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CSS Street Lighting Project SL4/2007
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The use of passively safe signposts and lighting columns

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Transport Research Laboratory

PUBLISHED PROJECT REPORT PPR 342

The Use of Passively Safe Signposts and Lighting Columns

by G L Williams, J V Kennedy, J A Carroll and R Beesley (TRL)

Prepared for:	**Project Record:**	**SL4/07: The Use of Passively Safe Signposts and Lighting Columns**
	Client:	**The County Surveyors Society Lighting Group (CSSLG) et al. (represented by Ian Jones and Wilf Newall)**

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Foreword

In pursuing its goals of providing advice and guidance to lighting practitioners, the CSS Lighting Group, in partnership with the SCOTS, Transport Scotland, ILE, and TfL has commissioned five research projects to advance some major lighting issues.

Targets to improve road safety and reduce road casualties are encouraging highway engineers to consider many different aspects of highway design. The promotion of passively safe street furniture has highlighted a need to assemble impartial evidence which will support the considered decisions of highway professionals.

This research project is the fourth in the series, TRL were commissioned to undertake the work which was managed on behalf of CSS-LG by Ian Jones, Cheshire CC and Wilf Newall, Durham CC.

A summary of the recommendations can be found on page iii and CSS-LG do hope that the document proves to be valuable in assisting highway professionals and lighting engineers with their decisions.

Copies of this report can be downloaded at www.trl.co.uk/store

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Executive summary

The use of passively safe lighting columns and signposts is becoming increasingly common on both Highways Agency and local authority rural roads. They are particularly suitable where it would be difficult to use a safety barrier, or where the safety barrier itself could pose a hazard, for example at a nosing or on a roundabout splitter island. Passively safe signposts have, to date, mainly been constructed of aluminium although more recently, steel and fibre reinforced composite posts have also become available.

Passively safe lighting columns used in the UK are constructed of steel, aluminium or fibre glass and usually look similar to conventional columns. They have been used extensively in Scandinavia; for example, in Finland, Jokinen (2008A) reported that over 90% of lighting columns are passively safe, most being breakaway wooden posts or energy absorbing metal columns.

TRL has been commissioned by Transport for London (TfL) to investigate the use of passively safe lighting columns and signposts on local roads, the research being initiated by the CSS Street Lighting Group. This report seeks to develop an understanding of any changes in safety risk that might result from introducing passively safe lighting columns and signposts in such areas.

Current Standards and Literature

The current standards and literature pertaining to the use of passively safe signposts and lighting columns show that street lighting column designs which minimise the severity of injury to occupants of a vehicle colliding with them, have been considered important in the UK, since the early 1960s. Subsequently, research was directed towards developing passively safe lighting columns, particularly in the 1960s and 1970s. However, their use only became widespread once new materials became available in the late 1990s.

In 2000, a European Standard (BS EN 12767) was published, providing a means of testing and assessing the level of passive safety offered by road equipment support structures. The standard specifies performance requirements and defines levels, in passive safety terms, which are intended to reduce the severity of injury to the occupants of vehicles impacting with permanent road equipment support structures. Three energy absorption types are defined and test methods for determining the level of performance under defined test conditions and various speeds of impact are given.

National road authority advice documents in Norway and Finland are known to have incorporated the performance levels defined in this standard, using them to recommend when and where certain categories of passively safe signposts should be provided. The advice for Norway and Finland considers the use of passively safe support structures for road equipment on roads with speed limits as low as 50 kph. Such recommendations are supported by cost-effectiveness studies and accident investigations.

Current US design manuals support the use of breakaway signposts on all public roads. Whilst lighting columns are not necessarily subject to this recommendation, the Federal Highway Administration is encouraging the use of breakaway designs on roads with speed limits as low as 25 mph.

In the UK, such recommendations for implementation are outlined in the new UK National Annex to BS EN 12767. This advises that Category NE (non-energy absorbing) supports provide a lower risk of injury to vehicle occupants than HE or LE (high energy or low energy absorbing), and can be the most appropriate choice on non-built up roads with insignificant volumes of non-motorised users. Category LE and HE supports reduce the risk of secondary collisions and collisions with non-motorised users, as the vehicle exit speed is lower and thus, can have advantages on built-up roads where there is a significant volume of non-motorised users.

On the basis of speed limit and potential impact speeds, it therefore seems appropriate to consider the use of passively safe signposts and lighting columns on almost all roads in the UK. However, the potential risk of secondary injury to other road users from a falling support structure and therefore the particular design requirement for the post should be assessed and determined for each installation location.

Design Loading

Detailed calculation methods have been developed in European standards to determine the design loads required for lighting columns and signposts. These design loads account for dead loads due to the mass of supported structures as well as wind loads. The exact requirements vary depending on the particular installation. These strength requirements may pose a problem for low- and non-energy absorbing passively safe supports which often have an intrinsic fragility.

Passively safe lighting columns which are energy absorbing will have components that are designed to deform in some way to absorb that energy. The particular mode of deformation or fragility may have implications for safety aspects other than those referenced above. For instance the risk of electric shock, difficulties with electrical maintenance and the risk of structural failure due to reduced load-bearing potential. Requirements of existing lighting columns associated with these aspects have been reviewed alongside consideration of the behaviour expected from passively safe columns.

Electrical Requirements

The review of literature suggests that electrical disconnection times of either 5 or 0.4 seconds are required for lighting columns depending on the particular electrical configuration being used in the installation. After a collision between a vehicle and a passively safe lighting column, hazards may arise if the electrical connection is still live. Therefore the shorter (0.4 sec) disconnection time may be more appropriate in these applications.

The Electricity at Work regulations and the IEE wiring regulations contain requirements for the safety of lighting column installations. They also include requirements relating to continuing the use of columns, for example inspection and maintenance, and these requirements must be met by passively safe support structures as well as by conventional designs.

Injury Collisions Involving Signposts and Lighting Columns

Data was obtained from the Department for Transport’s STATS19 for injury collisions in which a lighting column or a signpost/traffic signal was struck by a vehicle between 2001 and 2006 (inclusive).

The findings were as follows:

- The number and severity of impacts with lighting columns is generally higher than those with signposts/traffic signals. This is likely to be due to the greater numbers of lighting columns, and the use of barriers to protect these structures on rural roads.
- Most of the collisions occurred as a result of an errant vehicle leaving the carriageway to the nearside, with a large proportion of the drivers being male and aged between 18 and 25.
- Casualties from such impacts (including drivers, passengers and pedestrians) are also generally aged between 18 and 25, with 83% of those injured being less than 45 years of age.

- The majority of casualties were car occupants; however a disproportionately high number of motorcyclists are injured within such collisions, the severity of such impacts being approximately seven times the average.
- A disproportionately high number of such collisions occurred at weekends, generally between 21:00 and 00:59 in the evening.
- The most common location for these impacts was on two lane single carriageway A roads and roads with a 30 mph speed limit.
- In general, collisions occurred in daylight or where there was street lighting, probably because most unprotected lighting columns and signposts are in urban areas. Road surface and weather conditions appeared to have little effect on the number and/or severity of collisions.

Risk Assessment of Passively Safe Lighting Columns and Signposts on Rural Roads

On rural roads, the risk per year of hitting a passively safe lighting column or signpost will be lower than that associated with a conventional lighting column or signpost protected with a barrier. However, the balance of risk will be different, with the lower risk for vehicle occupants hitting a passively safe signpost partially offset by a small probability that the lighting column or signpost could fall onto the carriageway and causing a secondary collision. For a conventional post, there is a high risk to the occupant of an errant vehicle which reaches the post but very little risk to other road users (the risk of secondary collisions from a vehicle rebounding from the post or protective barrier has not been considered here).

It should be noted that passively safe lighting columns and signposts on rural roads are likely to be hit more frequently because of the absence of a barrier. This could increase the number of collisions in which debris falls from a lighting column. However, in practice there are unlikely to be pedestrians in the vicinity of these structures on rural roads.

The UK National Annex to BS EN 12767 recommends the use of 100 NE (100 kph rated non-energy absorbing) signposts and lighting columns on rural roads unless there are significant numbers of non-motorised users at risk from items falling on other carriageways.

Risk Assessment of Passively Safe Lighting Columns and Signposts on Urban Roads

The risk to pedestrians is much greater in urban areas than in rural ones. Risk depends strongly on the numbers exposed and therefore passively safe lighting columns and signposts might not be appropriate where there are likely to be substantially high numbers of pedestrians on a regular basis.

Where speeds are very low, for example, in 20 mph zones, or on housing estates, there is little advantage in using passively safe signposts and lighting columns over the more conventional rigid designs.

Passively safe lighting columns should be used on major roads where there is little likelihood of their falling onto the carriageway or of substantial numbers of pedestrians being in the vicinity. Since most of the run-off collisions occur at night, the latter will not be an issue in many locations. The errant vehicle itself will often pose the greatest risk to pedestrians.

The UK National Annex to BS EN 12767 recommends the use of 70 LE or HE (70 kph rated low or high energy absorbing) lighting columns in urban areas, and 70 LE for signposts.

Recommendations

It is recommended that passively safe lighting columns continue to be used in accordance with the National Annex to BS EN 12767. In particular, they should be used in most situations on rural roads, especially where it is difficult to use a safety barrier. They are less necessary where there is an existing barrier (or a need for one), or where there is a building or hard landscaping close to the carriageway. Passively safe systems with a shear base design should only be used where any impact will be at the correct height for the base to work correctly and if the ground conditions around the base are such that the column will perform as designed. The design requirement should be assessed on a site-by-site basis.

The risk to pedestrians depends strongly on the numbers exposed and therefore the recommendations in the current standard that passively safe lighting columns and signposts may not be appropriate where there are likely to be substantial numbers of pedestrians on a regular basis should be retained. In these circumstances, the safety of pedestrians might need to be considered separately as the risk of an errant vehicle may be greater than that from a falling lighting column or signpost.

Where speeds are low, for example, in 20 mph zones, or on housing estates, there is little if any advantage in using passively signposts and lighting columns.

Passively safe lighting columns should be used on major urban roads where there is little likelihood of their falling onto the carriageway or where there might be pedestrians. Since most of the run-off collisions occur at night, the latter will not be an issue in many locations.

1 Introduction

The use of passively safe lighting columns and signposts is becoming increasingly common on both Highways Agency and local authority rural roads. They are particularly suitable where it would be difficult to use a safety barrier, or where the safety barrier itself could pose a hazard, for example at a nosing or on a roundabout splitter island.

Passively safe signposts have, to date, mainly been constructed of aluminium (see Figure 1) although more recently, steel and fibre reinforced composite posts have also become available.

Passively safe lighting columns used in the UK are constructed of steel, aluminium or composite and usually look similar to conventional lighting columns (see Figure 2). They have been used extensively in Scandinavia; for example, in Finland, Jokinen (2008A) reported that over 90% of lighting columns are passively safe, most being breakaway wooden poles or energy absorbing steel columns.

Figure 1: Passively safe signpost

(Photo courtesy of 3M)

Figure 2: Passively safe lighting column

TRL has been commissioned by Transport for London (TfL) to investigate the use of passively safe lighting columns and signposts on local roads. The research was initiated by a consortium comprising The County Surveyors Society Lighting Group (CSSLG), The United Kingdom Lighting Board (UKLB), The Society of Chief Officer of Transportation in Scotland (SCOTS), the Highways Agency (HA) and Transport for London (TfL). The objective of the project was to develop and provide practical advice to Highway Authorities for determining the effectiveness of passively safe signposts and lighting columns, and advise on their use in different locations and situations.

The project has involved a review of international standards and literature, an analysis of collisions with lighting columns and signposts, and a risk assessment of the use of passively safe lighting columns on different road types. A Workshop with various stakeholders was also held in February 2008 to inform the process.

Risk assessment is an essential extension of collision analysis and safety audit techniques. It enables a more transparent assessment of the relative risk between options and provides a sound basis for investment decisions. It relies on a comprehensive assessment of potential hazards and their consequences in order to assess risk. In highway work, this usually involves a combination of collision knowledge, good understanding of the operational and structural performance of different designs, and professional judgement drawn from the experience of those working in the relevant environment. The risk assessment in this report follows the general principles set out by TRL in the Risk Assessment Framework for Highways Agency roads that culminated in the Road Restraint Risk Assessment Process (RRRAP) software that is part of the Road Restraint Standard TD 19/06 (DMRB Section 2.2.8).

The risk from a roadside object results from two main components:

- Probability of an errant vehicle reaching the object (which depends on the offset of the object and the speed of leaving the road);
- Consequences of doing so (which depend on the "aggressiveness" of the object and the speed at which it was hit).

On major rural roads, safety barriers have traditionally been used to reduce the likelihood of serious injury resulting from an errant vehicle hitting the posts supporting large signs. The advantages of passively safe lighting columns and signposts over the conventional rigid designs are that:

- They are much less likely to lead to serious injury for the occupants of the impacting vehicle;
- They are easier to replace if hit by an errant vehicle;
- They do not require a safety barrier.

However, the collapse of a lighting column or signpost might be expected to lead to debris which will potentially introduce risk to other road users and for pedestrians in the vicinity. If the debris lands on the carriageway, an important factor is how drivers react to it, what the traffic flow is, and how easily the debris can be seen, for example at night. However it should be noted that there is no evidence of debris on the carriageway causing problems in countries with large numbers of passively safe lighting columns and signposts.

On urban roads, lighting columns and signposts will not normally be protected by a length of safety barrier, potentially increasing the likelihood of them being hit. However, the lower speeds and the fact that drivers are less likely to be affected by fatigue than on rural roads will mitigate this risk. The consequences of hitting these objects on urban roads are also likely to be lower, because of the lower speeds. On the other hand, it is more likely that there will be pedestrians or cyclists in the vicinity who would be at risk from falling debris (and also from the errant vehicle itself).

In this report, Section 2 summarises the requirements of current standards for passively safe structures. Section 3 describes the results of the literature review. Section 4 presents collision statistics, Section 5 outlines a cost benefit analysis, whilst Section 6 presents a risk assessment of passively safe structures, compared to more conventional designs.

2 Impact Safety Performance

2.1 Review of Current Standards

2.1.1 BS EN 12767:2007

Passive safety of support structures for road equipment – Requirements and test methods

The European Standard BS EN 12767 specifies performance requirements for passively safe support structures for permanent road equipment and both defines and limits the levels of occupant injury severity when impacting these structures. Consideration is also given to other road users and to pedestrians. It is intended to provide a common basis for the testing of vehicle impacts with items of road equipment support structures so that test data and research can be used to improve future specifications, including a review of impact severity levels and the method of specifying impact severity.

The 2007 issue of the standard supersedes the original version released in 2000 (BS EN 12767:2000).

Test methods for determining the level of performance under various conditions of impact are given for three categories of passive safety support structures:

- High energy absorbing (HE);
- Low energy absorbing (LE);
- Non-energy absorbing (NE).

High energy absorbing support structures slow the vehicle considerably on impact and thus the risk of secondary collisions with trees, pedestrians and other road users is reduced, however the severity of the impact for vehicle occupants can be high. Non-energy absorbing support structures permit the vehicle to continue after the impact with a limited reduction in speed. They may therefore provide a lower primary injury risk than energy absorbing support structures, but a higher secondary injury risk if other hazards exist behind the support structure. Low energy supports are generally designed to yield in front of and under the impacting vehicle, before shearing or detaching towards the end of the impact event.

Two impact tests are required by BS EN 12767, one at 35 kph to ensure satisfactory functioning of the support structure at low speed, and a second at the class impact speed (50, 70 or 100 kph). All tests are conducted with a small (900kg) vehicle whose frontal stiffness has been calibrated through a head-on, frontal impact with a rigid pole of a specified diameter.

The occupant safety level is based on ASI (Acceleration Severity Index) and THIV (Theoretical Head Impact Velocity) results. The means of calculating these parameters is reported in a supporting standard, BS EN 1317-1. There are four levels of occupant safety. Levels 1, 2 and 3 provide increasing levels of safety in that order by reducing impact severity. Level 4 consists of very safe support structures (small structures expected to cause only minor damage or retardation of the vehicle), classified as such by means of a simplified test, at the class impact speed.

The standard also defines support structures with no performance requirements for passive safety as Class 0. All other structures require testing to determine their performance type. For each tested support structure, the performance type is expressed in terms of speed class, energy absorption category and occupant safety level, as shown in Table 1.

Table 1: Performance types from BS EN 12767:2000 (CEN, 2000)

	Alternatives
Speed class	50, 70 or 100
Energy absorption category	HE, LE or NE
Occupant safety level	1, 2, 3 or 4

In addition the Standard also contains general requirements pertaining to occupant safety. These are that:

- The test item shall behave in a manner predicted by the manufacturer;
- The test item or detached elements, fragments or other major debris from the test item shall not penetrate the occupant compartment or present an unnecessary hazard to other traffic, pedestrians, or personnel in a work zone;
- The vehicle shall remain upright for not less than 12 m beyond the impact point with a roll angle less than 45° and a pitch angle less than 45°.

The Standard contains other useful information for specifying the tests to be conducted, e.g. details of the test site and test vehicle, specification for the test to calibrate the test vehicle, test item installation, position of the impact point and impact angle, test data to be recorded, etc.

2.1.2 HA TA 89/05

Use of passively safe signposts, lighting columns and traffic signal posts to BS EN 12767

This Technical Advice Note (TA) from the Highways Agency gives guidance on the use of passively safe signposts, lighting columns and traffic signal posts to reduce risk of personal injury if errant vehicles strike such objects, i.e. once the performance class of the system has been established through the BS EN 12767 testing, the TA recommends the class most applicable for particular locations. According to the TA, there structures are an appropriate solution for roads with speed limits of 50 mph or more (and for lower speed limit locations where safety barrier protection would be inappropriate). The document provides designers and highway maintenance organisations with advice on:

(i) Where passively safe signposts, lighting columns and traffic signal posts may be used;

(ii) Selection of appropriate post or column types to BS EN 12767;

(iii) Size limits for tubular steel or aluminium posts without safety barrier provision;

(iv) Designing for wind loading;

(v) Foundation requirements;

(vi) Specification of signposts, lighting columns and traffic signal posts to BS EN 12767;

(vii) Sign face requirements;

(viii) Specification of lighting columns to BS EN 40;

(ix) Specification for traffic signal posts.

The TA describes conditions where the use of safety barriers may be difficult and therefore passively safe supports should be used:

- If there are services in the verge where the safety barrier posts would be located;
- Roundabouts where there is not enough room for full safety barrier provision;
- Locations where safety fences or signposts have been hit in the past (some types of passively safe posts are easier to replace than barriers);
- Nosing and splitter islands where safety fence end ramps may be a hazard or safety fences difficult to install;
- Where verge width is inadequate for both a support structure and a safety barrier;
- As a preferred solution where impacts are likely at 90 degrees to a safety fence guarding a traffic light or where safety fences cannot be provided for all the anticipated traffic movements.

The TA provides advice on the use of passively safe structures for urban areas as well as motorways, dual carriageways and rural single carriageway roads. It states that NE signposts and lighting columns are designed to shear or fail at the base. This allows them to fall a short distance from the foundation or over the roof of a vehicle, making them inadvisable in areas with regular or significant use by non-motorised users. LE lighting columns should be used at roundabouts and junctions in urban areas and at locations in rural areas frequented by non-motorised users. Signposts that are either LE or HE should be used in urban areas or at locations frequently used by non-motorised users. Lighting columns that comply with NE Category requirements at 100 kph and with LE Category requirements at 70 kph provide an acceptable solution for all locations.

Two TRL reports (Savin, 2002 and 2003) provided the background research supporting the TA.

The first of these reports (Savin, 2002) provides an explanation of the requirements of BS EN 12767 together with consideration of other pertinent standards. It also contains a review of UK experience with non-energy absorbing masts and advice from other European governments. It was concluded that NE masts meeting the requirements of BS EN 12767 are suitable for deployment in the verge as supports for large signs on parts of the UK road network which are unlikely to be occupied by pedestrians or cyclists. Savin did not consider NE masts to be suitable for the central reserve as a strike could cause the unrestrained mast to fall into an adjacent carriageway causing a potential hazard to other road users. This was taken into the advice given in TA 89/05.

The second report (Savin, 2003) reviews different designs of steel circular hollow section signposts. The aim of the research was to determine the largest size of single steel signpost that can be installed without the need for a protective safety fence. The two sizes investigated were 88.9 mm diameter with a 4 mm wall thickness and 114.3 mm diameter with a 5 mm wall thickness.

These tests are illustrated in Figures 3 and 4. In the test with the smaller signpost, the impact caused major damage to the front of the vehicle. There was minor vehicle body intrusion into the occupant footwell although this would be unlikely to cause injury. The sign became detached from the signpost but was substantially undamaged. The signpost was bent to the ground and flattened as the vehicle passed over it. This post was considered to meet the high speed test acceptance criteria for the Non Energy (NE) absorbing category, when assessed against the requirements of BS EN 12767.

Figure 3: Testing of 88.9 mm diameter conventional signpost at 100 kph

In the test with the larger post, the impact vehicle passed over the signpost but there was approximately 400mm of intrusion into the occupant footwell which would be likely to cause injury. The rear of the vehicle was pitched into the air and landed heavily. The vehicle continued and spun around to face the direction from which it had come before coming to rest (approximately 17 m beyond the signpost). The post was considered *unsatisfactory* when assessed against BS EN 12767.

Figure 4: Testing of 114.3 mm diameter conventional signpost at 100 kph

It was concluded that the smaller size of sign post only just met the expected requirements and therefore only posts with a smaller wall thickness should be used on the Highways Agency road network without protective safety fencing. This was incorporated into TA 89/05 and the HA's Road Restraint Standard Technical Document (TD) 19/06.

Additional testing of passively safe signposts has also been undertaken during various demonstration events at the Motor Industry Research Association (MIRA). These are described on the Passive Revolution website (Passive Revolution, 2008) (www.thepassiverevolution.com). An example is shown in Figure 5. This vehicle deformation was witnessed following a 100 kph test with a passively safe composite post manufactured by 3M.

(Photo courtesy of 3M)

Figure 5: Vehicle following test at 100kph with a passively safe composite post

2.1.3 BS EN 12767:2007 National Annex (NA)

The Highways Agency has now withdrawn TA 89/05 in favour of the recently published and updated BS EN 12767 and the new UK National Annex to this standard. The National Annex provides the UK's recommendations for passively safe support structures for road equipment.

The National Annex starts by explaining that it is the responsibility of the purchaser to specify which performance class is required. If a class is not given but the requirement to meet BS EN 12767 is specified, then manufacturers may supply Class 0: a support structure with no performance requirements. This may not be suitable in all instances, as the products will not have been tested to determine that they are passively safe and hence an emphasis on designers to specify their requirements for passively safe structures.

