Developing an alternative means of assessing speed limits on rural single carriageway roads in Ireland using observed driver behaviour.

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Abstract

Speed limits in Ireland have undergone many changes since first introduced, most notably in 2005 when the State adopted metric speed limits. The challenge presented to the Department of Transport, Tourism and Sport and Local Authorities is to assess, manage and implement a system of speed limits that are appropriate, credible, transparent and have the support and respect of the road user. Until 2005 a National Speed Limit applied to all roads outside built-up areas. Metrification then occurred, and the National Speed Limit was replaced by a system of Default Speed Limits that were assigned to each class of road. Over time, this led to a lack of credibility and inconsistency in the speed limit system. This thesis presents a history of how Irish speed limits have evolved and how they are currently set and looks at Ireland's collision history, its speed limits and its road safety performance in relation to other European countries. Current speed limit assessment methods, both in Ireland and in other jurisdictions, are also presented.

An alternative means of assessing the appropriate speed limit for rural single carriageway roads is proposed by deriving a Safe Profile Velocity (V_{sp}) and an Efficiency Index value for the road or section of road under assessment, by capturing actual driver behaviour - the hypothesis being that the derived Safe Profile Velocity (V_{sp}) reflects what is occurring on the road and simplifies the assessment method in relation to current methodologies like the Speed Assessment Framework, while retaining core principles. A simplified assessment method is becoming increasingly necessary as Local Authority resources are limited, but demand for a credible speed limit system remains.

This thesis contains seven case studies and shows the relationship between the Safe Profile Velocity (V_{sp}) and existing speed limits - the Efficiency Index, and shows the effect on this Index should the speed limit be altered. The question of considering the use of speed limit values that do not currently exist in legislation also emerges within this thesis. Areas where future analysis or further research may be beneficial are also proposed.

Acknowledgements

My sincerest thanks go to Dr. Tim McCarthy and the team, Dr. Lars Pforte, Daire Walsh and Dr. Paul Lewis, for their help and assistance during my work and for the previous work they did on Safe Profile Velocities, which was the catalyst for developing an alternative means to set Speed Limits.

Dr. Martin Charlton and Prof. Chris Brunsdon, though they may not have realised it at the time, frequently dropped in nuggets of wisdom and humour that, if not immediately apparent here in this thesis, make their way into some of these pages in some shape or form.

I would also like to sincerely thank my Employer, Kildare County Council, who agreed to assist the Department of Transport, Tourism and Sport in the review of the 2010 Special Speed Limit Guidelines and assigned me to that task. In doing so, it fuelled my desire to endeavour to make a tangible contribution to road safety, culminating in my volunteering to undertake research to support that work. Without the support of my Employer, colleagues and the DTTAS Support Office team, this thesis would not have been possible, as it came at a time when resources were tight, and workloads were intensifying. I would also like to thank the Department of Transport, Tourism and Sport for supporting this work.

If it were not for my parents, I wouldn't be here writing this, and I would like to thank them for their tremendous support through University, I will never be able to thank them both enough. I'm sorry Dad that you didn't get to see the finished product.

Finally, I cannot fail to mention the love, encouragement and support I received from my wife, Ciara. Her inquisitive mind and attention to detail and ability to bring me back into the correct 'driving lane' in my mind helped me remove any doubts I had. Thank You. I promise I'll tidy up now and we can have our house back, albeit temporarily...Ellie!

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Glossary of Terms

AGS – An Garda Síochána

CCMA – County and City Managers Association

DTTAS – Department of Transport, Tourism and Sport

EI – Efficiency Index

ETSC – European Transport Safety Council

EU – European Commission

FHWA – Federal Highway Administration

GPS – Global Positioning System

iSAFER - Intelligent Speed Assistance for European Roads

ITE – Institute of Transportation Engineers

LGMA – Local Government Management Agency

MASTER (Framework) – Managing Speeds of Traffic on European Roads

NCG – National Centre for Geocomputation

NRA – National Roads Authority

NSR – Network Safety Ranking

NTA – National Transportation Authority

OECD - Organisation for Economic Co-operation and Development

PMS – Pavement Management System

PSL – Posted Speed Limit

RSA – Road Safety Authority

SAF – Speed Assessment Framework

SSL – Special Speed Limit

TII – Transport Infrastructure Ireland (formerly NRA)

TRL – Transport Research Laboratory

V_{sp} – Safe Profile Velocity

Chapter 1

Background & Introduction

1.1 Background

"Speed kills". It's a phrase we hear all too often. We hear it because it's true. This research is motivated by the stark reality that excessive speed is a main contributory factor in the collisions that take place on our roads and in 32% of all fatal collisions (Road Safety Authority – Fatal Collisions 2008-2012, 2016). A robust and credible speed limit system will provide an environment whereby, if observed, road users will be travelling at appropriate speeds on our roads, thus reducing the probability of a collision caused by inappropriate or excessive speed.

In 2012, a Working Group was established by the Minister for Transport, Tourism and Sport to review the system of speed limits and items associated with speed limits and road safety. The group comprised many stakeholders, all of whom had a relevant interest in and experience of speed limits and their management. It comprised the Department of Transport, Tourism and Sport, An Garda Síochána, AA Ireland, National Transport Authority, National Roads Authority, Road Safety Authority, Local Government Management Agency, City and County Managers Association and two Local Authorities. Their terms of reference were to;

1. Review the existing overall speed limit system and make recommendations
2. Review and make recommendations on signage that accompany speed limits
3. Make recommendations on the issue of awareness and communications
4. Make recommendations on the implementation of the changes while setting out the actions required, timescales and cost implications.

The review (DTTAS, 2013) recommended 18 actions, one of which was to *"update and strengthen guidelines and circulars"* (action #8). During the review of the Special Speed Limit Guidelines 2010 (Department of Transport, 2010) in 2014, subsequently published in March 2015, the issue of the Speed Assessment Framework was raised with a view to researching and updating it to better suit Irish conditions.

Notwithstanding the publication of the 2015 Guidelines, the issue remains as to how to confidently set an appropriate speed limit on all roads across the state. The 2015 Guidelines introduced new concepts, most notably the concept of the Stage 1 Assessment whereby the starting point for the choice of an appropriate speed limit is the width of the road and not its classification.

This author, member of the 2014 Speed Limit Guidelines Review Group, volunteered to undertake this research and approached Maynooth University with a view to supporting the research through a Masters by Research programme in the National Centre for Geocomputation (NCG). It was obvious that the NCG would be well placed to assist with this task, as they had a prior and ongoing associations with the National Roads Authority (now Transport Infrastructure Ireland) and the Department of Transport, Tourism and Sport. For the purpose of this research the focus will be on Rural Single Carriageway roads outside built-up areas.

1.2 Introduction

The metrification of speed limits in Ireland in 2005 resulted in a change to the approach to setting speed limits. Previously there was, in effect, only built-up area speed limits (Urban) and the National Speed Limit (Rural). The National Speed Limit (Ordinary Speed Limit) applied to all roads outside urban areas, unless there was a Special Speed Limit in place, set by Local Authorities.

When metrification occurred, Default Speed Limits were applied to the different classes of roads. While the transition was delivered successfully, 14 years on, issues remain with speed limits and signs that cause confusion and frustration for road users. There are many examples of inconsistency and inappropriateness resulting from the change and there is also a general lack of consistency from one Local Authority area to the next, frequently giving rise to situations where a driver can encounter different speed limits on the same route from one county to the next – an example being the N51. The section of the N51 (National Secondary road) in Co. Louth carries the Default Speed Limit of 100 km/h. When a driver on this road crosses the County Boundary into Co. Meath the speed limit is reduced to 80 km/h (Special Speed Limit) for the duration of the journey along this route while in Co. Meath (except for a short section of dual carriageway outside Navan).

Another example is the N4 between Dublin and Sligo. A section of 'legacy' (i.e. a road not constructed to a formal design standard) narrow single carriageway in Sligo carries the Default Speed Limit of 100 km/h, while a section of 3-lane dual carriageway in Co. Dublin, constructed to formal design standards, carries a reduced Special Speed Limit of 80 km/h. There are many more examples. Many of them were caused by differences in how the Guidelines for the Application of Special Speed Limits (2010) were interpreted by Local Authorities. These Guidelines were reviewed and replaced by the 2015 Guidelines.

The change to metric speed limits resulted in situations where National roads, quite often with a poor cross-section due to it being a legacy road, carried a Default Speed Limit greater than a Regional Road that may have a more favourable cross-section, whilst also not being constructed to a formal design standard. While it was open to Local Authorities to set a Special Speed Limit on these roads to take this into account, few did so, choosing to persist with the Default Speed Limit.

Also, when roads of a lower speed limit join a road with a higher speed limit, a speed limit repeater sign is required on the road with the higher speed limit. This in turn creates many interface points where speed limit signs reminding the road user are located in areas where it may be inappropriate to do so. This creates a poor public perception of the way speed limits are set and managed. A 2012 project, managed by this author, identified and removed circa 700 inappropriate signs on the National Primary and Secondary Road network (Kildare National Roads Office, 2012). Notwithstanding the progress made then, the current national road signs maintenance contracts (administered by Transport Infrastructure Ireland - TII) resulted in some of these signs being reinstated and then removed again under the 2015 National Speed Limit Review (below).

In 2015, the Department of Transport, Tourism and Sport asked Local Authorities and the then National Roads Authority to review the use of repeater signs and remove inappropriate signs (Department of Transport, Tourism and Sport, 2015 Circular RSD/1/2015). This sequence of events further creates a poor public perception in relation to the ability of Local Authorities to properly set and manage speed limits and signage in their administrative areas.

A Speed Assessment Framework was included in the 2010 Guidelines and retained in the 2015 Guidelines. This Framework was exclusively based on the framework produced by the Transport Research Laboratory for the Department for Transport in the UK (TRL 2004). It is unclear as to how often it was used by Irish Local Authorities.

Returning to the example of the N51, it appears that Meath County Council have set this policy of a Special Speed Limit of 80 km/h on their National secondary roads in the absence of clear guidance as to how to confidently assess and set the speed limit. This is the purpose, and indeed the challenge, of this research; to produce a simple yet effective alternative method of evaluating and setting an appropriate speed limit on Ireland's rural single carriageway roads and to determine whether it is possible to use driver behaviour to adequately inform this assessment.

1.3 Methodology

This thesis evaluates the effectiveness of using a derived Safe Profile Velocity (V_{sp}), developed by McCarthy and Pforte (2014), to manage, assess and set speed limits on Irish single carriageway roads by capturing actual driver behaviour. The V_{sp} represents the way the average driver drives on a route and should provide a better understanding of the safety performance of the road taking account of the physical characteristics of the road. Global Positioning System data (GPS) is used to record driver behaviour, resulting in a speed profile for the journey. Using these captured GPS profiles, the V_{sp} is then derived. These are further assessed and developed to produce an Efficiency Index (EI). The EI becomes the indicator of the performance of the road in relation to its speed limit. The higher the EI value, the more appropriate the speed limit is..

1.4 Case Studies

Seven routes were assessed across different route classifications. Two routes are National primary roads (N2, N14), three routes are National secondary roads (N51, N52, N53) and two are Regional roads (R157, R410). Each route, or section thereof, was captured a minimum of three times in each direction. The total length of road captured and analysed is in the region of 160 km in each direction. The R157 was captured again a few months after the initial set of captures to carry out a data validation/repeatability exercise. The Methodology and Case Studies aims to answer the following questions;

A. Can Safe Profile Velocities (V_{sp}) be used to develop an alternative method of assessing and setting speed limits on rural single carriageway roads in Ireland that takes the road environment, vehicle and road user into account ?

B. Can the method developed replace the existing Speed Assessment Framework by being simple and effective without placing excessive demands on resources?

1.5 Thesis Structure

Chapter 1 provides the background to and introduces the issues that informed the need for researching a simple yet effective means of assessing speed limits on Irish single carriageway roads and briefly highlights some of the inconsistencies in the speed limit system. Chapter 2 gives an overview of Ireland's road network, basic design principles, factors that affect speed and speed limits. Chapter 3 explores Ireland's road safety performance presenting collision and fatal collision data going back as far as 1959 and focusses on fatal collisions where excessive speed was cited as either the sole contributory factor or a main contributory factor in the collision. Ireland's road safety performance and its speed limits system are compared to European Union member States in Chapter 4.

Current speed limit assessment methodologies in Europe, the United Kingdom, Ireland and the United States are outlined in Chapter 5. The proposed assessment methodology is presented in Chapter 6 and supported by seven case studies. Case studies were carried out on two National Primary roads, three National Secondary roads and two Regional roads. The National routes were selected based on their Network Safety Ranking.

Chapter 7 recaps the key issues, provides commentary on the results obtained in the case studies, outlines the theoretical effects changing the speed limit would have on the performance of the route (the Efficiency Index), and draws a conclusion as to whether using V_{sp} to develop an Efficiency Index, to assess and manage speed limits, has merit.

Appendix A contains more detailed individual maps of all collisions on Irish roads from 2006-2012 and explains Network Safety Ranking. Appendix B explores and proposes areas of future work, research or development to support the use of V_{sp} as a speed limit assessment method.

Chapter 2

Ireland’s Roads and Speed Limits

This chapter gives an overview of Ireland’s road network as it currently exists, how speed limits have evolved since their introduction and the current structure of Irish speed limits, showing clearly the inconsistencies in the speed limit system brought about by assigning a default value to particular road classifications. Basic road design information is included, highlighting parameters that affect speed on roads.

2.1 The Road Network

Table 2.1 shows how Ireland’s public road network is made up. The figures are approximate and were retrieved from the Pavement Management System (PMS) and provided by the Local Government Management Agency (LGMA).

<table>
<tr><th colspan="2">ROAD CLASSIFICATION</th><th>TOTAL LENGTH</th><th>% OF OVERALL NETWORK</th><th>DEFAULT SPEED LIMIT</th></tr>
<tr><td colspan="2">Motorway</td><td>1,000 km</td><td>1.01</td><td>120 km/h</td></tr>
<tr><td rowspan="2">National</td><td>Primary</td><td>1,843 km</td><td>1.86</td><td rowspan="2">100 km/h</td></tr>
<tr><td>Secondary</td><td>2,683 km</td><td>2.71</td></tr>
<tr><td colspan="2">Regional</td><td>11,600 km</td><td>11.7</td><td rowspan="4">80 km/h</td></tr>
<tr><td rowspan="3">Local</td><td>Primary</td><td rowspan="3">82,000 km</td><td rowspan="3">82.72</td></tr>
<tr><td>Secondary</td></tr>
<tr><td>Tertiary</td></tr>
</table>

Table 2.1: Ireland’s road network

Approximately 94% of the network is governed by the same Default Speed Limit (80 km/h), however, the typical cross-section of these roads varies considerably, with many roads evolving over time that are termed ‘legacy’ roads. Legacy roads are roads that have not been designed and constructed to a formal design standard. It is possible that routes will have had localised realignment projects carried out on them over time, however, for the substantial length of the legacy route, there will have been no formal design or construction. Sections 2.1.1 to 2.1.4 briefly outline the typical cross-section of each class of road (Transport Infrastructure Ireland, Standard Construction Details-Series 000, 2017), all values are in millimetres.

2.1.1 Motorways

A typical cross-section of a motorway is shown below. Motorways make up approximately 1000km of the road network and have a Default Speed Limit of 120 km/h. Motorways typically have 2 x 3.5m lanes with 2.5m hard shoulders.

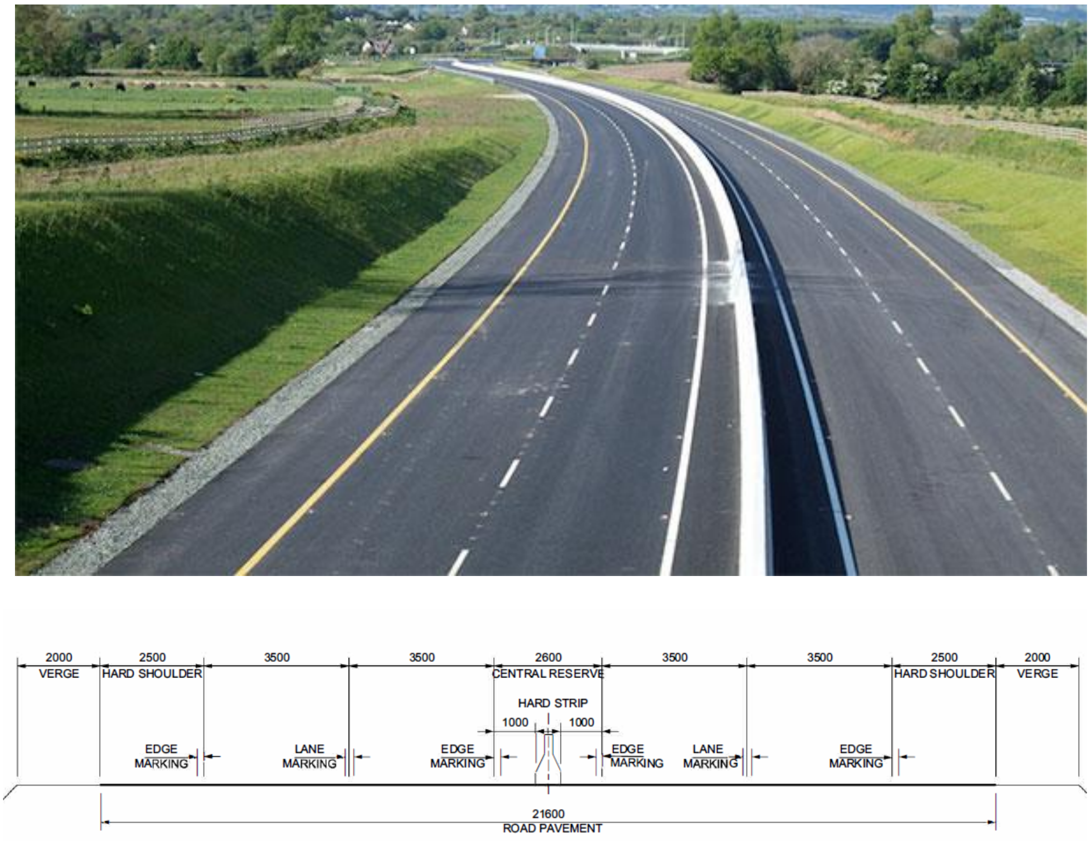

Figure 2.1: Typical Irish Motorway cross-section

Generally, there are no issues regarding speed limits on Motorways, as it is widely accepted that 120 km/h is an appropriate Motorway speed limit and most of the Motorway network carries this speed limit. The M50, however, has a 100 km/h Special Speed Limit applied due to the constrained alignment and its level of traffic.

2.1.2 National Roads

National primary roads can be designed and built to dual carriageway standard and, in such cases, the majority have been designated as Motorway (during the Major Inter-Urban road building programme). The most desirable cross-section for a single carriageway National primary road is shown below in Figure 2.2 and comprises 2 x 3.65m lanes with 2.5m hard shoulders. National roads make up approximately 4,500km of the road network.

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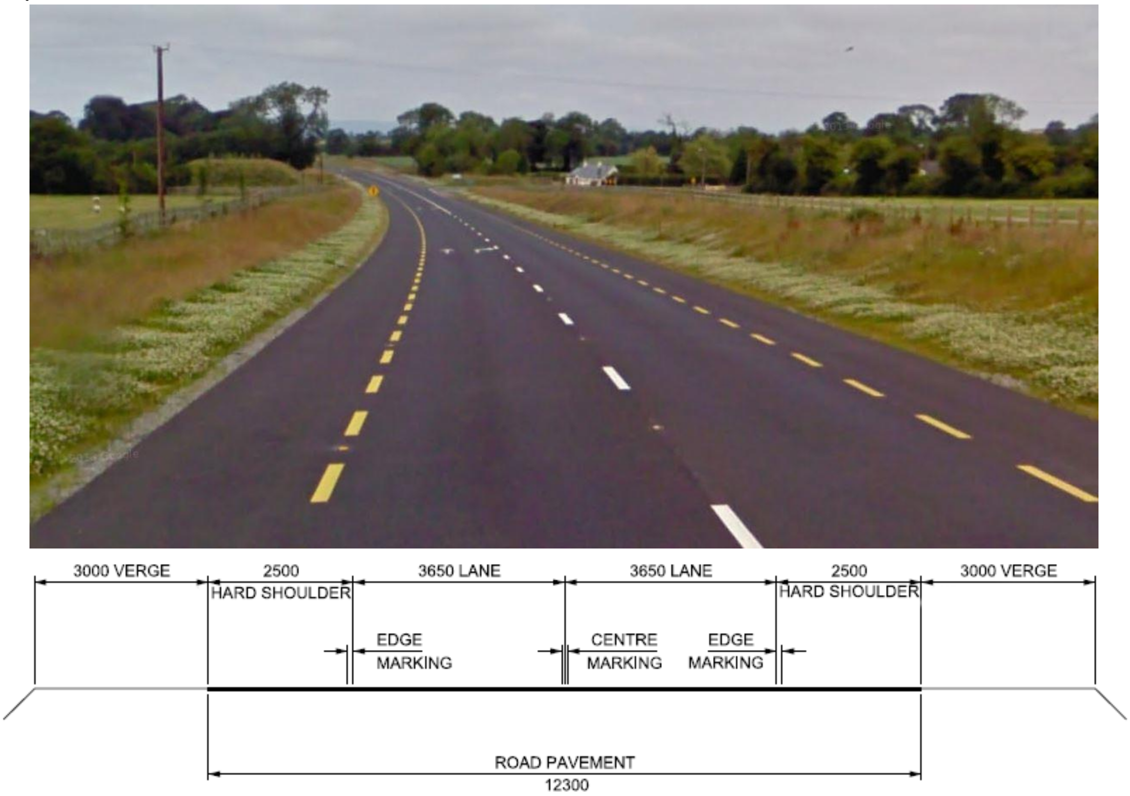


Figure 2.2: Typical Irish National primary road cross-section

As stated, this is the ideal cross-section for a National road, particularly a National primary road. In reality, however, there are many sections that are 'legacy' roads and have narrower cross-sections than shown above and would be more indicative of a good quality Regional road or, indeed, a Local primary road (section of the N4 near Sligo for example).

National secondary roads often have cross-sections as shown below. Improved or realigned sections of National secondary roads may be designed as per the cross-section shown previously but, for the most part, the cross-section of National secondary roads can vary considerably, often leading to situations where their cross-section is narrower or less desirable than Regional roads (sections of the N70 in Co. Kerry).

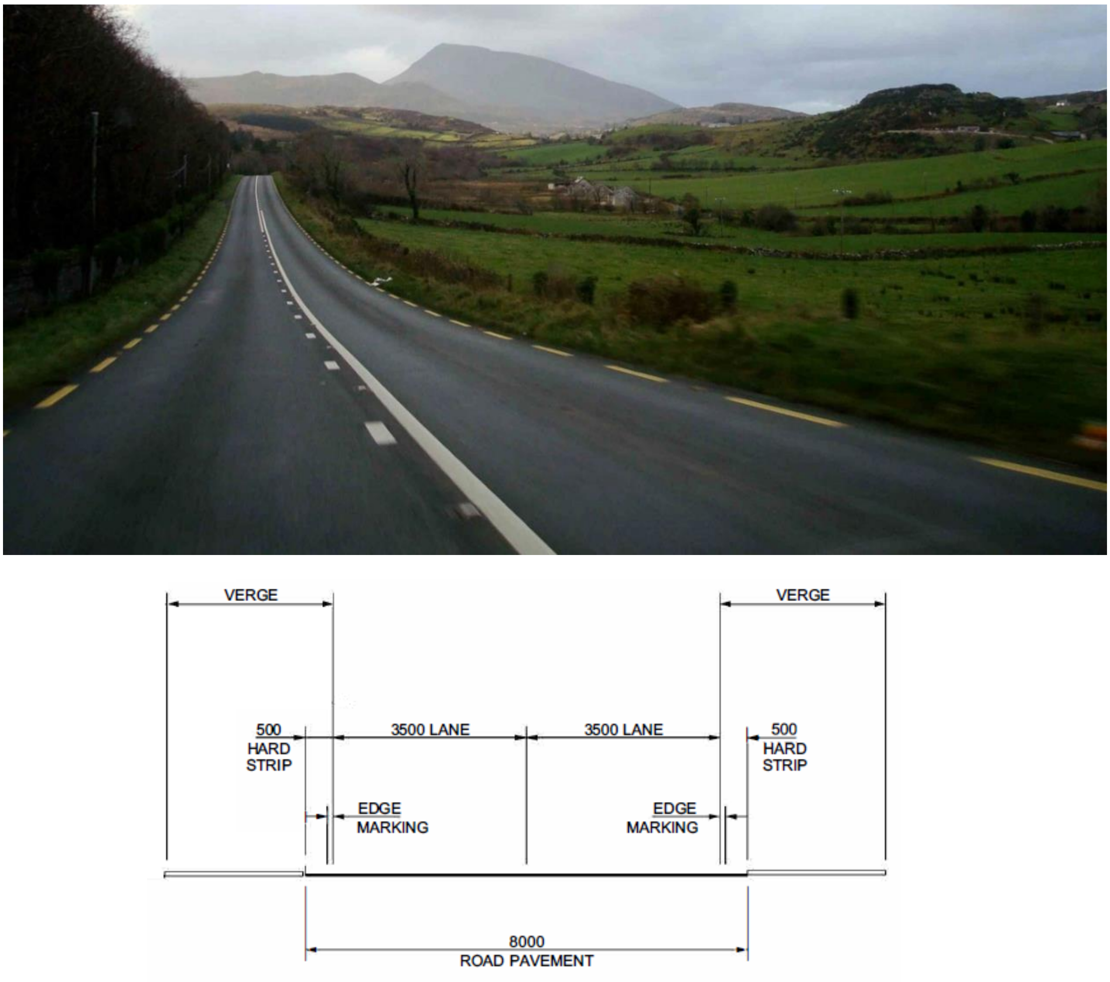


Figure 2.3: Typical Irish National secondary road cross-section

2.1.3 Regional Roads

Regional roads generally have a cross-section as shown below in Figure 2.4 which is similar to that of a National secondary road. Like National secondary roads, they can vary considerably. Both roads shown below are in Co. Kildare (R410 on left and R411 on right). It could be argued that the R411 has a cross-section more akin to that of a Local primary road i.e. 7m wide carriageway with 0.5m hard strips (by not having a hard shoulder or hard strip).

Figure 2.4: Typical Irish Regional road cross-sections

2.1.4 Local Roads

The Local road classification is split into three; Local primary, Local secondary and Local tertiary. While Local secondary roads are generally less than 4m wide and Local tertiary roads (minor roads and cul-de-sac roads) have a narrow cross-section, they most likely would only be wide enough for one vehicle, i.e. a single lane road. This may also be the case with Local primary roads, however, in the majority of cases, Local primary roads are generally wider than 4m and would normally have a cross-section as shown in Figure 2.5 below.

Figure 2.5: Typical Irish Local primary road cross-section

While most Local primary roads are of a standard shown in Figure 2.5, Local secondary and Local tertiary roads are mostly of a standard shown below in Figure 2.6. Local tertiary roads are commonly referred to as 'Boreens' – in this example, the Rural Speed Limit sign has been erected, The Rural Speed Limit sign was introduced in 2015 and is only erected on single lane Local tertiary roads and selected single lane Local secondary roads. The Rural Speed Limit sign signifies the speed limit is 80 km/h but removes the number and thereby the 'visual target' of an 80 km/h speed limit sign on these roads.

Figure 2.6: Typical Irish Local secondary (left) and tertiary road (right) cross-section

An analysis of the width of Ireland's 32 National secondary roads formed the basis of the decision to introduce a Stage 1 assessment in the Guidelines for Setting and Managing Speed Limits in Ireland (2015). Stage 1 assessment simply states that Local Authorities should use the width of the road to inform their decision as to whether to set a speed limit at 100 km/h or 80 km/h in the case of rural single carriageway roads, regardless of their classification. If the road width is 7m or less, 80 km/h is the appropriate choice. Where the road is greater than 7m then 100 km/h is the appropriate choice.

Much of the narrower sections of these 32 routes analysed would be similar to that of a Regional road. The analysis indicated that as much as 58% of the National secondary network could have its speed limit reduced to 80 km/h. It is clear from the varying cross-sections across the entire network, ignoring classification, that a 'one size fits all' approach, like a National Speed Limit, is no longer an appropriate way to set speed limits.

Measuring the width of every road in sufficient detail is impractical and would place a severe burden on Local Authorities. Desktop studies of routes using Ordnance Survey (OS) mapping available to Local Authorities will give what would appear to be the definitive width of the road, however, this mapping is limited in that generally what is being displayed is the width of the road boundary, not the actual paved width of the road. When Prime2, (Ordnance Survey Ireland's central database of spatial information) is in widespread use, it may improve the accuracy to which Local Authority engineers can measure road width without the need for physical surveys. For now, all they can do is estimate from OS maps and then plan to measure at particular points where they are sure the mapping is not solely showing paved width.

2.2 Ireland's Speed Limits

This section briefly outlines the history of speed limits in Ireland and highlights that from 1979 to 1992 Ireland had a National Speed Limit of 55 mph (90 km/h). The current structure of our speed limits is outlined in subsection 2.2.2 while subsection 2.2.3 gives details of the 2013 Speed Limit Review, a review that set out a roadmap for change in terms of how speed limits are managed in Ireland.

2.2.1 History

Speed limits in Ireland go back as far as 1876 by Regulations made under the Dublin Traffic Act of 1875, which set speed limits of 6mph for certain vehicles. This continued to be the case until 1896 when a maximum National speed limit of 12mph was introduced under the Light Locomotives on Highways (Ireland) Order. Traffic in towns, villages and the Dublin Metropolitan Police District was limited to 6mph. In 1933, the Road Traffic Act prescribed an Ordinary Speed Limit of 25mph for light motor vehicles and heavy motor vehicles with pneumatic tyres (Government of Ireland, Road Traffic Act, 1933)

The Act of 1933 was then repealed by the Road Traffic Act of 1961, which is the main piece of legislation responsible for the full introduction of speed limits in Ireland (Government of Ireland, Road Traffic Act, 1961). This Act allowed the Minister for the Environment to prescribe a General speed limit through Regulations made under the Act. It also allowed Local Authorities to set Special Speed Limits in their administrative areas through Regulations made under the Act. Regulations made in 1963 set a speed limit of 50mph on all roads except those that were subject to the Built-Up Area Speed Limit of 30mph or a Special Speed Limit of 40mph (Government of Ireland, Road Traffic (Speed Limits) Regulations, 1963).

In 1969 a general National Speed Limit of 60mph was set for all roads except those that were subject to the Built-Up Area Speed Limit of 30mph or a Special Speed Limit of 40mph (Government of Ireland, Road Traffic (General Speed Limit) Regulations, 1969. Special Speed Limits were indicated to motorists by the use of standard speed limit signs (circular, red outline, black numbers on white background), however, the National Speed Limit was indicated to motorists by a white circular sign with a black diagonal line bisecting it. The National Speed Limit was reduced to 55mph in 1979 during the Energy Crisis (Government of Ireland, Road Traffic (General Speed Limit) Regulations, 1979) and was restored to 60mph in 1992 (Government of Ireland, Road Traffic (General and Ordinary Speed Limits) Regulations, 1992).

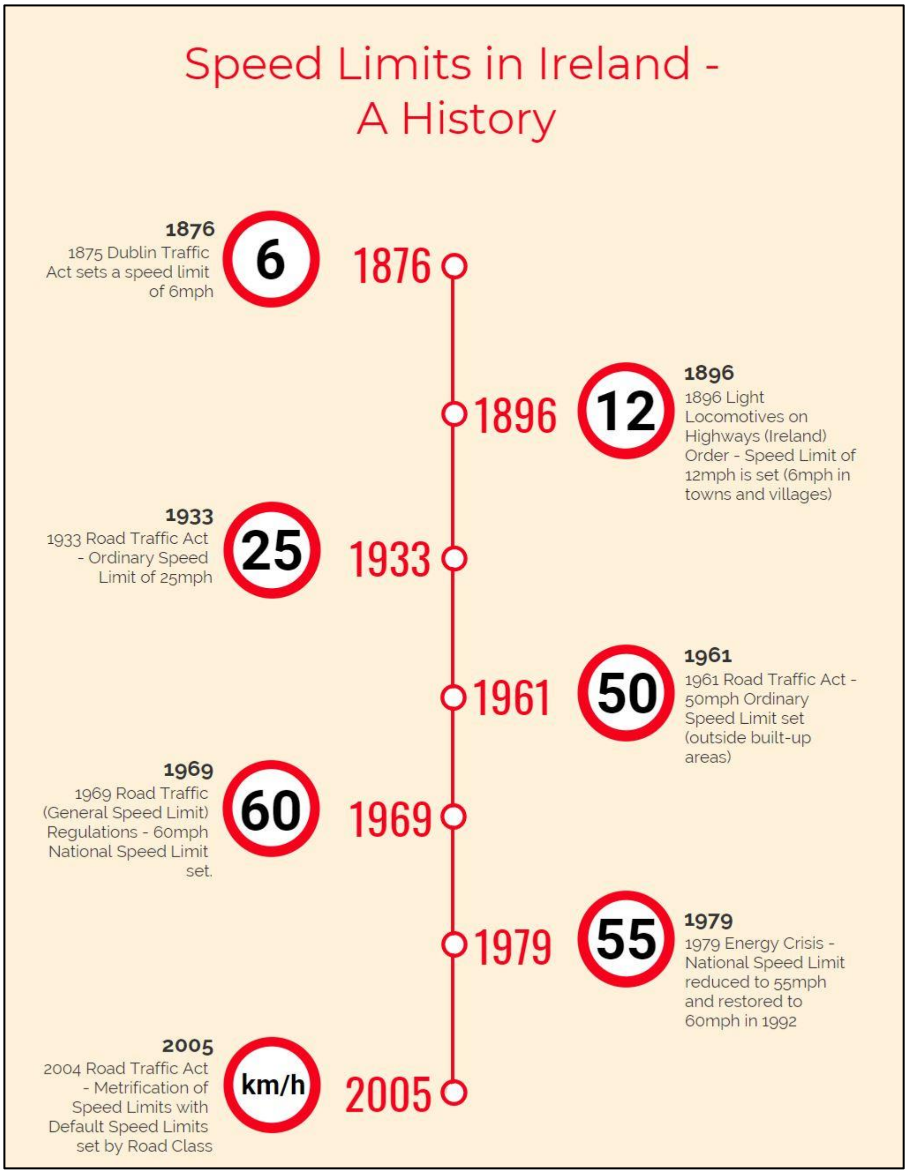


Figure 2.7: History of speed limits in Ireland – timeline infographic

2.2.2 Current Structure of Speed Limits

The next major change to Irish Speed Limits occurred in January 2005 (Government of Ireland, Road Traffic Act, 2004) when metric speed limits were adopted. The National Speed Limit was replaced with a series of Default Speed Limits (Ordinary Speed Limits) applied to the particular classes of roads as follows;

<table>
<tr><th colspan="2">CLASS OF ROAD</th><th>DEFAULT SPEED LIMIT</th></tr>
<tr><td colspan="2">Motorway</td><td>120 km/h</td></tr>
<tr><td rowspan="2">National</td><td>Primary</td><td rowspan="2">100 km/h</td></tr>
<tr><td>Secondary</td></tr>
<tr><td colspan="2">Regional</td><td rowspan="4">80 km/h</td></tr>
<tr><td rowspan="3">Local</td><td>Primary</td></tr>
<tr><td>Secondary</td></tr>
<tr><td>Tertiary</td></tr>
<tr><td colspan="2">Built-up area</td><td>50 km/h</td></tr>
</table>

Table 2.2: Current structure of speed limits

Special Speed Limits are available for use by Local Authorities, should using a Default Speed Limit be deemed inappropriate. Some speed limit values, however, can only be used on certain roads in certain specified situations. These are outlined in Chapter 7 of the Guidelines (DTTAS, 2015).

Default Speed Limit values can be used as Special Speed Limit values, i.e. 120 km/h, 100 km/h, 80 km/h and 50 km/h. Values that can be used as a Special Speed Limit that are not already default values are 60 km/h, 40 km/h and 30 km/h. Recently, 20 km/h has been adopted for use through Primary Legislation (Government of Ireland, Road Traffic Act, 2016). It is not intended for widespread use, full guidance and requirements for the use of 20 km/h is currently being prepared and will be included in the next update of the 2015 Guidelines.

As shown in Table 2.1, approximately 94% of the road network is governed by a Default Speed Limit of 80 km/h. This rises when Special Speed Limits of 80 km/h are included. This, in effect, could be considered by some to be a de-facto National Speed Limit.

2.2.3 2013 Speed Limit Review

The 2013 speed limit review group, in their published report, identified inconsistency and inappropriateness as the two key issues emerging from their work with respect to the speed limits system. The National primary road network with its Default Speed Limit of 100 km/h was found to be generally appropriate, however, some sections existed where anomalies were found (e.g. the N4, as described in section 1.2). The National secondary road network also has a 100 km/h Default Speed Limit, however, much of this network is narrow with a poor alignment and would be more suited to a lower speed limit. These roads were analysed during the review of the Special Speed Limit Guidelines 2014, which resulted in the introduction of a Stage 1 Assessment (2015 Guidelines). Further anomalies exist on some sections of these roads where a reduced Special Speed Limit is applied when the Default would be more appropriate.

Regional roads were viewed to be correctly set at a default of 80 km/h, however, there are sections where a Special Speed Limit of 100 km/h would be more appropriate.

Local roads with a Default Speed Limit of 80 km/h were also seen to be correct in terms of the speed limit, however, the vast number of signs erected in 2004 as a result of metrification of speed limits and the creation of a class-based speed limit system, led to many situations where the displayed speed limit would be viewed as inappropriate i.e. 80 km/h on a narrow single lane Local tertiary road. This led to the introduction of the Rural Speed Limit sign, which signifies that the speed limit is 80 km/h but removes the number and thereby the 'visual target'. The need to 'do-something' was clear.

In total, 18 actions were identified.

1. Revise Speed Limit Signs
2. Update and Implement Driver Education, Training and Communication
3. Implement Appeals, Oversight and Co-Ordination
4. Update National Road Speed Limits

5. Update Regional and Local Road Speed Limits
6. Remove Inappropriate Signs
7. Strengthen Road Works Speed Limits
8. Update and Strengthen Guidelines and Circulars
9. Update Function to Set Speed Limits
10. Update Legislation
11. Update Traffic Regulations and Signs Manual
12. Implement Speed Limit Management Awareness and Training
13. Maintain Digital Records and Maps
14. Strengthen Engineering and Infrastructure Guidelines and Standards
15. Trial and Implement Quiet Lanes and Shared Space
16. Trial Intelligent Speed Adaption
17. Develop New Legal Evidence Mechanisms
18. Improve Detection and Enforcement

Action No. 8 is the relevant action in terms of this thesis, it contained the following sub-actions.

- Improve Clarity on Speed Limits for Road Types
- Address Speed Limits for Approaches to Towns and Schools
- Address the Use of Variable Speed Limits
- Address the Use of Driver Feedback Signs
- Require Training in Assessing Speed Limits
- That the Speed Assessment Framework Should Be Monitored and Strengthened Where Necessary
- That Other Existing Circulars on Speed Limits Be Updated or Withdrawn

The Department of Transport, Tourism and Sport initiated this research with a view to updating the Speed Assessment Framework (SAF) and supported this author's approach and application to Maynooth University. This submission proposes an alternative, simplified methodology to assess and set speed limits on rural single carriageway roads.

2.3 Design Parameters

2.3.1 Design Speed

The Permanent International Association of Road Congresses (PIARC) defines design speed as the speed selected when designing or improving a road to determine the various geometric design features of a carriageway that allows a car to travel safely at that speed under normal road surface and weather conditions. The required design speed depends on the function of the road and, if higher speeds are required, the standard of roadside protection measures must be appropriate. Design speeds for the current Default speed limits are as follows;

DESIGN SPEED (KM/H)	SPEED LIMIT (KM/H)
120	120
100	100
85	80
60	50

Table 2.3: Design speeds for current Default speed limits

A speed limit should not be higher than the design speed and the design speed should be consistent along a route, however, there are unfortunate consequences to this. When road sections are improved or realigned under minor improvement schemes (TII TA/85 Schemes), one of the constraints on Local Authorities is the land available to them to carry out the improvements. For the minor improvement scheme to be cost effective, the amount of land required to be purchased under a Compulsory Purchase Order (CPO) must be minimised.

This can be facilitated by 'relaxing' the standard or allowing a 'departure' from the standard to be applied to the design. The requirements normally relaxed are the horizontal or vertical parameters, sightlines or curve radii. This can result in a design speed of 85 km/h being applied to a design of an improvement scheme on a National road (primary or secondary).

When this improvement scheme is then carried out, the maximum speed limit that can be applied to that section of road is 80 km/h. The Local Authority must then produce a Special Speed Limit Bye-law setting the speed limit at 80 km/h (as 100 km/h is the Default Speed Limit for National roads) on a newly constructed or greatly improved section of National road that will tie in to a much inferior cross-section of National road that is apparently appropriate to carry the Default Speed Limit of 100 km/h. If there must be a change in design speed, it should be supplemented by a change in road design characteristics – simply reducing the speed limit will most likely be ineffective (N2 Monaghan-Corracrin for example).

2.3.2 Factors Affecting Speed

The most relevant factors affecting speed are listed below (Transport Infrastructure Ireland, Rural Road Link Design, DN-GEO-03031-11, 2017)

Alignment Constraint (Ac) measures the degree of constraint the road alignment imparts on the user. On single carriageway roads it is a function of visibility and the total angle the road turns - bendiness.

Layout Constraint (Lc) measures the constraint the cross-section, verge width, junctions and accesses impart on the road user.

Stopping Sight Distance (SSD) is measured from the eye-height of the driver between 1.05m and 2m to an object height between 0.26m (low object) and 2.0m (high object).

Full Overtaking Sight Distance (FOSD) is the distance that should be provided to allow overtaking vehicles to use the opposite lane on a single carriageway road and should be available between 1.05m and 2m above the centre of the road. FOSD is much greater than SSD and can normally only be provided in relatively flat and straight alignments.

Table 2.4 shows the required stopping sight distance (SSD) and full overtaking sight distance (FOSD) for different design speeds while Table 2.5 lists the geometric requirements for different design parameters for different design speeds (both from Transport Infrastructure Ireland, Rural Road Link Design, DN-GEO-03031-11, 2017).

DESIGN SPEED (KM/H)	STOPPING SIGHT DISTANCE (M)	FULL OVERTAKING SIGHT DISTANCE (M)
120	295	n/a
100	215	580
85	160	490
70	120	410
60	90	345
50	70	290

Table 2.4: Design speeds, SSD and FOSD

DESIGN SPEED (km/h)	120	100	85	70	60	50
Stopping Sight Distance m						
Desirable Minimum Stopping Sight Distance	295	215	160	120	90	70
One Step below Desirable Minimum	215	160	120	90	70	50
Two Steps below Desirable Minimum	160	120	90	70	50	50
Horizontal Curvature m						
Minimum R^+ without elimination of Adverse Camber and Transitions	2880	2040	1440	1020	720	510
Minimum $R^{+ \text{ with}}$ Superelevation of 2.5%	2040	1440	1020	720	510	360
Minimum R with Superelevation of 3.5%	1440	1020	720	510	360	255
Desirable Minimum R with Superelevation of 5%	1020	720	510	360	255	180
One Step below Desirable Min R with Superelevation of 7%	720	510	360	255	180	127
Two Steps below Desirable Min R with Superelevation of 7%	510	360	255	180	127	90
Three Steps below Desirable Min R with Superelevation of 7%			180	127	90	65
Four Steps below Desirable Min R with Superelevation of 7%			127	90	65	44
Vertical Curvature – Crest						
Desirable Minimum Crest K Value	182	100	55	30	17	10
One Step below Desirable Min Crest K Value	100	55	30	17	10	6.5
Two Steps below Desirable Min Crest K Value	55	30	17	10	6.5	6.5
Vertical Curvature – Sag						
Desirable Minimum Sag K Value	53	37	26	20	13	9
One Step below Desirable Min Sag K Value	37	26	20	13	9	6.5
Two Steps below Desirable Min Sag K Value	26	20	13	9	6.5	6.5
Overtaking Sight Distances						
Full Overtaking Sight Distance (FOSD) m	N/A	580	490	410	345	290
FOSD Overtaking Crest K Value	N/A	400	285	200	142	100

Table 2.5: Design speed parameters

Bendiness is the total angle the road turns through per kilometre length. Design speed does not depend on the radius of individual curves, but does depend on the total degrees turned through and should be calculated as the average value over the length. Figure 2.8 below shows a section of road from X to Y containing three bends. To calculate bendiness (B), the angles Ø1, Ø2, and Ø3 are added together and divided by the length of the section (X to Y).

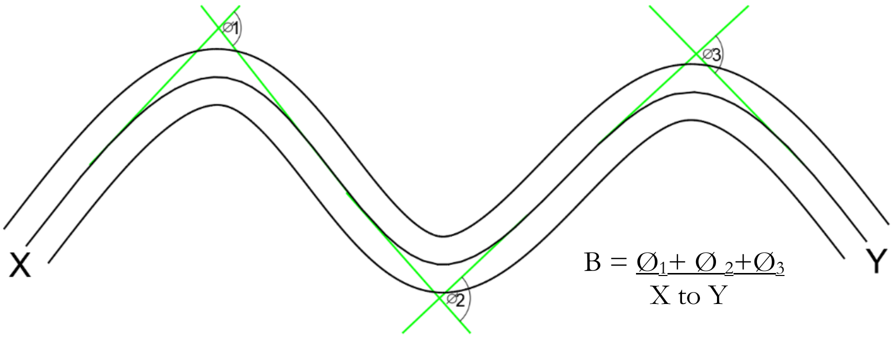


Figure 2.8: Calculation of bendiness

Sinuosity compares the bendiness of different sections. It is a ratio of the actual length between X and Y and the shortest path between X and Y.

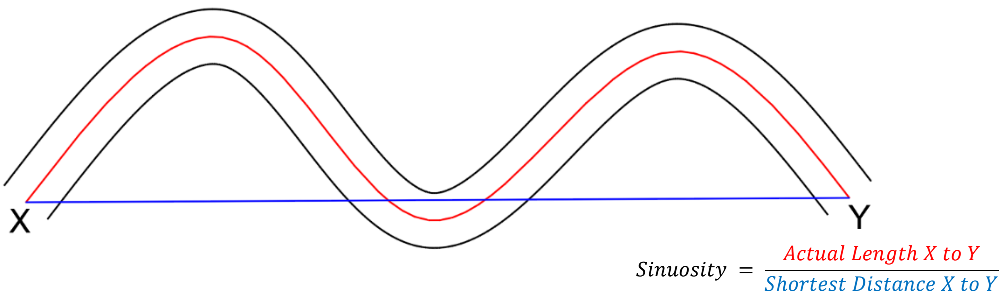


Figure 2.9: Calculation of sinuosity

A Sinuosity Index (SI) of 1 is perfectly straight. TII determined the Sinuosity Index of the National road network and produced three categories of Sinuosity Index.

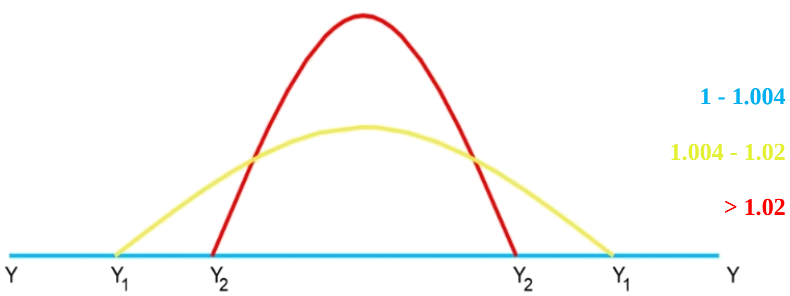


Figure 2.10: Sinuosity classification

Frequent issues that arise on rural single carriageway roads in Ireland include the following;

- Poor geometric characteristics for the observed operating speeds, including insufficient sight distances and narrow lanes, with or without hard shoulders.
- Transitions between two adjacent road segments that have different characteristics (sometimes caused by minor improvement schemes).
- The level of development along the roadside increases speed differentials and introduces additional traffic conflict.

Development is more of an issue on Regional and Local roads than it is on the National road network. Transport Infrastructure Ireland, through a policy decision, has sought to limit accesses onto the National road network in the high-speed zone, i.e. where the speed limit is greater than 60 km/h, by objecting to planning applications submitted to Local Authorities relating to National roads.

Overall, the design of the road should indicate the road function (traffic flow or access and recreational) and, along with its design speed, should inform the choice of the correct speed limit. It may be necessary to employ additional measures to ensure drivers drive at a safe speed. If this is necessary and carried out across the network in a consistent way, it could help drivers recognise the situation and the speed limit. This is similar to the concept of a self-explaining road. Self-explaining roads, if designed and constructed correctly, provide a roadway environment where the driver can interpret the safe operating speed correctly, minimise their mistakes and minimise the consequences of their mistakes. The driver should receive consistent information from the roadway, signage and the surrounding environment.

2.4 Summary

It can be seen in this chapter that the road network varies considerably and, consequently, so does the appropriateness of speed limits set on some sections of roads of varying classifications. It has also been shown that approximately 94% of the network is governed by the same speed limit and that when this is taken in context with the varying road cross-sections it is clear that a 'one size fits all' approach is not appropriate, reinforcing the need for an alternative means for assessing a speed limit.

While speed limits have been in existence for a long time, the timeline on page 16 shows that the current system of speed limits is in its infancy (since 2004). It was always likely that issues would emerge, and this was confirmed in the 2013 speed limit review. That review informed the need for a review of the 2010 Guidelines and, in so doing, led to this research being initiated. Many factors affect speed on our roads and in this chapter, factors that affect speed in terms of design parameters or features have been included for reference.

Chapter 3

Ireland's Road Safety Performance

Injuries and fatalities are an unfortunate consequence of vehicles using public roads. There are many reasons for this including speed, human behaviour, condition of vehicles, road conditions, etc. Statistics regarding fatalities and injuries have been collected by the state since 1959 to monitor trends and develop road safety policies nationally and regionally and to inform the progression and development of design standards and effective speed management policies. This chapter presents a selection of those statistics, particularly those collisions where excessive speed played a part.

3.1 Fatalities and Fatal Collisions

Since 1959 the number of people killed on Irish roads totals 23,982, an average of 413.48 per year, peaking in 1972 at 640 with a low of 161 in 2012. Table 3.1 and Figure 3.1 (RSA collision data 2006-2016; An Garda Síochána archived road collision statistics 1961-2007) show a general trend during this time of a reduction in fatalities.

Year	No.	Year	No.	Year	No.	Year	No.	Year	No.
1959	306	1971	576	1983	535	1995	437	2007	338
1960	302	1972	640	1984	465	1996	453	2008	279
1961	332	1973	592	1985	410	1997	472	2009	238
1962	339	1974	594	1986	387	1998	458	2010	212
1963	335	1975	586	1987	462	1999	413	2011	186
1964	341	1976	525	1988	463	2000	415	2012	161
1965	356	1977	583	1989	460	2001	411	2013	190
1966	382	1978	628	1990	478	2002	376	2014	197
1967	416	1979	614	1991	445	2003	335	2015	165
1968	447	1980	564	1992	415	2004	374	2016	188
1969	462	1981	572	1993	431	2005	396	**Total**	**23,982**
1970	540	1982	533	1994	404	2006	368	**Ave.**	**413.48**

Table 3.1: Fatalities on Irish roads 1959-2016

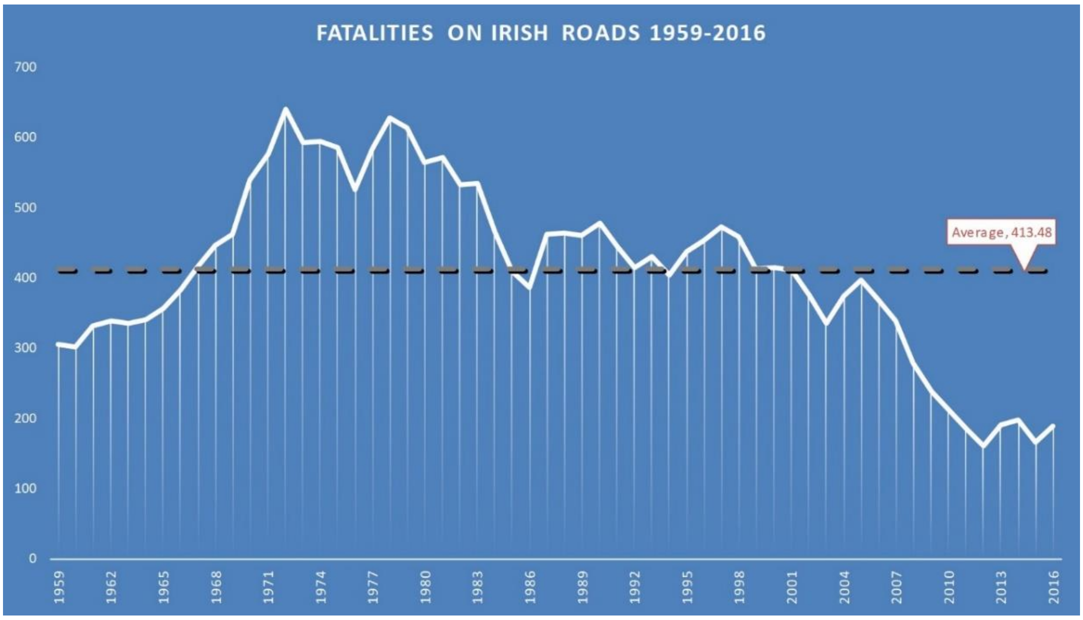


Figure 3.1: Fatalities on Irish Roads 1959 - 2016

Collision data supplied by the Road Safety Authority (RSA) has been used in this submission and covers the period from 2006 to 2012. The data was supplied in individual .csv files for each year and processed by the author using ArcGIS, a geographic information system (GIS) used for working with maps and geographic information, to produce Figure 3.2 (a heatmap of all collisions), Figure 3.3 (a summary of fatal collisions) and the figures contained in Appendix A (maps for individual years).

Is should also be noted that throughout this thesis the use of the word 'accident' is avoided in so far as is possible, it is contained in text in certain sections as represented in original publications or texts. The language around collisions has changed in the last 10 years to highlight the fact that collisions ('accidents') do not occur in a vacuum, there is always cause and effect. Words have meaning and to suggest something uncontrollable occurred by calling it an 'accident' can, potentially, be seen to minimise its severity and potentially miss the identification of possible improvement or mitigation measures. It should be noted, however, that by referring to something as a collision and contending it was not an 'accident' does not imply intent on the part of anyone.

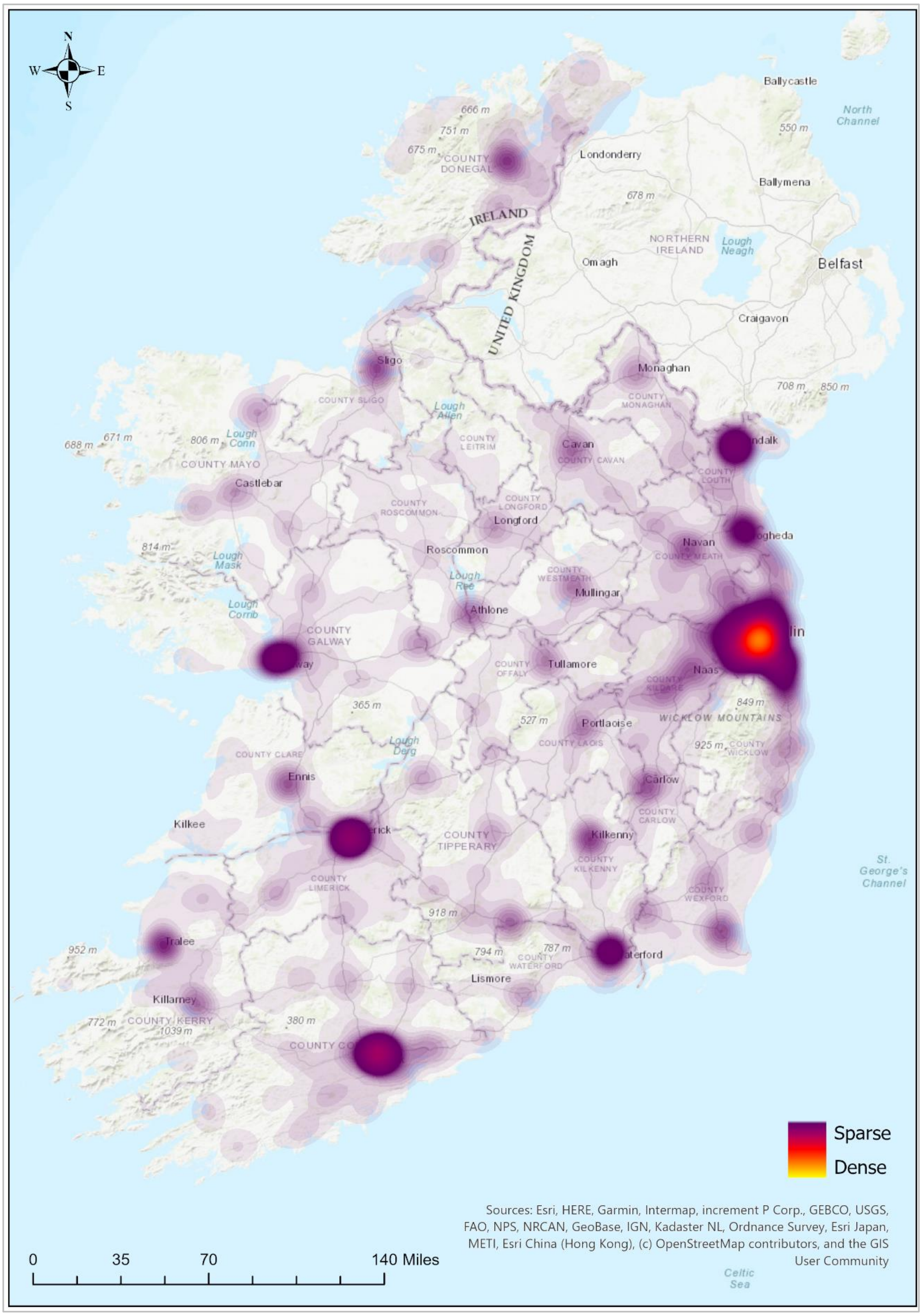


Figure 3.2: All collisions 2006-2012

Figure 3.3 (and figures in Appendix A) illustrate the spread of fatal collisions across the country between 2006 and 2012. They are summarised in Table 3.2.

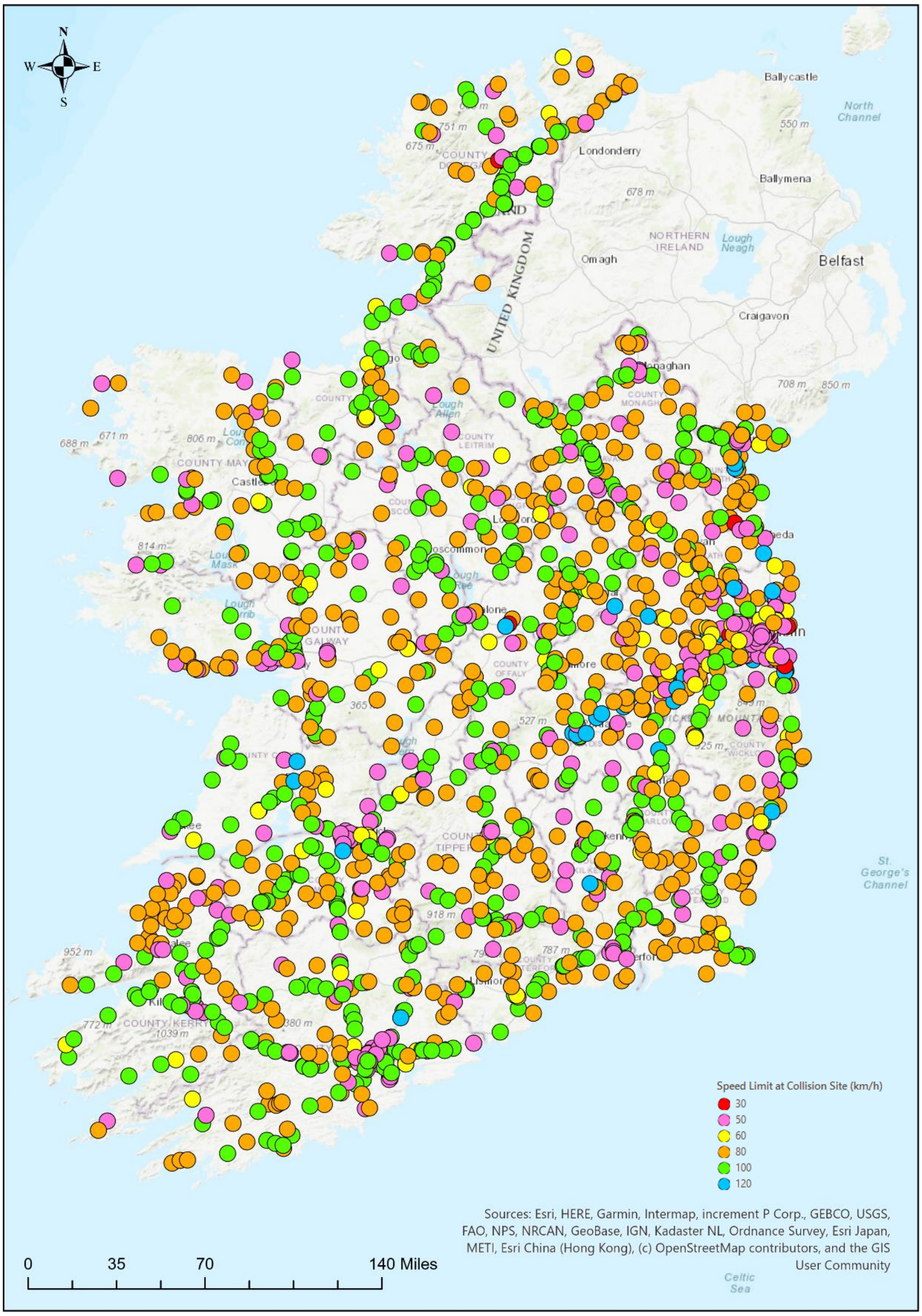


Figure 3.3: All fatal collisions 2006-2012

County	Fatal Collisions						
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Carlow	6	3	1	3	5	3	2
Cavan	7	10	8	9	6	5	10
Clare	9	11	7	6	4	2	2
Cork	29	28	24	19	16	26	20
Donegal	15	21	14	12	10	6	7
Dublin	32	33	21	30	19	11	11
Galway	14	22	21	19	5	12	18
Kerry	19	12	17	11	8	7	7
Kildare	19	11	12	9	10	14	1
Kilkenny	4	11	4	5	6	4	3
Laois	6	5	9	5	8	1	0
Leitrim	2	6	5	0	3	1	0
Limerick	15	14	15	19	15	14	5
Longford	6	4	3	2	2	2	4
Louth	13	15	7	5	7	5	7
Mayo	8	8	10	9	6	11	6
Meath	20	14	9	12	6	3	14
Monaghan	4	6	4	5	2	6	2
Offaly	9	5	6	4	4	4	4
Roscommon	5	6	2	4	9	4	3
Sligo	4	6	7	7	3	3	4
Tipperary NR	13	6	10	4	3	5	1
Tipperary SR	10	9	9	6	3	4	2
Waterford	7	6	6	3	4	7	3
Westmeath	16	13	3	4	7	5	4
Wexford	18	16	16	4	9	4	9
Wicklow	11	8	4	4	5	3	3

Table 3.2: Location of fatal collisions 2006-2012

Year	Fatal Collisions	Fatalities
2006	321	368
2007	309	338
2008	254	279
2009	220	238
2010	185	212
2011	172	186
2012	152	161

Tables 3.2 & 3.3 reveal that, over the period 2006-2012, the number of fatal collisions and resulting fatalities both decreased year on year.

Table 3.3: Fatal collisions and fatalities 2006-2012

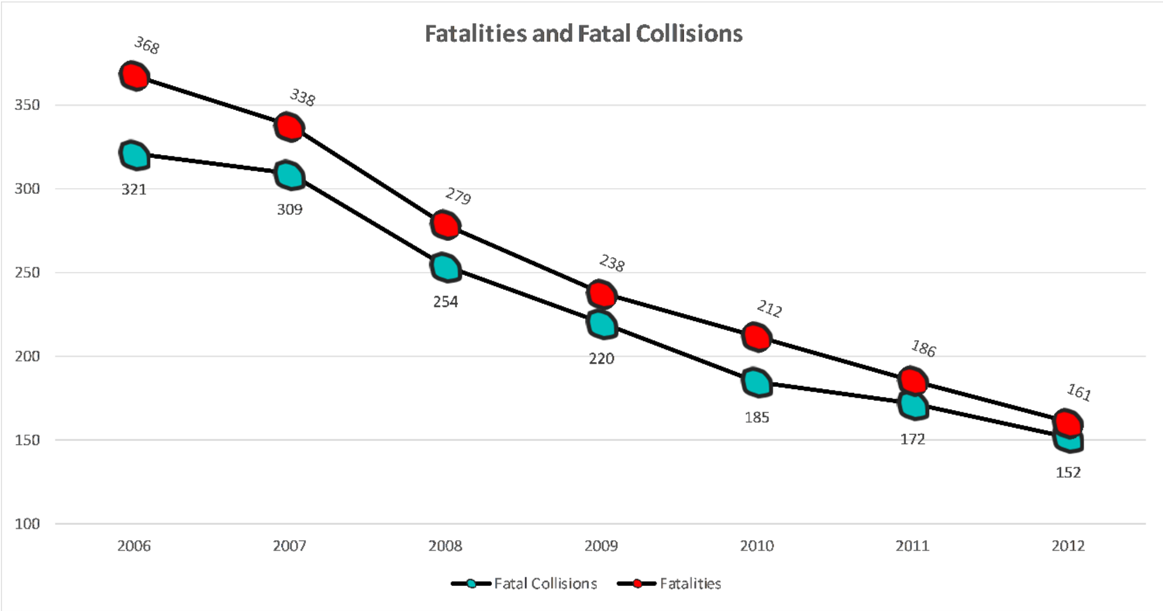


Figure 3.4: Fatal collisions and fatalities 2006-2012

On what type of road are these collisions occurring?

Year	Motorway		Nationals		Regional & Local		Total
2006	10	*3.12%*	134	*41.74%*	177	*55.14%*	321
2007	9	*2.91%*	126	*40.78%*	174	*56.31%*	309
2008	2	*0.79%*	91	*35.83%*	161	*63.69%*	254
2009	3	*1.36%*	75	*34.09%*	142	*64.55%*	220
2010	9	*4.86%*	70	*37.84%*	106	*57.30%*	185
2011	6	*3.49%*	55	*31.98%*	111	*64.53%*	172
2012	5	*3.29%*	46	*30.26%*	101	*66.45%*	152
Total	44	*2.73%*	597	*37.01%*	972	*60.26%*	1613

Table 3.4: Fatal collisions by road type 2006-2012

Year on year, from 2006-2012, the majority of fatal collisions occurred on the Regional and Local road network. These roads, shown in Table 2.1, account for approximately 94.5% of the road network. Motorways, statistically the safest roads, accounting for 1% of the road network, experienced the least amount of fatal collisions.

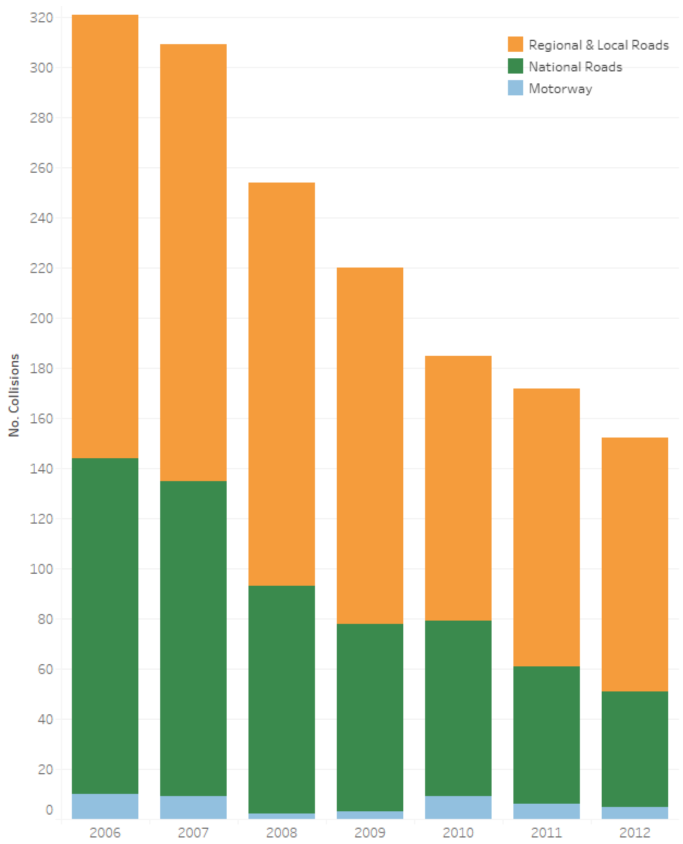


Figure 3.5: Fatal collisions by road type 2006-2012

The preceding figures (Figures 3.1-3.5) have been included to outline the number of collisions and fatalities that occur on Irish roads. They illustrate that improvements have been realised over the years but that there is a long way to go to achieve 'Vision Zero' – a European Commission initiative with the goal of achieving zero deaths on European roads by 2050 (see https://ec.europa.eu/transport/road_safety/what-we-do_en for further details). Fatal collisions, and indeed collisions as a whole, do not discriminate, the tables and figures show that every county and road type has experienced a fatal collision during the period 2006 – 2012. On three occasions only during that period were there no fatal collisions in a county – Leitrim in 2009 and Leitrim and Laois in 2012 (Table 3.2). The figures and charts in this section serve as a motivation for this thesis in that they outline the scale of the problem. Section 3.3 will show that excessive speed plays a significant role in fatal collisions. If this thesis can lead to the development of a tool that can help set speed limits correctly then it will have gone part of the way in addressing the overall issue.

3.2 Collisions Excluding Fatal Collisions

Data exists from 1968 to 2007 of the number of people injured in collisions on Irish roads). This data counts multiple injury collisions and is not the count of actual collisions. The data shows a peak number of injuries on Irish roads in 1996 (13,319), with a low in 1975 of 7,198. From 1995 to 2000, each year recorded at least 12,000 injuries, approximately 32 injuries per day, or 1.4 injuries per hour (An Garda Síochána, archived road collision statistics 1961 to 2007).

