Bonneagar Iompair Éireann
Transport Infrastructure Ireland

Review of Motorway Junction Lighting Energy Reduction Pilot Project

October 2021

Contents Page

1. Executive Summary 1
2. Introduction 2
3. Policy Context 3
4. Design Standards for Motorway Lighting 4
5. Pilot Project Concept 5
6. Pilot Scheme Safety Evaluation 8
7. Pilot Scheme Energy and Emissions Evaluation 11
8. Conclusions 12
9. Next Steps 12

1. Executive Summary

Road lighting on national roads results in significant energy use and associated emissions. Since the publication of TII's 2016 policy 'Energy Reduction in Public Lighting on National Roads', TII has been working to reduce road lighting energy consumption while maintaining appropriate levels of lighting.

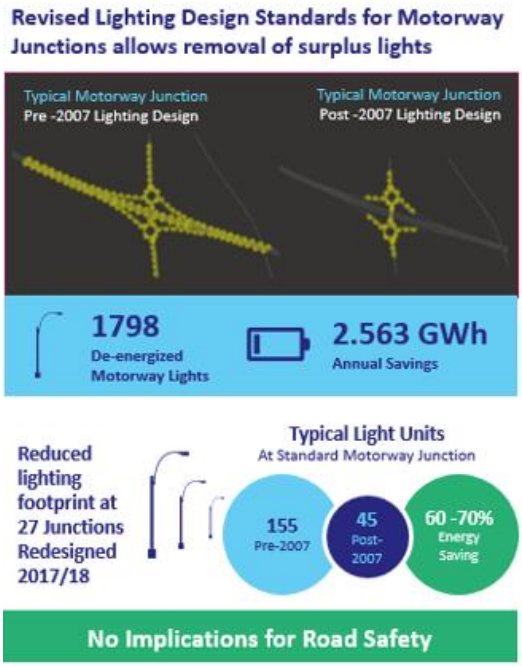
Specifically at motorway junctions, changes in design standards since circa 2007 have resulted in newly built junctions being more efficiently lit. However, a cohort of older junctions remains lit to the older lighting standards and uses significantly more energy than is necessary under modern standards.

With a view to reducing emissions, energy use and costs, and achieving a standard lighting format across all applicable motorway junctions, TII conducted a pilot study to assess the safety performance, energy emissions, costs and benefits of changing the lighting at older junctions to meet modern design standards. The modern standards require a smaller lighting "footprint" and applying this design standard to older junctions allows the identification of surplus lighting which can be switched off.

The pilot study was conducted in two phases, with four junctions trialled in the first phase and twenty-three junctions trialled in the second phase.

The study included analysis of available collision data at motorway junctions and this has confirmed that the removal of surplus lighting at 27 No. motorway junctions has not resulted in a material reduction in safety performance at those junctions where the layout is in accordance with the latest standards. Technical analysis has identified that the energy, emissions and costs savings are substantial.

The benefits of the project are summarised below.



This energy reduction programme results in reduced energy and costs and makes an important contribution to TII's sustainability efforts and to the national effort to reduce emissions, with the pilot bringing a reduction of nearly 900 tonnes of CO_2 in the first year. These harmful emissions will be avoided for years to come.

TII intends to remove the now surplus lighting poles at the treated junctions to reduce the number of roadside hazards, thus improving road safety, and will roll out road lighting redesign to all remaining applicable

junctions and mainline sections where lighting surplus to that required under current design standards is in place. TII will continue to monitor the safety, energy use, emissions and cost/benefits of any changes to the road lighting layouts

2. Introduction

TII's overall strategy in relation to road lighting is outlined in the policy document 'Energy Reduction in Public Lighting on National Roads' (2016) available at www.tii.ie. The strategy is based on targeting measures which have a sound safety and sustainability rationale and includes removal of surplus lights, dimming, voltage regulation and replacement of existing fittings with more efficient LED technology.

The implementation of this strategy in the period from May 2017 to July 2021 has resulted in improvements including:

1. The removal of surplus lighting at 27 No. motorway junctions.
2. Off-peak dimming of lighting on the M50 motorway.
3. The removal of mainline lighting on the M1 between junctions 3 and 4.