The recommended speed classes for different situations follow those given in HA TA 89/05 and are shown in Table 2.

Table 2: Recommended speed classes (BS EN 12767:2007 NA)

Situation of use	Speed class (kph)
Non-built up all-purpose roads and motorways with speed limits >40 mph	100
Built up roads and other roads with speed limit ≤40 mph	70

The National Annex provides the same advice as TA 89/05 regarding the use of the different energy absorption class support structures. The National Annex notes that the exit speed is measured some distance after the impact point (12 m), and this can still be significant with LE and HE supports. This should be borne in mind when locating such devices as the risk of a secondary impact should be considered. As a result, the National Annex requires that users should carry out a risk assessment to determine the appropriate category for a given situation although no prescribed format for this is given. It continues by giving recommended energy absorption categories for signposts, traffic signal supports and lighting columns. These recommendations are summarised in Table 3, where the type of support structure column shows the speed class, the energy absorption category and the occupant safety level.

Table 3: Summary of performance class recommendations from BS EN 12767:2007 NA

Situation	Location	Type of support structure		
		Lighting column	Sign or signal support	Non-harmful support structures
Non-built up all-purpose roads and motorways with speed limits > 40 mph	Generally in verges of motorways, dual carriageways and single carriageway roads	100:NE:1-3	100:NE:1-3	100:NE:4
	With significant volume of non-motorised users	100:LE:1-3 or 100:HE:1-3	100:LE:1-3	100:NE:4
	Where major risk of items falling on other carriageways	100:LE:1-3 or 100:HE:1-3	100:LE:1-3	100:NE:4 or 70:NE:4
Built up roads and other roads with speed limits ≤40 mph	All locations	70:LE:1-3 or 70:HE:1-3	70:LE:1-3	100:NE:4 or 70:NE:4

The National Annex also gives advice regarding:

- Roof deformation;
- Structural requirements;
- Traffic signpost spacing and recommendations;
- Sign plate recommendations;

- Gantry sign supports;
- Foundations;
- Underground electrical connections.

2.1.4 Summary

The European Standard BS EN 12767:2007 specifies performance requirements and defines levels for the severity of injury to the occupants of vehicles impacting with permanent road equipment support structures. Three energy absorption types are defined and test methods for determining the level of performance under set conditions and various speeds of impact are given.

The Highways Agency Technical Advice Note HA TA 89/05 gives guidance on the use of passively safe signposts, lighting columns and traffic signal posts to reduce the risk of personal injury if errant vehicles strike such objects. The advice includes recommendations for the selection of appropriate post or column types as assessed against the requirements of BS EN 12767:2007. It also includes additional advice for the designers and highway maintenance organisations that may use such passively safe support structures.

However the Highways Agency has now withdrawn TA 89/05 in favour of the recently published and updated BS EN 12767 and the new UK National Annex to this standard. The National Annex provides the same advice as HA TA 89/05 regarding the use of the different energy absorption class support structures. This is that Category NE (non-energy absorbing) supports provide a lower risk of injury to vehicle occupants than HE or LE (high energy or low energy absorbing), and can be the most appropriate choice on non-built up roads with insignificant volumes of non-motorised users. Category LE and HE supports reduce the risk of secondary collisions and collision with non-motorised users, as the vehicle exit speed is lower, and thus can have advantages on built-up roads where there is a significant volume of non-motorised users.

2.2 Review of Passive Safety

2.2.1 Impacts with roadside objects

The risk to errant vehicles from roadside objects has been discussed by a large number of authors (see for example Lynam and Kennedy, 2004). Mitigation measures are:

- Reducing the speed of vehicles hitting the object;
- Moving the object further from the road;
- Using a safety barrier in front of the object;
- Reducing the consequences of hitting the object.

Reducing the speed of vehicles might be achieved by a local reduction of the speed limit, for example on a bend, or by changing the local topography between the road and the object although this is unlikely to be useful as a global solution. Whilst the benefits of a 9 m clear zone at the side of the road are recognised, moving the object further from the road can have only a small benefit for lighting columns or signposts if they are to fulfil their function. Scope for reducing the numbers of signposts and lighting columns also appears to be limited.

The main option for mitigating risk to errant vehicles is therefore to reduce the consequences of an impact by using a barrier or by making the object passively safe.

2.2.2 UK Experience

Unpublished research at TRL during the 1960s into street lighting columns appears to be the first time that the notion of designing columns to minimise the injuries to the occupants of a vehicle colliding with it was considered.

Based on the testing of conventional concrete and steel columns, it was found that occupants of light cars colliding head on at speeds of 20 mph or greater are likely to suffer severe injuries. Further work reviewed the performance of installing columns in soft verges which allow the column to fall upon impact, and flexible columns. It was concluded that neither solution alone was capable of reducing the severity of a collision with a vehicle, and the potential "head impact" velocity of errant vehicle occupants to acceptable levels.

Further work involved testing 25 ft street lighting columns with a frangible shear bolt joint incorporated into their design. The impact speed was again chosen to be 20 mph. The results were encouraging in that the impact severity was less than 40% of that with the unmodified steel column design. However, it was recognised that a check was needed to confirm that they had not decreased the strength of the column too much for standard operational loading from the wind.

In an extension to this work, Hignett (1967) tested a 40 ft tubular steel column with the same design of break-away bolt joint at approximately 60 mph. In this case Hignett found that the impact would have resulted in an occupant deceleration so slight that it is unlikely they would have sustained injury. This was a vast improvement over the conventional column design. The column fell behind the car, not on top of it as in a low speed collision, which led Hignett to conclude that a lighter column would be advisable for lower velocity collisions.

Following this work, a series of small scale pilot public installations of breakaway tubular steel columns was undertaken (Walker, 1974). The numbers of personal injury and damage-only collisions occurring at these sites were compared with the figures expected on a normal trunk road installation. Walker discovered that the cost of the collisions with the breakaway columns was about one-fifth lower than with the normal installation. This suggested that breakaway designs would be cost-effective at similar sites.

Subsequently Moore (1976) reported on some of the advances made in breakaway column design during the early 1970s. He identified that more than half of the lighting column collisions at the time occurred on A-class roads, most on sections with a 30 or 40 mph speed limit. This showed that column collisions are not just a high speed phenomenon, although Moore also pointed out that the chance of being killed if involved in such a collision does increase on higher speed roads.

Moore then discusses the effectiveness of a breakaway design developed at Cambridge University, noting that it had received only limited endorsement by the lighting authorities in the UK. Moore suggests that this is because of concerns that the column will fall into the road after being struck, which is unlikely to be the case as long as it is not installed in the median of a dual carriageway.

In addition, Moore cites another difficulty with breakaway designs as being the possible injury to pedestrians from a falling column, but states that "No-one has suggested using breakaway columns in city centres thronged with pedestrians." Instead Moore suggests that there are hundreds of miles of roads where at all times of the day there are more lighting columns to be seen than pedestrians and that it is in these places that breakaway lamp columns should be used.

This early work does not appear to have been developed further until the last 10 years when more modern materials have increasingly became available and momentum for their use has gathered following the work of Andy Pledge who set up the Passive Revolution website, www.thepassiverevolution.com. This website cites examples of real world impacts with passively safe signposts in the UK:

- In March 2006 collision with a signpost on the slip road from the A182 Washington Highway to the A193 Western Highway. The report quotes a spokeswoman for Sunderland Council: "Without doubt the new signs have already proved their worth."
- A second example involved a collision with a post installed at a junction with the A92 near Perth. It is reported that the driver was able to drive away from the collision, with the assumption that he or she, and any passenger(s) were relatively uninjured as a result.

Another example of a real world impact was supplied by Newall (2008) as shown in Figure 6. A vehicle impacted a lighting column at approximately 10 mph on the West Auckland Bypass in County Durham. The column was a Low Energy absorbing type, with an underground electrical supply box, fitted with a pull-out plug disconnection arrangement.

Figure 6: Category LE lighting column struck in Durham

For comparison purposes, Figure 7 shows a conventional lighting column which collapsed following an impact by a car, although the impact conditions are unknown.

Figure 7: Collapse of conventional lighting column following impact

2.2.3 Swedish Experience

Over many years, VTI (the Swedish national road and transport research institute) has carried out collision tests on safety equipment for the traffic environment (Wenäll, 1995). National approval tests to the requirements of BS EN 12767 have been performed by VTI on lighting columns and other roadside structures with various designs and functions. From 1994, however, the Swedish National Road Authority road design documents incorporated international rules and requirements. Wenäll comments that less dangerous lighting columns were being installed on almost all new roads in Sweden at that time.

A further report from VTI reported on collisions with lighting columns and other hard roadside objects (Nilsson and Wenäll, 1997). The authors recommended that rigid steel posts should gradually be exchanged for deformable and energy absorbing posts when installing new road lighting.

A translation of sections from more recent Swedish Road Administration (SRA) road design guidelines (SRA, 2004) provides an insight into the current attitude of the SRA towards passively safe road equipment. According to the translated text, "Road equipment placed within the clear zone (the defined safety-critical region around the road) and not being protected by safety barriers shall be passively safe and must not be penetrating." The SRA consider road equipment as being passively safe if it fulfils the criteria necessary for safety level 1 for the chosen speed class according to BS EN 12767. Road equipment is regarded as being harmless from a traffic safety point of view if the criteria for occupant safety level 4, for speed class 50, are fulfilled. These requirements for passive safety apply mainly to support structures, e.g. lighting columns and signposts.

Regarding the choice of support, the guidelines make the following points:

- To avoid climbing, posts with an open structure should not be used in the vicinity of places where children dwell e.g. at bus stops for school buses;
- When choosing the type of post to be used, estimated maintenance costs should be taken into account, as well as the expected need for maintenance work. At places where parking of maintenance vehicles demands special protection e.g. along motorways and other roads with median barriers, posts with a low estimated maintenance frequency should be chosen;
- The probability of hitting a post from behind should be taken into account, e.g. on two lane roads. For placements in the centre of crossings, posts that are omni-directionally passively safe should be chosen;
- Posts with slip-bases should not be used where it is likely that an errant vehicle could hit the post at a higher level than for which it was designed. Otherwise it is possible that the slip-base will not function in the intended manner;
- Mounting of large signs on several smaller supports instead of one large support can increase safety.

The Swedish Road Administration guidelines also make the following key points regarding the speed class ratings of passively safe posts:

- Posts fulfilling demands for Speed Class 100 can be used on all kinds of roads;
- Posts fulfilling demands for Speed Class 70 can be used on roads with speed limits of 70 kph or lower;
- Posts fulfilling demands for Speed Class 50 should not be used, accounting for the fact that serious collisions in environments with a 50 kph speed limit often occur with vehicles travelling at higher speeds.

2.2.4 Finnish Experience

Passively safe lighting columns are in widespread used within Finland, and almost all are manufactured from steel (Lehtonen, 2008A).

The Finnish National Road Administration conducted a survey on the number of fatal collisions during 1983-1986 on information from the Finnish Traffic Accident Investigation Boards (Finnish National Road Administration, 1991). One of the topics studied was the number of safety barrier, lighting and other columns and structures, and the number of collisions involving these structures. The Finnish National Road Administration compared the costs arising from these collisions, with the construction costs associated with rigid and breakaway columns. They concluded that replacing old rigid columns with breakaway columns was often cost-effective. The investment could be covered by collision cost savings in four years, if the traffic was heavy.

On request, the Finnish Road Administration (Lehtonen, 2008B) provided details of the latest Finnish practice on roads. The Finnish municipalities do not use passively safe columns as often as the Finnish Road Administration, although it has been shown in a study that their use is cost-effective on main roads. Lehtonen acknowledged that actual speeds higher than 50 kph are common on main roads, even though they might be signed as 50 kph.

A Finnra Engineering News document provides details of the classes of support structures advised for use by the Finnish Road Administration (2005). According to this document;

- Products of the classes HE:100:3, LE:100:3 and NE:100:2-3 may be used on all roads;
- Products of the classes HE:70:3, LE:70:3 and NE:70:2-3 may be used on roads with a speed limit of 80 kph or less;
- When a signpost is located between a road and a pedestrian and/or bicycle path, then a structure of the classes HE or LE should be considered.

If support structures of vertical signs are available that meet these requirements, then they are classified as being Category 'A'. The Finnish Road Administration require Category A structures on roads with high traffic volume, unless alternative structures can be placed far enough from the road or behind a barrier with sufficient length.

On roads with little traffic or a low speed level (under 1500 vehicles per day or a speed limit less than 50 kph), borderline structures that do not meet all the requirements of Category A can be used. In such circumstances, the supports are classed as Category 'B'.

A third Category 'C' exists for "dangerous structures". The Finnish Road Administration does not recommend the use of such structures, although there is a caveat saying that, "very large signs shall be located behind a safety barrier since it is difficult to find passively safe supports with sufficient strength."

2.2.5 Norwegian Experience

Savin (2002) provides key points taken from a letter sent by the Norwegian Ministry of Transport to their local offices providing advice on the use of non-energy absorbing supports:

- The use of energy absorbing masts was made mandatory for lighting, signposts and other equipment, where the speed limit exceeds 60 kph or if the masts are not protected from being hit by a barrier or by other means;
- Energy absorbing masts should also be used on main roads and streets with a speed limit of 50 kph and if masts are situated less than 2 m from the road;

- The mast will not need to be energy absorbing if situated next to a house wall or other large fixed object;
- HE lighting masts and LE signposts, signal and other masts (less than 6m high) should be used:

  a) where it is particularly important to slow down and stop uncontrolled vehicles, because there is a risk that they can continue on to further dangerous obstacles such as bridges, rock faces and other projections.

  b) in built-up areas and other places where there are many pedestrians and/or cyclists who could be injured by an uncontrolled vehicle.

  c) on wide central reserves, such that a mast will not fall into the path of an oncoming vehicle.

  d) in areas between a road and a well-used cycle or pedestrian path, where the speed limit is greater than 60 kph and the road bendy.

  Generally, these types of masts will normally be used where the speed limit is 60 kph, energy absorption is required at 50 kph and on wide central reserves on motorways;
- These requirements are to be met on all national roads. They will also apply for county roads should the local authority not have their own requirements. The requirements are also recommended for borough roads.

2.2.6 European Experience

One of the deliverables from the European Commission Project RISER (Roadside Infrastructure for Safer European Roads) gives guidelines for roadside infrastructure on new and existing roads (RISER Consortium, 2005). This document states that man-made features in the roadside safety zone should only be there because of a functional requirement. The guidelines go on to suggest that where there is a functional requirement for a man-made feature, the hazard should be modified. "For lighting and utility columns, energy absorbing and break-away structures are important structures to incorporate in the roadside area." Throughout the document, modification of support structure hazards through the use of energy absorbing or breakaway structures is suggested; however, the document only specifies that these items should be tested to BS EN 12767. The document does not provide detailed information on exactly which situations require energy absorbing or breakaway support structures. Instead the use of such structures is recommended as a means of protection for specific point structures.

2.2.7 US Experience

Considerable research has been undertaken in the US regarding utility poles including lighting columns, covering both urban and rural roads, mostly the latter (e.g. Zegeer and Parker, 1984, Marquis, 2001). Breakaway columns have been in use for many years on high speed roads.

According to Artimovich (2008), the 2000 edition of the Manual on Uniform Traffic Control Devices extended the requirement for breakaway signposts to include all public roads in the United States. There are no similar requirements to use breakaway lighting columns on all roads. Most State Departments of Transportation routinely use breakaway structures on their major roads and also on many minor roads, even when they are not required by federal or national policy. Older highway/street design documents recognised that the presence of pedestrians led to designers avoiding the use of breakaway supports, perhaps with the notion that the errant vehicle should be brought to a halt before further damage was done. Artimovich states that breakaway structures are rarely used for traffic signals in the US.

The idea of a falling signpost or lighting column was also contributed to the authors by Sicking (2008). Artimovich suggests that the Federal Highway Administration is trying to change that mindset, noting that pedestrians are generally present during daylight hours whereas most run-off road collisions are night time events. He says that the recommendation now is that an engineering study is carried out before deciding whether or not to use non-breakaway structures.

Sicking (2008) adds that the only other exceptions to the use of breakaway structures, that he is aware of, is for low speed roads with speed limits of about 25 mph. Vehicles are considered to provide sufficient safety for their occupants, even with a rigid pole. Therefore some states take the position that stopping the car travelling on a pavement will be less dangerous than letting the vehicle continue on into a house or a commercial building.

Ross *et al.* in National Cooperative Highway Research Program Report NCHRP 350 (1993) report on test specifications for breakaway posts.

2.2.8 Summary

Since the early 1960s, street lighting column designs which minimise the injuries to occupants of a vehicle colliding with them have been considered important in the UK and throughout the world. Some obvious solutions to the problem of vehicle collisions with lighting columns were suggested around this time, such as reducing the number of columns or moving them further from the carriageway. In addition, research began on developing passively safe lighting columns. However, the use of such passively safe structures did not meet with general acceptance until much later.

By 1997, a report from the VTI in Sweden was published recommending the gradual exchange of rigid steel columns for deformable and energy-absorbing columns when installing new road lighting. Similar advice has since been issued in Norway and Finland. The advice includes recommendations for passively safe structures to be used on main roads and streets with a speed limit of 50 kph or more. Such recommendations are also supported in the US.

On the basis of potential impact speeds, it therefore seems appropriate to consider the use of passively safe signposts and lighting columns on almost all roads in the UK. However, the potential risk of secondary injury to other road users from the continued motion of the vehicle or from a falling support structure, and therefore the particular design requirement for the post should be assessed and determined on a site-specific basis. The potential for vehicles to have collisions at speeds in excess of the posted speed limit also needs to be assessed when deciding on the speed class performance of a passively safe structure.

3 Functional and Other Safety Requirements

Passively safe lighting columns which are energy absorbing to some extent will have components that are designed to deform in some way to absorb the impact energy. In the case of Low and High energy absorbing columns (as defined in BS EN 12767), this is likely to be brought about through the controlled deformation of the column itself. In non-energy absorbing columns it is more likely that a breakaway hinge or mounting is incorporated in the design. The particular mode of deformation or fragility may have implications for safety aspects other than those outlined above, for instance:

- Risk of electric shock;
- Difficulties with electrical maintenance;
- Risk of structural failure due to reduced load-bearing potential.

Requirements of existing lighting columns associated with these aspects are reviewed in the following sections alongside consideration of the behaviour expected from passively safe columns.

3.1 Disconnection / Isolation of Supply

With conventional lighting columns it may have been considered unlikely for the columns to be completely severed as a result of a vehicle impact. Therefore, the risk of exposing electrical connections was likely to be low. Despite this, general electrical design guidance on electrical disconnection to prevent electric shocks is summarised below. This is equally applicable to both passively safe and conventional lighting columns.

3.1.1 HA TA 89/05

Use of passively safe signposts, lighting columns and traffic signal posts to BS EN 12767

In addition to the performance and installation guidance outlined previously, this Highways Agency document also gives guidance on the electrical safety requirements for passively safe lighting columns. The TA requires that when passively safe signposts or lighting columns contain power supply cables, for any purpose, the electrical safety of the installation should be maintained at all times, and under all conditions. This includes instances when the post or column has been impacted by a vehicle.

As a result, it is generally necessary for the scheme designer to undertake a risk assessment to ensure the electrical safety of the project. For example, if the disconnection is below ground level the designer should be satisfied that the column will not be tethered during an impact, that the supplier has provided evidence of this, and that the risk of any broken live cables have been considered.

Two possible methods for achieving these requirements are outlined by the TA:

- Pull-out plug (or an equivalent) near the base of the post or column
- Circuit breaker to limit the power supply circuit loop impedance.

An alternative, or addition, to a circuit breaker is to use an impact sensor (such as a tilt switch or an inertia sensor).

The method employed will depend on the post or column type (solid or open), the material from which it is manufactured (aluminium, steel or fibre-reinforced composite), and whether the device is designed to breakaway when impacted. The supplier or contractor will also need to provide evidence that the post complies with BS EN 12767 when tested with the proposed cable arrangement.

3.1.2 Pull-out plugs (or an equivalent arrangement)

Plug and socket devices should be located near the base of the post or column to ensure that, should the signpost or lighting column shear on impact, it is not tethered in any way by a live electricity supply cable, and that it does not result in exposed live conductors due to a torn and/or damaged cable. The arrangement used must address vandalism, electrical safety, reliability and weather resistance when in service, electrical safety in vehicle accidents, and retention of pull-out/separation capability over the life of the signpost, lighting column or traffic signal post. A practical method of inspecting the installed pull-out plug must also be possible. In addition, the pull-out plug must comply with the requirements of BS EN 60309-1 and BS EN 60309-2.

Furthermore, the TA states that where a pull-out plug is used on a post with an open design, the interface with the cable network and the fused cut-out may need to be housed in an underground chamber. In such circumstances, the design of the chamber must include a suitable method for the free drainage of water from the chamber. If used, underground cut-outs and cable connection (pull-out) plugs etc must have additional protection to stop the ingress of foreign objects and water.

From further Internet-based research it has become apparent that there are currently a number of manufacturers within the UK who are promoting pull-out plug power supply disconnection systems for passively safe lighting columns and signposts. These appear to comply with each of the requirements of the TA. In one instance it is quoted that a disconnection time of under 0.2 seconds is achievable with the system. This is within the preferred 0.4 second disconnection time, with some systems being promoted specifically for passively safe systems.

3.1.3 Limiting the power supply circuit impedance

An alternative method to the use of a pull-out plug is to limit the power supply circuit loop impedance such that sufficient current flows in the event of a fault to cause the operation of a protective device within a maximum disconnection time of 0.4 seconds. Such a protective device could be a mercury switch. It should be noted that this will place limitations on the installation design due to the required cable and earthing conductor sizes, and/or the number of lighting columns permissible on a circuit.

3.1.4 BS EN 12767:2007 National Annex

Due to the recent withdrawal of TA 89/05, the National Annex to BS EN 12767 (CEN, 2007) contains the UK requirements for electrical safety for passively safe lighting columns.

In the National Annex, there is guidance concerning the type of underground electrical connections to be used with passively safe supports:

> "In the UK it is recommended practice, for supports other than Class 0, to install cables which have a physical connection/disconnection device at ground level, which readily disconnects on impact when subject to an appropriate load, determined by laboratory testing of the device. Thus the support is not tethered in any way by the cable, and such disconnecting systems are suitable for use with supports which have not been impact crash tested with cables in place. Such disconnecting systems also provide electrical safety in impacts, by physically isolating the electricity supply to the impacted object and minimising the possibility of an exposed live broken cable end."

