion. Traffic restraint on interchanges will improve efficiency on the mainline.	Slight Positive	Incident detection and Variable Speed Limits will reduce incidents and increase response times – leading to reduction in incident related congestion. Fiscal proposals will reduce traffic volumes in certain areas and hence improve traffic conditions.	Moderate Positive
Environmental				
Encourage public transport on national roads	Allocating lanes to Public Transport will actively encourage usage.	Significant Positive	A reduction in traffic volumes will lead to increased patronage and improved traffic conditions for public transport.	Moderate Positive
Contribute to reductions in CO_2 emissions, air pollution and noise	Potential shift from car to PT would reduce overall CO_2. Variable speed limits can also result in more efficient vehicle usage.	Slight Positive	Reduction in travel demand and a shift from car to PT will reduce overall CO_2 and other emissions. Variable speed limits can also result in more efficient vehicle usage.	Moderate Positive
Accessibility and Social Inclusion				
Maintain and improve opportunities for access to business, employment, education, health and recreation where appropriate on national roads	Large improvements for freight and PT if designated lanes provided	Moderate Positive	The reduction in traffic volumes will improve movement along the M50, leading to accessibility benefits.	Moderate Positive
Integration				
Promote an understanding of integrated land use and transport planning policies	Demand Management measures form part of the Control Strategy on the M50, and support the objectives set out in Smarter Travel	Moderate Positive	Demand Management measures form part of the Control Strategy on the M50, and support the objectives set out in Smarter Travel	Moderate Positive
Encourage the use of public transport on national roads through supporting network integration	Public transport lanes will provide for public transport movement along national road corridors	Moderate Positive	Improved traffic conditions will benefit public transport along national road corridors	Moderate Positive
Safety				
Reduce knock-on safety risks that result from incidents.	Use of VSL, supported by incident detection will improve incident detection and reduce potential for secondary incidents.	Moderate Positive	Use of VSL, supported by incident detection will improve incident detection and reduce potential for secondary incidents.	Moderate Positive
Reduce the frequency and severity of accidents on National Roads	Use of VSL will reduce the level of incidents on congested roads.	Significant Positive	Use of VSL will reduce the level of incidents on congested roads.	Significant Positive

Table 24-2: Strategic Appraisal of Greater Dublin Area Traffic Management Study

Objective	Control Strategy		Fiscal Strategy	
Economy				
Improve allocative efficiency	Allocating lanes to Public Transport and Freight, and in particular use of Toll lanes will potentially provide a more cost effective use of the available road space.	Moderate Positive	Tolls will reduce discretionary trips, and therefore lead to more efficient usage of network	Moderate Positive
Reduce the economic impact of delay through effective incident management	Incident detection will facilitate better incident management.	Moderate Positive	Incident detection will facilitate better incident management.	Moderate Positive
Address excessive reliance on national roads as a means of supporting commuting traffic	Public Transport and Toll lanes will encourage mode shift and car sharing with a reduction in car-based commuting.	Moderate Positive	A reduction in traffic volumes will lead to increased patronage and improved traffic conditions for public transport.	Slight Positive
Maximise the capacity of congested areas through effective management solutions	Incident detection and Variable Speed Limits will reduce incidents and increase response times – leading to reduction in incident related congestion. Traffic restraint on interchanges will improve efficiency on the mainline.	Slight Positive	Incident detection and Variable Speed Limits will reduce incidents and increase response times – leading to reduction in incident related congestion. Fiscal proposals will reduce traffic volumes in certain areas and hence improve traffic conditions.	Moderate Positive
Environmental				
Encourage public transport on national roads	Allocating lanes to Public Transport will actively encourage usage.	Significant Positive	A reduction in traffic volumes will lead to increased patronage and improved traffic conditions for public transport.	Moderate Positive
Contribute to reductions in CO_2 emissions, air pollution and noise	Potential shift from car to PT would reduce overall CO_2. Variable speed limits will result in more efficient vehicle usage.	Slight Positive	Reduction in travel demand and a shift from car to PT will reduce overall CO_2 and other emissions. Variable speed limits can also result in more efficient vehicle usage.	Moderate Positive
Accessibility and Social Inclusion				
Maintain and improve opportunities for access to business, employment, education, health and recreation where appropriate on national roads	Large improvements for freight and PT if designated lanes provided	Moderate Positive	Reduction in traffic volumes and allocation of roadspace to public transport/freight on specific corridors will generate benefits	Moderate Positive
Integration				
Promote an understanding of integrated land use and transport planning policies	Demand Management measures form part of the Control Strategy along each corridor, and support the objectives set out in Smarter Travel	Moderate Positive	Demand Management measures form part of the Control Strategy along each corridor, and support the objectives set out in Smarter Travel	Moderate Positive
Encourage the use of public transport on national roads through supporting network integration	Improved traffic conditions will benefit public transport along national road corridors	Moderate Positive	Improved traffic conditions will benefit public transport along national road corridors	Moderate Positive
Safety				
Reduce knock-on safety risks that result from incidents.	Use of VSL, supported by incident detection will improve incident detection and reduce potential for secondary incidents.	Moderate Positive	Use of VSL, supported by incident detection will improve incident detection and reduce potential for secondary incidents.	Moderate Positive
Reduce the frequency and severity of accidents on National Roads	Use of VSL will reduce the level of incidents on congested roads.	Significant Positive	Use of VSL will reduce the level of incidents on congested roads.	Significant Positive