Item 1 above was conducted as part of a pilot project and this document presents a review of that pilot project, summarising road safety, energy and emissions performance for the 27 motorway junctions where surplus lighting[1] was removed**.**

[1] Surplus lighting is defined in this document as lighting that exceeds the requirements of the current lighting design standards.

3. Policy Context

Energy reduction is the primary requirement for the 2016 strategy, with cost and emissions reductions being essential outcomes of that energy reduction. The strategy was rooted in a firm policy footing and continues to be so rooted as the conversation around climate action has evolved.

Ireland's National Energy Efficiency Action Plan (NEEAP) launched in 2009 set out several objectives to improve Ireland's energy efficiency by the year 2020. A national improvement target of 20% was set, with a higher target of energy efficiency improvement of 33% for the public sector. The Public Sector Energy Efficiency Strategy (PSEES) published in 2020 credits road lighting improvements as having played a significant role in the achievement of these targets.

TII's energy efficiency improvement is currently at over 30% as compared to the 2009 baseline and road lighting energy reduction measures have contributed to that achievement. A prime example of the success of the strategy is the M50, which has seen a reduction of over 40% in energy consumption based on lighting modifications focused on reduction of lighting intensity in line with off-peak night-time traffic volumes.

For the next decade, there are more demanding European, national and public sector targets relating to energy efficiency. The Climate Action Plan[2] (CAP) and Low Carbon Development Bill (Amendment) 2021 "*will establish a legally binding framework with clear targets and commitments set in law, and ensure the necessary structures and processes are embedded on a statutory basis to ensure we achieve our national, EU and international climate goals and obligations in the near and long term".* These commitments include emissions reductions of 7% per annum, 51% by 2030 and a net zero target/goal by 2050.

TII's Statement of Strategy 2021 - 2025 documents, inter alia, a vision for TII which involves ensuring Ireland's national road and light rail infrastructure is safe, while being a leader in the delivery and operation of sustainable transport infrastructure – road lighting energy reduction measures relate to both of those elements of TII's vision.

Further, TII has developed a Sustainability Implementation Plan (SIP) that outlines its vision to be a leader in the delivery and operation of sustainable transport and defines a roadmap for shaping sustainable transport infrastructure within the organisation. Reduction of energy use and carbon emissions is a key objective of the SIP, as part of a drive towards net-zero emissions.

[2] A revision of the CAP is expected in 2021.

4. Design Standards for Motorway Lighting

Prior to 2007, in Ireland, there were various standards in operation resulting in bespoke designs where motorway junctions, including mainline and ramps, were fully lit. Such designs are typically referred to as 'Large Footprint' lighting designs.

The UK modified their design standards in 2006 to reduce the lighting footprint and light only conflict areas, referred to as 'Small Footprint' lighting designs. The scale of the change is evident in the typical examples shown in Figure 1.

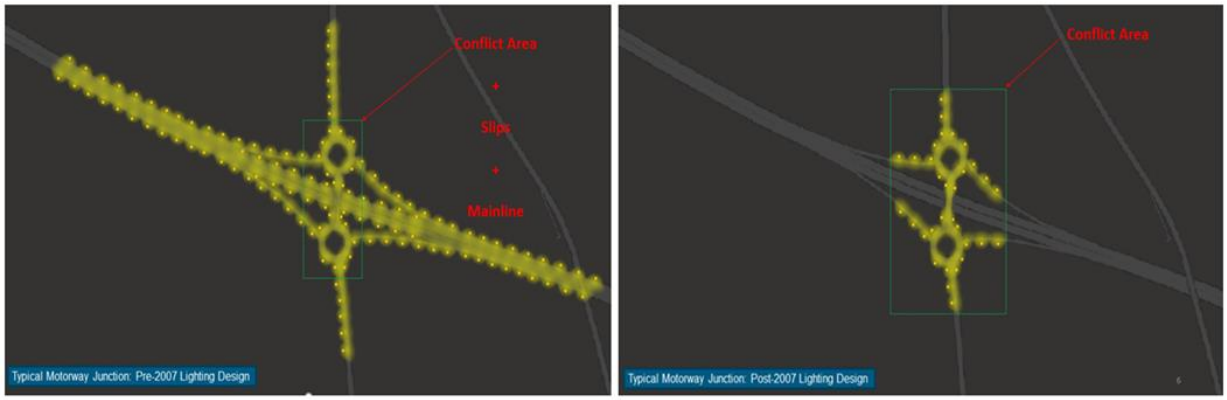


Figure 1 – Typical Large Footprint (Pre-2007) and Small Footprint (Post-2007) junction lighting designs.