It is also noted that:

> "The requirements of BS EN 12767 and these recommendations are essentially concerned with the potential tethering of supports, but as

indicated the physical connection/disconnection device also provides electrical safety in impacts. An alternative solution for electrical safety is an electrical circuit protection device that operates within a maximum disconnection time of 0.4 s when fault conditions occur. This implies appropriate limitation of the power supply circuit loop impedance Zs, which may limit the installation design regarding cable sizes and the number of units on a circuit."

3.1.5 BS 7671:2008

Requirements for electrical installations. IEE Wiring Regulations

According to Geoff Cronshaw of the Institution of Engineering and Technology, BS 7671, although not a legal requirement, is a set of "golden rules" for electrical installation work, and it encourages best practice amongst the profession. The regulations are extensively referred to in health and safety documentation and, since 30 June 2008, all installations in the UK have had to comply with them. BS 7671:2008 is being introduced to supersede BS 7671:2001. The 2008 version includes changes necessary to maintain technical alignment with harmonization documents from CENELEC (the European Committee for Electrotechnical Standardization).

The requirements for electrical standards BS 7671:2008 (BSI, 2008), provides requirements for fault protection which could be applied in the case of a lighting column being struck by an errant vehicle. Of particular relevance is Section 411.3.2.2 which provides maximum disconnection times to be applied to circuits not exceeding 32 A.

Section 559 of BS 7671:2008 refers specifically to lighting columns and states that a maximum disconnection time of 5 seconds shall apply to all circuits feeding fixed equipment used in highway power supplies for compliance with Regulation 411.3.2.3 or 411.3.2.4.

3.1.6 Electricity at Work Regulations

Regulation 4 (1) of the Electricity at Work Regulations (HMSO, 1989) requires that systems shall, at all times, be of such construction as to prevent, so far as is reasonably practicable, danger (Buck and Hooper, 1989). Amplification of this general duty is provided through more specific duties contained in subsequent Regulations. Of particular relevance is Regulation 12 which specifies that; "where necessary to prevent danger, suitable means (including, where appropriate, methods of identifying circuits) shall be available for:

a) cutting off the supply of electrical energy to any electrical equipment; and

b) the isolation of any electrical equipment."

3.1.7 Summary

From the literature reviewed it appears that disconnection times of either 5 or 0.4 seconds are appropriate for lighting columns. In terms of a crash event, 5 seconds is a long time. One might expect that 0.4 seconds would coincide better with the end of significant motion resulting from a collision and hence is considered to be a more appropriate disconnection time for the power supply to passively safe lighting columns and signposts. This is due to the hazard which may arise if the electrical connection has not been disconnected immediately after an impact.

3.2 Strength of Columns for Supporting Other Hardware

3.2.1 BS 5489-1:2003

Code of practice for the design of road lighting – Part 1: Lighting of roads and public amenity areas

BS 5489 (BSI, 2003) contains guidance and recommendations which enable designers of lighting systems to comply with that standard. The new edition of BS 5489 consists of two parts. Part 1 gives guidance and recommendations for the lighting of roads and public amenity areas, and states that:

> "When specifying lighting columns, it should be ensured that the weight and windage area of the luminaire(s), the wind speeds to be expected at the location, and any loads imposed by additional items fixed to the lighting column such as signs and banners, are taken into consideration."

3.2.2 BS EN 60598-2-3:2003

Luminaires – Part 2-3: Particular Requirements – Luminaires for Road and Street Lighting

This British Standard is identical to IEC 60958-2-3:2002 and specifies the requirements for:

- Luminaires for road, street lighting and other public outdoor lighting applications;
- Tunnel lighting;
- Column-integrated luminaires with a minimum total height above normal ground level of 2.5m.

According to this standard:

> "The means for attaching the luminaire or external part to its support shall be appropriate to the weight of the luminaire or external part. The connection shall be designed to withstand wind speeds of 150kph on the projected surface of the assembly without undue deflection."

Compliance with this requirement is checked via inspection and, for mast-arm or post-top mounted luminaires or external parts, by a static load test.

The standard also states that:

> "With regard to load calculation and verification of structural design by testing, column-integrated luminaires, except for their external part, shall comply with ISO standards, where available, otherwise regional or national standards, where applicable." In Europe the applicable standard is EN 40.

3.2.3 BS EN 40-2:2004

Lighting columns – Part 2: General requirements and dimensions

The European Standard, BS EN 40-2:2004 (CEN, 2004), gives the necessary requirements for those specifying purchase requirements and manufacturing of lighting columns.

3.2.4 BS EN 40-3-1:2000

Lighting columns – Part 3-1: Design and verification – specification for characteristic loads

The European Standard, BS EN 40-3-1:2000 (CEN, 2000), specifies design loads for lighting columns. It applies to columns not exceeding 20 m height for post top lanterns and not exceeding 18 m height for side entry lanterns.

The structural design can be verified either by calculation or by testing in accordance with the subsequent Parts 3-2 and 3-3 of BS EN 40.

The requirement for a lighting column to be designed to safely sustain the dead loads and the wind loads are stated in the particular parts of BS EN 40 relevant to the construction material. The exact interpretation of these requirements in terms of a maximum size and weight of sign for different column types is not given in the Standard. This may be expected as the functional stability will be directly related to the design of the column itself.

As with any other types of lighting column, passively safe columns have to meet these design load requirements if they are to be considered fit for purpose. In addition, any further fittings to the lighting columns, e.g. traffic signs, will also need to be included in the calculations.

The calculation of design load requirements for fixing traffic signs is specified in BS EN 12899-1:2002 (CEN, 2001). Both this and the procedure in BS EN 40 are derived from the Eurocode ENV 1991-2-4.

It is possible that the intrinsic fragility of a passively safe signpost makes it unsuitable for attaching large traffic signs, as the design loads required for the sign may exceed the strength of the post.

3.3 Ongoing Electrical Maintenance

3.3.1 Electricity at Work Regulations

The Electricity at Work Regulations state that, with regard to on-going electrical maintenance:

Regulation 3 – Persons on whom duties are imposed by these Regulations:

Except where otherwise expressly provided in the Electricity at Work Regulations (HMSO, 1989):

[1] It shall be the duty of every employer and self-employed person to comply with the provisions of these Regulations in so far as they relate to matters which are within his control.

[2] It shall be the duty of every employee while at work:

- a) to co-operate with his employer so far as is necessary to enable any duty placed on that employer by the provisions of these Regulations to be complied with;
- b) to comply with the provisions of these Regulations in so far as they relate to matters which are within his control.

Regulation 4 – Systems, work activities and protective equipment:

[1] All systems shall at all times be of such construction as to prevent, so far as is reasonably practicable, danger;

[2] As may be necessary to prevent danger, all systems shall be maintained so as to prevent, so far as is reasonably practicable, such danger;

[3] Every work activity, including operation, use and maintenance of a system and work near a system, shall be carried out in such a manner as not to give rise, so far as is reasonably practicable, to danger;

[4] Any equipment provided under these Regulations for the purpose of protecting persons at work on or near electrical equipment shall be suitable for the use for which it is provided, be maintained in a condition suitable for that use, and be properly used.

Regulation 13 – Precautions for work on equipment made dead:

Adequate precautions shall be taken to prevent electrical equipment, which has been made dead in order to prevent danger while work is carried out on or near that equipment, from becoming electrically charged during that work if danger may thereby arise.

Regulation 14 – Work on or near live conductors:

No person shall be engaged in any work activity on or so near any live conductor (other than one suitably covered with insulating material so as to prevent danger) that danger may arise unless-

[1] It is unreasonable in all the circumstances for it to be dead;

[2] It is reasonable in all the circumstances for him to be at work on or near it while it is live;

[3] Suitable precautions (including where necessary the provision of suitable protective equipment) are taken to prevent injury.

Regulation 15 – Working space, access and lighting:

For the purposes of enabling injury to be prevented, adequate working space, adequate means of access, and adequate lighting shall be provided at all electrical equipment on which or near which work is being done in circumstances which may give rise to danger.

Regulation 16 – Persons to be competent to prevent danger and injury

No person shall be engaged in any work activity where technical knowledge or experience is necessary to prevent danger or, where appropriate, injury, unless he possesses such knowledge or experience, or is under such degree of supervision as may be appropriate having regard to the nature of the work.

3.3.2 BS 7671:2008

Requirements for electrical installations. IEE Wiring Regulations

As noted in Section 3.1.5 of this report, Section 559 of the IEE Wiring Regulations (BS 7671:2008) refers specifically to luminaires and lighting installations. The standard requires the following points to be met:

- Protection against fire: In selection and erection of a luminaire, the thermal effects of radiant and convected energy on the surroundings shall be taken into account.
- Connection to the fixed wiring: At each fixed lighting point a luminaire to BS EN 60598 shall be used.

- Fixing of the luminaire: Adequate means to fix the luminaire shall be provided. For suspension devices, they should be capable of carrying five times the mass of the luminaires (including their lamps) intended to be supported, but not less than 5 kg.
- Protective measure: Automatic disconnection of supply, where the protective measure 'automatic disconnection of supply' is used: This requirement seems to agree with, or supersede, earlier requirements regarding disconnection times and also contains some more general safety points;
    - All live parts of electrical equipment shall be protected by insulation or by barriers or enclosures providing basic protection. A door in street furniture, used for access to electrical equipment, shall not be used as a barrier or enclosure.
    - For every accessible enclosure, live parts shall only be accessible with a key or a tool, unless the enclosure is in a location where only skilled or instructed persons have access.
    - A door giving access to electrical equipment and located less than 2.50 m above ground level shall be locked with a key or shall require the use of a tool for access…
    - For a luminaire at a height of less than 2.80 m above ground level, access to the light source shall only be possible after removing a barrier or an enclosure requiring the use of a tool.
    - For an outdoor lighting installation, a metallic structure (such as a fence, grid, etc.), which is in the proximity of but is not part of the outdoor lighting installation need not be connected to the main earthing terminal.
    - It is recommended that equipment such as lighting arrangements in places such as telephone kiosks, bus shelters and town plans is provided with additional protection by a residual current device (RCD) having the characteristics specified in Regulation 415.1.1.

Some of the other general requirements also seem appropriate to the ongoing electrical safety of installations, e.g. accessibility of electrical equipment (132.12), periodic inspection and testing (135):

- Electrical equipment shall be arranged so as to afford as may be necessary:
    - Sufficient space for the initial installation and later replacement of individual items of electrical equipment;
    - Accessibility for operation, inspection, testing, fault detection, maintenance and repair.
- It is recommended that every electrical installation is subjected to periodic inspection and testing.

Furthermore, the standard then relates to the requirements for this periodic inspection and testing:

- Where required, periodic inspection and testing of every electrical installation shall be carried out in order to determine, so far as is reasonably practical, whether the installation is in a satisfactory condition for continued service…
- Periodic inspection consisting of a detailed examination of the installation shall be carried out without dismantling, or with partial dismantling as required, supplemented by appropriate tests to show that the requirements for disconnection times, for protective devices, are complied with, to provide for:
    - Safety of persons and livestock against the effects of electric shock and burns;

    - Protection against damage to property by fire and heat arising from an installation defect;
    - Confirmation that the installation is not damaged or deteriorated so as to impair safety;
    - The identification of installation defects and departures from the requirements of these Regulations that may give rise to danger.
- Precautions shall be taken to ensure that the periodic inspection and testing shall not cause danger to persons or livestock and shall not cause damage to property and equipment even if the circuit is defective…
- The extent and result of the periodic inspection and testing of an installation, or any part of an installation, shall be recorded;
- Periodic inspection and testing shall be undertaken by a competent person;
- The frequency of periodic inspection and testing of an installation shall be determined having regard to the type of installation and equipment, its use and operation, the frequency and quality of maintenance and the external influences to which it is subjected. The results and recommendations of the previous report, if any, shall be taken into account;
- In the case of an installation under an effective management system for preventive maintenance in normal use, periodic inspection and testing may be replaced by an adequate regime of continuous monitoring and maintenance of the installation and all its constituent equipment by skilled persons, competent in such work. Appropriate records shall be kept.

3.4 Practical Issues

3.4.1 Installation and non-electrical maintenance

In general, the installation of passively safe lighting columns and signposts is easier than that for conventional systems. There are no special maintenance issues with passively safe signposts, the materials used generally being of a better quality and having a longer lifespan than their conventional counterparts. Anodised aluminium is claimed to have a life of up to 75 years and composite 60 years, compared with 40 years for steel (provided the base of the system remains intact). However, if paint is used, this will need to be renewed every 6 to 7 years.

Passively safe signposts are easier to replace than conventional ones due to the design of the base plate. These base plates are normally re-usable following an impact by an errant vehicle. Manual handling is easier as the signposts are much lighter than conventional ones.

The absence of a barrier potentially increases the number of times a signpost is hit and therefore the number of times it has to be replaced. However, repairing a barrier may be more costly than replacing a post. Some companies offer a free replacement signpost where the cost cannot be reclaimed from the insurance of the driver striking it.

3.4.2 Vandalism / Theft

Vandalism or theft may occur with aluminium posts as theft of aluminium signs has become common in recent years. However, theft has traditionally been of the smaller signs or sections of larger signs. There have been no widespread reports of theft or vandalism of aluminium posts to date.

There is much less concern over the theft of lighting columns as they are not obviously different to conventional columns. However, they need to be sufficiently robust to withstand deliberate damage.

Painting may help to reduce vandalism if it makes it less obvious that the signposts are made of aluminium. However, as stated in Section 3.4.1, they will then require repainting. The main advantages of aluminium over steel are its appearance and that it does not need painting for reasons of durability.

3.5 Summary

The literature examined within this Section suggest that disconnection times of either 5 or 0.4 seconds are required for lighting columns depending on the particular electrical configuration being used in the installation. In the event of a vehicle collision with a lighting column it would seem logical to disconnect the electrical supply quickly so as to reduce the risk of further danger at the collision location. Therefore the shorter, 0.4 seconds, disconnection time may be more appropriate for passively safe lighting columns, and systems currently exist in the market place which are capable of achieving this requirement.

Detailed calculation methods have been developed in European standards, to determine the design loads required for lighting columns. These design loads account for dead loads due to the mass of luminaires, as well as wind loads. The exact requirements vary depending on the particular installation. Passively safe supports will also have to meet these strength requirements, which may pose a conflict with low- and non-energy absorbing supports which may have an intrinsic fragility. Therefore it is necessary to ensure that the designers of the columns have considered this requirement.

Similar strength requirements are also in place for traffic signposts. Again it may be that the passively safe support structures are not suitable for all types, masses and sizes of signs, unless so designed. Therefore the use of passively safe structures for traffic sign supports should include consideration of these design load requirements.

The Electricity at Work regulations and the IEE wiring regulations contain requirements for the safety of lighting column installations. They also include requirements supporting their use, for instance inspection and maintenance. These requirements must be met by passively safe support structures in the same way as for conventional designs.

Installation should be undertaken by trained staff. Non-electrical maintenance for passively safe supports is minimal, and they are generally easier to erect and replace than conventional designs because of their lightweight structure and the often reusable nature of their foundations.

4 Collisions Involving Lighting Columns and Signposts

4.1 Background

Statistics on personal injury road collisions are published annually on the Department for Transport's website (Department for Transport, 2007A). These data are based on information collected by the police in a system known as STATS19, named after the number of the first questionnaire issued when the system was introduced in 1949 (Department for Transport, 2007B). STATS19 covers collisions involving injury occurring on the public highway (including footways) in which at least one road vehicle, or a vehicle in collision with a pedestrian, is involved which becomes known to the police within 30 days of its occurrence. The vehicle need not be moving at the time of the collision and collisions involving stationary vehicles and pedestrians or users are included. Excluded from STATS19 are confirmed suicides, death from natural causes, injuries to pedestrians with no vehicle involvement (e.g. a fall on the pavement), and collisions in which no one is injured but a vehicle is damaged. From the 1st January 2005, STATS19 has also included the reporting of contributory factors to the collision.

The STATS19 system collects some fifty data items for each collision, including the time, location and severity, the type of vehicle(s) and their movement at the time of the collision as well as information on the drivers and casualties involved. An example of the data collection form is located on the Department for Transport website (Department for Transport, 2004).

4.2 Searching of STATS19 Database

A search of the STATS19 database was carried out to identify single vehicle collisions attended by the police in which an injury has occurred as a result of an impact with a lighting column or a signpost/traffic signal, between 2001 and 2006 inclusive, on any road in Great Britain.

Within the STATS19 reporting process, no distinction is made between impacts with a signpost or a traffic signal and hence, these items of roadside hardware are grouped together within this analysis.

In addition, STATS19 does not record whether or not the object hit is passively safe. None of the participants at the Workshop carried out as part of this project were aware of any records of death or serious injury resulting from hitting passively safe lighting columns or signposts in the UK.

4.3 Summary of the Findings

The results from the STATS19 search are tabulated in Appendices A and B, with pictorial representations in Appendices C and D.

Table 4 shows the number of collisions and casualties in which a vehicle struck a lighting column or a signpost/traffic signal between 2001 and 2006.

On rural roads there are few lighting columns and many will be protected by a safety barrier. Signposts on rural roads with no barrier protection are likely to be small in number and/or on more minor roads with lower flows. It was therefore expected that most of the collisions would be with lighting columns and signposts on urban roads and this was in fact the case.

The percentages of serious and fatal injuries resulting from impacts with lighting columns and signposts/traffic signals were higher than the average severity values. Comparable severity data for safety barrier impacts has shown that the severity of such collisions is higher than the average, but lower than that for lighting columns, signposts and traffic signals.

Table 4: Collision statistics for Great Britain, 2001-2006

	Number of Collisions	Casualties			
		All	Fatal (%)	Serious (%)	Slight (%)
All types of collisions	1,260,101	1,716,782	1.2	11.4	87.4
With lighting column	12,391	16,987	2.4	17.6	80.0
With signpost / traffic signal	8,849	11,524	2.2	16.0	81.8

4.3.1 Casualties resulting from lighting column impacts

- In 24% of collisions, the impact with a lighting column followed the striking of a kerb.
- 64% of the casualties resulted from the vehicle leaving the carriageway to the nearside, 28% leaving to the offside.
- The majority of the drivers involved in the collisions were also aged between 18 and 25 (43%), with 78% of the drivers being male. Similarly, the majority of the casualties (41%) were aged between 18 and 25, with 85% being aged 45 or less.
- The majority of the collisions involved a car (90%) whilst 4% of the casualties were motorcyclists. Road traffic in the UK in 2006 was comprised of 86% cars, with 4% being motorcycles (Department for Transport, 2007). Hence the percentage of casualties in vehicles from lighting column impacts is consistent with these figures. However, examination of the severity of injuries sustained by motorcyclists shows that 18% of casualties received fatal injuries, 50% serious injuries, with the remaining 32% receiving slight injuries. This is much higher than the severity for car occupants (2% fatal, 17% serious and 82% serious injuries).
- 40% of the impacting vehicles were skidding at the time of impact.
- 27% of the casualties received their injuries between 21:00 and 00:59, with a peak between 23.00 and 23:59. There was also a slight increase in casualties in the afternoon (i.e. from 12:00).
- 19% of the casualties result from collisions occurring on Saturdays and 20% occurring on Sundays. This is much higher than the number of casualties occurring on a weekday, where the average percentage of casualties is 12%.
- The number of casualties receiving injuries from impacts with lighting columns is fairly evenly spread throughout the year
- 63% of the casualties occurred on two lane single carriageway roads, with 57.3% of the collisions occurring on 30 mph roads; 51% of the collisions occurred on A roads, and 27% occurred on unclassified roads. Hence the most common location for an injury collision with a lighting column is a two lane single carriageway 30 mph A road; however this may be due, in part, to the number of unprotected lighting columns on such roads. The much lower number of casualties on motorways (2%) is likely to be due, in part, to the provision of safety fencing in front of the lighting columns and/or the relative number of lighting columns on such roads.
- 42% of casualties occurred where the road surface was wet or damp.

- 51% of casualties came as a result of a collision occurring during the hours of darkness, but in locations lit by street lights. In 95% of cases, it was reported that street lighting was present at the collision scene. This is curious as street lighting would have needed to have been present in order for an impact with a lighting column to have occurred. This should invoke caution when examining STATS19 data as the information collated is only as good as that reported by the police at the collision location.
- 11% of collisions occurred at roundabouts. This is likely to be due to the requirement that roundabouts are lit and the need to negotiate a curve.
- The majority (74%) of the collisions occurring during fine weather without high winds.

4.3.2 Casualties resulting from road signpost/traffic signal impacts

- 15% of collisions with a road signpost or a traffic signal occurred after the striking of a kerb.
- 55% of the casualties resulted from the vehicle leaving the carriageway to the nearside, 29% leaving to the offside.
- The majority of the drivers involved in the collisions were aged between 18 and 25 (39%), with 76% of the drivers being male; the majority of the casualties (37%) were also aged between 18 and 25, with 82% being aged 45 or less.
- The majority of the collisions involved a car (87%) whilst 6% of the casualties were motorcyclists. Department for Transport statistics show that road traffic in the UK in 2006 was comprised of 84% cars, with 4% being motorcycles (Department for Transport, 2007). Hence motorcyclists are over-represented in the statistics. Motorcyclists also had a much higher percentage of fatal and serious casualties (12% fatal and 51% serious injuries compared with 2% fatal and 14% serious for car occupants)
- 34% of the impacting vehicles were skidding at the time of impact.
- 18% of the casualties received their injuries between 21:00 and 00:59, with a peak between 23.00 and 23:59. There was also a slight increase in casualties in the afternoon (i.e. from 12:00).
- 18% of the casualties result from collisions occurring on Saturdays and 20% on Sundays. This is markedly higher than the 12% occurring on a weekday
- The number of casualties receiving injuries from impacts with a signpost or a traffic signal is fairly evenly spread throughout the year
- 56% of the casualties occurred on two lane single carriageway roads, with 33% of the collisions occurring on 30 mph roads; 60% of the collisions occurred on A roads and 14% occurred on unclassified roads. Hence the most common location for an impact with a signpost or a traffic signal to result in a casualty is on a two lane single carriageway 30 mph A road, however this may be due, in part, to the number of unprotected signposts and traffic signals on such roads.
- 42% of casualties occurred where the road surface was wet or damp.
- 33% of collisions occurred during darkness, but in locations lit by street lights; overall, 80% of collisions occurred on roads with street lighting or in daylight. This suggests that poor visibility (due to lighting) was not a contributory factor, but may also be because large signs on rural roads are most likely to be protected by a barrier
- The majority (74%) of the collisions occurred during fine weather without high winds.

4.4 Summary

The number and severity of impacts with lighting columns were generally higher than those with signposts/traffic signals. This may be because there are a greater number of lighting columns than sign, and as larger signs on rural roads are generally protected with a length of safety barrier.