Year	Injuries	Year	Injuries	Year	Injuries	Year	Injuries
1968	9,716	1980	8,509	1992	10,188	2004	7,867
1969	9,566	1981	8,283	1993	9,831	2005	9,318
1970	9,269	1982	8,006	1994	10,229	2006	8,575
1971	9,629	1983	7,946	1995	12,673	2007	7,806
1972	8,955	1984	8,210	1996	**13,319**	**Total**	**367,273**
1973	8,762	1985	7,818	1997	13,115	**Peak**	**13,319**
1974	8,288	1986	8,329	1998	12,773	**Low**	**7,198**
1975	**7,198**	1987	8,409	1999	12,340		
1976	7,798	1988	8,437	2000	12,043		
1977	8,515	1989	8,803	2001	10,222		
1978	9,313	1990	9,429	2002	9,206		
1979	8,250	1991	9,874	2003	8,262		

Table 3.5: Injuries 1968-2007

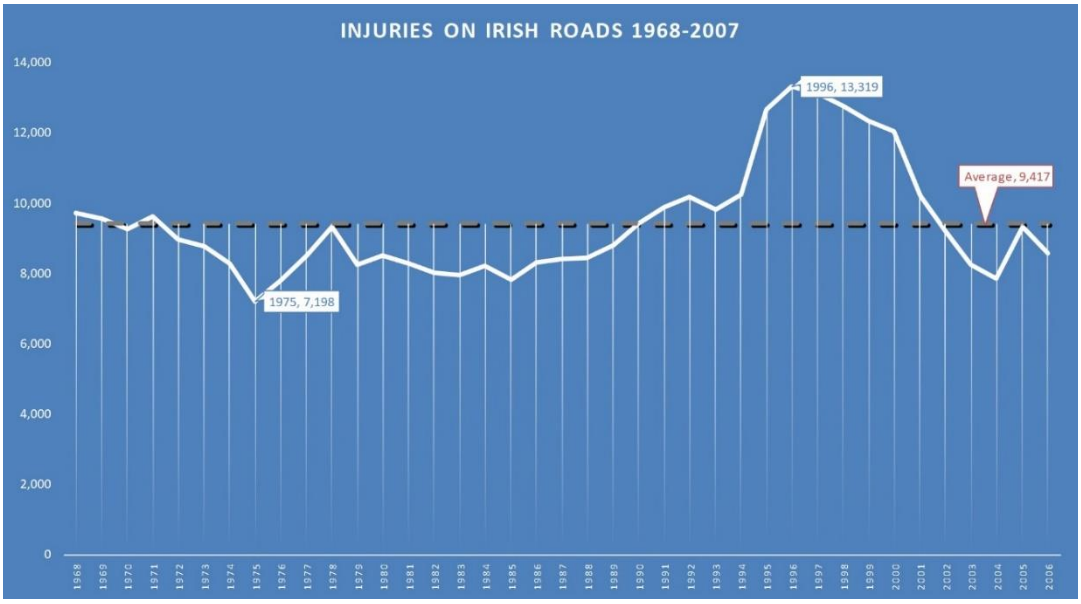


Figure 3.6: Injuries on Irish roads 1968-2007

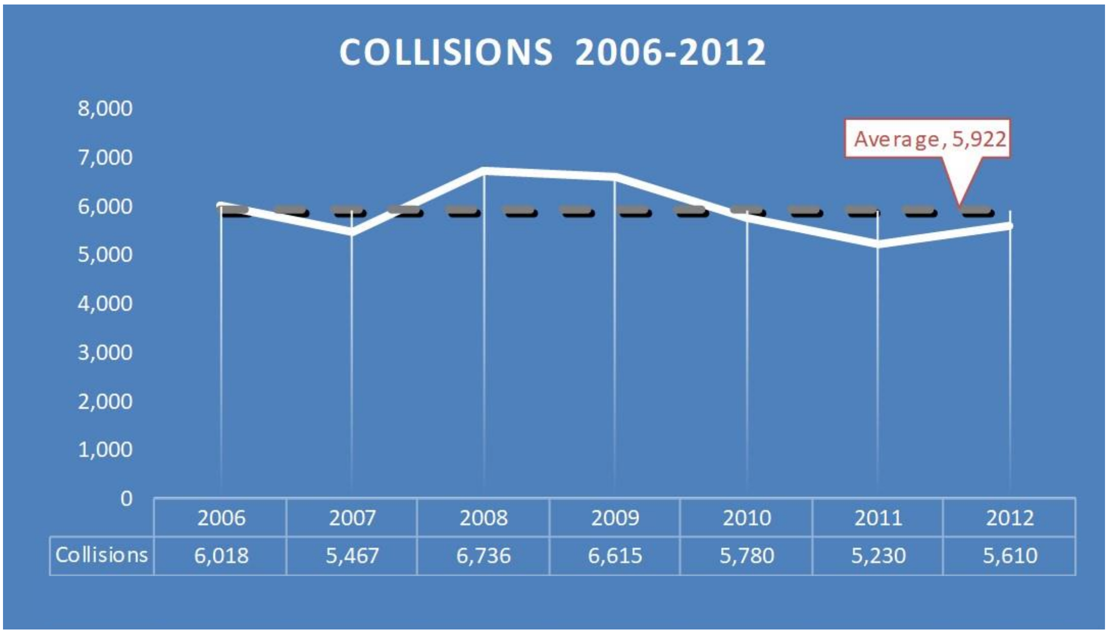


Figure 3.7: Collisions 2006 – 2012

3.3 Fatal Collisions – Excessive Speed as a Contributory Factor

According to the Organisation for Economic Co-operation and Development (OECD), the biggest safety problem in many countries, including Ireland, often contributing to as much as one third of fatal collisions and an aggravating factor in all collisions is Excessive Speed, which is driving above the speed limit, and Inappropriate Speed, which is driving too fast for the prevailing conditions, but within the speed limit (The OECD – Speed Management, 2006)

Excessive speed is a widespread social problem that affects the entire road network. At any point in time, it is estimated that 50% of drivers are driving above the speed limit. The majority are speeding less than 20 km/h above the speed limit, however, there is still a proportion that are speeding at greater amounts than that.

A speed limit is not a target, it is the maximum speed at which a vehicle may legally travel on a section of road between speed limit signs. It was also found that young drivers are the group most involved in speeding behaviour (RSA, 2016).

Many countries worldwide have a known detection/enforcement tolerance that is applied on different roads. This may also exist in Ireland, but it is not known in an official capacity. It is widely suspected that this it is set at 10% + 2km/h above the speed limit. It would appear sensible that some enforcement tolerance is applied due to the possible discrepancy in calibration between the detection device and the speedometer of the vehicle, but it may have the effect of 'giving' an increased 'target' to motorists.

Road Safety Authority - Fatal Collisions from 2008 – 2012

For the remainder of this chapter only fatal collision data from 2008-2012 is considered. The road collision database in Ireland is created from the Garda Pulse Database which is partly populated using a form called PC16 (formerly known as C(T)68). Pulse data is then forwarded to the Road Safety Authority by An Garda Síochána (RSA, 2016). The information provided in the PC16 form is based on preliminary information collected at the scene of a collision and does not constitute the findings of the final investigation. The RSA regularly issues reports using the data contained in this database, which is the best available representation of fatal and injury collisions. In total, there were 983 fatal collisions with 1077 people losing their lives. Tables and figures in the remainder of this section have been created using data contained in RSA publications (Fatal Collisions from 2008-2012 and Collision Fact Books 2006-2012).

Of these 983 fatal collisions, the Road Safety Authority were granted access to 867 fully completed Garda Investigation Files. 116 were not released for analysis due to continuing and ongoing investigation by An Garda Síochána. A fully completed Garda Investigation File consists of 2 reports;

- An Garda Síochána Investigation Report
- Forensic Collision Investigation Report.

Their analysis (RSA – Fatal Collisions 2008-2012, 2016, used to create Figures 3.8-3.15) determined that, of these 867 collisions, 274 (32%) were fatal collisions where excessive speed was a main contributory factor. This is in line with the findings of the Organisation for Economic Co-operation and Development (OECD) report of 2006 that states speed is a major contributory factor in a third of all fatal collisions. In 52 (19%) of those 274 fatal collisions, excessive speed was the sole contributory factor in the collision. A total of 322 people died in these excessive speed related collisions. These 274 collisions were then further analysed to gain a better understanding of the use and effect of excessive speed on our roads.

Of these 274 fatal collisions where excessive speed was deemed to be a main contributory factor, 153 (55.8%) were single vehicle collisions and in 89 of these (58%), the driver was aged between 16-24 years. Furthermore, 91% of the 274 drivers were male and 50% of the 274 drivers were aged between 16-24 years, again concurring with the OECD findings, and in 76% of cases were driving a private car. Finally, 43% of the collisions happened between the hours of 9pm and 4am, with 46% of the collisions taking place between 10pm Friday night and the early hours of Monday morning (see Figures 3.8-3.11).

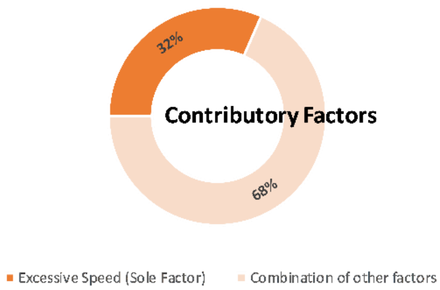


Figure 3.8: Contributory factors

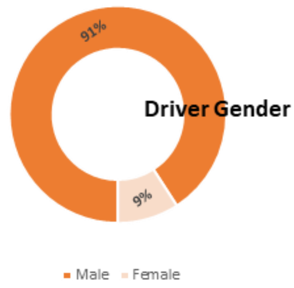


Figure 3.9: Driver Gender

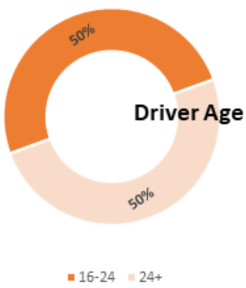


Figure 3.10: Driver Age

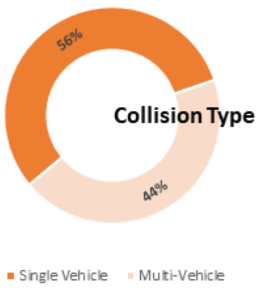


Figure 3.11: Collision Type

Of all collisions, 88% occurred in rural areas (outside the 50 km/h speed limit of a built-up area/urban area). These collisions occurred on Regional roads in 52% of cases, on National roads in 33% of cases, Local roads in 12% of cases and 3% on Motorways, see Figure 3.12.

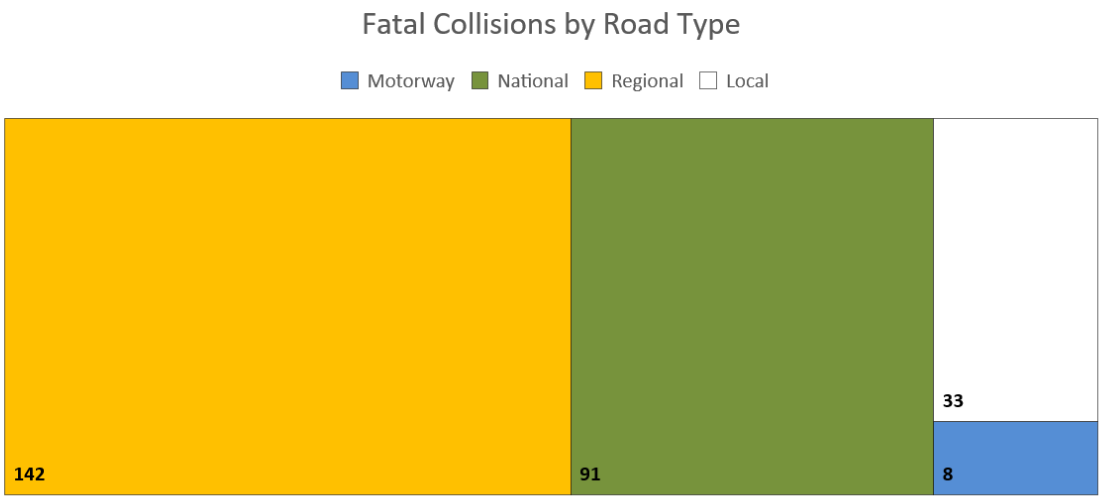


Figure 3.12: Fatal collisions 2008-2012 by road type

The speed limit at the collision locations was as follows (shown in Figure 3.13). 149 fatal collisions occurred in an 80 km/h speed limit zone, 80 occurred in a 100 km/h zone, with the remainder occurring in 120 km/h, 60 km/h, 50 km/h and 30 km/h zones.

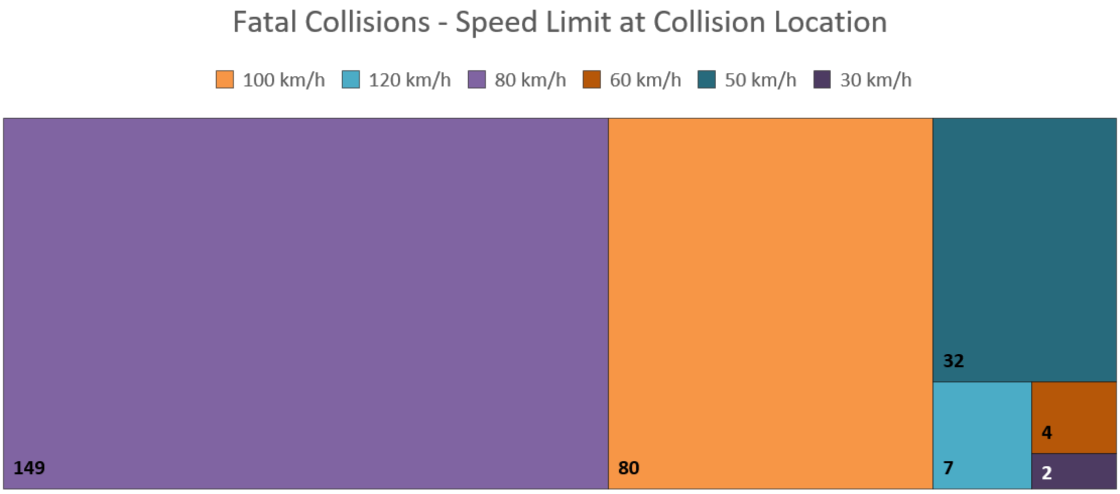


Figure 3.13: Fatal collisions 2008-2012 speed limit at location

The weather in 86% of the collisions was recorded in the investigation reports and C(T)68 forms as being dry.

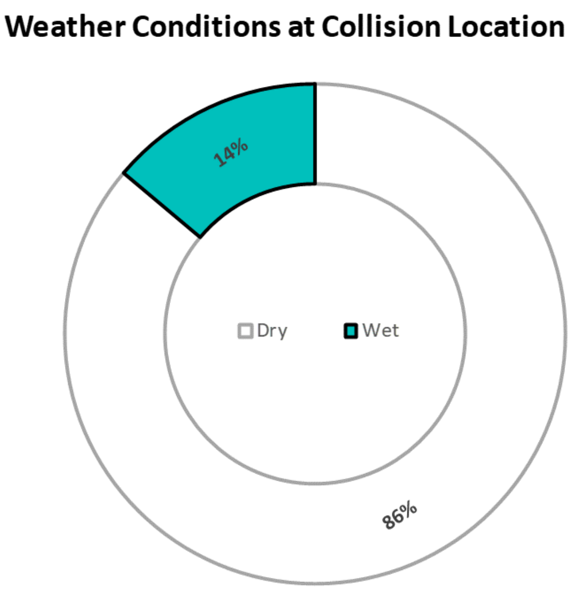


Figure 3.14: Fatal collisions 2008-2012 weather conditions at location

The condition of the vehicles involved also plays a part and in 33% of collisions, the car being driven was between 10-14 years old, 11% were deemed defective to unroadworthy, with 4% deemed dangerously defective. In this period, 2008-2012, a fatal collision occurred in every county in the State, broken down as follows.

County	Total Collisions	County	Total Collisions
Carlow	6	Longford	2
Cavan	20	Louth	5
Clare	2	Mayo	16
Cork	22	Meath	11
Donegal	23	Monaghan	6
Dublin	18	Offaly	5
Galway	20	Roscommon	2
Kerry	14	Sligo	5
Kildare	15	Tipperary	17
Kilkenny	4	Waterford	5
Laois	10	Westmeath	7
Leitrim	4	Wexford	22
Limerick	9	Wicklow	4
		Grand Total	**274**

Table 3.6: Fatal collisions 2008-2012 by county

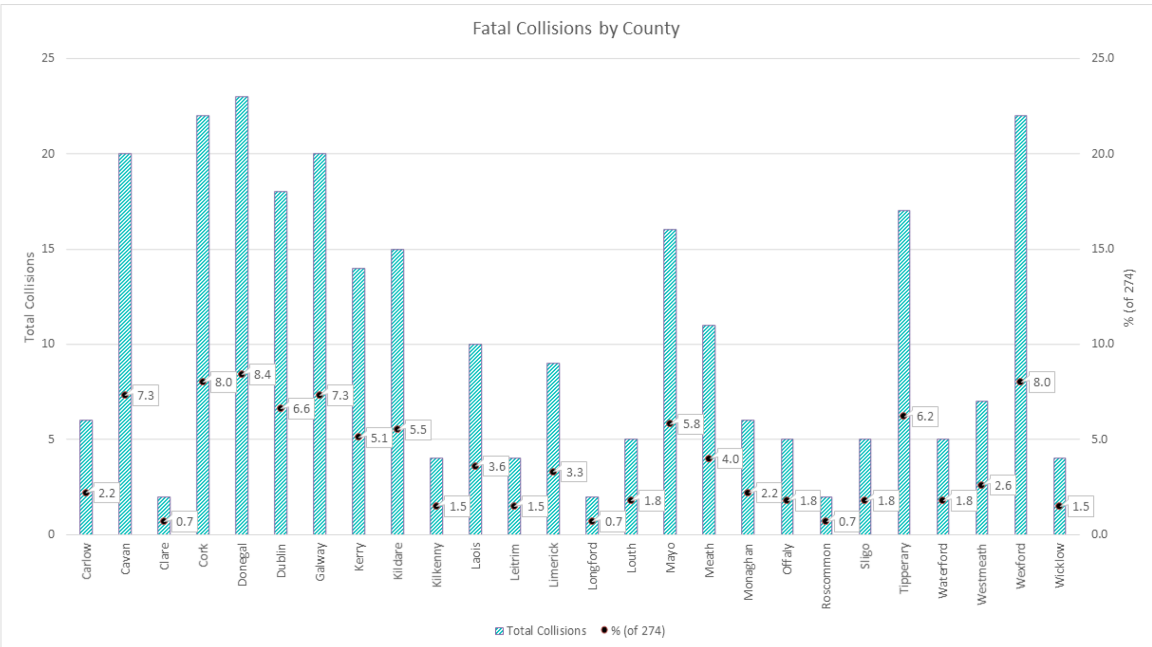


Figure 3.15: Fatal collisions 2008-2012 by county

Other statistics:

- In 84% of excessive speed related collisions, the purpose of the journey was social related and occurred between 10pm and 4am.
- 32% had no insurance.
- 32% had no licence.
- 17% held learner permits.
- 7% were driving while disqualified.
- 5 drivers with a full licence had previous penalty points for speeding.
- 4 drivers, driving while disqualified, had a known history of disqualification.
- Driving forward was the recorded manoeuvre in 82% of the collisions, with loss of control of the vehicle being recorded as the main action in 70% of collisions.

The statistics presented in this chapter highlight an overwhelming societal problem when it comes to our relationship with speed on our roads. Humans normally underestimate risk, particularly the risk to others, and, when this occurs with drivers, it greatly reduces the overall safety of the road network. Young males aged between 16 and 24 years, driving old vehicles in rural areas late at night between 10pm on a Friday and the early hours of Monday morning account for a large amount of fatal collisions in the period from 2008 to 2012. While this thesis deals with predominantly engineering and road safety aspects, the author feels it is necessary to highlight the foregoing and reiterate that the relevant agencies must continue to educate, communicate, train and attempt to put an end to the culture that a speed limit is a target and road users of all ages must be reminded that they have a duty of care to other road users, their passengers and themselves and that there are consequences to irresponsible behaviour on our roads, at any time of the day or night.

3.4 Summary

While some of the tables and figures in this chapter show the many different factors or influencers that can combine or contribute to a road traffic collision (reiterated below), they also show that almost one third of all fatal collisions between 2008 and 2012 were caused solely by excessive speed. As already mentioned, there is a societal problem regarding our attitude towards speed, this chapter shows that while speed does not discriminate in collisions, 55% of these collisions were single vehicle loss of control collisions, outlining a driver profile that is most at risk (young males 18-24 years of age). A cultural change is needed, and the relevant agencies must continue to educate, communicate, train and enforce. For speed limits to have any credibility, a credible speed limit system must be in place to assist in achieving road user buy-in. A credible speed limit system is one that the road user accepts as being appropriate, is easily understood, delivers consistent speed limits and is respected.

Chapter 4

Comparing Ireland with Europe

The previous chapter showed that, generally, Ireland's road safety record, or performance, is improving. It also showed that there are societal issues that must be addressed if its road safety record is to improve further; for example, it can be clearly seen that young males have a relaxed or complacent attitude towards speeding, they do not associate consequences with their actions when taking to the roads late at night on a weekend. Lack of respect for authority may be part of the reason for this but more likely it is down to the fact that the Gardaí cannot carry out enforcement measures everywhere, at all times, especially late at night on a weekend in rural areas. This fosters an attitude among younger drivers that as long as they 'cannot' be caught by the Gardaí then their behaviour on the roads is acceptable. No consequences, in so far as being caught, equals no deterrent. Having a crash is not something that will happen to them, in their opinion. In this chapter, Ireland's road safety performance is compared to European statistics and Ireland's speed limits are also compared with those of other European countries.

4.1 Road Safety Performance

Collision data and statistics available from the European Commission have been used to create the tables and figures in this section. They demonstrate that Ireland, since 1991, has made significant progress in improving its road safety record overall and also when compared to other European Union countries and against the European Union average (European Commission. Statistics-accidents data. https://ec.europa.eu/transport/road_safety/specialist/statistics_en (accessed 18th May 2016)).

Figure 4.1 below shows the improvement in fatality figures on Irish roads between 1991-2015 per 1 million inhabitants. It shows an overall decrease/improvement, however, there were occasions, in 1993, 1995-1997, 2003-2005 and 2013-2014, when there was an increase.

Year	Fatalities per 1m inhabitants	Year	Fatalities per 1m inhabitants	Year	Fatalities per 1m inhabitants
1991	126	2000	111	2009	53
1992	117	2001	107	2010	47
1993	121	2002	96	2011	41
1994	113	2003	85	2012	35
1995	121	2004	94	2013	41
1996	125	2005	97	2014	42
1997	129	2006	87	2015	36
1998	124	2007	78		
1999	111	2008	63		

Table 4.1: Ireland fatalities per 1m inhabitants 1991-2015

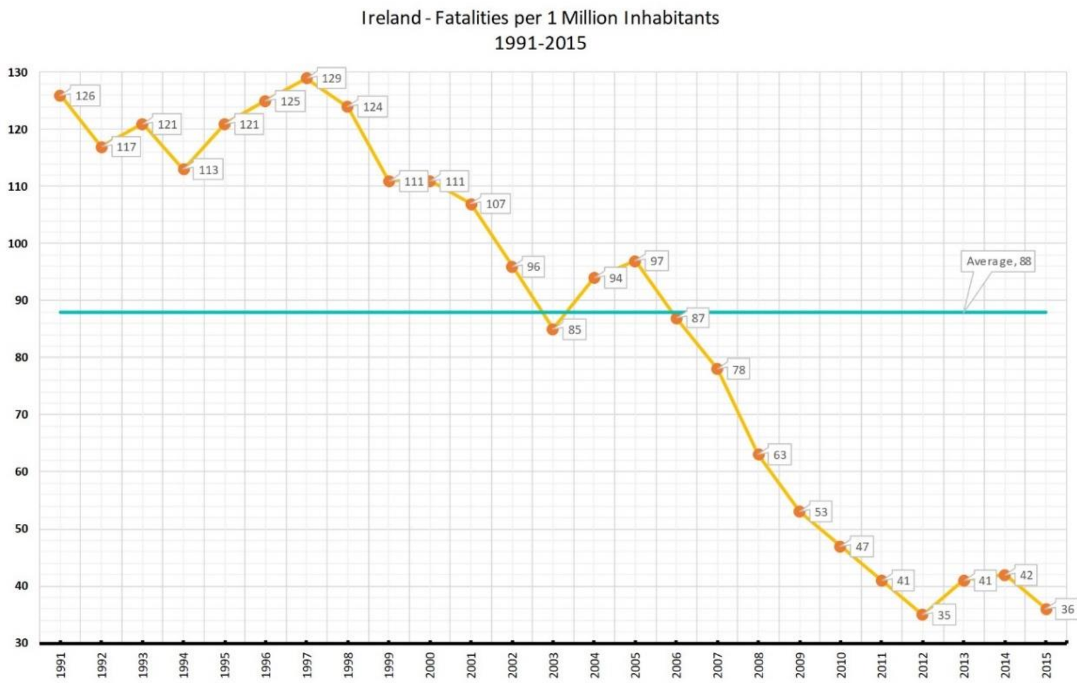


Figure 4.1: Ireland fatalities per 1m inhabitants 1991-2015

Interestingly, the longest period of improvement was between 2005-2012, which coincides with two significant developments;

1. The metrification of speed limits in 2005, which abolished the national speed limit.
2. The substantial completion of the major inter-urban motorway building programme – this removed significant amounts of traffic from national single carriageway roads and put them on what are, statistically, the safest roads - motorways.

There are undoubtedly many other factors to explain this decrease, for example, the economic downturn in 2008 had the effect of major job losses across the country, which resulted in less car journeys and, potentially, reduced vehicle ownership figures. High levels of emigration meant less people lived in Ireland to drive on Irish roads. Nevertheless, great improvements have been made over the years with regard to reducing the number of fatalities on Irish roads.

Figures 4.2 & 4.3 show the reduction in fatalities for each of the 28 EU member states between 2010 and 2015. The average across the EU was a 17% reduction in fatalities and Ireland was one of only ten countries to exceed that with a 22% reduction in fatalities while the UK achieved a reduction of 5%. This shows that Ireland is making great strides in its road safety performance but can still do better.

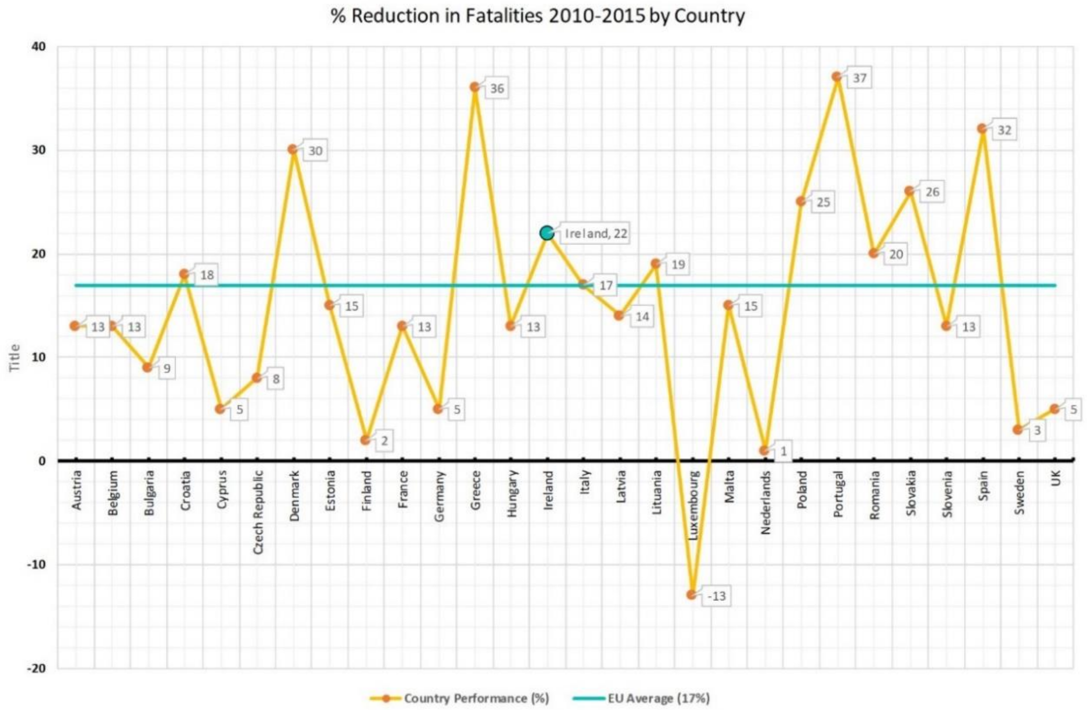


Figure 4.2: Reduction (%) in fatalities by country between 2010 and 2015

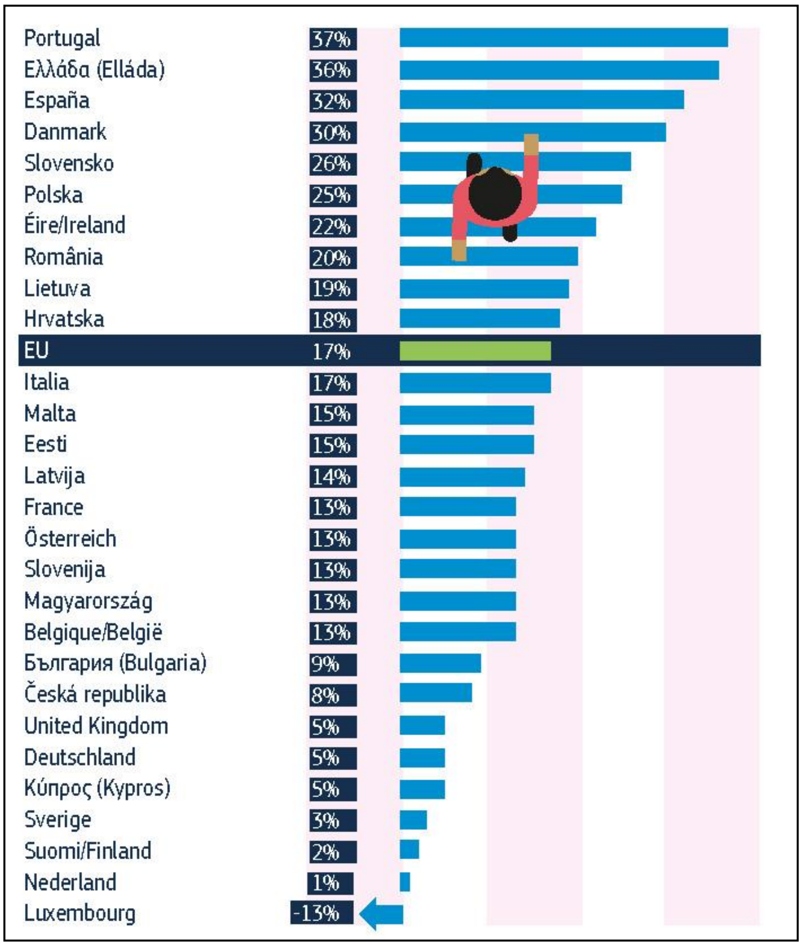


Figure 4.3: Reduction in fatalities by country between 2010 and 2015

4.2 Speed Limits

The continent of Europe is divided into 50 countries. Typically, their speed limits are governed by state and regional legislation – the national government decides on the general or national speed limits for different types of roads and any exceptions. The road authority then sets specific speed limits on roads in their jurisdiction, providing it is acceptable under the National speed limit system.

A common approach is for the road authority to determine the 85th percentile speed (see page 52) along the road and set the speed limit as close as possible to that, however, across these 50 countries, there exists only 4 major speed limits/values (upper values) across the major road network. Obviously, variations (Special Speed Limits) are set on different types of roads but, for the purpose of this work, the speed limits referred to are those set on major rural single carriageways (Wikipedia. Speed Limits by Country and associated references contained within. https://en.wikipedia.org/wiki/Speed_limits_by_country (accessed 18th May 2016)).

Figures 4.4 and 4.5 show the speed limits on rural single carriageways across Europe. Note that among the 50 European countries the most common speed limit in use is 90 km/h, which was opted for by 31 nations. This particular speed limit does not exist in Irish legislation and is therefore not used, either by default or by way of a Special Speed Limit. Ireland, like 7 other European countries, has set its rural single carriageway speed limit at 100 km/h. Nine countries have chosen 80 km/h and 2 (Belgium and San Marino) have chosen 70 km/h, which also does not exist in Irish legislation.

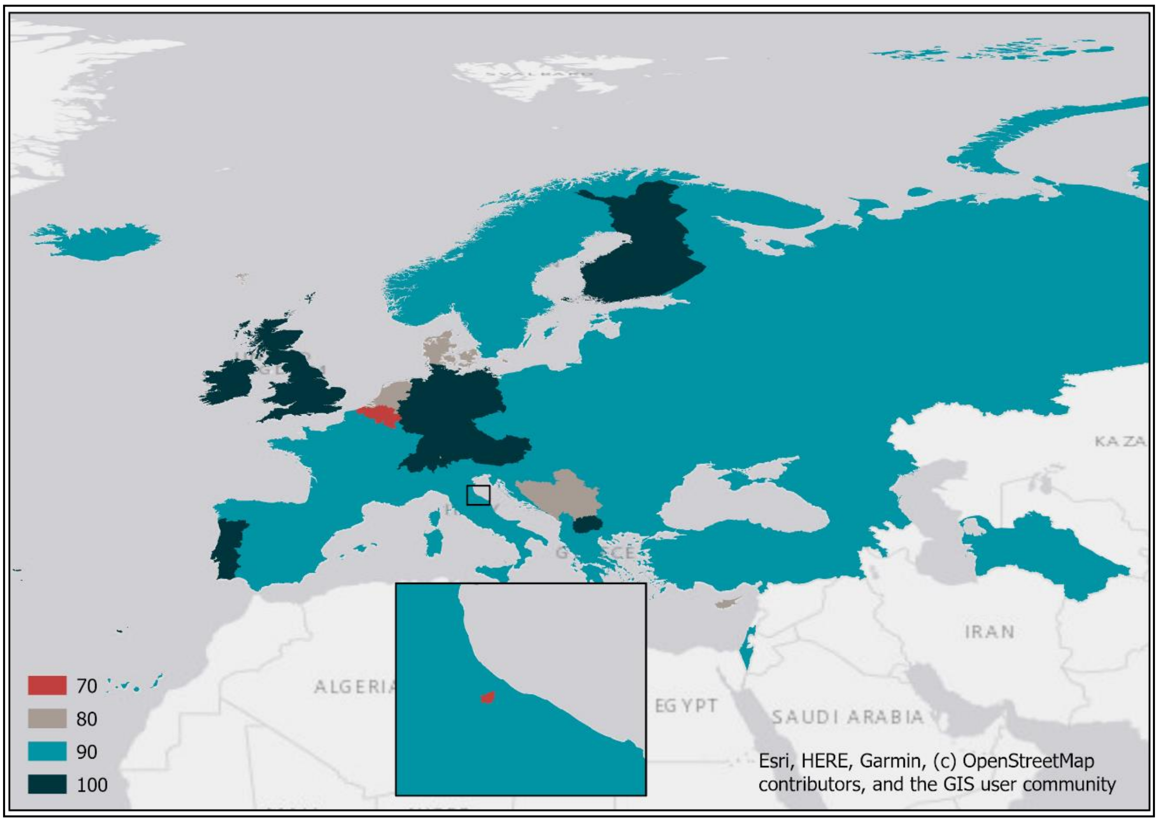


Figure 4.4: Speed Limits on rural single carriageways across Europe

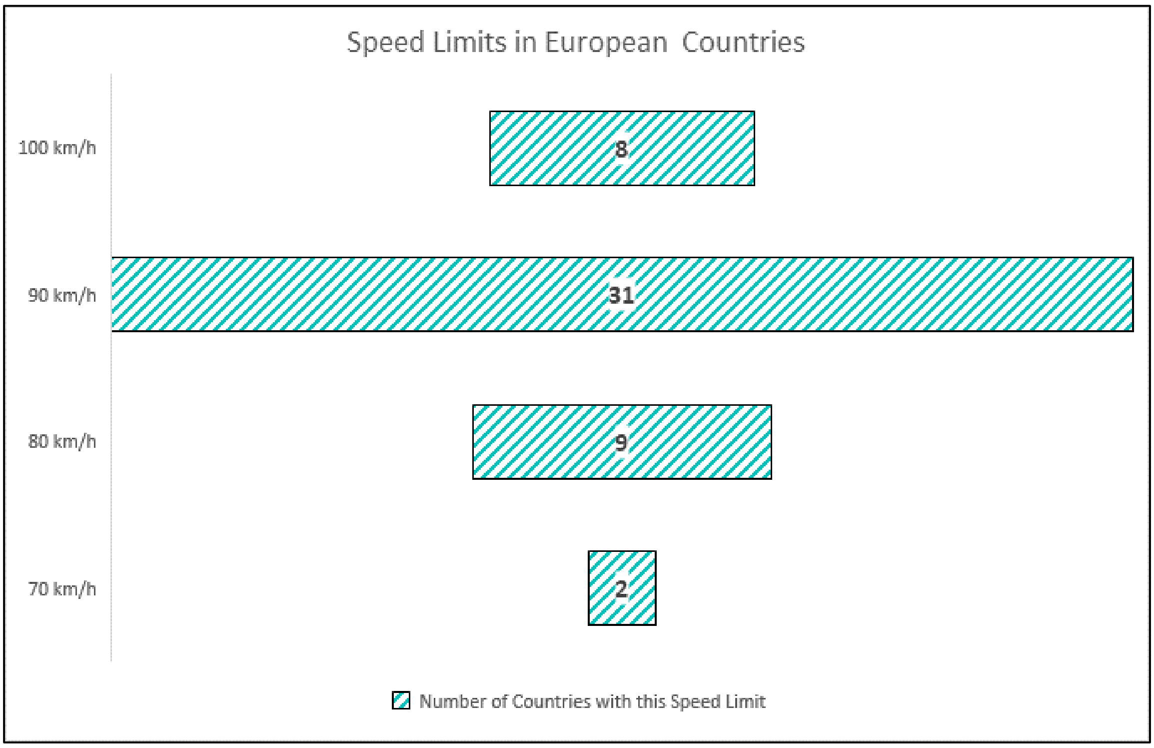


Figure 4.5: Speed Limits on rural single carriageways across Europe

Finland and France have made provision in legislation for the reduction in their speed limits during winter and during specific weather events respectively. It is possible to employ this strategy in Ireland using Variable Speed Limits, whereby the speed limit could be reduced during certain weather events, however, this would only be feasible on the motorway network, where overhead gantries have been installed allowing electronic signage to be erected that would advise motorists of the reduced limit.

Legislation does not exist in Ireland that would set the speed limit at different values at specific times of the year. A possible way of achieving this in Ireland would be for Local Authorities to produce a Special Speed Limit Bye-law setting the speed limit by means of a Periodic Speed Limit. Periodic Speed Limits are limits that are only in effect at specified times and are accompanied by electronic speed limit signage that is illuminated only when the speed limit is in force, for example from 8:45-9:15 on school mornings (the Guidelines, p62), however, this approach would not be ideal for prolonged periods of time.

Interestingly, Sweden has set a speed limit of 80 km/h on rural single carriageway roads that do not have separation measures, i.e. median type barriers. They based this partially on advice they received from Volvo, who stated that their vehicles can withstand a head-on collision with both vehicles travelling at 80 km/h without their occupants receiving serious injuries (Anders Lie, Swedish Transport Administration). In Sweden, the concept of safe speed was adopted as a basis for selecting appropriate speed limits. The combined system of the driver, vehicle and road should operate and interact in a way that if there is an impact, forces exerted on the vehicle or occupants would not lead to a fatality. Therefore, if pedestrians are present, the speed limit should not be greater than 30 km/h.

Figure 4.6 (2015 Guidelines) shows that the probability of a pedestrian being killed if struck at 30 km/h is in the region of 10%. This increases to 35% at 40 km/h and to 85% at 50 km/h.

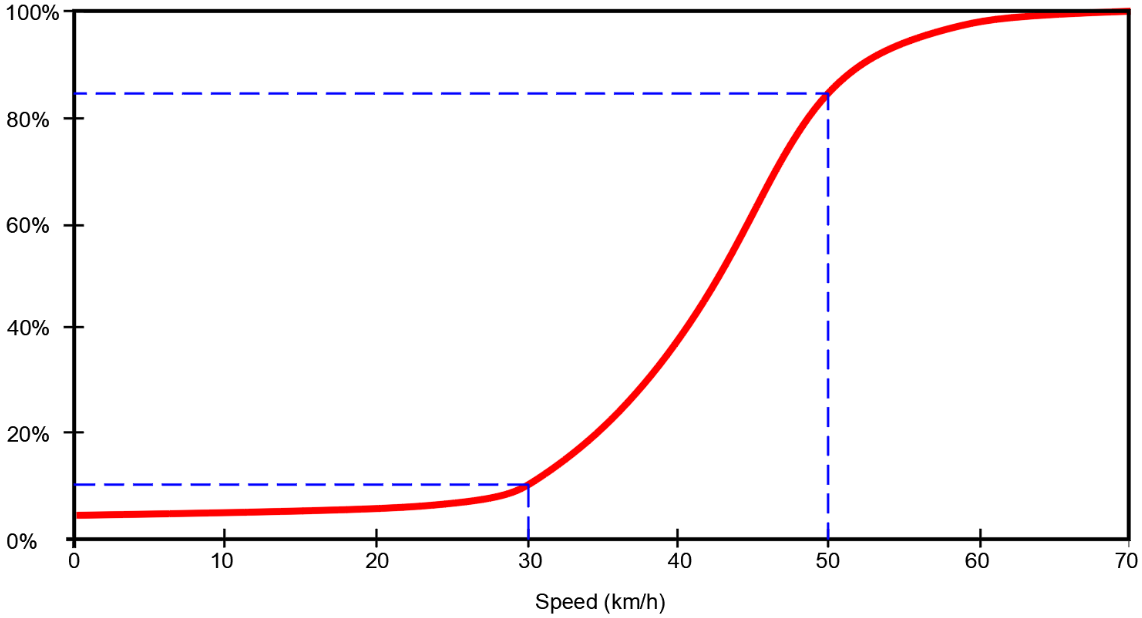


Figure 4.6: Probability of fatal injury for a pedestrian colliding with a vehicle

Where vehicle to vehicle impacts occur, these impacts should be at speeds below the impact speeds at which cars can be shown, through the European New Car Assessment Programme, to safeguard occupant life. Ratings are being developed through the European Road Assessment Programme showing how well the road is designed to ensure forces involved in impacts with road infrastructure also keep within the same thresholds. These ratings are currently being used in Sweden to indicate appropriate speed limits for roads with different ratings.

Country	Rural Single Carriageways	Notes
Albania	90	
Armenia	90	
Andorra	90	
Austria	100	
Azerbaijan	90	
Belarus	90	
Belgium	70	
Bosnia and Herzegovina	80	
Bulgaria	90	
Croatia	90	
Cyprus	80	
Czech Republic	90	
Denmark	80	
Estonia	90	
Faroe Islands	80	
Finland	100	80 in winter
France	90	80 in rain
Georgia	90	
Germany	100	
Greece	90	
Hungary	90	
Iceland	90	
Ireland	100	classification dependent
Israel	90	
Italy	90	
Latvia	90	
Liechtenstein	80	
Lithuania	90	
Luxembourg	90	
Macedonia	100	
Malta	80	
Moldova	90	
Montenegro	80	
Netherlands	80	100 on single carriageway expressways
Norway	90	
Poland	90	
Portugal	100	
Romania	90	100 on tern network roads
Russia	90	
San Marino	70	
Serbia	80	
Slovakia	90	
Slovenia	90	
Spain	90	100 in specific conditions
Sweden	90	
Switzerland	100	
Turkey	90	
Turkmenistan	90	
Ukraine	90	
United Kingdom	100	

Figure 4.7: European speed limits

Ireland is in a minority of countries that have an upper single carriageway speed limit of 100 km/h, however, this is set on only 4.5% of its network. Most of the network, 94.5%, has a Default speed limit of 80 km/h. Ireland is in a minority grouping there also, 62% of European countries have an upper speed limit on single carriageways of 90 km/h. A question that emerges is should Ireland allow, through legislation, for the use of 90 km/h as a speed limit on its roads? While the goal in developing a robust assessment method would be a confident choice of speed limit of either 80 km/h or 100 km/h, is this specific choice of two speed limits, 20 km/h apart, perhaps something that would warrant further analysis and/or assessment through a trial of alternatives? The effect of changing the speed limit to 90 km/h can be seen in Chapter 7 on the N2. It provides a 'happy medium' between 80 km/h and 100 km/h, however, as identified in the 2013 Speed Limit Review, the Irish system of speed limits is too flexible with many speed limit values to 'choose' from. Adding 90 km/h may exacerbate the issue. Robust guidance, however, could help to alleviate the impact of introducing additional speed limit values.

4.3 Summary

This chapter illustrated Ireland's general improvement in its road safety performance, in terms of its own year on year figures and compared to European averages. Ireland has a wide range of speed limits but is in the minority of European countries that have a speed limit of 100 km/h on rural roads. While that accounts for only 4.5% of its network, it is also in the minority of countries that have rural speed limits set at 80 km/h. It also becomes apparent in this chapter that the majority of European countries consider 90 km/h to be an appropriate choice of speed limit to be used on a widespread basis – raising the question of whether to allow the use of 90km/h in Ireland and reserve 100 km/h for dual carriageways?

Chapter 5

Contemporary Assessment Methodologies

In this chapter, existing speed limit assessment methodologies are presented. The MASTER (MAnaging Speeds of Traffic on European Roads) Framework presented in section 5.1 is the Framework developed in Finland in 1997 (Toivanen, Sami & Kallberg, Veli-Pekka. Framework for assessing the impacts of speed, 2017).

This Framework was later adapted by the Transport Research Laboratory (TRL) in the United Kingdom for use on their roads. This UK version of the MASTER Framework was then adopted by Ireland. An online system used in the United States, USLIMITS, further developed from first the Australian system (VLIMITS) and then the collective Australian and New Zealand systems (XLIMITS), is also presented. Many of these approaches have their own merits and are included for completeness, however, it is apparent that there is a large emphasis placed on data collection and complex interrelationships between same to produce a speed limit.

Throughout this chapter there are references to Mean Speed and 85th Percentile Speed, these are explained below.

What is 85th Percentile Speed?

The 85th percentile speed (the Guidelines, p79) is the speed at or below which 85% of all vehicles are observed to travel under free-flowing conditions past a particular point and assumes that all drivers are reasonable and prudent and do not want to have a collision but want to get to their destination in the shortest possible time. It is also suggested that this speed is the maximum safe speed for that point (Texas

Department of Transportation, Procedures for Establishing Speed Zones, 2015). Motorists observed in the lower 15 percent are considered to be traveling unreasonably slow and those observed above the 85th percentile value are assumed to be exceeding a safe and reasonable speed.

What is Mean Speed?

Mean speed (the Guidelines, p80) is the average speed calculated for a route by taking speed measurements for a fixed time period at a reference area (time mean speed) or by taking the whole road into account and measuring the speed of individual vehicles and calculating the average (space mean speed). This method of calculating mean speed is considered to be more accurate than time mean speed (Knoop V et al., 2009). There is a move towards the use of mean speeds when assessing speed limits and speed management strategies, moving away from the use of the 85th percentile. In Ireland, it was left open to Local Authorities whether they used 85th percentile or mean speeds to make their assessments, thus immediately introducing inconsistency into the process of achieving a credible and consistent speed limit system across the country.

5.1 Europe - The MASTER Framework

It is likely that many forms of assessment techniques exist throughout European countries to assess and implement speed limits. Many of those would most likely be derived in some way from the MASTER Framework that was developed in 1997 by Kallberg and Toivanen in Finland that took a 14km section of rural single carriageway road as a case study. Two MASTER reports were produced in 1997 and 1998 and it was presented at the 9th International Conference on Road Safety in Europe in September 1998.

The Abstract to that report described the MASTER framework as follows;

The MASTER Framework for assessing the impact of speed considers the effects of speed on accidents and accident costs, time and vehicle operating costs, as well as environmental effects and answers the question: what are acceptable ranges of speed of road traffic? The framework can be applied to the assessment of direct (link level) and indirect (network level) impacts. The assessment of impacts takes place on three levels; a) monetary impacts, b) other quantitative impacts and c) qualitative impacts. Distributional impacts are described by indicating population or road user groups that are affected differently by the various effects. Special attention has been paid to the ease of application, transparency of the calculations and clear presentation of the results. The framework allows the user to select the impact functions (how accidents or exhaust emissions depend on speed) and unit values of monetary effects. This enables the use of the latest research results and the consideration of national or local preferences.

5.2 The United Kingdom

In 2004, the Transport Research Laboratory in the UK (TRL) produced a report for the Department for Transport Road Safety Division entitled "*Developing a Speed Management Assessment Framework for Rural Single Carriageway Roads*". They decided that the MASTER Framework should be developed for use in Great Britain, with the objective of developing a more effective way of determining speed limits that may form the basis of revised guidance to Local Authorities. They indicated that the key to the success of that work would be to ensure that speed limits are chosen to better match the appropriate speed for a particular road type. They proposed that single carriageway roads be divided into two groups, upper and lower tier, based on the desired function of the road, strategic or local.

UPPER TIER roads made up mainly all A & B class roads which, compared to Ireland, are effectively National and Regional roads. An initial speed limit of 50 mph would be chosen, with the higher quality roads within this tier being assigned a speed limit of 60 mph should their collision history (accident rate as it was referred to) be below a certain threshold.

LOWER TIER roads were all other roads (minor roads) which, in effect, were C-class roads. Their initial speed limit was 40 mph, with roads with a low collision history (accident rate) being assigned a speed limit of 50 mph.

In the final TRL report their approach and revised system is summarised as follows:

- Two tiers based on road function.
- Two options for a speed limit within each tier.
- The upper tier speed limit should be 60 mph, but only a minority of the roads would be of sufficient quality to sustain a 60 mph speed limit, mean speeds were around the 50 mph mark, leaving a Local Authority with a choice of whether to implement a 50 mph speed limit (Special Speed Limit) on these roads if the National Speed Limit remained at 60 mph.
- The lower tier speed limit should be 40 mph, with better quality low collision history roads allowed to be set at 50 mph, but the low accident rate and relatively low mean speeds may mean that the re-signing of the speed limit change may not be a cost-effective endeavour unless a strong environmental case is made.

5.3 The Irish Approach

In 2010, guidance on setting Special Speed Limits was issued to Local Authorities by the Department of Transport (Guidelines for the Application of Special Speed Limits, Department of Transport, 2010). Included within that guidance was a Speed Assessment Framework based on the UK's version. For reference, and to avoid confusion within this submission, the Department of Transport, Tourism and Sport, as it is now known, was named Department of Transport until 2011.

It appears that the approach taken was to include the Speed Assessment Framework as it was, converting imperial values to metric values on the speed curves. This, presumably, was because it was deemed to be the most suitable assessment method available for use in Ireland, as UK roads were similar in nature to Irish roads and it may have been felt that route consistency, at least in terms of speed limits, would be important (ironically, as already stated, there exists many examples of inconsistency from Local Authority to Local Authority in Ireland). In terms of the physical characteristics of the roads themselves, cross-border road-users will be aware that the cross-section of a road can be vastly different in Northern Ireland to the same route in the Republic, notwithstanding the fact that design standards have evolved here from UK standards.

The Speed Assessment Framework is included in Appendix A3. There appears to be repetition of some areas, some other areas do not immediately appear to relate to others and overall the entire text seems disorganised and confusing. This is not to say that it is unusable, it does however make the process more of a daunting endeavour for the user. It should be noted here that it is not the intention of the Speed Assessment Framework to enable drivers to exceed the speed limit. Its intention is to allow the confident choice of an appropriate speed limit for the road, or section, being analysed.

5.4 The United States

As with the UK and Ireland, the Federal Highways Administration in the United States feels that a rational speed limit is one that is safe, appropriate, protects the public and can be enforced. They believe a knowledge based expert system (Appendix L User Guide for USLIMITS, March 2012, Federal Highway Administration) can provide assistance to those setting speed limits for specific conditions on road sections.

The expert system described in the user guide employs a decision algorithm to advise the user of the appropriate maximum speed limit for the specific road section of interest. The expert system is accessed through the internet and provides recommended speed limits for speed zones on all types of roadways from rural two-lane roads to urban freeway segments. The types of speed limits not addressed by the system include statutory limits, such as maximum limits (set by State legislatures for interstates and other roadways), temporary or part-time speed limits, speed limits posted in work and school zones and variable speed limits that are raised or lowered based on traffic, weather, and other conditions.

The system is outlined in full in documentation available at the Federal Highway Administration website (https://safety.fhwa.dot.gov/uslimits/). The system is web based. User inputs for each route type are as follows.

Limited Access Freeway

- Operating speed: 85^{th} percentile speed and 50^{th} percentile speed
- Section length
- Annual average daily traffic

- Presence/absence of adverse alignment
- Current statutory limit for the type of road
- Terrain (level, rolling, mountainous)
- Is this section transitioning to a non-limited access highway?
- Number of interchanges within this section
- Crash statistics

Road Section in Undeveloped Areas

- Operating speed: 85th percentile speed and 50th percentile speed
- Section length
- Annual average daily traffic
- Presence/absence of adverse alignment
- Current statutory limit for this type of road
- Is this section transitioning to a road section in a developed area?
- Roadside rating
- Divided/undivided section
- Number of through lanes
- Crash statistics

Road Sections in Developed Areas

- Operating speed: 85th percentile speed and 50th percentile speed
- Section length
- Annual average daily traffic
- Presence/absence of adverse alignment
- Current statutory limit for this type of road
- Whether it is a one-way street?

- Number of through lanes
- Area type
- Number of driveways within the section
- Number of traffic signals within the section
- Presence/usage of on-street parking
- Extent of pedestrian/bike activity
- Crash statistics

Collision data is required, and this data is analysed by a developed crash module. Two types of speed limit are recommended. SL_1 is the suggested speed limit based on analysis without collision data and SL_2 is the limit suggested with collision data analysed. The system appears to be complex, but apparently all encompassing. The desired outcome is as per the various speed assessment frameworks – a safe suitable speed limit is suggested for the route or section under assessment. Appendix K is available on the FHA website and contains flowcharts that illustrate decision rules. It is apparent from Appendix K that, in areas of adverse alignment, the use of Advisory Speed Limits is also employed. This provision is not available in Ireland yet.

5.5 Summary

Contemporary assessment methods highlighted in this Chapter show that many jurisdictions focus on setting speed limits based on various factors, for instance setting the speed limit at or close to the 85th percentile, or other methods that put a lot of emphasis on computational interrelationships between various factors (environmental, road environs, human factors, etc.) requiring vast amounts of data gathering. They assess what a speed limit should be and apply it and afterwards adjust it based on various factors analysed.

For example, the Institute of Transportation Engineers (ITE) in the United States (Methods and Practices for Setting Speed Limits: An Informational Report, Institute of Transportation Engineers, 2012) outlines the four main methods commonly used to set speed limits;

The Engineering Approach where the speed limit is set based on either the 85th Percentile or the Design Speed of the road and then adjusted based on traffic and infrastructure conditions.

Expert system approach: Speed limits set by computers using knowledge and inference processes to simulate expert knowledge and behaviour.

Optimisation: Setting speed limits by considering journey times, operating costs, collisions and environmental impacts when assessing optimal speed limits.

Injury minimisation/safe systems approach: Speed limits are set according to the crash types that are likely to occur, the impact forces that result, and the human body's tolerance to withstand these forces – see also page 49 (Anders Lie) and Chapter 7 (Safe Systems Approach) of this thesis and Ayoola, Oke et al., A mathematical model to set speed limits for vehicles on the highway, 2006.

For example, in Illinois, the procedure considers access, pedestrian traffic, kerbside parking, and safety performance, along with existing speed profiles to recommend a speed limit with specific numerical adjustments (factors) specified for the items listed whereas the Northwestern Speed Zoning technique is similar to Illinois but they also consider the median/protection measures, lane widths, alignment etc by applying factors for different features. These approaches are outlined in the 2012 ITE report referenced above.

While operating speed model approaches to speed limit determination have been published, for both urban and rural scenarios and for single and dual carriageway type roads, they all collect speed and develop mathematical formulae based on certain parameters to arrive at a point where the model informs what the speed limit should be. Those parameters that are factored into the speed profile are those that are commonly accepted as being influencers on safe speeds and the selection of a driving speed by a driver, i.e.;

- Vehicle mechanical condition and characteristics;
- Driving ability/capabilities;
- Traffic volume: vehicles, pedestrians, cyclists;
- Weather and visibility;
- The roadway features;
  - Road function
  - Road Width
  - Horizontal and vertical alignment
  - Sight distances
  - Roadside development etc

The methodology proposed in this thesis (Chapter 6) attempts to develop a process of speed limit assessment based on what is happening in real life and allowing the observed driver behaviour (Safe Profile Velocity-V_{sp}) be 'the model' instead of taking operating speeds and further manipulating them with complex mathematical formulae for the items above because, it is proposed, this has already occurred and the items above have been accounted for when actual driver behaviour has been captured and processed by the V_{sp} process.

This chapter has highlighted the different methodologies that exist with respect to assessing and setting speed limits in many scenarios in the UK, Ireland and the United States. Some advantages and disadvantages of each are tabulated below.

Adapted from MASTER Framework				Adapted from Australia-New Zealand (XLIMITS-VLIMITS)	
United Kingdom		Ireland		United States	
Advantage	Disadvantage	Advantage	Disadvantage	Advantage	Disadvantage
Tries to distinguish between different road classes	In terms of lower tier roads, it may not be cost effective	Tries to distinguish between different road classes (but contradicts itself)	Speed limits to be lower on lower tier/access function roads (high density of bends - much of the 'strategic' national road network is like this)	Splits assessments into 3 categories of road, akin to our motorways, urban roads, rural roads.	Appears to be a complicated set of interrelationships to be developed should a similar system be employed here
Sensible starting point for upper and lower tier speed limits			No confidence in it from the Local Authorities and very little understanding of it	Federally supported online system	Greater amount of inputs and data to be collected
			Tier based on collision rates which could result in a conflict with the strategic function	Can have two options for a speed limit based on the availability of collision data	Having the option to proceed without collision data could result in collision data being routinely ignored and an inappropriate speed limit chosen

They appear complex and time consuming. The need for a simplified system becomes apparent when resources are limited, particularly when part of a major review and overhaul of an existing system. The UK and Ireland’s systems (derived ultimately from the MASTER Framework developed in Finland), in this author’s opinion, represent the past. They do not properly or exclusively consider all physical aspects of the road and actual driver behaviour.

They are based on a class/function/tiered system. Lower tier roads do exist in Ireland (likely in the UK as well) that have a higher AADT than an upper tier road. One example would be the R445 in Kildare that in some parts has an AADT in the region of 21,000 compared to the N56 in Donegal that has an AADT in the region of 11,000.

The Irish Speed Assessment Framework sprawls across several headings that offers little in the way of practical rules and advice and offers philosophies instead of hard and fast rules and frequently refers to "….a two-tiered hierarchical approach". It is not easy to read or follow in a coherent fashion and would come as no surprise if it were to be discovered that it had not been used in the last nine years. It is for that reason that the methodology in the following chapter is being proposed as a more effective and simplified way of assessing speed limits in Ireland and one that would be more likely to be used by Local Authorities.

In this author's opinion, Ireland may have been using (to what extent remains unquantified) a Speed Assessment Framework that was not fully suitable for use in its jurisdiction. The US system, while online and browser based, requires a large amount of data gathering with complex unseen interrelationships and would be difficult to either replicate or adapt for use in setting speed limits on Irish roads.

Chapter 6

Proposed Methodology and Case Studies

6.1 Introduction

The preceding chapters outline Ireland's road network, its speed limits, its collision history and how it compares with European countries in terms of its road safety performance. Contemporary assessment methodologies have also been outlined and, in the opinion of this author, the need for a simplified system has become apparent.

While the current approach across Europe is to move towards the use of mean speeds as opposed to 85th percentile speeds and to try and match speed limits with design speeds on newly designed and constructed roads, how can this be achieved on 'legacy' roads (roads not constructed to a formal design standard)? It is relatively simple to set a speed limit on a newly constructed road with a known, chosen or calculated design speed. On the existing legacy road network, the design speed is largely unknown.

In 2014, a design speed standard was developed by the National Roads Authority, Maynooth University and ARUP Consulting Engineers following a research project (McCarthy and Pforte, 2014) that investigated a methodology for computing design speed along the existing national road network. Safe Profile Velocity (V_{sp}) was developed during that research and it is that (and the resulting Efficiency Index) which is being proposed as an alternative method of assessing or selecting an appropriate speed limit on Irish rural single carriageway roads.

The concept of using V_{sp} and an Efficiency Index, if found to be effective, would be proposed as a replacement of the Speed Assessment Framework, at least in terms of the rural single carriageway network.

The methodology was built on the comparison of both theoretical and empirical measurements of speed along a route under investigation. V_{sp} represents the way the average driver would drive on a road and would provide a better understanding of the safety performance of the road, taking account of the physical characteristics of the road along with actual driver behaviour. It would appear logical to align the speed limit with what is actually happening on the whole road, rather than basing it on an arbitrary Default Speed Limit value. Indeed, that is what happens when the speed limit is set based on the Mean or 85^{th} percentile speed. Mean speeds and 85^{th} percentile speeds provide a certain amount of value; however, the Safe Profile Velocity would appear to provide a more accurate reflection of what is actually occurring on the road.

The underlying design speed methodology proposed was to record, measure and compare both the static physical road network environment as well as the typical dynamic speed profile for the same route section. The static physical route network environment comprises essential geometric elements such as alignment, cross-sectional attributes and layout. The dynamic speed profile is a measure of how average drivers travel along the same section of road in a safe fashion, while not exceeding the posted speed limit. This is what is captured and processed to produce a V_{sp} for the section being assessed by simply driving the route a number of times. An outline of how V_{sp} is derived is presented in section 6.2.

6.2 Empirical Modelling - Deriving V_{sp}

Empirical modelling enables a dynamic speed profile of how typical drivers drive a road section under typical conditions while remaining under the posted speed limit. This is usually collected by driving the route a number of times and recording the journey using a GPS-enabled device. V_{sp} represents how drivers travel along a route in a safe and progressive manner. A GPS device is used to record the journey along a road section, usually three or more times. In Figure 6.1 the profiles for a route section that was captured seven times are shown. From these captures the V_{sp} is then derived. It is advisable that one of the surveys is also captured with a GPS Video recording device.

The test GPS traces, for outward and return legs, are uploaded from the GPS device for processing. All GPS traces are registered to a single evenly spaced sample reference road centre line. The velocity values at every sample point for each of the passes are examined and sorted from highest to lowest. An average value, as described in step 3 below, is computed and returned for that sample location. The variation between all passes is measured and a report is issued indicating whether the sample traces are robust.

Step 1 Data collation: the driver travels along both directions of the test route, recording the journey using a GPS. The guidelines for capturing V_{sp} include;

- Remain within posted speed limit
- Drive in a safe but progressive manner
- Manoeuvres into and out of bends should be smooth
- Traffic free-flow
- Ensure the data capture is under good weather and illumination conditions
- Low driver work-load
- Average vehicle
- Overtaking is not allowed
- Minimum of three journeys, both directions are recorded at different times of the day

Step 2

GPS trace processing: the GPS traces comprise point values usually acquired at rates of 1Hz. These are then interpolated against the same 5m reference layer.

Step 3

Calculating V_{sp}: V_{sp} is then determined for given sample point S. The values of all recorded speed profiles are retrieved at that point S (Raw velocity Data below). These values are then ordered from lowest to highest and 80% of the largest value is determined (Processed velocity Data below). Speed values that fall below the 80% value are substituted by the 80% value (e.g. Velocity 5 - Raw v Processed Data below). All other speed values remain unchanged. Finally, the mean of all speed values (unchanged and changed) is taken. This value is the V_{sp} value at the sample point S (V_{sp} below).

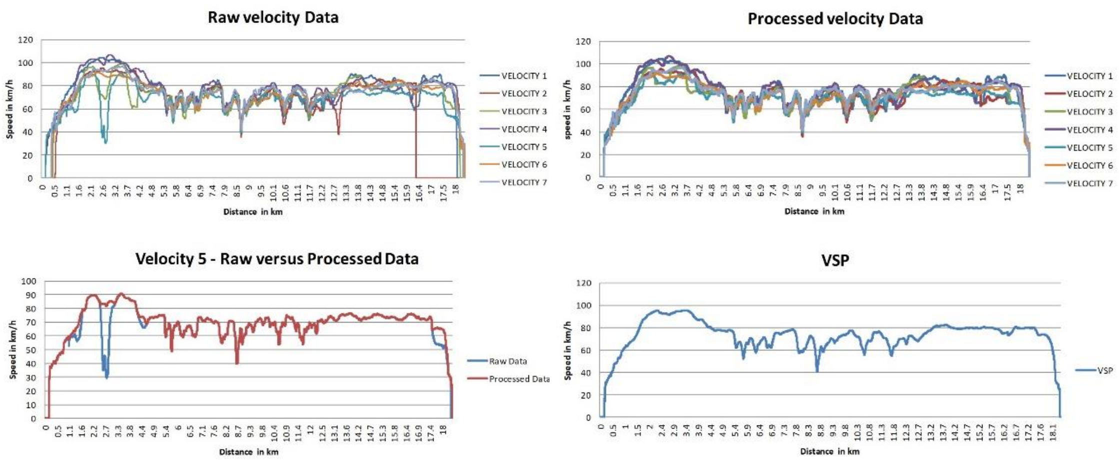


Figure 6.1: Four Stages in deriving V_{sp} as described in Step 3.

Upon further analysis by the research team in 2014, it was concluded that it is sufficient to capture a route three or four times as, at this point, the derived V_{sp} starts to consolidate and usually experiences only little change even if the number of captured routes is increased. Anomalous GPS readings, should they occur, i.e. sudden spikes or sudden drops to zero, are removed by taking the average of the point immediately preceding and following the spike or drop.

6.3 Case Studies

The seven route sections, in Table 6.1, were selected based on Network Safety Ranking values, location and for other features that warranted analysing the appropriateness of their speed limits and the effects altering the speed limit would have. The N2 is a National primary road with recent improvements that reduced the Default 100 km/h speed limit on a section. The N14 is a narrow National primary road that connects to the Northern Ireland border carrying a single speed limit. The N51 is a National Secondary route that passes through three Local Authority areas with differing approaches to setting the speed limit. The N52 is similar but shorter and passes through two Local Authority Areas. The N53 is a single speed limit National secondary route that crosses the Northern Ireland border twice carrying lots of commuter traffic. The R157 is a narrow twisty Regional road and the R410 is a Regional road that carries traffic eastwards to the N81 with Special Speed Limits at an isolated hazard and on the approach to a small village.

Table 6.1 lists the relevant details for each route; location (origin/destination), its classification, the default speed limit, the length investigated, traffic volumes, the amount of collisions between 2006 and 2012 and the number of times it was captured.

In terms of sinuosity, as described in section 2.3.2, all routes can be classed as one that imparts a high demand on drivers.

Sinuosity	Level of Bends	Demand on Driver	N2	N14	N51	N52	N53	R157	R410
<1.001	Straight	Low							
<1.008	Easy								
<1.032	Moderate	High	1.030						
<2.488	Severe			1.133	1.122	1.211	1.074	1.119	1.077

Route	Location	Route Classification	Default Speed Limit	Length (km)	AADT	Collisions	Times captured each direction
N2	Monaghan Town to NI border	National Primary	100 km/h	15.6	6,086	22	3
N14	Lifford to N13, Co. Donegal	National Primary	100 km/h	16.8	11,319	38	3
N51	Delvin, Co. Westmeath to Drogheda, Co. Louth	National Secondary	100 km/h	53	5,096	67	3
N52	Mullingar, Co. Westmeath to Kells, Co. Meath	National Secondary	100 km/h	37.8	5,046	26	3
N53	Dundalk, Co. Louth to Castleblayney, Co. Monaghan	National Secondary	100 km/h	22	5,110	30	4
R157	Maynooth, Co. Kildare to Dunboyne, Co. Meath	Regional	80 km/h	7.5	n/a	8	4
R410	Naas, Co. Kildare to Blessington, Co. Wicklow	Regional	80 km/h	7.5	n/a	7	4

Table 6.1: Details of Case Study Routes

Figure 6.2 shows the length of five of the case study routes (NSR is not available for the Regional network yet) and how much of each route is above or below the collision rate for this type of road (the reference population - single carriageway roads) by simply counting the number of 1km sections that are classed as being above or below the collision rate (datasets retrieved from the open data portal, www.data.gov.ie, July 2016).

It tells us that nearly 34% of the overall combined length of the case studies has an average collision rate above what the expected collision rate is for these roads. Individual route values range from 31.75% on the N52 to 41.67% on the N14.

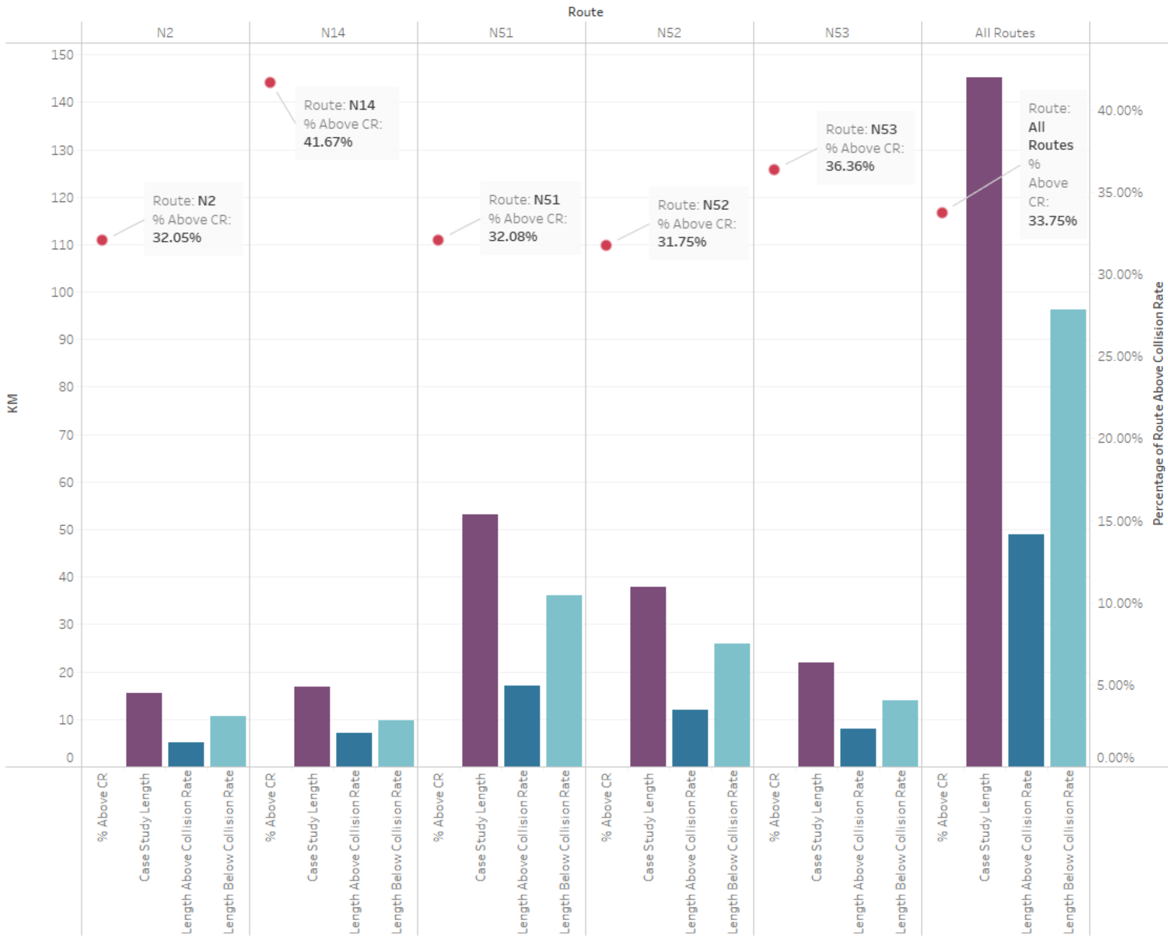


Figure 6.2: Case Study Routes – Length above or below Collision Rate

While this could be a starting point in selecting routes or sections of routes to analyse, the actual collision rate per 100 million vehicle kilometres is an accurate representation of the route. Figure 6.3 below shows the collision rate for the reference population (7.73), the twice above (15.46) and twice below (3.865) values and the collision rates for each case study routes, all calculated using Equation 3 in Appendix A.2.2 and collision data for the 3 years from 2012-2014 (Table 6.2). One case study route is above, two are more than twice above and two are below the reference population collision rate.