Table 24-3: Strategic Appraisal of Cork Area Traffic Management Study

Objective	Control Strategy		Fiscal Strategy	
Economy				
Improve allocative efficiency	Allocating lanes to Public Transport and Freight, and in particular use of Toll lanes will potentially provide a more cost effective use of the available road space.	Moderate Positive	Tolls will reduce discretionary trips, and therefore lead to more efficient usage of network, particularly on South Ring Road	Moderate Positive
Reduce the economic impact of delay through effective incident management	Incident detection will facilitate better incident management.	Moderate Positive	Incident detection will facilitate better incident management.	Moderate Positive
Address excessive reliance on national roads as a means of supporting commuting traffic	Public Transport and Toll lanes will encourage mode shift and car sharing with a reduction in car-based commuting.	Moderate Positive	A reduction in traffic volumes will lead to increased patronage and improved traffic conditions for public transport.	Slight Positive
Maximise the capacity of congested areas through effective management solutions	Traffic restraint on western end of South Ring Road and on interchanges will limit potential for reduction in congestion. Benefits will result from Dunkettle upgrade	Neutral	Multiple junction upgrades and tolling will significantly reduce congestion.	Significant Positive
Environmental				
Encourage public transport on national roads	Allocating lanes to Public Transport, and facilitation of Park & Ride will actively encourage usage.	Significant Positive	A reduction in traffic volumes will lead to increased patronage and improved traffic conditions for public transport.	Moderate Positive
Contribute to reductions in CO_2 emissions, air pollution and noise	Shift from car to PT would reduce overall CO_2. Variable speed limits will result in more efficient vehicle usage.	Slight Positive	Reduction in travel demand and a shift from car to PT will reduce CO_2 and other emissions. Variable speed Limits can also result in more efficient vehicle usage.	Moderate Positive
Accessibility and Social Inclusion				
Maintain and improve opportunities for access to business, employment, education, health and recreation where appropriate on national roads	Large improvements for freight and PT if designated lanes provided.	Moderate Positive	Reduction in traffic volumes and allocation of roadspace to public transport/freight on specific corridors will generate benefits	Moderate Positive
Integration				
Promote an understanding of integrated land use and transport planning policies	Demand Management measures form part of the Control Strategy in the Cork Area, and support the objectives set out in Smarter Travel	Moderate Positive	Demand Management measures form part of the Control Strategy in the Cork Area, and support the objectives set out in Smarter Travel	Moderate Positive
Encourage the use of public transport on national roads through supporting network integration	Improved traffic conditions will benefit public transport along national road corridors	Moderate Positive	Improved traffic conditions will benefit public transport along national road corridors	Moderate Positive
Safety				
Reduce knock-on safety risks that result from incidents.	Use of VSL, supported by incident detection will improve incident detection and reduce potential for secondary incidents.	Moderate Positive	Use of VSL, supported by incident detection will improve incident detection and reduce potential for secondary incidents.	Moderate Positive
Reduce the frequency and severity of accidents on National Roads	Use of VSL will reduce the level of incidents on congested roads.	Significant Positive	Use of VSL will reduce the level of incidents on congested roads.	Significant Positive