Approximately two thirds of the collisions have occurred as a result of an errant vehicle leaving the carriageway to the nearside.

A large proportion of the drivers involved in impacts with lighting columns and signposts were male and aged between 18 and 25. Casualties (including drivers, passengers and pedestrians) were also generally aged between 18 and 25, with 83% of those injured being less than 45 years of age.

The majority of casualties were car occupants, however a disproportionately high number of motorcyclists were injured in such collisions, the severity of such impacts being approximately seven times the average severity of collisions occurring during the same time period.

Disproportionately high numbers of such collisions occurred at the weekend, generally between 21:00 and 00:59 in the evening.

The most common location for such impacts was two lane, single carriageway A roads, and roads with a 30mph speed limit. Again this is likely to be due, in part, to this being where the majority of lighting columns are situated. In general, collisions occurred where there was street lighting and hence, light levels appear to have little effect on the probability of a collision occurring. Road surface and weather conditions appeared to have only a minimal effect on the number and/or severity of collisions.

5 Cost Benefit of Using Passively Safe Lighting Columns and Signposts

Using a simple First Year Rate of Return (FYRR) approach is not straightforward for passively safe lighting columns and signposts for several reasons. Individual lighting columns are rarely hit and passively safe columns and posts are relatively new to the road network. For rural roads, the conventional equivalents are often protected by a safety barrier. In addition the FYRR approach does not reflect the potentially increased lifespan and lower maintenance of passively safe products.

Whole life costing is preferable to FYRR as it includes the length of life, ease of replacement, maintenance issues and whether or not the post will be in a rural or urban area. It is not proposed that lighting columns or signposts should be replaced before they are life expired. However, the use of passively safe structures should be considered when there is a general replacement of signposts or lighting columns.

An alternative approach was proposed by Simpson (2008) following the Workshop held in February 2008 as part of the project and is described below. The figures supplied were for 2005 and have been adjusted in the following text by the average number of run-off collisions over the period from 2001 to 2006 (see Table 4 and Section 4.3).

The total number of single vehicle collisions hitting lighting columns in 2005 and their costs are given in Table 5. Based on the 2005 collision costs in the Highway Economic Note 1 (HEN1) (Department for Transport, 2006C), the total cost of these collisions is £185.5 million per year. However, if it is assumed that the use of passively safe columns reduces the severity of injuries by one step (fatal to serious; serious to slight; slight to damage only) the costs would be reduced as shown in the bottom line of the table. Thus the use of passively safe columns might be expected to reduce annual collision costs by £162.7 million to £22.8 million.

Table 5: Single vehicle collisions with lighting columns from 2001 to 2006

	Fatal	Serious	Slight	Total
Urban	49	373	1637	2058
Rural	19	127	628	774
Total per year	65	411	1590	2065
Cost per collision £ (from HEN1)	£1,644,790	3188,920	£19,250	£89,820
Total cost per year from collisions with lighting columns, in £M	£106.4	£77.6	£30.6	£185.5
Total projected cost with passively safe columns, in £M	£0.0	£12.2	£7.9	£22.8

Simpson estimated that there are approximately 6.7 million lighting columns on UK roads, 6.5 million excluding motorways. Very few collisions of this type occur on residential and other minor urban roads but the majority of columns will be on roads of this type. A reasonable estimate of the number of columns on major roads where single vehicle collisions are more likely to occur might be 2.5 million. If the extra cost of replacing each lighting column with a passively safe one is estimated to be £150, the total additional cost would be £375 million, which would give a First Year Rate of Return of 50%. Waller (Passive Safety Handbook, 2008) states that, in Durham, the extra initial cost of a passively safe lighting column is £750 per column. Clearly this is much less cost-effective; however, this figure includes a significant improvement in safety which comes from the improved electrical arrangement and a longer expected lifetime than for conventional columns. On rural roads, there will be no need for a safety barrier, giving an additional cost saving.

It is recommended that a whole life costing of passively safe lighting columns and signposts is undertaken.

5.1 Summary

There appears to be a good economic case for the introduction of passively safe lighting columns, based on a small additional cost per lighting column, due to the reduction in collision severity, particularly in locations where there would otherwise need to be a safety barrier.

6 Risk Assessment of Use of Passively Safe Lighting Columns and Signposts

6.1 Introduction

The purpose of this risk assessment is to compare the risk of using passively safe lighting columns and signposts with that of conventional ones in both rural and urban areas, including possible effects on other road users and third parties.

The approach is based on the Road Restraint Risk Assessment Process (RRRAP) developed for use with the Road Restraint Standard (TD 19/06; DMRB Section 2.2.8) which applies only to rural roads. Lighting columns on rural single carriageway roads are considered in detail in Appendix E. The approach for signposts and for structures on dual carriageways and urban roads is similar, but the figures for urban roads are less readily available.

Passively safe lighting columns or signposts are intended to reduce the risk of injury to errant vehicle occupants following an impact by allowing the post to fail without transferring much energy from the impacting vehicle. However, they are designed to collapse on impact and this increases the risk of injury to other road users and to third parties.

There is very little data available from observed collapses on which to base estimates of either the probability of collapse or the likelihood of consequent injury. As many of the numbers used in the risk calculation are subject to a high degree of uncertainty, the sensitivity of the estimates needs to be tested by using a range of values. The approach taken is intended to look at risk at a 'broad brush' level, and to understand general patterns and levels of risk with different generic design choices.

From the testing described in Section 2, it was concluded that when a vehicle hits a conventional post:

- Small diameter/thin walled posts do little to slow impacting vehicles and do not have serious consequences for vehicle occupants;
- The consequences of hitting a larger diameter/thicker walled post are likely to be more severe for the occupants of the impacting vehicle;
- The post remains attached to the ground;
- The sign may become detached and fly into the air, but will remain broadly undamaged and land close to the base of the post.

With passively safe posts, the mast will become detached from its base, but is unlikely to fall in the carriageway. However it is assumed in the risk assessment that lighting columns are more likely to fall into the carriageway than signposts because of their greater length. It is also more likely that debris such as the luminaire will fall from a lighting column, although this risk is considered to be no worse than with conventional posts.

6.2 Project on Risk Assessment of Lightweight Gantry

6.2.1 Background

In 2005, TRL undertook a risk assessment of the use of a lightweight (passively safe) gantry for the Highways Agency. This project is outlined in some detail in this section as the risk assessment methodology undertaken in this report has close parallels with this earlier work.

Conventional gantries in the UK are protected from errant vehicles by higher containment safety barriers. These gantries are designed for collision loading such that if they were to be hit by a large vehicle or by a vehicle getting behind the safety barrier, they are unlikely to collapse (although the consequences for the vehicle occupants are likely to be serious or fatal, particularly for the occupants of light vehicles). As a result, collapse is very rare, but when it does occur, the gantries fall in the carriageway. If a gantry collapsed, both it and its fixtures would land on the main carriageway and would be likely to at least partially block the running lanes. The effect would be two-fold, in that vehicles other than the errant vehicle might be hit by falling debris, and following drivers might need to brake sharply and/or take evasive action.

There is a known instance of the collapse of a passively safe gantry in Poland (Figure 8). There were no casualties and only minor damage to the heavy goods vehicle.

(Photo supplied by Juralco)

Figure 8: Collapsed gantry in Poland

The number of times a gantry or other roadside object is hit would increase if there were no barrier in place to provide protection, unless the object was located so far away from the running lanes that few vehicles reached it.

6.2.2 Testing of a Passively Safe Lightweight Gantry

The Lattix gantry tested was a prototype supplied by Juralco. It was 41 m long, large enough to span both carriageways of a dual 3 lane motorway (including a hard shoulder) with an offset of 4.5 m from the running lanes. It had to be capable of supporting the full set of equipment used on a motorway under Active Traffic Management (as used on the M42), but also passively safe to the requirements of BS EN 12767 if hit by an errant vehicle.

The gantry had 3 pairs of legs, each pair forming an A shape (see Figure 9). The legs were fixed to a base plate using shear bolts which were intended to break away on impact leaving the base plate attached to the foundation and undamaged following an impact.

Figure 9: Gantry at start of trials

A number of impact tests were carried out, all with a car of mass 1,500 kg travelling at a speed of 110 kph.

Testing the Removal of a Single Leg

The first test involved hitting the upstream leg of the verge-side support to check that the gantry remained upright following the collision. The gantry was fitted with a lightweight variable message sign (VMS). The vehicle hit the gantry leg at a speed of 110 kph and an angle of 20 degrees. After the impact, the vehicle veered 15 degrees to the right (towards the carriageway) and the estimated exit speed at 5 m beyond the impact point was 80 kph. The vehicle suffered some frontal impact damage but there was very little intrusion into the occupant compartment.

The gantry leg broke away from its base and came down on top of and over the vehicle, landing approximately 23 m beyond the impact point. The overhead transom remained supported by the five remaining legs. Figure 10 shows photos during and after impact. All the signs remained attached to the transom.

Figure 10: Test with lightweight sign and remaining leg after impact

Testing the Removal of Two Legs

The second test was a repeat of the first on the remaining leg with the lightweight sign replaced by a full weight sign. The purpose of the test was to collect data which could be used in the TRL Driving Simulator to test driver reaction to a collapsing gantry. Figure 11 shows photographs of the fallen gantry following the test.

Figure 11: Gantry following collapse

Test with Fallen Gantry

An impact test was also carried out on a section of the transom lying in the carriageway supported by the signs, with the bottom of the transom approximately 560 mm above ground level. The aim of the test was to observe the capacity of the transom to absorb energy when impacted directly by the vehicle (see Figure 12). In the test, the vehicle went under the transom and continued with an almost unaffected trajectory. The vehicle remained upright but suffered general frontal impact damage. There was no visible intrusion into the occupant compartment.

Figure 12: Transom before and after test with fallen gantry

It was concluded that the risk to other vehicles on the motorway was no worse than that of a lane-changing or shunt collision if the gantry collapsed, and potentially much less serious if the gantry did not collapse.

6.2.3 Simulator Trial

The collapsing gantry scenario was reproduced in the TRL driving simulator to evaluate driver reactions to the event. The trial comprised a 14 mile drive along a generic 3-lane motorway with lightweight gantries added at approximate one mile intervals along the entire route.

The collapse of the gantry was triggered when the participant was within sight of the gantry but was still able to stop before reaching it. The participants had to drive through a moderate level of traffic initially. After 12 miles, the ambient traffic was removed with the exception of one large white saloon car ahead of the driven vehicle. This lead vehicle drifted across the hard shoulder and off the motorway, impacting with the gantry leg in the grass verge, causing the transom to fall to the ground whilst remaining intact at the support in the central reserve. Realistic noise effects were included.

The 24 simulator trial participants displayed a variety of behaviours in response to the gantry collapse. Age, sex, and experience were not good indicators of the response of the driver. Responses, shown in Figure 13, depended on the lane in which the vehicle was travelling at the time of collapse. Because of the absence of other traffic, most of the drivers (19 out of 24) were travelling in lane 1. Of these 19 drivers, 10 stopped, 5 braked but then continued under the gantry, whilst 4 did not brake at all. The remaining 5 drivers in lane 2 all continued under the gantry. All participants reacted to the event by removing their foot from the accelerator.

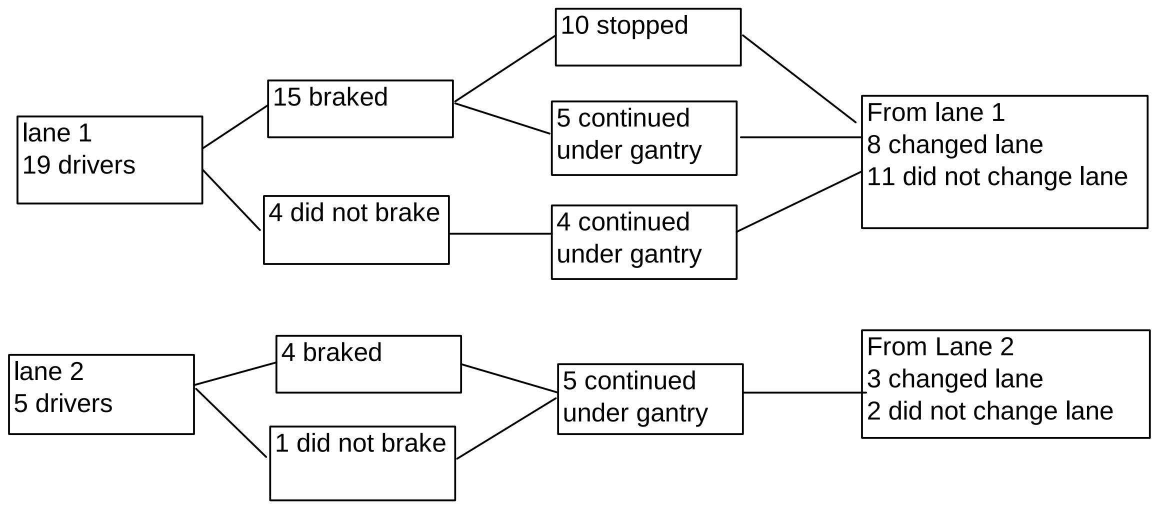

Figure 13: Pattern of simulator responses to collapsing gantry

Participants all completed a questionnaire after their drive. These responses indicated that participants initially felt the best course of action would be to change lanes, whilst with hindsight they felt that it would have been better to stop. In practice, it is likely that some drivers would stop, some would continue under a collapsed gantry if space permitted (with or without reducing speed) and some would change lanes in response to its fall.

All of these possible reactions might lead to a secondary collision and were therefore considered in the risk assessment.

6.2.4 Risk Assessment of Collapsing Gantry

The risk assessment methodology adopted for the collapsing gantry work was similar to that outlined in Section 6.3. The conclusions were:

- Overall risk with the lightweight gantry tested is the same order of magnitude as for a steel gantry protected by a barrier;
- However, there is a transfer of risk – there is a lower risk for the errant vehicle occupants, with an increased for other road users and third parties.

6.3 Approach to Risk Assessment of Passively Safe Lighting Columns or Signposts

The types of safety-related risk that might arise as a result of an impact with a passively safe lighting column or signpost and which are included in the risk assessment are as follows:

- Risk to the occupants of the errant vehicle which hits a lighting column or signpost;
- Risk to other road users and/or third parties of being hit by the column, signpost or associated debris e.g. luminaire;
- Risk to other road users of running into a fallen column or post;
- Risk to other road users of secondary collisions resulting from vehicles braking sharply or taking evasive action;
- Risk to pedestrians of being hit by the falling column / post or debris.

Other risks that are not included in the risk assessment include:

- Risk to maintenance workers in removing debris from the road and replacing the post (quicker than repairing or replacing a safety barrier);
- Risk to pedestrians arising from the errant vehicle not being stopped by the column or post (little changed from risk with conventional columns);
- Operational risks arising from the loss of a sign, leading to possible driver confusion (mitigated by swift replacement of the sign);
- Failure of a lighting column leading to a widespread loss of lighting along the road (mitigated by electrical regulations).

An event tree for an impact with a lighting column or signpost is given in Figure 14.

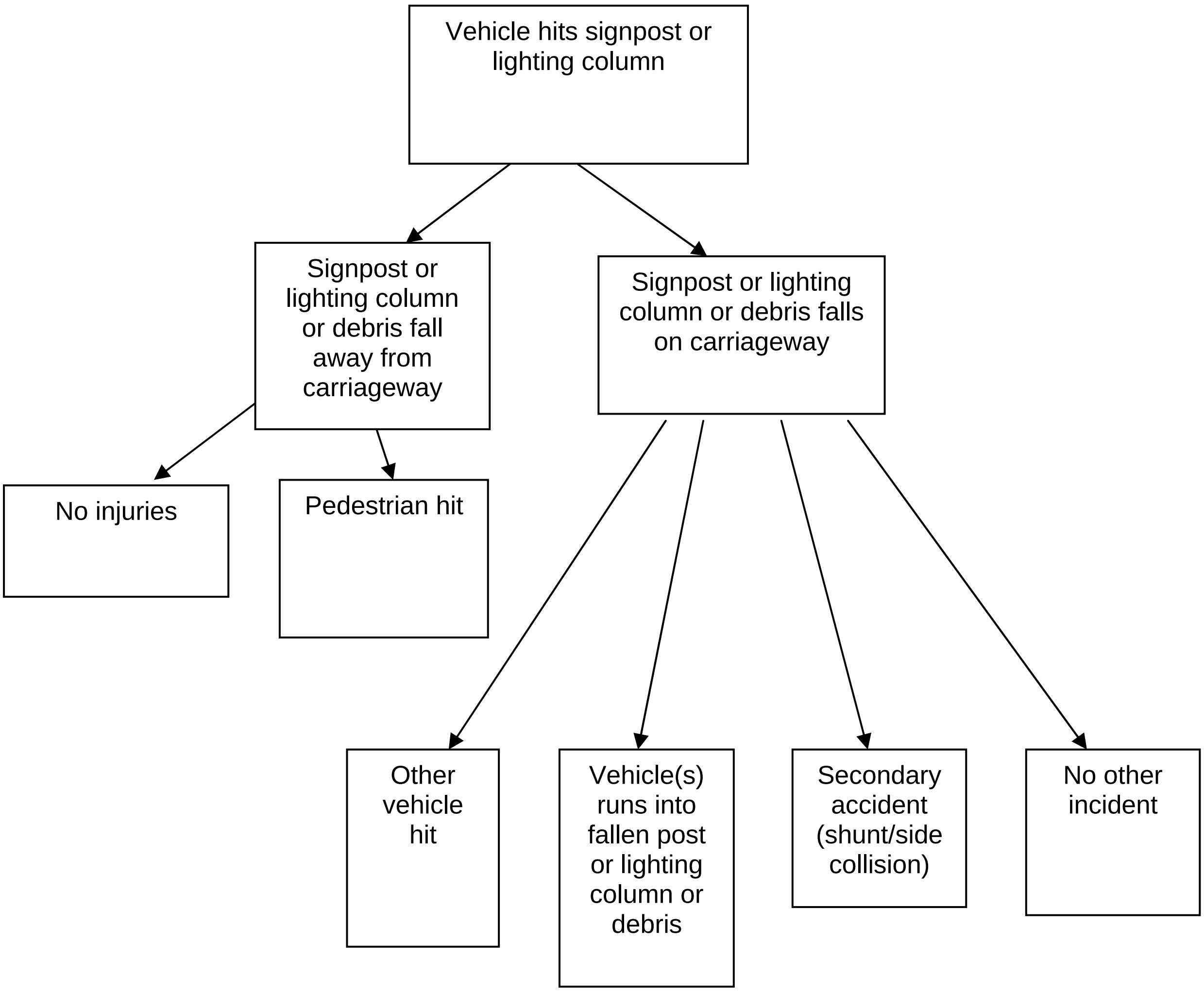

Figure 14: Event tree for an impact with a passively safe lighting column or signpost

The results of the tests with a car hitting the leg of a Lattix gantry (Section 6.2) and demonstrations of what happens when a vehicle hits a passively safe lighting column or signpost (Section 2) have been used to form the basis of the assumptions for the likelihood of injury resulting from an impact of a passively safe lighting column or signpost by a vehicle.

The risk assessment is detailed in Appendix E for the case of a lighting column on a single carriageway rural road.

6.4 Summary of Results

Table 6 summarises the risk estimates for a conventional and a passively safe lighting column on a rural single carriageway road in terms of the number of equivalent fatalities per year. Estimates are shown separately for the casualties in the errant vehicle and for the different types of secondary collisions that might result. It should be noted that an impact with a conventional lighting column may also result in the column collapsing or debris falling from it, and therefore the risk associated with an unprotected conventional lighting column is likely to be an underestimate.

Table 6: Risk for different options on a rural single carriageway road

Option	Risk (number of equivalent fatalities per year) on rural single carriageway					
	Errant vehicle occupants	Other road users				All road users
		Hit by falling column	Run into fallen column or debris	Shunt collision	Lane change collision	
Unprotected conventional lighting column 2.5m from edge of carriageway	0.0146	-	-	-	-	0.0243
Conventional column 2.5m from edge of carriageway with safety barrier protection	0.0036	-	-	-	-	0.0058
Passively safe column 2.5m from edge of carriageway	0.0017	0.000087	0.00013	0.000075	0.00017	0.0032

In Table 6 and Figure 15, a summation of the separate risks associated with an unprotected passively safe lighting column for all vehicle occupants still produces a total below the level of risk from a conventional column protected by a safety barrier. However, the estimates are likely to have large confidence intervals, so the real risk could be substantially higher than the estimates shown.

The risk to pedestrians in the vicinity was also estimated and will depend strongly on the likelihood of a pedestrian presence. This is considered to be very low in rural areas. It is not shown in Table 6 or Figure 15.

Given that in many cases there will be a large degree of uncertainty in the values assumed for input variables, the sensitivity of the conclusions to alternative values was tested by calculating a sensitivity factor for the risk estimate associated with each potential collision type in Table 6. An example is given in Appendix E. This shows that even adopting considerably higher values, the conclusion remains that passively safe structures have a lower risk than conventional ones.

The results for lighting columns on rural dual carriageways and signposts on both single carriageway and dual carriageway rural roads are not reproduced in this report, but led to similar conclusions.