Network Safety Ranking – Collision Rates per 100 million vehicle km's						
f_i = *Collision Frequency*, P = *Period of Analysis (3 years-2012, 2013, 2014)* L_i = *Length (km)*, Q_w = *Weighted AADT*						
Parameter	**Reference Population**	**Case Study**				
		N2	**N14**	**N51**	**N52**	**N53**
f_i	1740	7	19	18	11	19
P	3	3	3	3	3	3
L_i	3561.25	12.586	16.305	45.375	36.907	18.143
Q_w	5776.76	5648.19	5993.791	5657.946	4370.493	5040.331
Collison Rate $R_{rp} = \frac{\Sigma f_i \times 10^8}{365.25 \times P \times \Sigma L_i \times Q_w}$	= 1740x10⁸ / 365.25 x 3 x 3561.25 x 5766.76	= 7x10⁸ / 365.25 x 3 x 12.856 x 5648.19	= 19x10⁸ / 365.25 x 3 x 16.305 x 5993.791	= 18x10⁸ / 365.25 x 3 x 45.375 x 5657.946	= 11x10⁸ / 365.25 x 3 x 36.907 x 4370.493	= 19x10⁸ / 365.25 x 3 x 18.143 x 5040.331
	7.73	**8.797**	**17.742**	**6.398**	**6.223**	**18.961**
		Above	**> Twice Above**	**Below**	**Below**	**> Twice Above**

Table 6.2: Calculation of Collision Rates

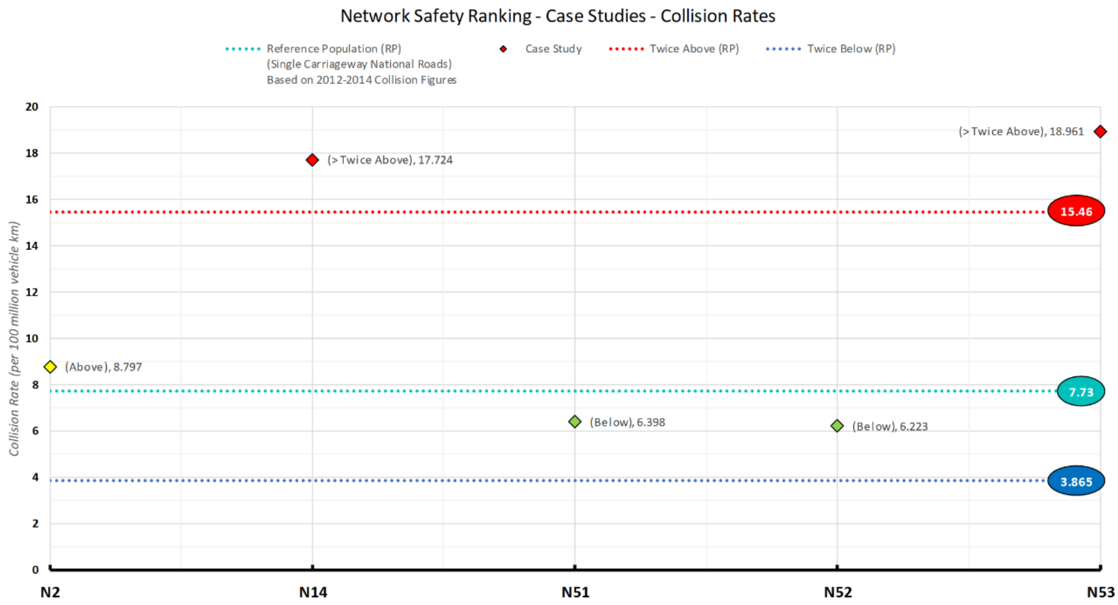


Figure 6.3: Case Study Routes – Calculated Collision Rates

Each route was captured in both directions and the following charts have been produced for each direction of travel.

- All captured GPS traces, derived V_{sp}, Posted Speed Limit
- Posted Speed Limit, derived V_{sp} and '*appropriate*' band.

Anomalous GPS readings, should they occur, i.e. sudden spikes or sudden drops to zero, are removed by taking the average of the points immediately preceding and following the spike or drop and smoothed out during V_{sp} processing.

Speed Distribution, Route Efficiency and the Efficiency Index

Speed distribution is the distribution of the V_{sp} through 5 km/h bands above and below the speed limit which gives a basic insight as to how the route is performing. **Route Efficiency** is a measure of the V_{sp} in relation to the posted speed limit (PSL) and the 'appropriate', 'too slow' and 'too fast' bands (Table 6.3). It is determined by analysing the V_{sp} and determining the amount of time spent above or below the posted speed limit along the route and to what degree the V_{sp} is above or below the posted speed limit at each GPS observation point.

As previously mentioned, it is possible that an enforcement tolerance of 10%+2 km/h of the posted speed limit is applied. Therefore, assuming that to be the case, speeds within the range

$$\text{PSL} - (10\%\text{PSL}+2\text{ km/h}) \text{ to } \text{PSL} + (10\%\text{PSL}+ 2\text{ km/h})$$

can be viewed to be *'appropriate'* for the route. An efficient route is one that is travelled mostly within that range (Figure 6.5). V_{sp} values above or below that are considered to be too fast or too slow for those speed limits - the Efficiency bands are shown below;

Too Slow	Appropriate			Too Fast
	PSL – (10%+2km/h)	Posted Speed Limit (PSL)	PSL + (10%+2km/h)	
Existing Speed Limits				
<88 km/h	88 km/h	**100 km/h**	112 km/h	>112 km/h
<70 km/h	70 km/h	**80 km/h**	90 km/h	>90 km/h
<52 km/h	52 km/h	**60 km/h**	68 km/h	>68 km/h
Theoretical Speed Limits				
<79 km/h	79 km/h	**90 km/h**	101 km/h	>101 km/h
<61 km/h	61 km/h	**70 km/h**	79 km/h	>79 km/h

Table 6.3: Efficiency bands per speed limit

The percentage of time spent in the 'appropriate' band becomes the **Efficiency Index** by representing that percentage as a decimal. The Efficiency Index is calculated for the *rural sections only* of each case study route, for two reasons;

1. This submission is concerned only with achieving a solution for rural single carriageways outside built-up areas.
2. Built-up areas generally have higher concentrations of Vulnerable Road Users (VRU's) and, therefore, the built-up area speed limit of 50 km/h is generally viewed as being appropriate in these areas. Any analysis suggesting an increase of the speed limit above 50 km/h in built-up areas would not be accepted or implemented by Local Authorities and/or Elected Representatives.

A speed limit of 60 km/h is considered as being an appropriate speed limit for transition zones between 100 km/h (or 80 km/h) and 50 km/h on the approach to towns and villages. It has also been included in Table 6.3 as it is commonly used to solve the problem of an isolated hazard in rural areas even though the Guidelines advise against it. Figure 6.4 shows an example where the V_{sp} along the route was observed to be too fast (posted speed limit plus 10%+2 km/h) for 0% of the time, too slow (posted speed limit minus 10%+2 km/h) for 57% of the time and appropriate (between those two bands) for 43% of the time. This results in an Efficiency Index of 0.43 (fair)

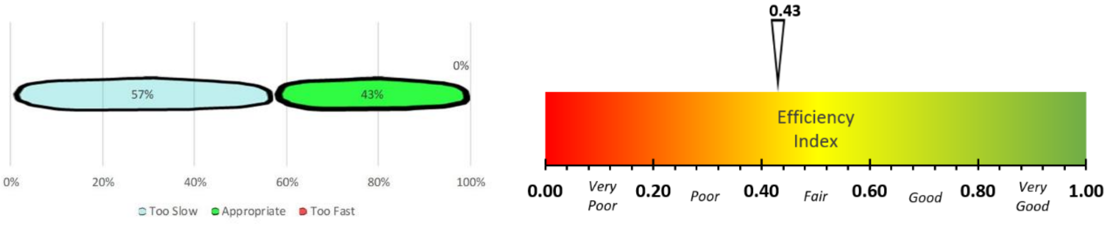


Figure 6.4: Route Efficiency & Efficiency Index

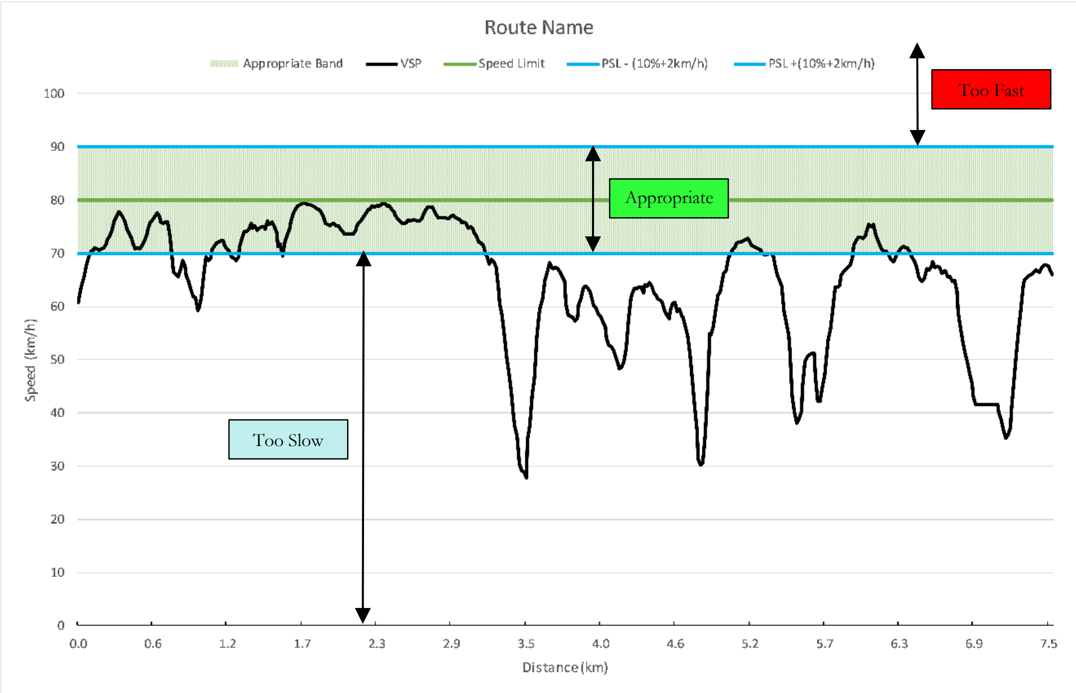


Figure 6.5: Visual Representation of Efficiency bands

Tables and charts have been produced for each case study route depicting the time spent above or below the posted speed limit within different bands (speed distribution and route efficiency). This approach enables us to theoretically determine what effect changing the speed limit would have on driver behaviour and compliance with the posted speed limit (i.e. improve efficiency). The case studies are structured as follows;

- Route information
- Collision history & Collisions in poorly performing section
- Direction 1 – charts, Speed Distribution, Route Efficiency and Efficiency Index and discussion
- Direction 2 – charts, Speed Distribution, Route Efficiency and Efficiency Index and discussion
- Effect of altering the speed limit
- Conclusions

6.3.1 N2 – Monaghan Town to Northern Ireland Border

The section of the N2 chosen for analysis commences at a point north of Monaghan town where the built-up area speed limit of 50 km/h ends and continues in a northerly direction through the town of Emyvale to its connection with the A5 at the Northern Ireland boundary just south of Aughnacloy, Co. Tyrone. It is 15.6km in length, carries 6,086 vehicles per day (2016 figures) and has experienced 22 collisions over the period 2006-2012.

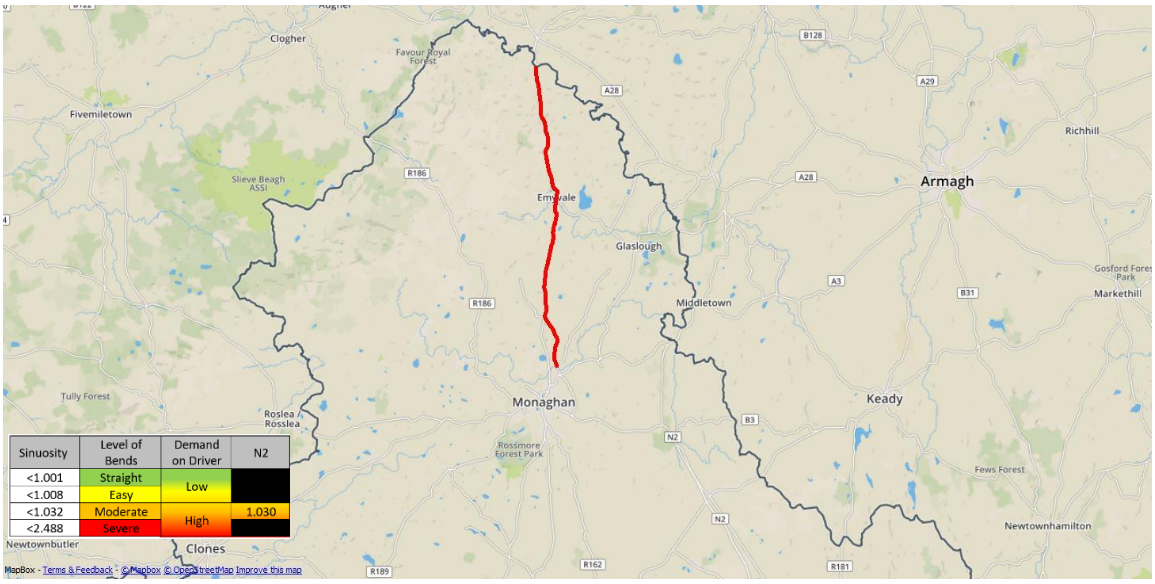


Figure 6.6: Location of N2 Case Study

As it is a National primary road, the Default Speed Limit is 100 km/h. For the 5.5km section from its commencement to the village of Corracrin, a reduced Special Speed Limit of 80 km/h has been applied (a section that has recently been 'improved'). Through the village of Corracrin, the speed limit reduces to 60 km/h on approach to the 50 km/h built-up area speed limit and the 50 km/h built-up area speed limit is also applied through the village of Emyvale. The route was captured 3 times in each direction.

COLLISION HISTORY

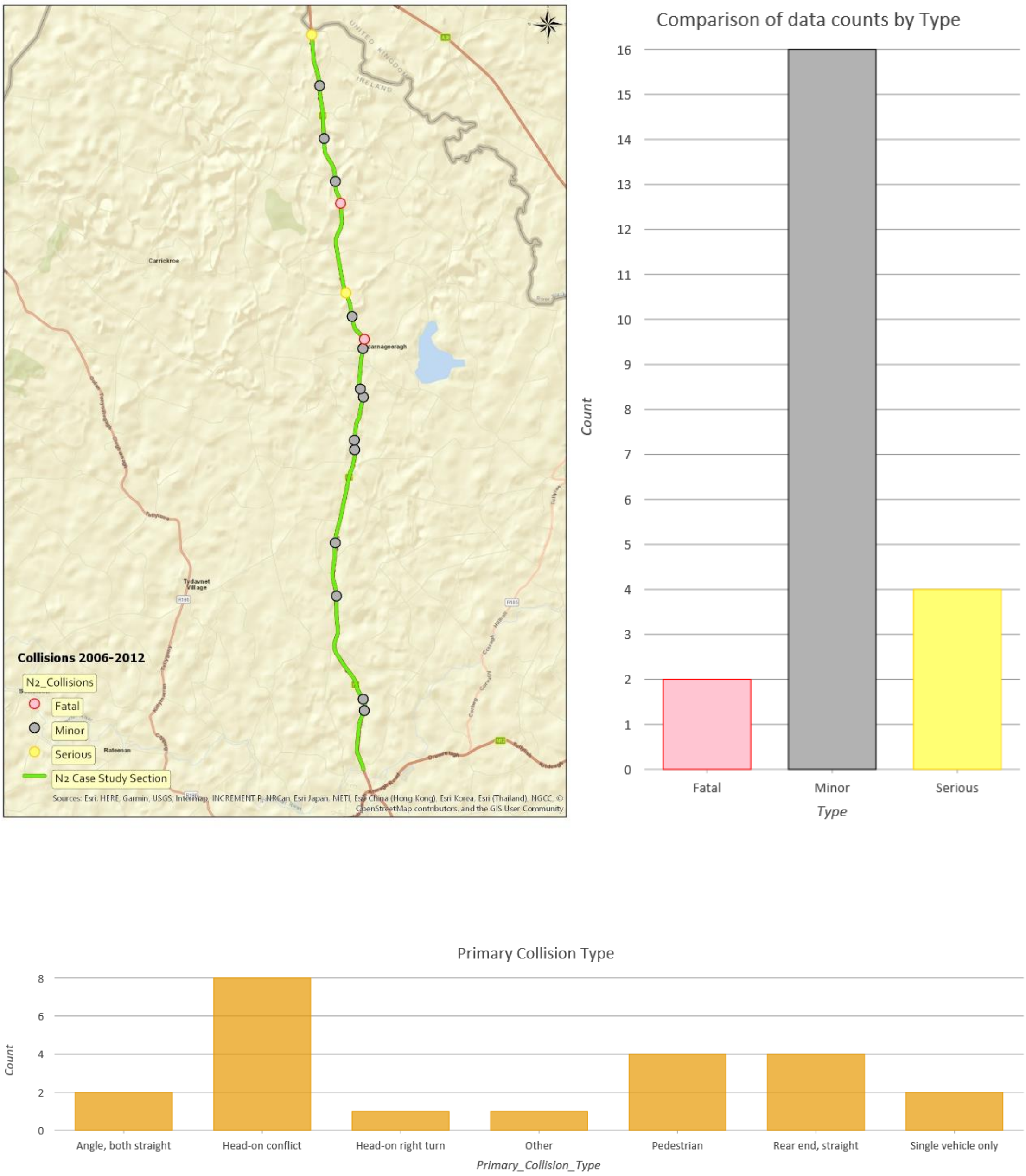


Figure 6.7: N2 Case Study – Collision History

In the period 2006-2012 there was a total of 22 collisions on this section of the N2 between Monaghan town and the Northern Ireland border - 16 minor, 4 serious and 2 fatal collisions. Eight of these collisions were head on collisions with 4 rear end collisions. As we will see later, the V_{sp} in the location of the fatal collisions was determined to be 90 km/h.

COLLISIONS IN POORLY PERFORMING SECTION

The analysis of the derived V_{sp} and Route Efficiency will show that the section between Emyvale and the border is performing poorly. This section is travelled between 10 and 15 km/h below the speed limit for approximately 78% of the time, the V_{sp} is mostly between 80 and 90 km/h. The section is generally a wide single carriageway, however, there are frequent accesses with right turning traffic.

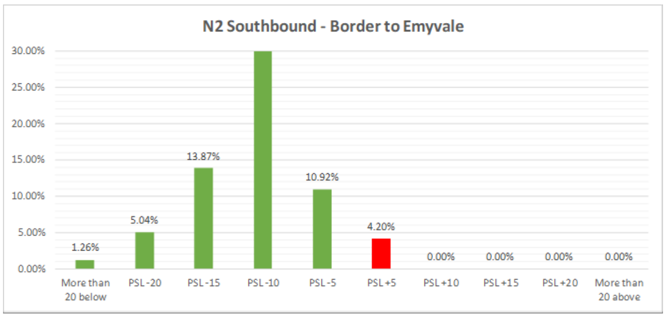


Figure 6.8: Emyvale to Border Collisions

From 2006 to 2012 there were ten collisions along this section including one pedestrian fatality in 2006 involving a car. The recorded V_{sp} at that location was 90 km/h. There were three collisions recorded within meters of each other, two minor collisions in 2008 – one a head-on collision and the other a rear end collision and one serious collision – a rear end collision where one of the vehicles was deemed to have been exceeding the speed limit.

NORTHBOUND

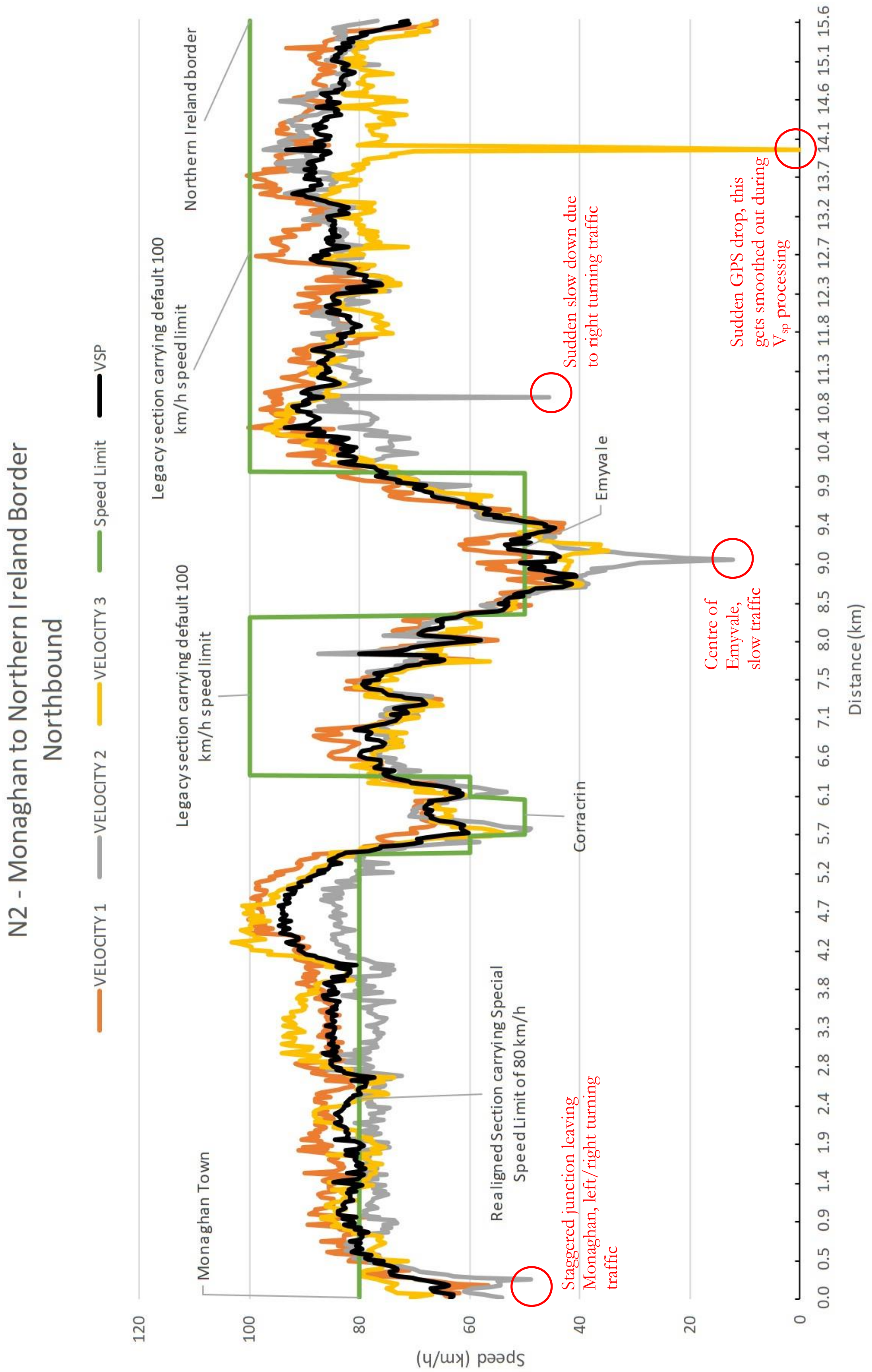


Figure 6.9: N2 velocities, V_{sp} and speed limit - Northbound

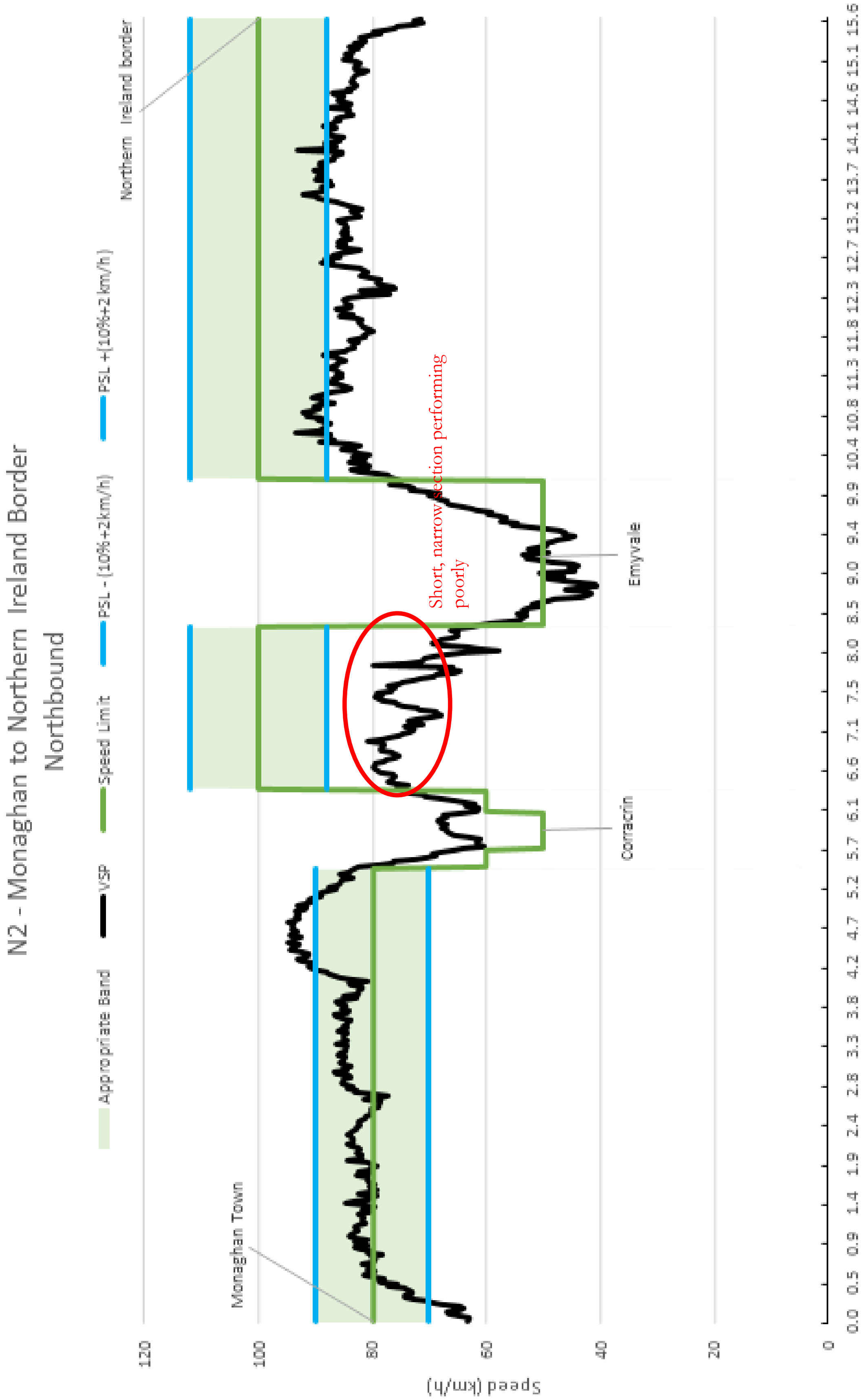


Figure 6.10: N2 V_{sp}, speed limit and 'appropriate' band - Northbound

Speed Distribution, Route Efficiency And Efficiency Index

N2 - NORTHBOUND	Above Posted Speed Limit					Max V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	94.72
GPS Observations	123	36	39	0	0	Min V_{sp}
% of Route	21.47%	6.28%	6.81%	0.00%	0.00%	57.93
	Below Posted Speed Limit					Ave V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	82.36
GPS Observations	23	18	116	111	107	85^{th} %
% of Route	4.01%	3.14%	20.24%	19.37%	18.67%	88.16

Table 6.4: N2 Northbound Speed Distribution

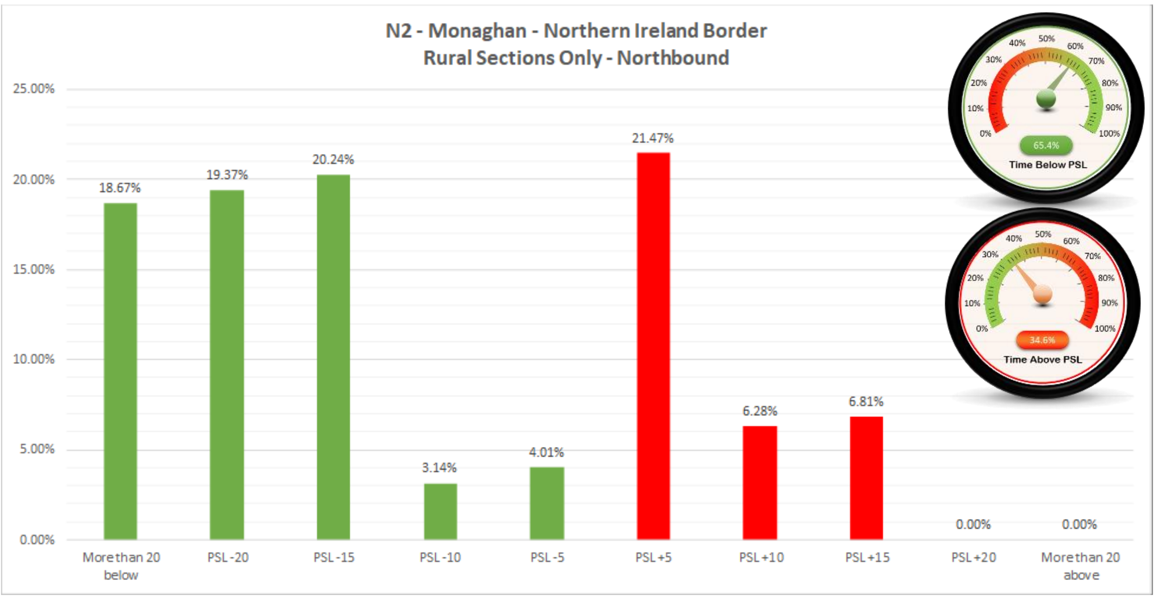


Figure 6.11: N2 Northbound Speed Distribution

The above table and chart reveal that over the length of this route in the Northbound direction traffic is travelling below the speed limit 65.4% of the time with 27% being in a range of 0-15km/h below with the remainder at least 15 km/h below the speed limit. While analysing the speed distribution appears to be a useful indicator of what is occurring along the route, a simple metric of time spent above or below the speed limit may not tell the full story. Just over 34% of the time is spent above the speed limit. Taken in isolation, that metric is stating that traffic is travelling too fast for too long. However, 21% of that is only, at most, 5 km/h above the speed limit.

Using the ‘appropriate’ band approach to analysing the V_{sp} output, and determining an Efficiency Index based on that analysis, produces a more definitive commentary of the performance of the route and the behaviour of traffic on it. As shown in Table 6.3, the ‘*appropriate*’ band for this route is 70 km/h to 90 km/h for the 80 km/h section and 88 km/h to 112 km/h for the 100 km/h section. Applying those bands to the V_{sp} (visualised in Figure 6.10) reveals that traffic is travelling in the ‘appropriate’ band for 41.19% of the time, with traffic deemed to be travelling too fast for only 6.81% of the time. Slow traffic, however, is the main problem on this route with traffic travelling below the ‘appropriate’ band for 52% of the time. Thus, the Efficiency Index for this direction of the N2 between Monaghan and the Northern Ireland border is 0.41.

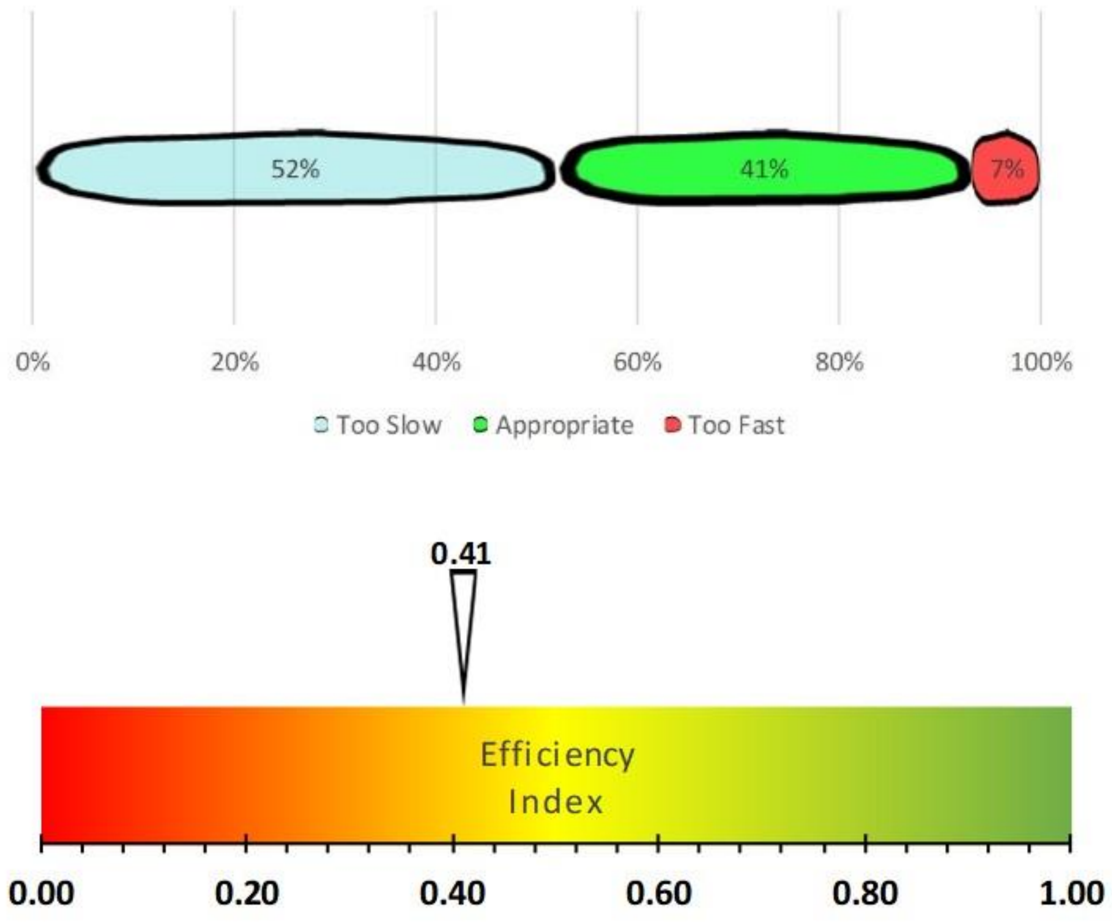


Figure 6.12: N2 Northbound Route Efficiency & Efficiency Index

SOUTHBOUND

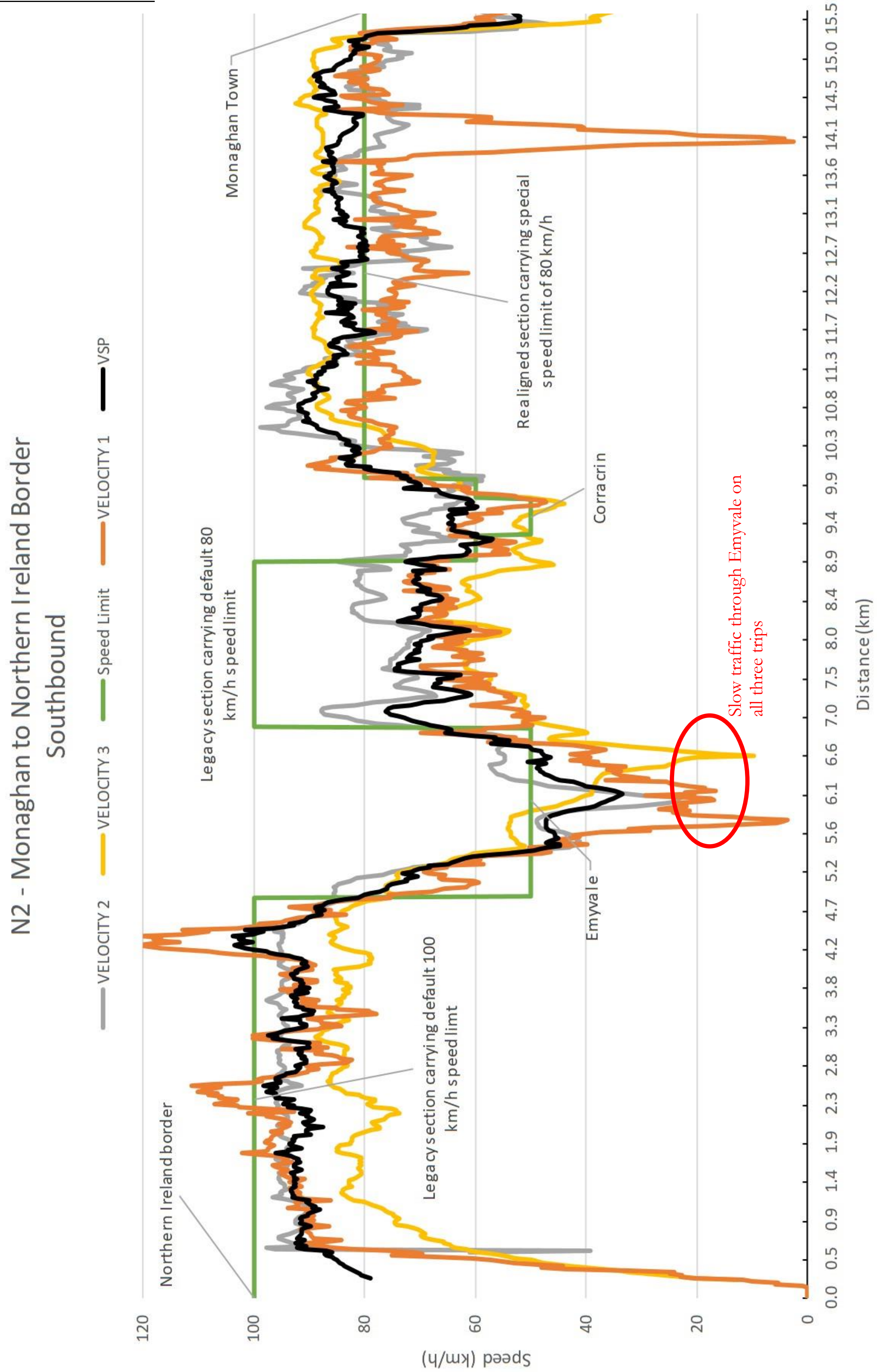


Figure 6.13: N2 velocities, V_{sp} and speed limit - Southbound

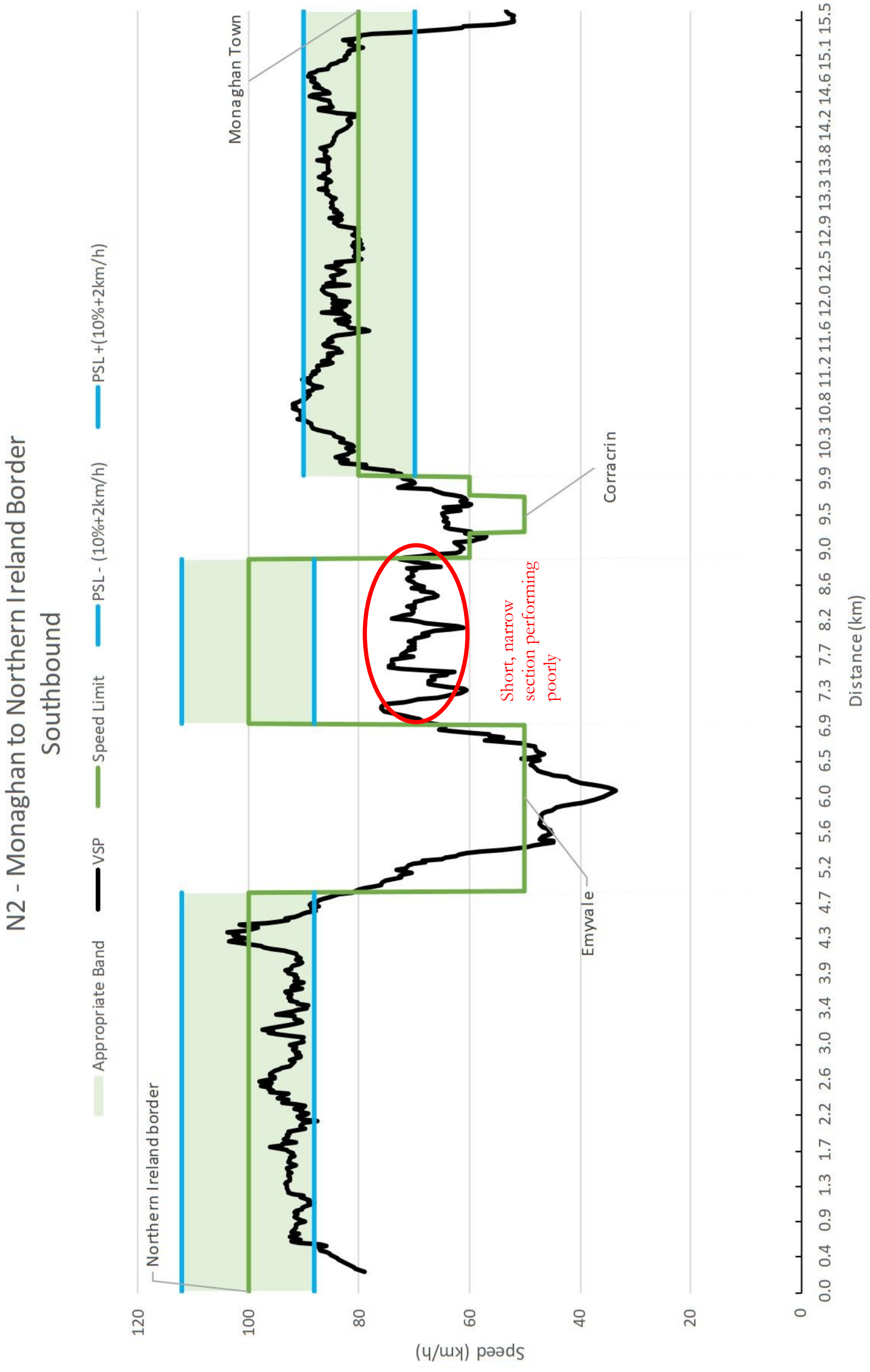


Figure 6.14: N2 V_{sp}, speed limit and 'appropriate' band - Southbound

Speed Distribution, Route Efficiency And Efficiency Index

N2 - SOUTHBOUND	Above Posted Speed Limit					Max V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	103.92
GPS Observations	141	113	13	0	0	Min V_{sp}
% of Route	22.35%	17.91%	2.06%	0.00%	0.00%	53.21
	Below Posted Speed Limit					Ave V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	84.80
GPS Observations	41	159	34	15	115	85th %
% of Route	6.50%	25.20%	5.39%	2.38%	18.23%	92.71

Table 6.5: N2 Southbound Speed Distribution

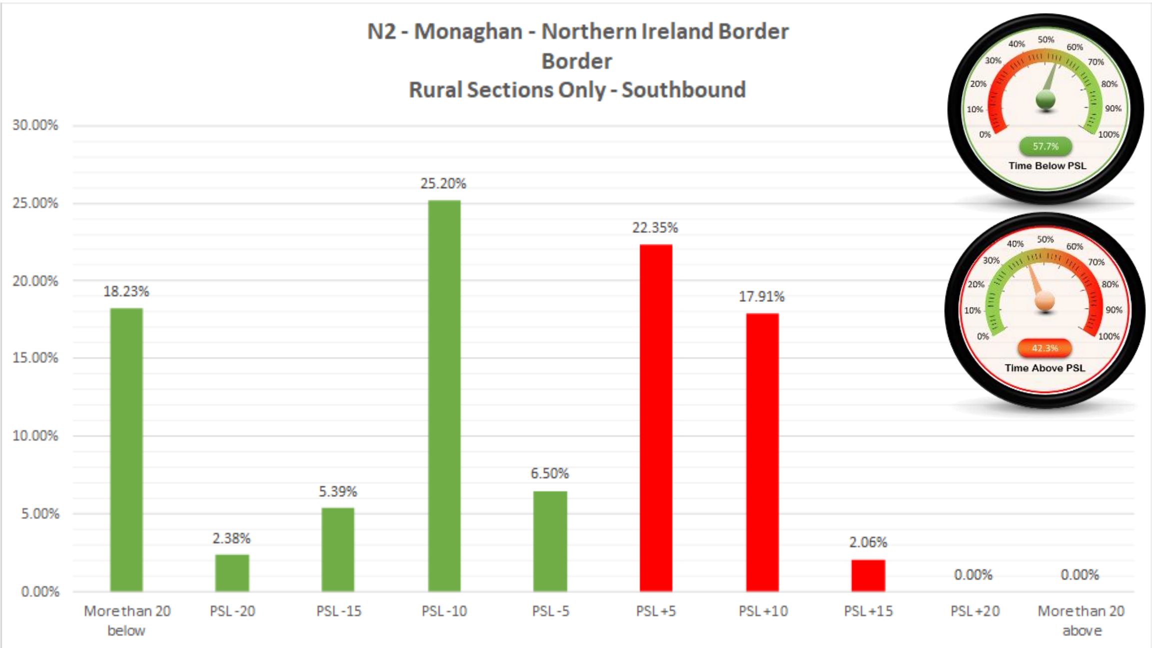


Figure 6.15: N2 Southbound Speed Distribution

The above table and chart reveal that over the length of this route in the Southbound direction traffic is travelling below the speed limit 57.7% of the time with nearly 32% being no more than 10 km/h below the speed limit. Again, Route Efficiency appears to be a useful indicator of what is occurring along the route, there is a close split between the above and below percentage, indicating drivers are having trouble accepting the speed limit as being correct. Again, this may not tell the full story. While just over 42% of the time is spent above the speed limit, half of that is only, at most, 5 km/h above the speed limit.

As per the Northbound direction, the '*appropriate*' band for this route is 70 km/h to 90 km/h for the 80 km/h section and 88 km/h to 112 km/h for the 100 km/h section. Applying those bands to the V_{sp} (visualised in Figure 6.14) reveals that traffic is travelling in the '*appropriate*' band for 75% of the time, with traffic deemed to be travelling too fast only 2% of the time. Traffic travels too slowly for 25% of the time in this direction. The Efficiency Index therefore is 0.75 for this direction of the N2 between Monaghan and the Northern Ireland border.

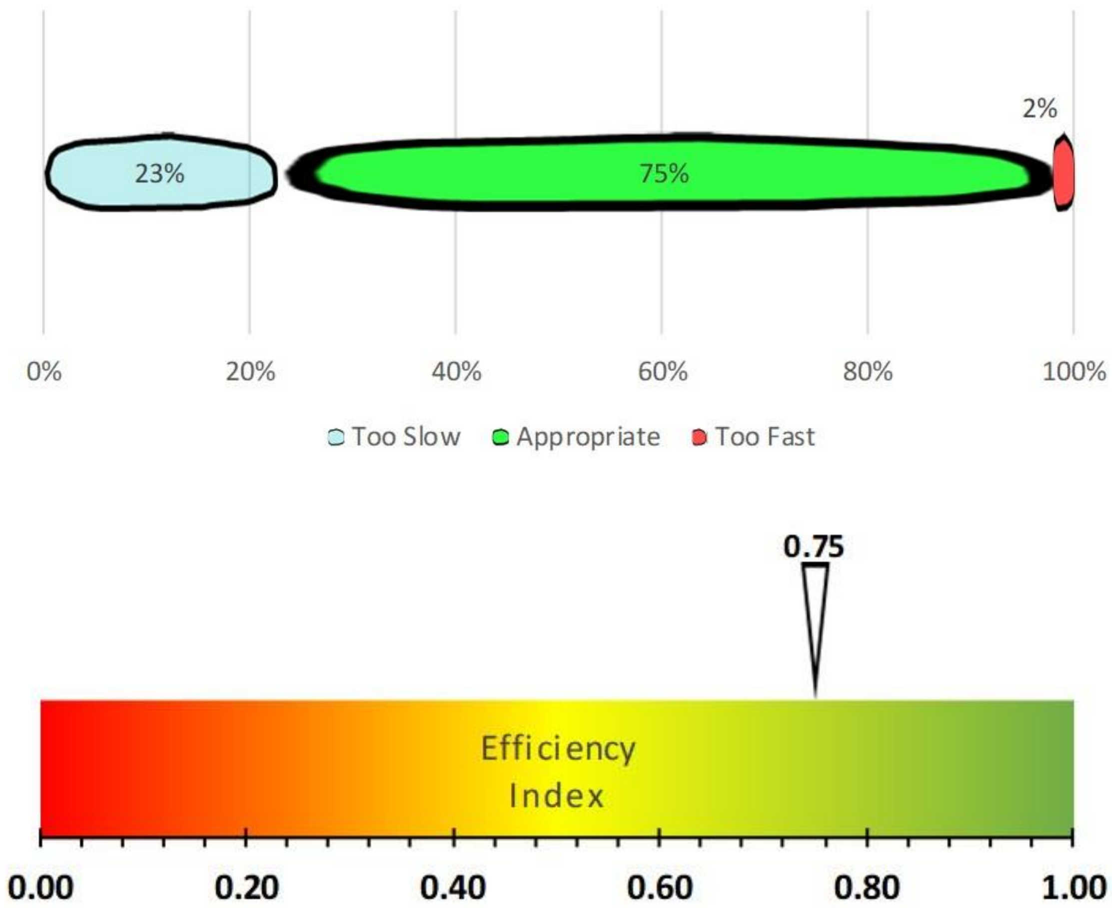


Figure 6.16: N2 Southbound Route Efficiency & Efficiency Index

EFFECT OF ALTERING THE SPEED LIMIT

This case study route section is made up of 3 sections; Monaghan to Corracrin, Corracrin to Emyvale and Emyvale to the border. The V_{sp} can be analysed against theoretically altered speed limits to determine the effect changing the speed limit would have on the Efficiency Index. Speed limits can be altered on the entire section or on any of the 3 individual sections in an attempt to realise an improvement.

<table>
<tr><th></th><th>Section</th><th>Speed Limit</th><th>Efficiency Index Northbound</th><th>Efficiency Index Southbound</th></tr>
<tr><td rowspan="3">Existing Configuration</td><td>Monaghan-Corracrin</td><td>80 km/h</td><td rowspan="3">0.41</td><td rowspan="3">0.75</td></tr>
<tr><td>Corracrin-Emyvale</td><td>100 km/h</td></tr>
<tr><td>Emyvale-Border</td><td>100 km/h</td></tr>
<tr><td rowspan="3">Altered Scenario 1</td><td>Monaghan-Corracrin</td><td rowspan="3">100 km/h</td><td rowspan="3">0.16</td><td rowspan="3">0.40</td></tr>
<tr><td>Corracrin-Emyvale</td></tr>
<tr><td>Emyvale-Border</td></tr>
<tr><td rowspan="3">Altered Scenario 2</td><td>Monaghan-Corracrin</td><td rowspan="3">90 km/h</td><td rowspan="3">0.79</td><td rowspan="3">0.79</td></tr>
<tr><td>Corracrin-Emyvale</td></tr>
<tr><td>Emyvale-Border</td></tr>
<tr><td rowspan="3">Altered Scenario 3</td><td>Monaghan-Corracrin</td><td rowspan="3">80 km/h</td><td rowspan="3">0.85</td><td rowspan="3">0.57</td></tr>
<tr><td>Corracrin-Emyvale</td></tr>
<tr><td>Emyvale-Border</td></tr>
</table>

Table 6.6: N2 Efficiency Index – Altered Speed Limits

In an attempt at achieving route consistency, 3 altered scenarios were considered, all of which applied a single speed limit value along the entire section outside of the built-up areas. Scenario 1, applying the Default Speed Limit of 100 km/h to the route resulted in a significant deterioration in the EI. Scenario 2, applying a speed limit of 90 km/h to the route resulted in a significant improvement in the Northbound direction and a minor improvement Southbound, both directions coming out with an improved EI of 0.79. Scenario 3, applying a speed limit of 80 km/h to the route resulted in an improvement to 0.85 in the Northbound direction but a deterioration to 0.57 in the Southbound direction. These can be visualised on the following charts.

Figure 6.17: N2 – V_{sp} and Appropriate Bands (Altered Speed Limits)

CONCLUSIONS

The Speed Distribution tables show that motorists are having trouble 'deciding' what the appropriate speed limit should be on this route, possibly due to the horizontal alignment, the wider hard shoulders with motorists driving half in-half out of them and right turning traffic (in the narrow sections), particularly in the Northbound direction where 58% of the journey is travelled at least 15 km/h below the speed limit. The Southbound direction performs better with a more definite concentration of time spent in and around the 10 km/h below to 10 km/h above range. Overall, particularly in the Northbound direction, the motorist does not appear to 'buy-in' to the posted speed limit. Taking that information and analysing it in terms of the Route Efficiency bands results in an Efficiency Index of 0.41 Northbound and 0.75 Southbound. The next step should be to attempt to improve the EI on the route by altering the speed limit and achieve a balance or consistent EI in both directions.

Restoring the route to its Default speed limit of 100 km/h results in a deterioration of the EI in both directions. Applying 80 km/h results in a substantial improvement (0.41 to 0.85) in the Northbound direction but shows deterioration Southbound (0.75 to 0.57)

Applying 90 km/h shows the greatest improvement in the Efficiency Index in both directions (0.41 and 0.75 to 0.79), and that a 90 km/h speed limit warrants consideration, it seems to represent what is occurring on this section of the N2 between Monaghan and the Border.

It may be tempting to apply 80 km/h and achieve an improvement in one direction and adopt a 'see what happens' approach to the other but this process has shown that it is possible to achieve a balance and consistency between both directions of travel.

Adopting 90 km/h would also bring an element of consistency to our speed limits in relation to the rest of Europe (Figure 4.5). The additional option of a 90 km/h speed limit could be managed by a robust guidance and implementation system.

6.3.2 N14 – Lifford to N13 Junction, Co. Donegal.

The section of the N14 chosen for analysis commences at the point north of Lifford, Co. Donegal where the built-up area speed limit ends and continues to its junction with the N13 near Manorcunningham, Co. Donegal. It is 16.8km in length, carries 11,319 vehicles per day (2016 figures) and has experienced 38 collisions over the period 2006-2012.

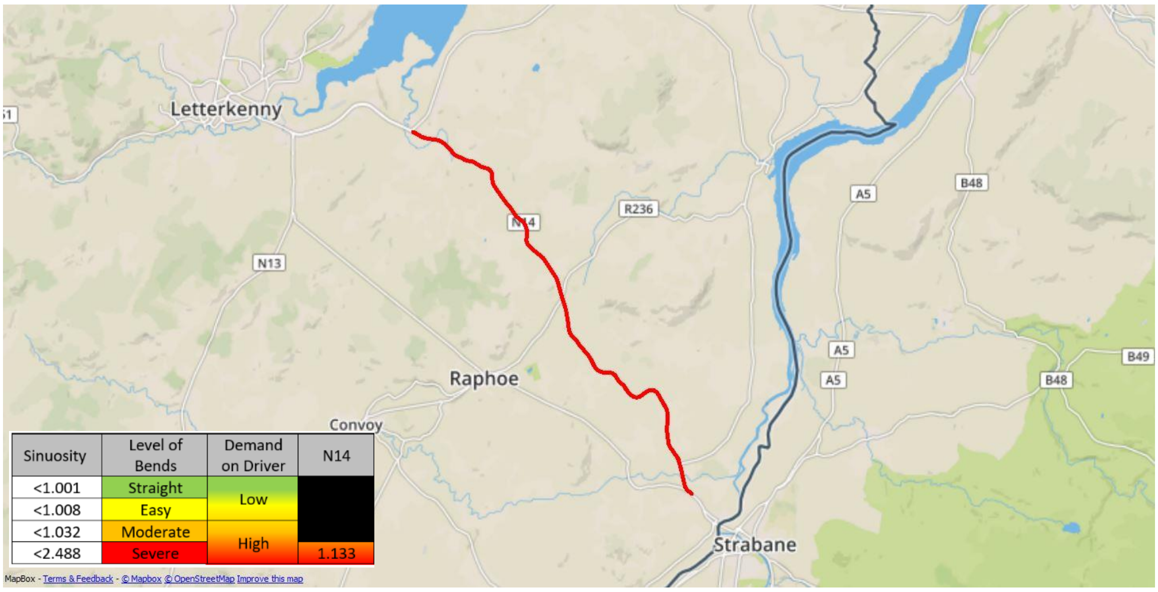


Figure 6.18: Location of N14 Case Study

As it is a National primary road, the Default Speed Limit of 100 km/h is applied throughout. There are no areas with a Special Speed Limit applied. The route was captured 3 times in each direction.

COLLISION HISTORY

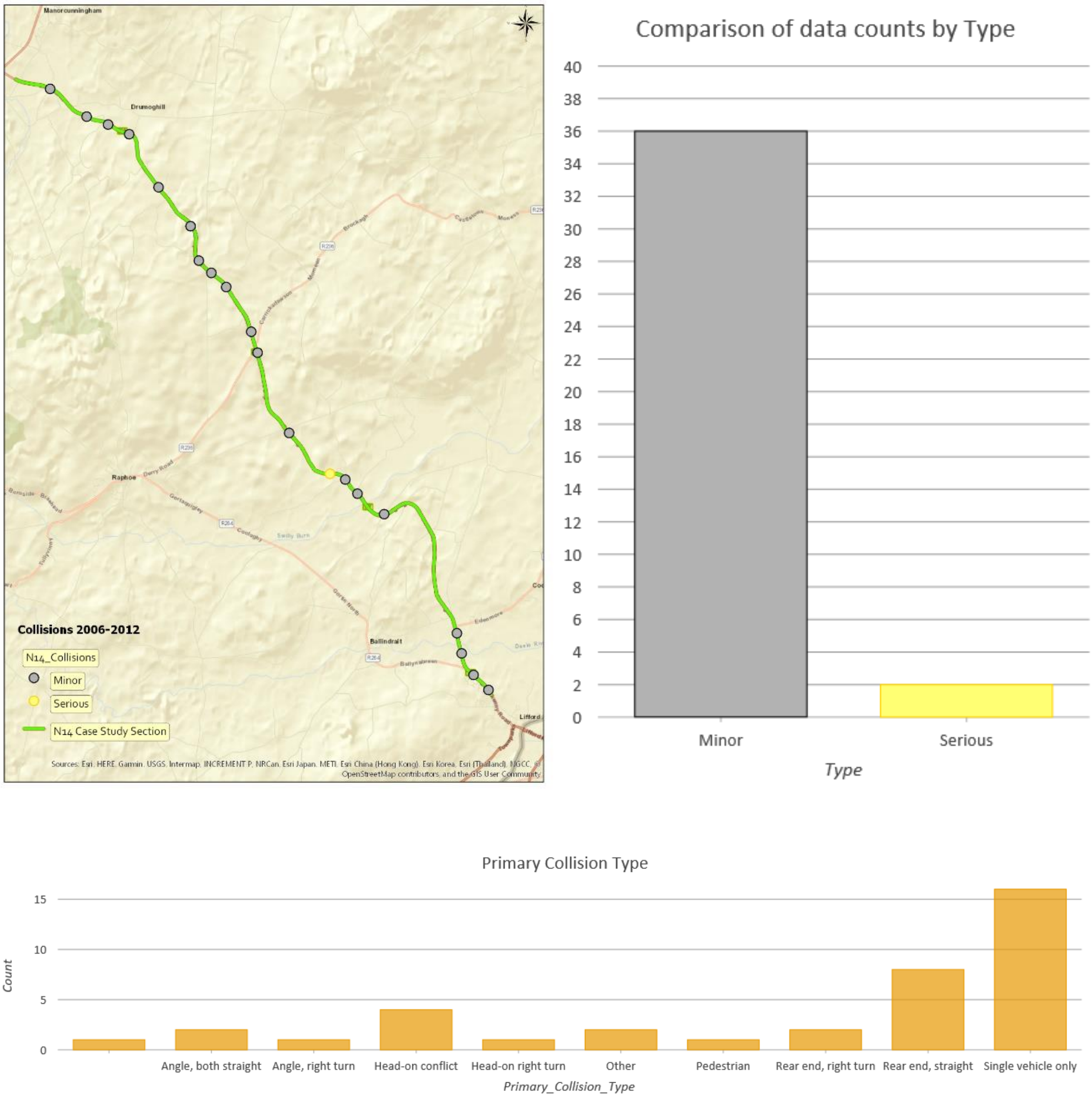


Figure 6.19: N14 Case Study – Collision History

In the period 2006-2012 there was a total of 38 collisions on this section of the N14 between Lifford and Manorcunningham - 36 minor and 2 serious. 16 of these collisions were single vehicle collisions, 10 were rear-end collisions and 4 were head on collisions.

COLLISIONS IN POORLY PERFORMING SECTION

The V_{sp} analysis will show that the section between Lifford and Manorcunningham is performing poorly over the whole of its length. The route is travelled at speeds of more than 20 km/h below the posted speed limit for 71% of the time in the Westbound direction. The section is generally a narrow single carriageway with no hard shoulders except for a short section at either end that is wider with hard shoulders. From 2006-2012 there was a total of 38 collisions - 36 minor and 2 serious; 16 of these collisions were single vehicle collisions, 10 were rear-end collisions and 4 were head on collisions. Nine collisions occurred in a section approximately 475m long, in two clusters, one of 6 collisions and one of 3 collisions, shown below. The points have been moved slightly to avoid clutter and enable clear display. The V_{sp} recorded in this section ranges from 72 km/h to 68 km/h.

Figure 6.20: N14 Collisions – Clustered Section

EASTBOUND

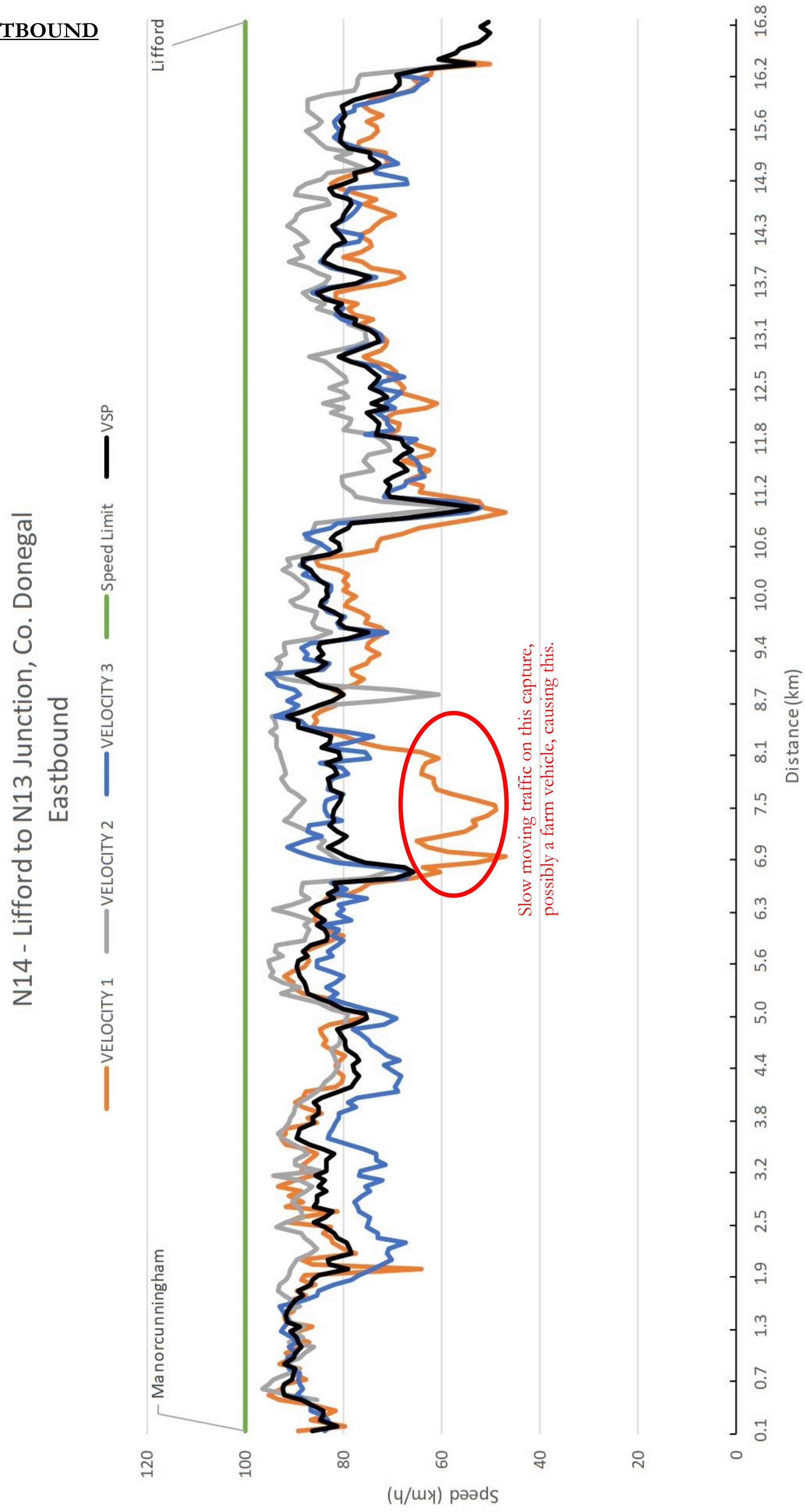


Figure 6.21: N14 velocities, V_{sp} and speed limit – Eastbound

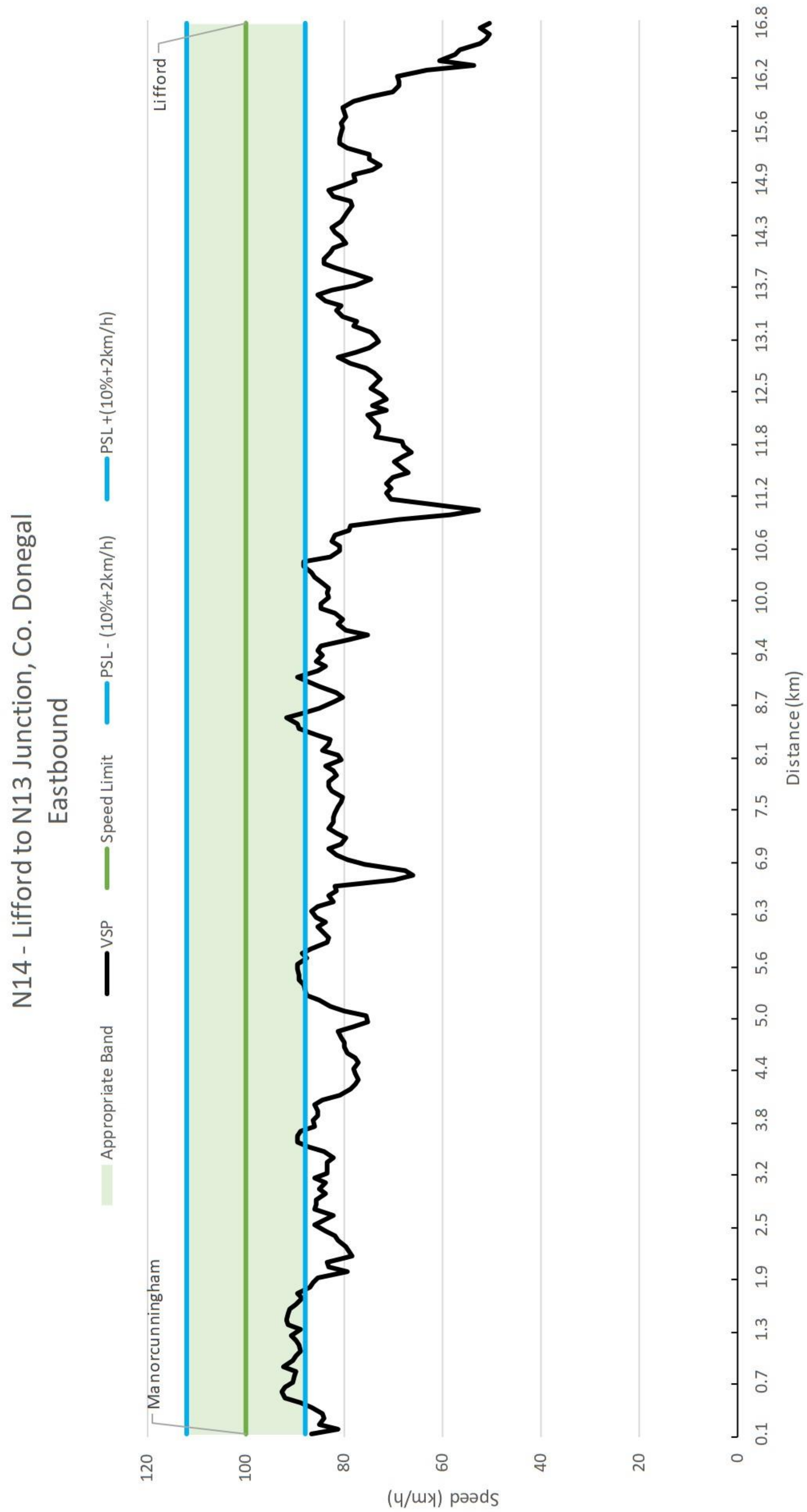


Figure 6.22: N14 V_{sp}, speed limit and 'appropriate' band - Eastbound

Speed Distribution, Route Efficiency And Efficiency Index

N14 - EASTBOUND	Above Posted Speed Limit					Max V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	92.60
GPS Observations	0	0	0	0	0	Min V_{sp}
% of Route	0.00%	0.00%	0.00%	0.00%	0.00%	50.36
	Below Posted Speed Limit					Ave V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	80.22
GPS Observations	0	13	61	97	100	85th %
% of Route	0.00%	4.80%	22.51%	35.79%	36.90%	87.48

Table 6.7: N14 Eastbound Speed Distribution

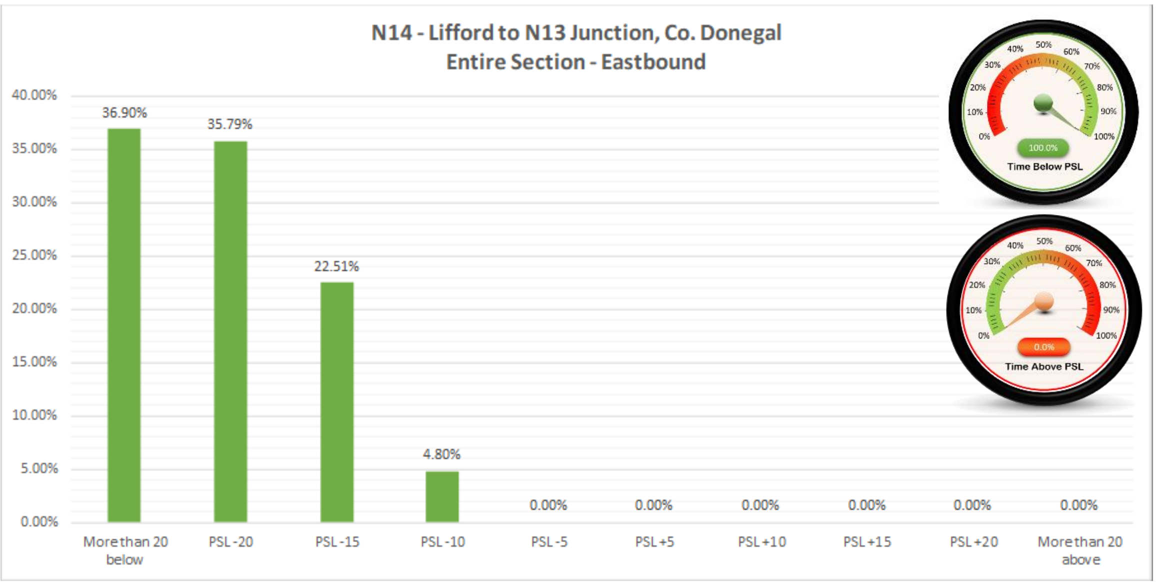
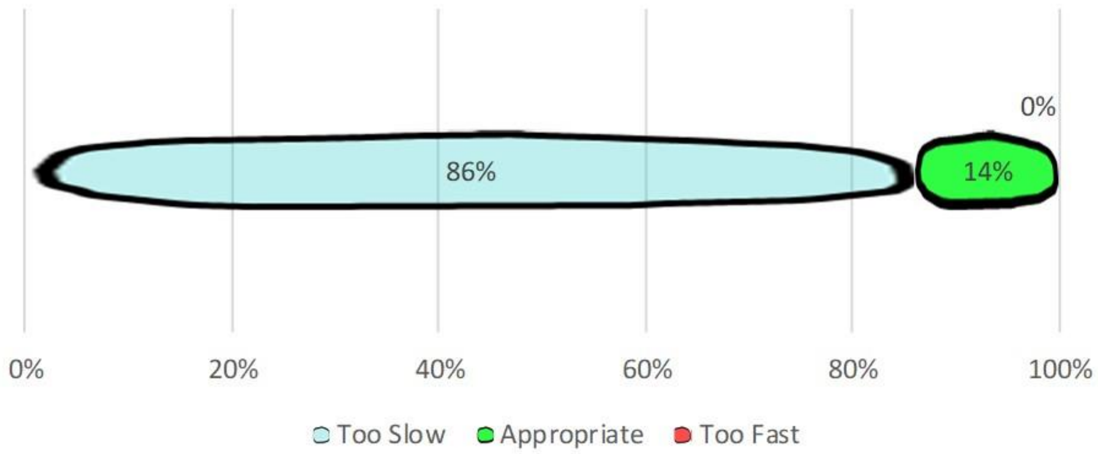


Figure 6.23: N14 Eastbound Speed Distribution

Figure 6.21 shows that Velocity 1 experienced a prolonged slowing down/speeding up over a 1.5km section about half way along the section. These occurrences are unavoidable, especially on narrow sections. The V_{sp} calculation process attempts to account for this and reduce the effects of these on the overall V_{sp} profile. We can see from the charts that the route is travelled below the speed limit for 100% of the time, which is positive, however, over 70% is spent at least 15km/h below, indicating that the speed limit is 'unattainable'. There is no doubt that the driver doesn't accept the speed limit here.