Taking into account the reduced construction and operating costs and the evidence on safety performance which informed the UK changes, the 2006 UK Standard was effectively adopted for use in Ireland from 2007.

In 2009, following a 2008 CEDR Report on Road Lighting and Safety, Ireland changed their approach to be formally consistent with the UK. The commitment to reduced lighting footprint design has been maintained in the updated 2018 TII standard. The timeline of the various standards as applied in Ireland, is summarised below.

Year	Action	Outcome
Pre-2006	Various Standards	Typically bespoke designs with various interpretations by Consulting Engineers. Mainline and Ramps fully lit (Large Footprint)
2006	Modifications to UK Standards	Reduced lighting footprint (Small Footprint) adopted. Conflict Areas at end of Off-Ramps and Junction extents were lit.
2007[3]	Adaptation of 2006 UK Standard for most schemes under/going to construction	Design and Build Schemes prompted a move by Designers to utilise the 2006 UK Standard. From 2007 onwards most Road Schemes opened in Ireland were constructed with a Small Footprint
2009	NRA New Standard	Consistent with UK 2006 and 2008 CEDR Report on Road Lighting and Safety. Formally adopted a Small Footprint.
2018	TII Standard	Consistent with NRA 2009, reinforced continued use of the Small Footprint.

Table 1 – Evolution of Lighting Design Standards for Motorway Lighting.

[3] As lighting design for most road schemes completed in Ireland since 2007 have been consistent with the UK 2006 Standard giving a small footprint for lighting, in subsequent sections reference is made to "Pre-2007" and "Post-2007" design types. The difference in lighting points between the two design types is generally referenced in this report as "surplus" lighting, in that it exceeds the requirement under current standards.

5. Pilot Project Concept

The change in standards from Large to Small Footprint has resulted in a lack of uniformity in junction lighting layouts, a position that is in conflict with the principle of standardisation which is central to TII design standards.

An examination of the Pre-2007 legacy junctions, identified that those junctions were now considered to be lit to a substantially larger footprint than would be required by current requirements.

Designs for new builds obviously must accommodate new standards, however it was not clear that substantially altering existing lighting could be done without a material safety implication.

A two-phase pilot programme was developed to assess the safety performance and benefits of switching off lighting to reduce the footprint in line with current standards.

Pilot Phase 1: Surplus lighting switch-off at four junctions

Phase 1 of the pilot scheme implemented by TII resulted in a surplus lighting switch-off at four junctions, typically reducing about 130 lighting points to about 40 lighting points at each junction. This pilot scheme began in May 2017 and lighting was switched off at slips and the mainline at four junctions whilst keeping conflict areas lit, consistent with the Post-2007 Small Footprint design. Figure 2 shows an example of the lighting switch-off pilot.

The four junctions where this pilot scheme was implemented were:

- M1 Junction 6 (Balbriggan)
- M6 Junction 3 (Rochfortbridge)
- M9 Junction 3 (Athy)
- M4 Junction 9 (Enfield)