24.4 Results of Strategic Appraisal

24.4.1 The M50 Traffic Management Study

The M50 is clearly unique within Ireland in terms of the volume of traffic it carries in comparison to other parts of the national network and also its function in respect of the regional and wider strategic network. This is reflected in the relative merits of the potential strategies which have been appraised as part of this study.

A strategy which relies solely on control methods will be limited in the extent to which it can manage demand, but instead relies on maximising available capacity to cater for current growth projections. There are clear benefits to be had from the implementation of measures such as improved monitoring and the associated dissemination of information to users. Likewise, particular segments of demand will benefit from the allocation of roadspace to particular types of vehicle or class of user. The Control Strategy will therefore respond well to many of the objectives of the Traffic Management Study, but does fall short of managing congestion on a broader scale. Notwithstanding this, the technical and institutional risks with such an approach are low providing those issues relating to enforcement (in respect of PTF and PTFT lanes etc.) can be addressed. Such a strategy could be rolled out relatively quickly and in an incremental fashion so that the associated costs can be spread to match available resources.

The fiscal approach seeks to identify a solution that is based on a solid foundation of fiscal interventions, with supporting control measures to address residual deficiencies. A multi-point tolling approach will successfully manage demand, and other features such as variable tolling by time of day and assist in generating better use of the off peak periods. Nevertheless, the impact on local roads would result from any tolling strategy on the M50 and would require careful consideration – although the analysis suggests that the M50 strategy would lead to significant reductions in diverting traffic through the Lucan and Strawberry Beds area. With the fiscal approach, dedication of lanes to public transport is less warranted, as all traffic would benefit from reduced journey times equally.

24.4.2 The Dublin Radials Traffic Management Study

The radial routes are generally major Inter-Urban routes, with the exception of the N2 and M3. Although acting as significant commuter routes during peak periods, many such routes carry relatively high proportions of freight and business traffic.

The control strategy that emerged for the radials focuses on the allocation of lanes to specific users (with or without potential for tolling), along with improved incident detection and variable speed limits to minimise disruption due to incidents. This strategy produces positive results across a range of objectives although again there is a limit to the extent that such a strategy will affect the underlying patterns of demand. The strategy particularly supports Public Transport and Freight priority which, particularly in the latter case, is an important aspect of the role of these parts of the network. Such provisions, linked to the existing arrangements at Dublin Port Tunnel provide a coherent approach to supporting freight movements from around the country to the international network.

The fiscal approach maintains much of the control strategy, albeit with a reduction in the potential provision of Public Transport and Freight lanes, made possible through single point tolling on the approaches to the built up area. The inclusion of a degree of public transport priority alleviates some of the concerns surrounding a fiscal-only strategy and the use of well placed access control should mitigate some of the environmental impacts of tolling points due to diversion onto the local network

24.4.3 The Cork Area Traffic Management Study

The catchment area for a regional city such as Cork is much smaller than Dublin and the level of transport infrastructure is equally not as well developed or as comprehensive in terms of travel choice alternatives. The scope for adopting a broad fiscal approach to managing traffic demand is therefore more limited than elsewhere.

A control approach, which includes a degree of capacity enhancement at Dunkettle, has been shown to bring benefits across many objectives. Nevertheless, it is unlikely to deal with all of the congestion related areas and will require some degree of residual restraint.