Traffic is travelling too slowly relative to the posted speed limit. Because so long is spent at such low speeds the Efficiency Index can be expected to be poor. The charts below confirm this. The 'appropriate' band for this route is 88 km/h to 112 km/h. Applying Route Efficiency to the V_{sp} (visualised in Figure 6.22) reveals that traffic is travelling in the 'appropriate' band for only 14% of the time, with traffic deemed to be travelling too slowly 86% of the time.

This results in an Efficiency Index of 0.14 for the N14 Eastbound between Lifford and the N13 junction, which can be deemed to be very poor (Figure 6.4). Consequently, 100 km/h per hour is not an appropriate speed limit for this route.



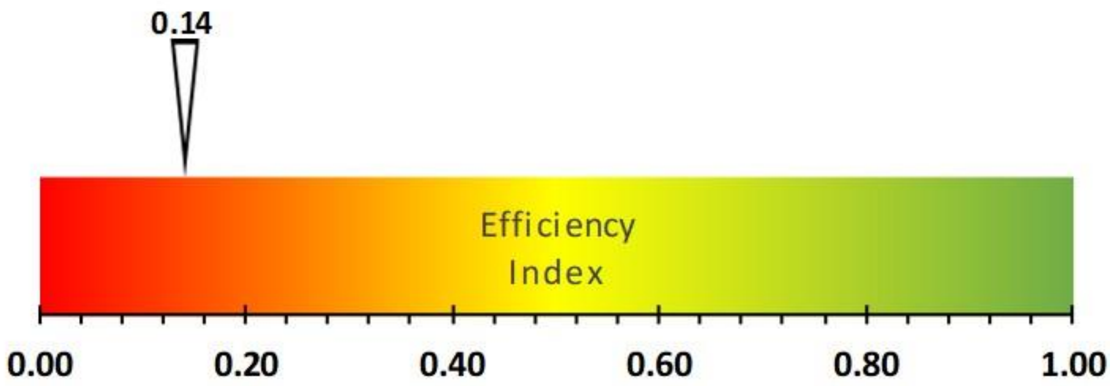


Figure 6.24: N14 Eastbound Route Efficiency & Efficiency Index

WESTBOUND

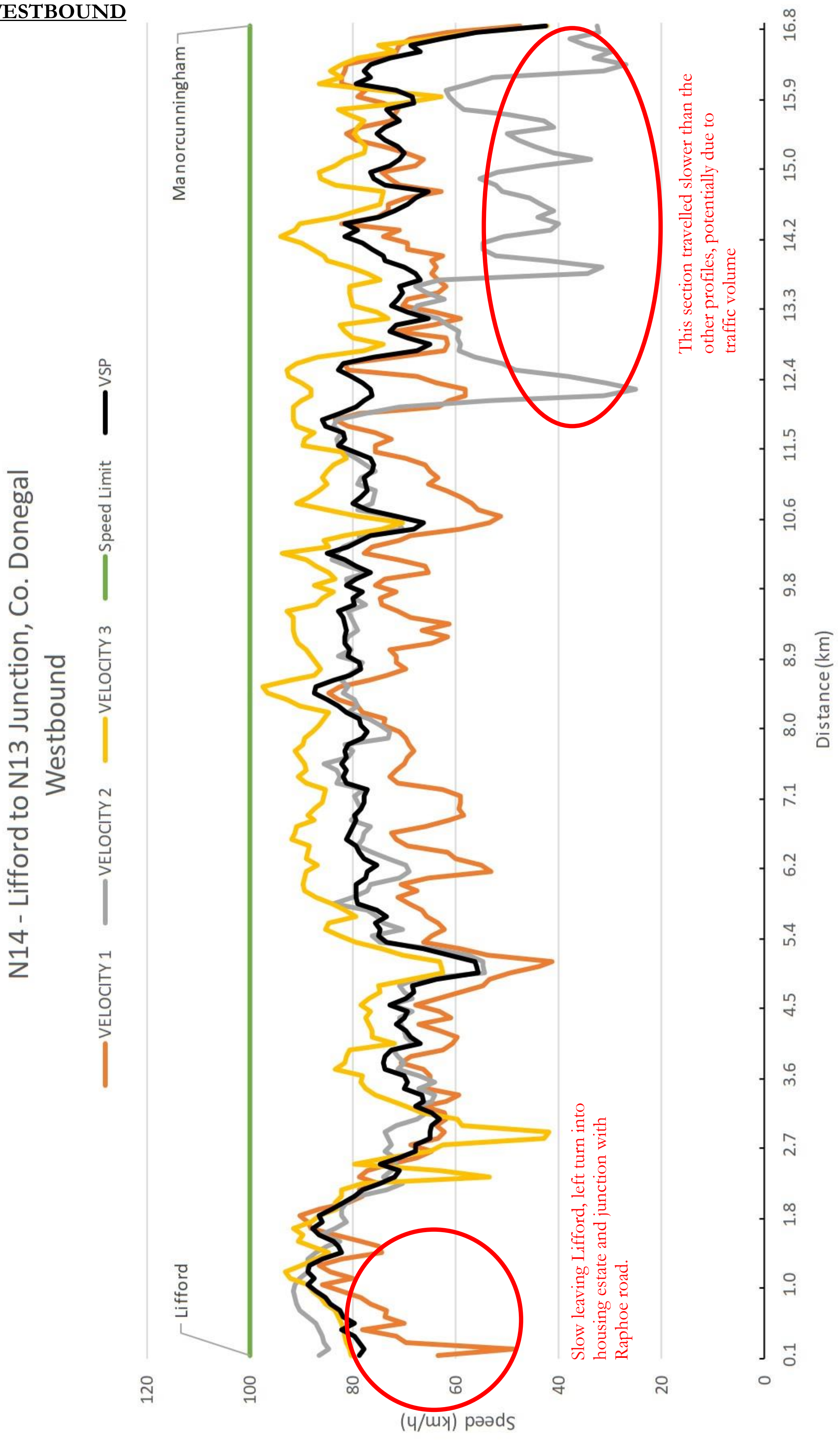


Figure 6.25: N14 velocities, V_{sp} and speed limit - Westbound

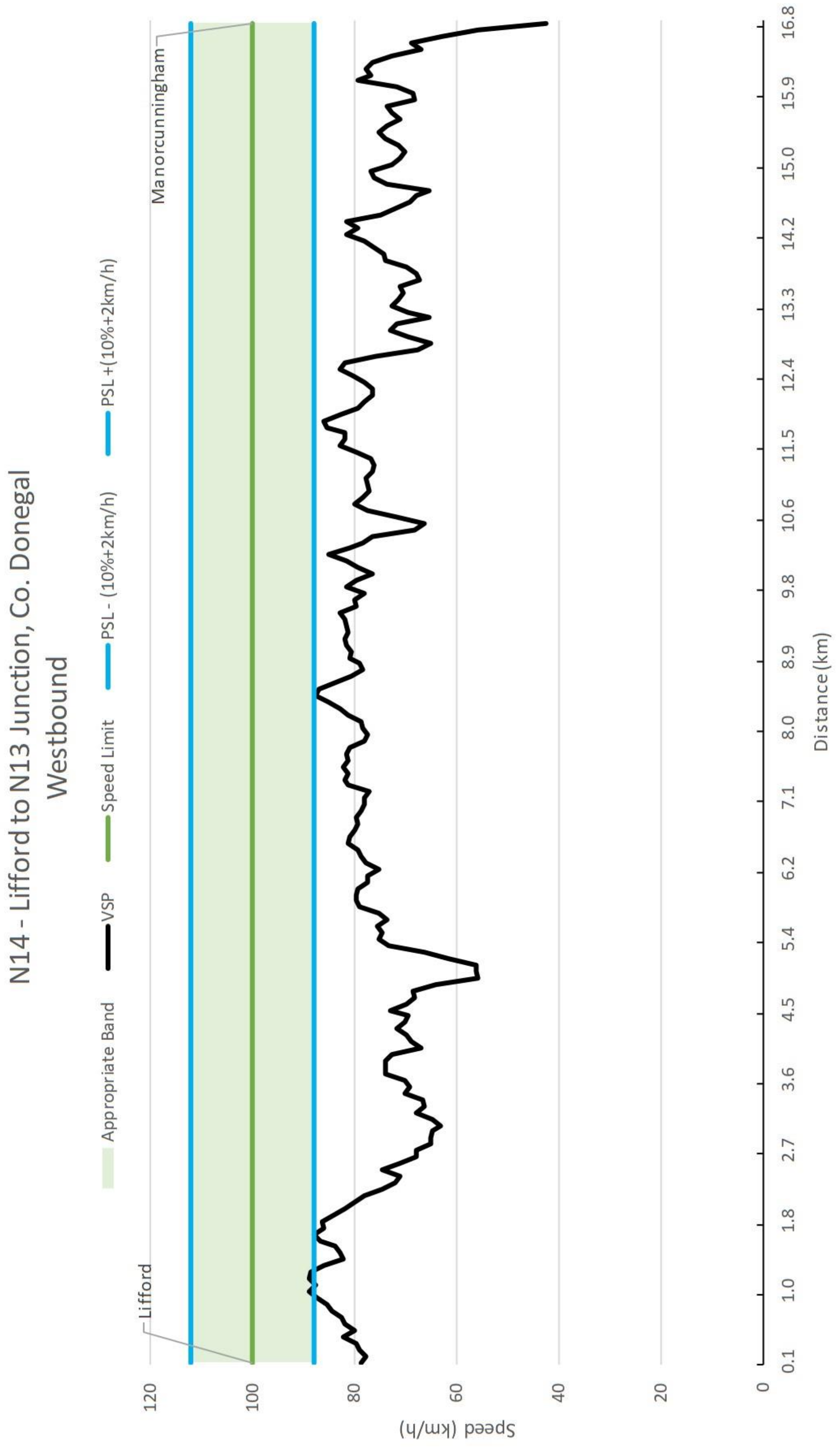


Figure 6.26: N14 V_{sp}, speed limit and 'appropriate' band - Westbound

Speed Distribution, Route Efficiency And Efficiency Index

N14 - WESTBOUND	Above Posted Speed Limit					Max V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	88.81
GPS Observations	0	0	0	0	0	Min V_{sp}
% of Route	0.00%	0.00%	0.00%	0.00%	0.00%	42.55
	Below Posted Speed Limit					Ave V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	75.82
GPS Observations	0	0	16	46	148	85th %
% of Route	0.00%	0.00%	7.62%	21.90%	70.48%	82.05

Table 6.8: N14 Westbound Speed Distribution

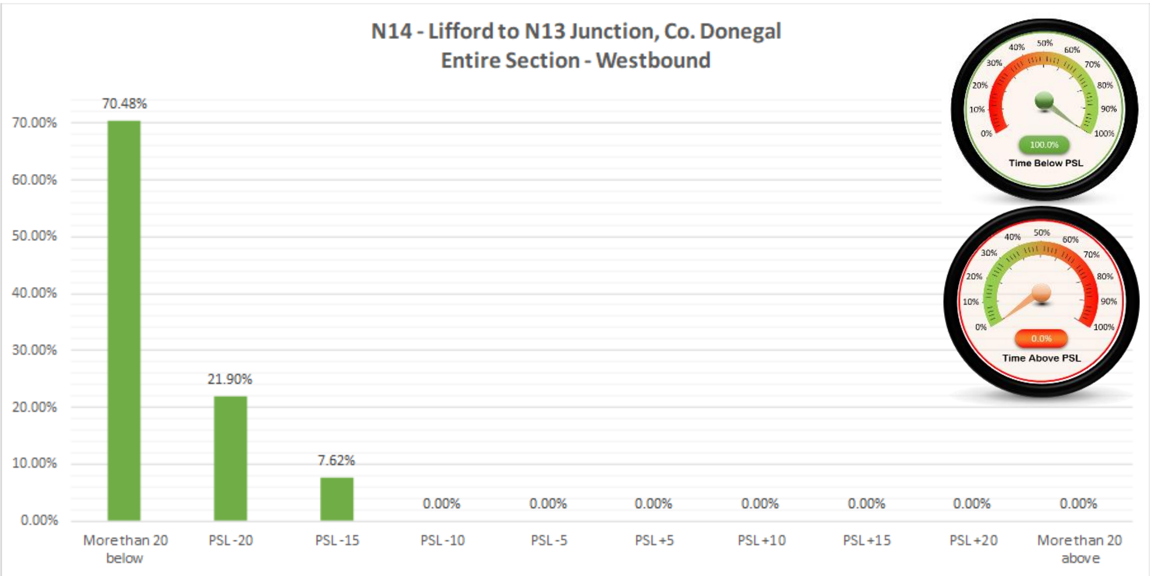


Figure 6.27: N14 Westbound Speed Distribution

In this direction we can see that the route is performing even worse than in the Eastbound direction. Traffic is travelling below the speed limit for 100% of the time but 70% of that is at speeds more than 20 km/h below the posted speed limit of 100 km/h. There is, yet again, no doubt in the mind of the driver that the speed limit is inappropriate and is unattainable. A very poor Efficiency Index is to be expected here. Appropriate band analysis shows that traffic only travels in this band for 1% of the time with the remainder being in the 'too slow' bracket.

This results in an Efficiency Index of 0.01 for the N14 Westbound between Lifford and the N13 Junction, which can be deemed to be very poor (Figure 6.4). A speed limit of 100 km/h per hour is not an appropriate speed limit for this route.

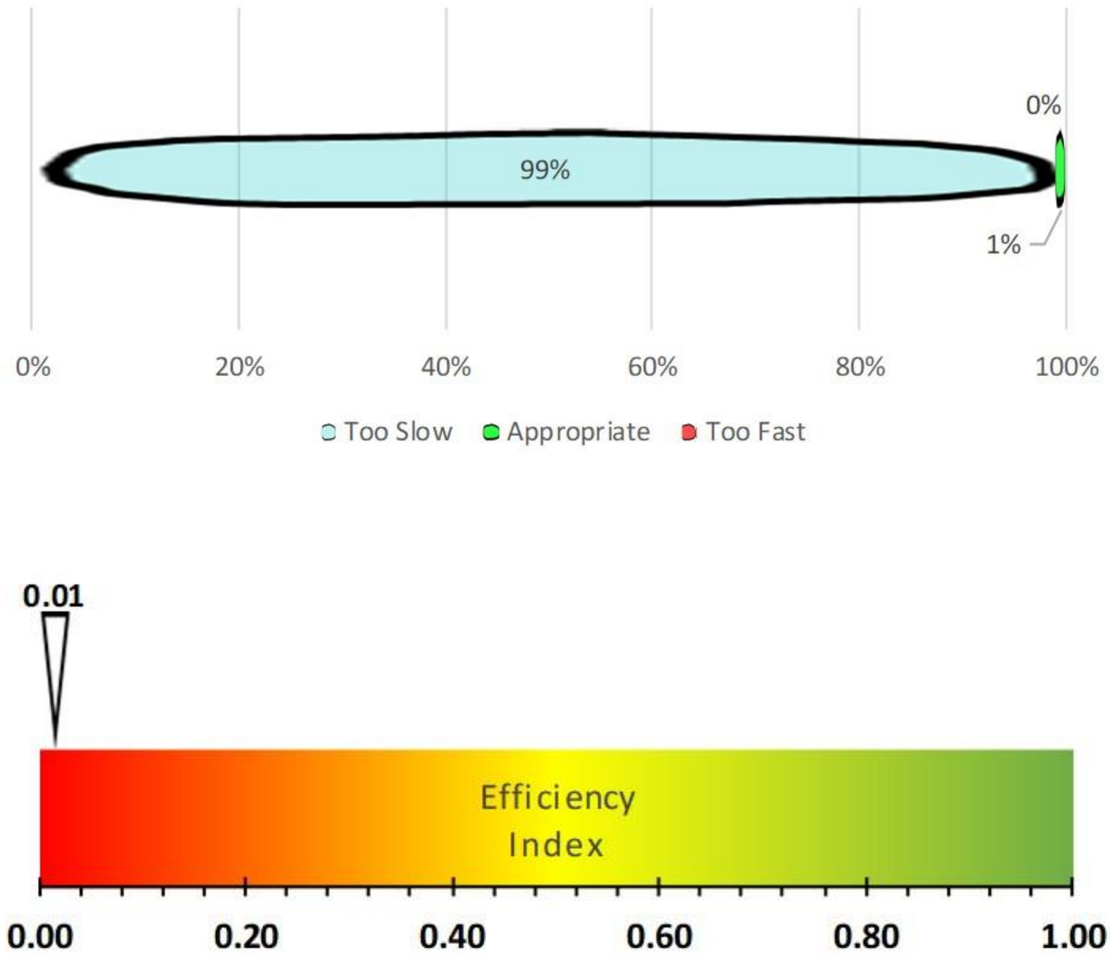


Figure 6.28: N14 Westbound Route Efficiency & Efficiency Index

EFFECT OF ALTERING THE SPEED LIMIT

The default speed limit of 100 km/h is clearly not an appropriate speed limit for this route. Overall, in both directions, the route is performing badly with very poor Efficiency Index values being returned. As the Efficiency Index is very poor with the Default Speed Limit applied, any alteration (reduction) would result in an improvement in the EI, however, the goal should be to select a speed limit that will result in a relatively similar EI being returned for each direction. The following table and figures show the improvement in the Efficiency Index when the speed limit is altered.

	Speed Limit	Efficiency Index Eastbound	Efficiency Index Westbound
Existing	100 km/h	0.14	0.01
Altered Scenario 1	80 km/h	**0.85**	**0.79**
Altered Scenario 2	90 km/h	0.69	0.37

Table 6.9: N14 Efficiency Index – Altered Speed Limits

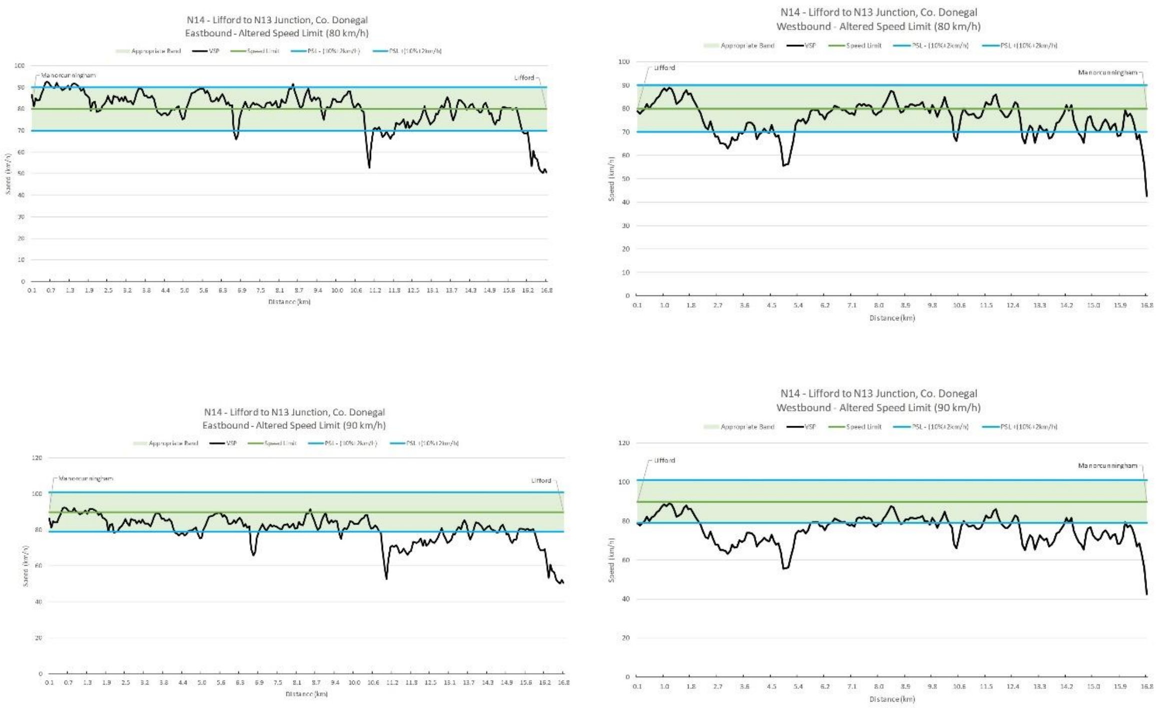


Figure 6.29: N14 – V_{sp} and Appropriate Bands (Altered Speed Limits)

CONCLUSIONS

The Speed Distribution tables show that motorists are stating quite clearly that the speed limit on this road is inappropriately high, they are not able to make full use of it, in either direction. Of course, speed limits are not targets, however, drivers tend to strive to reach the speed limit, the easier it is to safely travel close to the speed limit, the more likely it is the speed limit is set correctly. On this route it is almost impossible to safely drive for a sustained period near to the speed limit due to the narrow carriageway and frequent slow bends combined with the relatively high level of traffic - this is reflected in the very poor Efficiency Index values returned.

In this case, 90 km/h is not an appropriate choice of speed limit - while it does result in an improvement in the EI, there is a large difference between the EI values in each direction – 0.69 Eastbound and 0.37 Westbound. As stated previously, the goal should be to affect positive change in both directions that results in a similar performance in each direction.

Changing the speed limit to 80 km/h has a positive effect on the EI in both directions, resulting in EI values of 0.85 and 0.79, giving a more consistent performance in both directions and as such appears to be the appropriate speed limit for this route.

6.3.3 N51 – Delvin, Co. Meath to Drogheda, Co. Louth

The section of the N51 chosen for analysis commences at Delvin, Co. Westmeath and continues eastwards through the towns of Athboy, Navan and Slane, Co. Meath, through to Drogheda, Co. Louth. It is 53km in length, carries 5,906 vehicles per day (2016 figures) and has experienced 67 collisions over the period 2006-2012.

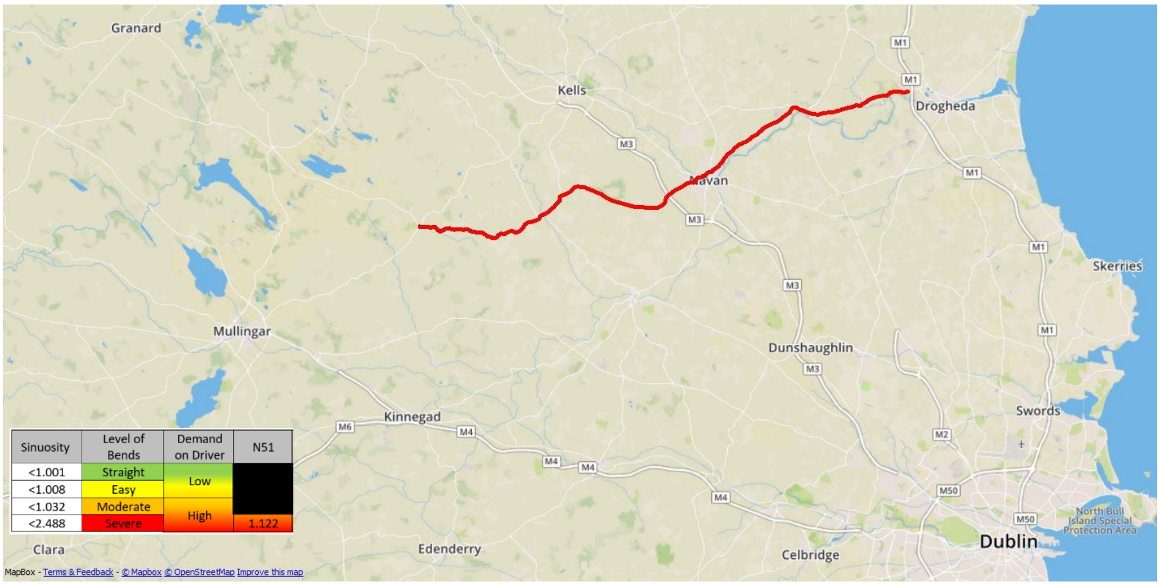


Figure 6.30: Location of N51 Case Study

As it is a National secondary road the Default Speed Limit is 100 km/h, however, it is only applied to the section within Co. Westmeath, as the entire section of the N51 in Co. Meath is subject to a Special Speed Limit of 80 km/h, except for a short section of dual carriageway outside Navan where the Default Speed Limit of 100 km/h is applied. Built-up area speed limits are applied in the towns and Special Speed Limits of 60 km/h are applied at the approaches. A Special Speed Limit of 30 km/h is applied in Slane, Co. Meath. When the route crosses into Co. Louth, the Default Speed Limit of 100 km/h resumes.

COLLISION HISTORY

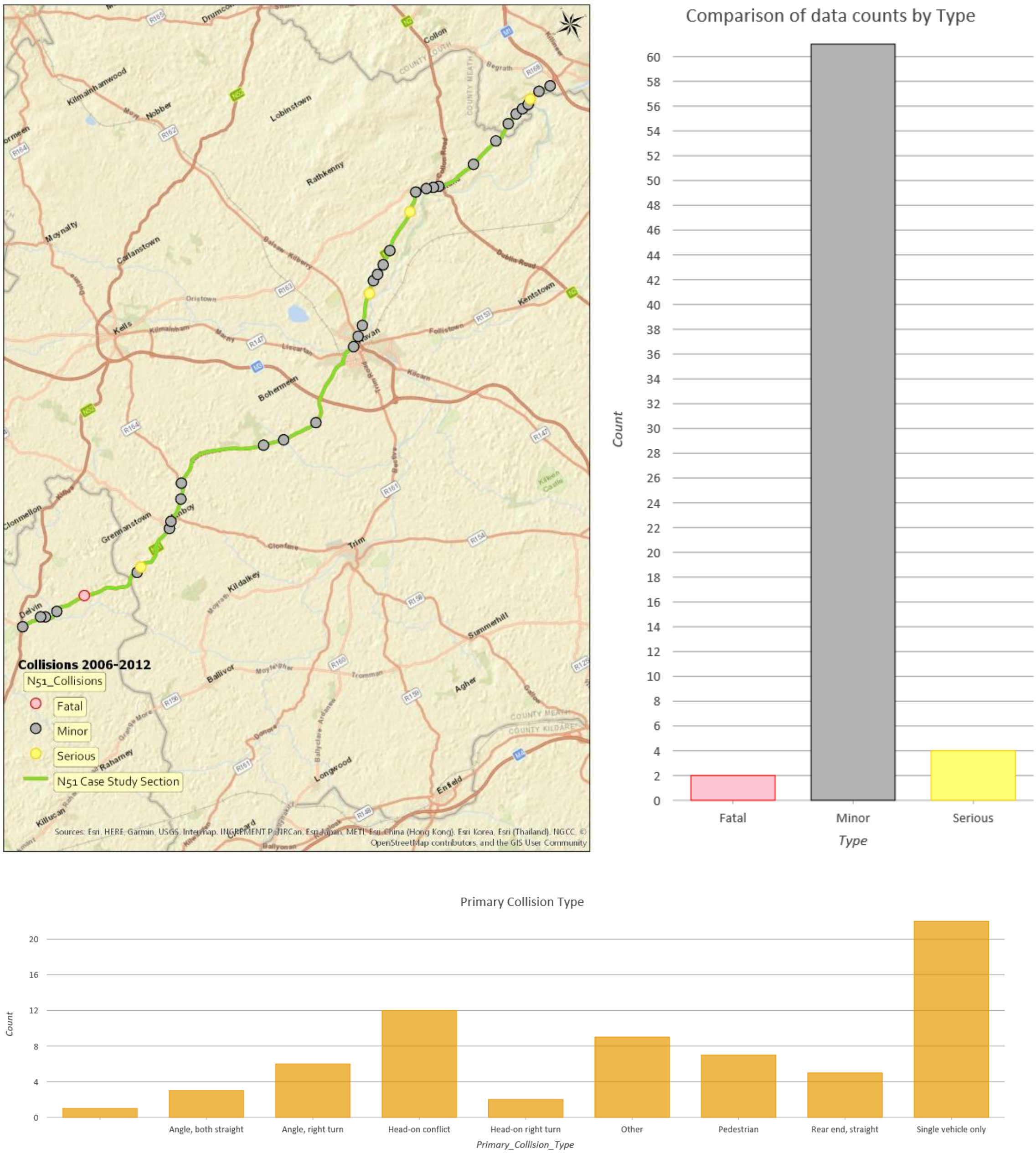
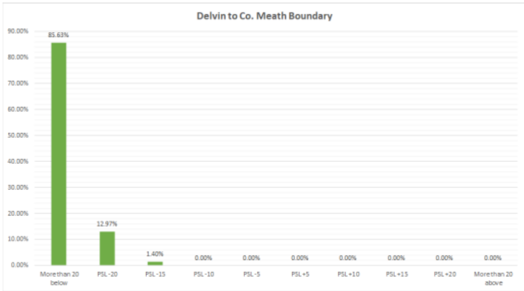


Figure 6.31: N51 Case Study – Collision History

In the period 2006-2012 there was a total of 67 collisions on the N51 between Delvin and Drogheda - 61 minor, 4 serious and 2 fatal collisions. Twelve of these collisions were head on collisions with 5 rear end collisions and 22 single vehicle collisions.

COLLISIONS IN POORLY PERFORMING SECTION

The section of the N51 from its junction with the N52 to the Meath County boundary has the Default speed limit of 100 km/h applied and is shown later to be performing poorly with V_{sp} observed to be over 20 km/h below the speed limit 85% of the time.



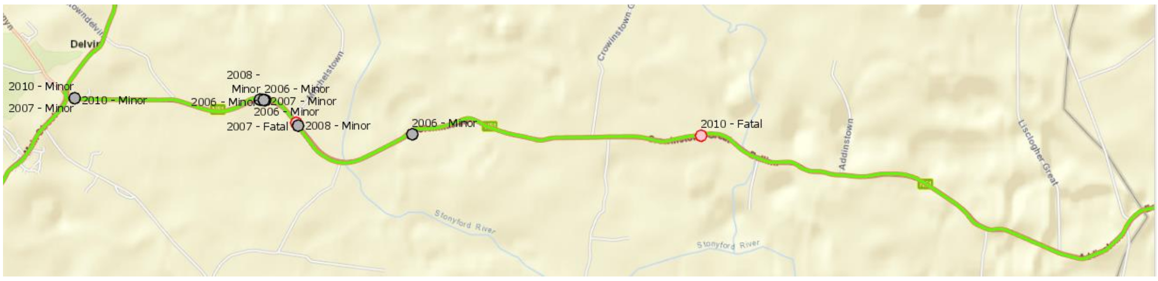


Figure 6.32: N51 Collisions – Clustered Section

In this section, there were 2 head-on collisions, 7 single vehicle collisions and 1 collision involving a pedestrian. There were 2 fatalities, one of which (in 2007) is in the vicinity of junction. The V_{sp} in this section ranges from 74 km/h to 78 km/h and the carriageway width is around 2.75m, this section has a speed limit of 100 km/h. This may be a factor in the collisions, slow moving traffic could be causing frustration leading to drivers taking overtaking risks because the speed limit is much higher than the free-flowing speeds.

EASTBOUND

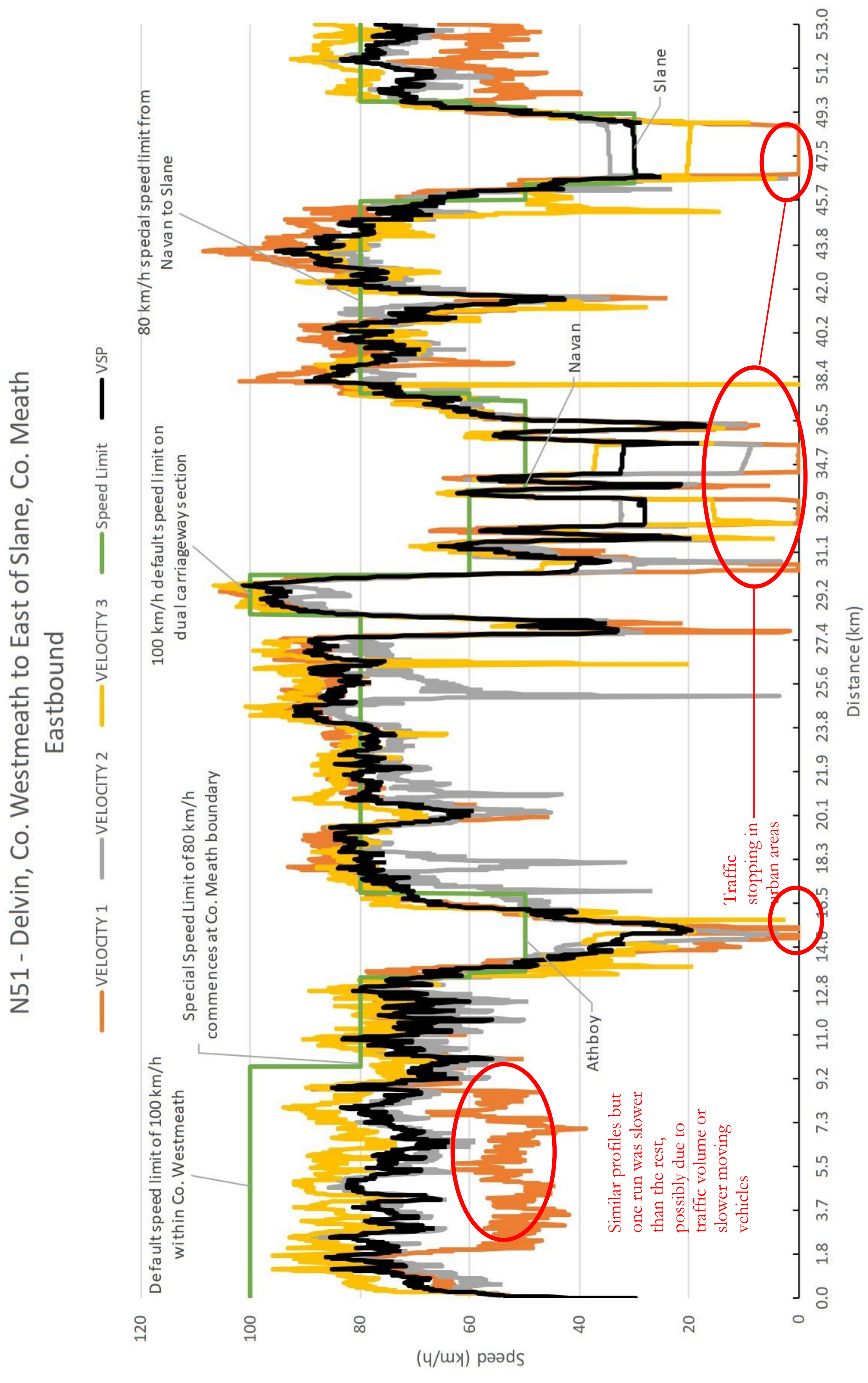


Figure 6.33: N51 velocities, V_{sp} and speed limit - Eastbound

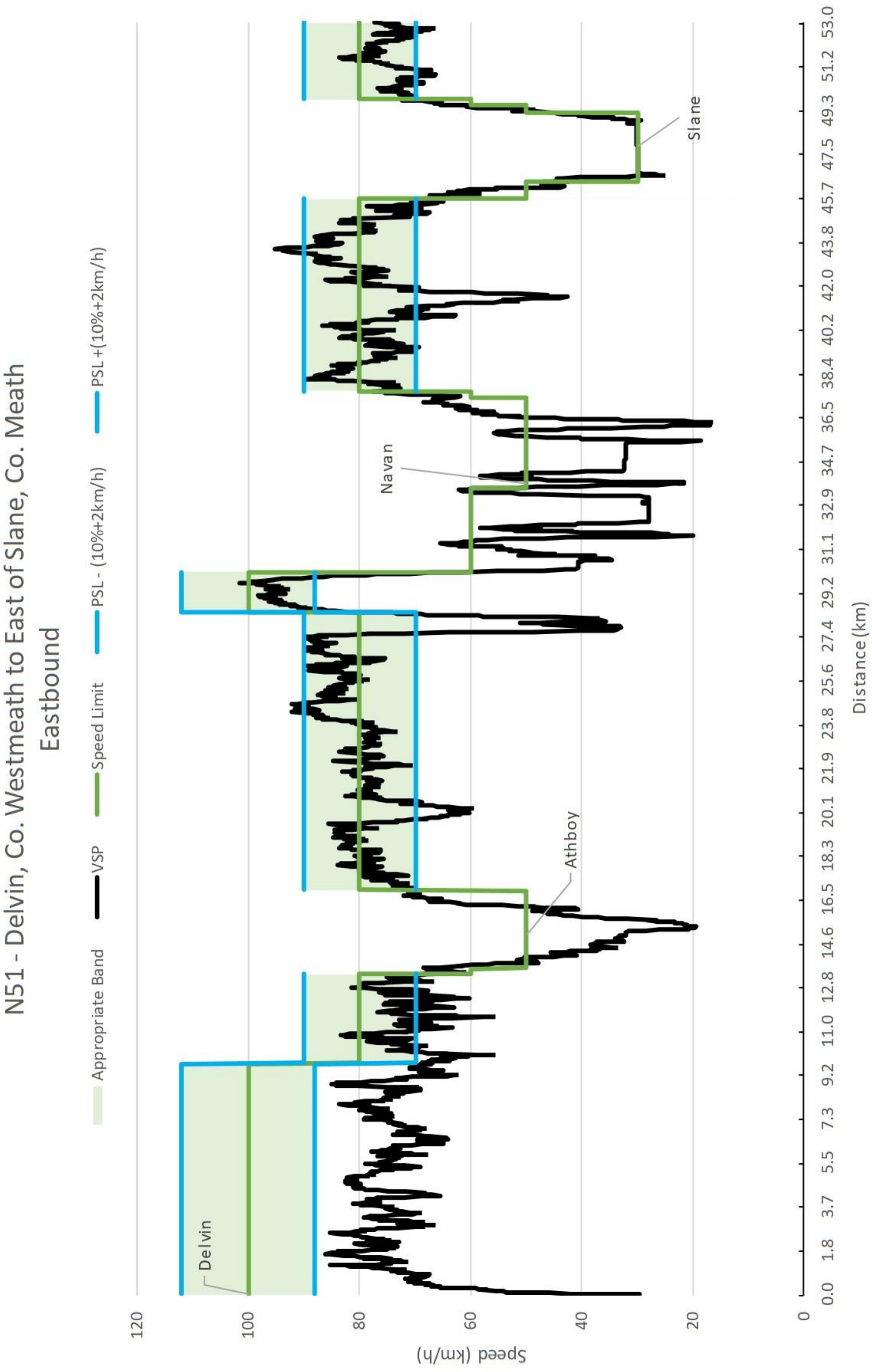


Figure 6.34: N51 V_{sp}, speed limit and 'appropriate' band - Eastbound

Speed Distribution, Route Efficiency And Efficiency Index

N51 - EASTBOUND	Above Posted Speed Limit					Max V_{sp}
	0-5 km/h	**5-10 km/h**	**10-15 km/h**	**15-20 km/h**	**>20 km/h**	86.17
GPS Observations	274	164	24	1	0	**Min V_{sp}**
% of Route	13.92%	8.33%	1.22%	0.05%	0.00%	29.70
	Below Posted Speed Limit					**Ave V_{sp}**
	0-5 km/h	**5-10 km/h**	**10-15 km/h**	**15-20 km/h**	**>20 km/h**	73.50
GPS Observations	428	301	151	125	500	**85th %**
% of Route	21.75%	15.29%	7.67%	6.35%	25.41%	79.95

Table 6.10: N51 Eastbound Speed Distribution

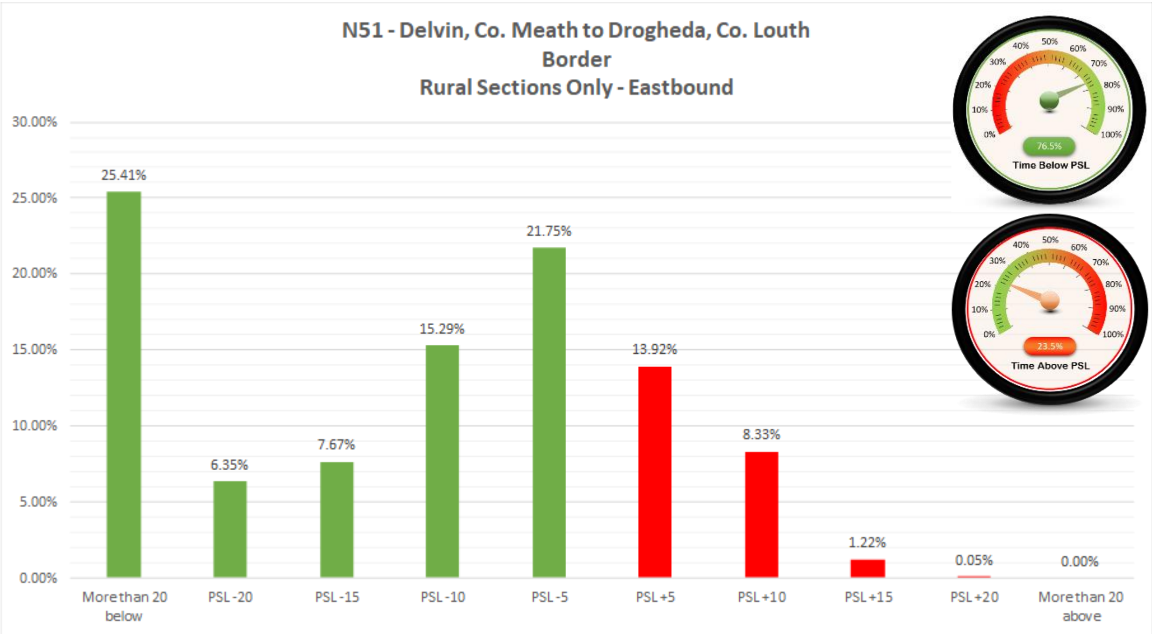
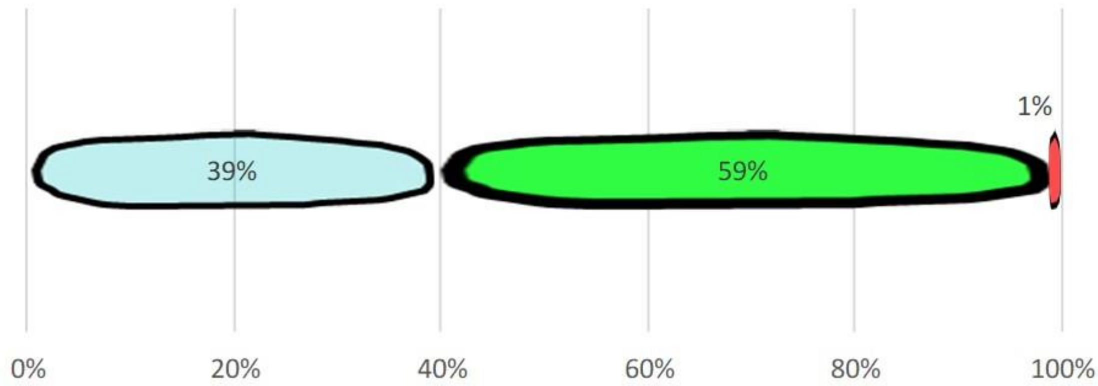


Figure 6.35: N51 Eastbound Speed Distribution

In this direction, the route is travelled below the speed limit for almost 77% of the time, and, over a section 53km in length, this could be considered significant. The driver is indicating that speed limits on this route are affecting the performance of the road. 31% of this time is spent travelling at a speed more than 20 km/h below and a further 35% of time is spent driving within 5 km/h of the speed limit. Figure 6.34 reveals, however, that the section between Delvin and the County Boundary outside Athboy at the beginning of the route is considerably affecting the Route Efficiency and hints at a fair EI being returned.

This is the case, looking at the V_{sp} in terms of the 'appropriate' band we determine that traffic is travelling at an appropriate speed for 59% of the time, which is reasonable. This results in an Efficiency Index of 0.59. This would be much higher if the section at the beginning had a reduced speed limit of 80 km/h applied. This is a good example of a situation where Local Authorities should work together and consider their speed limits on routes that cross County Boundaries.



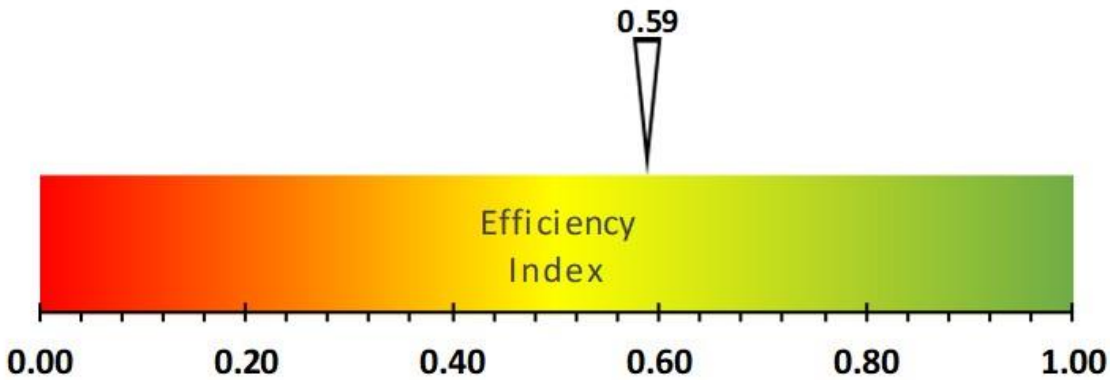


Figure 6.36: N51 Eastbound Route Efficiency & Efficiency Index

WESTBOUND

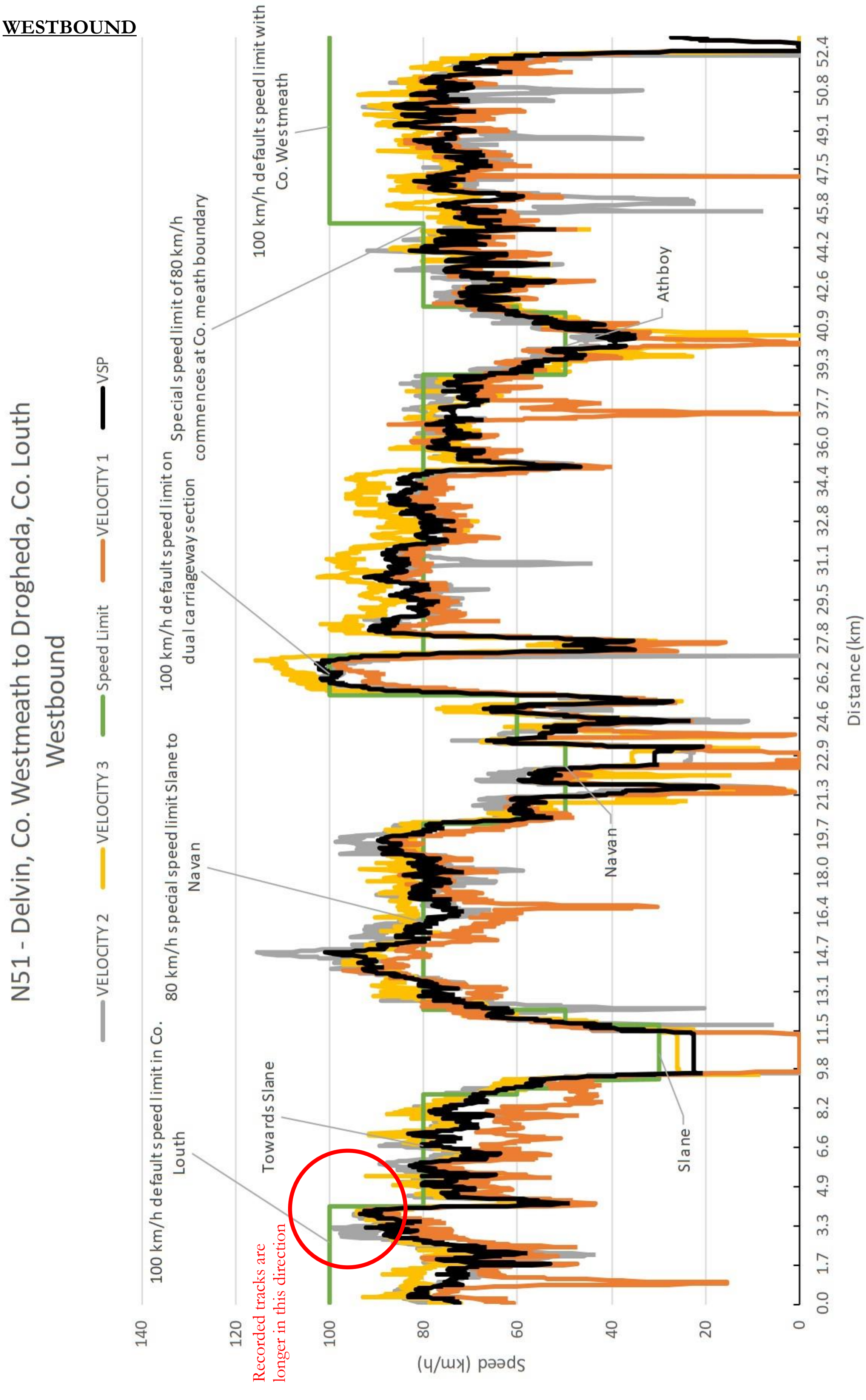


Figure 6.37: N51 velocities, V_{sp} and speed limit - Westbound

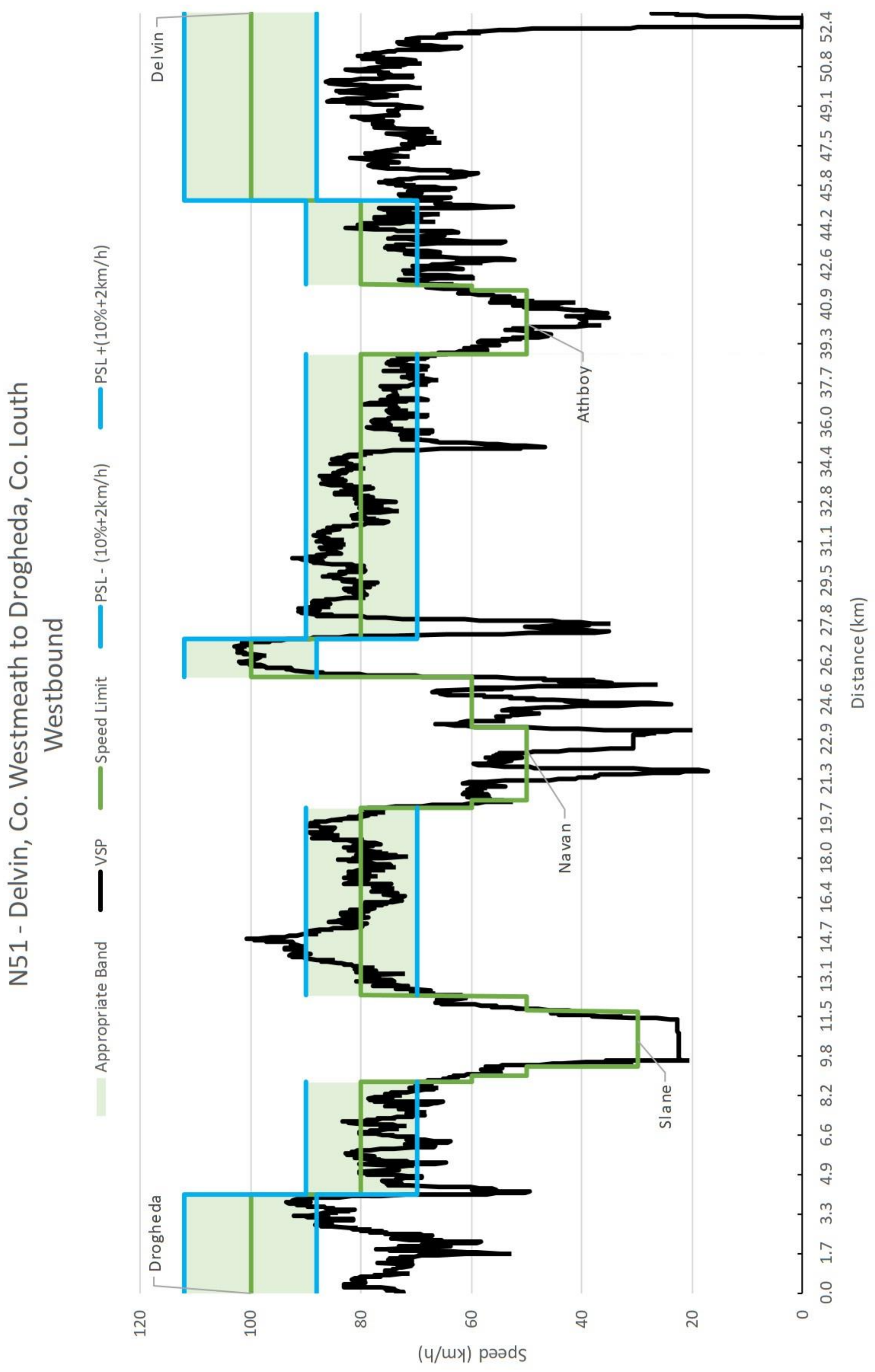


Figure 6.38: N51 V_{sp}, speed limit and 'appropriate' band - Westbound

Speed Distribution, Route Efficiency And Efficiency Index

N51 - Westbound	Above Posted Speed Limit					Max V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	92.18
GPS Observations	352	198	57	10	1	Min V_{sp}
% of Route	14.73%	8.29%	2.39%	0.42%	0.04%	53.22
	Below Posted Speed Limit					Ave V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	76.36
GPS Observations	402	372	237	123	617	85th %
% of Route	16.83%	15.57%	9.92%	5.15%	25.83%	85.47

Table 6.11: N51 Westbound Speed Distribution

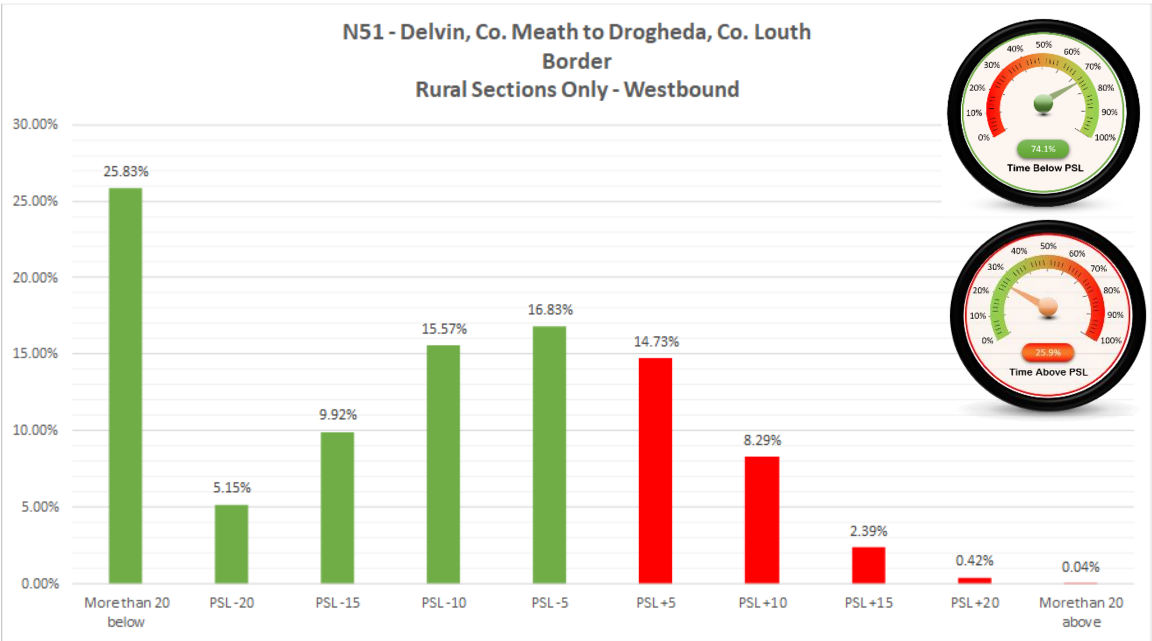


Figure 6.39: N51 Westbound Speed Distribution

A very similar performance is observed in the Westbound direction, 74% of time is spent below the speed limit with 26% spent more than 20 km/h below the speed limit and 31% of time within 5 km/h. Again, the section between Delvin and the County Boundary is having a significant effect on Route Efficiency, a fair Efficiency Index can be expected due to the fact around 56% of time is spent within 10 km/h of the speed limit.

Again, this turns out to be the case, looking at the V_{sp} in terms of the 'appropriate' band we determine that traffic is travelling at an appropriate speed for 56% of the time, which is reasonable. This results in an Efficiency Index of 0.56 and, as in the Eastbound direction, it would be much higher if the section at the Delvin end had a reduced speed limit of 80 km/h applied. The GPS tracks recorded in this direction are slightly longer than Eastbound and includes a longer section between Drogheda and Slane that crosses the County Boundary and into a higher speed limit in Co. Louth (80 km/h to 100 km/h) that is performing poorly as well.

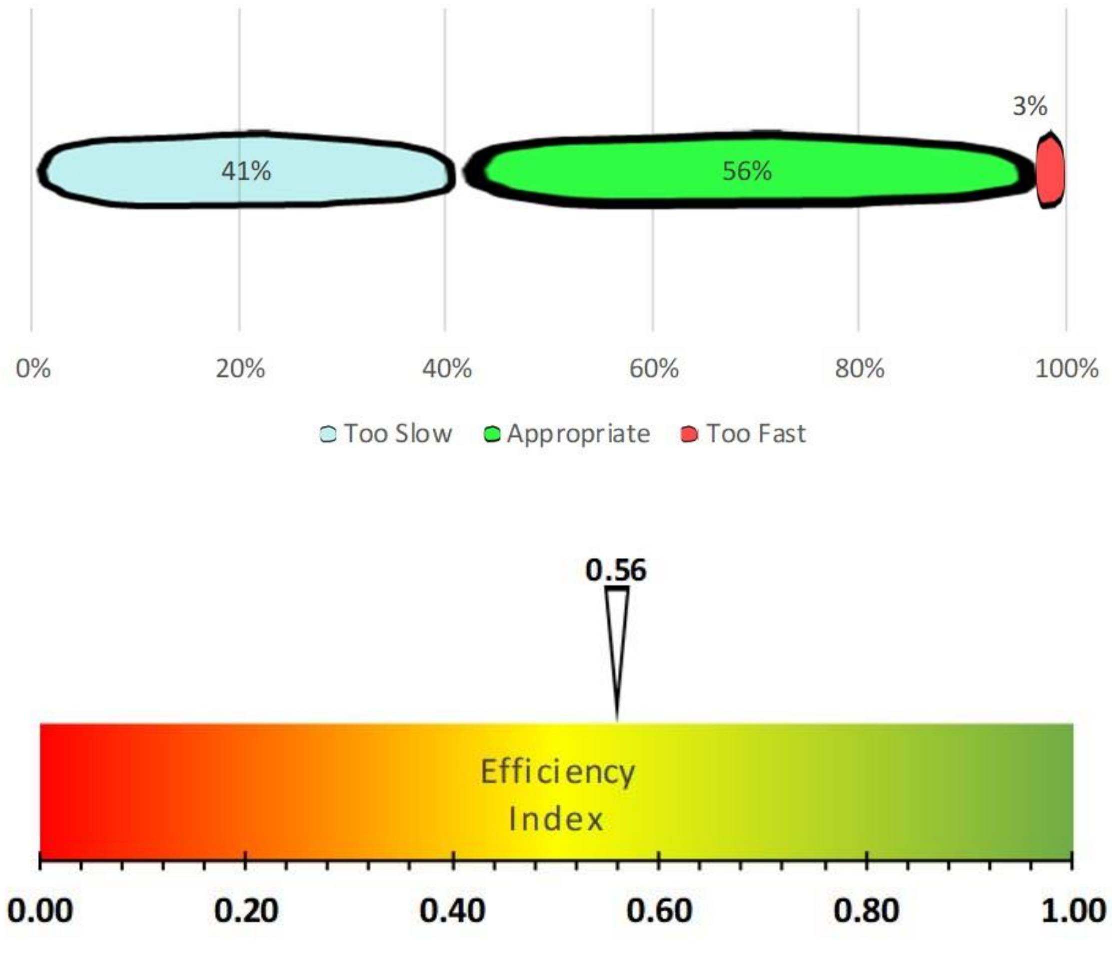


Figure 6.40: N51 Westbound Route Efficiency & Efficiency Index

EFFECT OF ALTERING THE SPEED LIMIT

It appears from the Efficiency Index values returned and figures that, generally, the speed limit on this road is appropriate except for the 100 km/h sections in Co. Westmeath and Co. Louth. It appears that Meath County Council have applied an acceptable reduced Special Speed Limit of 80 km/h on the single carriageway sections of the N51 in their Administrative Area. Again, the goal should be to select a speed limit that will result in a relatively similar EI being returned for each direction. Table 6.12 and Figure 6.41 shows the improvement in the Efficiency Index when the speed limit is altered.

	Section	Speed Limit	Efficiency Index Eastbound	Efficiency Index Westbound
Existing Configuration	Delvin-Co. Meath boundary	100 km/h	0.59	0.56
	Co. Meath boundary – Athboy	80 km/h		
	Athboy-Navan (dual c/way)	80 km/h		
	Navan dual c/way-Navan	100 km/h		
	Navan-Slane	80 km/h		
	Slane-Co. Louth boundary	80 km/h		
	Co. Louth boundary-Outside Drogheda	100 km/h		
Altered Scenario 1	All Sections Except Dual Carriageway	80 km/h	**0.79**	**0.75**
	Navan dual c/way-Navan	100 km/h		
	Co. Louth boundary-Outside Drogheda	80 km/h		
Altered Scenario 2	All Sections Except Dual Carriageway	90 km/h	0.65	0.62
	Navan dual c/way-Navan	100 km/h		
	Co. Louth boundary-Outside Drogheda	90 km/h		

Table 6.12: N51 Efficiency Index – Altered Speed Limits

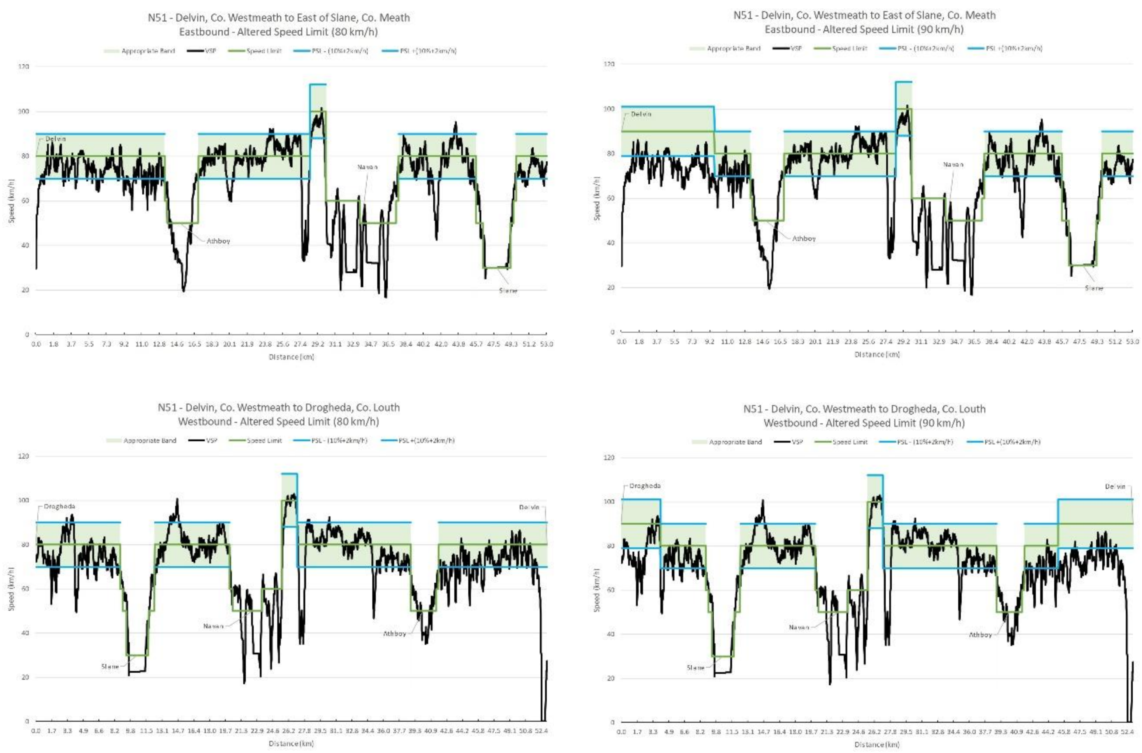


Figure 6.41: N51 – V_{sp} and Appropriate Bands (Altered Speed Limits)

CONCLUSIONS

It appears that the road user is indicating that generally this road is performing moderately, the EI is fair with the sections carrying a reduced Special Speed Limit of 80 km/h appearing to perform well when the V_{sp} is visualised alongside the 'appropriate' band. The sections at the start and end carrying the Default Speed Limit of 100 km/h are having a negative effect on the EI, the speed limit seems to be '*out of reach*' for the driver and is driven entirely below the 'appropriate' band. Altering the speed limit on both of these sections to 80 km/h and to 90 km/h produces an improved EI. The greatest improvement is seen when 80 km/h is chosen; 0.79 in the Eastbound direction and 0.75 in the Westbound direction. While 90 km/h also produces improved EI's, which are similar in each direction, it is not as strong as the 80 km/h option. It appears, therefore, that the appropriate speed limit for this route is 80 km/h throughout the entire section, except for the dual carriageway section outside Navan which is set at the default 100 km/h.

6.3.4 N52 – Mullingar, Co. Westmeath to Kells, Co. Meath

The section of the N52 chosen for analysis commences west of Mullingar, Co. Westmeath and continues north-eastwards through the towns of Delvin and Clonmellon to Kells, Co. Meath. It is 37.8km in length, carries 5,046 vehicles per day (2016 figures) and has experienced 26 collisions over the period 2006-2012.

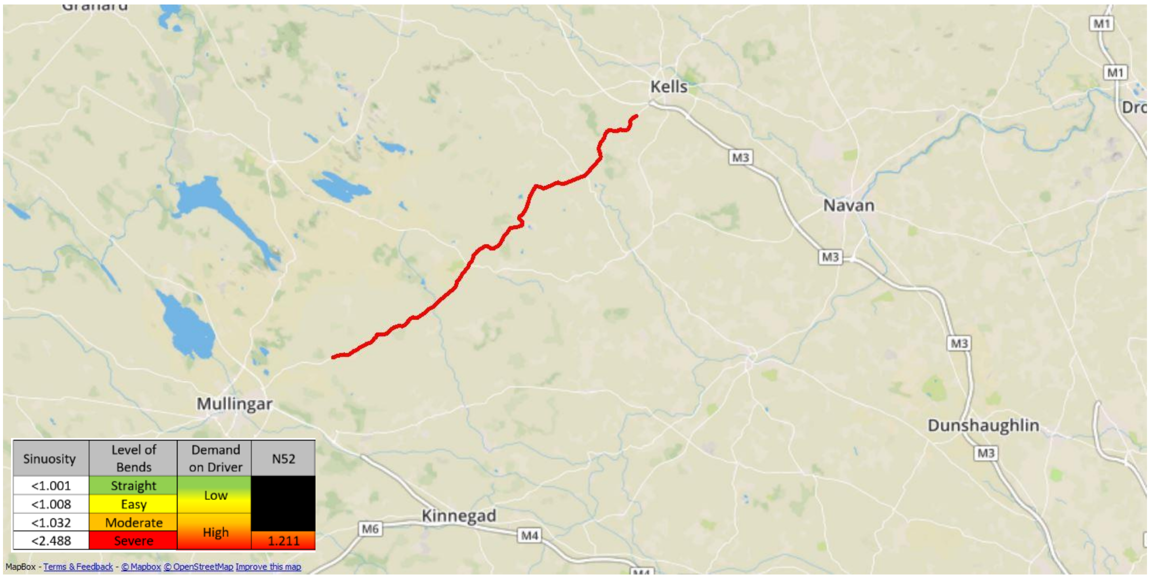


Figure 6.42: Location of N52 Case Study

As it is a National secondary road, the Default Speed Limit is 100 km/h, however, it is only applied to the section within Co. Westmeath, as the entire section of the N51 in Co. Meath is subject to a Special Speed Limit of 80 km/h. Built-up area speed limits are applied in the towns of Delvin and Clonmellon.

COLLISION HISTORY

Figure 6.43: N52 Case Study – Collision History

In the period 2006-2012 there was a total of 26 collisions on the N52 between Mullingar and Kells - 18 minor, 4 serious and 4 fatal collisions. Eleven of these collisions were single vehicle collisions with 3 rear end collisions.

COLLISIONS IN POORLY PERFORMING SECTION

The section of the N52 from Delvin to Clonmellon has a speed limit of 100 km/h applied (Default) and is shown to be performing poorly in terms of its route efficiency with the V_{sp} in this section in the Eastbound direction more than 20 km/h below the speed limit 80% of the time.

In this section, where there was a fatality in 2010, there was also a minor collision involving a single vehicle. This is in the vicinity of a junction and the V_{sp} ranges from 56 km/h to 72 km/h in a section with a Default speed limit of 100 km/h.