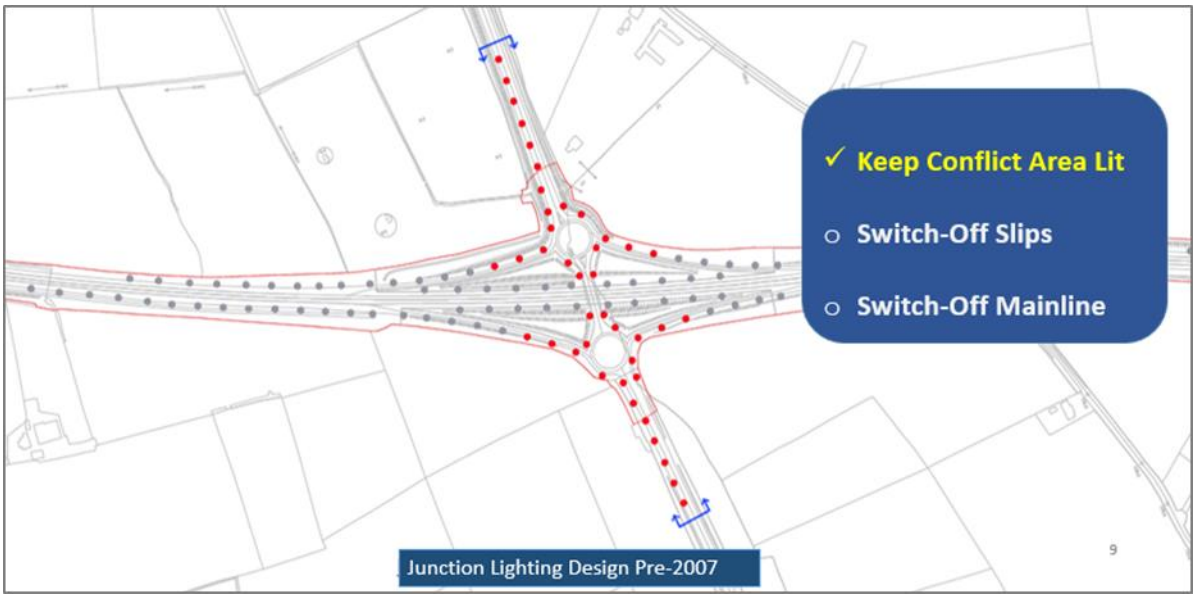


Figure 2 – Example of the lighting switch-off pilot. Remaining Lights in RED.

An interim review by Arup carried out in September 2017 found that these pilot junctions were no less safe than fully lit junctions. No safety, or other, issues were identified in the pilot study and a 60% - 70% energy saving per junction was identified.

While Phase 1 was a small-scale implementation, it provided additional confirmation that the move to use the UK 2006 standard was justified in the period commencing in 2007 and supported the continued use of the current TII standard.

This finding enabled a second larger phase to proceed, which is described below.

Pilot Phase 2: Surplus Lighting Switch-off at an additional 23 No. junctions

Phase 2 of the pilot scheme consisted of a wider switch-off of surplus lighting at twenty-three junctions that were previously lit in accordance with Pre-2007 standards. Implementation of this wider switch-off phase began on September 1st 2018.

A further 24 No. junctions where no changes were implemented remained in place, as a control group to facilitate road safety evaluation. The results of the evaluation are presented in section 6.

Figure 3 shows the locations of both the control group and junctions involved in the pilot study where surplus lighting switch-off was implemented.