The fiscal strategy includes a number of capacity enhancements which could be seen as potentially encouraging traffic into the corridor, but this would need to be effectively offset by a suitably set toll on the Jack Lynch Tunnel (possibly combined with tolls at other locations along the South Ring Road) in order to manage demand responses. Such a strategy provides a degree of flexibility in responding to conditions although the timing of the implementation of the various measures, particularly capacity enhancement versus capacity improvement would require careful consideration

Chapter 25 Conclusions

25.1 Overview

It is estimated that over the period 2006 to 2025, demand for travel will increase by up to 50% in the absence of active measures to manage and influence demand. The forecasted growth is higher than the anticipated increase in population and reflects increased mobility and car ownership over that period. Growth at this scale will lead to a notable deterioration in the levels of service offered by the road network. This deterioration will be most noticeable in the Greater Dublin Area and on the networks serving other major urban areas.

Whilst the forecasts adopt the population and employment distribution set out in the National Spatial Strategy[2] and reflect increased mobility and car ownership levels, they are based on a 'business as usual' approach to travel demand, with no significant changes in travel behaviour anticipated. Accordingly, there is a need to actively promote change from 'business as usual' by introducing policy and interventions that counteract the negative consequences of growth in traffic whilst preserving mobility that is economically productive, lessens impact on the environment, can be delivered in a sustainable means, and provides access to social and cultural opportunities.

Given that the funding for new road infrastructure is likely to be limited in the future, managing travel demand on the network in tandem with efficient and effective operation and maintenance regimes is critical to safeguarding the long term economic, environmental and safety benefits from the recently constructed national motorway network.

In addition, our review of international best practice in this area has highlighted a good understanding internationally by road authorities of the potential benefits of traffic management measures at a network level. The review also highlighted an increasing trend in real investment in this area across all potential solutions (perhaps with the exception of GNSS-based national road user charging) with the general objective of trying to unlock greater benefits from the existing network without needing to resort to expensive additional capacity schemes, which traditionally would have been the only option examined. In short the attitude is clearly one of using these options to "squeeze what you can out of the existing infrastructure".

The National Traffic Management Study has developed a set of measures for the national road network which will ensure that this growth in travel demand will be managed in a way which ensures that outcomes support wider government goals associated with economic growth, social interaction and the environment. In developing the National Traffic Management Study, supporting analysis has been drawn from:

- A detailed review of existing travel demands, and likely future growth in demand over the period to 2025;
- A review of existing network performance, and how this will change;
- A review of international experience in the development and application of traffic management measures, to understand the impacts of those measures, and the issues that they were intended to address;
- A series of engineering feasibility studies in order to ascertain the applicability of certain traffic management solutions (i.e. designs or technologies);
- Traffic modelling and analytical exercises to understand the impacts of relevant proposals;

- Research of traffic flows and driver behaviour to establish a series of principles guiding the implementation of key proposals; and
- A strategic appraisal to guide the preparation of strategies for each of the key areas.

In developing the strategies, it was considered that the chosen policy on fiscal management of the road network was fundamental to the future direction of traffic management. In this regard, the Traffic Management Study identified two altrnative high-level approaches to network management, which comprise:

- Control Approach, which actively manages traffic movement to offer priority to higher value road users, and maximises capacity of existing roads insofar as is possible to increase their carrying capacity; and
- Fiscal Approach, which adopts a basic set of fiscal measures, and introduces further control measures where residual demand requires further management.

25.2 Key Findings

Progressing the alternatives through analysis and feasibility studies has allowed a number of significant conclusions to be drawn. Some key findings which define the strategy are:

- That National Road Pricing using a satellite based system is probably the most appropriate form of Road Pricing in Ireland if such were to be implemented on a national scale. Nevertheless, given that congestion in Ireland is focused in a few key locations on the network, GNSS-based Road Pricing is not likely to offer any real difference to fuel taxation throughout most of the network, and the subset of roads where road pricing is warranted remains small. As such, there is no outstanding case for GNSS-based Road Pricing which applies a road user charge on the basis of external costs of congestion. This option may have more to recommend it as a tax collection option in the case that vehicle fuel economy significantly increased (so that vehicles pay significantly less fuel tax per mile) and / or the percentage of alternative fuelled vehicles (hydrogen, electric) within the national fleet increases to significant levels:
- When that subset of the national road network where congestion occurs is considered for road pricing, it is concluded that a DSRC (Tag and Beacon) based system is wholly appropriate and deliverable. An appropriate multi-point tolling system based on the M50 technologies can form the basis for a Regional Road Pricing strategy for national roads, migrating in the medium term to a closed system of distance-based charging on major roads in the Dublin Area;
- Whilst the implementation of Hard-Shoulder Running has been used in broadly similar environments in the UK (e.g. Birmingham's Managed Motorways, UK), the delivery of such technology is not feasible on recently constructed roads in Ireland where a reduced-width hard shoulder has been provided. On roads where a reservation has been provided for the provision of a third lane, the implementation of hard-shoulder running would require a higher life cycle cost than provision of the additional lane, and so is discounted in a large number of circumstances;
- Many traffic management proposals comprise the collation and distribution of information, whether this is weather, traffic flows, traffic conditions, incident information or event management. The systems for such processes are already in place, and the Dublin Port Tunnel Control Centre provides an excellent opportunity to further develop existing information management processes across the motorway network; and
- Whilst the Traffic Management Study proposes measures which focus on areas of traffic congestion, the delivery of Smarter Travel initiatives will play an important national role in securing efficient use of future road capacity. Sustainable planning policies, as advised

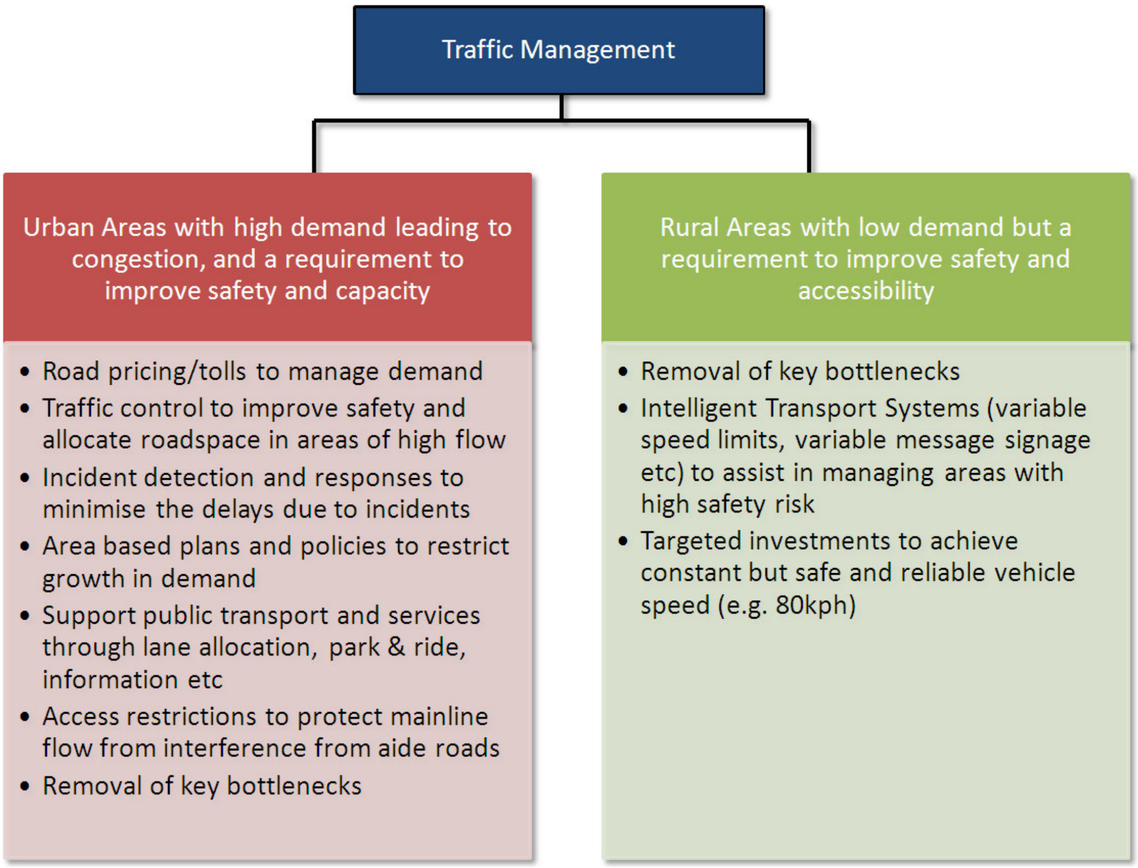
in the Guidelines on Spatial Planning and National Roads, will be necessary to mitigate adverse impacts of further growth in travel demand which has the potential to erode the strategic value of the national road network.