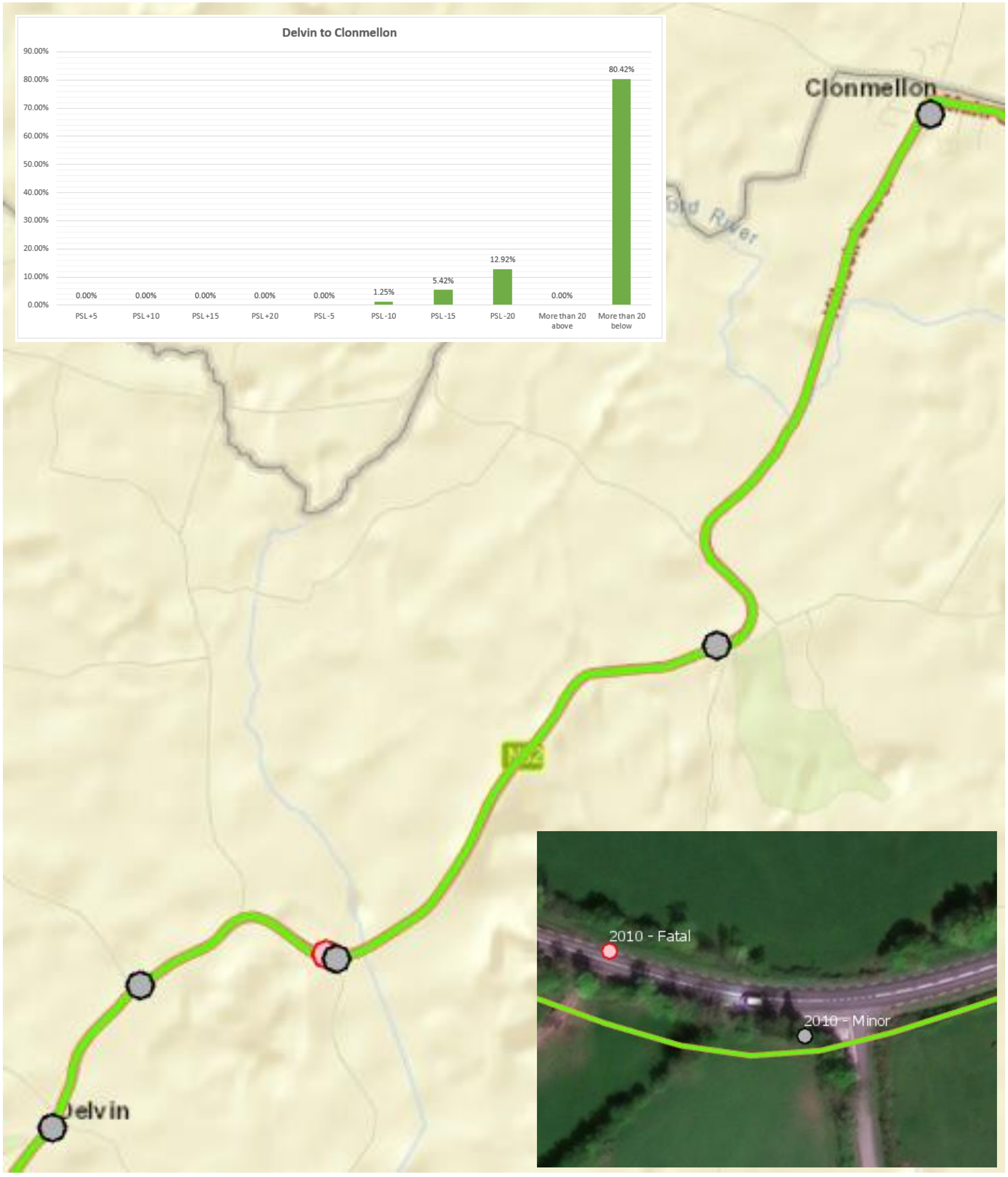


Figure 6.44: N52 Delvin to Clonmellon Collisions

EASTBOUND

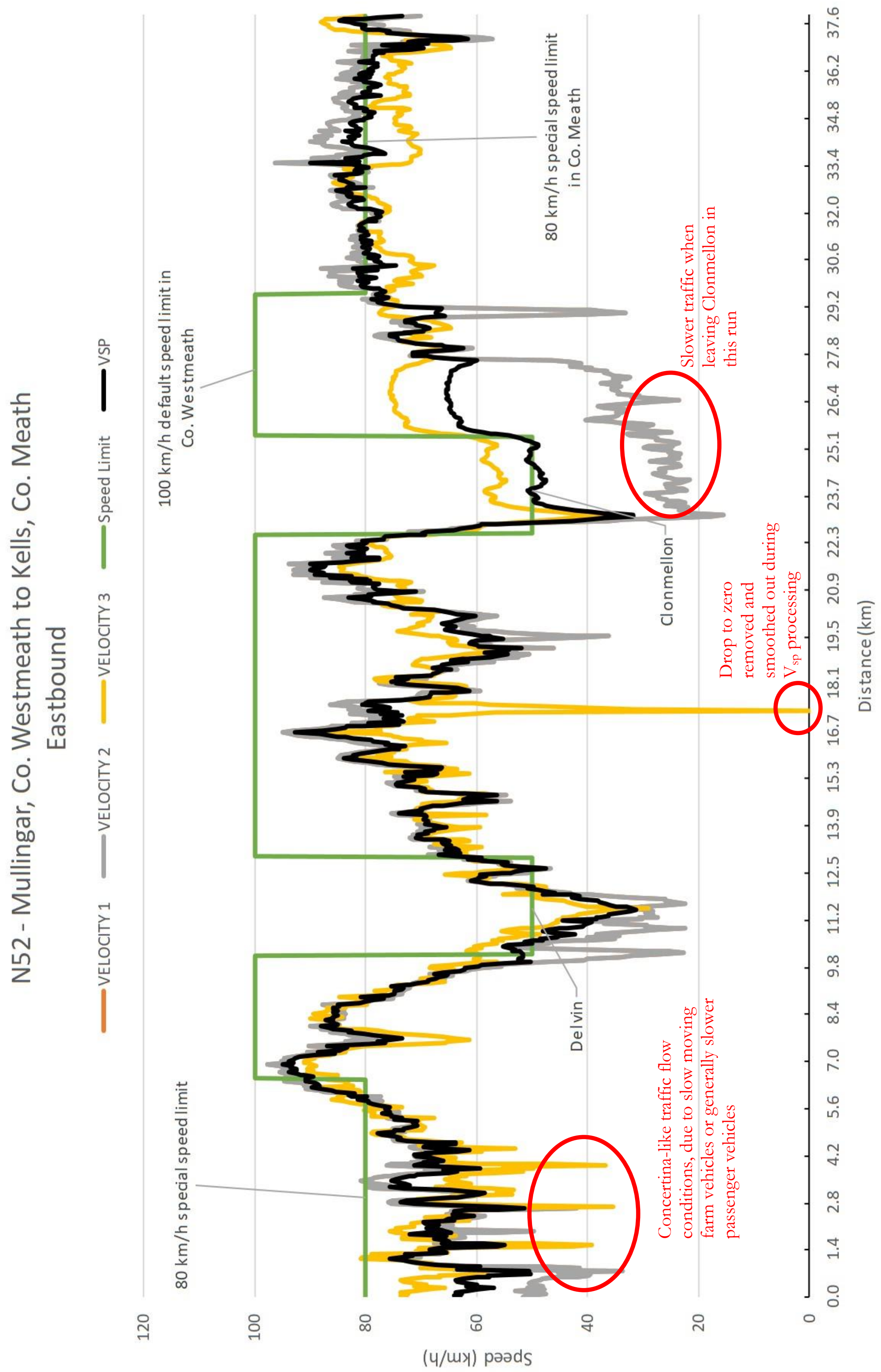


Figure 6.45: N52 velocities, V_{sp} and speed limit - Eastbound

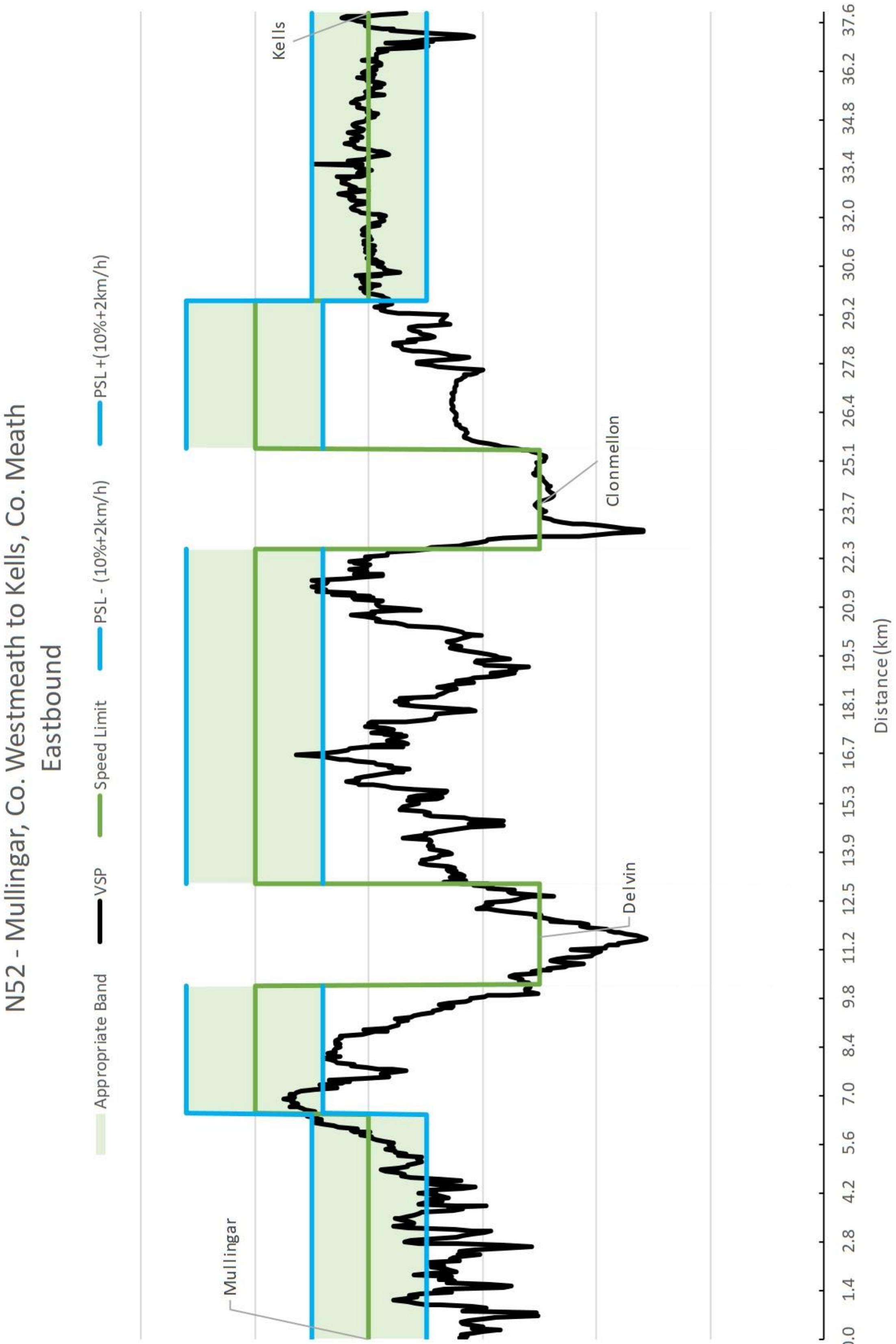


Figure 6.46: N52 V_{sp}, speed limit and 'appropriate' band - Eastbound

Speed Distribution, Route Efficiency And Efficiency Index

N52 – EASTBOUND	Above Posted Speed Limit					Max V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	95.07
GPS Observations	115	11	2	0	0	Min V_{sp}
% of Route	14.25%	1.36%	0.25%	0.00%	0.00%	50.20
	Below Posted Speed Limit					Ave V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	73.27
GPS Observations	100	65	76	80	358	85th %
% of Route	12.39%	8.05%	9.42%	9.91%	44.36%	86.71

Table 6.13: N52 Eastbound Speed Distribution

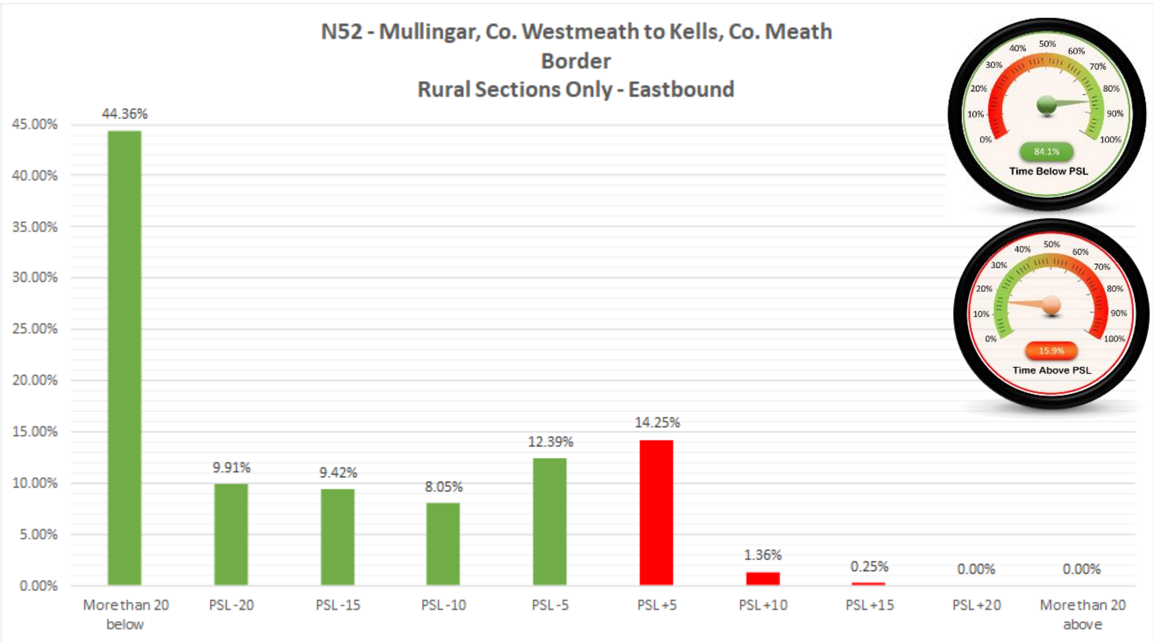


Figure 6.47: N52 Eastbound Speed Distribution

We can see from the plots and the Table 6.13 that the route is travelled below the speed limit 84% of the time with almost 50% of this being more than 20 km/h below the speed limit, the other 50% fairly evenly spread over the other bands. 36% of the time is spent within 10 km/h of the speed limit. A poor Efficiency Index can be expected.

Applying appropriate band analysis results in an Efficiency Index of 0.37, which is in the poor range - traffic is travelling too slowly for the posted speed limit for 63% of the time. The driver has clearly stated that the speed limits along this route, apart from the 80 km/h section approaching Kells, are not appropriate.

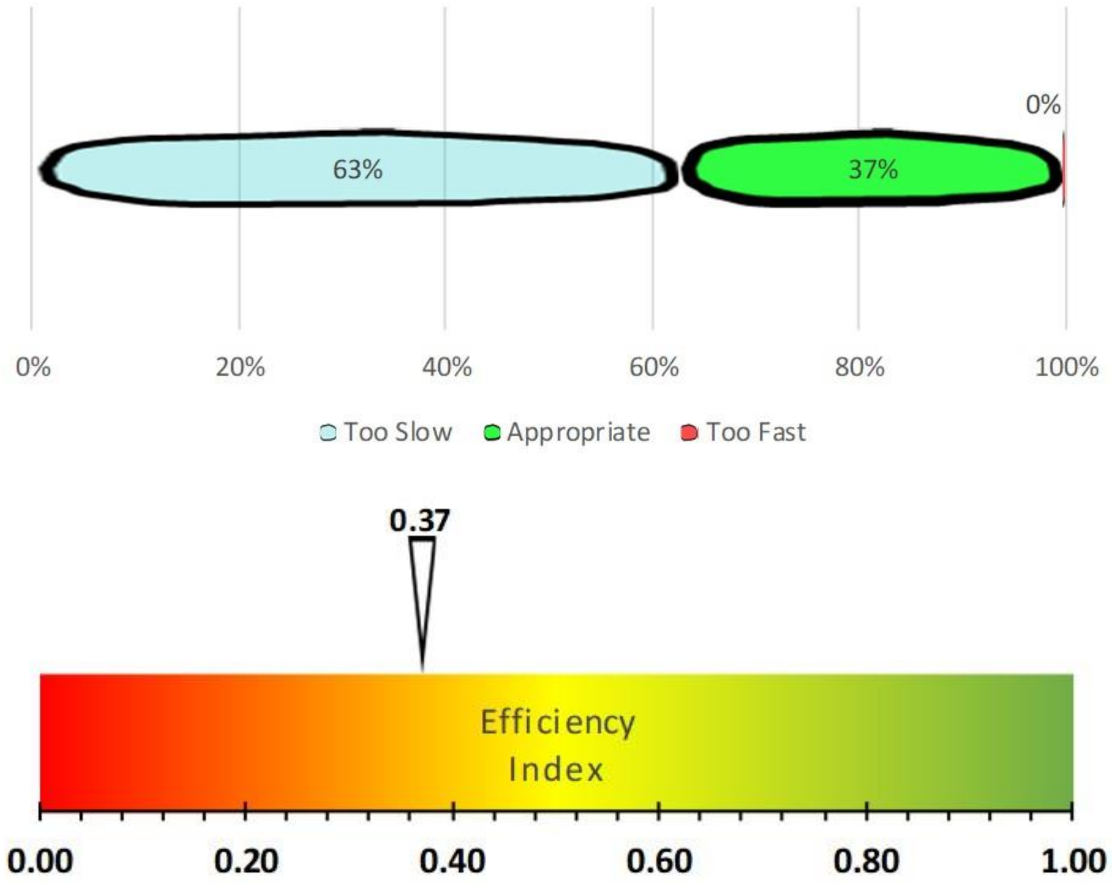


Figure 6.48: N52 Eastbound Route Efficiency & Efficiency Index

WESTBOUND

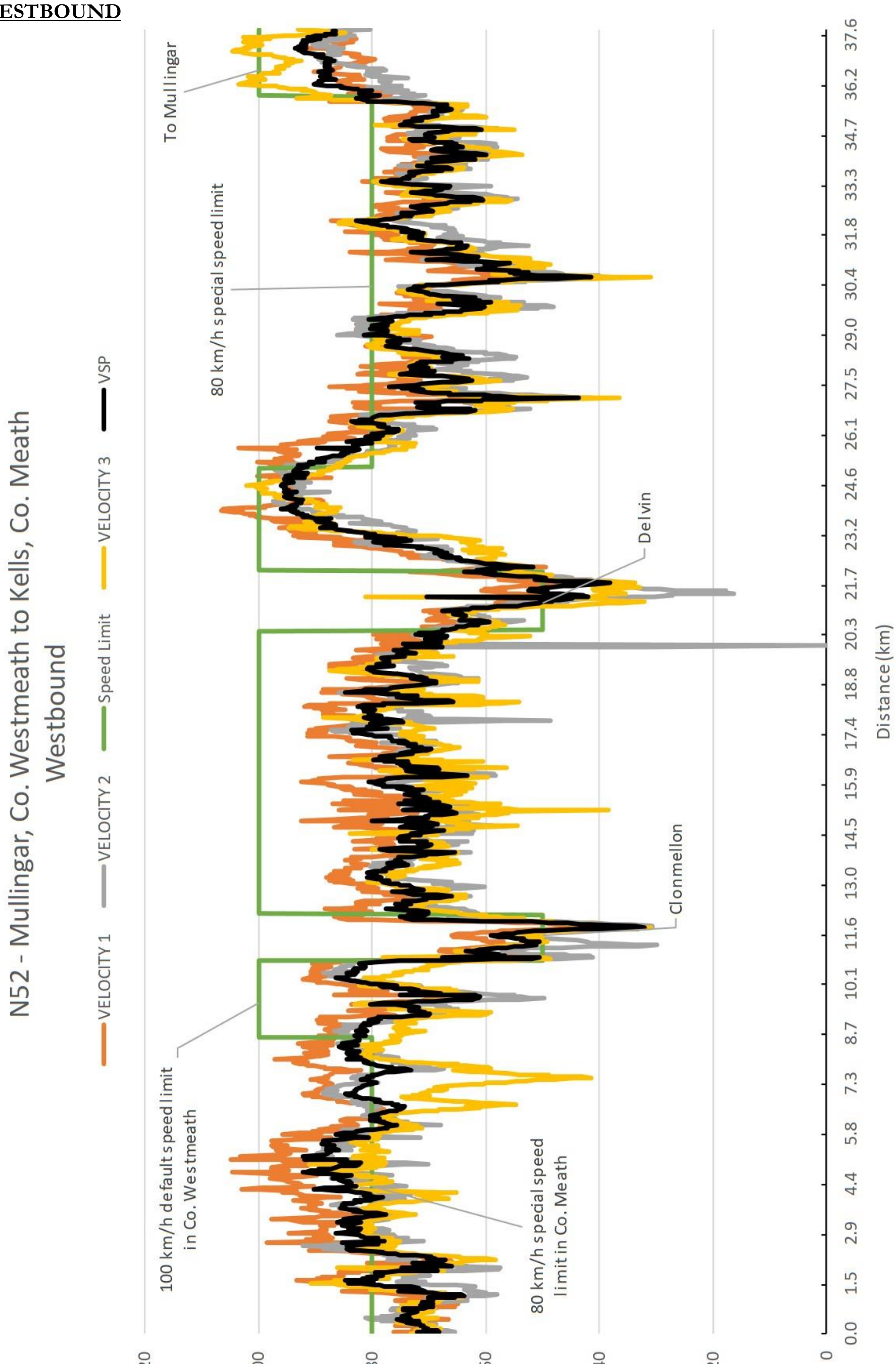


Figure 6.49: N52 velocities, V_{sp} and speed limit - Westbound

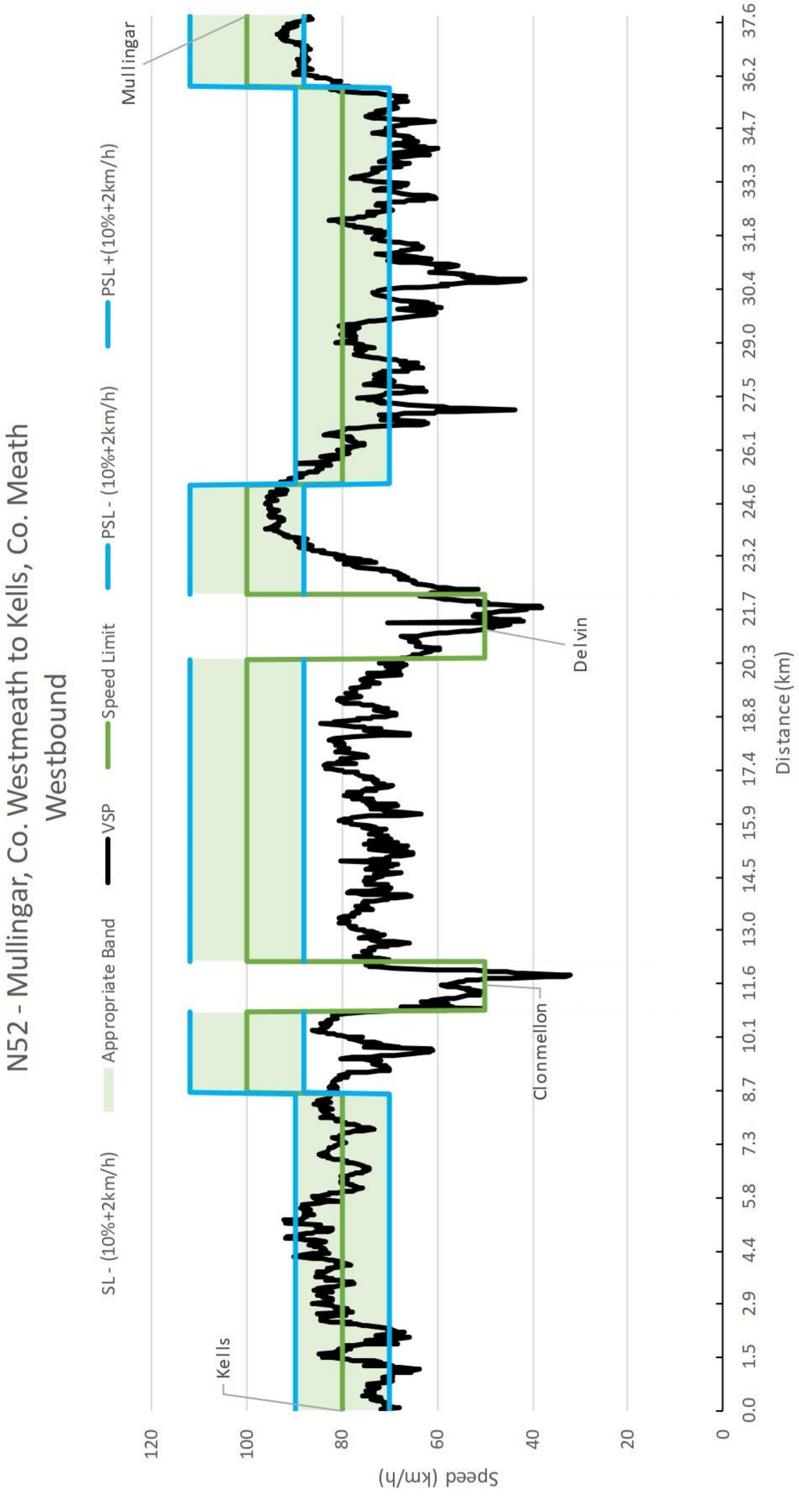


Figure 6.50: N52 V_{sp}, speed limit and 'appropriate' band - Westbound

Speed Distribution, Route Efficiency And Efficiency Index

N52 - WESTBOUND	Above Posted Speed Limit					Max V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	92.08
GPS Observations	177	72	13	0	0	Min V_{sp}
% of Route	12.30%	5.00%	0.90%	0.00%	0.00%	63.93
	Below Posted Speed Limit					Ave V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	78.59
GPS Observations	161	241	193	160	422	85th %
% of Route	11.19%	16.75%	13.41%	11.12%	29.33%	85.21

Table 6.14: N52 Westbound Speed Distribution

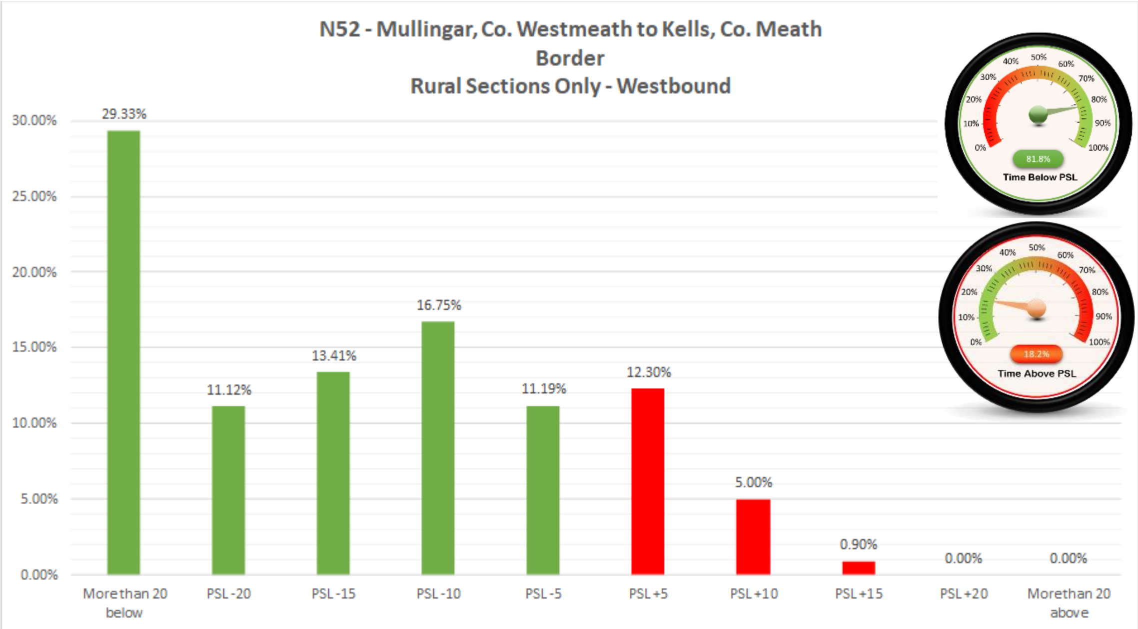


Figure 6.51: N52 Westbound Speed Distribution

We see from Table 6.14 and charts that there is great variation between the V_{sp} and posted speed limit and that the route is travelled below the speed limit for almost 82% of the time, with 30% of this being more than 20 km/h below the speed limit. The remainder of the time is also fairly evenly spread across the other bands but there is a higher concentration of time spent around the bands up to 10 km/h within the speed limit, and, as such, an EI better that the Eastbound should be expected.

As expected, when applying appropriate band analysis, an Efficiency Index of 0.47 - better than Eastbound, emerges. This, however, is only fair and can be improved. Again, the traffic is travelling too slowly for the posted speed limit for too long (52% of the time). The driver has clearly stated the speed limits on this route are not appropriate and should be revised, most notably on the 100 km/h section between Clonmellon and Delvin where the V_{sp} derived bears almost no relation to the posted speed limit.

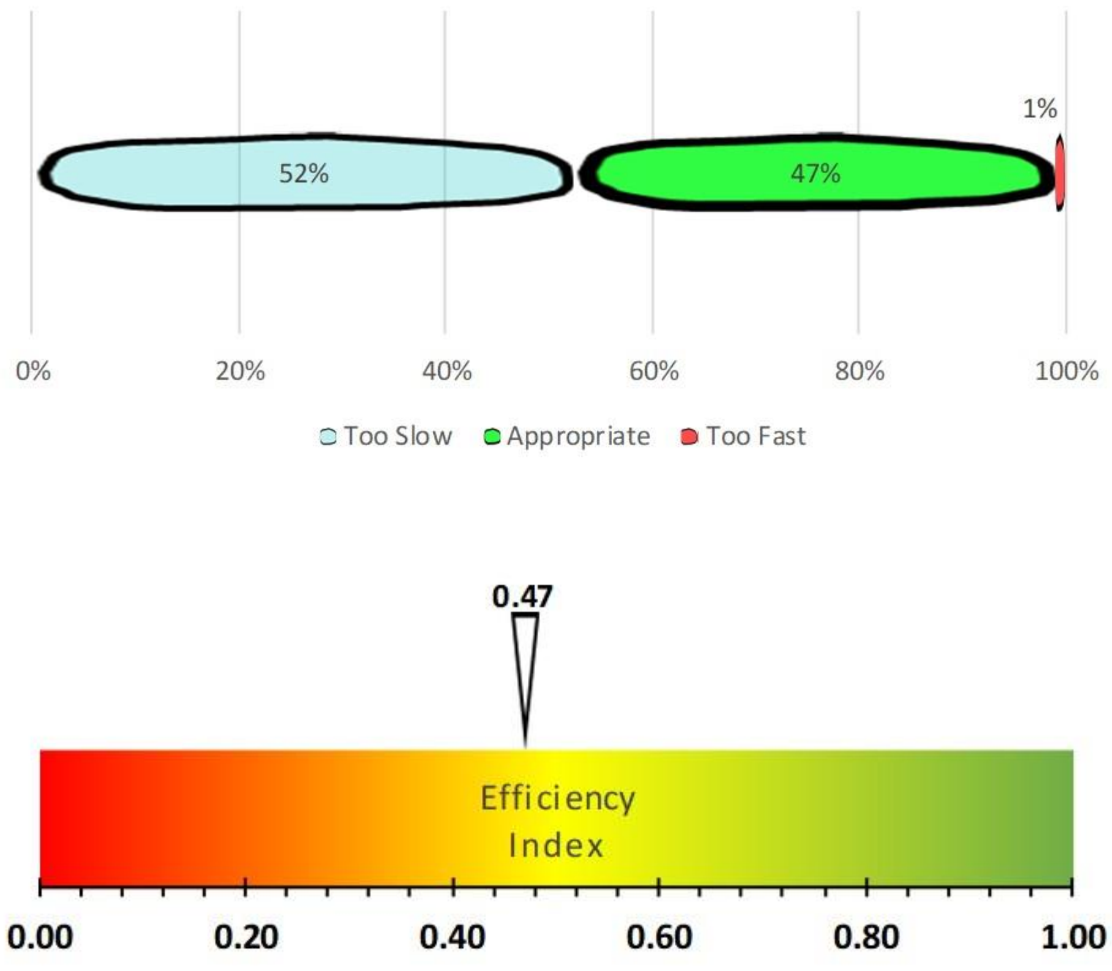


Figure 6.52: N52 Westbound Route Efficiency & Efficiency Index

EFFECT OF ALTERING THE SPEED LIMIT

The route appears to be performing well in the 80 km/h speed limit areas, particularly in the Westbound direction. The Efficiency Index is being greatly affected in the 100 km/h section with traffic unable to reach the 'appropriate' zone. The route is configured as shown below and the effect of changing the speed limit is as follows;

Section		Speed Limit	Efficiency Index Eastbound	Efficiency Index Westbound
Existing Configuration	Mullingar – Outside Delvin	80 km/h	0.37	0.47
	Towards Delvin	100 km/h		
	Delvin - Clonmellon	100 km/h		
	Clonmellon – Co. Meath Boundary	100 km/h		
	Co. Meath Boundary - Kells	80 km/h		
Altered Scenario 1	All Sections	80 km/h	**0.60**	**0.72**
Altered Scenario 2	All 100 km/h sections	90 km/h	0.48	0.56

Table 6.15: N52 Efficiency Index – Altered Speed Limits

Both scenarios result in an improved EI over the existing situation. While the difference between the EI in each direction in Altered Scenario 1 is 0.12 as opposed to 0.08 in Altered Scenario 2, it is a more favourable option than scenario 2, as it results in a single speed limit being applied along the entire 37km section that passes through two Local Authorities providing consistency from one Local Authority area to the next.

Figure 6.53: N52 – Vsp and Appropriate Bands (Altered Speed Limits)

CONCLUSIONS

This route was observed as having a fair EI in both directions, mainly due to the good performance of the section from the Meath county boundary to Kells. The route performed poorly elsewhere. We can see from the velocities that all three are quite similar except for the section between Clonmellon and the Meath county boundary in velocity 2, it seems to be quite a bit slower than Velocities 1&3, this could be due to the presence of slow-moving agricultural machinery on this run. Nevertheless, drivers again seem to be unable to make full use of the speed limit available to them and an alteration of the speed limit is necessary to improve the overall performance of the road. Altered Scenario 1, setting the speed limit at 80 km/h throughout the entire route provides substantial improvement in both directions and sets a consistent speed limit on the entire route.

6.3.5 N53 – Dundalk, Co. Louth to Castleblayney, Co. Monaghan

The N53 commences at its junction with the M1 at Dundalk, Co. Louth and continues westwards, through Northern Ireland, to Castleblayney, Co. Monaghan. It is 22km in length, carries 5,110 vehicles per day (2016 figures) and has experienced 30 collisions over the period 2006-2012.

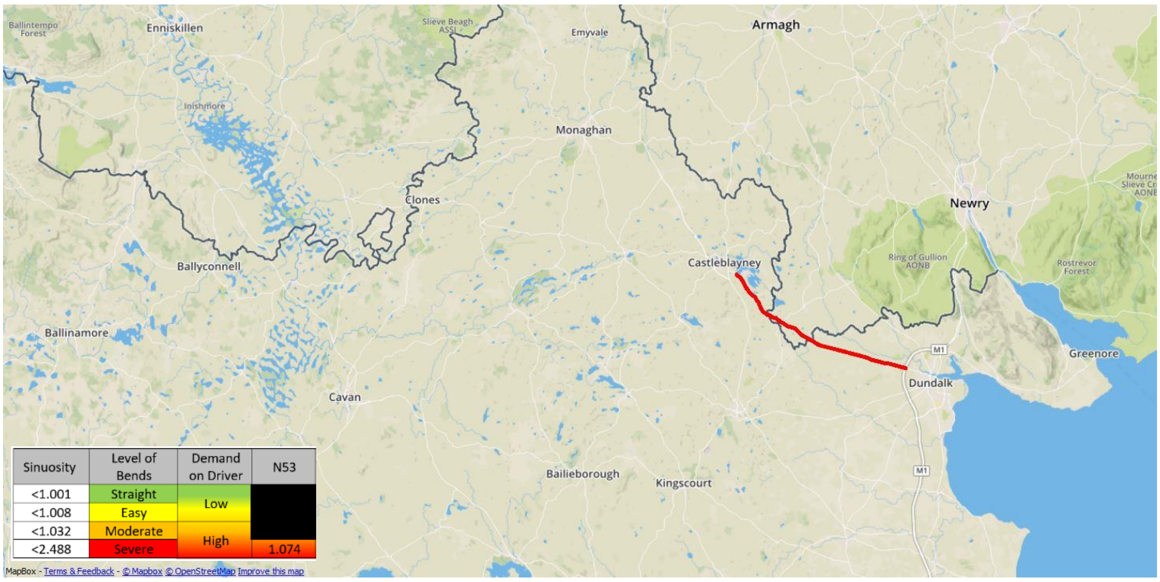
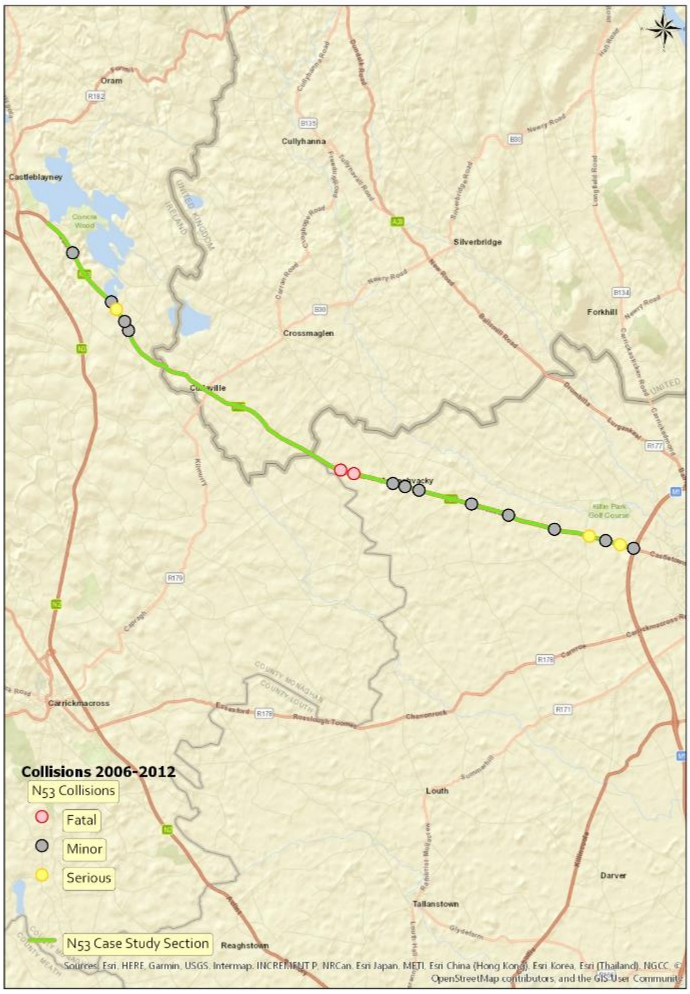
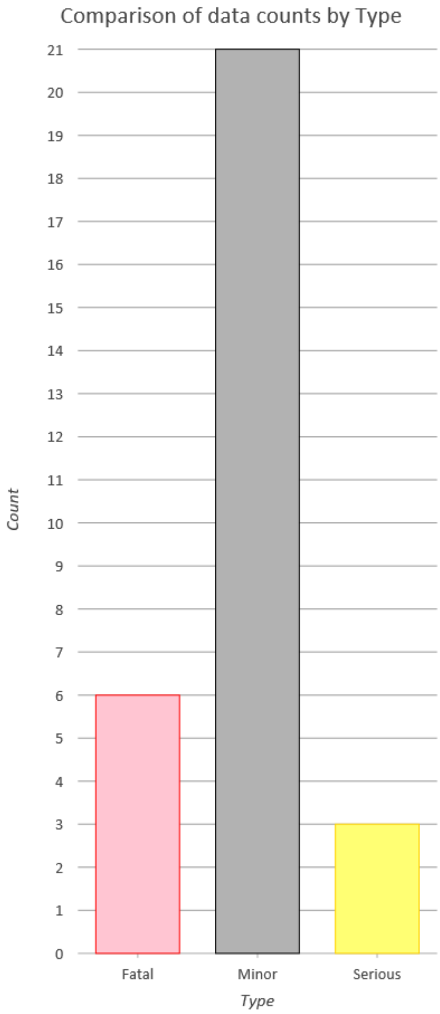


Figure 6.54: Location of N53 Case Study

As it is a National secondary road, the Default Speed Limit is 100 km/h and is applied to the entire route. No Special Speed Limits have been applied along the route. The route passes through Northern Ireland – while the Safe Profile Velocity has been derived for this section and is depicted, the speed limit through Northern Ireland is not shown and it is left blank on the charts.

COLLISION HISTORY





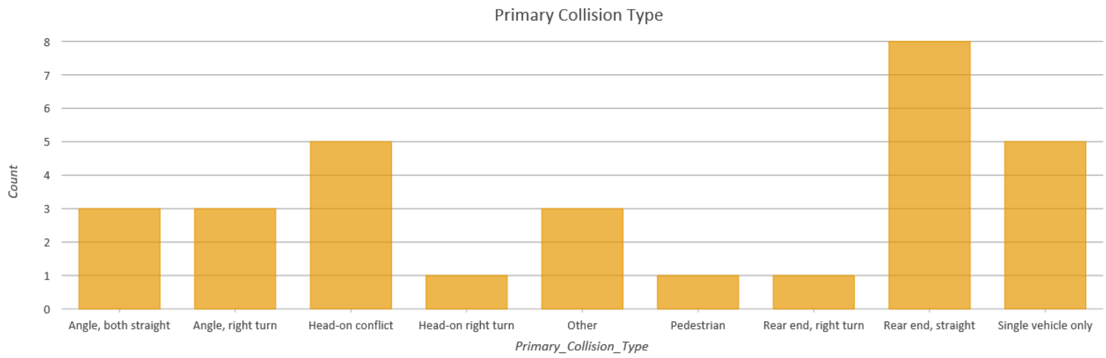


Figure 6.55: N53 Case Study – Collision History

In the period 2006-2012 there was a total of 30 collisions on this section of the N53 between its junction with the M1 and Castleblayney - 21 minor, 3 serious and 6 fatal collisions - all occurring between the M1 and the border on the eastern side. Five of these collisions were head on collisions with 8 rear end collisions.

COLLISIONS IN POORLY PERFORMING SECTION

The section of the N53 from the M1 outside Dundalk to Castleblayney has a speed limit of 100 km/h applied (Default) and crosses through Northern Ireland. In the section between the border and the M1 there were 17 minor collisions, 2 serious collisions and 6 fatal collisions with 3 of those occurring in a 450m section in the space of 2 years, the V_{sp} there ranges from 90 km/h to 92 km/h – the road is wide with hard shoulders and is approximately 1.5km from the border.

Figure 6.56: N53 Dundalk to Castleblayney Collisions

There is a junction in the vicinity of the 3 fatal collisions shown above. The junction does not have right turning refuges and this may be a contributory factor in these collisions. As the Guidelines state, the immediate response to an isolated hazard should not be the setting of a reduced Special Speed Limit - the Local Authority should try to engineer out the problem by, for example, installing additional warning signage, right turning refuges, etc. It is possible that a more appropriate speed limit in this case would be 90 km/h.

EASTBOUND

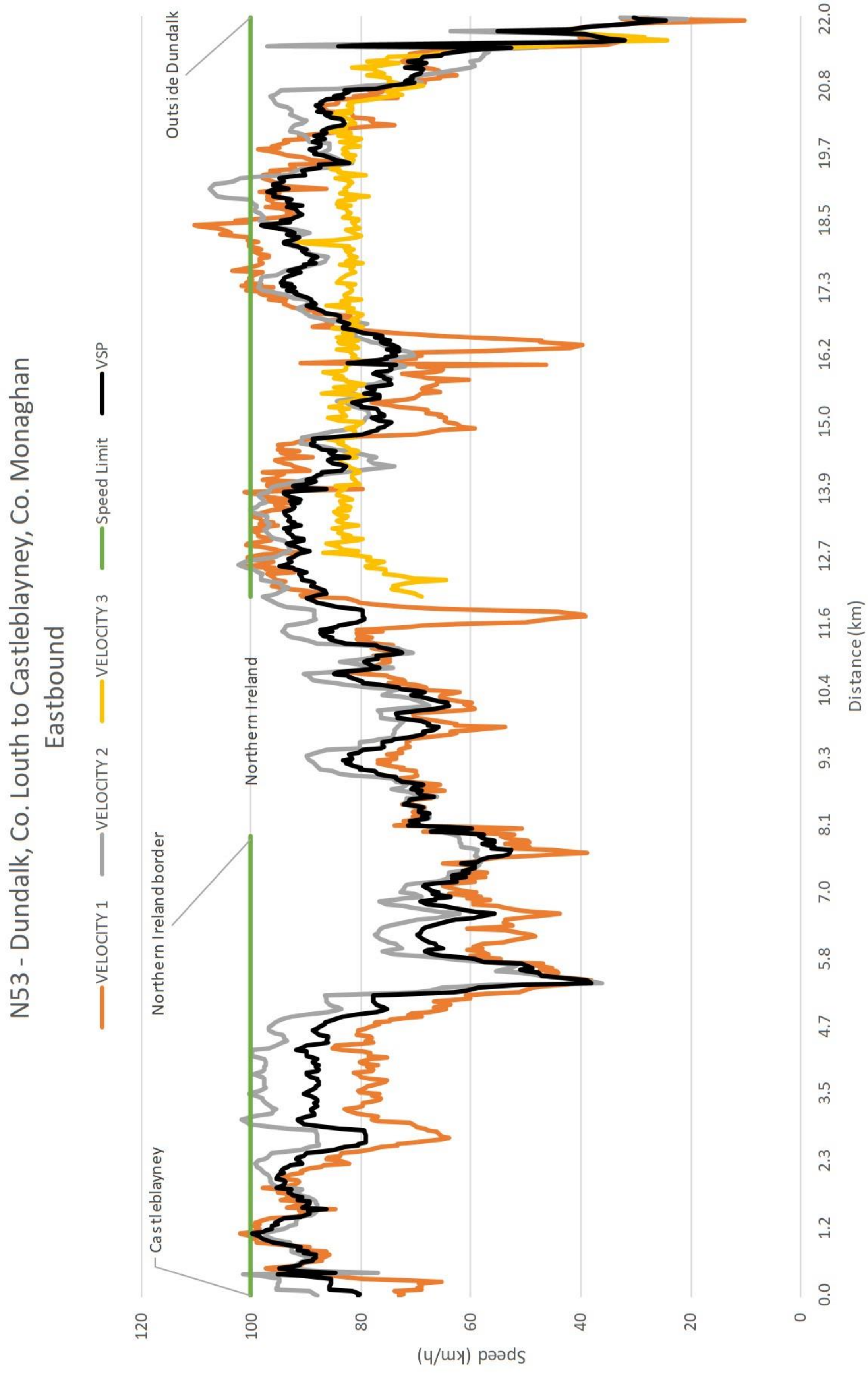


Figure 6.57: N53 velocities, V_{sp} and speed limit - Eastbound

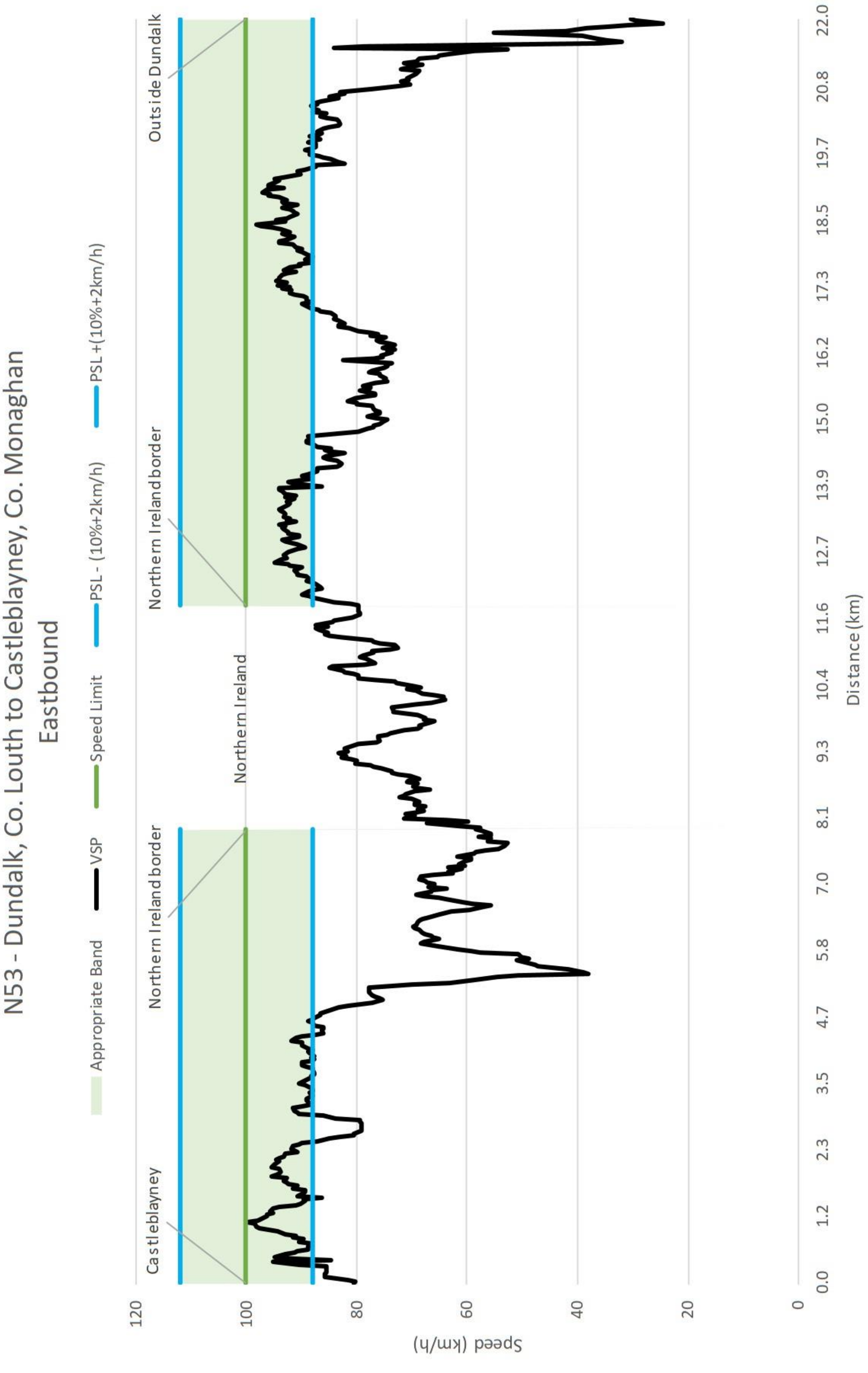


Figure 6.58: N53 V_{sp}, speed limit and 'appropriate' band – Eastbound

Speed Distribution, Route Efficiency And Efficiency Index

N53 - EASTBOUND	Above Posted Speed Limit					Max V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	99.85
GPS Observations	0	0	0	0	0	Min V_{sp}
% of Route	0.00%	0.00%	0.00%	0.00%	0.00%	38.19
	Below Posted Speed Limit					Ave V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	81.49
GPS Observations	25	142	148	47	188	85th %
% of Route	4.55%	25.82%	26.91%	8.55%	34.18%	92.98

Table 6.16: N53 Eastbound Speed Distribution

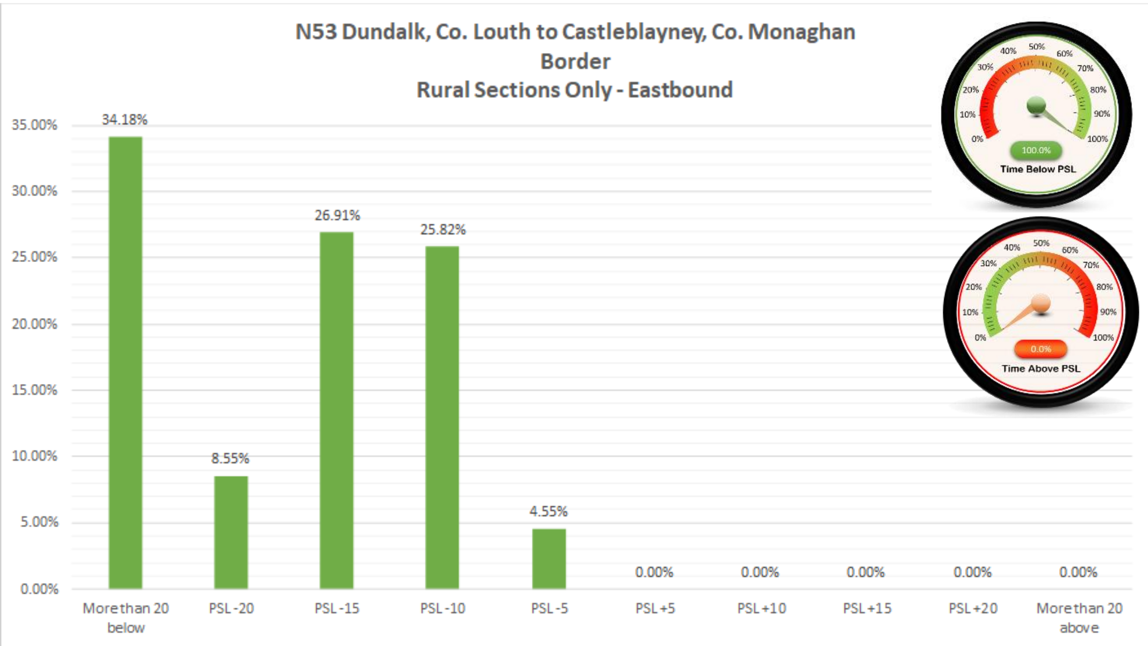


Figure 6.59 N53 Eastbound Speed Distribution

We can see that the route is travelled below the speed limit 100% of the time with 34% of this being more than 20 km/h below the speed limit. It appears, however, that a fair Efficiency Index may be returned as almost 60% of time is spent at speeds no greater than 15 km/below. There are frequent drops in the speed profile suggesting the presence of right turning traffic in areas where the carriageway is narrow and does not facilitate passing on the left. It appears a speed limit of 100 km/h is not an appropriate speed limit on this road.

Carrying out an appropriate band analysis on the V_{sp} track shows us that traffic is indeed travelling too slowly on this route in the Eastbound direction - more than half the time. An EI of 0.45 (fair) is returned. A simple alteration to the speed limit could do a lot to improve efficiency on this route. The entire section consists of one speed limit, 100 km/h, that seems unattainable or out of reach to the driver.

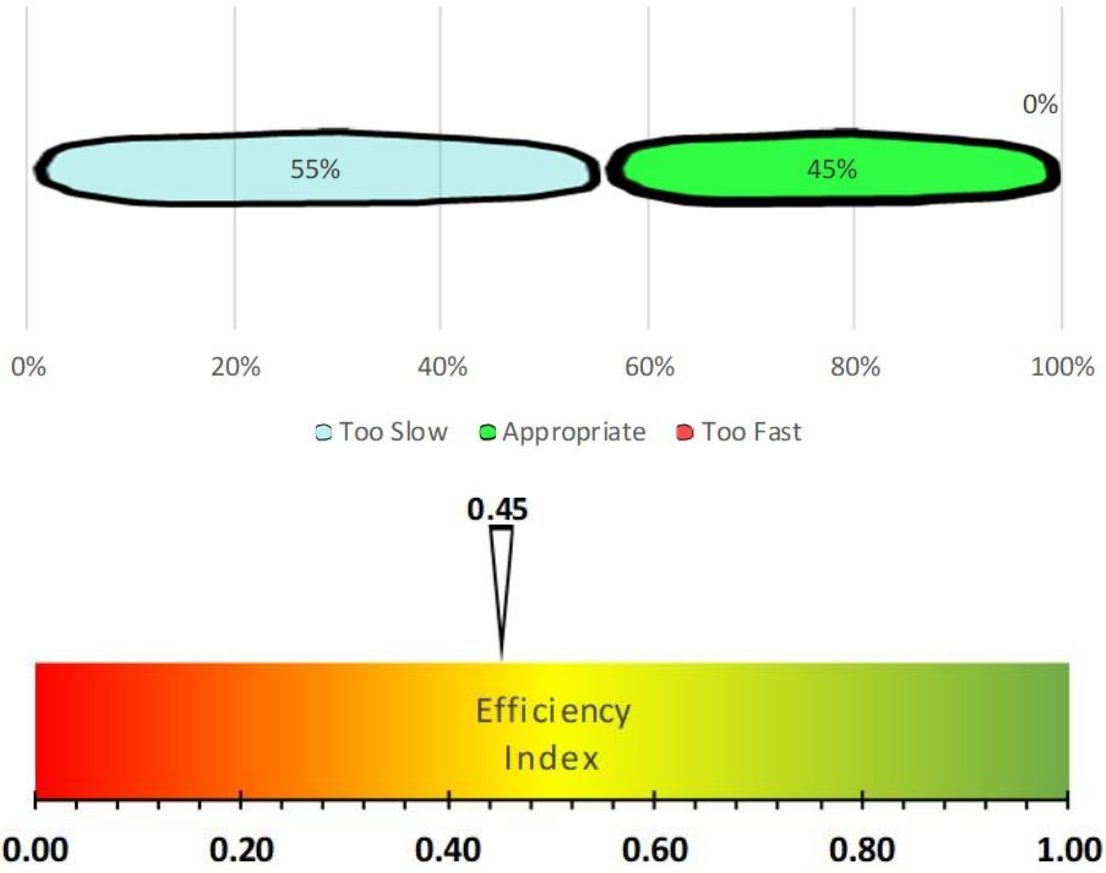


Figure 6.60: N53 Eastbound Route Efficiency & Efficiency Index

WESTBOUND

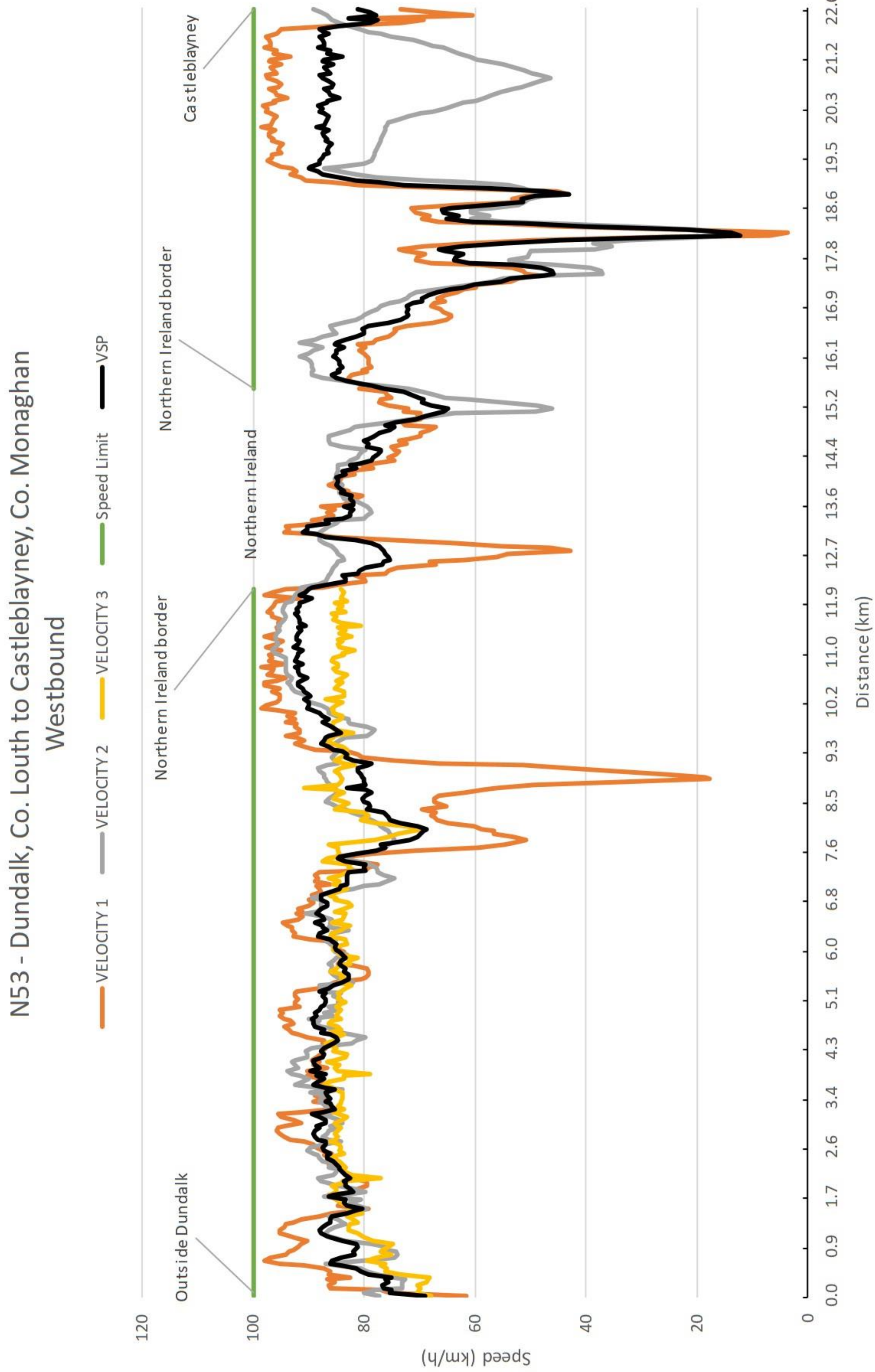


Figure 6.61: N53 velocities, V_{sp} and speed limit - Westbound

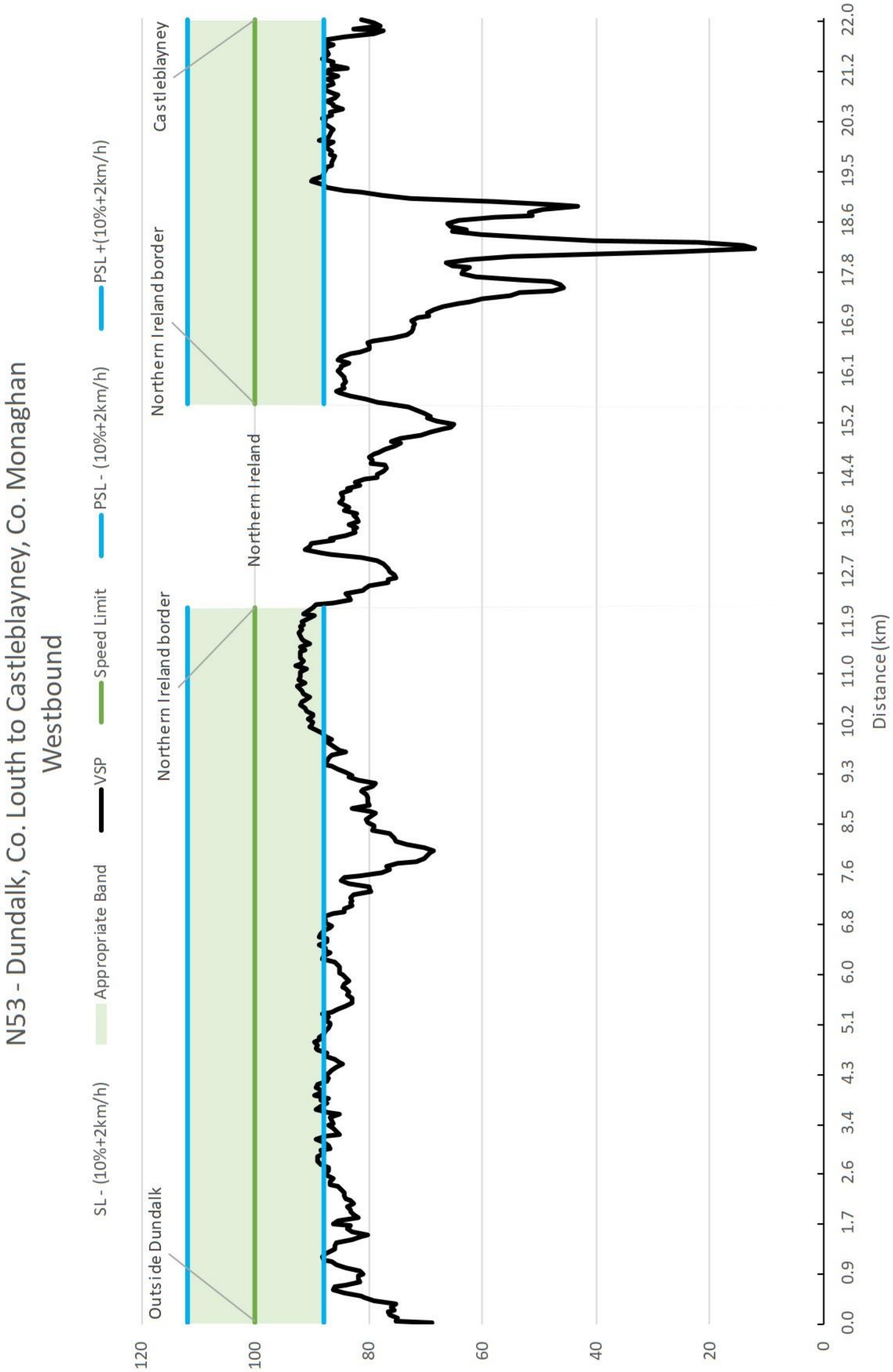


Figure 6.62: N53 V_{sp}, speed limit and 'appropriate' band - Westbound

Speed Distribution, Route Efficiency And Efficiency Index

N53 - WESTBOUND	Above Posted Speed Limit					Max V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	92.78
GPS Observations	0	0	0	0	0	Min V_{sp}
% of Route	0.00%	0.00%	0.00%	0.00%	0.00%	12.24
	Below Posted Speed Limit					Ave V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	81.66
GPS Observations	0	40	170	71	44	85th %
% of Route	0.00%	10.08%	44.33%	21.41%	24.18%	88.88

Table 6.17: N53 Westbound Speed Distribution

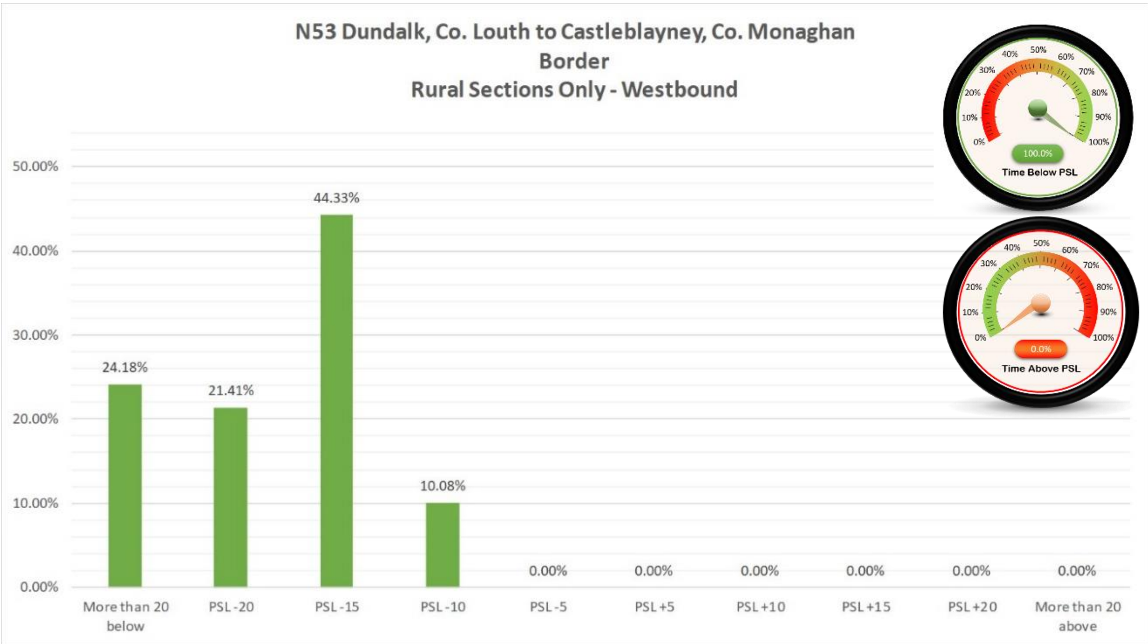


Figure 6.63: N53 Westbound Speed Distribution

We can see that the route is travelled below the speed limit 100% of the time, again, this is positive, almost 45% of this time is spent up to 15 km/h below the speed limit suggesting a less than favourable Efficiency Index may be returned. Traffic is travelling too slowly for the remainder of the time, approximately 55%, is spent at least 15 km/h below the speed limit. The profile is proving to be inefficient but is more consistent and smoother than in the Eastbound direction, consistently slower with less peaks and troughs along the profile, but still shows that the 100km/h speed limit is not an appropriate speed limit in this case.

A poor Efficiency Index is returned. The appropriate band analysis reveals that traffic is only travelling at appropriate speeds for 26% of the time, the rest of the time it is travelling too slowly. Again, this shows the route is performing poorly in relation to the posted speed limit.

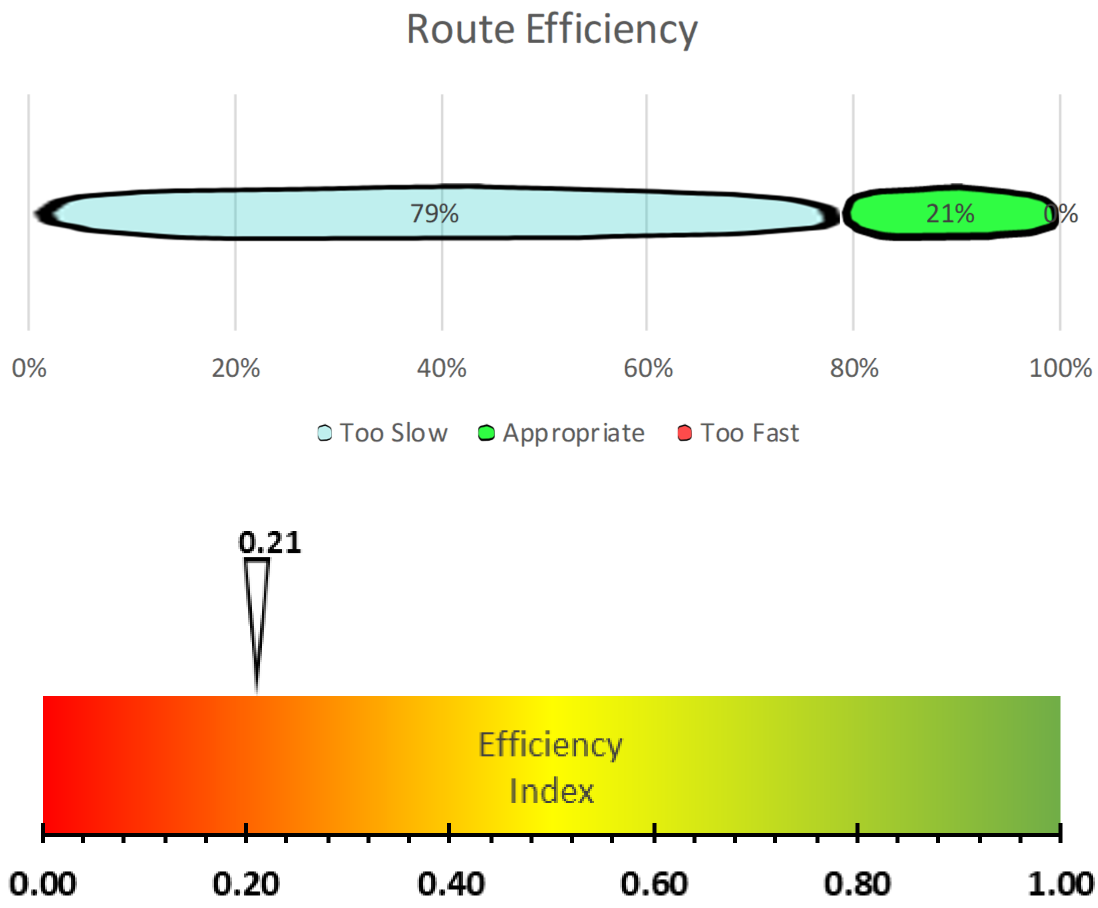


Figure 6.64: N53 Westbound Route Efficiency & Efficiency Index

EFFECT OF ALTERING THE SPEED LIMIT

The route is not performing well in either direction, the Efficiency Index is fair in the Eastbound direction and poor in the Westbound direction. Altering the speed limit along the entire route has the following effect on the Efficiency Index.

	Section	Speed Limit	Efficiency Index Eastbound	Efficiency Index Westbound
Existing Configuration	Entire Section	100 km/h	0.45	0.21
Altered Scenario 1	Entire Section	80 km/h	0.50	0.78
Altered Scenario 2	Entire Section	90 km/h	**0.68**	**0.79**

Table 6.18: N53 Efficiency Index – Altered Speed Limits

Both scenarios result in an improved EI over the existing situation, with the most dramatic improvement observed in the Westbound direction. There is a significant difference between the EI's in each direction in all speed limit scenarios. There is a section, approximately 4km in length, near the NI border on the Castleblayney side that appears to warrant a speed limit of 60 km/h. This, however, is not possible if we strive to achieve a uniform solution and set a speed limit that improves the Efficiency Index in both directions. The best results, overall, are observed by altering the speed limit to 90 km/h, it provides the greatest increase in performance and results in the smallest difference in the Efficiency Index between directions (not including the existing situation).