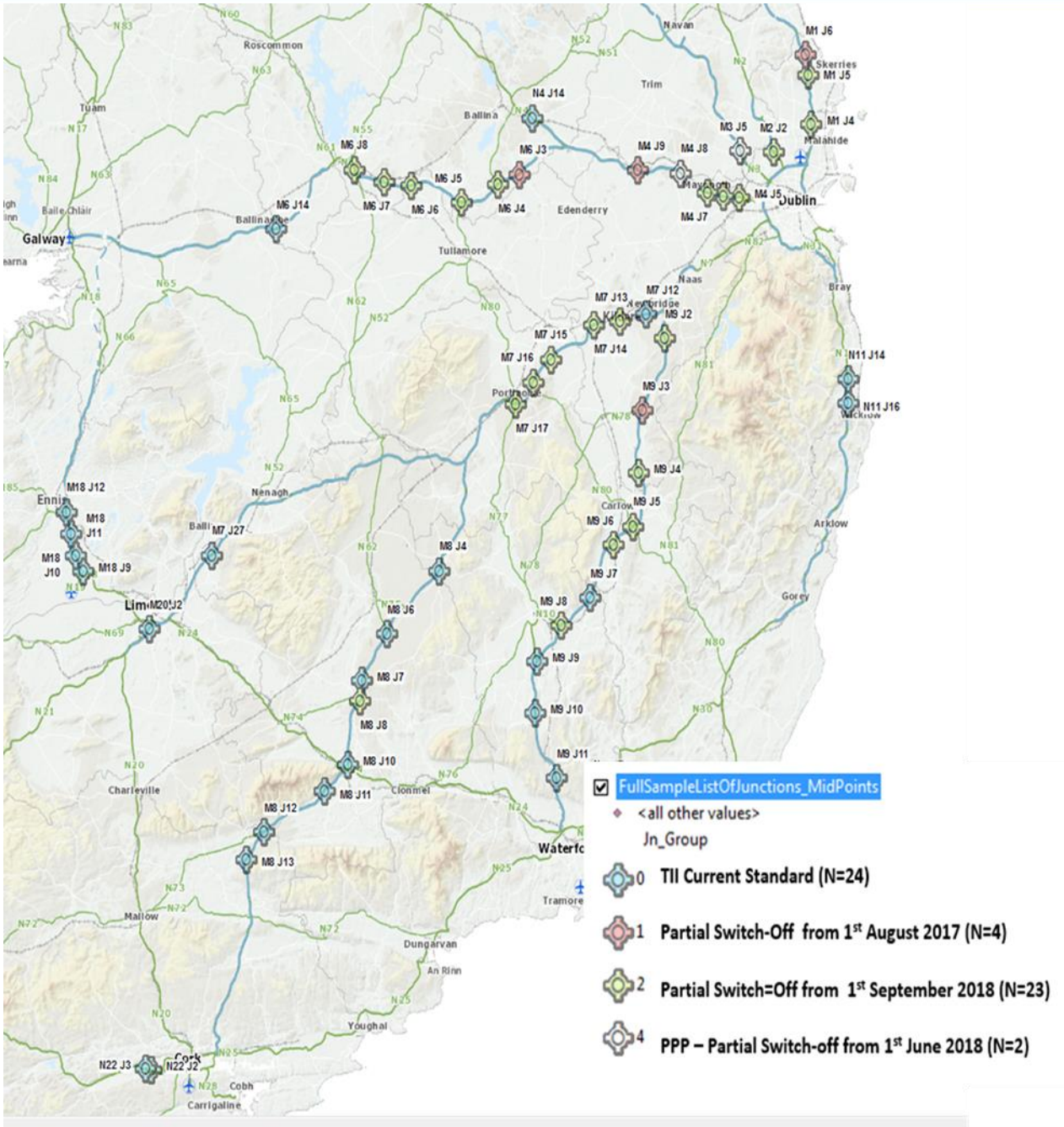


Figure 3 – Mapped Locations of Motorway Junctions involved in the pilot study and control group.

6. Pilot Scheme Safety Evaluation

An evaluation of the pilot study was carried out looking at An Garda Síochána PULSE collision data for time intervals before and after the pilot study began.

Collision data records for 32 months before, and 16 months after the lighting change implementation were examined.

- The **control group** are referred to as **Group 0** – these are the junctions where no changes were made to the lighting.
- The **treated junctions** are referred to as **Group 2** – these are the junctions where lighting reductions took place.

The outputs for Group 0, and for Group 2 highlighted no difference between the percentage of personal injury collisions (PIC) that occurred in darkness, with 32% of collisions occurring in darkness in both the before and after phases of the pilot study as shown below.

PULSE data analysis

Group 2	*Before**	*Darkness%*	*After***	*Darkness %*
No. Daylight PIC	28		17	
No. Darkness PIC	13	32	8	32
No. Daylight PIC & Material Damage	213		131	
No. Darkness PIC & Material Damage	65	23	56	30

** 32 months before -PULSE records analysed*

*** 16 months after-PULSE records analysed*

Table 2 – PULSE Collision Data Analysis for Group 2, the treated junctions.

A chi squared analysis confirmed there is no significant statistical difference between all injury collisions in the before and after period, and collisions that occurred during the hours of darkness in the before and after period.

	All PIC				PIC (Darkness)				
Group	*Before*	*After*	*%Difference*	χ^2	*Before*	*After*	*%Difference*	χ^2	*No. of Junctions*
0*	10	7	-30		7	8	23		24
2	21	25	22	0.42	3	5	67	0	24

**Average over 16 months*

No Significant Difference

Chi sq. > 3.84 - result is significant at 5%. Confidence Interval 95% the result is correct

Table 3 - Chi squared Analysis of Before/After Personal Injury Collisions.