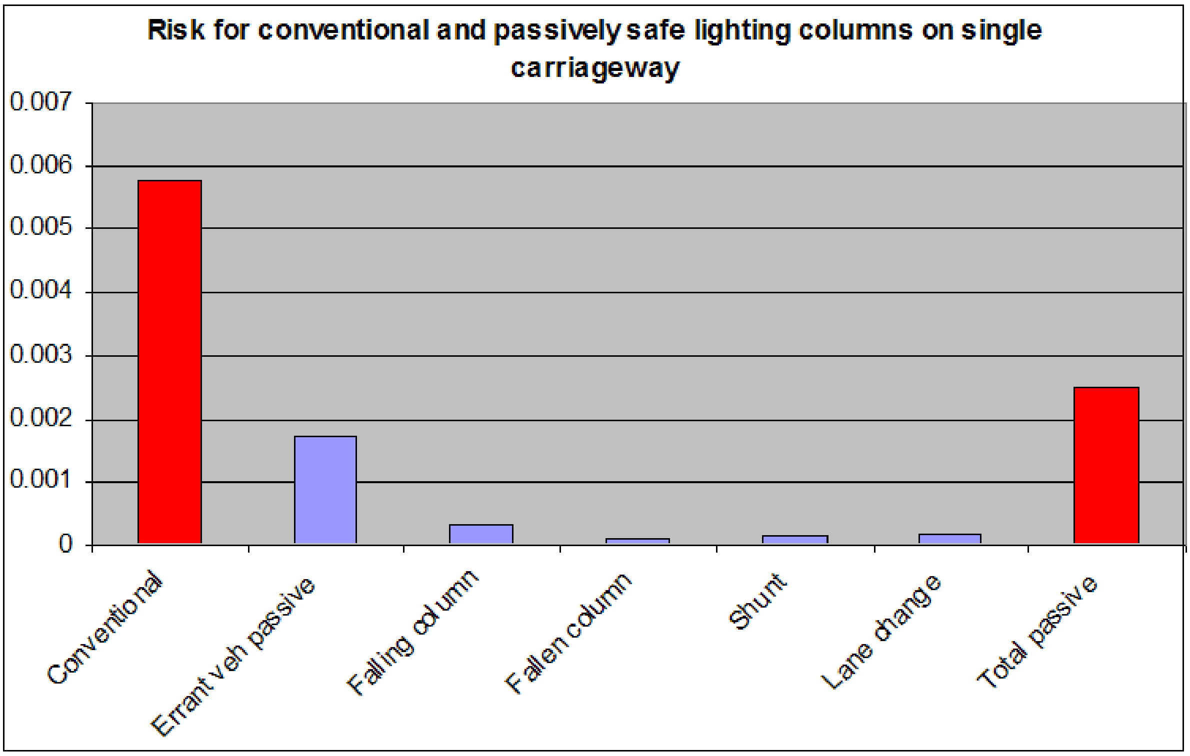

Figure 15: Comparison of risk for a conventional lighting column with barrier protection and a passively safe lighting column on a rural single carriageway

6.5 Risk in Urban Areas

On average, speeds are lower in urban areas and therefore there is less benefit for errant vehicle occupants in using passively safe structures. There is also a greater likelihood of pedestrians being in the vicinity and hence the risk of injury to pedestrians is increased. On the other hand, there are many more lighting columns and signs on urban roads. In addition, drivers may exceed the speed limit on major single carriageway urban roads where the majority of injury collisions involving signs and lighting columns occur.

7 Conclusions

7.1 Current Standards and Literature

The current standards and literature pertaining to the use of passively safe signposts and lighting columns show that street lighting column designs which minimise the injuries to occupants of a vehicle colliding with them have been considered important in the UK since the early 1960s. As a result, research was directed towards developing passively safe lighting columns, particularly in the 1960s and 1970s. However, their use only became widespread once new materials became available in the late 1990s.

In 2000, a European Standard (BS EN 12767) was published providing a means of testing and assessing the level of passive safety offered by road equipment support structures. The standard specifies performance requirements and both defines and limits the levels, in passive safety terms, intended to reduce the severity of injury to the occupants of vehicles impacting with permanent road equipment support structures. Three energy absorption types are defined and test methods for determining the level of performance under set conditions and various impact speeds are given.

National road authority advice documents in Norway and Finland are known to have incorporated the performance levels defined in this standard, using them to recommend when and where certain categories of passively safe posts should be provided. This considers the use of passively safe support structures for road equipment on roads with speed limits down to 50 kph. Such recommendations are supported by cost-effectiveness studies and collision investigations. Current US design manuals support the use of breakaway sign supports on all public roads. Whilst lighting columns are not necessarily subject to this recommendation, the Federal Highway Administration is encouraging the use of breakaway designs on roads with speed limits as low as 25 mph.

In the UK, the Highways Agency has provided advice on the use of passively safe support structures along the motorway and trunk road network in Technical Advice Note TA 89/05, including the selection of appropriate post or column types as assessed against the testing requirements of BS EN 12767.

The Highways Agency has recently withdrawn TA 89/05 in favour of the recently updated BS EN 12767 and the new UK National Annex to this standard. The National Annex provides the same advice as TA 89/05 regarding the use of the different energy absorption class support structures. This is that Category NE (non-energy absorbing) supports provide a lower risk of injury to vehicle occupants than HE or LE (high energy or low energy absorbing), and can be the most appropriate choice on non-built up roads with insignificant volumes of non-motorised users. Category LE and HE supports reduce the risk of secondary collisions and collisions with non-motorised users, as the vehicle exit speed is lower and thus, can have advantages on built-up roads where there is a significant volume of non-motorised users.

The HA advice provides information on the speed class and energy absorption requirements for the support structures to be used on roads with speed limits of 40 mph or greater.

On the basis of speed limit and potential impact speeds, it therefore seems appropriate to consider the use of passively safe signposts and lighting columns on almost all roads in the UK. However, the potential risk of secondary injury to other road users from a falling support structure and therefore the particular design requirement for the post, should be assessed and determined for each installation. Also, the potential for vehicles to have collisions at speeds in excess of the posted speed limit also needs to be assessed when deciding on the speed class for that installation location.

7.2 Design Loading

Detailed calculation methods have been developed in European standards to determine the design loads required for lighting columns and signposts. These design loads account for dead loads due to the mass of supported structures as well as wind loads. The exact requirements vary depending on the particular installation. These strength requirements may pose a problem for low- and non-energy absorbing passively safe supports which often have an intrinsic fragility.

Passively safe lighting columns which are energy absorbing to some extent will have components that are designed to deform in some way, to absorb the impact energy. The particular mode of deformation or fragility may have implications for safety aspects other than those referenced above. For instance the risk of electric shock, difficulties with access during electrical maintenance and the risk of structural failure due to reduced load-bearing potential. Requirements of existing lighting columns associated with these aspects have been reviewed alongside consideration of the behaviour expected from passively safe columns.

7.3 Electrical Requirements

The review of literature suggests that disconnection times of either 5 or 0.4 seconds are required for lighting columns depending on the particular electrical configuration being used in the installation. After a collision between a vehicle and a passively safe lighting column, hazards may arise if the electrical connection is still live. Therefore the shorter, 0.4 s disconnection time is strongly recommended for electrical supplies to passively safe lighting columns and illuminated signs.

The Electricity at Work regulations and the IEE wiring regulations contain requirements for the safety of lighting column installations. They also include requirements relating to the continuing use of columns, for instance inspection and maintenance. These requirements must be met for passively safe support structures as well as with by conventional designs.

7.4 Injury Collisions involving Signposts and Lighting Columns

Data was obtained from the Department for Transport's STATS19 database for injury collisions in which a lighting column or a signpost/traffic signal was struck by a vehicle between 2001 and 2006 (inclusive) on any road in Great Britain.

The findings were as follows:

- The number and severity of impacts with lighting columns is generally higher than those with signposts/traffic signals. This is likely to be due to the greater numbers of lighting columns, and the use of barriers to protect these structures on rural roads;
- Most of the collisions occurred as a result of an errant vehicle leaving the carriageway to the nearside, with a large proportion of the drivers being male and aged between 18 and 25;
- Casualties from such impacts (including drivers, passengers and pedestrians) are also generally aged between 18 and 25, with 83% of those injured being less than 45 years of age;
- The majority of casualties were car occupants; however a disproportionately high number of motorcyclists are injured within such collisions, the severity of such impacts being approximately seven times the average;
- A disproportionately high number of such collisions occurred at weekends, generally between 21:00 and 00:59 in the evening;

- The most common location for these impacts was on two lane single carriageway A roads and roads with a 30 mph speed limit;
- In general, collisions occurred in daylight or where there was street lighting, probably because most unprotected lighting columns and signposts are in urban areas. Road surface and weather conditions appeared to have little effect on the number and/or severity of collisions.

7.5 Cost Benefit of Passively Safe Lighting Columns and Signposts

In cost benefit terms, passively safe lighting columns and signposts can have a better whole life cost than conventional posts if made from longer lasting materials. Their capital cost has fallen since they have become more widely used, particularly if compared with the combined cost of a conventional post and protective barrier, although this saving may not apply to posts in urban areas. The cost of erecting a short length of barrier is greater where energy absorbing terminals are used instead of ramped ends.

It is difficult to estimate the cost-benefit as a First Year Rate of Return, but a more general estimate suggests a substantial return on investment due to the predicted reduction in impact severity.

7.6 Risk Assessment of Passively Safe Lighting Columns and Signposts on Rural Roads

On rural roads, the risk per year of hitting a passively safe lighting column or post will be lower than that associated with a conventional lighting column or signpost protected with a barrier. However, the balance of risk will be different, with the lower risk for vehicle occupants hitting a passively safe post partially offset by a small probability that the lighting column or signpost could fall onto the carriageway and causing a secondary collision. For a conventional post, there is a high risk to the occupant of an errant vehicle which reaches the post, but very little risk to other road users (the risk of secondary collisions from a vehicle rebounding from the post or protective barrier has not been considered here).

It should be noted that passively safe lighting columns and signposts on rural roads are likely to be hit more frequently because of the absence of a barrier. This could increase the number of collisions in which debris falls from a lighting column. However, in practice there are unlikely to be pedestrians in the vicinity of columns on rural roads.

The National Annex recommends the use of 100 NE signposts and lighting columns on rural roads unless there are significant numbers of non-motorised users at risk from items falling on other carriageways.

7.7 Risk Assessment of Passively Safe Lighting Columns and Signposts on Urban Roads

The risk to pedestrians is much greater in urban areas than in rural ones. Risk depends strongly on the numbers exposed and therefore passively safe lighting columns and signposts may not be appropriate where there are likely to be substantial numbers of pedestrians on a regular basis.

Where speeds are very low, for example, in 20 mph zones, or on housing estates, there is little advantage in using passively safe signposts and lighting columns.

Passively safe lighting columns should be used on major roads where there is little likelihood of their falling onto the carriageway or of there being pedestrians. Since most of the run-off collisions occur at night, the latter will not be an issue in many locations. The errant vehicle itself will often pose the greatest risk to pedestrians.

The National Annex recommends the use of 70 LE or HE lighting columns in urban areas and 70 LE for signposts.

8 Recommendations

It is recommended that passively safe lighting columns and signposts continue to be used in accordance with the National Annex to BS EN 12767. In particular, they should be used in most situations on rural roads, especially where it is difficult to use a safety barrier. They are less necessary where there is an existing barrier (or a need for one), or where there is a building or hard landscaping close to the carriageway. A shear base should only be used where any impact will be at the correct height for the base to work correctly. The design requirement should be assessed on a site-specific basis.

The risk to pedestrians depends strongly on the numbers exposed and therefore the recommendations in the National Annex to BS EN 12767 that passively safe lighting columns and signposts may not be appropriate where there are likely to be substantial numbers of pedestrians on a regular basis should be retained. In these circumstances, the safety of pedestrians might need to be considered separately as the risk of an errant vehicle is greater than that from a falling column or signpost.

In urban areas where speeds are low, for example in 20 mph zones or on housing estates, there is little if any advantage in using passively safe signposts and lighting columns.

Passively safe lighting columns should be used on major urban roads where there is little likelihood of their falling onto the carriageway or of substantial numbers of pedestrians being in the vicinity. Since most of the run-off collisions occur at night, the latter will not be an issue in many locations. The errant vehicle itself will often pose the greatest risk to pedestrians.

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Appendix A Casualties from Lighting Column Impacts

TOTAL NUMBER OF COLLISIONS: 12391

TOTAL NUMBER OF CASUALTIES: 16987

Object Hit in Carriageway

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
None	271	2035	9710	**12016**	*66.7*	*68.0*	*71.5*
Previous Accident	0	1	0	**1**	*0.0*	*0.0*	*0.0*
Roadworks	0	4	11	**15**	*0.0*	*0.1*	*0.1*
Parked vehicle	0	1	7	**8**	*0.0*	*0.0*	*0.1*
Bridge - roof	0	0	1	**1**	*0.0*	*0.0*	*0.0*
Bridge - side	3	5	20	**28**	*0.7*	*0.2*	*0.1*
Bollard/refuge	11	96	378	**485**	*2.7*	*3.2*	*2.8*
Open door of vehicle	0	2	0	**2**	*0.0*	*0.1*	*0.0*
Central island of roundabout	2	31	136	**169**	*0.5*	*1.0*	*1.0*
Kerb	117	803	3209	**4129**	*28.8*	*26.8*	*23.6*
Other object	2	14	107	**123**	*0.5*	*0.5*	*0.8*
An animal	0	1	7	**8**	*0.0*	*0.0*	*0.1*
Unknown	0	1	1	**2**	*0.0*	*0.0*	*0.0*
TOTAL	**406**	**2994**	**13587**	**16987**	*100.0*	*100.0*	*100.0*

Vehicle Leaving Carriageway

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Did not leave carriageway	6	121	732	**859**	*1.5*	*4.0*	*5.4*
Left the carriageway to the nearside	227	1634	7617	**9478**	*55.9*	*54.6*	*56.1*
Left the carriageway to the nearside and rebounded	33	255	1164	**1452**	*8.1*	*8.5*	*8.6*
Left the carriageway straight ahead at a junction	8	66	353	**427**	*2.0*	*2.2*	*2.6*
Left the carriageway to the offside onto the central reserve	23	86	402	**511**	*5.7*	*2.9*	*3.0*
Left the carriageway to the offside onto the cen res and rebounded	6	33	94	**133**	*1.5*	*1.1*	*0.7*
Left the carriageway to the offside and crossed the cen res	8	22	117	**147**	*2.0*	*0.7*	*0.9*
Left the carriageway to the offside	86	657	2699	**3442**	*21.2*	*21.9*	*19.9*
Left the carriageway to the offside and rebounded	9	120	409	**538**	*2.2*	*4.0*	*3.0*
Unknown	0	0	0	**0**	*0.0*	*0.0*	*0.0*
TOTAL	**406**	**2994**	**13587**	**16987**	*100.0*	*100.0*	*100.0*

Casualty Age

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
<18	59	423	1959	**2441**	*14.5*	*14.1*	*14.4*
18 - 25	181	1267	5482	**6930**	*44.6*	*42.3*	*40.3*
26 - 35	84	591	2600	**3275**	*20.7*	*19.7*	*19.1*
36 - 45	43	279	1434	**1756**	*10.6*	*9.3*	*10.6*
46 - 55	14	145	783	**942**	*3.4*	*4.8*	*5.8*
56 - 65	6	94	437	**537**	*1.5*	*3.1*	*3.2*
65+	19	142	618	**779**	*4.7*	*4.7*	*4.5*
Unknown	0	53	274	**327**	*0.0*	*1.8*	*2.0*
TOTAL	**406**	**2994**	**13587**	**16987**	*100.0*	*100.0*	*100.0*

Driver Age

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
<18	45	241	878	**1164**	*11.1*	*8.0*	*6.5*
18 - 25	186	1326	5813	**7325**	*45.8*	*44.3*	*42.8*
26 - 35	91	645	2959	**3695**	*22.4*	*21.5*	*21.8*
36 - 45	43	308	1686	**2037**	*10.6*	*10.3*	*12.4*
46 - 55	15	152	844	**1011**	*3.7*	*5.1*	*6.2*
56 - 65	5	89	464	**558**	*1.2*	*3.0*	*3.4*
65+	18	136	609	**763**	*4.4*	*4.5*	*4.5*
Unknown	3	97	334	**434**	*0.7*	*3.2*	*2.5*
TOTAL	**406**	**2994**	**13587**	**16987**	*100.0*	*100.0*	*100.0*

Driver Sex

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Male	369	2492	10443	**13304**	*90.9*	*83.2*	*76.9*
Female	33	439	2965	**3437**	*8.1*	*14.7*	*21.8*
Not traced	4	63	179	**246**	*1.0*	*2.1*	*1.3*
Unknown	0	0	0	**0**	*0.0*	*0.0*	*0.0*
TOTAL	**406**	**2994**	**13587**	**16987**	*100.0*	*100.0*	*100.0*

Skidding and Overturning

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
No skidding, jack-knifing or overturning	167	1368	6134	**7669**	*41.1*	*45.7*	*45.1*
Skidded	145	1129	5469	**6743**	*35.7*	*37.7*	*40.3*
Skidded and overturned	59	308	1074	**1441**	*14.5*	*10.3*	*7.9*
Jack-knifed	0	0	18	**18**	*0.0*	*0.0*	*0.1*
Jack-knifed and overturned	0	1	8	**9**	*0.0*	*0.0*	*0.1*
Overturned	34	187	877	**1098**	*8.4*	*6.2*	*6.5*
Unknown	1	1	7	**9**	*0.2*	*0.0*	*0.1*
TOTAL	**406**	**2994**	**13587**	**16987**	*100.0*	*100.0*	*100.0*

Vehicle Type

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Pedal cycle	2	10	19	**31**	*0.5*	*0.3*	*0.1*
Motorcycle 50cc or less	3	38	25	**66**	*0.7*	*1.3*	*0.2*
Motorcycle 50-125cc	37	111	70	**218**	*9.1*	*3.7*	*0.5*
Motorcycle 125-500cc	55	133	95	**283**	*13.5*	*4.4*	*0.7*
Motorcycle over 500cc	22	40	20	**82**	*5.4*	*1.3*	*0.1*
Taxi	0	8	59	**67**	*0.0*	*0.3*	*0.4*
Car	275	2520	12408	**15203**	*67.7*	*84.2*	*91.3*
Minibus (8-16 passenger seats)	0	7	57	**64**	*0.0*	*0.2*	*0.4*
Bus or coach (17 or more passenger seats)	1	12	161	**174**	*0.2*	*0.4*	*1.2*
Other motor vehicle	1	5	46	**52**	*0.2*	*0.2*	*0.3*
Agricultural vehicle	0	0	4	**4**	*0.0*	*0.0*	*0.0*
Goods vehicle 3.5T or less	8	53	332	**393**	*2.0*	*1.8*	*2.4*
Goods vehicle over 3.5T and under 7.5T	0	6	24	**30**	*0.0*	*0.2*	*0.2*
Goods vehicle over 7.5T	2	51	267	**320**	*0.5*	*1.7*	*2.0*
Unknown	0	0	0	**0**	*0.0*	*0.0*	*0.0*
TOTAL	**406**	**2994**	**13587**	**16987**	*100.0*	*100.0*	*100.0*

Time of Incident

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
00:00 - 00:59	40	229	875	**1144**	*9.9*	*7.6*	*6.4*
01:00 - 01:59	34	214	678	**926**	*8.4*	*7.1*	*5.0*
02:00 - 02:59	25	192	679	**896**	*6.2*	*6.4*	*5.0*
03:00 - 03:59	24	144	514	**682**	*5.9*	*4.8*	*3.8*
04:00 - 04:59	11	98	313	**422**	*2.7*	*3.3*	*2.3*
05:00 - 05:59	9	79	296	**384**	*2.2*	*2.6*	*2.2*
06:00 - 06:59	8	52	351	**411**	*2.0*	*1.7*	*2.6*
07:00 - 07:59	9	75	437	**521**	*2.2*	*2.5*	*3.2*
08:00 - 08:59	6	63	460	**529**	*1.5*	*2.1*	*3.4*
09:00 - 09:59	8	63	409	**480**	*2.0*	*2.1*	*3.0*
10:00 - 10:59	7	49	457	**513**	*1.7*	*1.6*	*3.4*
11:00 - 11:59	9	64	396	**469**	*2.2*	*2.1*	*2.9*
12:00 - 12:59	14	94	481	**589**	*3.4*	*3.1*	*3.5*
13:00 - 13:59	7	97	479	**583**	*1.7*	*3.2*	*3.5*
14:00 - 14:59	16	93	524	**633**	*3.9*	*3.1*	*3.9*
15:00 - 15:59	16	123	551	**690**	*3.9*	*4.1*	*4.1*
16:00 - 16:59	11	120	572	**703**	*2.7*	*4.0*	*4.2*
17:00 - 17:59	13	87	493	**593**	*3.2*	*2.9*	*3.6*
18:00 - 18:59	13	112	594	**719**	*3.2*	*3.7*	*4.4*
19:00 - 19:59	15	124	604	**743**	*3.7*	*4.1*	*4.4*
20:00 - 20:59	16	150	711	**877**	*3.9*	*5.0*	*5.2*
21:00 - 21:59	31	196	811	**1038**	*7.6*	*6.5*	*6.0*
22:00 - 22:59	24	225	889	**1138**	*5.9*	*7.5*	*6.5*
23:00 - 23:59	40	251	1013	**1304**	*9.9*	*8.4*	*7.5*
Unknown	0	0	0	**0**	*0.0*	*0.0*	*0.0*
TOTAL	**406**	**2994**	**13587**	**16987**	*100.0*	*100.0*	*100.0*

Day

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Monday	55	372	1790	**2217**	*13.5*	*12.4*	*13.2*
Tuesday	32	333	1571	**1936**	*7.9*	*11.1*	*11.6*
Wednesday	26	331	1525	**1882**	*6.4*	*11.1*	*11.2*
Thursday	45	313	1558	**1916**	*11.1*	*10.5*	*11.5*
Friday	70	394	1927	**2391**	*17.2*	*13.2*	*14.2*
Saturday	96	642	2549	**3287**	*23.6*	*21.4*	*18.8*
Sunday	82	609	2667	**3358**	*20.2*	*20.3*	*19.6*
TOTAL	**406**	**2994**	**13587**	**16987**	*100.0*	*100.0*	*100.0*

Month of Incident

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
January	29	244	1176	**1449**	*7.1*	*8.1*	*8.7*
February	34	204	1056	**1294**	*8.4*	*6.8*	*7.8*
March	26	233	942	**1201**	*6.4*	*7.8*	*6.9*
April	37	256	965	**1258**	*9.1*	*8.6*	*7.1*
May	38	265	1102	**1405**	*9.4*	*8.9*	*8.1*
June	46	255	1183	**1484**	*11.3*	*8.5*	*8.7*
July	35	258	1181	**1474**	*8.6*	*8.6*	*8.7*
August	33	259	1160	**1452**	*8.1*	*8.7*	*8.5*
September	28	258	1161	**1447**	*6.9*	*8.6*	*8.5*
October	42	287	1161	**1490**	*10.3*	*9.6*	*8.5*
November	24	242	1189	**1455**	*5.9*	*8.1*	*8.8*
December	34	233	1311	**1578**	*8.4*	*7.8*	*9.6*
Unknown	0	0	0	**0**	*0.0*	*0.0*	*0.0*
TOTAL	**406**	**2994**	**13587**	**16987**	*100.0*	*100.0*	*100.0*

Road Type

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Roundabout	11	220	1716	**1947**	*2.7*	*7.3*	*12.6*
One way street	8	81	384	**473**	*2.0*	*2.7*	*2.8*
Dual carriageway - 2 lanes	99	499	2278	**2876**	*24.4*	*16.7*	*16.8*
Dual carriageway - 3 or more lanes	20	124	345	**489**	*4.9*	*4.1*	*2.5*
Single track road	1	20	104	**125**	*0.2*	*0.7*	*0.8*
Single carriageway - 2 lanes	263	1976	8439	**10678**	*64.8*	*66.0*	*62.1*
Single carriageway - 3 lanes	3	46	220	**269**	*0.7*	*1.5*	*1.6*
Single carriageway - 4 lanes	0	23	77	**100**	*0.0*	*0.8*	*0.6*
Unknown	1	5	24	**30**	*0.2*	*0.2*	*0.2*
TOTAL	**406**	**2994**	**13587**	**16987**	*100.0*	*100.0*	*100.0*