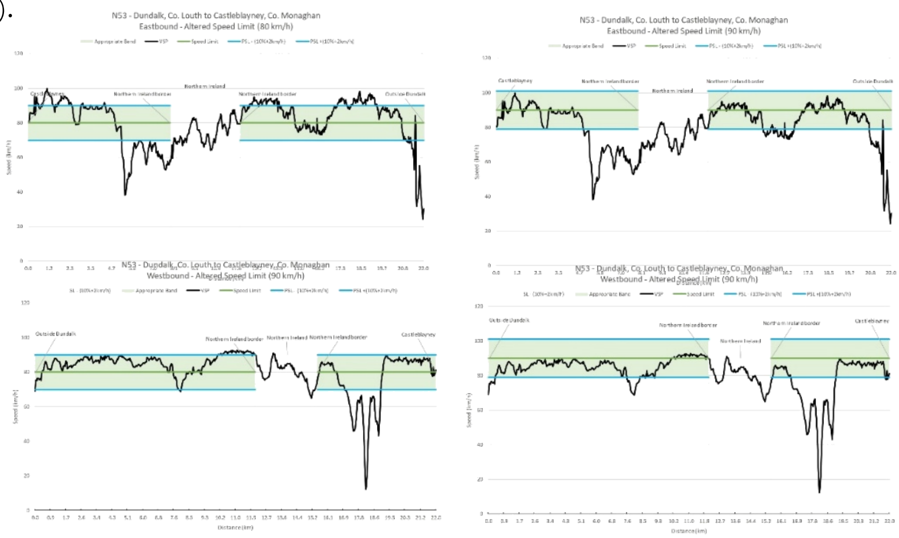


Figure 6.65: N53 – V_{sp} and Appropriate Bands (Altered Speed Limits)

CONCLUSIONS

The profiles show that 100 km/h is not proving to be an appropriate speed limit on this route. Road users are not exceeding the speed limit, however, the route (both directions) is driven below the speed limit 100% of the time with 50% of this more than 20 km/h below the speed limit. Time spent more than 10 km/h below the speed limit (10 km/h is close to the edge of the 'appropriate' band) is 70% in the Eastbound direction and 88% in the Westbound direction. This is an immediate indicator that the EI can be expected to be relatively poor. The appropriate band analysis confirms this - the Eastbound EI is 0.45 (fair) and the Westbound EI is 0.21 (poor).

Note that Velocity 3, in both directions, is shorter and only covers the section between Dundalk (M1) and the NI border. While at least three captures would be optimal, it appears that 2 captures of the section (from personal experience of the route) between the NI border and Castleblayney is returning a reliable representation of V_{sp}.

Alterations to the speed limit were applied across the entire route leaving a single speed limit in place (as per existing situation) as, particularly in the Westbound direction, driver behaviour is producing similar results with respect to the relationship between speeds driven and the speed limit on both sections either side of the border. The fact that there is a more consistent (consistently poor) V_{sp} along the Westbound direction that results in a substantial improvement when the speed limit is altered means that changing the speed limit on only one section to achieve a better result in the Eastbound direction is unnecessary and wouldn't achieve a better result. It appears the appropriate speed limit for this route is 90 km/h.

6.3.6 R157 – Maynooth, Co. Kildare to Dunboyne, Co. Meath

The section of the R157 chosen for analysis commences east of Maynooth, Co. Kildare and continues in an easterly direction to Dunboyne, Co. Meath. It is 7.5 km in length and has experienced 8 collisions over the period 2006-2012.

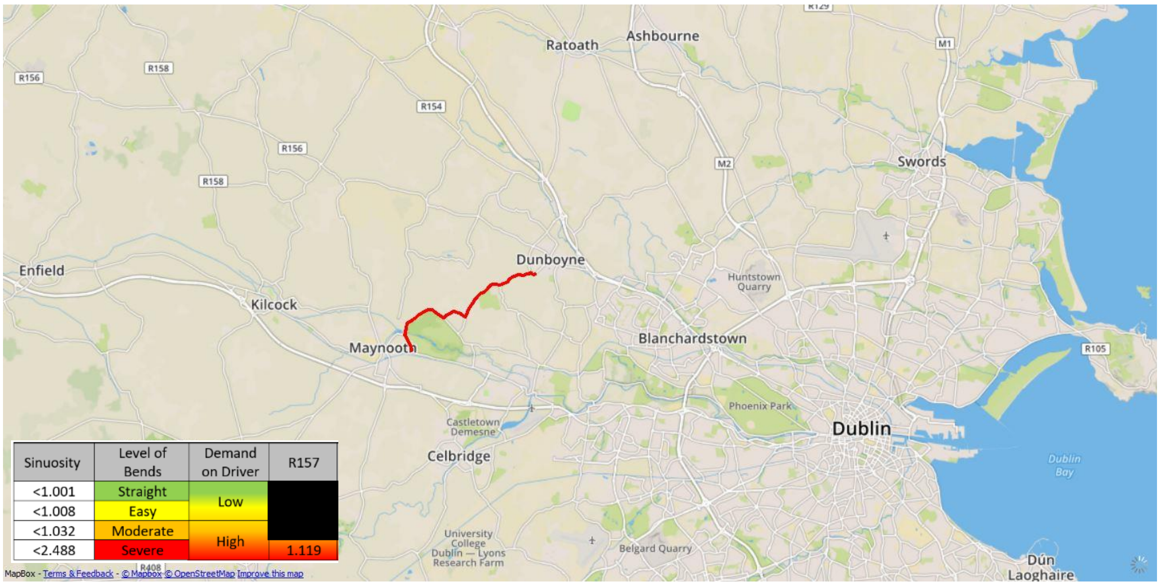


Figure 6.66: Location of R157 Case Study

It is a narrow Regional road with the Default Speed Limit of 80 km/h applied - no Special Speed Limits have been applied on this route. There are frequent junctions and accesses along the route and it also possesses three near right angled bends. The narrow cross-section provides few overtaking opportunities.

COLLISION HISTORY

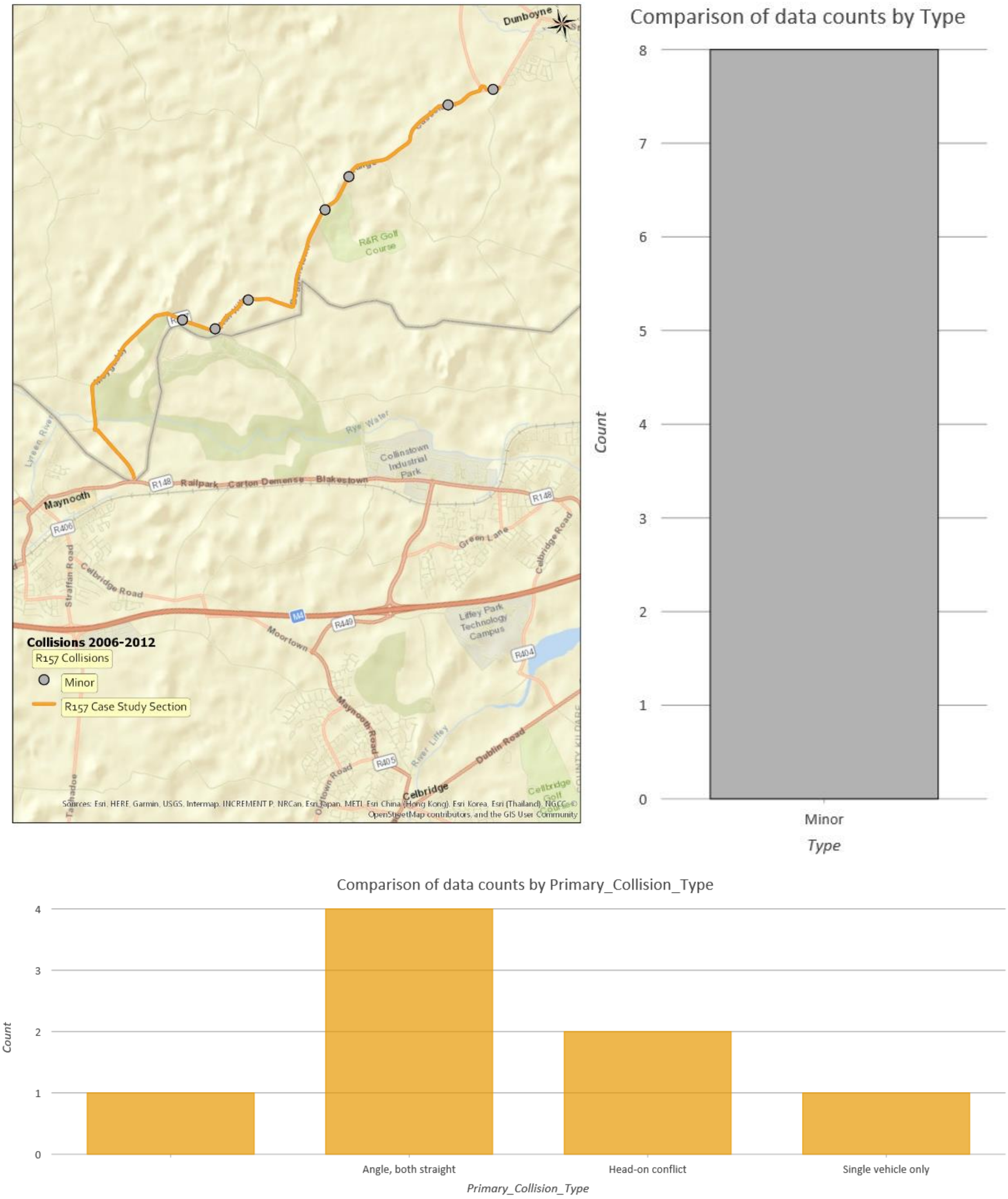


Figure 6.67: R157 Case Study – Collision History

In the period 2006-2012 there was a total of 8 collisions on this section of the R157 between Maynooth and Dunboyne, all minor. Four of them were recorded as 'angle, both straight', which implies head-on conflict or could also mean a side-swipe type collision, and 2 others were recorded as head-on collisions.

COLLISIONS IN POORLY PERFORMING SECTION

The section of the R157 from Maynooth to Dunboyne has a speed limit of 80 km/h applied (Default). The section, as we will see, performs poorly, the road is narrow and twisty with many accesses. Four of the collisions occurred in a 1 km section where the V_{sp} ranges from 55 km/h to 70 km/h.

Figure 6.68: R157 Maynooth to Dunboyne Collisions – Cluster 1

Three collisions occurred within 2.5 km of the eastern end of the section where the V_{sp} ranges from 66 km/h to 70 km/h.

Figure 6.69: R157 Maynooth to Dunboyne Collisions – Cluster 2

The character of this road and the 85th percentile V_{sp} values suggest that there may be a case to explore the use of a 70 km/h speed limit here but that at the very least the speed limit should be no more than 80 km/h.

EASTBOUND

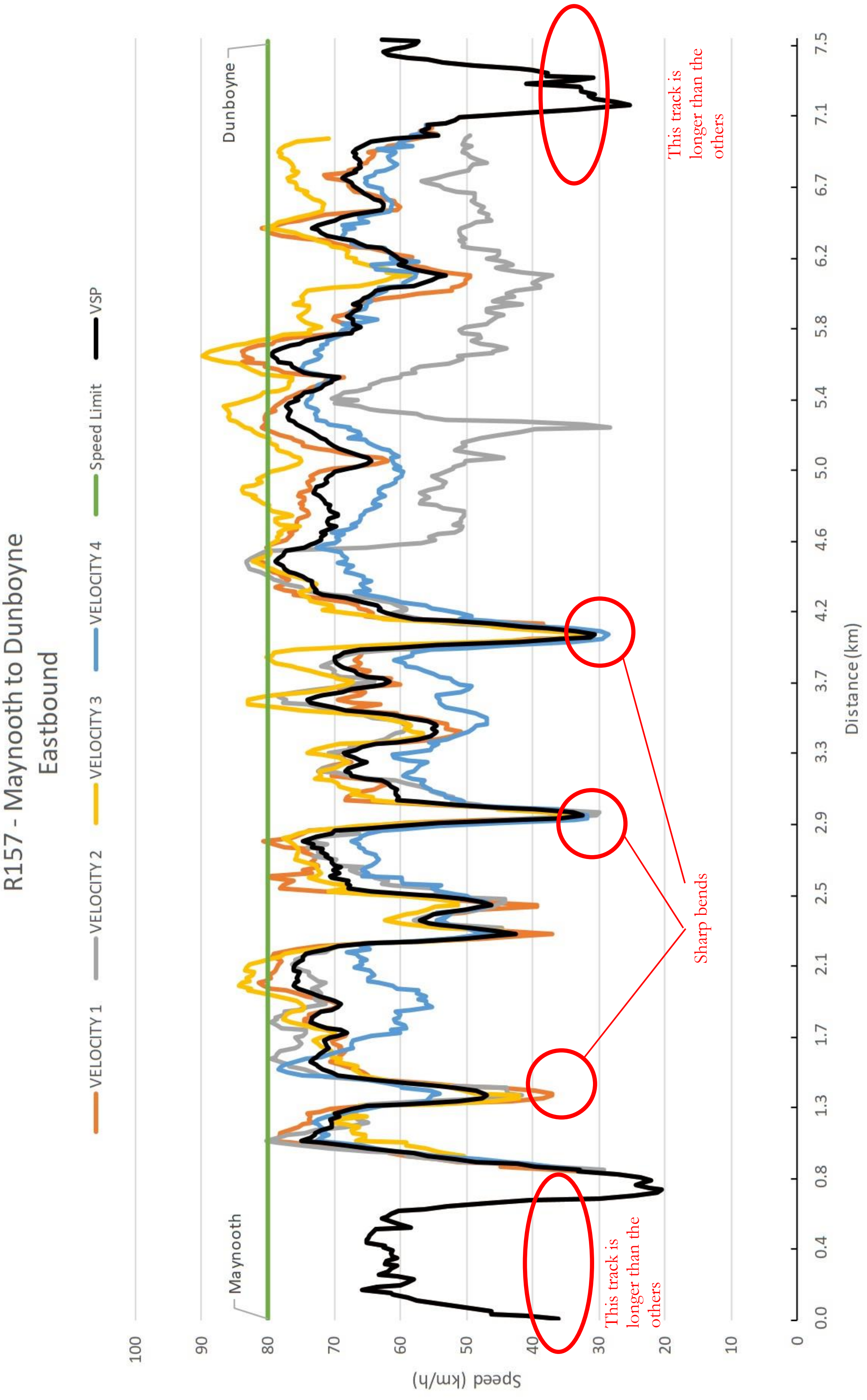


Figure 6.70: R157 velocities, V_{sp} and speed limit - Eastbound

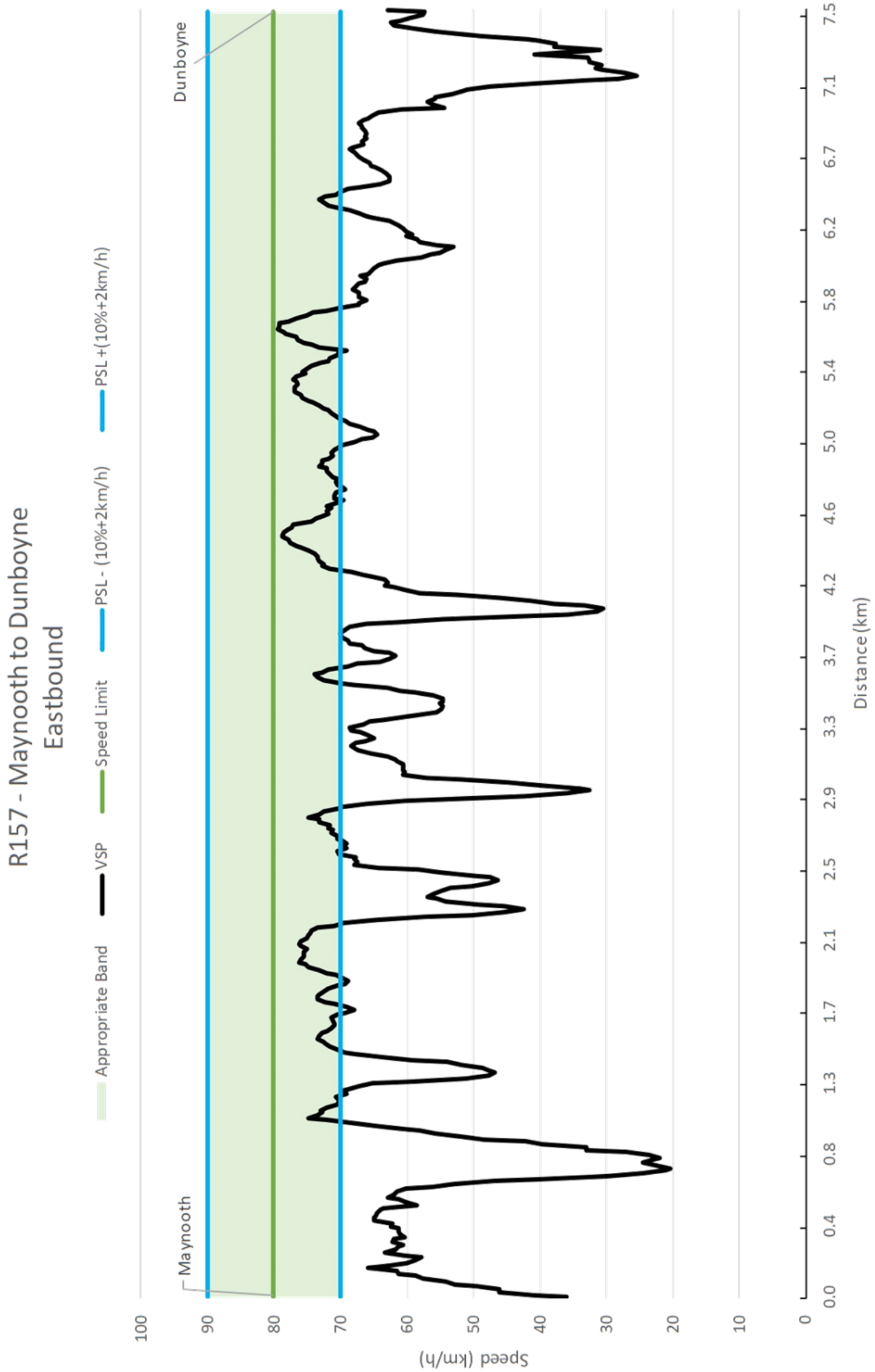


Figure 6.71: R157 V_{sp}, speed limit and 'appropriate' band - Eastbound

Speed Distribution, Route Efficiency And Efficiency Index

R157 - EASTBOUND	Above Posted Speed Limit					Max V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	76.16
GPS Observations	0	0	0	0	0	Min V_{sp}
% of Route	0.00%	0.00%	0.00%	0.00%	0.00%	20.48
	Below Posted Speed Limit					Ave V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	60.62
GPS Observations	43	121	109	81	134	85th %
% of Route	8.81%	24.80%	22.34%	16.60%	27.46%	72.76

Table 6.19: R157 Eastbound Speed Distribution

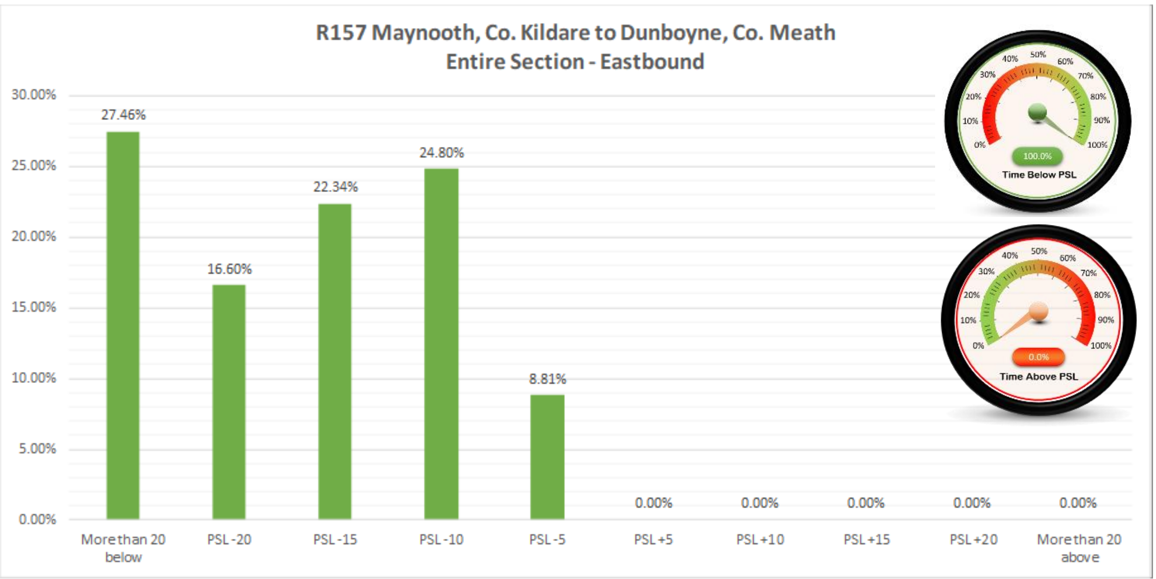


Figure 6.72: R157 Eastbound Speed Distribution

The first GPS track in this direction, Velocity 1 on the chart, is longer than the rest, however, given the other three are approximately the same length it was felt that it would have a negligible effect on the V_{sp} output. The profile of the individual tracks are fairly similar, indicating for the most part that the geometry of the road itself is having more of an effect than traffic volumes. There are definte troughs where there are almost 90° bends. There is a fairly even spread of time spent below the speed limit through the bands as shown above but nearly 45% of time is spent travelling at speeds no higher than 60 km/h. This will have an adverse effect on the Efficiency Index.

This proves to be the case with the appropriate band analysis showing that traffic is only travelling in the 'appropriate' zone for 34% of the time, giving an Efficiency Index of 0.34, which is poor (Figure 6.4).

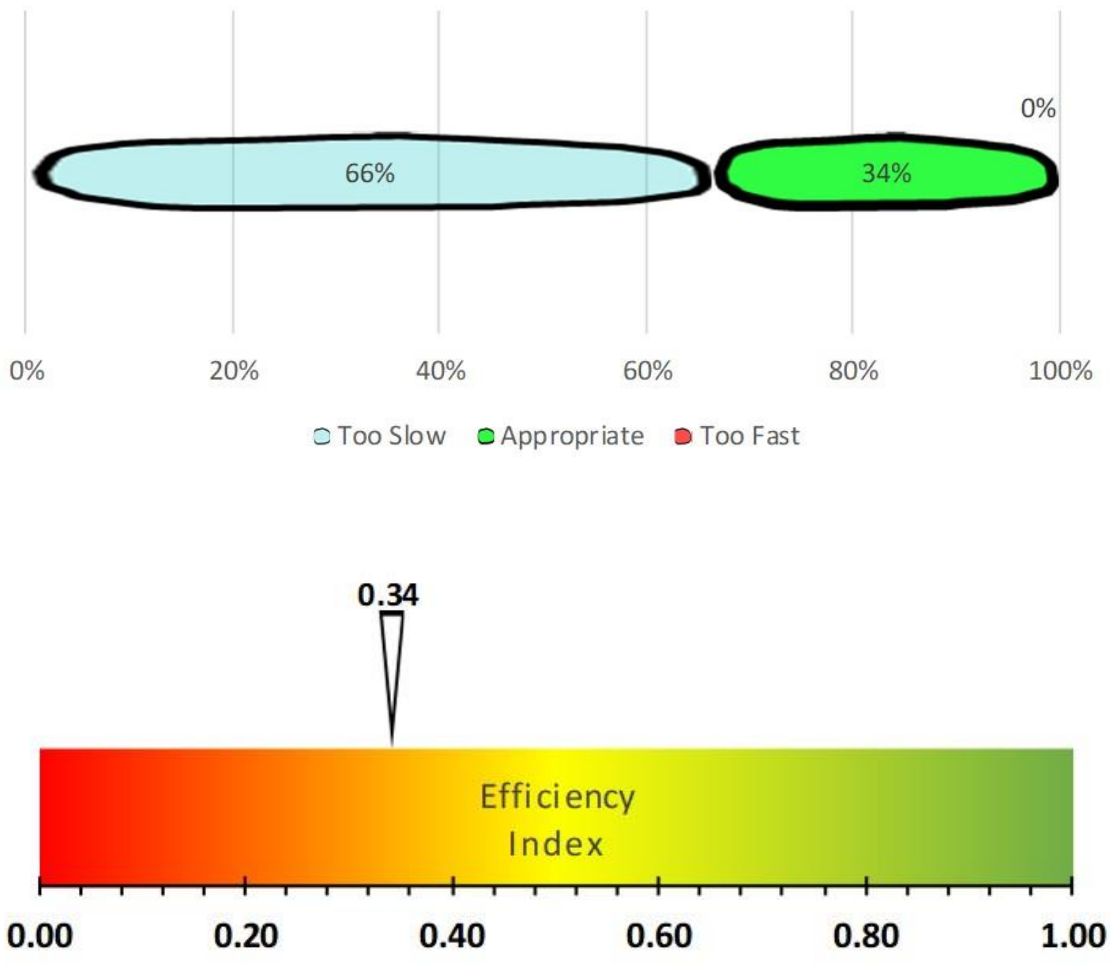


Figure 6.73: R157 Eastbound Route Efficiency & Efficiency Index

WESTBOUND

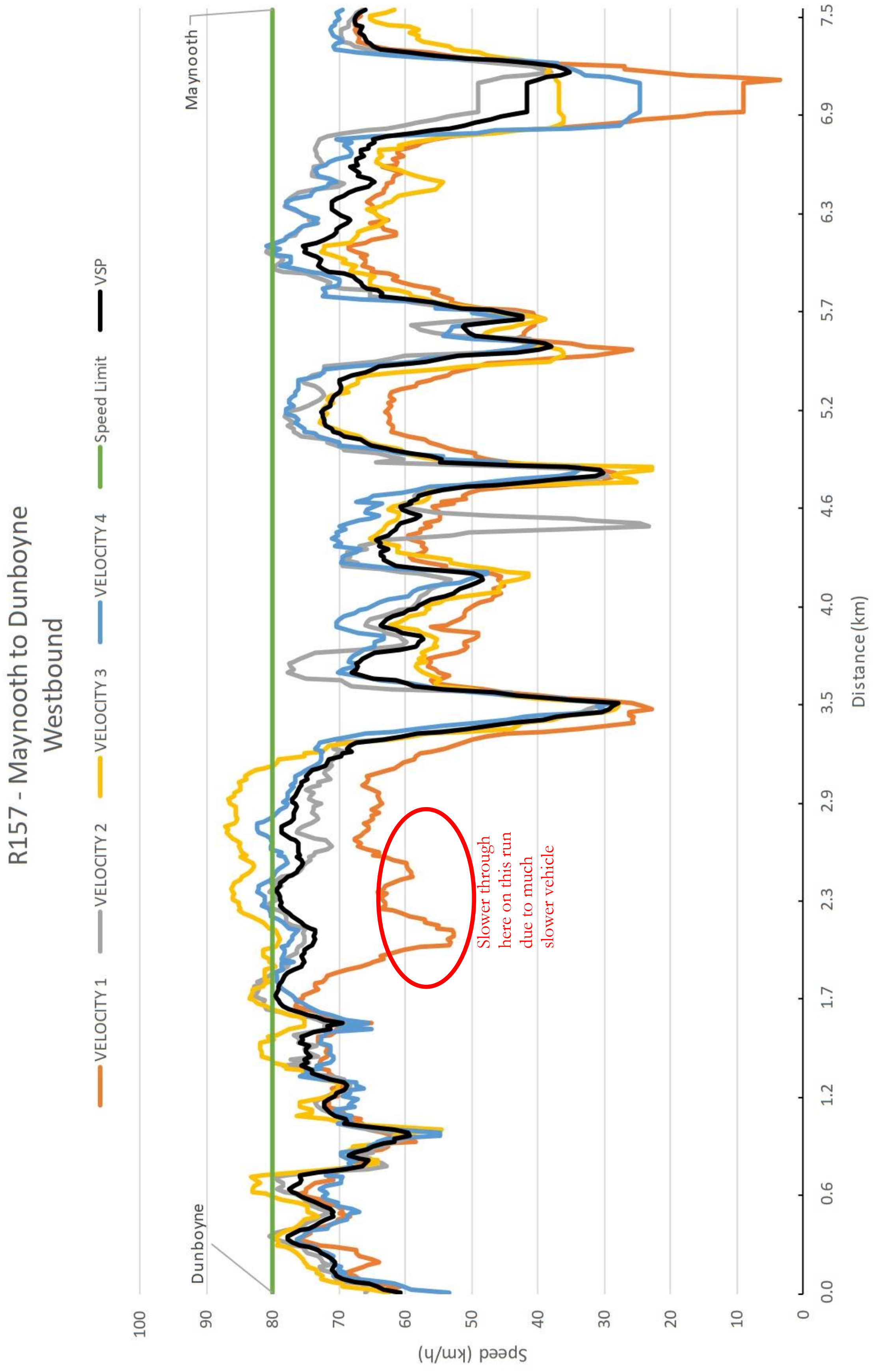


Figure 6.74: R157 velocities, V_{sp} and speed limit - Westbound

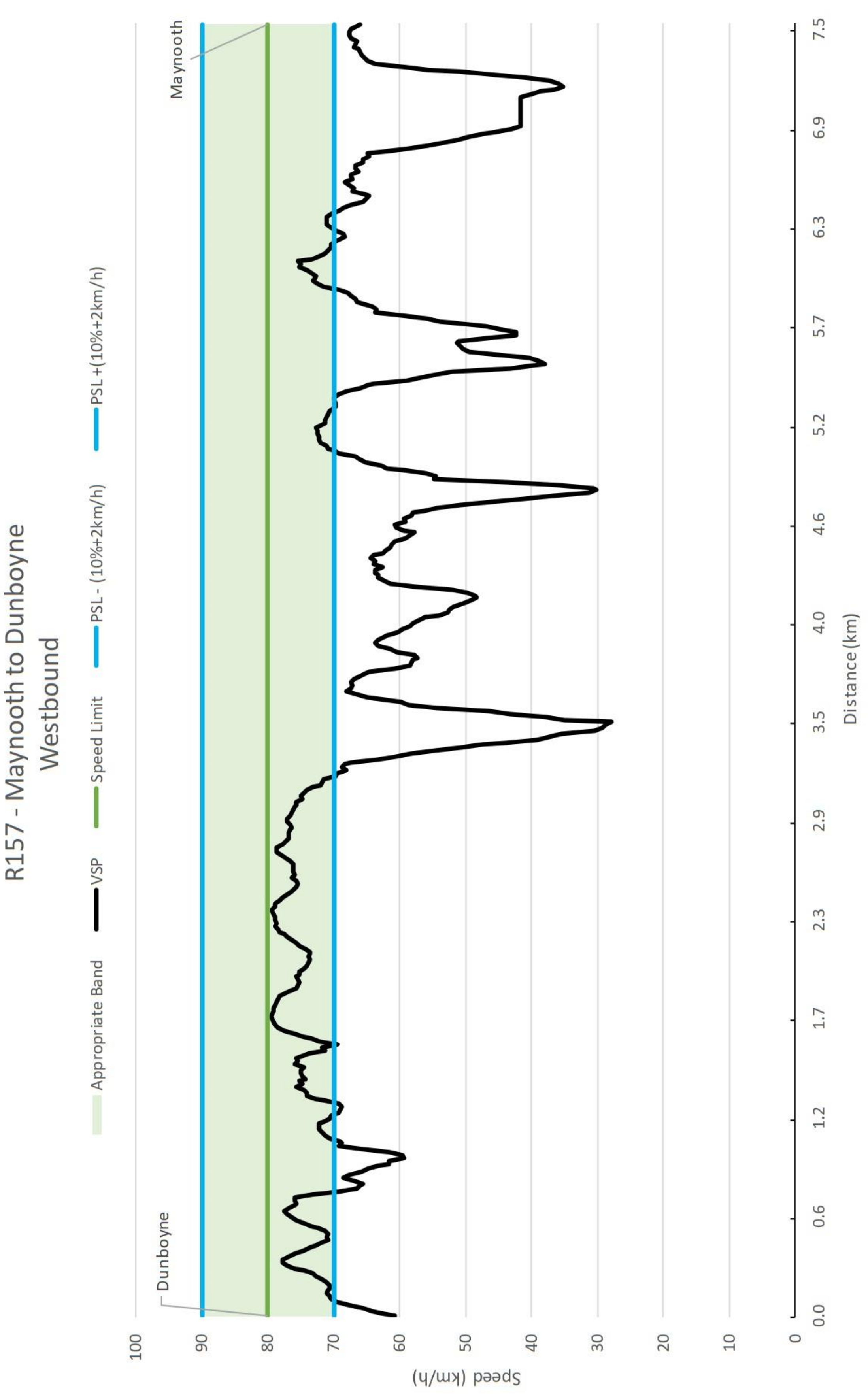


Figure 6.75: R157 V_{sp}, speed limit and 'appropriate' band - Westbound

Speed Distribution, Route Efficiency And Efficiency Index

R157 - WESTBOUND	Above Posted Speed Limit					Max V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	79.62
GPS Observations	0	0	0	0	0	Min V_{sp}
% of Route	0.00%	0.00%	0.00%	0.00%	0.00%	59.28
	Below Posted Speed Limit					Ave V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	73.06
GPS Observations	98	99	90	52	119	85th %
% of Route	21.40%	21.62%	19.65%	11.35%	25.98%	77.80

Table 6.20: R157 Westbound Speed Distribution

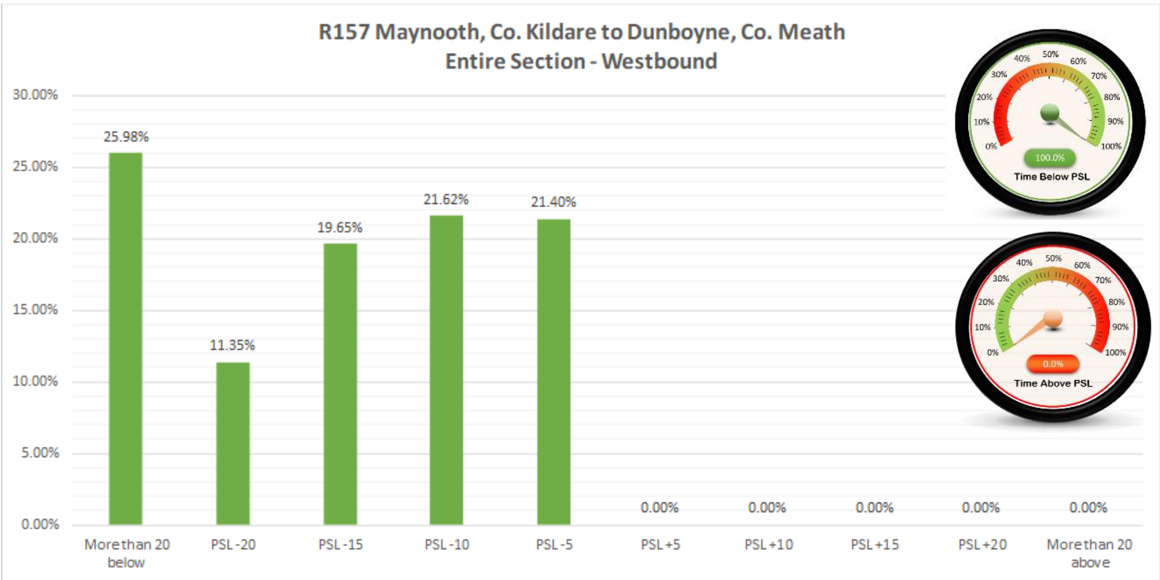
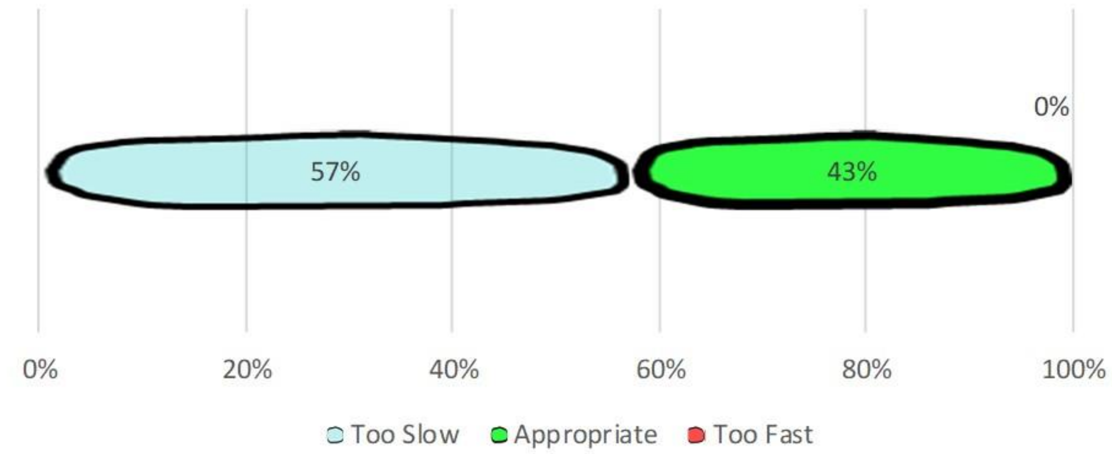


Figure 6.76: R157 Westbound Speed Distribution

The GPS tracks in this direction are of a similar length and are fairly similar in their profiles, again suggesting that, mainly, the geometry of the road is the limiting factor and not traffic volumes. This direction performs slightly better, drivers are reaching the speed limit about two-thirds of the time, however, there are many troughs in the vicinity of the tight 90° bends. More time (43%) is spent in and around the 0-10 km/h below the speed limit i.e. no less than 70 km/h, which is the limit of the appropriate zone for a default speed limit of 80 km/h, suggesting a better EI will be returned than for the Eastbound direction.

That is what emerges from the appropriate band analysis, a fair Efficiency Index of 0.43 emerges for the Westbound direction.



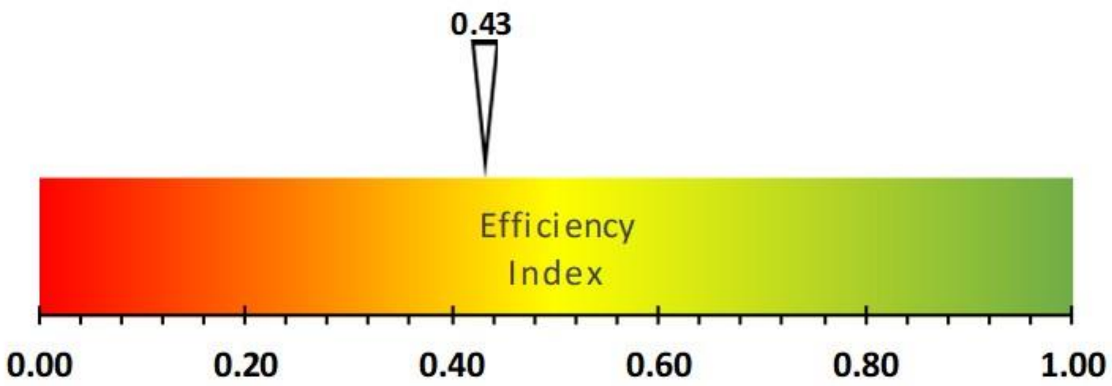


Figure 6.77: R157 Westbound Route Efficiency & Efficiency Index

EFFECT OF ALTERING THE SPEED LIMIT

The route is not performing well in either direction, the Efficiency Index is poor in the Eastbound direction and fair in the Westbound direction. Altering the speed limit along the entire route has the following effect on the Efficiency Index.

Section		Speed Limit	Efficiency Index Eastbound	Efficiency Index Westbound
Existing Configuration	Entire Section	80 km/h	0.34	0.43
Altered Scenario 1	Entire Section	70 km/h	**0.68**	**0.70**
Altered Scenario 2	Entire Section	60 km/h	0.42	0.34

Table 6.21: R157 Efficiency Index – Altered Speed Limits

Altering the speed limit to 60 km/h in the Eastbound direction produces a marginal improvement in the EI but results in a deterioration in the EI in the Westbound direction. As previously stated, the intention of the analysis is to model the effect changing a speed limit would have, in both directions. In this case, applying a speed limit of 60 km/h only shows benefit in one direction and is not an option that should be considered. Applying a 70 km/h speed limit would result in a substantial improvement in the EI in both directions and also produces EI's that are almost identical.

Figure 6.78: R157 – V_{sp} and Appropriate Bands (Altered Speed Limits)

CONCLUSIONS

The profiles show that, overall, across both directions, 80 km/h is proving to be a difficult speed limit for drivers to '*make full use of*'. The Efficiency Index in both directions is poor, in fact this route, overall, performs worse than all the other case study routes except the N14 (see fig 7.2). Road users are not exceeding the speed limit, the cross-section and alignment does not appear to facilitate that, which is positive, however, users are unable to stay within the appropriate zone for more than 38% of the time (averaged over both directions). The Efficiency Index is better in the Westbound direction but would, at 0.43, be considered to only be fair, at best. We will see later in section 6.3.8 that when this route is captured again at a later date for a repeatability test that similar results are obtained.

6.3.7 R410 – Naas, Co. Kildare to Blessington, Co. Wicklow

The R410 commences in Naas, Co. Kildare and continues in an easterly direction to Blessington, Co. Wicklow. It is 7.5km in length and has experienced 7 collisions over the period 2006-2012.

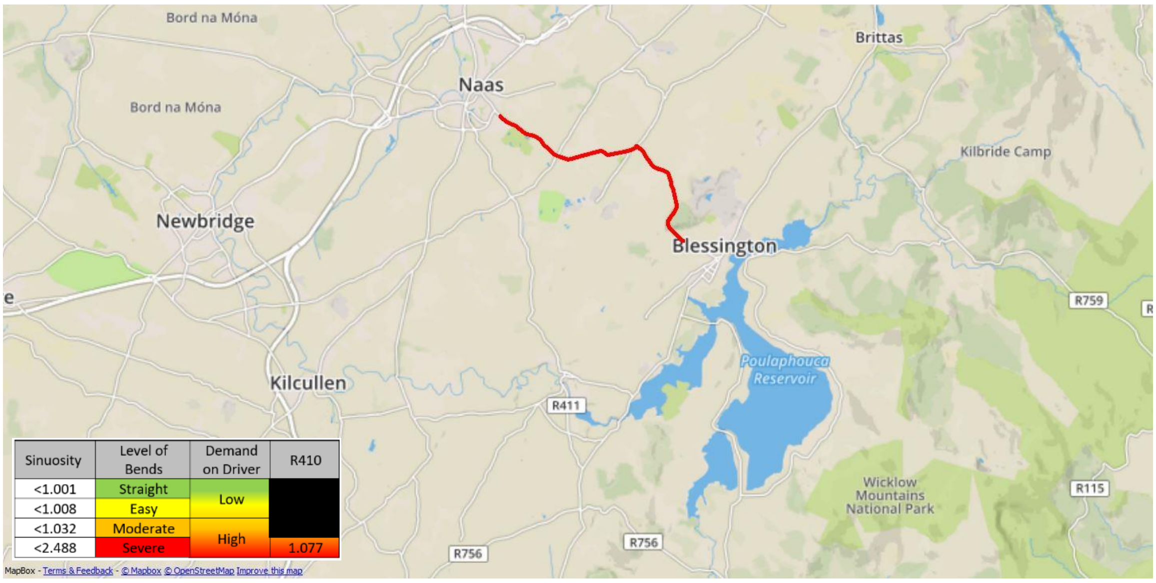


Figure 6.79: Location of R410 Case Study

As it is a Regional road, the Default Speed Limit is 80 km/h and is applied to the entire route. There is a Special Speed Limit of 60 km/h applied at a staggered junction along the route at Beggars End crossroads, which has been inappropriately treated as an isolated hazard requiring a reduced speed limit. The reduction is applied over a short length and the road user can almost see the restoration of the speed limit from the entry point of the reduction, this is against advice given in the Guidelines. The built-up area speed limit of 50 km/h is applied through the village of Eadestown, with a Special Speed Limit of 60 km/h applied on the approach to Eadestown from the Westbound direction (the transition from 80 km/h to 50 km/h), likely due to the presence of a graveyard, again, treating an isolated hazard by reducing the speed limit.

COLLISION HISTORY

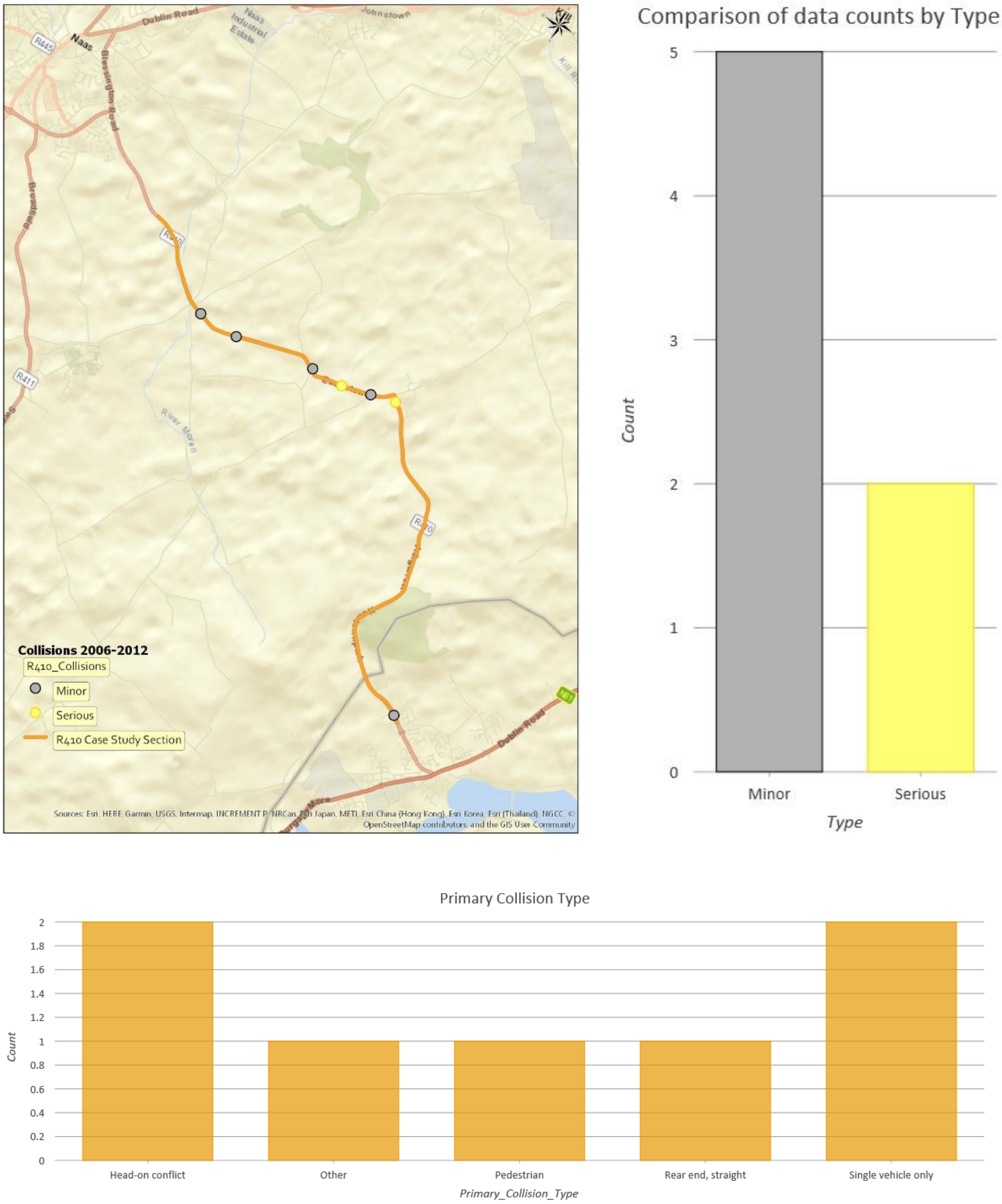


Figure 6.80: R410 Case Study – Collision History

In the period 2006-2012 there was a total of 7 collisions on this section of the R410 between Naas and Blessington – 5 minor and 2 serious. Two were single vehicle collisions, 2 were head-on collisions and there was 1 each of a pedestrian collision and rear end collision.

COLLISIONS IN POORLY PERFORMING SECTION

The section of the R410 from Naas to Blessington has a speed limit of 80 km/h applied (Default). There is a Special Speed Limit of 60 km/h in place for a short section at Beggars End cross-roads. This section, between Beggars End cross-roads and Eadestown, has seen six collisions during the period 2006-2012 where the V_{sp} ranges from 65 km/h to 72 km/h. The road is narrow, or, appears to be, due to the lack of hard shoulders or hard strips and the overgrown 'feel' of the surrounding environment. There is a short section where overtaking is permitted, this may be a contributory factor in some collisions.

Figure 6.81: R410 Beggars End to Eadestown Collisions

EASTBOUND

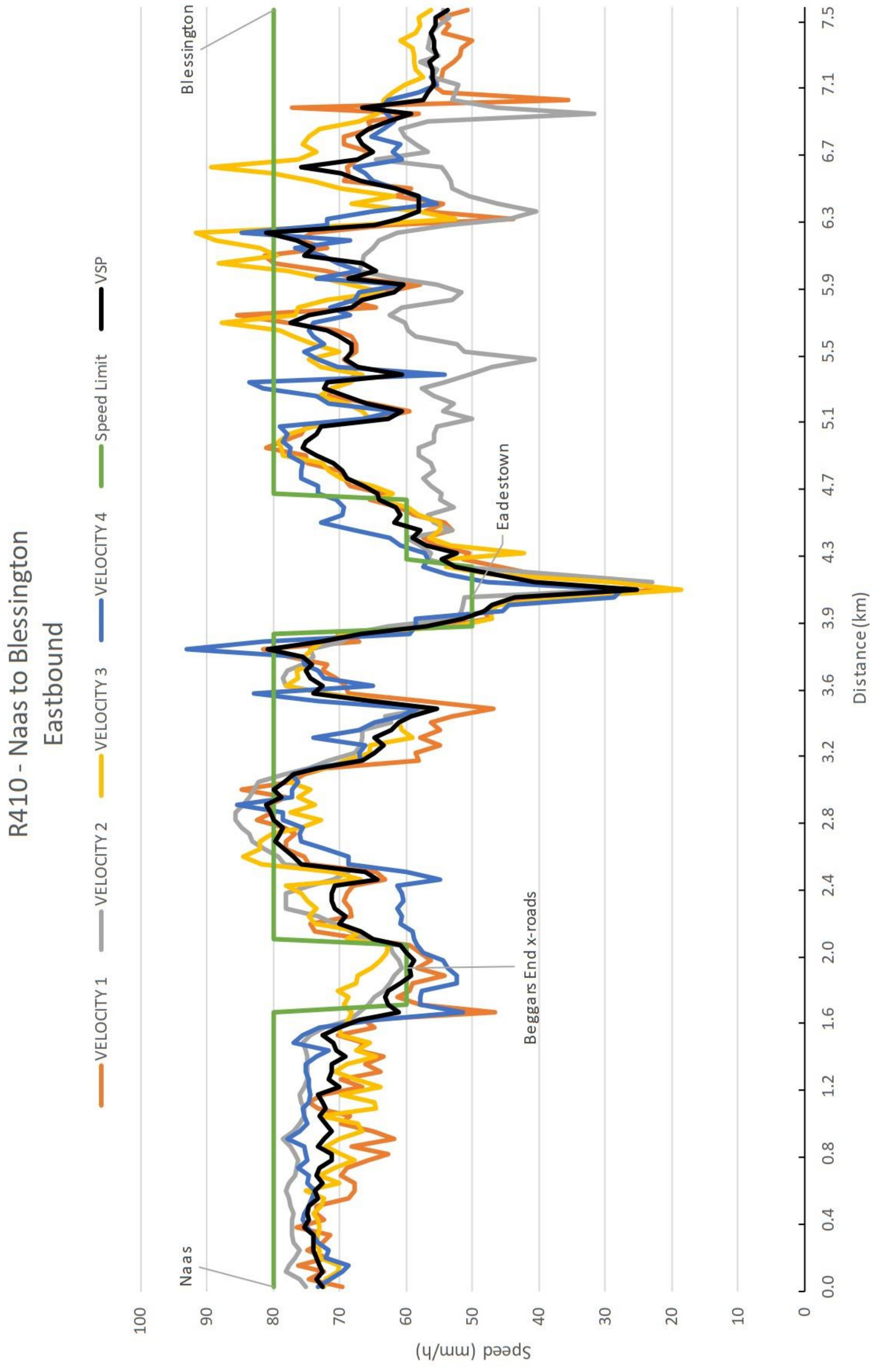


Figure 6.82: R410 velocities, V_{sp} and speed limit - Eastbound

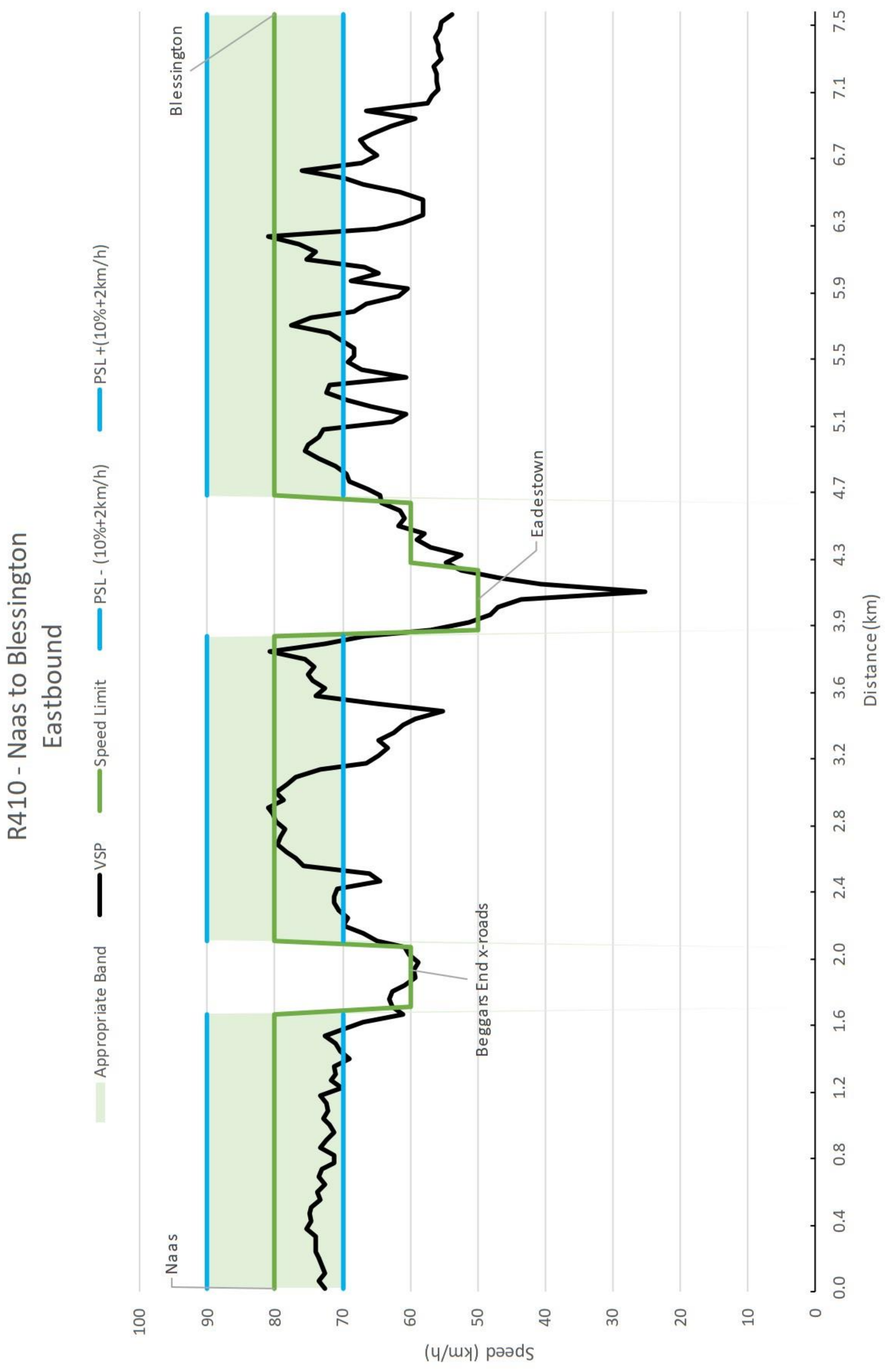


Figure 6.83: R410 V_{sp}, speed limit and 'appropriate' band - Eastbound

Speed Distribution, Route Efficiency And Efficiency Index

R410 - EASTBOUND	Above Posted Speed Limit					Max V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	81.10
GPS Observations	10	0	0	0	0	Min V_{sp}
% of Route	6.45%	0.00%	0.00%	0.00%	0.00%	55.25
	Below Posted Speed Limit					Ave V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	70.41
GPS Observations	23	54	30	19	19	85th %
% of Route	14.84%	34.84%	19.35%	12.26%	12.26%	75.56

Table 6.22: R410 Eastbound Speed Distribution

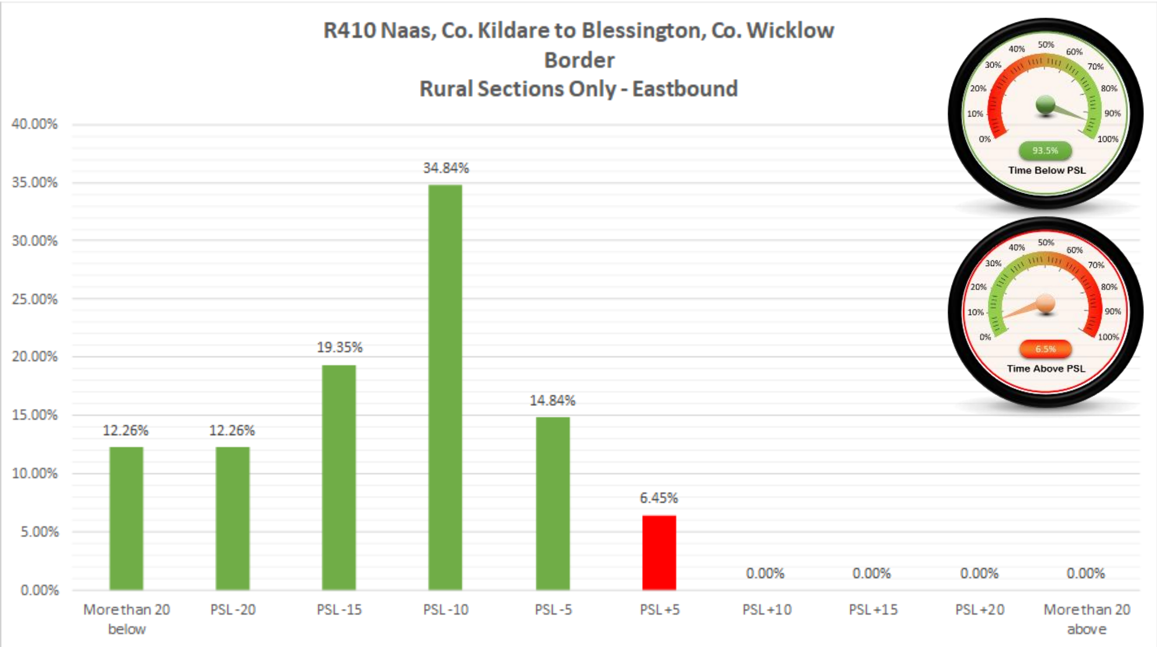


Figure 6.84: R410 Eastbound Speed Distribution

We can see that the route is travelled below the speed limit over 90% of the time and almost 50% of this is spent between 0-10 km/h below the speed limit. This, combined with the almost 7% of time spent above the speed limit, suggests a reasonable Efficiency Index should be returned. Traffic appears to be able to travel at speeds that would be considered appropriate with only 25% of time spent at speeds no greater than 60 km/h.

The appropriate band analysis results in a fair Efficiency Index being returned. Traffic is not travelling at speeds considered to be too fast and for the remainder of the time (44%) traffic is deemed to be travelling too slowly.

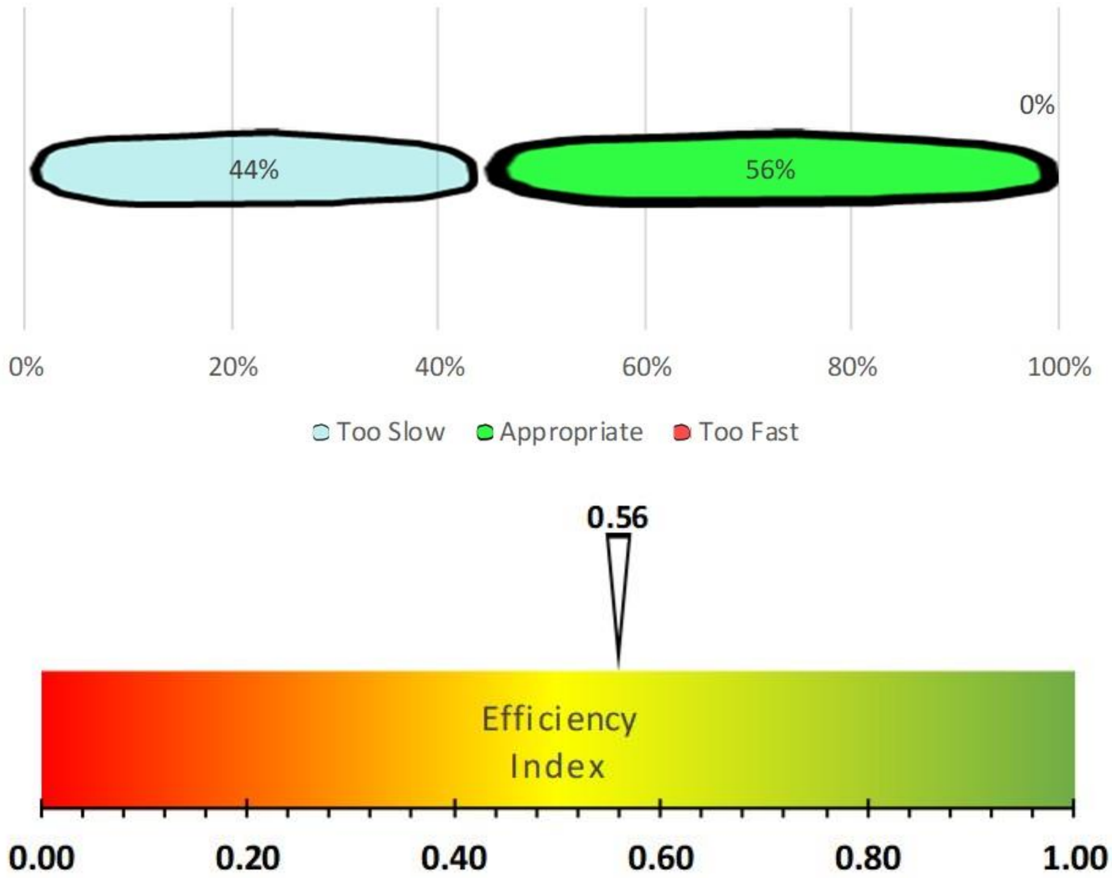


Figure 6.85: R410 Eastbound Route Efficiency & Efficiency Index

WESTBOUND

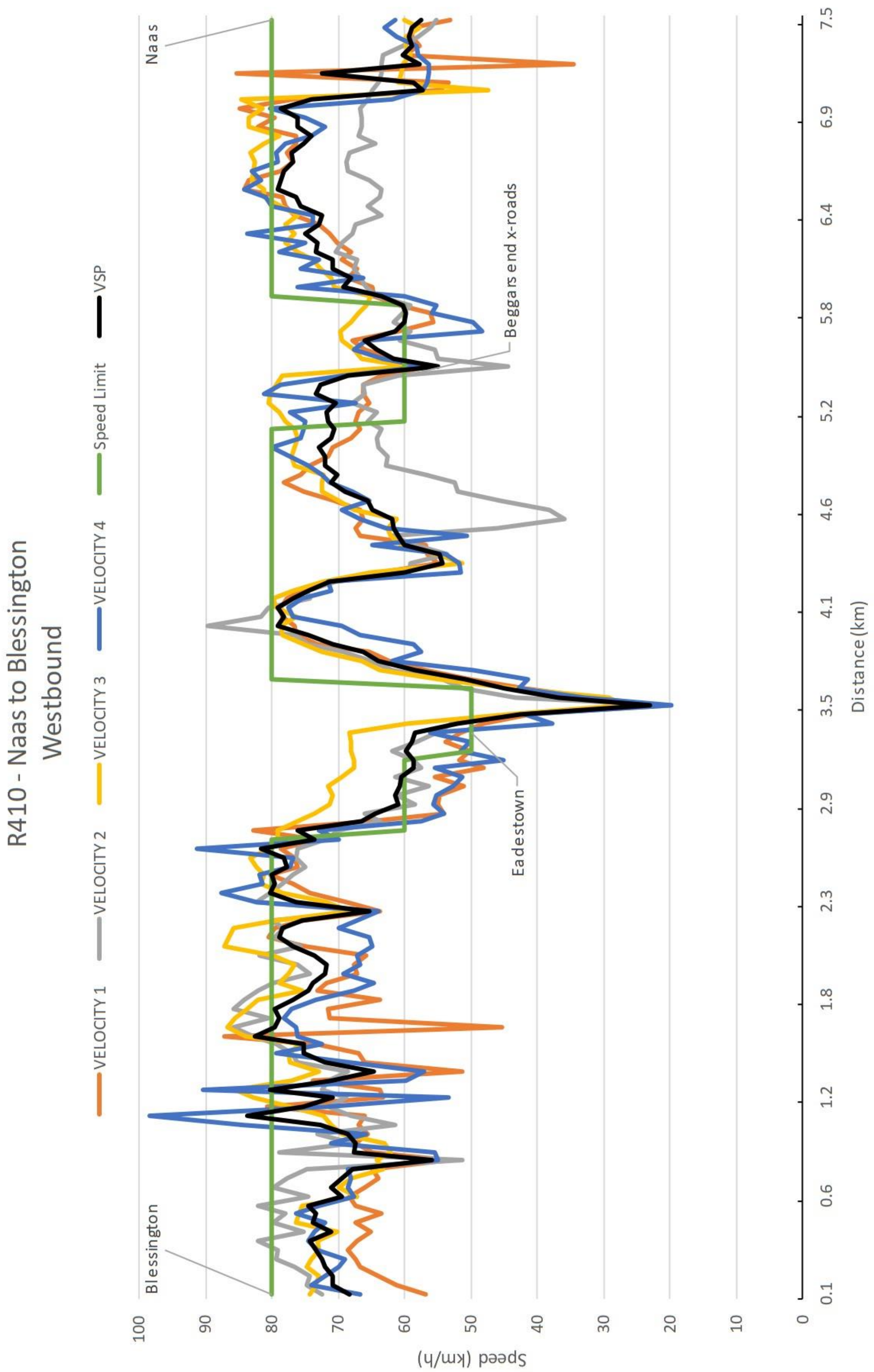


Figure 6.86: R410 velocities, V_{sp} and speed limit - Westbound

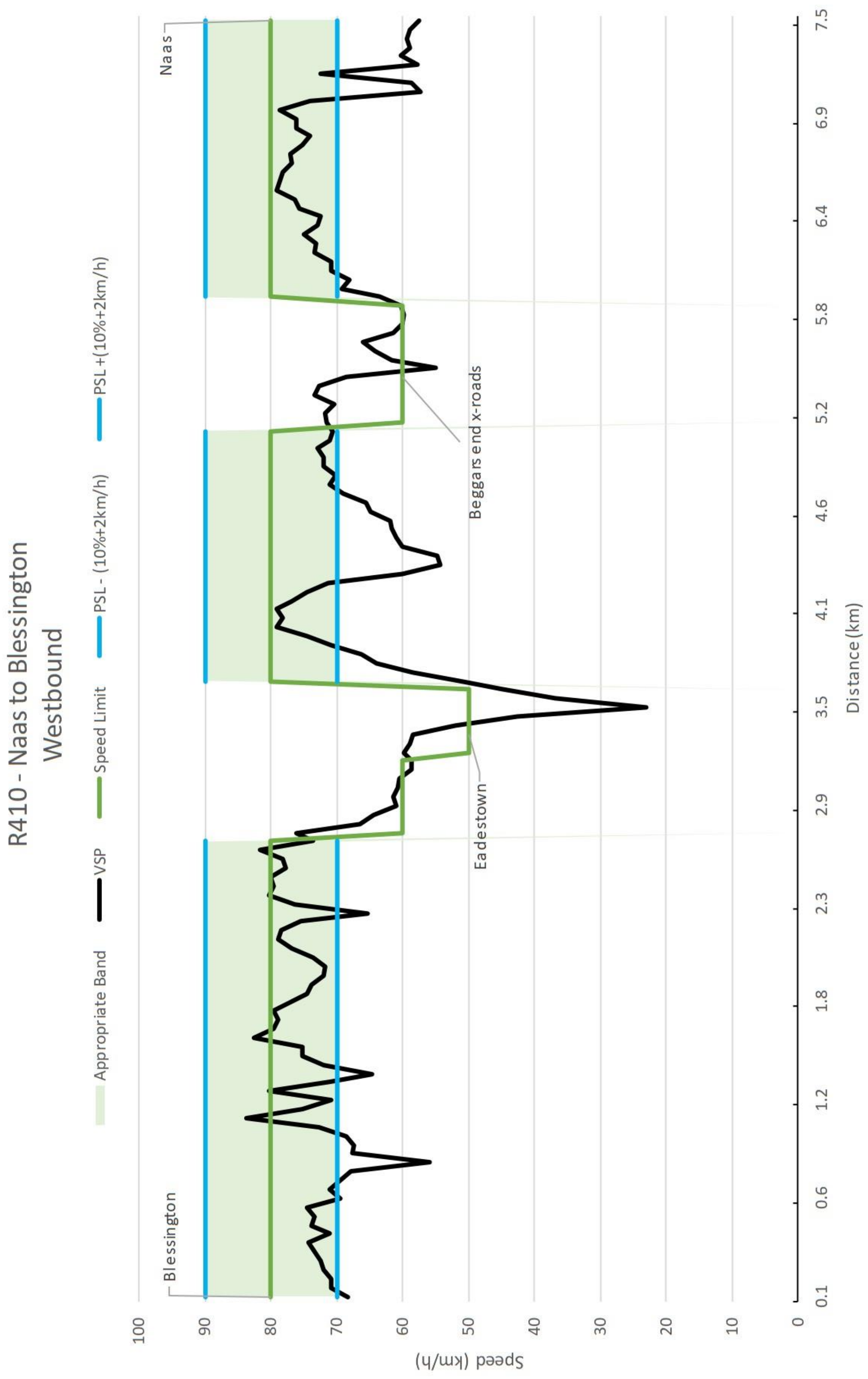


Figure 6.87: R410 V_{sp}, speed limit and 'appropriate' band - Westbound

Speed Distribution, Route Efficiency And Efficiency Index

R410 - WESTBOUND	Above Posted Speed Limit					Max V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	83.75
GPS Observations	10	2	5	0	0	Min V_{sp}
% of Route	7.87%	1.57%	3.94%	0.00%	0.00%	50.79
	Below Posted Speed Limit					Ave V_{sp}
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 km/h	70.56
GPS Observations	32	43	13	10	12	85th %
% of Route	25.20%	33.86%	10.24%	7.87%	9.45%	78.25

Table 6.23: R410 Westbound Speed Distribution

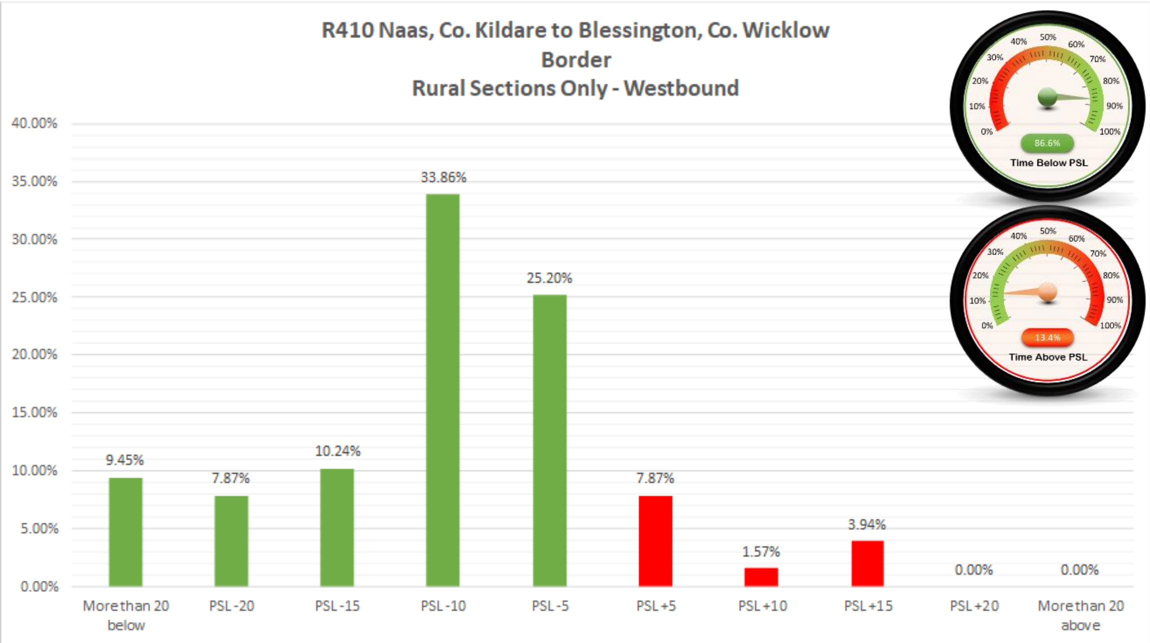


Figure 6.88: R410 Westbound Speed Distribution

We can see above that this direction is performing better than the Eastbound direction, traffic is below the speed limit 86% of the time but the speed is more concentrated around the bands that would be considered appropriate – almost 70%. This suggests a good Efficiency Index will be returned, only approximately 25% of the time is spent outside the 'appropriate' zone.