Further collision analysis looked at both injury and material damage collisions. The statistical analysis found that there is no signficant difference in injury and material damage collisions from the before and after periods of the pilot study.

	Daylight PIC & Mat. Damage				Darkness PIC & Mat. Damage				
Group	*Before*	*After*	*%Difference*	χ^2	*Before*	*After*	*%Difference*	χ^2	*No. of Junctions*
0*	62.5	45	-28		18	33	83		24
2	107	131	23	4.8**	26	24	-8	2.23	24

**Average over 16 months*

No Significant Difference

*** Chi sq. > 3.84 - result is significant at 5%. Confidence Interval 95% the result is correct*

Table 4 - Chi squared Analysis of Before/After Personal Injury Collisions.

Collision data records indicate that, between January 2014 and December 2016, there were 48 injury collisions on national roads involving a pole or post, and a further 23 recorded injury collisions involving a lighting pole.

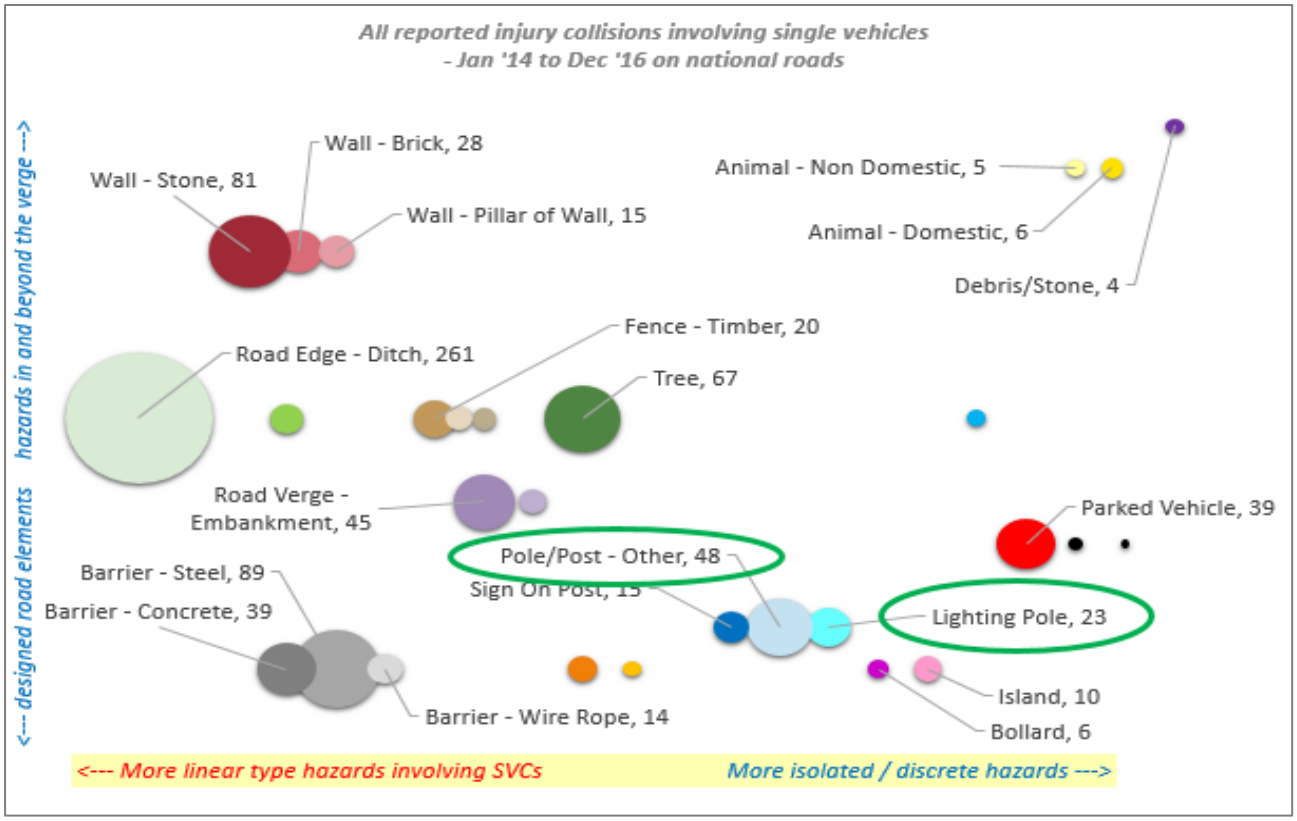


Figure 4 – Reported Single Vehicle Injury Collisions on National Roads (Jan 2014 – Dec 2016).