Road Speed Limit

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
20	1	4	39	**44**	*0.2*	*0.1*	*0.3*
30	221	1786	7735	**9742**	*54.4*	*59.7*	*56.9*
40	69	445	2045	**2559**	*17.0*	*14.9*	*15.1*
50	18	158	604	**780**	*4.4*	*5.3*	*4.4*
60	39	305	1923	**2267**	*9.6*	*10.2*	*14.2*
70	58	296	1241	**1595**	*14.3*	*9.9*	*9.1*
Unknown	0	0	0	**0**	*0.0*	*0.0*	*0.0*
TOTAL	**406**	**2994**	**13587**	**16987**	*100.0*	*100.0*	*100.0*

Road Class

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Motorway	20	77	275	**372**	*4.9*	*2.6*	*2.0*
A(M)	1	6	18	**25**	*0.2*	*0.2*	*0.1*
A	213	1547	6970	**8730**	*52.5*	*51.7*	*51.3*
B	47	362	1578	**1987**	*11.6*	*12.1*	*11.6*
C	31	217	1022	**1270**	*7.6*	*7.2*	*7.5*
Unclassified	94	785	3724	**4603**	*23.2*	*26.2*	*27.4*
Unknown	0	0	0	**0**	*0.0*	*0.0*	*0.0*
TOTAL	**406**	**2994**	**13587**	**16987**	*100.0*	*100.0*	*100.0*

Road Surface

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Dry	257	1769	6880	**8906**	*63.3*	*59.1*	*50.6*
Wet/damp	138	1110	5897	**7145**	*34.0*	*37.1*	*43.4*
Snow	1	19	123	**143**	*0.2*	*0.6*	*0.9*
Frost/ice	7	80	579	**666**	*1.7*	*2.7*	*4.3*
Flood (3cm of water or deeper)	3	8	36	**47**	*0.7*	*0.3*	*0.3*
Oil or diesel	0	8	51	**59**	*0.0*	*0.3*	*0.4*
Mud	0	0	16	**16**	*0.0*	*0.0*	*0.1*
Unknown	0	0	5	**5**	*0.0*	*0.0*	*0.0*
TOTAL	**406**	**2994**	**13587**	**16987**	*100.0*	*100.0*	*100.0*

Lighting

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Daylight; street lights present	141	1081	5844	**7066**	*34.7*	*36.1*	*43.0*
Daylight; no street lights present	8	75	431	**514**	*2.0*	*2.5*	*3.2*
Daylight; street lights unknown	2	19	122	**143**	*0.5*	*0.6*	*0.9*
Darkness; street lights present and lit	243	1727	6747	**8717**	*59.9*	*57.7*	*49.7*
Darkness; street lights present but unlit	7	57	243	**307**	*1.7*	*1.9*	*1.8*
Darkness; no street lights present	3	19	100	**122**	*0.7*	*0.6*	*0.7*
Darkness; street lights unknown	2	16	100	**118**	*0.5*	*0.5*	*0.7*
Unknown	0	0	0	**0**	*0.0*	*0.0*	*0.0*
TOTAL	**406**	**2994**	**13587**	**16987**	*100.0*	*100.0*	*100.0*

Weather

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Fine without high winds	333	2364	9860	**12557**	*82.0*	*79.0*	*72.6*
Raining without high winds	38	427	2529	**2994**	*9.4*	*14.3*	*18.6*
Snowing without high winds	3	16	131	**150**	*0.7*	*0.5*	*1.0*
Fine with high winds	8	35	149	**192**	*2.0*	*1.2*	*1.1*
Raining with high winds	12	32	215	**259**	*3.0*	*1.1*	*1.6*
Snowing with high winds	0	4	31	**35**	*0.0*	*0.1*	*0.2*
Fog or mist	1	26	125	**152**	*0.2*	*0.9*	*0.9*
Other	10	80	462	**552**	*2.5*	*2.7*	*3.4*
Unknown	1	10	85	**96**	*0.2*	*0.3*	*0.6*
TOTAL	**406**	**2994**	**13587**	**16987**	*100.0*	*100.0*	*100.0*

Appendix B Casualties from Signpost / Traffic Signal Impacts

TOTAL NUMBER OF COLLISIONS: 8849

TOTAL NUMBER OF CASUALTIES: 11524

Object Hit in Carriageway

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
None	174	1332	6962	**8468**	*69.6*	*72.3*	*73.8*
Previous Accident	0	0	0	**0**	*0.0*	*0.0*	*0.0*
Roadworks	0	9	36	**45**	*0.0*	*0.5*	*0.4*
Parked vehicle	1	4	1	**6**	*0.4*	*0.2*	*0.0*
Bridge - roof	0	0	4	**4**	*0.0*	*0.0*	*0.0*
Bridge - side	3	3	19	**25**	*1.2*	*0.2*	*0.2*
Bollard/refuge	6	83	540	**629**	*2.4*	*4.5*	*5.7*
Open door of vehicle	0	1	1	**2**	*0.0*	*0.1*	*0.0*
Central island of roundabout	5	101	432	**538**	*2.0*	*5.5*	*4.6*
Kerb	57	292	1334	**1683**	*22.8*	*15.8*	*14.1*
Other object	3	17	88	**108**	*1.2*	*0.9*	*0.9*
An animal	1	1	10	**12**	*0.4*	*0.1*	*0.1*
Unknown	0	0	4	**4**	*0.0*	*0.0*	*0.0*
TOTAL	**250**	**1843**	**9431**	**11524**	*100.0*	*100.0*	*100.0*

Vehicle Leaving Carriageway

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Did not leave carriageway	11	101	728	**840**	*4.4*	*5.5*	*7.7*
Left the carriageway to the nearside	134	928	4393	**5455**	*53.6*	*50.4*	*46.6*
Left the carriageway to the nearside and rebounded	11	118	692	**821**	*4.4*	*6.4*	*7.3*
Left the carriageway straight ahead at a junction	15	190	889	**1094**	*6.0*	*10.3*	*9.4*
Left the carriageway to the offside onto the central reserve	15	50	278	**343**	*6.0*	*2.7*	*2.9*
Left the carriageway to the offside onto the cen res and rebounded	6	19	70	**95**	*2.4*	*1.0*	*0.7*
Left the carriageway to the offside and crossed the cen res	1	25	92	**118**	*0.4*	*1.4*	*1.0*
Left the carriageway to the offside	49	321	1892	**2262**	*19.6*	*17.4*	*20.1*
Left the carriageway to the offside and rebounded	8	91	396	**495**	*3.2*	*4.9*	*4.2*
Unknown	0	0	1	**1**	*0.0*	*0.0*	*0.0*
TOTAL	**250**	**1843**	**9431**	**11524**	*100.0*	*100.0*	*100.0*

Casualty Age

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
<18	11	169	1130	**1310**	*4.4*	*9.2*	*12.0*
18 - 25	94	625	3596	**4315**	*37.6*	*33.9*	*38.1*
26 - 35	57	415	1804	**2276**	*22.8*	*22.5*	*19.1*
36 - 45	43	278	1167	**1488**	*17.2*	*15.1*	*12.4*
46 - 55	22	148	666	**836**	*8.8*	*8.0*	*7.1*
56 - 65	12	72	378	**462**	*4.8*	*3.9*	*4.0*
65+	11	113	526	**650**	*4.4*	*6.1*	*5.6*
Unknown	0	23	164	**187**	*0.0*	*1.2*	*1.7*
TOTAL	**250**	**1843**	**9431**	**11524**	*100.0*	*100.0*	*100.0*

Driver Age

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
<18	11	96	520	**627**	*4.4*	*5.2*	*5.5*
18 - 25	90	652	3756	**4498**	*36.0*	*35.4*	*39.8*
26 - 35	57	418	1976	**2451**	*22.8*	*22.7*	*21.0*
36 - 45	43	290	1311	**1644**	*17.2*	*15.7*	*13.9*
46 - 55	21	158	775	**954**	*8.4*	*8.6*	*8.2*
56 - 65	13	78	411	**502**	*5.2*	*4.2*	*4.4*
65+	12	116	516	**644**	*4.8*	*6.3*	*5.5*
Unknown	3	35	166	**204**	*1.2*	*1.9*	*1.8*
TOTAL	**250**	**1843**	**9431**	**11524**	*100.0*	*100.0*	*100.0*

Driver Sex

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Male	221	1550	6973	**8744**	*88.4*	*84.1*	*73.9*
Female	26	268	2371	**2665**	*10.4*	*14.5*	*25.1*
Not traced	3	25	87	**115**	*1.2*	*1.4*	*0.9*
Unknown	0	0	0	**0**	*0.0*	*0.0*	*0.0*
TOTAL	**250**	**1843**	**9431**	**11524**	*100.0*	*100.0*	*100.0*

Skidding and Overturning

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
No skidding, jack-knifing or overturning	115	722	3557	**4394**	*46.0*	*39.2*	*37.7*
Skidded	68	576	3295	**3939**	*27.2*	*31.3*	*34.9*
Skidded and overturned	39	324	1609	**1972**	*15.6*	*17.6*	*17.1*
Jack-knifed	0	0	8	**8**	*0.0*	*0.0*	*0.1*
Jack-knifed and overturned	0	3	14	**17**	*0.0*	*0.2*	*0.1*
Overturned	28	217	944	**1189**	*11.2*	*11.8*	*10.0*
Unknown	0	1	4	**5**	*0.0*	*0.1*	*0.0*
TOTAL	**250**	**1843**	**9431**	**11524**	*100.0*	*100.0*	*100.0*

Vehicle Type

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Pedal cycle	0	6	17	**23**	*0.0*	*0.3*	*0.2*
Motorcycle 50cc or less	4	25	26	**55**	*1.6*	*1.4*	*0.3*
Motorcycle 50-125cc	8	53	51	**112**	*3.2*	*2.9*	*0.5*
Motorcycle 125-500cc	55	208	145	**408**	*22.0*	*11.3*	*1.5*
Motorcycle over 500cc	21	79	45	**145**	*8.4*	*4.3*	*0.5*
Taxi	1	9	67	**77**	*0.4*	*0.5*	*0.7*
Car	154	1346	8481	**9981**	*61.6*	*73.0*	*89.9*
Minibus (8-16 passenger seats)	0	1	29	**30**	*0.0*	*0.1*	*0.3*
Bus or coach (17 or more passenger seats)	0	1	47	**48**	*0.0*	*0.1*	*0.5*
Other motor vehicle	1	6	34	**41**	*0.4*	*0.3*	*0.4*
Agricultural vehicle	1	0	2	**3**	*0.4*	*0.0*	*0.0*
Goods vehicle 3.5T or less	2	54	257	**313**	*0.8*	*2.9*	*2.7*
Goods vehicle over 3.5T and under 7.5T	0	7	21	**28**	*0.0*	*0.4*	*0.2*
Goods vehicle over 7.5T	3	48	208	**259**	*1.2*	*2.6*	*2.2*
Unknown	0	0	1	**1**	*0.0*	*0.0*	*0.0*
TOTAL	**250**	**1843**	**9431**	**11524**	*100.0*	*100.0*	*100.0*

Time of Incident

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
00:00 - 00:59	22	142	590	**754**	*8.8*	*7.7*	*6.3*
01:00 - 01:59	11	119	420	**550**	*4.4*	*6.5*	*4.5*
02:00 - 02:59	9	110	515	**634**	*3.6*	*6.0*	*5.5*
03:00 - 03:59	9	72	320	**401**	*3.6*	*3.9*	*3.4*
04:00 - 04:59	19	49	224	**292**	*7.6*	*2.7*	*2.4*
05:00 - 05:59	11	49	208	**268**	*4.4*	*2.7*	*2.2*
06:00 - 06:59	11	45	306	**362**	*4.4*	*2.4*	*3.2*
07:00 - 07:59	4	57	337	**398**	*1.6*	*3.1*	*3.6*
08:00 - 08:59	8	55	327	**390**	*3.2*	*3.0*	*3.5*
09:00 - 09:59	6	44	284	**334**	*2.4*	*2.4*	*3.0*
10:00 - 10:59	3	49	264	**316**	*1.2*	*2.7*	*2.8*
11:00 - 11:59	7	48	300	**355**	*2.8*	*2.6*	*3.2*
12:00 - 12:59	5	64	359	**428**	*2.0*	*3.5*	*3.8*
13:00 - 13:59	7	64	344	**415**	*2.8*	*3.5*	*3.6*
14:00 - 14:59	8	70	342	**420**	*3.2*	*3.8*	*3.6*
15:00 - 15:59	11	75	381	**467**	*4.4*	*4.1*	*4.0*
16:00 - 16:59	5	83	403	**491**	*2.0*	*4.5*	*4.3*
17:00 - 17:59	8	73	397	**478**	*3.2*	*4.0*	*4.2*
18:00 - 18:59	8	70	414	**492**	*3.2*	*3.8*	*4.4*
19:00 - 19:59	9	91	431	**531**	*3.6*	*4.9*	*4.6*
20:00 - 20:59	8	87	532	**627**	*3.2*	*4.7*	*5.6*
21:00 - 21:59	25	97	497	**619**	*10.0*	*5.3*	*5.3*
22:00 - 22:59	9	98	576	**683**	*3.6*	*5.3*	*6.1*
23:00 - 23:59	27	132	658	**817**	*10.8*	*7.2*	*7.0*
Unknown	0	0	2	**2**	*0.0*	*0.0*	*0.0*
TOTAL	**250**	**1843**	**9431**	**11524**	*100.0*	*100.0*	*100.0*

Day

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Monday	24	211	1181	**1416**	*9.6*	*11.4*	*12.5*
Tuesday	18	190	1080	**1288**	*7.2*	*10.3*	*11.5*
Wednesday	30	202	1085	**1317**	*12.0*	*11.0*	*11.5*
Thursday	28	225	1148	**1401**	*11.2*	*12.2*	*12.2*
Friday	34	264	1393	**1691**	*13.6*	*14.3*	*14.8*
Saturday	54	332	1683	**2069**	*21.6*	*18.0*	*17.8*
Sunday	62	419	1861	**2342**	*24.8*	*22.7*	*19.7*
TOTAL	**250**	**1843**	**9431**	**11524**	*100.0*	*100.0*	*100.0*

Month of Incident

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
January	10	138	796	**944**	*4.0*	*7.5*	*8.4*
February	18	131	733	**882**	*7.2*	*7.1*	*7.8*
March	23	130	722	**875**	*9.2*	*7.1*	*7.7*
April	11	153	743	**907**	*4.4*	*8.3*	*7.9*
May	26	166	741	**933**	*10.4*	*9.0*	*7.9*
June	23	177	744	**944**	*9.2*	*9.6*	*7.9*
July	28	166	790	**984**	*11.2*	*9.0*	*8.4*
August	28	181	805	**1014**	*11.2*	*9.8*	*8.5*
September	22	147	783	**952**	*8.8*	*8.0*	*8.3*
October	22	182	826	**1030**	*8.8*	*9.9*	*8.8*
November	20	150	844	**1014**	*8.0*	*8.1*	*8.9*
December	19	122	904	**1045**	*7.6*	*6.6*	*9.6*
Unknown	0	0	0	**0**	*0.0*	*0.0*	*0.0*
TOTAL	**250**	**1843**	**9431**	**11524**	*100.0*	*100.0*	*100.0*

Road Type

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Roundabout	19	284	1417	**1720**	*7.6*	*15.4*	*15.0*
One way street	5	36	254	**295**	*2.0*	*2.0*	*2.7*
Dual carriageway - 2 lanes	75	392	1825	**2292**	*30.0*	*21.3*	*19.4*
Dual carriageway - 3 or more lanes	16	82	281	**379**	*6.4*	*4.4*	*3.0*
Single track road	1	15	105	**121**	*0.4*	*0.8*	*1.1*
Single carriageway - 2 lanes	126	990	5309	**6425**	*50.4*	*53.7*	*56.3*
Single carriageway - 3 lanes	7	28	165	**200**	*2.8*	*1.5*	*1.7*
Single carriageway - 4 lanes	1	11	52	**64**	*0.4*	*0.6*	*0.6*
Unknown	0	5	23	**28**	*0.0*	*0.3*	*0.2*
TOTAL	**250**	**1843**	**9431**	**11524**	*100.0*	*100.0*	*100.0*

Road Speed Limit

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
20	1	2	17	**20**	*0.4*	*0.1*	*0.2*
30	56	520	3166	**3742**	*22.4*	*28.2*	*33.6*
40	41	218	1088	**1347**	*16.4*	*11.8*	*11.5*
50	14	80	429	**523**	*5.6*	*4.3*	*4.5*
60	81	650	3241	**3972**	*32.4*	*35.3*	*34.4*
70	57	373	1490	**1920**	*22.8*	*20.2*	*15.8*
Unknown	0	0	0	**0**	*0.0*	*0.0*	*0.0*
TOTAL	**250**	**1843**	**9431**	**11524**	*100.0*	*100.0*	*100.0*

Road Class

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Motorway	15	107	314	**436**	*6.0*	*5.8*	*3.3*
A(M)	2	3	36	**41**	*0.8*	*0.2*	*0.4*
A	164	1151	5636	**6951**	*65.6*	*62.5*	*59.8*
B	35	238	1341	**1614**	*14.0*	*12.9*	*14.2*
C	8	113	717	**838**	*3.2*	*6.1*	*7.6*
Unclassified	26	231	1387	**1644**	*10.4*	*12.5*	*14.7*
Unknown	0	0	0	**0**	*0.0*	*0.0*	*0.0*
TOTAL	**250**	**1843**	**9431**	**11524**	*100.0*	*100.0*	*100.0*

Road Surface

	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Dry	173	1174	4686	**6033**	*69.2*	*63.7*	*49.7*
Wet/damp	75	618	4186	**4879**	*30.0*	*33.5*	*44.4*
Snow	0	13	69	**82**	*0.0*	*0.7*	*0.7*
Frost/ice	2	31	408	**441**	*0.8*	*1.7*	*4.3*
Flood (3cm of water or deeper)	0	2	30	**32**	*0.0*	*0.1*	*0.3*
Oil or diesel	0	3	34	**37**	*0.0*	*0.2*	*0.4*
Mud	0	2	18	**20**	*0.0*	*0.1*	*0.2*
Unknown	0	0	0	**0**	*0.0*	*0.0*	*0.0*
TOTAL	**250**	**1843**	**9431**	**11524**	*100.0*	*100.0*	*100.0*

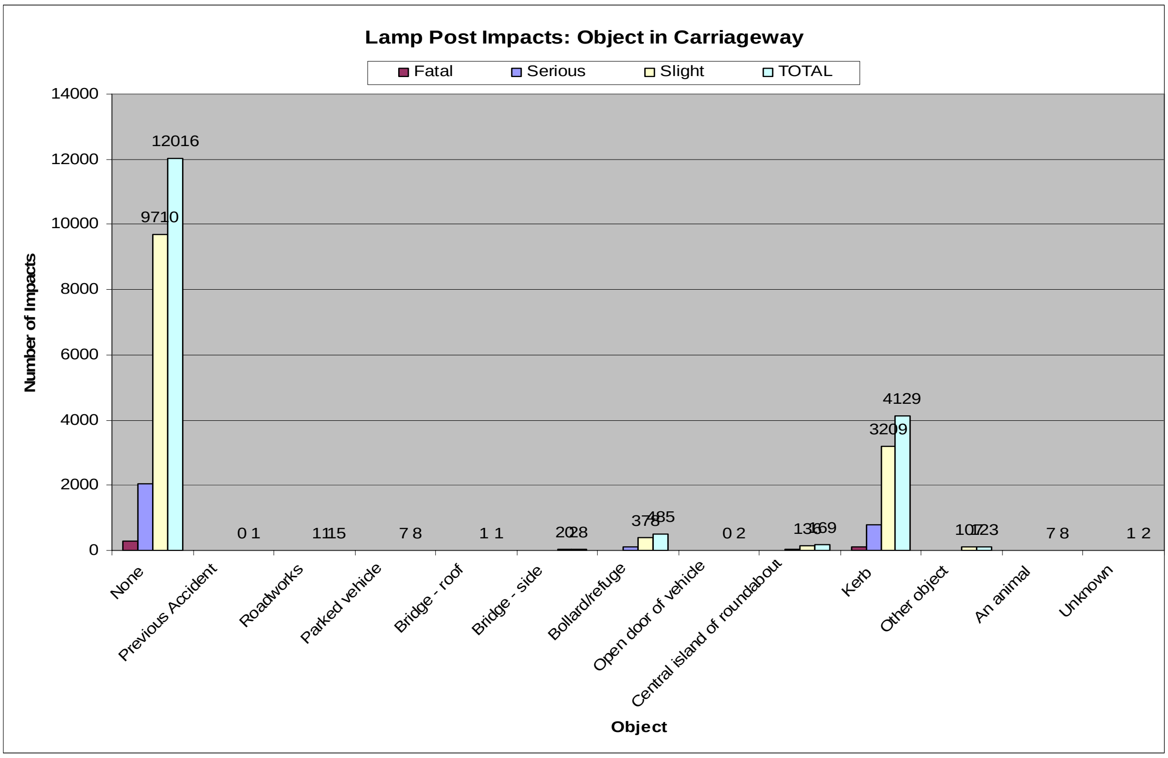
Lighting

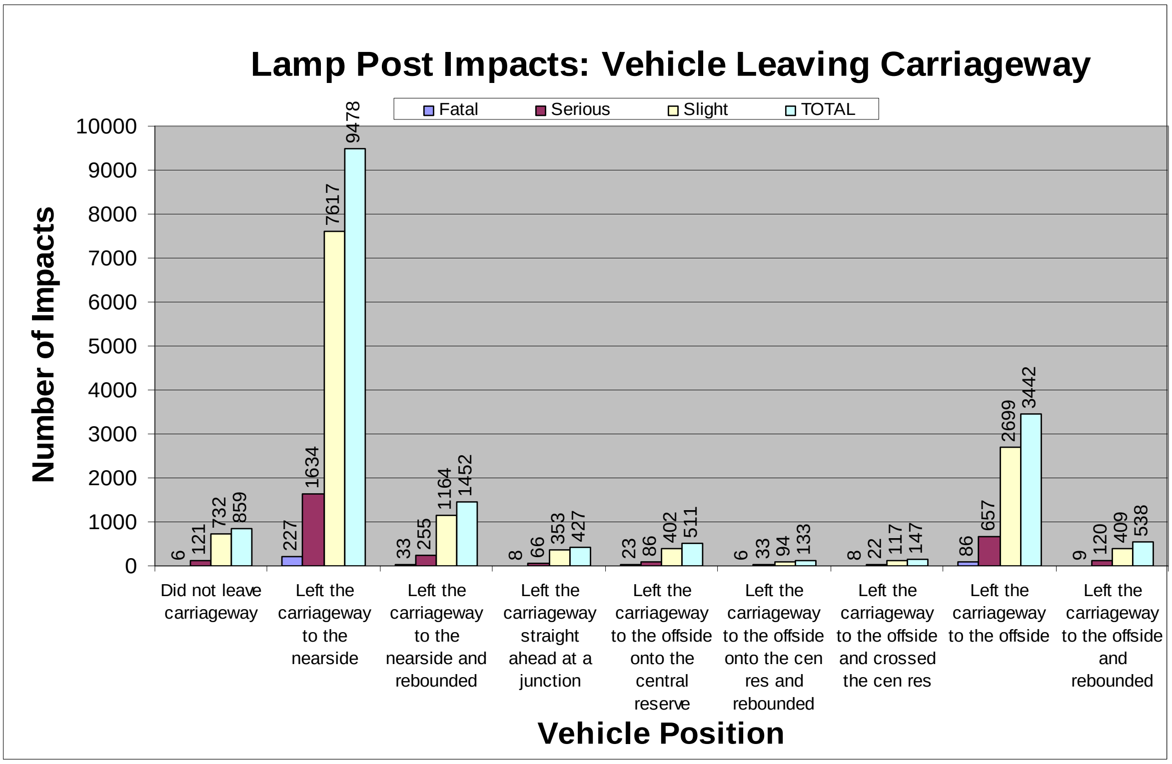
	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Daylight; street lights present	56	444	2458	**2958**	*22.4*	*24.1*	*26.1*
Daylight; no street lights present	46	389	1894	**2329**	*18.4*	*21.1*	*20.1*
Daylight; street lights unknown	3	16	166	**185**	*1.2*	*0.9*	*1.8*
Darkness; street lights present and lit	85	602	3078	**3765**	*34.0*	*32.7*	*32.6*
Darkness; street lights present but unlit	4	24	121	**149**	*1.6*	*1.3*	*1.3*
Darkness; no street lights present	53	347	1627	**2027**	*21.2*	*18.8*	*17.3*
Darkness; street lights unknown	3	21	87	**111**	*1.2*	*1.1*	*0.9*
Unknown	0	0	0	**0**	*0.0*	*0.0*	*0.0*
TOTAL	**250**	**1843**	**9431**	**11524**	*100.0*	*100.0*	*100.0*