A good Efficiency Index is returned from the appropriate band analysis (0.68) with traffic travelling too slowly only 28% of the time compared to 44% in the Eastbound direction. Traffic is travelling too fast 5% of the time.

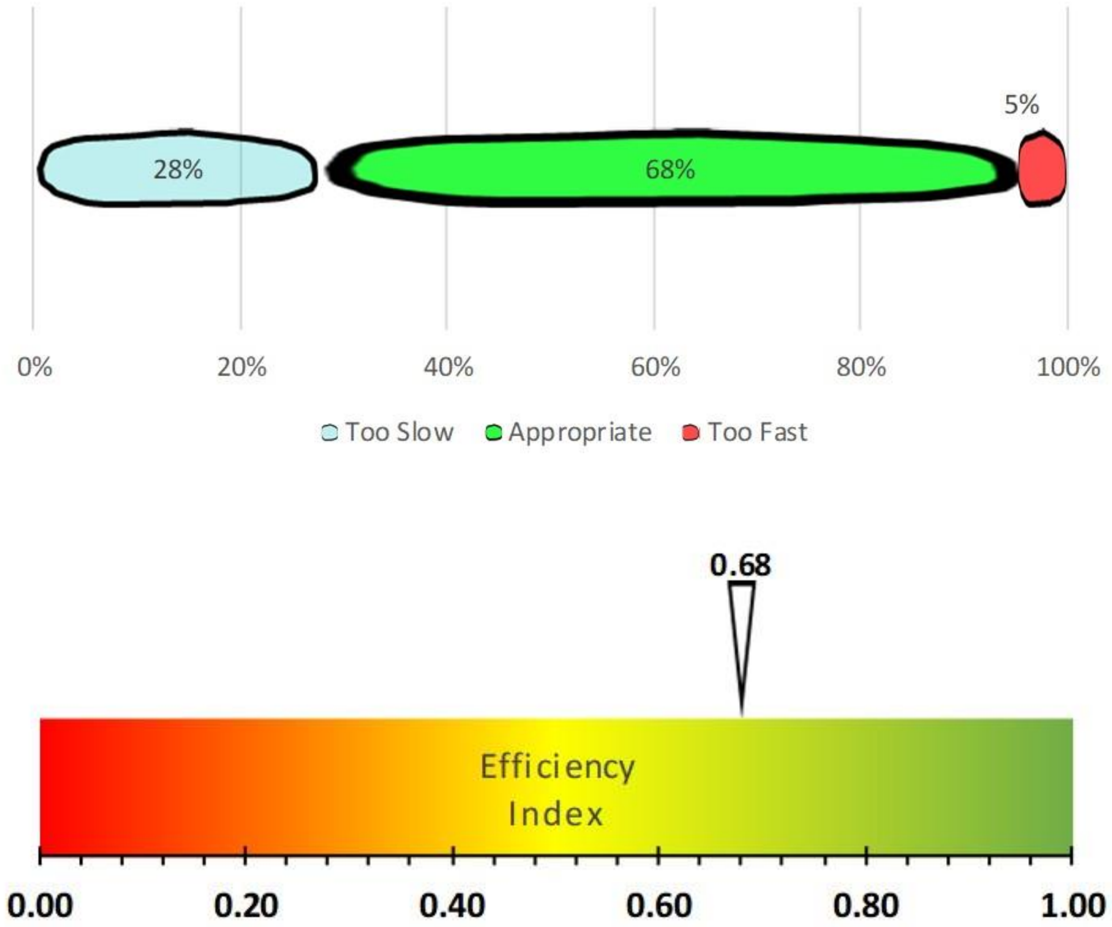


Figure 6.89: R410 Westbound Route Efficiency & Efficiency Index

EFFECT OF ALTERING THE SPEED LIMIT

The route is performing adequately in both directions, the Efficiency Index is fair in the Eastbound direction and good in the Westbound direction. The Special Speed Limit (60 km/h) through Beggars End crossroads is a classic case of a Local Authority using a Special Speed Limit to solve the issue of an isolated hazard.

Section		Speed Limit	Efficiency Index Eastbound	Efficiency Index Westbound
Existing Configuration	Naas-Beggars End Crossroads	80 km/h	0.56	0.68
	Beggars End Crossroads	60 km/h		
	Beggars End Crossroads – Eadestown	80 km/h		
	Eadestown-Blessington	80 km/h		
Altered Scenario 1	Entire Section	80 km/h	0.50	0.65
Altered Scenario 2	Entire Section	60 km/h	0.42	0.28
Altered Scenario 3	Entire Section	70 km/h	**0.81**	**0.74**

Table 6.24: R410 – V_{sp} and Appropriate Bands (Altered Speed Limits)

Altered scenario 1 tests whether this is having an effect on the EI overall, restoring the Default Speed Limit of 80 km/h results in a deterioration of the EI. We can see that the 60 km/h reduced speed limit at Beggar's End cross-roads is being respected more so in the Eastbound direction than in the Westbound direction but is not having a negative effect on the EI overall. Altered Scenario 2, applying a Special Speed Limit of 60 km/h to the entire route, also has a negative effect on the EI in both directions. Altered Scenario 3, a Special Speed Limit of 70 km/h, appears to be the optimal speed limit for this route.

Figure 6.90: R410 – V_{sp} and Appropriate Bands (Altered Speed Limits)

CONCLUSIONS

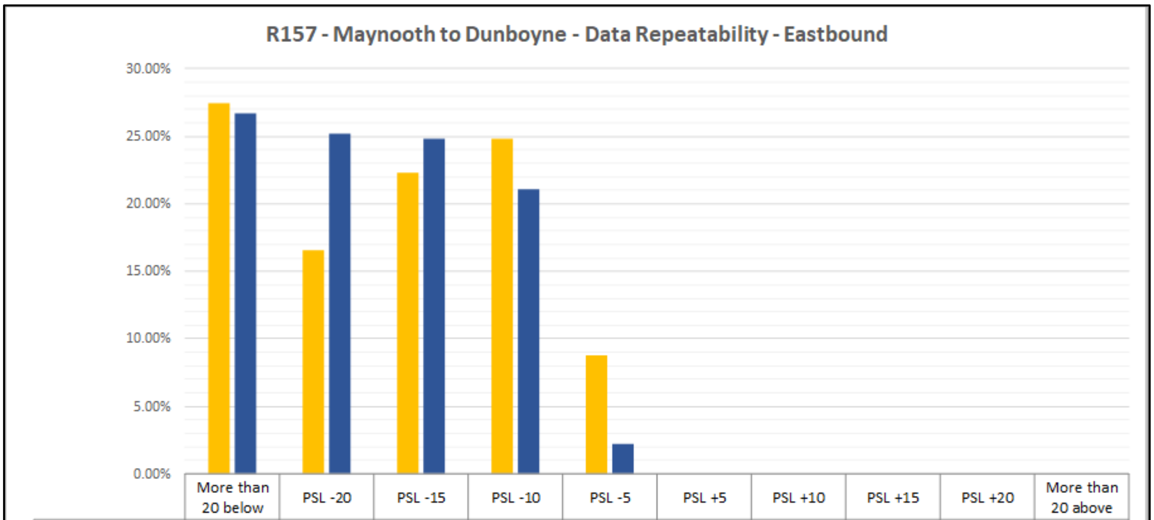
It appears from the profiles returned, the road user is suggesting the speed limit on this route is set too high. Again, while not suggesting a speed limit is a target, the road user appears to suggest the speed limit is unattainable overall but returns a reasonable Efficiency Index in both directions (0.56 and 0.68). The user is not able to make 'full use' of the speed limit, however, the profiles suggest that the Efficiency Index can be improved if the speed limit is reduced.

By reducing the speed limit, the Efficiency Index deteriorates, significantly in the Westbound direction (from 0.68 to 0.28), when the speed limit is reduced to 60 km/h. If the speed limit is reduced by only 10 km/h to 70 km/h (leaving the section through Beggars End cross-roads at 60 km/h) an improvement in the Efficiency Index is returned for both directions, most notably in the Eastbound direction (from 0.56 to 0.81).

As per the R157 case study, the character of the road and the V_{sp} values suggest the exploration of a 70 km/h speed limit. The average V_{sp} value in this direction, along the rural sections, is 70 km/h with the 85th percentile V_{sp} value returned being 75 km/h. 60 km/h appears to be too much of a reduction to apply and 60 km/h therefore becomes too low, this aligns with the approach the Department has taken with its advice to Local Authorities in that a Regional road should not have a Special Speed Limit of 60 km/h applied to it. A speed limit of 80 km/h seems to be too high. It appears the road user has decided that the appropriate speed limit for this route is around the 70 km/h mark.

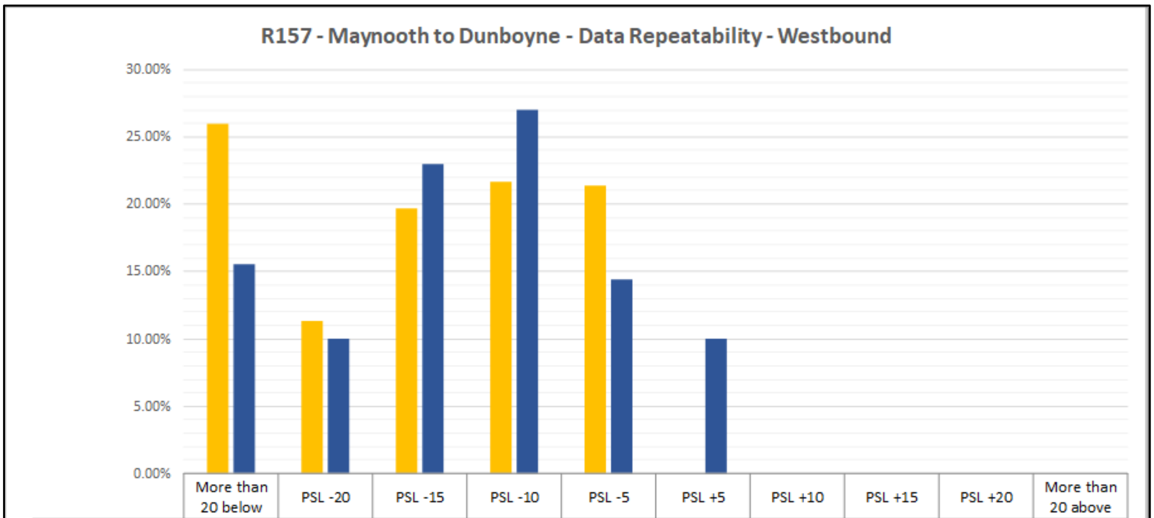
6.3.8 Data Repeatability

To determine if the V_{sp} derived for each route was a one-off result and to determine if the proposed methodology for assessing and setting a speed limit has merit, it was deemed necessary to demonstrate repeatability of the results. The R157, from Maynooth to Dunboyne, was captured again – 4 times in each direction, as before. Graphs of speed limit versus V_{sp} for both the initial derivation of V_{sp} and the repeat are shown in Figures 6.93 and 6.94. The charts below show that the speed distributions are relatively similar in both directions.



	More than 20 below	PSL -20	PSL -15	PSL -10	PSL -5	PSL +5	PSL +10	PSL +15	PSL +20	More than 20 above
Initial Capture	27.46%	16.60%	22.34%	24.80%	8.81%	0.00%	0.00%	0.00%	0.00%	0.00%
Validation Capture	26.67%	25.19%	24.81%	21.11%	2.22%	0.00%	0.00%	0.00%	0.00%	0.00%

Figure 6.91: R157 - Data Repeatability – Comparison of Speed Distributions



	More than 20 below	PSL -20	PSL -15	PSL -10	PSL -5	PSL +5	PSL +10	PSL +15	PSL +20	More than 20 above
Initial Capture	25.98%	11.35%	19.65%	21.62%	21.40%	0.00%	0.00%	0.00%	0.00%	0.00%
Validation Capture	15.56%	10.00%	22.96%	27.04%	14.44%	10.00%	0.00%	0.00%	0.00%	0.00%

Figure 6.92: R157 - Data Repeatability – Comparison of Speed Distributions

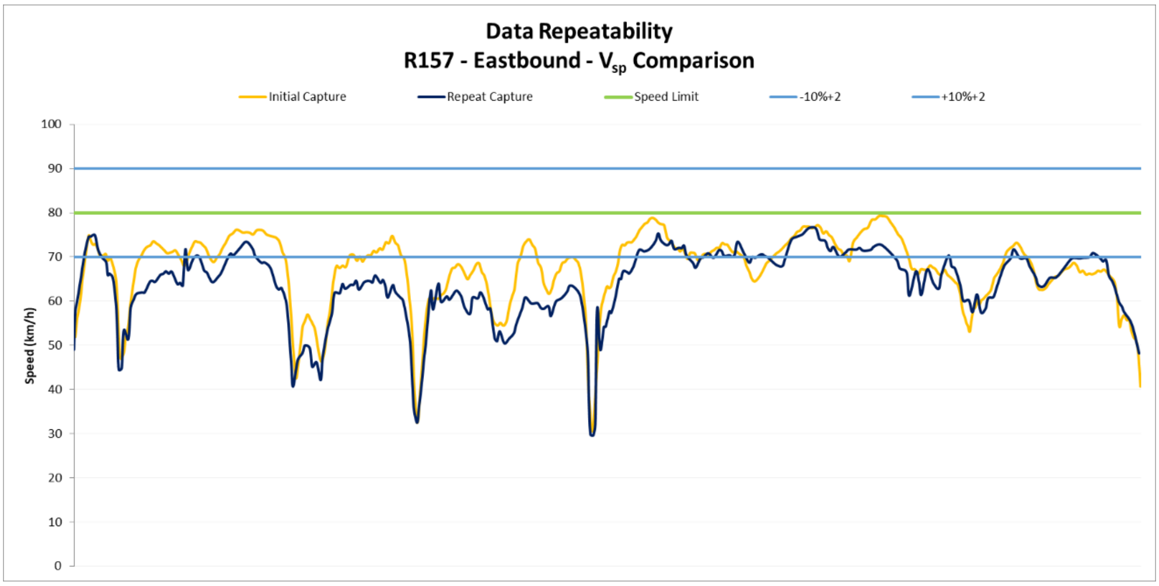


Figure 6.93: R157 - Data Repeatability – Eastbound V_{sp} Comparison

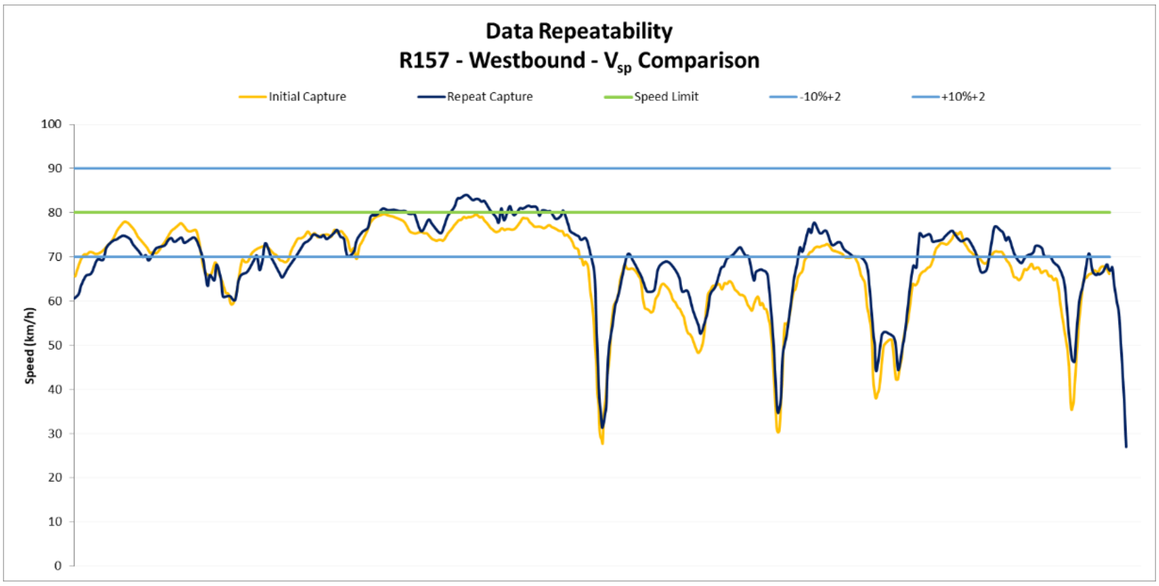


Figure 6.94: R157 - Data Repeatability – Westbound V_{sp} Comparison

In both directions, the repeat capture V_{sp} profiles are very similar to the initial capture. Common points where the driver slows, accelerates, etc are easily identified. This exercise demonstrates that the process is repeatable. To further demonstrate repeatability, the Efficiency Index was calculated for the repeat capture and compared against the initial EI and shown in Fig 6.95. There is, obviously, a difference between the initial and repeat EI's, however the difference is not considered to be significant as the values returned for the repeatability capture, remain within the original band i.e. in the '*poor*' band in for the Eastbound direction and in the '*fair*' band for the Westbound direction.

Figure 6.95: R157 - Data Repeatability – Efficiency Index Comparison

In section 6.3.6, the effect on the Efficiency Index when altering the speed limit was shown. The alternative speed limits used were 70 km/h and 60 km/h. This was repeated for the repeatability capture, with the results shown below.

	Speed Limit	Efficiency Index Eastbound	Efficiency Index Westbound	EI Gap	Average EI
INITIAL CAPTURE					
Existing	80 km/h	0.34	0.43	0.09	0.385
Altered Scenario 1	70 km/h	0.68	0.70	0.02	0.69
Altered Scenario 2	60 km/h	0.42	0.34	0.08	0.38
REPEAT CAPTURE					
Existing	80 km/h	0.23	0.51	0.28	0.37
Altered Scenario 1	70 km/h	0.67	0.69	0.02	0.68
Altered Scenario 2	60 km/h	0.54	0.31	0.23	0.425

Table 6.25: R157 Efficiency Index – Data Repeatability

The Efficiency Index values are further apart in the repeat capture than the initial capture with existing speed limits (0.28 compared to 0.09) but the average EI returned over both directions of travel is almost unchanged (0.37 compared to 0.385). The difference in the gaps serves as a further indicator that the existing speed limit is not appropriate for this route. This is also demonstrated by the fact that a 70 km/h speed limit returns such similar figures in the initial capture and repeat capture analysis (Altered Scenario 1).

We can see from Figure 6.96 that the repeat capture EI values and the altered scenarios for the repeat captures fall in the same bands as for the initial capture and altered scenarios.

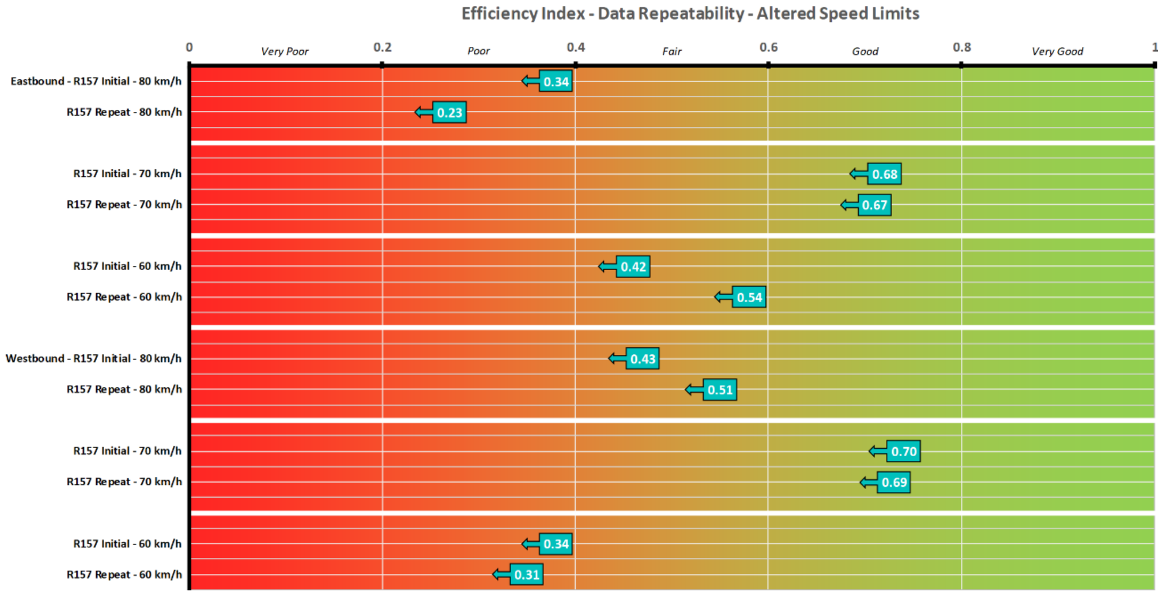


Figure 6.96: R157 - Data Repeatability – Efficiency Index Comparison

It is possible that 60 km/h is the most 'sensitive' speed limit for this route, indicating that it is bordering on being too slow. The values are practically identical when the speed limit is 70 km/h, reinforcing the point made previously that 70 km/h is a speed limit that should be given consideration as it appears to be the most appropriate speed limit for this route. This repeatability exercise has shown the V_{sp} process to be repeatable and reliable.

6.4 Summary

In this chapter, the proposed methodology for assessing and setting speed limits was presented and tested on seven sections of road of differing classification totalling approximately 160 km in each direction. The strength of the relationship between the posted speed limit and the derived Safe Profile Velocity (V_{sp}) was represented by plotting the V_{sp} profile against the posted speed limit (PSL). The speed distribution of the V_{sp} profile was then derived, this can help gain a basic understanding of the performance of the route. The 'appropriate' band analysis process was then carried out to determine Route Efficiency and the Efficiency Index. This was carried out in both directions of travel for each route chosen. A summary of the results is presented in Table 7.1.

The results show a weak relationship between the posted speed limit and the V_{sp} in terms of road users '*making full use*' of the available speed limit. Speed limits are not targets, however, most road users attempt to keep up with the flow of traffic and drive as close to the speed limit as possible. A robust and appropriate speed limit would be one that a road user does not feel the need to exceed, ideally the entire route would be travelled below the speed limit 100% of the time in a band up to 5 km/h below the speed limit. It is not, however, an ideal world. It may be more realistic to expect an efficient route to be one that is driven entirely within a reasonable distance from the speed limit - the '**appropriate**' zone. This zone is defined as the zone that covers the range;

$$\boldsymbol{PSL - ((PSL\ x\ 0.1) + 2) \qquad to \qquad PSL + ((PSL\ x\ 0.1) + 2)}$$

The results show that road users are 'suggesting' speed limits on these sections of road are incorrect. This broadly supports the observations of the speed limit working group in 2014 whose analysis suggested that approximately 58% of the National secondary road would see its speed limit reduced from 100 km/h to 80 km/h if a Stage 1 Assessment was carried out.

Chapter 7

Summing up, Discussion and Conclusions

7.1 Introduction

The purpose of this research is to develop an alternative method of assessing speed limits on Irish rural single carriageway roads. The reason for doing so was to provide a tool for those assessing speed limits that would enable them to confidently assess and set a speed limit on a rural single carriageway road. It was also a sub-item of action no. 8 of the 2013 Speed Limit Review report (previously mentioned on Page 2 of this thesis). In reviewing the 2010 speed limit guidelines, a basic tool was introduced, namely the Stage 1 Assessment procedure that was included in the 2015 Guidelines. It was a departure from the way Special Speed Limits were previously set. The class and function of the road was set aside, and the most basic physical characteristic of the road was the indicator as to whether 80 km/h or 100 km/h was chosen. If the road was greater in width than 7m, then the speed limit should be set at 100 km/h.

The methodology employed to arrive at the 7m width was to evaluate 32 different National secondary routes and their respective widths, coupled with visual inspections and experience of these routes, the Working Group, tasked with the revision and update of the 2010 Special Speed Limit Guidelines, was confident that this was the approach that should be taken and consequently included Stage 1 Assessment in the 2015 Guidelines. It offered a simple choice to those tasked with setting speed limits in their respective administrative areas and was based on information that could be relatively easily obtained.

It was expected that the next question posed to the Department would be '*what should be done when the road is 6.8m wide or 7.2m wide, for example'*. The answer to this was to suggest in the Guidelines that, if such a borderline scenario were to arise, the following factors should be considered.

- The geometry of the road – width, visibility, bendiness, verge width
- Amount of development accessing directly onto the road
- Forgiving nature of the roadsides
- Collision history
- Level of use by vulnerable road users
- Annual Average Daily Traffic
- Mean and 85th percentile speeds
- Use the Speed Assessment Framework

To ensure the above factors are considered and analysed properly, the process to capture this information and assess it must be simple and be seen to be effective. Stage 1 delivers simplicity and is effective. It may be basic, but it does make the task of undertaking a full review of speed limits much less daunting. Also, when resources are stretched, it can be carried out quickly. The same should be true of the Speed Assessment Framework. It is not clear how widely it was used when it was included in the 2010 Guidelines, however, anecdotally, it appears that few Local Authorities made use of it. The goal of this research is to develop a solution that would satisfy the need for simplicity and allow those using it to do so easily and without trepidation. Having a clearly defined method and way of doing something makes one, generally, more likely to engage in a process.

The approach to setting speed limits has now changed (since 2015) and, with the Stage 1 Assessment, the Guidelines and philosophy of setting speed limits is at a point where the desired approach begins to take account of the physical characteristics of the road itself, ignoring its classification, whether it's an upper or lower tier road and ignoring whether it is a strategic route or not.

Strategy, or strategic routes, can be defined in many ways. The N2 from Dublin to Derry (connecting to the A5 at Aughnacloy) may be strategic in terms of commuters or haulage, but the N56 around Co. Donegal is strategic in its own way for tourism, for example. The same is true of the N71 and many similar routes in terms of tourism.

So, with regard to upper and lower tier roads, why discriminate or favour one over the other when assessing speed limits? Collisions do not discriminate. Collisions happen on every road type, whether they are strategic or not, regardless of whether they are higher tier or lower tier. Obviously, more collisions tend to happen when and where there are higher levels of traffic. A responsibility of Local Authorities should be to set the appropriate speed limit for the road in question, taking the relevant factors into account. In this author's opinion, the classification, the strategic nature or the function of the road are not the most relevant factors to consider when assessing an appropriate speed limit for rural single carriageway roads that could potentially deliver savings in terms of reduced collisions and fatalities. To effectively set appropriate speed limits, the process that Local Authorities must employ to assess and set a speed limit must be seen to be as simple and transparent as possible. Something that Local Authorities and the Department of Transport, Tourism and Sport cannot control is a young male driver losing control of his vehicle at 3am on Saturday or Sunday morning and crashing into a ditch. In these single vehicle loss of control collisions, the speed limit on the road is irrelevant. Whether it was 60 km/h, 80 km/h or 100 km/h would not make a difference, unfortunately these types of collisions speak to a wider issue. What can be controlled is the development of appropriate guidance and supplementary tools to assess and implement appropriate speed limits. This, to a certain extent, has been achieved with the introduction of the revised Guidelines in 2015 that contained Stage 1 Assessment. A more detailed data capture and analysis solution being proposed in this thesis can go a long way to delivering certainty in the assessment process as a whole without having to use or overhaul the Speed Assessment Framework.

On rural roads, there is often a difference of opinion as to what constitutes a reasonable balance between collision risk, reliable journey times and environmental impact. It is often perceived that reducing a speed limit to 80 km/h from 100 km/h would result in many road users facing increased travel times and be at a greater risk of receiving penalty points for speeding. This appears to suggest that the issue of appropriate speed limits is not taken seriously enough and that we do not take our responsibility to drive safely within the speed limit seriously. The fear of receiving penalty points is a real one, and correctly so. Leaving a speed limit set inappropriately high to reduce the chance of receiving penalty points for speeding is irresponsible, and irrational. Drivers must accept responsibility for their own actions and that includes observing speed limits. Also, if a speed limit is set appropriately it may well be self-regulating.

This can also be seen when Local Authorities are unable to get Special Speed Limit Bye-laws adopted because Elected Members will not support a reduction in a speed limit like that. It could also be argued that it might not yield many votes. Higher speed is often perceived to bring benefits in terms of shorter travel times for people and goods, however, evidence suggests that when traffic is moving at constant speeds, even at a lower level, it may result in shorter and more reliable overall journey times and that journey time savings from travelling at higher speeds are often overestimated (Stradling et.al, 2009). Crimecall carried out a comparison test between two identical cars that travelled a round trip from Dublin to Castlebar, Co. Mayo - one car travelled normally, not exceeding the speed limit and the other travelled 10km below the speed limit. The aim of the test was to discourage speeding by illustrating that the journey time differential between both vehicles was miniscule - less than 10 minutes over a 5.5-hour journey (RTE Crimecall, March 2015). It should also be considered that, with an inappropriately low speed limit, e.g. 80 km/h on a Regional road, with a paved width greater than 7m, good sightlines and visibility, etc, not all traffic will observe the limit and those who are inclined to break the speed limit with impunity will invariably find themselves behind someone observing the speed limit, which may result in driver frustration and lead some drivers to 'take a chance' and attempt to overtake.

This might not result in a collision, but what may happen is, the next time the same driver encounters a similar scenario, they will be emboldened by previous successful overtaking manoeuvres and attempt a similar manoeuvre again. The more this happens, the greater the likelihood of a collision. It is also possible that the driver is frustrated at the speed limit and not at the driver in front observing it – this shows that a robust, transparent and obvious speed limit must be chosen. If the speed limit is obvious and makes sense, people are more likely to respect it.

The goal of this research was to develop an alternative means of assessing a speed limit, one that is simple, not time consuming, yet effective. This, it is proposed, has been achieved using the following methodology which builds on previous work carried out on Safe Profile Velocities and the development of the Efficiency Index. The methodology was tested in seven case studies and was shown to be repeatable and reliable.

7.2 Methodology & Case Studies

The methodology chosen for this research was to build on previous work carried out on Safe Profile Velocities by Dr. Tim McCarthy and Dr. Lars Pforte of Maynooth University. This author felt that the process they developed could have merit in assisting Local Authorities with regard to setting speed limits. The Safe Profile Velocity methodology is outlined in Chapter 6 and V_{sp} is depicted visually in Figure 7.1. In this author's opinion, it encapsulates everything that influences or occurs on a typical journey and can be tied into the concept of self-explaining or self-regulating roads. Surely that is what should be evaluated when assessing or choosing an appropriate speed limit?

The process being proposed is depicted in Figure 7.2. It shows that the process beings with driving the route, progresses to deriving V_{sp}, determining Speed Distributions and the Route Efficiency culminating in the Efficiency Index of the route being determined.

The Efficiency Index is being proposed as the value that best reflects the performance of the route and the appropriateness of the posted speed limit.

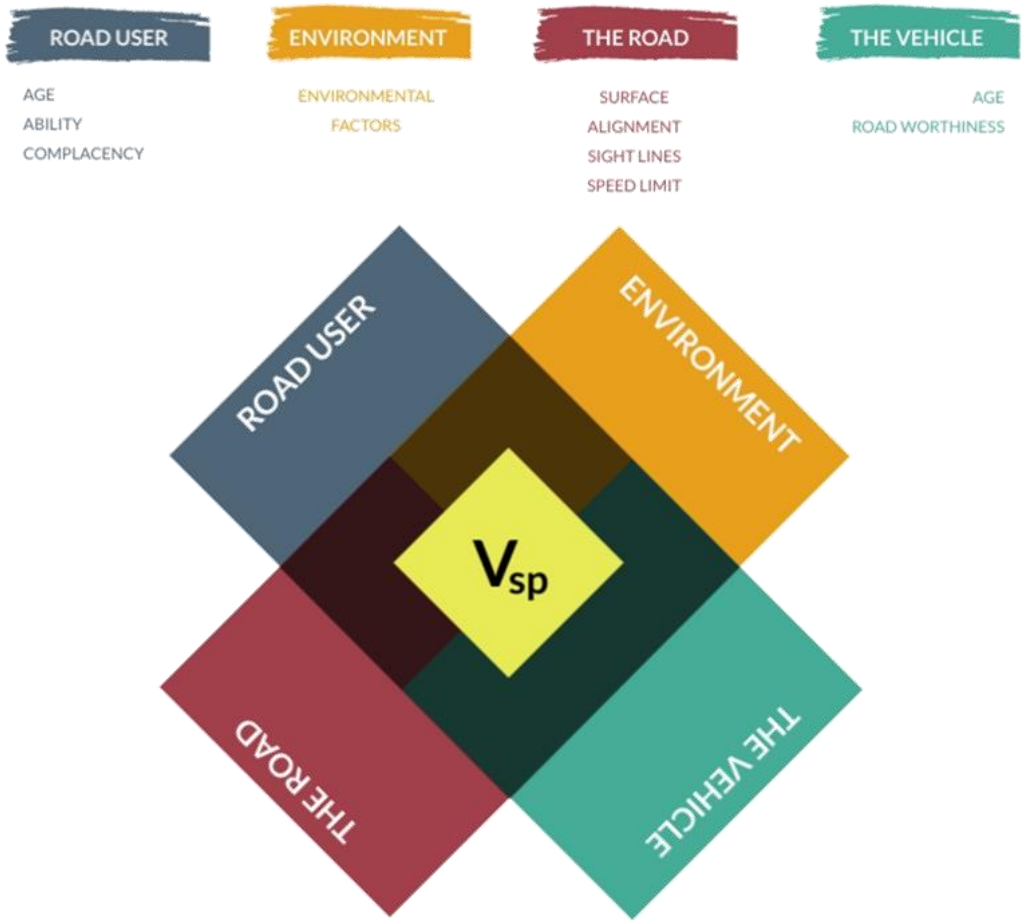


Figure 7.1: Visual representation of V_{sp}

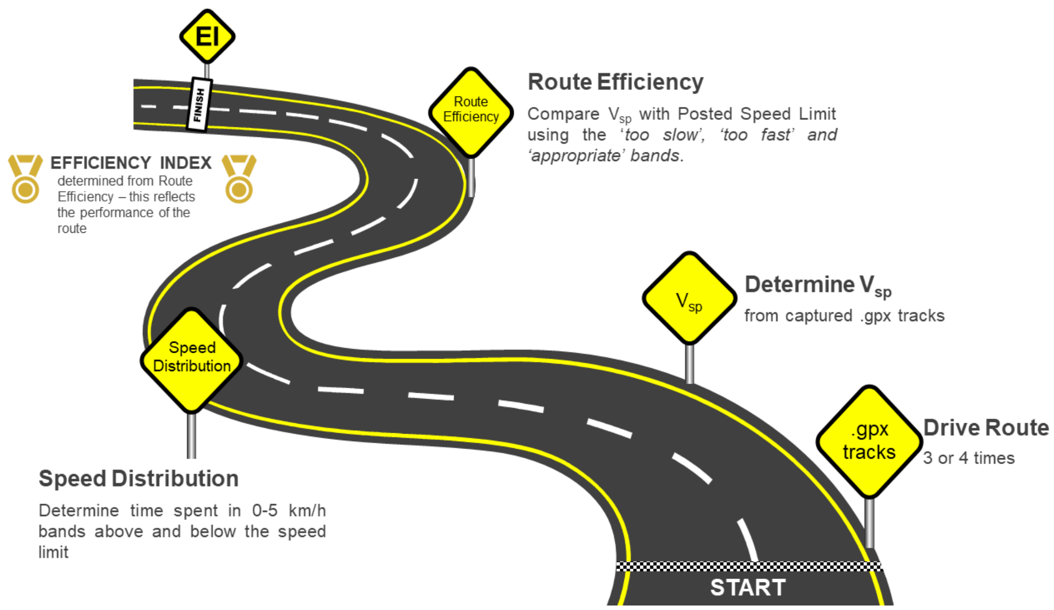


Figure 7.2: Overview of proposed Methodology

The results of the case studies are tabulated below showing bands above or below the speed limit and the percentage of the time that is spent travelling within that band. The total percentage of time spent travelling above or below the speed limit is shown in red and green text respectively.

Route & Direction	Time Spent Above Speed Limit (%)					Time Spent Below Speed Limit (%)					Max V_{sp} (km/h)	Min V_{sp} (km/h)	Ave V_{sp} (km/h)
	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 Km/h	0-5 km/h	5-10 km/h	10-15 km/h	15-20 km/h	>20 Km/h			
N2 Northbound	21.5	6.3	6.8	0.0	0.0	4.0	3.1	20.2	19.4	18.7	94.7	57.9	82.4
	34.6%					65.4%							
N2 Southbound	22.4	17.9	2.1	0.0	0.0	6.5	25.2	5.4	2.4	18.2	103.9	53.2	84.8
	42.3%					57.7%							
N14 Eastbound	0.0	0.0	0.0	0.0	0.0	0.0	4.8	22.5	35.8	36.9	92.6	50.4	80.2
	0.0%					100.0%							
N14 Westbound	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.6	21.9	70.5	88.8	42.6	75.8
	0.0%					100.0%							
N51 Eastbound	13.9	8.3	1.2	0.1	0.0	21.8	15.3	7.7	6.4	25.4	86.2	29.7	73.5
	23.5%					76.5%							
N51 Westbound	14.7	8.3	2.4	0.4	0.0	16.8	15.6	9.9	5.2	25.8	92.2	53.2	76.4
	25.9%					73.3%							
N52 Eastbound	14.3	1.4	0.3	0.0	0.0	12.4	8.1	9.4	9.9	44.4	95.1	50.2	73.3
	15.9%					84.1%							
N52 Westbound	12.3	5.0	0.9	0.0	0.0	11.2	16.8	13.4	11.1	29.3	92.1	63.9	78.6
	18.2%					81.8%							
N53 Eastbound	0.0	0.0	0.0	0.0	0.0	4.6	25.8	26.9	8.6	34.2	99.9	38.2	81.5
	0.0%					100.0%							
N53 Westbound	0.0	0.0	0.0	0.0	0.0	0.0	10.1	44.3	21.4	24.2	89.6	68.7	84.0
	0.0%					100.0%							
R157 Eastbound	0.0	0.0	0.0	0.0	0.0	8.8	24.8	22.3	16.6	27.5	76.2	20.5	60.6
	0.0%					100.0%							
R157 Westbound	0.0	0.0	0.0	0.0	0.0	21.4	21.6	19.7	11.4	26.0	79.6	59.3	73.1
	0.0%					100.0%							
R410 Eastbound	6.5	0.0	0.0	0.0	0.0	14.8	34.8	19.4	12.3	12.3	81.1	55.3	70.4
	6.5%					93.6%							
R410 Westbound	7.9	1.6	3.9	0.0	0.0	25.2	33.9	10.2	7.9	9.5	83.8	50.8	70.6
	13.4%					86.6%							

Table 7.1: Case Studies – Summary of Speed Distributions

The closer the split between the above and below percentages the more the user is having difficulty in accepting, understanding or making efficient use of the posted speed limit. An efficient route, or a route that appears to have an appropriate speed limit set on it, would, ideally, be one that is travelled below the speed limit for 100% of the time within the 0-5 km/h below speed limit band. This would show that the road user is comfortable with the posted speed limit and does not feel the need to exceed it. It is not, however, an ideal world, this may be unrealistic or could be setting the bar too high in terms of what may be achievable. It may be more realistic to expect an efficient route to be one that is driven entirely within an appropriate distance either side of the speed limit (the 'appropriate' zone). For this proposal, the 'appropriate' zone is defined as a zone covering the range PSL - (10%PSL+2 km/h) to PSL + (10%PSL+ 2 km/h). (Figure 6.5 and Table 6.3). The longer the time spent in this zone the more efficient the route is, resulting in a higher Efficiency Index.

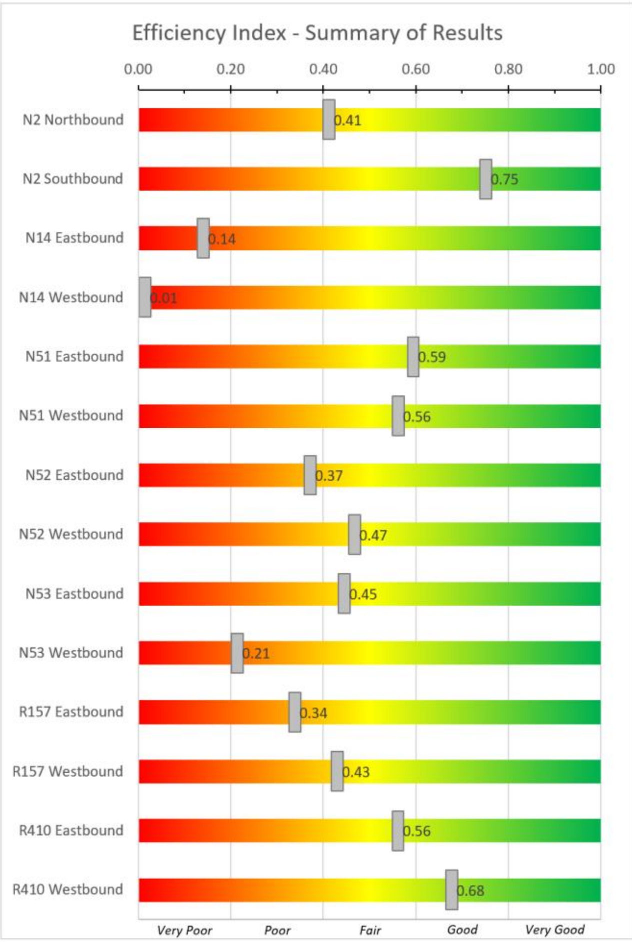


Table 7.1 shows at first glance that the N2 performs the worst as the red cell/green cell split is not as conclusive as the other routes. However, as Figure 7.3 shows, the N2 Southbound returns a '*good*' EI of 0.75 as, while the split is less conclusive, the time spent within an 'appropriate' distance of the speed limit is greater. The Efficiency Indices range from 0.01 to 0.75 (very poor to good) across the seven case study routes.

Figure 7.3: Efficiency Indices of Case Study Routes

Figure 7.4 below shows the *'too slow'*, *'appropriate'* and *'too fast'* breakdown for each route.

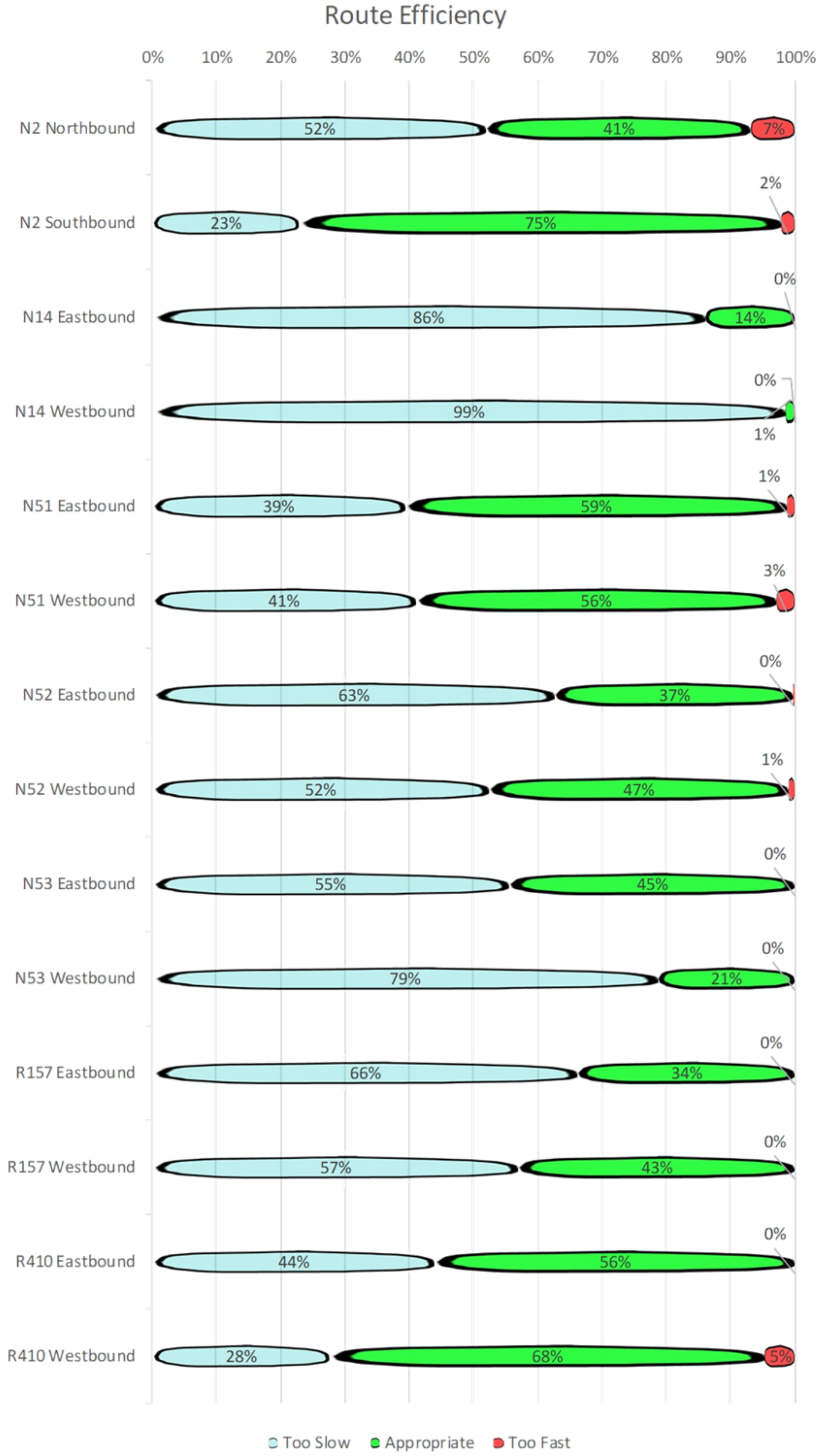


Figure 7.4: Case Studies – Route Efficiency (bands) - Summary

7.2.1 Effect of changing the speed limit on the Efficiency Index

To conclusively determine the effect on the Efficiency Index, the speed limit would need to be altered by producing a Special Speed Limit Bye-law and the route captured again. Notwithstanding this, theoretically, it has been demonstrated that using Safe Profile Velocities (V_{sp}) and the Efficiency Index does indeed have substantial merit in the assessment and setting of speed limits. Table 7.2 summarises the effect changing the speed limit has on the Efficiency Index of the case studies.

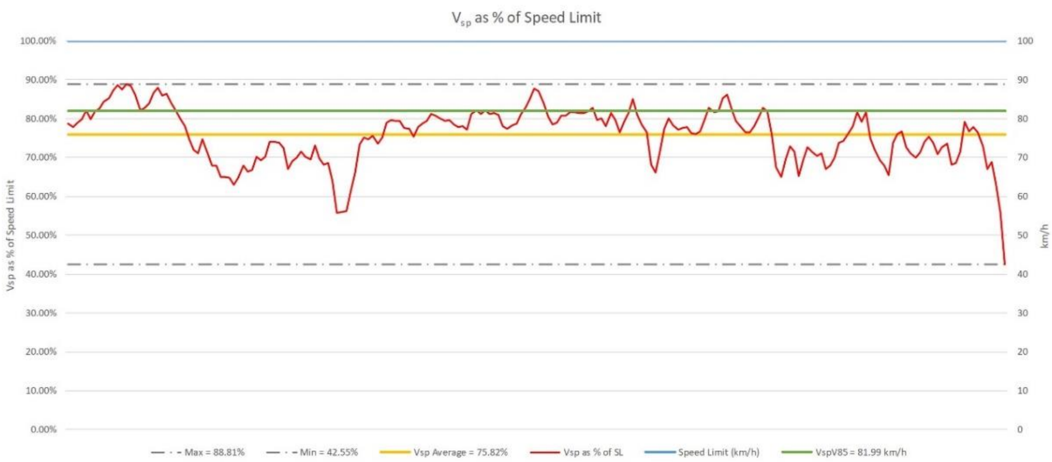
Route and Direction		Efficiency Index with….						
		Existing Speed Limits		Change to….				
		EI	Route Average EI	100 km/h	90 km/h	80 km/h	70 km/h	60 km/h
N2	NB	0.41	0.58	0.16 ↓	**0.79** ↑	0.85 ↑		
	SB	0.75		0.40 ↓	**0.79** ↑	0.57 ↑		
N14	EB	0.14	0.08		0.69 ↑	**0.85** ↑		
	WB	0.01			0.37 ↑	**0.79** ↑		
N51	EB	0.59	0.58		0.65 ↑	**0.79** ↑		
	WB	0.56			0.62 ↑	**0.75** ↑		
N52	EB	0.37	0.42		0.48 ↑	**0.56** ↑		
	WB	0.47			0.56 ↑	**0.72** ↑		
N53	EB	0.45	0.33		**0.68** ↑	0.50 ↑		
	WB	0.21			**0.90** ↑	0.86 ↑		
R157	EB	0.34	0.38				**0.68** ↑	0.42 ↑
	WB	0.43					**0.70** ↑	0.34 ↓
R410	EB	0.56	0.62			0.50 ↓	**0.81** ↑	0.42 ↓
	WB	0.68				0.65 ↓	**0.74** ↑	0.28 ↓

Table 7.2: Case Studies – Effect on EI by Speed Limit Change

The table above shows how the Efficiency Index changes as the speed limit is altered. The further away from the posted speed limit the V_{sp} is, the more it can be assumed the driver is having trouble '*deciding*' what the appropriate speed limit is, this affects the Efficiency Index. The lower the Index value, the more inappropriate the speed limit is and changes to the limit along the route should be investigated. Using V_{sp} to determine Route Efficiency and an Efficiency Index has substantial merit and has been proven to be repeatable and reliable. It is a relatively simple process to collect .gpx tracks along a route and process them to output the V_{sp} and thus produce an Efficiency Index for a route.

Another way of looking at V_{sp} is to represent it as a percentage of the posted speed limit. The N14 has been selected for this example for convenience as there is only one speed limit to consider (default of 100 km/h).

N14 – Westbound (Speed Limit = 100 km/h, GPS Observations=210)		
Maximum V_{sp} along route	$V_{sp\ MAX}$	88.81%
Minimum V_{sp} along route	$V_{sp\ MIN}$	42.55%
Average V_{sp} along route	$V_{sp\ AVE}$	75.82%
Time above average V_{sp}	$T_{VspAVE+}$	57.62%
Time below average V_{sp}	$T_{VspAVE-}$	42.38%
85th Percentile speed (of V_{sp})	$V_{SP\ V85}$	81.99 km/h



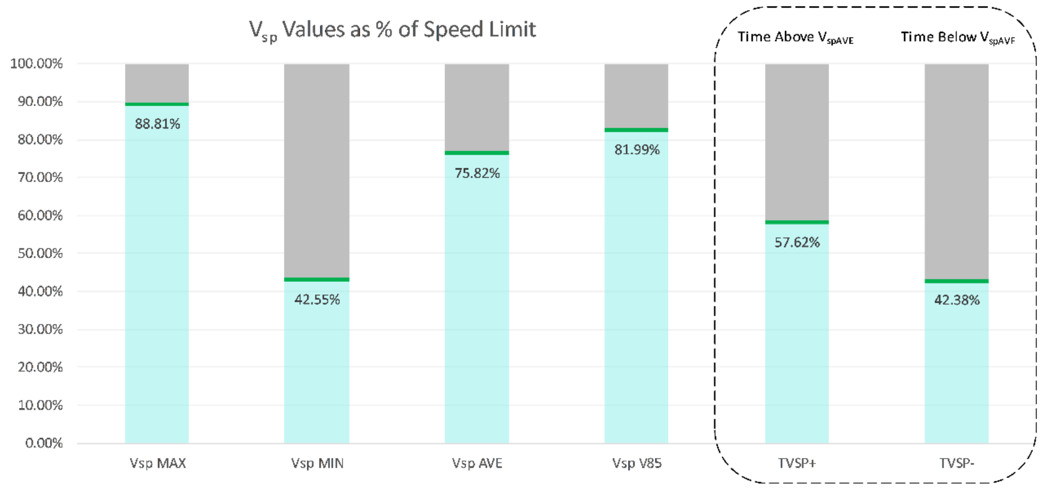
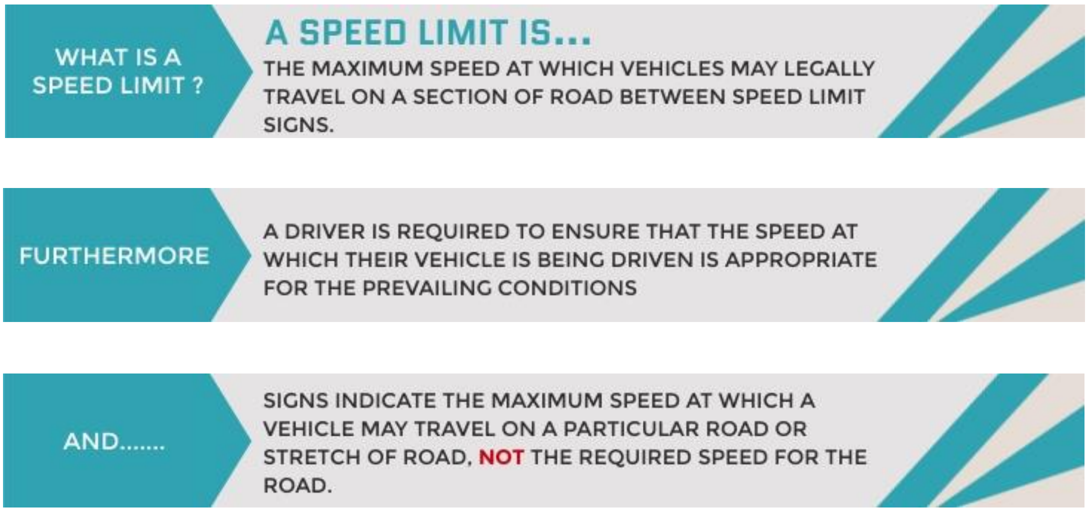


Figure 7.5: N14 Westbound - V_{sp} Values as percentage of posted Speed Limit

Looking at the N14 in the Westbound direction, it showed a weak relationship between the posted speed limit and the derived V_{sp} and looking at the V_{sp} values represented as a percentage of the posted speed limit, reveals that drivers are travelling the route at between 42.55% and 88.81% of the speed limit and at an overall average of 75.82% and spent 57.62% (T_{VSP+}) of the time travelling above the average V_{sp} value (V_{spAVE}), through 210 observations of V_{sp}. The 85th percentile V_{sp} value is 81.99 km/h.

If the 85th percentile (of V_{sp}) is used to inform the choice of speed limit, then the speed limit on this road should be set at 80 km/h. This concurs with the case study analysis which showed that the speed limit that achieves the highest Efficiency Index is 80 km/h (Table 7.2). If the function and class of this road is considered along with its width and alignment it then conflicts with the current standard convention that higher speed limits should be applied to upper tier roads. This road does not support the higher Default Speed Limit of 100 km/h.



(the Guidelines, 2015, p26, p29)

Figure 7.6: What is a Speed Limit?

A speed limit is … **NOT A TARGET**

However, whilst having regard to the above, to illustrate Route Efficiency, drivers do not seem to be able to maximise or take full advantage of the speed limit 'available' to them in this case. This suggests that the speed limit is set inappropriately high on this road. It should be noted that references are made to altering speed limits in both directions, this refers only to the theoretical analysis as shown on the graphs. Obviously, there cannot be separate speed limits in both directions on a single carriageway road.

7.3 To Conclude

The object of this thesis was to develop an alternative means of assessing speed limits on rural single carriageway roads in Ireland using observed driver behaviour

The methodology employed was to derive a Safe Profile Velocity (V_{sp}) from observed driver behaviour and use this to assess the appropriateness of existing speed limits and alternatives through the development and introduction of the Efficiency Index to ultimately provide a safer speed limit that can reduce the chances of a collision occurring and help mitigate the consequences of a collision. Safe Profile Velocity (V_{sp}) and the Efficiency Index (EI) can play a significant role in this. The Efficiency Index is the value that best represents the performance of the road in relation to the Posted Speed Limit. If two risk factor frameworks for road traffic injuries are considered (Road traffic injury prevention training manual, World Health Organisation, 2006) – the Haddon Matrix and the Systems Approach, we can begin to see that V_{sp} has a role to play in mitigating risk factors for road traffic injuries by positively influencing the appropriate choice of a speed limit.

The Haddon Matrix, presented in Table 7.3, is an analytical tool that helps to identify all factors associated with a crash. When they have been identified and analysed, countermeasures can be developed and prioritised for implementation over short and long-term periods.

For the pre-crash phase, it is necessary to select all countermeasures that prevent the crash from occurring. The crash phase is associated with countermeasures that prevent injury from occurring or reduce the severity if one should occur. The post-crash phase involves all activities that reduce the adverse outcome of the crash after it has occurred.

		FACTORS		
PHASE		HUMAN	VEHICLES & EQUIPMENT	ENVIRONMENT
Pre-crash	Crash prevention	Information Attitudes Impairment Police enforcement	Roadworthiness Lighting Braking Handling Speed management	Road design and road layout Speed limits Pedestrian facilities
Crash	Injury prevention during the crash	Use of restraints Impairment	Occupant restraints Other safety devices Crash protective design	Crash-protective roadside objects
Post-crash	Life sustaining	First-aid skill Access to medics	Ease of access Fire risk	Rescue facilities Congestion

Table 7.3: The Haddon Matrix

Considering Figure 7.1, and applying the Haddon Matrix to Speed Management, all countermeasures relating to speed can be addressed by employing V_{sp} as an assessment method. In the pre-crash, crash prevention phase of the matrix, all factors in the three categories are encapsulated by V_{sp}. If a Local Authority was focusing on speed in terms of crash prevention V_{sp} would be of major benefit as it reflects everything under the Human, Vehicles & Equipment and Environment factors.

		FACTORS		
PHASE		HUMAN	VEHICLES & EQUIPMENT	ENVIRONMENT
Pre-crash	Crash prevention		V_{sp}	
Crash	Injury prevention during the crash	Use of restraints Impairment	Occupant restraints Other safety devices Crash protective design	Crash-protective roadside objects
Post-crash	Life sustaining	First-aid skill Access to medics	Ease of access Fire risk	Rescue facilities Congestion

Table 7.4: The Haddon Matrix – Applied to Speed Management

Traditionally, analysis of risk has examined the road user, vehicle and road environment separately. The Systems Approach builds on Haddon's insights, and seeks to identify and rectify the major sources of error, or design weaknesses, that contribute to fatal crashes or crashes that result in severe injury, as well as to mitigate the severity and consequences of injury. Making a road traffic system less hazardous requires a systems approach — understanding the system, the interaction between its elements and identifying where there is potential for interventions. Each crash and its consequences can be represented by Figure 7.7.

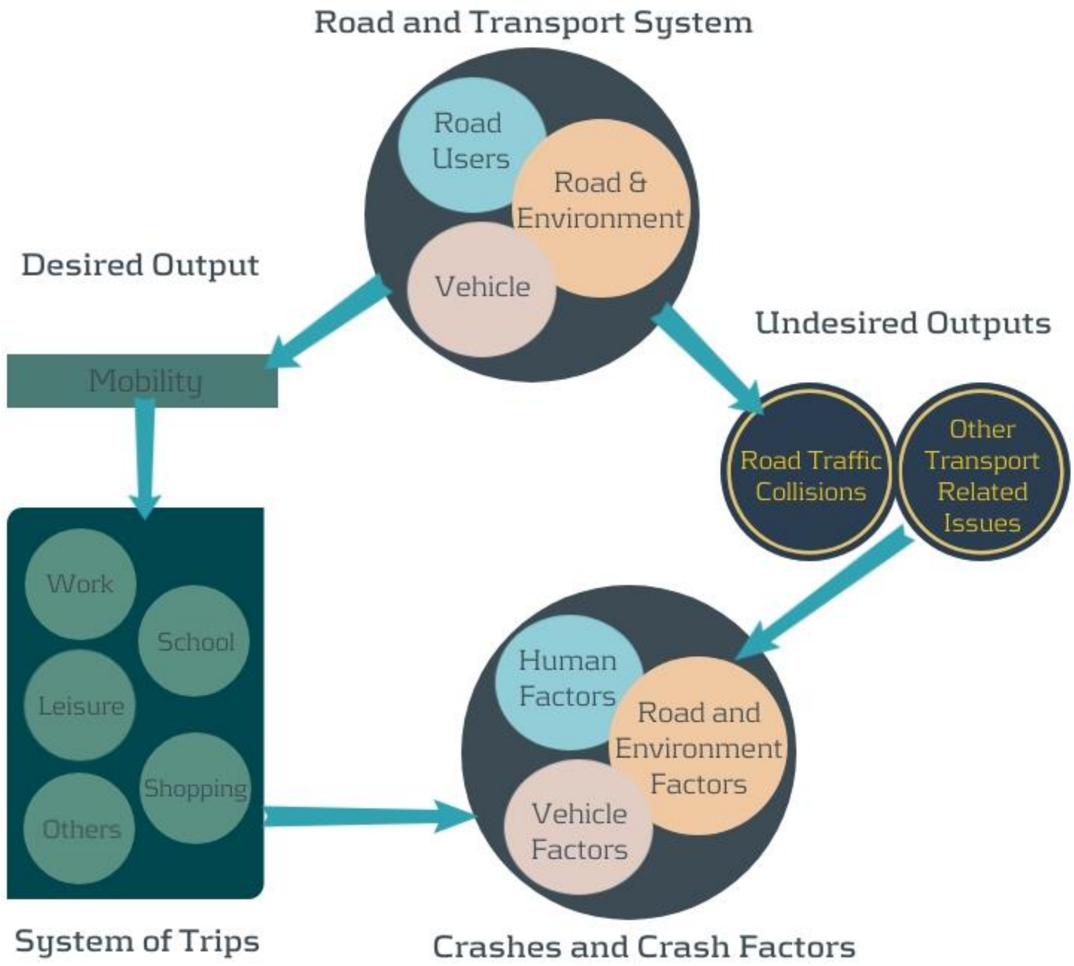


Figure 7.7: Safe System Approach to Road Traffic Injuries Risk Factors

The top part concerns the road and transport system, but, if we take the safe systems approach to speed as a contributory factor in collisions then we can replace the top part with V_{sp}, as road users, the road itself and the environment and the vehicle being driven all combine to influence the speed chosen by the driver. All the elements above can be tackled individually to mitigate the effects of a collision, however, opportunities for one to positively influence another could be missed, e.g. improve driver behaviour by changes to the road environment (self-enforcing roads philosophy). If Figure 7.7 was considered in terms of a speed management exercise to positively mitigate the undesired outputs of a road and transport system (collisions for example) then the use of V_{sp} would play a major part in the analysis.

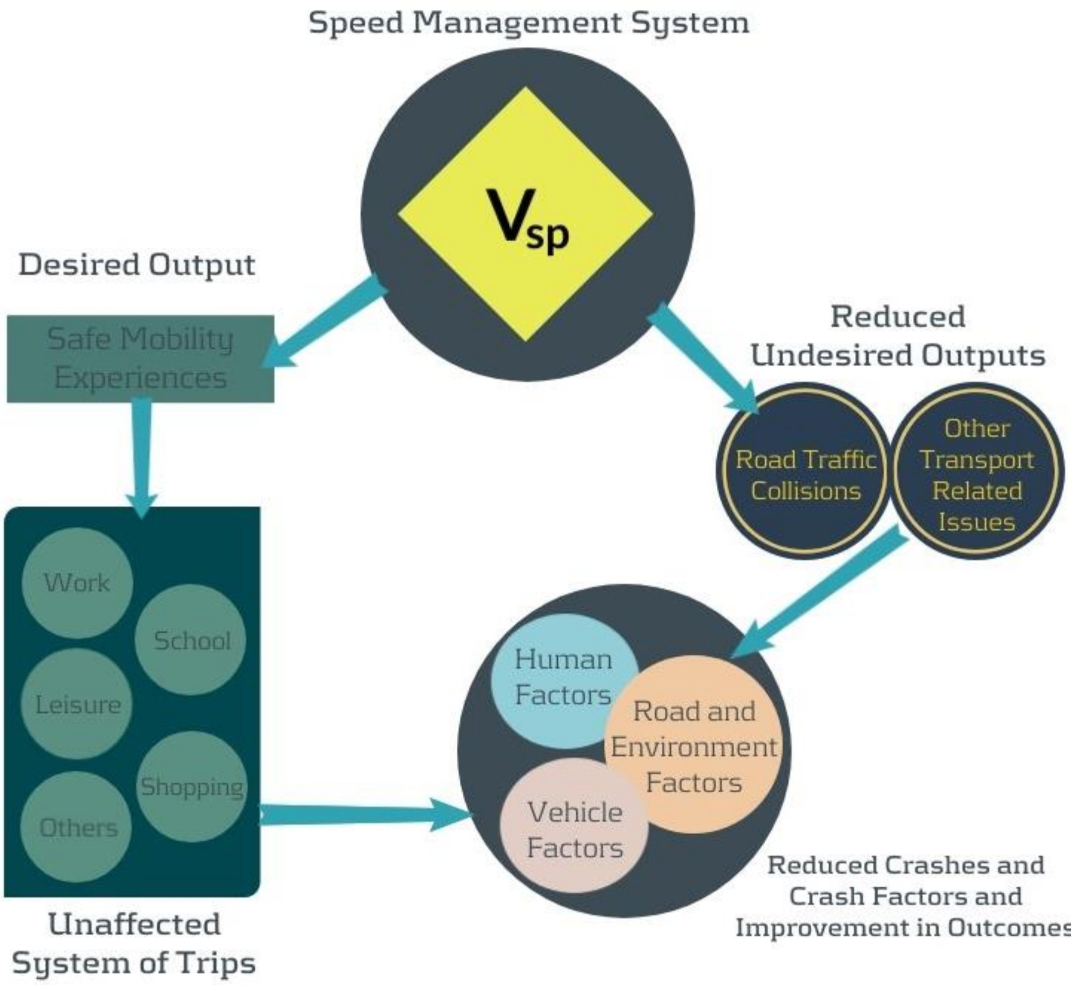


Figure 7.8: Safe System Approach to Speed Management

The seven case studies across all road classifications have shown that there is substantial merit in using V_{sp} and the relationship between it and the posted speed limit (the Efficiency Index). The case studies also showed that it is possible to model the effect that changing a speed limit would have. While this would be a theoretical effect, it would nonetheless be a strong indicator as to what speed limit should be chosen and demonstrates that V_{sp} and the Efficiency Index can be used effectively to assess and manage speed limits.

The case studies also highlighted that, along the N51 and N52, there is a general lack of consistency among the neighbouring Local Authorities – if the sections within Co. Westmeath were reduced to 80 km/h, matching Co. Meath's policy, there would be an improved relationship between the speed limit and the V_{sp}, thus ensuring a more suitable and consistent speed limit along both routes. Safe Profile Velocities (V_{sp}) and the Efficiency Index can better inform road safety engineers as to the appropriate speed limit to be implemented on a route. It is proposed that it is a more appropriate means of assessment than using the 85th percentile as it is based on a continuous measurement rather than a measurement at a singular point along the route. Also, the 85th percentile only removes the upper 15% (the 'boy racer'), it does not remove the slow tractor.

The Efficiency Index returns a value that serves to best represent the actual reality of the performance of the route in terms of its Posted Speed Limit and driver behaviour. Every vehicle/road user on the road at the time the GPS trace is being captured is influencing the journey and the performance of the route. The Efficiency Index is based on the entire experience of driving the route or section thereof, from start to finish, it is not based on a simple metric of the mean or 85th percentile speed determined at an arbitrary point on the road and, therefore, is a more robust indicator of the appropriateness of the speed limit in effect at the time of capture.

With regard to the existing Speed Assessment Framework, it should be robust and take account of all relevant factors and to a certain extent it does, however, like USLIMITS, the process is complex and data intensive. V_{sp} takes all of those inputs into consideration, it can highlight the safer sections of a route as well as the riskier ones from a spatial-temporal point of view. It is a simple process to capture a route and as such is more likely to be used in the long term than the Speed Assessment Framework. It has been shown to be a repeatable and reliable method of assessment and has been shown to be fit for purpose either as a standalone endeavour or in conjunction with the items listed in Appendix B when used to determine the Efficiency Index. It can also be used to theoretically determine the suitability of a 90 km/h speed limit, which emerged in the case studies as being a limit that warrants further investigation. As outlined in Chapter 4, much of Europe has speed limits of 90 km/h and Ireland had it as its National Speed Limit from 1979 to 1992 (as 55mph - Fig 2.7 p16). It also exists in the USA (as 55 mph) and introducing a 90 km/h speed limit in Ireland would bring about consistency with the majority of Europe. Primary Legislation, however, would need to be enacted to facilitate a trial of this speed limit as it does not currently exist in Irish Legislation. In the absence of Legislation, and indeed to possibly strengthen the case for its consideration in the long term, a trial of the V_{sp} / Efficiency Index process to determine appropriate speed limits could be conducted. The trial would consist of the following workflow (this is also contained in Appendix B3);

1. Select routes in one or two counties,
2. Determine the V_{sp} of the routes,
3. Analyse/determine relationship between V_{sp} and Posted Speed Limit (route EI),
4. Model the effect of altering speed limits,
5. Local Authority to make Bye-laws to alter the speed limit,
6. Monitor the effect of the change of speed limit (collisions, journey times, V_{85})
7. Recapture V_{sp} under altered speed limit conditions and repeat step 3,
8. Compare results from steps 3 and 7.

The benefit of a successful trial would be twofold, it would confirm V_{sp} and the EI as being a suitable indicator as to the appropriate speed limit to be chosen and would give confidence to the implementation of 90 km/h as a speed limit.

Appendix A

A.1 All Collisions 2006 - 2012

Collision data supplied by the Road Safety Authority (RSA) has been used in this submission and covers the period from 2006 to 2012. The data was supplied in individual .csv files for each year. Collision data is represented on the following figures (Figures A.1 to A.7 inclusive), produced by using ArcGis.