With regard to the overall approach to Road Safety in scheme development, TII operates on the principles of 'Forgiving Roadsides'. This approach entails providing a hazard free verge and roadside area which can allow errant drivers to regain control of their vehicles and safely bring their vehicle to a halt within the clear zone or to safely re-join the carriageway.

TII Standard DN-GEO-03036 states that '*the range of possible treatments to provide a more Forgiving Roadside has been categorised and should be implemented in order of preference as follows:*

> *1. Mitigation of hazards through the removal or relocation of any obstacle to provide an adequate clear zone width;*
>
> *2. Modifying road layout or roadside elements to provide a passive roadside where the removal or relocation of hazards cannot be reasonably achieved;*
>
> *3. Shielding obstacles through the use of a VRS where mitigation or modification measures cannot be reasonably implemented.*

A lighting column is considered a roadside hazard, which is a physical obstruction which may, in the event of an errant vehicle leaving the carriageway, cause harm to the occupants of the vehicle in the event of a collision. As such it is clear that removal of the lighting columns is the preferred option regarding providing a forgiving roadside and the opportunity to remove lighting columns following switch-off is another significant benefit of the scheme.

Pilot Scheme Safety Conclusions

The results of the pilot study indicate that there is no significant safety difference between the control sites and the treated sites. There was no significant change in the proportion of collisions occurring during the hours of darkness observed in the before and after data examined.

Furthermore, a comparison of the collision types at junctions with Small & Large lighting footprints, revealed that junctions with Small Footprint lighting (post-2007 Design) had less collisions involving a lighting pole. The predominant reason for this observation is that there are significantly fewer lighting poles located in the clear zone of the road thus removing the potential hazard. There are approximately 90 less poles in the Post-2007 design, i.e. approx. 130 poles Pre-2007 and 40 poles Post-2007, with the majority of these remaining poles being in a lower speed zone.

Limitations to this study include a small sample size of junctions to pilot the lighting switch-off as well as a lack of exposure data[4]. In addition, there was a shorter than anticipated after period of collision analysis due to the impacts of Covid-19.

However, TII Safety and Network Operations sections continue to monitor the performance of all junctions with no trends emerging which would contradict the analysis to date.

[4] Exposure data refers to traffic volume data. Any changes to traffic volumes were not part of the analysis.

7. Pilot Scheme Energy and Emissions Evaluation

Section 5 outlines that the results of the pilot study indicate that there is no significant safety difference between the control sites and treated sites, while the energy, emissions and cost savings benefits are found to be significant.

The energy, carbon intensity and costs of the lighting at the junctions was assessed for Pre-2007 and Post-2007 design standards. In the first year, there is a reduction of over 40,500 kg in carbon intensity (representing approx. 70 % reduction from previous level) and significantly reduced costs for each junction.

While the energy reductions (kWh) remain fixed, the costs and emissions information are based on 2018 / 2019 information. Costs are variable while electricity related emissions have been falling and so the carbon saving reduces year on year.

As an example of the benefits, analysis of the M6 Junctions 3 to 8 inclusive indicates a 45% energy reduction on lighting, and reduced carbon emissions of 167 tonnes for the six junctions.

Area	De-energised Units	Energy Saving, kWh	Cost Savings, € ex VAT	Carbon Savings, Tonnes CO2. (Based on 2018/2019 factors)	Junctions
Co. Westmeath (all)	***557***	***476997***	***€66,651***	*167*	***6***
M6 Junction 3	71	59449	€8,307	*21*	1
M6 Junction 4	73	51804	€7,239	*18*	1
M6 Junction 5	96	80792	€11,289	*28*	1
M6 Junction 6	121	103132	€14,411	*36*	1
M6 Junction 7	110	92736	€12,958	*32*	1
M6 Junction 8	86	89084	€12,448	*32*	1
Average per Junction	***93***	***79,499***	***€11,109***	*28*	-

Figure 5 – Year 1 energy, carbon, and cost benefits for M6 (Westmeath) junctions

For the whole pilot programme, across all 27 junctions, the estimated carbon reduction was circa 900 tonnes, and the cost reduction was approximately €300,000 ex VAT, for the first year.