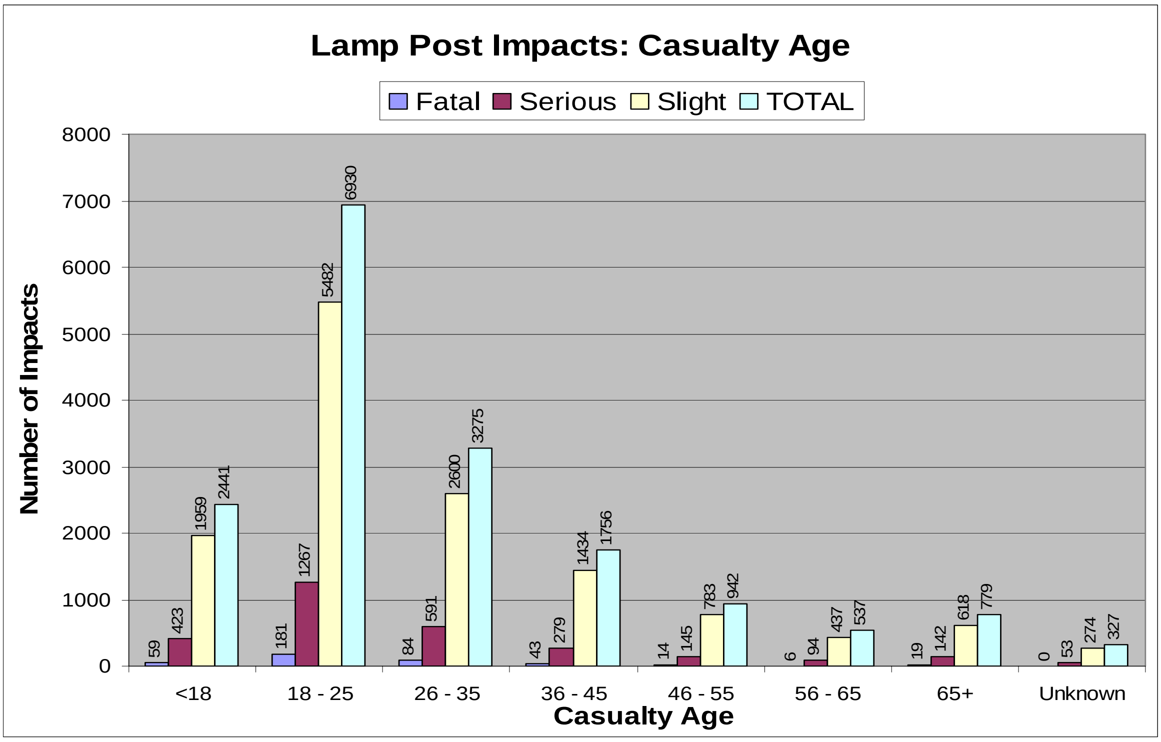
Weather

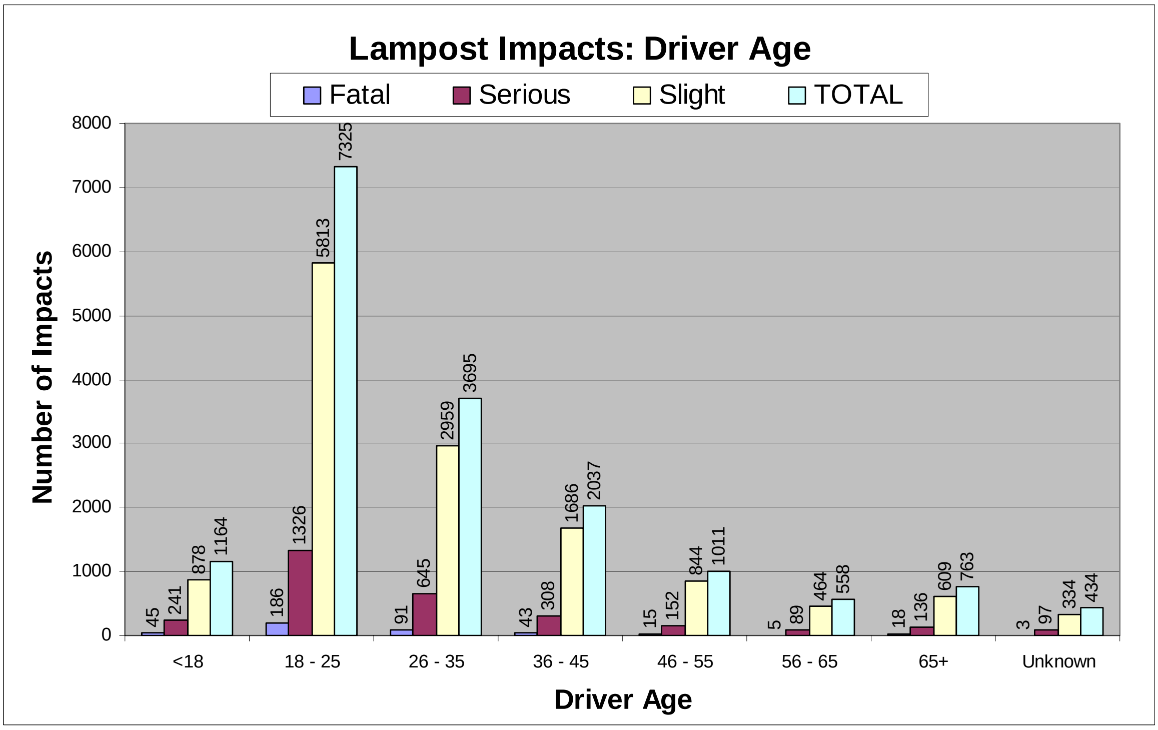
	Fatal	Serious	Slight	TOTAL	%age Fatal	%age Serious	%age Slight
Fine without high winds	218	1516	6779	**8513**	*87.2*	*82.3*	*71.9*
Raining without high winds	21	184	1651	**1856**	*8.4*	*10.0*	*17.5*
Snowing without high winds	0	13	83	**96**	*0.0*	*0.7*	*0.9*
Fine with high winds	1	25	135	**161**	*0.4*	*1.4*	*1.4*
Raining with high winds	3	29	165	**197**	*1.2*	*1.6*	*1.7*
Snowing with high winds	0	2	24	**26**	*0.0*	*0.1*	*0.3*
Fog or mist	2	31	186	**219**	*0.8*	*1.7*	*2.0*
Other	2	32	304	**338**	*0.8*	*1.7*	*3.2*
Unknown	3	11	104	**118**	*1.2*	*0.6*	*1.1*
TOTAL	**250**	**1843**	**9431**	**11524**	*100.0*	*100.0*	*100.0*

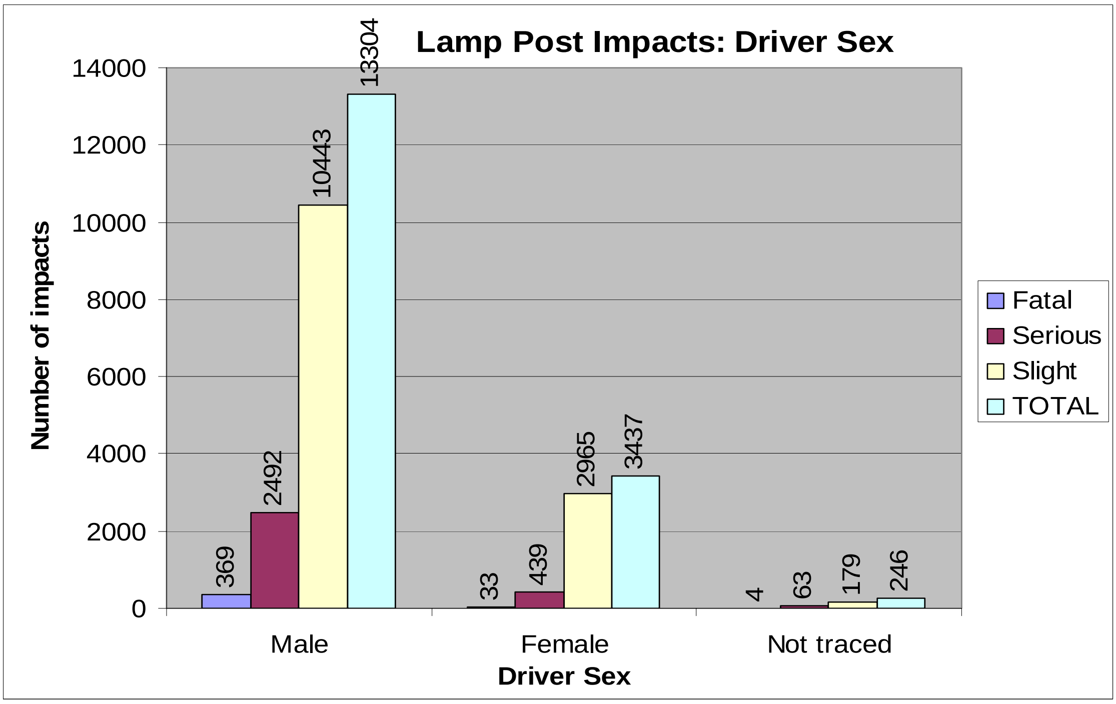
Appendix C Lighting Column Impacts - Graphs

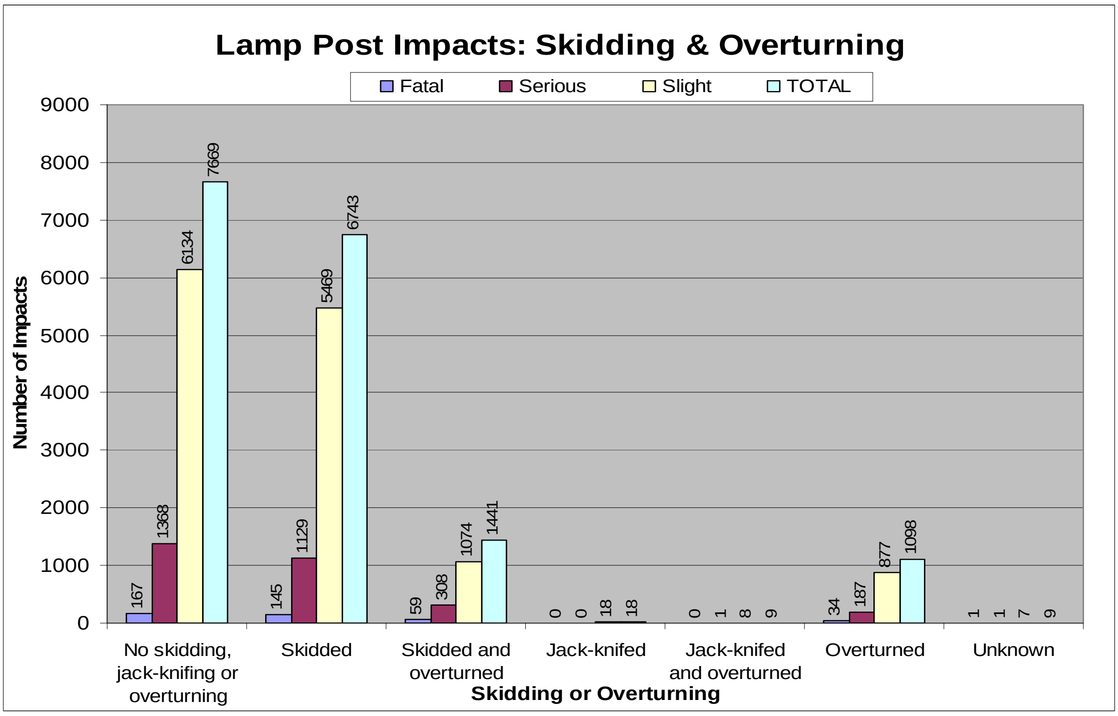


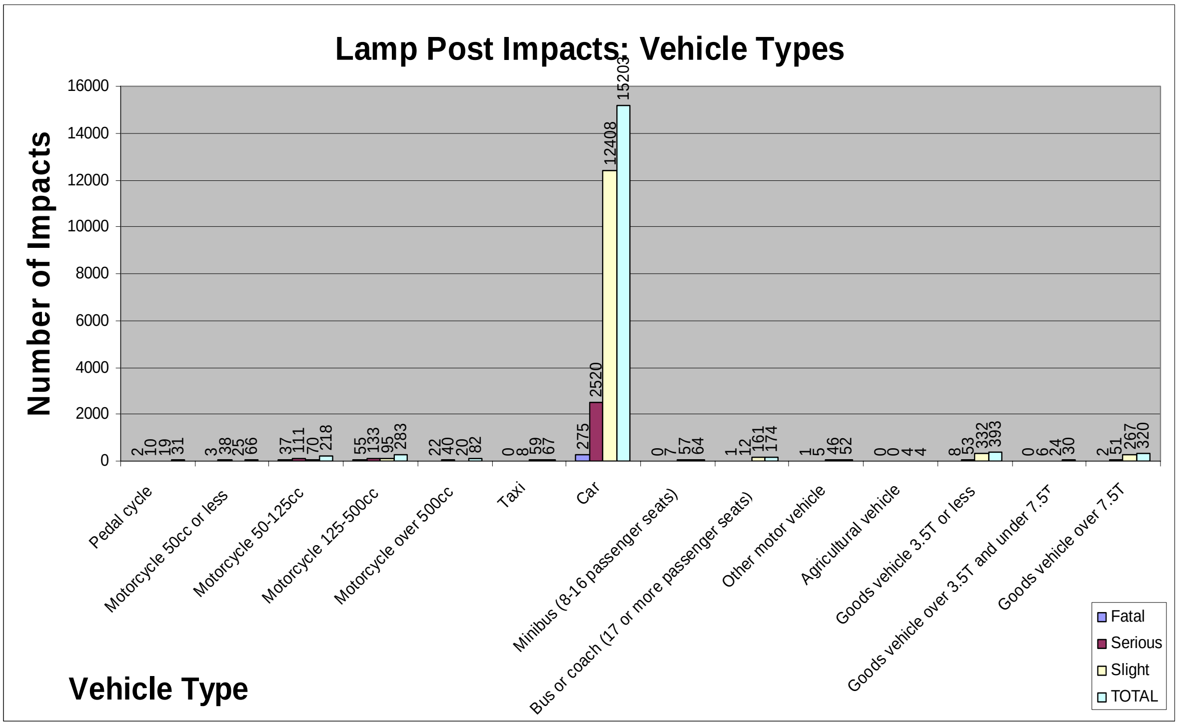


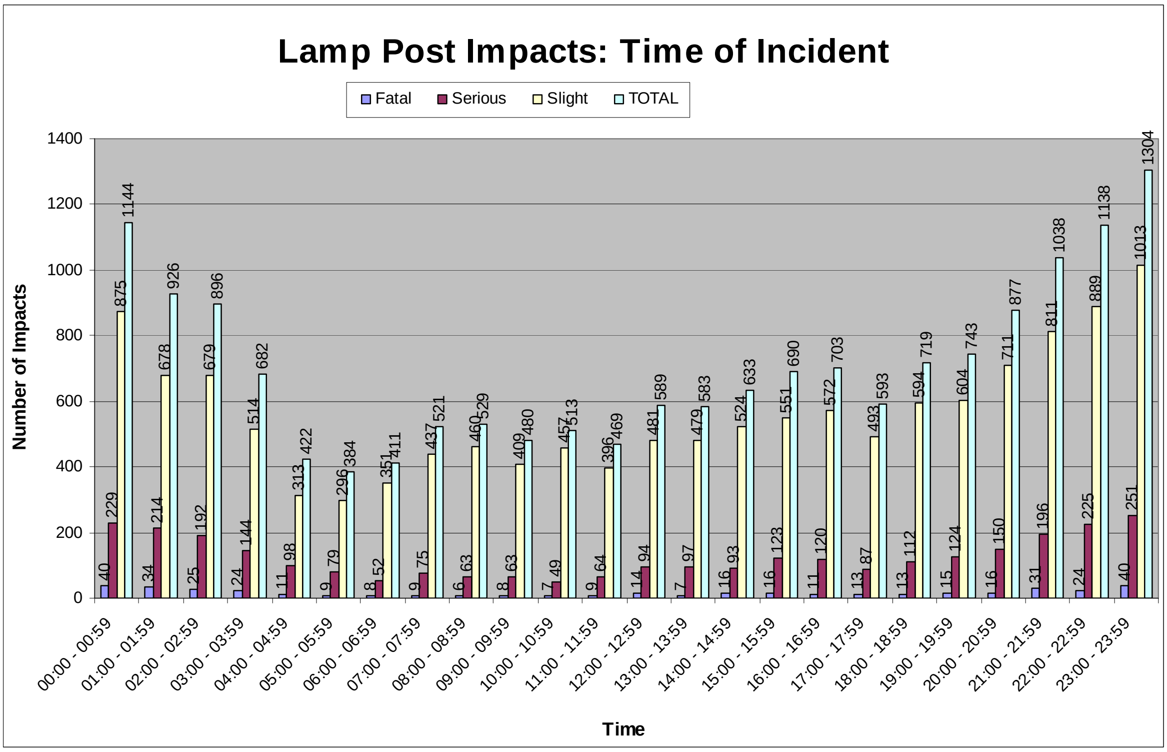

Lamp Post Impacts: Casualty Age
Fatal
Serious
Slight
TOTAL
Number of Impacts
0
1000
2000
3000
4000
5000
6000
7000
8000
59 423 1959 2441
181 1267 5482 6930
84 591 2600 3275
43 279 1434 1756
14 145 783 942
6 94 437 537
19 142 618 779
0 53 274 327
<18
18 - 25
26 - 35
36 - 45
46 - 55
56 - 65
65+
Unknown
Casualty Age

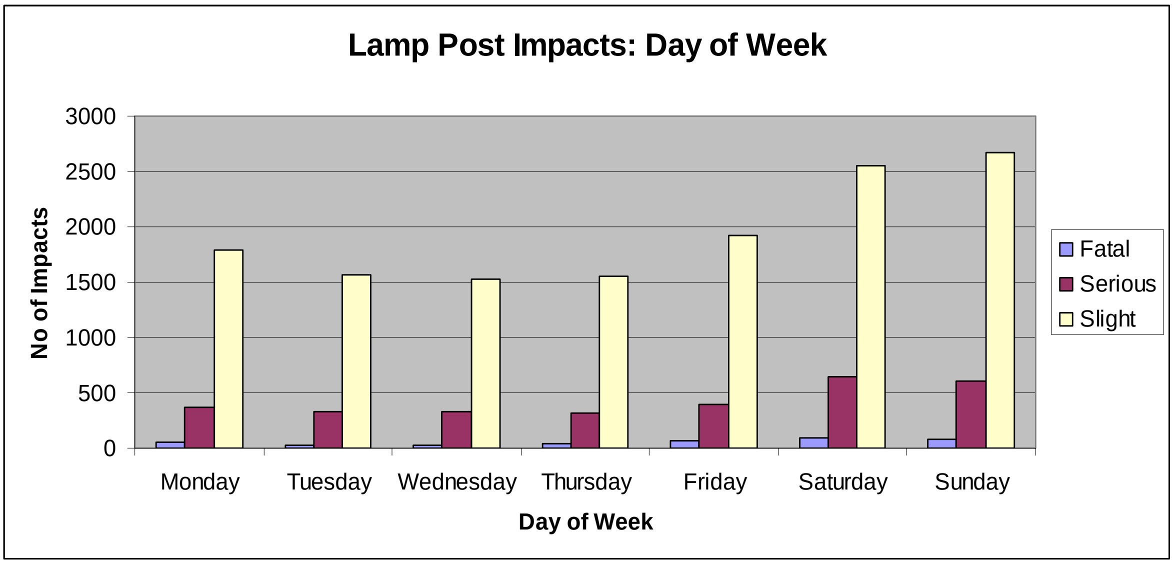

Lampost Impacts: Driver Age
Fatal
Serious
Slight
TOTAL
Number of Impacts
0
1000
2000
3000
4000
5000
6000
7000
8000
45 241 878 1164
186 1326 5813 7325
91 645 2959 3695
43 308 1686 2037
15 152 844 1011
5 89 464 558
18 136 609 763
3 97 334 434
<18
18 - 25
26 - 35
36 - 45
46 - 55
56 - 65
65+
Unknown
Driver Age