25.3 Applications to Scheme Development

Throughout the Traffic management Study, continuous reference has been made to those areas where traffic congestion exists or will exist through the life of the assessment. Nevertheless, this does not imply that traffic management solutions are not appropriate in areas where congestion does not exist. Returning to the definitions offered in chapter 5 of this report, the term Traffic Management refers to measures which seek to maximise the value of existing infrastructure without resorting to major expenditure. As such, traffic management describes the toolkit of measures that can be applied where such interventions are warranted, and are therefore likely to form the basis of future investment in the transport network which is likely to continue to be subject to funding constraints.

In Ireland, although a relatively high proportion of the road network is uncongested, investment continues in those uncongested areas to address issues of safety, accessibility, and environmental impact. It has been demonstrated in the appraisal of traffic management strategies that, although not the focus of the current study, traffic management can offer substantial benefits to these criteria. Ultimately, the choice of measures will respond to the specific objectives of each area - which are likely to be quite different between urban or semi-urban high capacity roads, and rural low-volume roads. A typical range of options for urban and rural scenarios is outlined below.

Figure 25-1: Traffic Management in Urban and Rural Areas



The Traffic Management concept has recently been incorporated into the NRA Project Appraisal Guidelines[39] (PAG) in *PAG Unit 4.0: Definition of Alternatives*. That Unit of the PAG sets out a requirement to consider a Traffic Management Alternative when developing options for specific schemes. Such considerations would incorporate, and may be guided by, many of the techniques outlined in this report.

25.4 Strategy Appraisal

The appraisal process has been based on the Sketch Appraisal as set out in the Common Appraisal Framework, and provides a preliminary evaluation of each strategy alternative against the study objectives, which are in turn structured beneath the headings set out in the Appraisal Framework.

The appraisal process has focused on the three 'priority areas' that have been defined through the strategy document, namely the M50 Motorway in the Dublin area, the Radial Routes providing access to the Dublin area and the Cork Area. Whilst the appraisal deals with each geographical area individually, a clear theme emerges when comparing the alternative approaches to strategy development.

The Control Strategy is founded on a series of measures which reallocate roadspace to higher-value road users, influence traffic flows in order to release some minor additional capacity and reduce the frequency of incidents and the period of disruption resulting from incidents, and systems to provide advance information to road users. Although the Control Strategy will generate benefits, it is unlikely to provide a means to manage growth in demand – this additional capacity will be simply used by future growth in traffic. As such, the Control Measures might be seen as an interim set of solutions to provide some additional capacity where a significant future intervention is expected, and a number of years of additional growth are to be accommodated or where the management and reduction of incidents on a network link is considered critical (e.g. Dublin Port Tunnel). This is certainly the case in Galway, where traffic management measures have been proposed on the existing Galway Ring Road in advance of the Galway City Outer Bypass, which may be some years into the future.

The Fiscal Strategy adopts many of the measures outlined in the Control Strategy in order to improve safety and traffic flow on the busiest national roads. The Fiscal Strategy also, however, introduces a system of multi-point tolling through the Greater Dublin Area, and a further single-point toll in Cork, in an attempt to manage future traffic demand, and provide a significantly longer lifespan for the road infrastructure in the region. This Fiscal Strategy will generate a number of responses:

- It will reduce travel demand by discouraging non-necessary trips, particularly beneficial during peak periods;
- It will manage growth in traffic demand, by encouraging appropriate land use responses – i.e. consolidation of urban centres and a greater reliance on public transport;
- It will ensure that roadspace is available for high-value road users, namely freight, public transport and business travel. All these uses have been defined as high priority uses in the setting of objectives;
- It will generate revenue, although the form of revenue collection will be more focused (i.e. based on user-pays principles) – leading to more positive economic benefits as opposed to raw taxation of income or services; and
- It will encourage and be complementary to use of public transport for commuters, thereby supporting the significant investment in rail and bus as outlined in Transport 21.