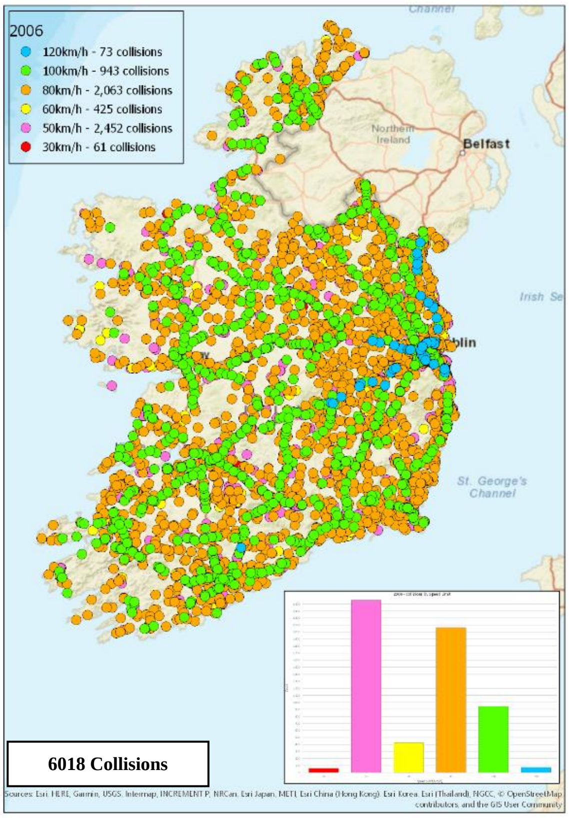


Figure A.1: All collisions 2006

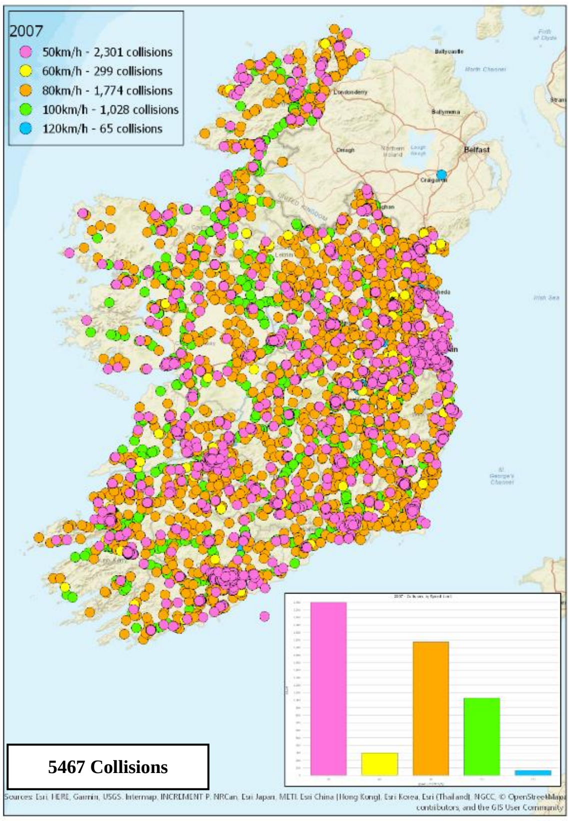


Figure A.2: All collisions 2007

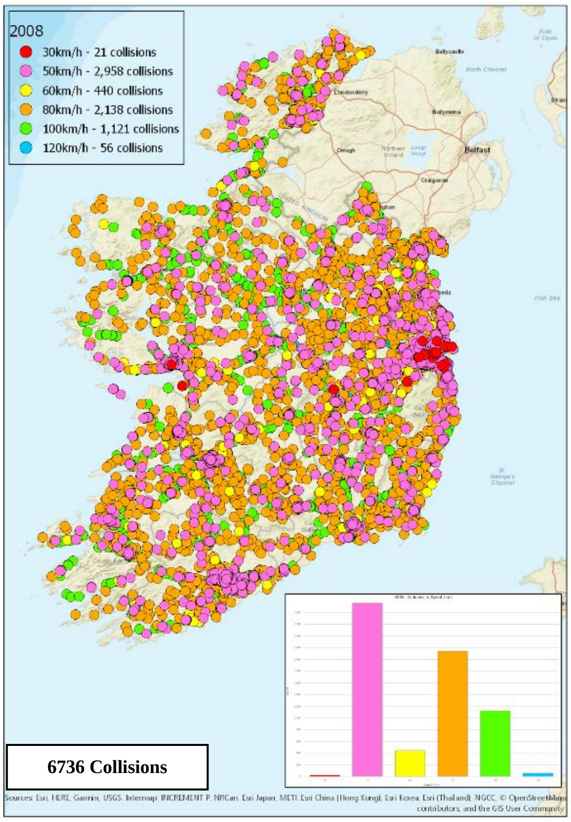


Figure A.3: All collisions 2008

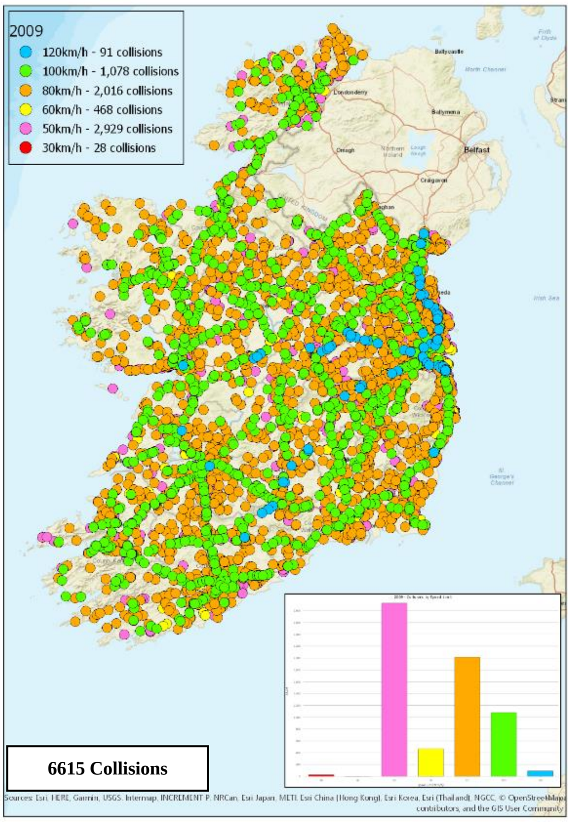


Figure A.4: All collisions 2009

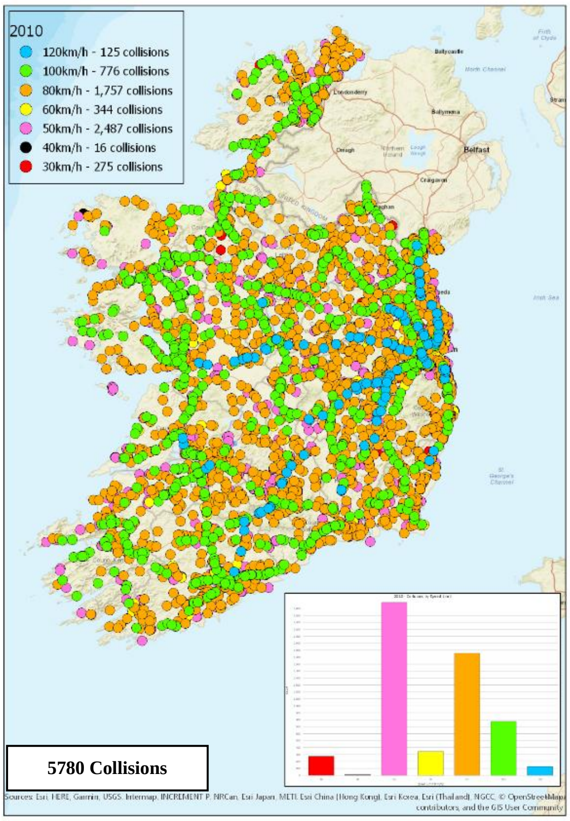


Figure A.5: All collisions 2010

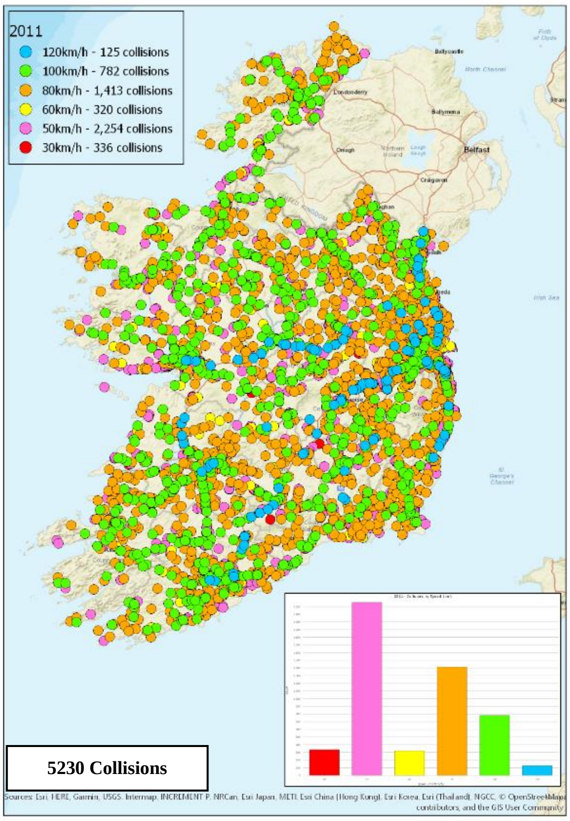


Figure A.6: All collisions 2011

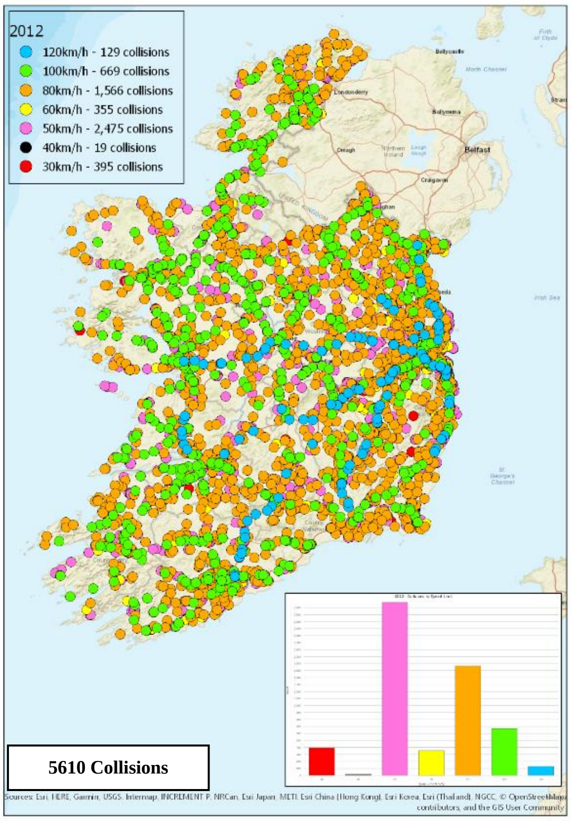


Figure A.7: All collisions 2012

A.1.1 Fatal Collisions 2006 - 2012

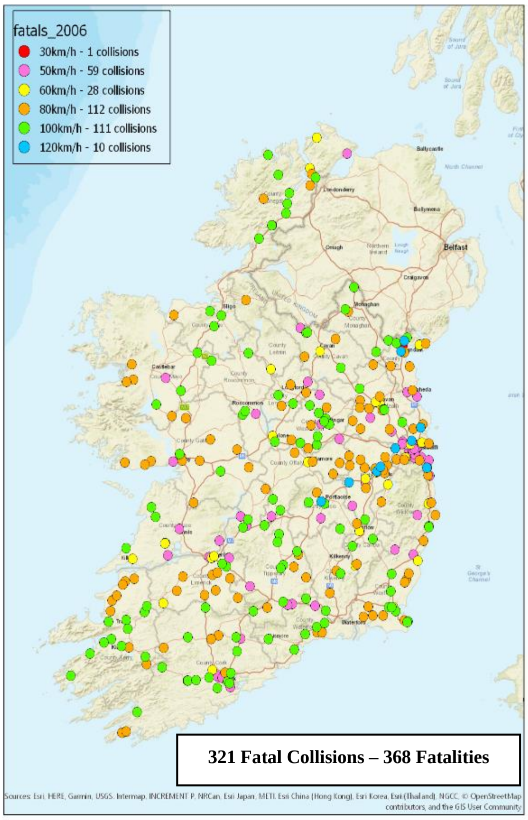


Figure A.8: Fatal collisions 2006

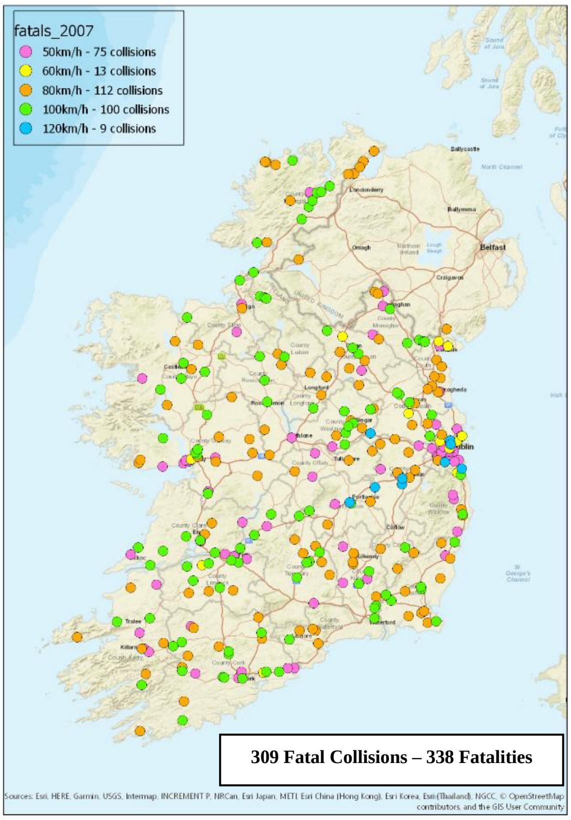


Figure A.9: Fatal collisions 2007

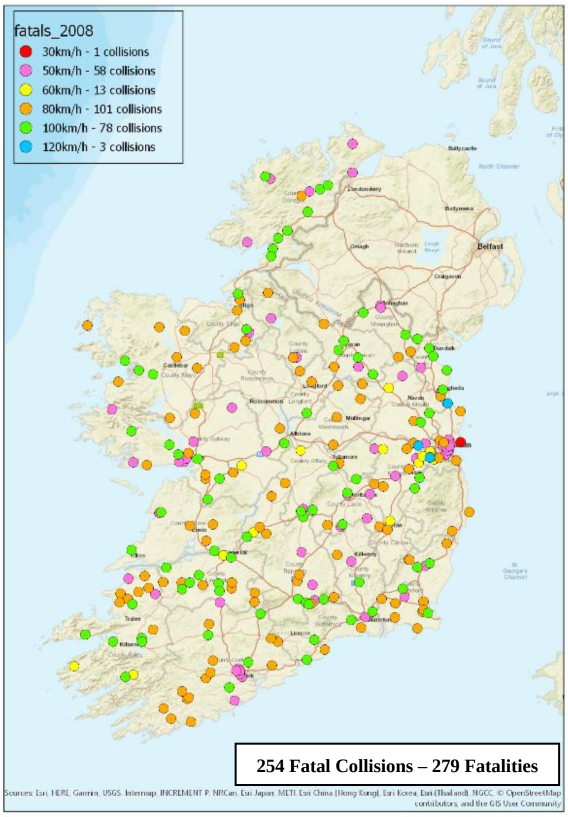


Figure A.10: Fatal collisions 2008

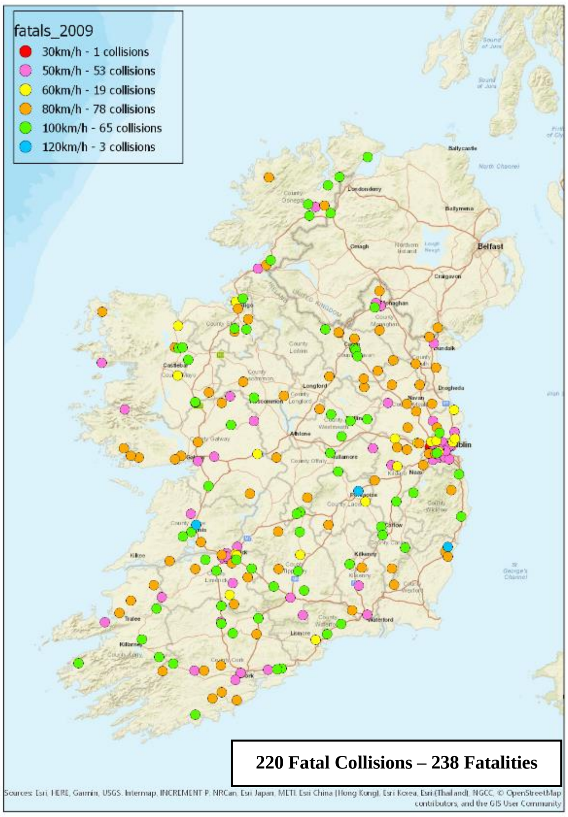


Figure A.11: Fatal collisions 2009

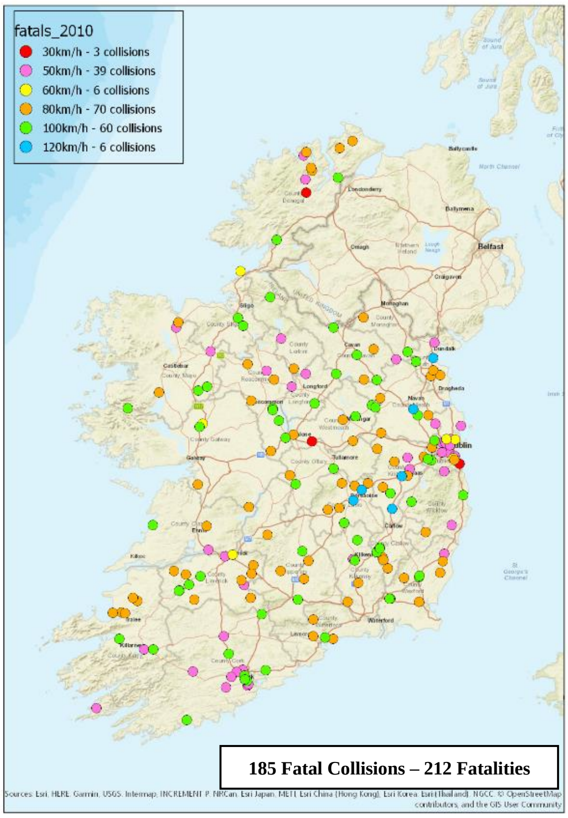


Figure A.12: Fatal collisions 2010

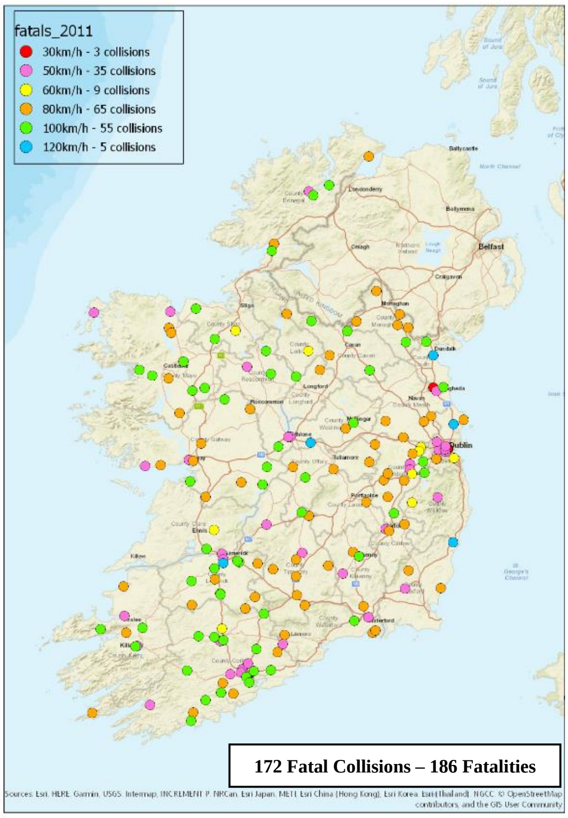


Figure A.13: Fatal collisions 2011

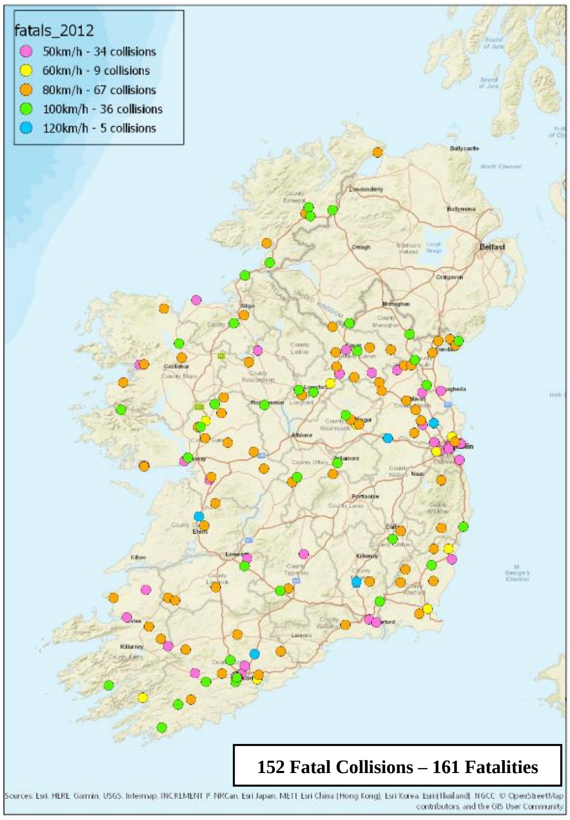


Figure A.14: Fatal collisions 2012

A.2 Network Safety Ranking

A.2.1 Introduction

Network Safety Ranking (NSR) is a method of identifying, analysing and classifying parts of the existing road network according to their potential for safety development, improvement and accident cost saving (European parliament, 2008). Transport Infrastructure Ireland publication, Network Safety Analysis (GE-STY-01022-03) identifies collision locations and network safety ranking using collision frequency (number of collisions) and collision rate (ratio of collision frequency to Annual Average Daily Traffic (AADT)).

Network Safety Ranking has not yet been carried out on the Regional and Local road network and therefore Network Safety Ranking values are not available for two of the case study routes. It is expected that a determination of Network Safety Ranking will be carried out on the Regional road network in the near future.

A.2.2 Calculation of NSR

The Network Safety Ranking is calculated as follows using the formula defined in PIARC's-World Road Association Road Safety Manual.

$$\mathbf{R_{rp} = \sum f_i \times 10^8 \ / \ 365.25 \times P \times \sum L_j \times Q_w}$$

R_{rp} = Average Collision Rate for the reference population / f_i = Collision Frequency at Site / P = Period of analysis in years / L_j = Length of Section (km) / Q_w = Weighted AADT

Reference populations are subsets of the road network that have similar features and are expected to have similar safety performances.

For National roads, Transport Infrastructure Ireland defined the following Reference Populations in rural areas.

1. Standard and Wide Motorways
2. Type 1, 2 and 3 Dual Carriageways
3. Type 1, 2 and 3 Single Carriageways

They based their reviews on 1 km section lengths. The collision frequency is the number of collisions and the collision rate is the ratio of collision frequency to the AADT. Three years of collision data is required. Using data available from 2012, 2013 and 2014 for rural 2-lane roads (Reference Population 3 above), the Average Collision rate (R_{rp}) was calculated as follows.

2012 – 2014			
R_{rp}	Average Collision Rate for the reference population		
f_i	Collision frequency at site j	1740	
P	Period of analysis in years	3	
L_i	Length of section j	3561.25	
Q_w	Weighted annual average daily traffic	5766.76	
$R_{rp} = 1740 \times 10^8 / 365.25 \times 3 \times 3561.25 \times 5766.76$			
$R_{rp} = 7.73$ per 100 million Vehicle Km			
Twice Below	Below	Above	Twice Above
< 3.866	< 7.73	> 7.73	15.464 >

Collision Frequency (C.F.) and Collision Rates (C.R.)

Equation 1. Average Collision Frequency for the Reference Population

$$f_{rp} = \sum f_j / n$$

f_{rp} = Average Collision Frequency for the Reference Population / f_j = collision frequency at site j of a Reference Population / n = number of sites

Collision Rate (C.R.) is a ratio between the number of collisions and an exposure to traffic volume.

Equation 2. Collision Rate for individual site (j)

$$R_j = f_j \times 10^8 / 365.25 \times P \times L_j \times Q_j$$

R_j = Collision Rate of site j (collisions per 100 million vehicle km) / f_j = Collision Frequency at site j / P = Period of analysis (years) / L_j = Segment length of site j (km) / Q_j = average annual daily traffic of site j

Equation 3. Collision Rate for Reference Population

$$R_{rp} = \sum f_i \times 10^8 / 365.25 \times P \times \sum L_j \times Q_w$$

R_{rp} = Average Collision Rate for the reference population / f_i = Collision Frequency at Site

P = Period of analysis in years / L_j = Length of Section (km) / Q_w = Weighted AADT

Equation 4. Weighted AADT

$$\mathbf{Q_w = \sum (Q_j \times L_j) / \sum L_j}$$

Q_w = Weighted average annual daily traffic / Q_j = AADT of site j / L_j = Segment length of site j (km)

A.2.3 Benefits and Value of NSR

Network Safety Ranking, set by EU Directive 2008/96/EC, offers tremendous benefits immediately after its implementation. When road sections with high collision rates/frequencies have been identified and treated and remedial measures have been employed, safety inspections as a preventive measure will then assume a more important role. The NSR results in a clear systematic way of identifying and resolving issues on the roads network. Regular inspections are essential for preventing possible dangers for all road users, including vulnerable users, and also in the case of roadworks. The identification of road sections with a high collision concentration takes into account the number of fatal accidents that have occurred in previous years per unit of road length in relation to the volume of traffic. For National routes, all collisions are considered.

The identification of sections for analysis in Network Safety Ranking takes into account their potential savings in accident costs. Road sections shall be classified into categories - Reference Populations. For each category of road, they shall be analysed and ranked according to safety-related factors, such as accident concentration, traffic volume, etc. For each road category, developing a Network Safety Ranking results in a priority list of road sections where an improvement of the infrastructure is expected to be highly effective, or indeed, necessary. Site visits carried out yield the following information that can then be further analysed or evaluated.

- A description of the road section
- A reference to previous reports on the same road section
- Analysis of possible accident reports
- Number of accidents, of fatalities and of severely injured persons in the three previous years
- A set of potential remedial measures set against different timescales considering the following possible actions
    - Removing or protecting fixed roadside obstacles
    - ***Reducing speed limits*** and intensifying local speed enforcement
    - Improving visibility under different weather and light conditions
    - Improving roadside equipment such as road restraint systems
    - Improving coherence, visibility, readability and position of road markings (including application of rumble strips), signs and signals
    - Protecting against rocks falling, landslips and avalanches
    - Improving grip/roughness of pavements
    - Changing the overtaking layout
    - Improving junctions, including road/rail level crossings
    - Changing width of road, adding hard shoulders
    - Installing traffic management and control systems
    - Reducing potential conflict with vulnerable road users
    - Upgrading the road to current design standards
    - Restoring or replacing pavements
    - Using intelligent road signs
    - Improving intelligent transport systems and telematics services for interoperability, emergency and signage purposes.

With respect to ***reducing speed limits***, it should be noted that it is stated in the Guidelines for Setting and Managing Speed Limits in Ireland that reducing a speed limit to solve the problem of an isolated hazard should not be the immediate response. Engineering measures should be employed first to improve the safety rating of the section in question. The analysis of the site then becomes critical to determine the root cause of the collisions that have occurred. Junctions, crossroads, staggered junctions, etc., represent isolated hazards and the advice given in the Guidelines is to identify and employ physical engineering measures to provide a solution. Simply setting a reduced Special Speed Limit will not have the desired effect (it is possible that it will initially), however, over time, without visible enforcement by An Garda Síochána, many drivers will not slow down to the posted speed limit, as they perceive there to be no consequences for failing to do so. Also, when setting a reduced Special Speed Limit over a very short section, it is likely that the driver will be able to see the signage indicating the change back up to the Default Speed Limit at the entry point of the reduced limit, thus making it less likely that they will slow down.

It is, of course, accepted that the ability of a Local Authority to develop effective engineering measures at every location like this would be determined by their available resources, both in terms of personnel and financing. This is partly the reason many ineffective reduced speed limit areas can be seen across the country.

A popular measure among Local Authorities is to install yellow transverse carriageway markings (commonly referred to as rumble strips) in locations such as the approaches to bad bends or at the approach to a crossroads. These transverse markings are thought to be effective but, in reality, cause additional problems for traffic, particularly motorbikes. When these markings become wet, because of their relatively smooth surface after the synthetic resin, additives and fillers have cooled after application, skid resistance across them becomes almost zero. At the point and time where the road user needs grip the most, it can be taken away by the presence of the yellow transverse carriageway markings in wet conditions. It should be noted that these markings are only permitted for use on single lane approaches to roundabouts, they are not permitted for use in any other circumstance.

A.3 Speed Assessment Framework (Ireland)

The text below is a full reproduction of the Irish Speed Assessment Framework as contained in the Guidelines for Setting and Managing Speed Limits in Ireland and has been included as an Appendix to highlight the issues raised in Chapter 5 in relation to its content.

Principles of the Irish Speed Assessment Framework

A speed assessment framework should help achieve an appropriate and consistent balance between safety and mobility objectives on single carriageway rural roads. Local Authorities were initially encouraged to consider its use on those roads with high collision rates or simply as a way of helping decisions in cases where the choice of the appropriate speed limit is difficult or not obvious.

- **STRATEGIC FUNCTION**

Higher speed limits should be restricted to 'upper tier' or high quality strategic single carriageway roads where there are few bends, junctions or accesses.

- **LOCAL ACCESS FUNCTION**

Lower speed limits would be appropriate on 'lower tier' single carriageway roads passing through a local community or having a local access or recreational function. They would also be appropriate where there are significant environmental considerations or where there is a high density of bends, junctions or accesses, or the road has frequent and often steep changes in elevation.

- The Default Speed Limit on National roads is 100km/h and on Regional and Local roads is 80km/h.
- The speed limit on single carriageway rural roads should take into account traffic and road user mix, the road's geometry and general characteristics, its surroundings, and the potential safety and environmental impacts.
- Where it is not possible or obvious to set a speed limit based on the above criteria, Local Authorities can adopt this Speed Assessment Framework and adopt a two-tier hierarchical approach that differentiates between single carriageway roads with a strategic function and with a local access function.

The basis for the Speed Assessment Framework procedure is as follows.

- A firm theoretical basis for choosing speed limits for road functions, taking account of safety, mobility and environmental factors.
- Roads, regardless of classification are further classified into two tiers based on their function.
- Closer integration of speed limit choice, with more general rural road safety management measures.
- Driver choice of desired speed to be reflected by mean speed.
- Local flexibility of choice within a consistent overall procedure.

1.0 Introduction

Road Lengths:	National Road – approximately 5,400 km
	Regional and Local – approximately 93,600 km

Default speed limits:	Motorways – 120 km/h
	National Roads – 100 km/h
	Regional and Local roads – 80 km/h
	Towns and Villages (built-up area) – 50 km/h

In certain cases, drivers cannot reach or exceed the speed limit on many single carriageway roads because it is often difficult to do so due to geometric characteristics such as narrow cross-section, bends, junctions and accesses.

VULNERABLE ROAD USERS: Pedestrians and cyclists are referred to as vulnerable road users because of their unprotected state. Because riders of motorised two-wheelers (motorcycles, mopeds and light mopeds) are also, to a large extent, unprotected, they are also referred to as vulnerable. Users of motorised two-wheelers are often overlooked in this category because they travel at much higher speeds than pedestrians or cyclists. There is a need to improve speed management in rural areas and, in particular, to further help drivers understand the underlying risks and tackle the problems caused by inappropriate speed. Local Authorities should particularly intervene on roads where there is a case for encouraging use by, or safeguarding the needs of, vulnerable road users.

RURAL SAFETY MANAGEMENT: Speed limits should be considered as only one part of rural safety management. The following must also be taken into account.

- How the road looks to road users
- The road function
- The traffic mix
- Road and rural characteristics

In the event that speed limits cannot be decided based on these criteria or where a road has high collision figures then Local Authorities can adopt the rural Speed Assessment Framework. This involves a two-tier (upper and lower) hierarchical approach which differentiates between roads with a strategic or local access function. Using this approach, higher limits should be restricted to 'upper tier' or high-quality strategic roads where there are few bends, junctions or accesses and lower limits are appropriate on 'lower tier' roads with a predominantly local, access or recreational function. Lower limits may also be appropriate where there are significant environmental considerations such as in any future National Parks, Areas of Outstanding Natural Beauty, or where there is a high density of bends, junctions or accesses, or the road has frequent and often steep changes in elevation. This guidance is to assist Local Authorities by helping to define the appropriate traffic speed on different types of rural road, taking into account traffic and road user mix, geometry, general characteristics of the road and its surroundings, and the potential safety and environmental impacts.

COLLISION RATES: Where they are high, Local Authorities should seek cost-effective improvements to reduce these rates by targeting the particular types of collisions taking place. To help in this process, collision data is available from the Road Safety Authority. This is a spatial dataset of all injury-related road traffic collisions reported to An Garda Síochána. Collision rates and the methodology for calculating collision rates are available from the NRA (now TII) for national routes. Identifying locations where there are above-average collision rates assists Local Authority engineers in identifying the types of site or route specific intervention measures that might be appropriate to manage speeds and reduce collisions along the route.

BALANCE: In rural areas, every effort should be made to achieve an appropriate balance between speeds, speed limits, road function and design, the differing needs of road users, and other characteristics. This balance may be delivered by introducing one or more speed management measures in conjunction with the new speed limits and/or as part of an overall route safety strategy. The aim should be to align the local speed limit so that the original mean speed driven on the road is at or below the new posted speed limit for that road. Local Authority engineers should also consider the use of vehicle-activated signs, which have proven to be particularly effective at the approaches to isolated hazards, junctions and bends in rural areas. Overuse of these signs, however, can lead to over-familiarity by drivers and hence detract from their effectiveness.

2.0 Single Carriageway Roads and the Speed Assessment Framework

2.1. In the vast majority of instances, the road function, characteristics and environment and actual speeds being driven should enable Local Authority engineers to determine the appropriate speed limit on single carriageway rural roads.

2.2. In cases where further guidance is required to aid decision-making, a Speed Assessment Framework has been developed. It is based on the principles of the Speed Assessment Framework developed by TRL (Transport Research Laboratory) for the Department for Transport in the UK. It was produced to help achieve an appropriate and consistent balance between safety and mobility objectives on single carriageway rural roads. The assessment framework is designed to assist decision-makers evaluate, in a clear and transparent way, the advantages and disadvantages of each speed limit option and reach a well-founded conclusion and is based on the presumption that single carriageway rural roads should operate at speeds near to those that give the minimum total costs taking safety, mobility and environmental impact into account.

2.3. Mean speeds should be used where the assessment framework is being applied. Local issues in relation to particular routes can be further reflected through final decisions on the acceptable mean speed for each limit, on the importance given to local environmental or social factors, and on the choice of additional engineering or educational measures.

2.4. Differentiation Of Roads By Traffic Function

		Collision Threshold
Upper tier roads	Roads with a primarily through traffic function, where mobility is important, typically all the National primary and secondary roads, important Regional roads and some important Local primary roads;	22 injury collisions per 100 million vehicle km
Lower tier roads	Roads with a local or access function, where quality of life benefits are important, typically the Local secondary and tertiary roads and remaining elements of the Regional road and Local primary network.	38 injury collisions per 100 million vehicle km

By way of comparison, the average Irish collision rate for undivided 2-lane National roads is 10 injury collisions per 100 million vehicle kilometres of travel. This analysis was carried out by the NRA (now TII) and is based on three years of collision data (2005 to 2007) and estimates of 2007 traffic volumes. Previous work by O'Cinneide et al, UCC (2004) established a collision rate for undivided 2-lane National roads at 14 injury collisions per 100 million vehicle kilometres using five years of collision data (1996 to 2000). Similarly, the average collision rate for Irish urban National roads has been calculated at 15 injury collisions per 100 million vehicle kilometres by the NRA (now TII).

2.5. The Speed Assessment Framework operates on the principle that the speed limit choice should be guided by whether the collision rate on a section of road is above or below the respective 22 or 38 injury collision thresholds and is designed to assist local decision making and promote greater consistency.

2.6. Initial trials in the UK using the assessment framework proved the practical value of the methodology, resulting in speed limits for upper tier roads which were generally accepted as reasonable by local safety officers in relation to speed, crash risk and road character. In the first instance, Local Authorities should consider its application to those roads with high collision rates or simply as a way of helping decisions in borderline cases where the choice of the appropriate speed limit is not immediately obvious.

2.7. Recommended speed limits for the two tiers subject to meeting local needs and considerations are as follows.

<table>
<tr><th>SPEED LIMIT</th><th>UPPER TIER ROADS – PREDOMINANT TRAFFIC FLOW FUNCTION</th><th>50 km/h</th></tr>
<tr><td>100</td><td>High quality strategic National primary and secondary and limited high-quality Regional roads with few bends, junctions or accesses. When the assessment framework is being used, the collision rate should be below a threshold of 35 injury collisions per 100 million vehicle kilometres.</td><td rowspan="8">Should be the norm in built up areas regardless of function</td></tr>
<tr><td>80</td><td>Lower quality strategic National primary and secondary roads which may have a relatively high number of bends, junctions or accesses. When the assessment framework is being used, the collision rate should be above a threshold of 35 injury collisions per 100 million vehicle kilometres and/or the mean speed already below 80 km/h.</td></tr>
<tr><td>60</td><td>Where there are high numbers of bends, junctions or accesses, substantial development, where there is a strong environmental or landscape reason, or where the road is used by considerable numbers of vulnerable road users.</td></tr>
<tr><td>SPEED LIMIT</td><td>LOWER TIER ROADS – IMPORTANT ACCESS AND RECREATIONAL FUNCTION</td></tr>
<tr><td>100</td><td>Only the best quality regional and Local primary roads with a mixed function (i.e. partial traffic flow and local access) with few bends, junctions or accesses (in the longer term these roads should be assessed using the upper tier criteria).</td></tr>
<tr><td>80</td><td>Appropriate for good quality regional and Local roads with a mixed function where there are a relatively high number of bends, junctions or accesses. When the assessment framework is being used, the collision rate should be below a threshold of 60 injury collisions per 100 million vehicle kilometres.</td></tr>
<tr><td>60</td><td>Roads with a predominantly local, access or recreational function, or where the road forms part of a recommended route for vulnerable road users. When the assessment framework is being used, the collision rate should be above 60 injury collisions per 100 million vehicle kilometres.</td></tr>
</table>

It is important to note that the above does not imply that speed limits should automatically be reduced. In some cases, the assessment may suggest that the existing speed limit may already be inappropriately set or too low, and an increased limit should be considered.

3.0 Approach to Speed Limit Setting for Single Carriageway Roads in Rural Areas

3.1. Speed limits should be considered as only one part of rural safety management. Where collision rates are high, the priority should be to seek cost-effective improvements to reduce these rates, targeting the collision types that are over-represented.

3.2. If, despite these measures, high collision rates persist, lower speed limits may also be considered. Lower speed limits on their own, without supporting physical measures, driver information and publicity will not necessarily change driver behaviour. Drivers will therefore continue to travel at inappropriate or excessive speeds. This may lead to significant enforcement costs. Every effort should be made to achieve an appropriate balance between speeds, speed limits, road design and other measures. This balance may be delivered by introducing one or more speed management measures in conjunction with Special Speed Limits and/or as part of an overall route safety strategy.

3.3. The assessment framework is designed to assist decision-makers evaluate, in a clear and transparent way, the advantages and disadvantages of each speed limit option and reach a well-founded conclusion and is based on the presumption that single carriageway rural roads should operate at speeds near to those that give the minimum total costs taking safety, mobility and environmental impact into account.

3.4. A simple two-tier functional hierarchy should be used, with roads having either primarily a through traffic function (upper tier) or a local access (lower tier) function. Both need to be provided safely. Mobility benefits will be more important for the upper tier than for the lower tier roads, whilst environmental benefits are likely to be of greater importance for the lower tier roads.

3.5. There may be many regional and Local roads which serve a mixed through-traffic and access function. Where that traffic function is currently being achieved without a high collision rate, these roads should be judged against the criteria for upper tier roads. If, however, for all or parts of these roads there is a substantial potential risk to vulnerable road users, these sections should be assessed against the criteria for lower tier roads.

3.6. Decisions on speed limits should take account of other collision reduction measures that might be applied, information such as typical collision rates and typical proportions of different collision types on different types of rural road. These can be used to assist in the determination of whether other site or route-specific measures might be appropriate that would reduce either speeds or collisions along the route.

3.7. Mean speed should be used for the assessment. For the majority of roads, there is a consistent relationship between mean speed and 85th percentile speed. Where this is not the case, it will usually indicate that drivers have difficulty in deciding the appropriate speed for the road, suggesting that a better match between road design and speed limit is required.

3.8. The aim should be to align the speed limit to the prevailing conditions and that all vehicles are moving at speeds as close to the posted speed limit as possible. An important step in the procedure is to gain agreement with local enforcement agencies that the mean speed of drivers on the road with any new speed limit is acceptable.

3.9. The aim of the framework approach is to assist in the consistent application of speed limit policy throughout the country.

- Local issues in relation to particular routes can be reflected in the functional tier to which the road is assigned,
- final decisions can be based on acceptable mean speeds for each limit with importance given to local environmental factors.

3.10. Research (Finch et al., 1993, Taylor et al., 2000) shows that for every 1 mph reduction in the average speed the accident frequency reduces by 5%.

The monetary cost of an accident has been estimated (LIFE SAVERS NOT REVENUE RAISERS - SAFETY CAMERAS IN IRELAND: A COST BENEFIT ANALYSIS - Derek Rafferty Department of Economics, University of Dublin, Trinity College 2014) as follows.

Fatal	€2,706,000	Serious Injury	€310,039
Minor Injury	€28,388	Damage only	€3,190

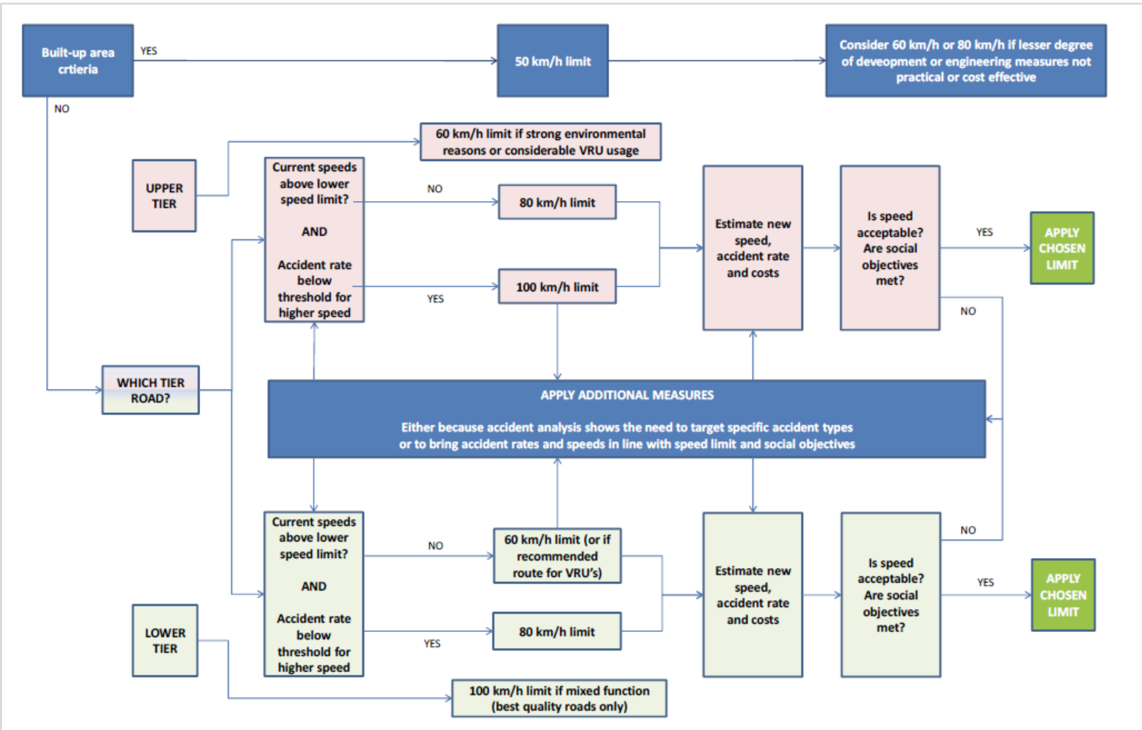
Speed limits on their own, however, only have a limited effect on actual speeds. According to the Organisation for Economic Co-operation and Development/European Transport Safety Council (2006), analysis shows that lowering the limit by 10km/h decreases speed by 3 to 4 km/h. In places where speed limits have been changed and no other action taken, the change in average speed is only about 25% of the change of the speed limit. Changes in speed limits must also therefore be accompanied by appropriate enforcement, infrastructure and information measures (European Transport Safety Council 2010).

4.0 Selection Procedure

4.1. Within routes, separate assessments can be made for individual sections of road of 600m or more for which a separate speed limit might be considered appropriate. When this is completed, the final choice of appropriate speed limit for individual sections might need to be adjusted to provide consistency over the route as a whole.

4.2. A flow chart of the decision-making process for selecting speed limits for rural single carriageway roads is shown below. It includes the following steps.

Step 1	Consider whether the level of development requires special treatment.
Step 2	Consider which functional tier is appropriate for the road.
Step 3	Measure the current mean speed and calculate the collision rate as all injury collisions per 100 million vehicle km
Step 4	Check the collision rates against acceptable thresholds
Step 5	If the collision rate is high, check the proportions of different crash types and consider whether site or route treatment is appropriate before deciding the speed limit.
Step 6	If a speed limit lower than the current one is indicated, estimate the mean speed and collision rate and the influence on social factors and vulnerable road users that would result from implementing the new limit.
Step 7	Check that these values are acceptable; if not, consider whether further measures are necessary to bring speed and collision rates into balance.

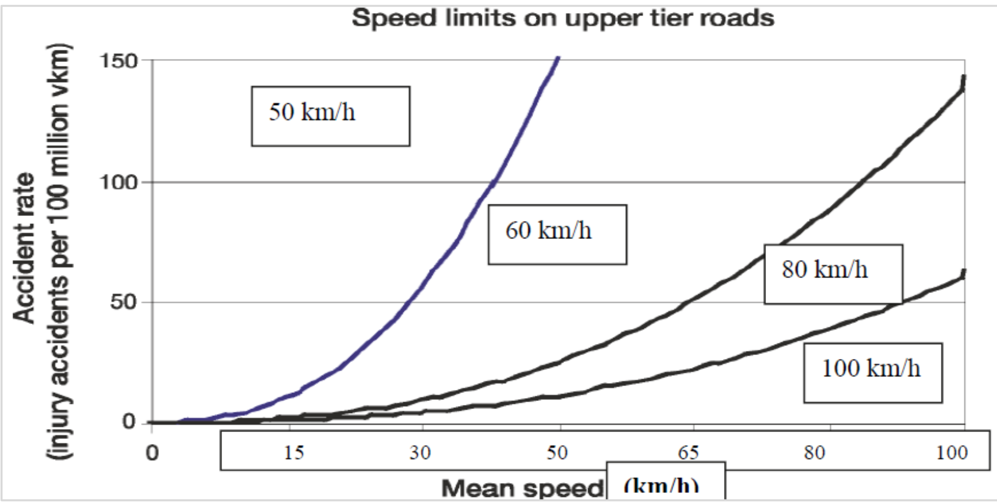


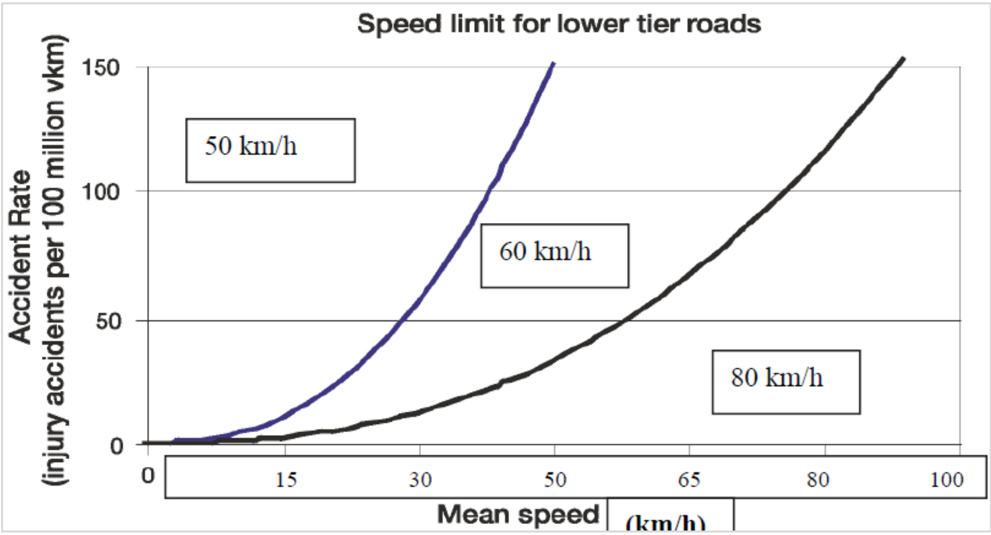
4.3. For mean speeds to be acceptable, they should be no higher than the posted limit after it has been implemented. Research shows that, for a typical distribution of vehicle speeds on single carriageway rural roads, the 85th percentile speed is about 10 km/h above the mean speed for roads with an 80 km/h limit and about 13km/h above mean speed on roads with a 100 km/h limit. Setting acceptable mean speeds at or below the limit is therefore consistent with current enforcement thresholds.

4.4. The choice of speed limit within each tier should take account of the following;

- whether the collision rate is below the appropriate threshold of injury collisions per 100 million vehicle kilometres,
- whether there is substantial development,
- whether the road forms part of a recognised route for vulnerable road users.

4.5. The bands of appropriate collision rates by speed and speed limit are illustrated in the figures below. If walking, cycling, equestrians or environmental factors are particularly important on the road section, consideration should be given to using the lower limit, even if the collision rate is below the threshold shown.





4.6. The influence of development should be taken into account through the following factors

- If the road section qualifies for built-up area status then the advice given in the guidelines should be followed, i.e. built-up area speed limit should apply.
- If the section does not meet the definition for a village, but the level of development is at least half the density implied (over a minimum of 600 metres), a speed limit of 60 km/h should be considered.

4.7. Other factors that would strengthen the case for a 60 km/h limit are

- a high incidence of bends or junctions,
- high collision rates,
- specific development in terms of schools, public houses and use by vulnerable road users.

Appendix B

Future areas for consideration or further work

Further work that could be carried out to develop supplementary tools to assess appropriate speed limits along with Safe Profile Velocities (V_{sp}) are briefly outlined below.

B.1 Determine Theoretical Design Speeds

Work carried out by McCarthy & Pforte in 2014 introduced a process for effectively reverse calculating the design speed of a road that was not designed or constructed to formal design standards ('legacy' roads). This Enhanced Design Speed, or Theoretical Design Speed, has been shown to have merit in a paper presented at the National Roads Authority Annual Conference in 2013 (http://www.tii.ie/tii-library/conferences_and_seminars/nrc/nra-nrc-2013/2.5-A-Review-of-Design-Speed-based-on-Observed-Behaviour-Z-Langenbach-P-Lewis.pdf).

Enhanced design speeds can be calculated, and relationships between them and the posted speed limits and the derived V_{sp} can be examined or tested. At the very least, each road would theoretically have a design speed. There is value in determining this information as currently the Guidelines state that the design speed of a road can be defined as the highest speed that can be maintained safely and comfortably when traffic is light (the N2 case study seems to contradict this). It also states that the design speed <u>should not</u> be lower than the speed limit and the speed limit <u>should not</u> be significantly lower than the design speed of a road.

Transport Infrastructure Ireland, in publication DN-GEO-03034 (formerly known as TD9) states that a design speed of 85 km/h should be selected when designing and constructing a Type 3 single carriageway road and is only applicable to National secondary roads. This also corresponds to the philosophy of higher and lower tier roads; National secondary roads would be seen to be a lower tier than National primary roads.

The N2 is a strategic National Primary Route linking Dublin and Derry, the N2 connects to the A5 at Aughnacloy, Co. Tyrone. The section of the N2 between Monaghan town and Corracrin was shown in section 6.3.1 to be performing poorly in terms of its efficiency, the relationship between the V_{sp} and posted speed limit in the Southbound direction was poor with the V_{sp} between 10-15 km/h above the posted limit, a Special Speed Limit of 80 km/h.

This section was recently the subject of two improvement schemes. The road was 'improved', however, it was improved by two minor realignment schemes using a design speed of 85 km/h. This means the Default Speed Limit of 100 km/h, as per the 2004 Road Traffic Act, could not be applied because a speed limit could not be set greater than 80 km/h – because of this a Special Speed Limit Bye-law was required to facilitate the inappropriate selection of a design speed of 85 km/h, or Type 3 carriageway, which, for Level of Service D (traffic streams approaching unstable flow. LOS A = Free Flow) should have a maximum AADT of 5,000. The nearest TII permanent traffic counter at Mullinderg outside Emyvale, Co. Monaghan, within the case study area, has recorded the AADT as 5,485, 5,712, 6,080 and 6,221 for the last four years. (https://www.nratrafficdata.ie/c2/calendar_alt.asp?sgid=ZvyVmXU8jBt9PJE$c7UXt6&spid=NRA_000000020024)

It is unclear as to what the correct approach would be to address a situation like this (it is possible there are other examples of this around the country). It is likely that the IPBMI (Irish Public Bodies Mutual Insurance) would not insure a Local Authority if they did set a speed limit higher than the design speed. The Guidelines state ***should not***, not ***must not***, so this immediately introduces a grey area where there is no right or wrong answer. This, of course, only applies to improved or realigned roads; legacy roads are not considered at all. It is quite acceptable at present to leave every legacy road in the country with its Default speed limit whether or not it would theoretically be higher or lower than its 'design speed'. Presently it is not advisable to set a speed limit on a road that is higher than the design speed even though for as long as speed limits have existed we have been driving mostly on legacy roads without design speeds.

Using Enhanced design speed to find out what the design speed of a road is would be of benefit to IPBMI and to Local Authorities who would be given increased confidence about the speed limit they have selected.

Finding the relationship between the Enhanced Design Speed, the posted speed limit and the V_{sp}, and analysing the collision history, would give the clearest indication possible as to the appropriateness of a speed limit on a legacy road. The following datasets are required;

- A sampled (5m) road centre line comprising survey grade XYZ co-ordinates and ideally listing road lane width together with hard-shoulder width (if present).
- Table listing vehicular speeds for various radii of curvature
- Look-up table listing combinations of hard shoulder width, lane width, sight distance and associated vehicle speed.

Survey grade XYZ co-ordinates are readily available from survey companies who have surveyed the network, in whole or in part, using LIDAR. Acquiring this information would be a routine task, however, funding to acquire such substantial amounts of data may be a potential barrier. To further test the use of Enhanced Design Speeds, and to avoid lengthy procurement and survey periods the initial approach should be to make use of currently available survey data and, in future, procure services to survey routes that have not been surveyed previously, as the need arises.

B.2 Develop Visual Interrogation/Assessment Tool

In terms of pavement management, strip maps have been developed to assist those involved in pavement management projects to visualise the many pieces of relevant information along the chainage of a road, such as the Roughness Index (IRI), rut depth, gradient, crossfall, cracking, SCRIM coefficient etc. The data is presented without units in colour coded bands. Ground penetrating radar surveys can then be imported to display a cross-section of the layers that make up the pavement. This helps decision makers to target the sections of pavement that are in need of rehabilitation.

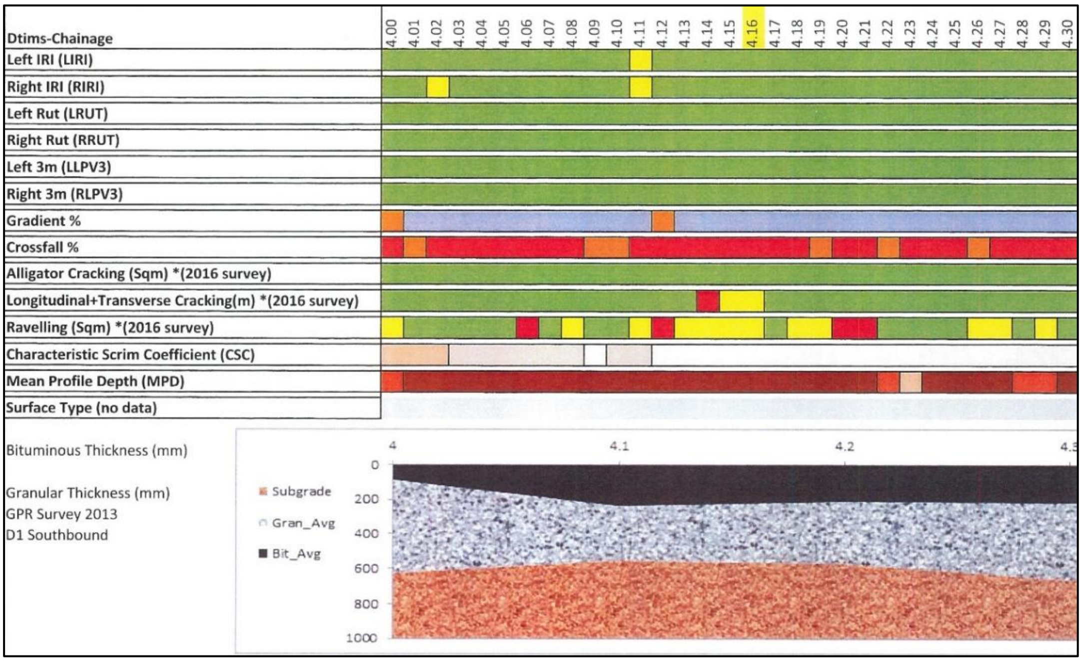


Figure B.1: Pavement Asset Management System Strip Map

A similar type of visualisation tool (the Speed Limit Assessment and Management Tool; mock-up screens below), web based, could be developed to assist in the assessment of speed limits by displaying all the pertinent information in one place at the same time for the route, or section thereof. Data to be displayed should include; (see figures B.2 to B.6 below)

- Posted Speed Limit,
- Default Speed Limit,
- traffic and safety data,
- width information,
- derived V_{sp}, Design Speed and Enhanced Design Speed.

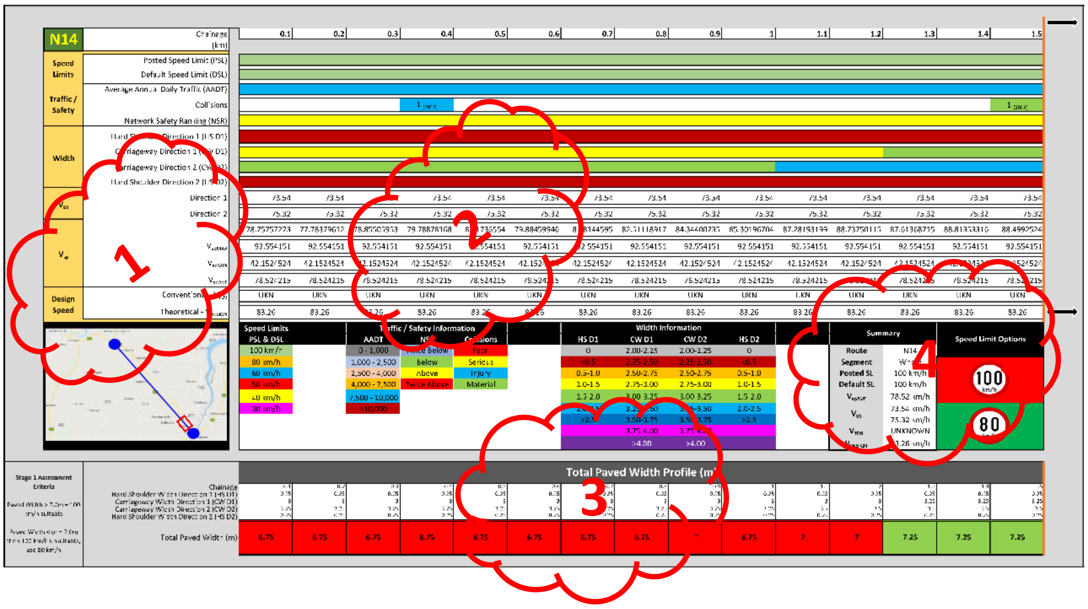
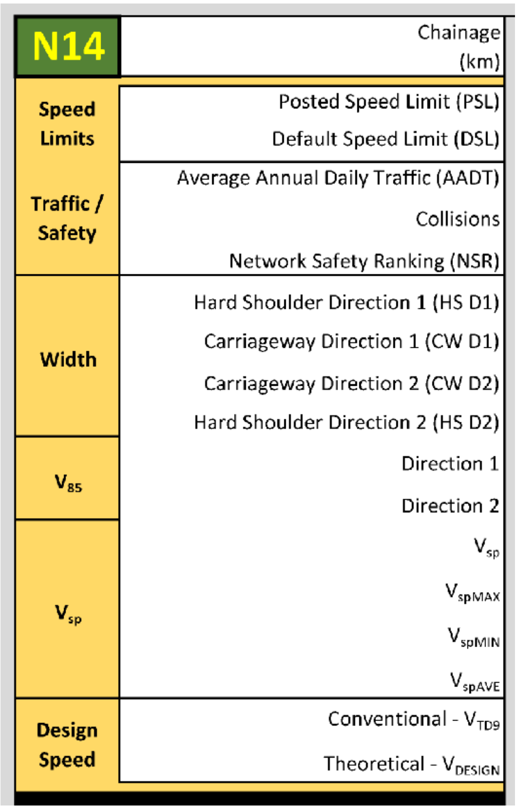


Figure B.2: Speed Limit Assessment and Management Tool

1



The data to be collected is shown opposite. Much of this information has already been captured. The Speed Limit Assessment and Management tool would simply act as a viewer with regard to the data, it would be taken from a separate database(s) and displayed within this tool. The map could be linked to OSi or other mapping services with a simple linework overlay shown for the route in question.

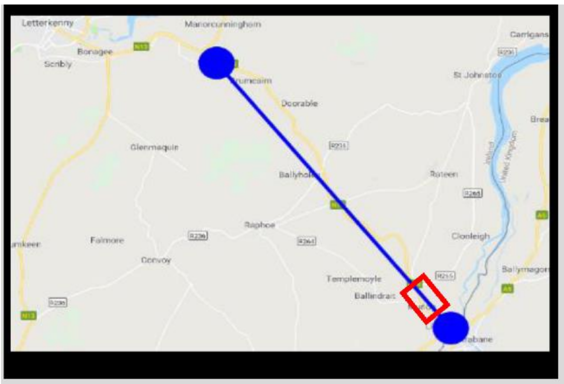


Figure B.3: Data Input Categories and Map.

Speed limits, traffic, collisions and width data is displayed below in coloured bands with a legend. 85th Percentile speed (V_{85}), Safe Profile Velocity (V_{sp}) and design speed data is displayed in numerical form. The route runs from left to right (chainage increases) and the window is scrollable either using the arrow as a grip or by dragging the red rectangle overlaid on the linework in the map window.

2

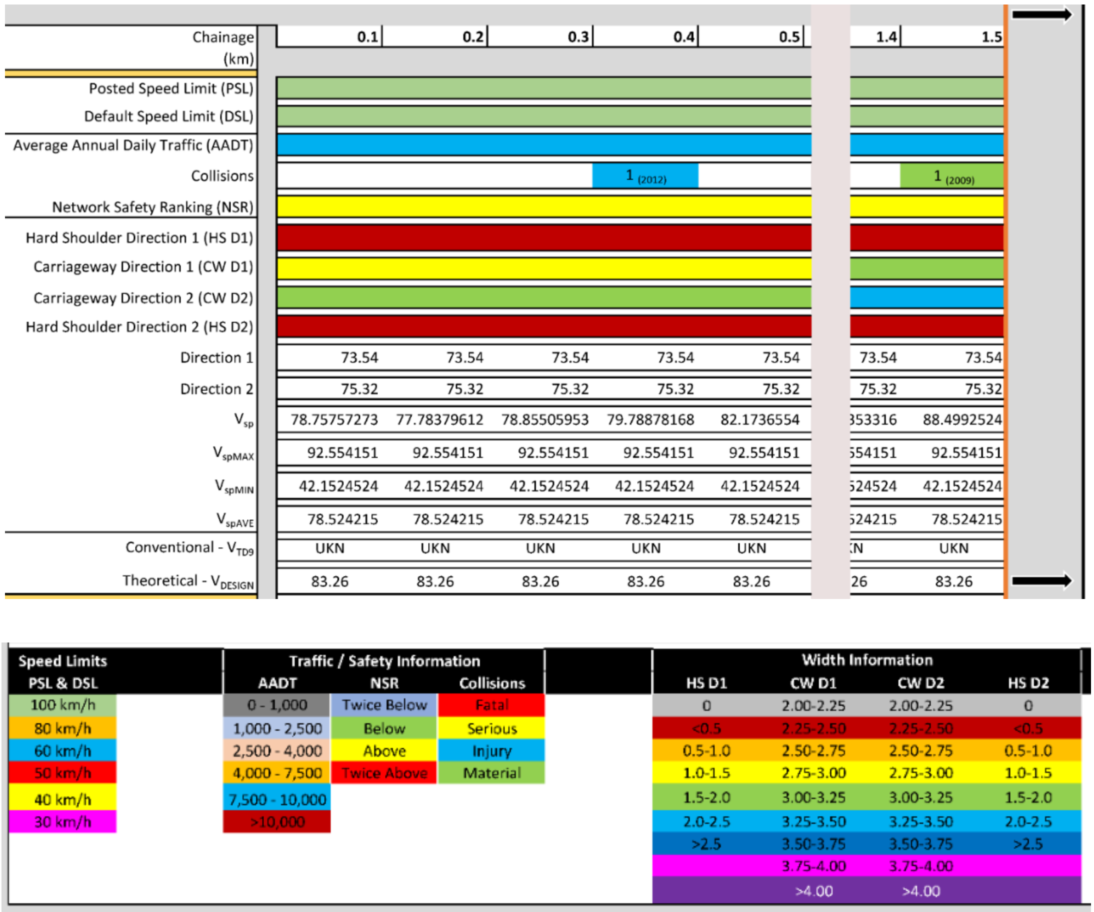


Figure B.4: Data window and legend.

The total paved width profile is shown in the lower window, this easily identifies whether any sections of the road satisfy the Stage 1 Assessment criteria.

3

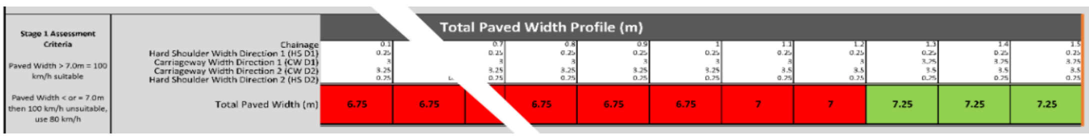


Figure B.5: Paved Width Profile Window.

Finally, the summary window lists the speed limits, V_{sp} and design speeds for the whole route and recommends the speed limit that should be applied to the section (green cell). It could be configured to work on a section by section basis (i.e. between towns along a route) and could further be configured to alert the assessor if there is potentially more than two changes of speed limit over a 10 km length or if there are altered speed limits within 3 km of each other (Guidelines 2015, p41).

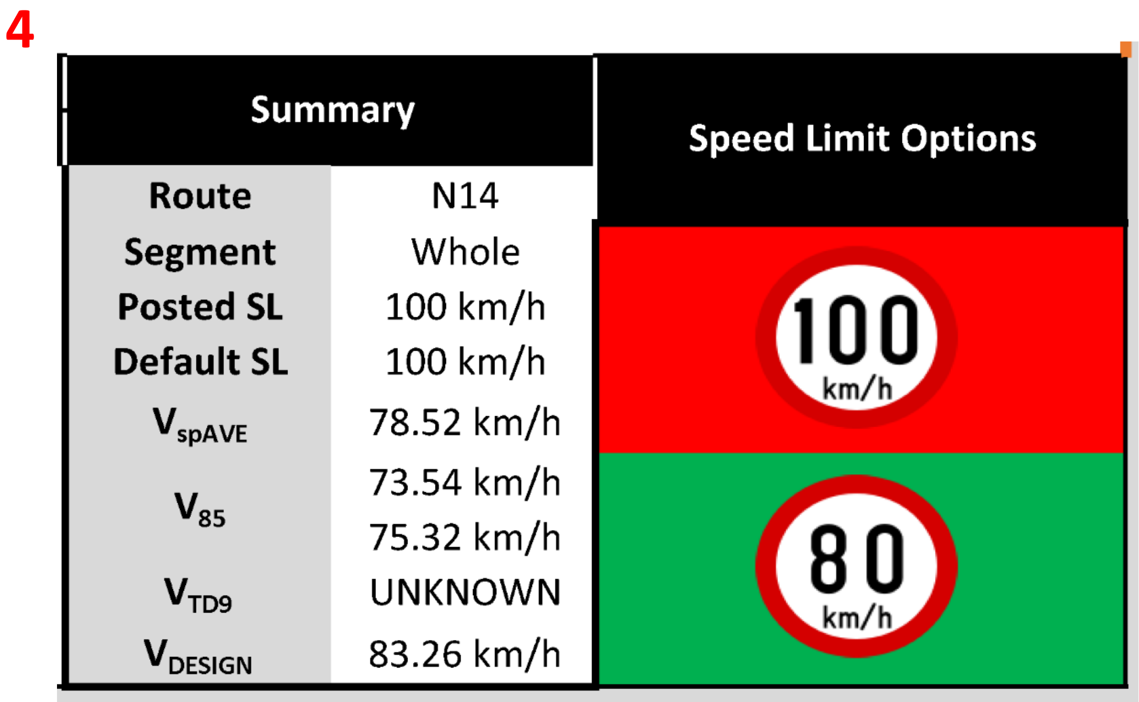


Figure B.6: Summary and Speed Limit Recommendation Window.

In this example, of the N14, the data shown is example data and may not reflect the true data and assumes the Enhanced Design Speed has been determined. As such, as V_{DESIGN} is determined to be 83.26 km/h, the Speed Limit Assessment and Management Tool recommends 80 km/h as the appropriate speed limit to be applied to the route as, as previously discussed, the speed limit cannot be posted higher than the design speed.

B.3 Trial 90 km/h or select counties for testing alternative speed limits based on V_{sp}

While the case studies in Chapter 6 focused on choosing either 80 km/h or 100 km/h on the National roads, 90 km/h emerged as a speed limit option that may warrant further investigation. As outlined in Chapter 4, much of Europe has speed limits of 90 km/h and Ireland had it as its National Speed Limit from 1979 to 1992 (as 55mph - Fig 2.7 p16). It also exists in the USA (as 55 mph). 90 km/h here would bring about consistency with the majority of Europe.

Primary Legislation, however, would need to be enacted to facilitate a trial of this speed limit as it does not currently exist in Irish Legislation. In the absence of Legislation, and indeed to possibly strengthen the case for its consideration in the long term, a trial of V_{sp} to determine appropriate speed limits should be conducted.

The trial would consist of;

1. Select routes in one or two counties,
2. Determine the V_{sp} of the routes,
3. Analyse/determine relationship (Efficiency/Efficiency Index of the route) between V_{sp} and posted speed limit,
4. Model the effect of altering speed limits,
5. Local Authority to make Bye-laws to alter the speed limit,
6. Monitor the effect of the change of speed limit (collisions, journey times, V_{85})
7. Recapture V_{sp} under altered speed limit conditions and repeat step 3,
8. Compare results from steps 3 and 7.

The benefit of a successful trial would be twofold, it would confirm V_{sp} as being a suitable indicator as to the appropriate speed limit to be chosen and in doing so would give confidence to the implementation of 90 km/h as a speed limit (possibly to replace 100 km/h on rural single carriageways). The implication being that should the V_{sp} methodology be proven conclusively, then, theoretically modelling the effect of using 90 km/h could be done with increased confidence.

B.4 Crowdsource. gpx tracks to derive V_{sp} and Route Efficiency nationwide

To derive V_{sp} (and, therefore, the Efficiency Index) a route requires 3 or 4 passes in both directions of travel. To derive V_{sp} for all rural single carriageway roads in the State would be an enormous undertaking. Local Authorities would not have the resources in terms of time or personnel to carry it out themselves. One way of capturing large amounts of data like this is through crowdsourcing the data. Crowdsourcing is, in its simplest definition, outsourcing work to a crowd or group of unspecified people by making an appeal, often using the Internet. Payment or compensation for participation does not necessarily have to be involved.

In this scenario, it would simply involve a campaign to collect as many .gpx tracks as possible for processing on a route by route basis. The .gpx tracks themselves would not contain any personal data and would be submitted with participants' free will. A process would be developed to verify the integrity of the submitted files before processing. A V_{sp} and Efficiency Index processing module could be built into the Speed Limits Assessment and Management tool, example interface shown in Figure B.7, which would use existing Python scripts developed by McCarthy and Pforte (2014).

Figure B.7: V_{sp} Processing Module.

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