Area	Energy Saving, kWh	Cost Savings, € ex VAT.	Carbon Savings, Tonnes CO2. (Based on 2018/19 factors)
All 27 Junctions, 1st year	**2.6m kWh**	**€370k**	**900 Tonnes**

Figure 6 – Year 1 energy, carbon, and cost benefits for all 27 junctions

The figures quoted are for the implementation year, but the energy, cost and emissions reductions continue to be avoided for each year since and will continue to do so for years to come. In addition to the energy, carbon reduction and associated energy cost savings, there are significant further advantages in the area of:

- Reduced maintenance and replacement costs for lighting assets
- Improved safety environment for both the road operatives and traffic due to the elimination of high-risk interventions on the live carriageway.

8. Conclusions

Modern lighting standards for motorway junctions specify significantly less lighting than was the case Pre-2007. Junctions procured after that time are constructed to the modern standard, whereas a significant cohort of Ireland's motorway junctions pre-date those changes. Those older junctions have what may be deemed to be surplus lighting when compared with those constructed to the Post-2007 design standards. TII conducted a two-phase pilot study to examine the effects of eliminating the surplus lighting at these junctions designed to the Pre-2007 standards.

The pilot study has concluded that the removal of surplus lighting at 27 No. motorway junctions has not resulted in a material reduction in safety performance during the hours of darkness when compared to the control data based on the before and after collision analysis study. The proportion of collisions occurring in the hours of darkness in the before and after period did not change.

Furthermore, the removal of a significant number of unprotected lighting columns from the clear zone at each junction will mitigate the potential for errant vehicles to hit a lighting pole at the 'treated sites'. There are additional occupational health and safety benefits for road operatives by eliminating work associated with unnecessary road infrastructure, associated work/operations/renewal risks, and reducing general maintenance at these junctions, and the time spent by maintenance operatives on the road. Lighting poles that are no longer lit should be removed for road safety as well as occupational health and safety reasons.

The switch-off of surplus lighting also ensures junctions are meeting the latest lighting design standards and will contribute to achieving consistency of lighting layout at all motorway junctions.

The environmental benefits of implementing the revised lighting design include substantial reductions in energy usage, associated carbon emissions and light pollution. In addition, there are significant benefits to fauna and biodiversity in general. Furthermore, if required, a portion of the energy that has been saved at these locations can be reallocated to locations where additional route lighting may be warranted. There is also an overall reduction in costs associated with road lighting.

TII's sustained commitment to the reduction of energy in road lighting is central to the success of TII's Strategy and to TII's Sustainability Implementation Plan (SIP) and makes an important contribution to national efforts on climate action, including the drive towards net-zero emissions. Achieving that contribution with no material change to safety performance is a considerable success.

9. Next Steps

The next steps are to continue with the 'Switch-Off Programme' and continue monitoring treated and control sites. There are approximately 28 further junctions or mainline sections with the potential for inclusion in the programme, the majority of which are on the Public Private Partnership (PPP) motorway network. Operational speed impacts will be investigated and monitored, and the policy of requiring new road markings and road studs associated with removal or switch-off of lighting columns will be continued.

Steps will also be taken by TII through its Motorway Maintenance and Renewal Contracts (MMaRC) and Public Private Partnership (PPP) contracts to remove all redundant lighting poles at junctions on a phased basis with priority being given to those locations where lighting poles are not protected by safety barrier. Further analysis of the achievements of carbon and energy reductions will also be continued as part of the programme.

Bonneagar Iompair Éireann
Transport Infrastructure Ireland

Ionad Ghnó Gheata na Páirce,
Stráid Gheata na Páirce
Baile Átha Cliath 8, Éire

Parkgate Business Centre,
Parkgate Street,
Dublin 8, Ireland

www.tii.ie

info@tii.ie

+353 (01) 646 3600

+353 (01) 646 3601