In effect, the choice of the approach to traffic management pivots on the chosen solution for fiscal measures, and as such will define the residual control measures that are warranted. Further discussion on the scale, form and impact of fiscal interventions is therefore expected prior to any definitive conclusions being drawn on the ultimate form of traffic management on national roads.

Glossary of Terms

Glossary of Terms

AADT	Annual Average Daily Traffic
AID	Automatic Incident Detection
ALS	Area Licensing Scheme
ANPR	Automatic Number Plate Recognition
ASF	Autoroute du Sud de la France
ATM's	Automated Teller Machines
BAM	BAM Construction Contractors
BRT	Bus Rapid Transit
CASP	Cork Area Strategic Plan
CBD	Central Business District
CCS	Central Computer System
CCTV	Close Circuit Television
CO2	Carbon Dioxide
COBA	Cost Benefit Analysis
CSO	Central Statistics Office
DaSTS	Delivering a Sustainable Transport System
DED	Division of Electoral Districts
DMRB	Design Manual for Roads and Bridges
DOEHLG	Department of Environment Heritage and Local Government
DPT	Dublin Port Tunnel
DSRC	Direct Short Range Communications
EPSRC	Engineering and Physical Sciences Research Council
ERA	Emergency Refuge Area
ERP	Electronic Road Pricing
ETC	Electronic Toll Collection
EU	European Union
FCC	Fingal County Council
GCOB	Galway City Outer Bypass
GDA	Greater Dublin Area
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSM	Global Systems Mobile
HA	Highways Agency
HGV	Heavy Goods Vehicle
HOT	High Occupancy Toll
HOV	High Occupancy Vehicle
IFPLUT	Integrated Framework Plan for Land Use and Transport
ITB	Influencing Travel Behaviour
ITS	Intelligent Transport Systems
IVU's	In Vehicle Units
LED	Light Emitting Diode
LGV	Light Goods Vehicle
LoS	Level of Service
LTA	Land Transport Authority
LUTS	Land Use Transport Strategies
MEB	Marginal External Benefits
MECC	Marginal External Cost of Congestion
MIDAS	Motorway Incident Detection and Automatic Signalling
MIU	Major Inter Urban routes

MPS	Mobile Positioning System
MSB	Marginal Social Benefit
MSC	Marginal Social Cost
NDP	National Development Plan
NPRA	Norwegian Public Roads Administration
NRA	National Roads Authority
NRN	National Road Network
NRTMS	National Traffic Management Study
NSS	National Spatial Strategy
NTA	National Transport Authority
NTM	National Traffic Model
NTPM	National Transport Model
NTR	National Toll Road
O&M	Operation and Maintenance
OBU	On Board Unit
OVG	Ordinary Goods Vehicle
PABS	Project Appraisal Balance Sheet
PAG	Project Appraisal Guidelines
PARAMICS	Micro-simulation Package
PCU's	Passenger Car Units
PIA	Personal Injury Accident
POWCAR	Place of Work Census of Anonymised Records
PPP	Public Private Partnership
PT	Public Transport
PTF	Public Transport Freight
PTFT	Public Transport Freight Toll
PTP	Personal Travel Plan
RFID	Radio Frequency Identification
RSA	Road Safety Authority
RSE	Road Side Equipment
SANDAG	San Diego Association of Governments
SARTRE	Social Attitudes to Road Traffic Risk in Europe
SATURN	Simulation and Assignment of Traffic to Urban Road Networks
SOV	Single Occupant Vehicle
TAGM	Trip Attraction Generation Model
TCS	Toll Collection Service
TRB	Transport Research Board
TRL	Transport Research Laboratory
UCC	University College Cork
UK	United Kingdom
US	United States
VAS	Video Audit System
VDM	Variable Demand Model
VES	Video Enforcement System
VMS	Variable Message Sign
VoT	Value of Time
VRT	Vehicle Road Tax
VSL	Variable Speed Limit
WSP	WSP Engineering Consultancy
WTP	Willingness to Pay

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