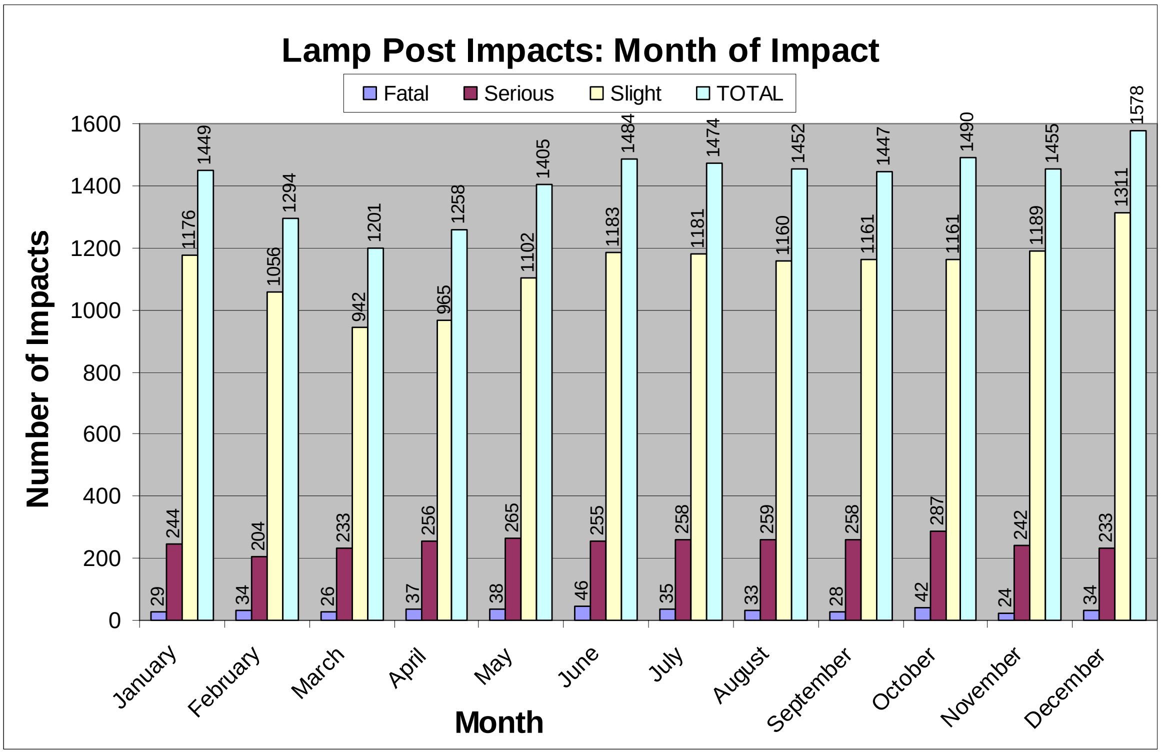

Lamp Post Impacts: Driver Sex
Number of impacts
14000
12000
10000
8000
6000
4000
2000
0
369
2492
10443
13304
33
439
2965
3437
4
63
179
246
Male
Female
Not traced
Driver Sex
Fatal
Serious
Slight
TOTAL

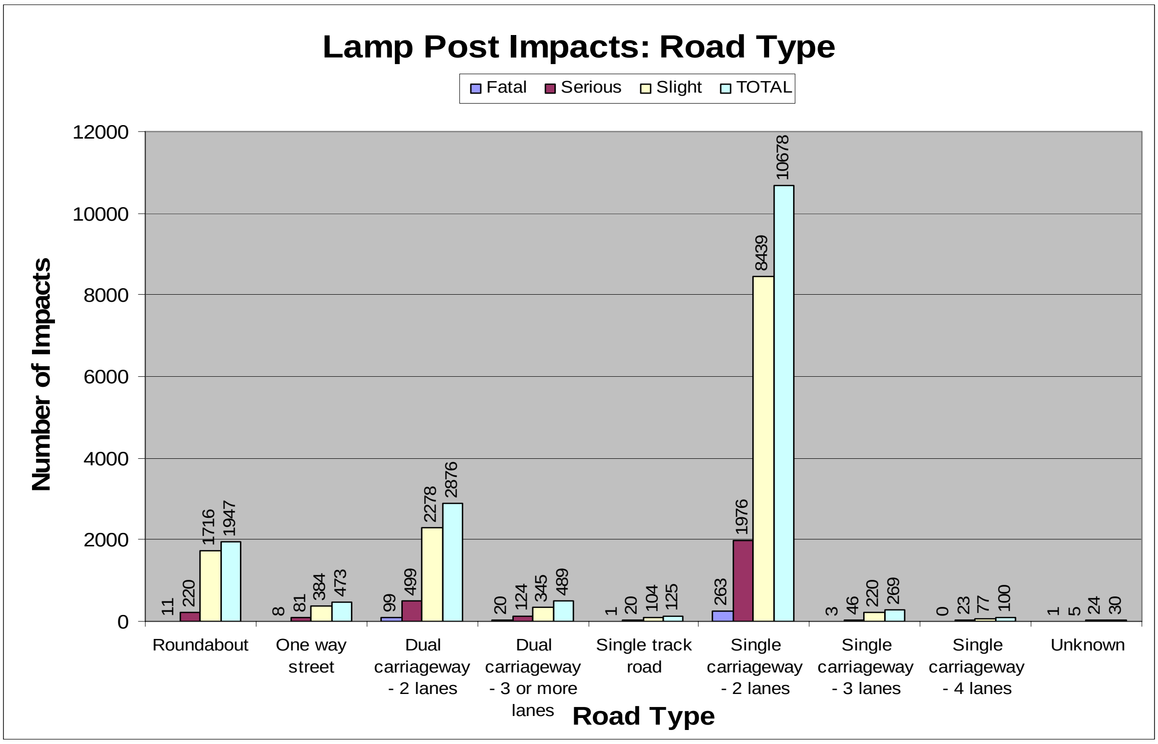

Lamp Post Impacts: Skidding & Overturning
Fatal
Serious
Slight
TOTAL
Number of Impacts
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
167
1368
6134
7669
145
1129
5469
6743
59
308
1074
1441
0
0
18
18
0
1
8
9
34
187
877
1098
1
1
7
9
No skidding, jack-knifing or overturning
Skidded
Skidded and overturned
Jack-knifed
Jack-knifed and overturned
Overturned
Unknown
Skidding or Overturning

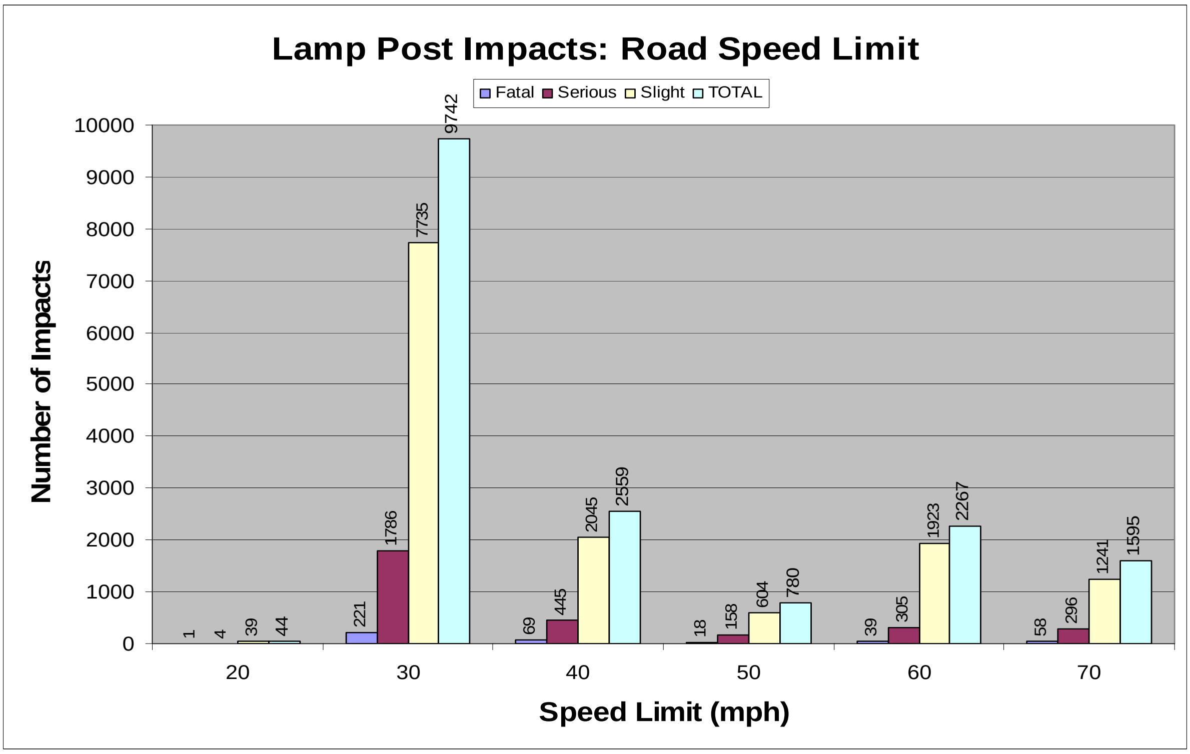

Lamp Post Impacts: Vehicle Types
Number of Impacts
Vehicle Type
Pedal cycle
Motorcycle 50cc or less
Motorcycle 50-125cc
Motorcycle 125-500cc
Motorcycle over 500cc
Taxi
Car
Minibus (8-16 passenger seats)
Bus or coach (17 or more passenger seats)
Other motor vehicle
Agricultural vehicle
Goods vehicle 3.5T or less
Goods vehicle over 3.5T and under 7.5T
Goods vehicle over 7.5T
Fatal
Serious
Slight
TOTAL

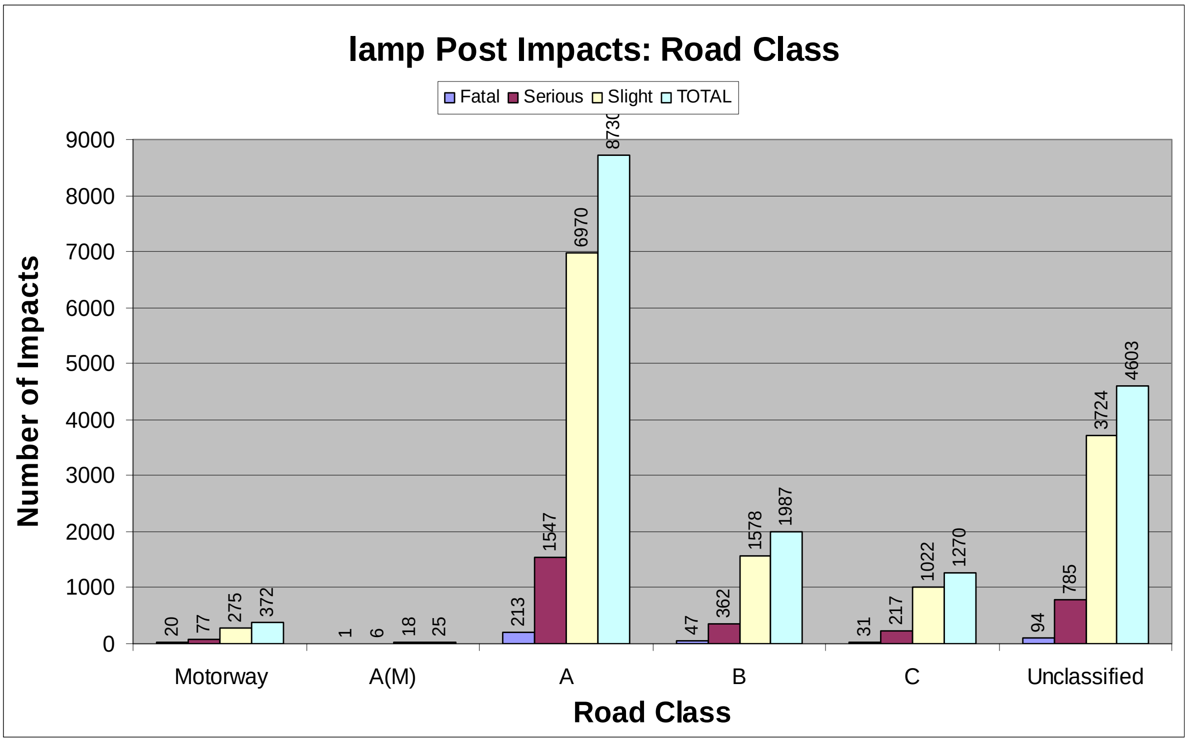

Lamp Post Impacts: Time of Incident
Fatal
Serious
Slight
TOTAL
Number of Impacts
Time

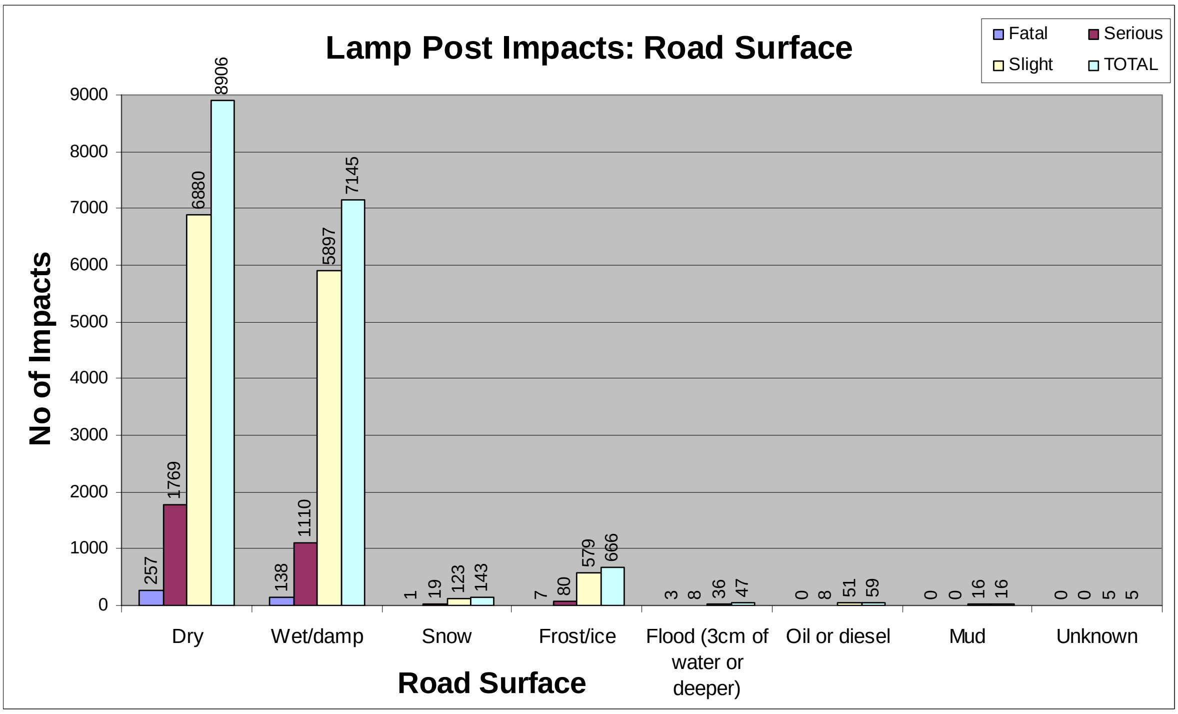

Lamp Post Impacts: Day of Week
No of Impacts
3000
2500
2000
1500
1000
500
0
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Day of Week
Fatal
Serious
Slight

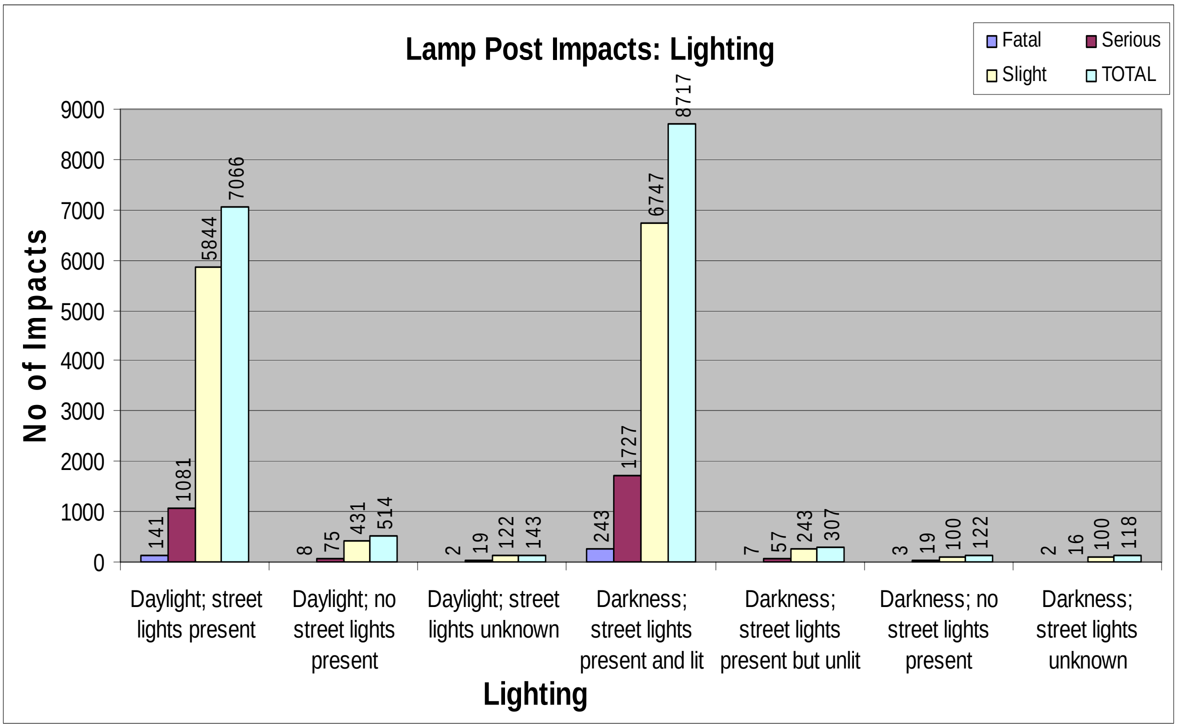

Lamp Post Impacts: Month of Impact
Fatal
Serious
Slight
TOTAL
Number of Impacts
1600
1400
1200
1000
800
600
400
200
0
29
244
1176
1449
34
204
1056
1294
26
233
942
1201
37
256
965
1258
38
265
1102
1405
46
255
1183
1484
35
258
1181
1474
33
259
1160
1452
28
258
1161
1447
42
287
1161
1490
24
242
1189
1455
34
233
1311
1578
January
February
March
April
May
June
July
August
September
October
November
December
Month

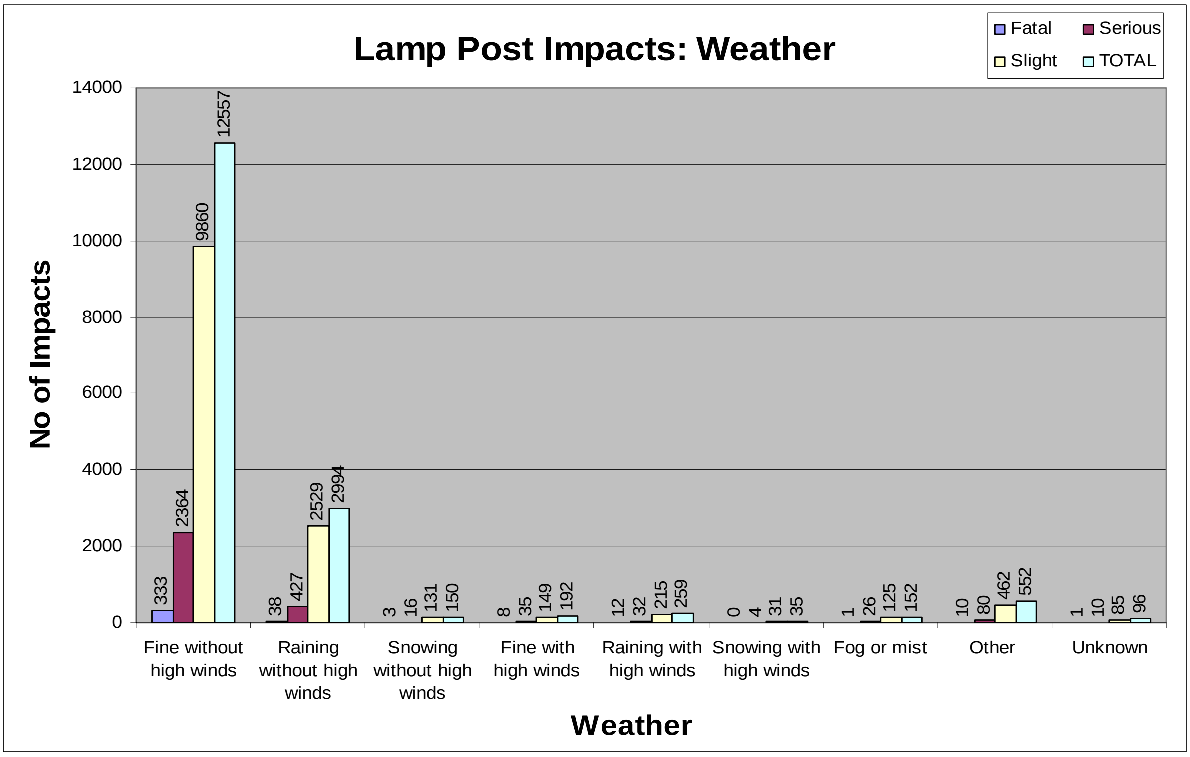

Lamp Post Impacts: Road Type
Fatal
Serious
Slight
TOTAL
Number of Impacts
12000
10000
8000
6000
4000
2000
0
11 220 1716 1947
8 81 384 473
99 499 2278 2876
20 124 345 489
1 20 104 125
263 1976 8439 10678
3 46 220 269
0 23 77 100
1 5 24 30
Roundabout
One way street
Dual carriageway - 2 lanes
Dual carriageway - 3 or more lanes
Single track road
Single carriageway - 2 lanes
Single carriageway - 3 lanes
Single carriageway - 4 lanes
Unknown
Road Type


Lamp Post Impacts: Road Speed Limit
Fatal
Serious
Slight
TOTAL
Number of Impacts
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1 4 39 44
221 1786 7735 9742
69 445 2045 2559
18 158 604 780
39 305 1923 2267
58 296 1241 1595
20
30
40
50
60
70
Speed Limit (mph)

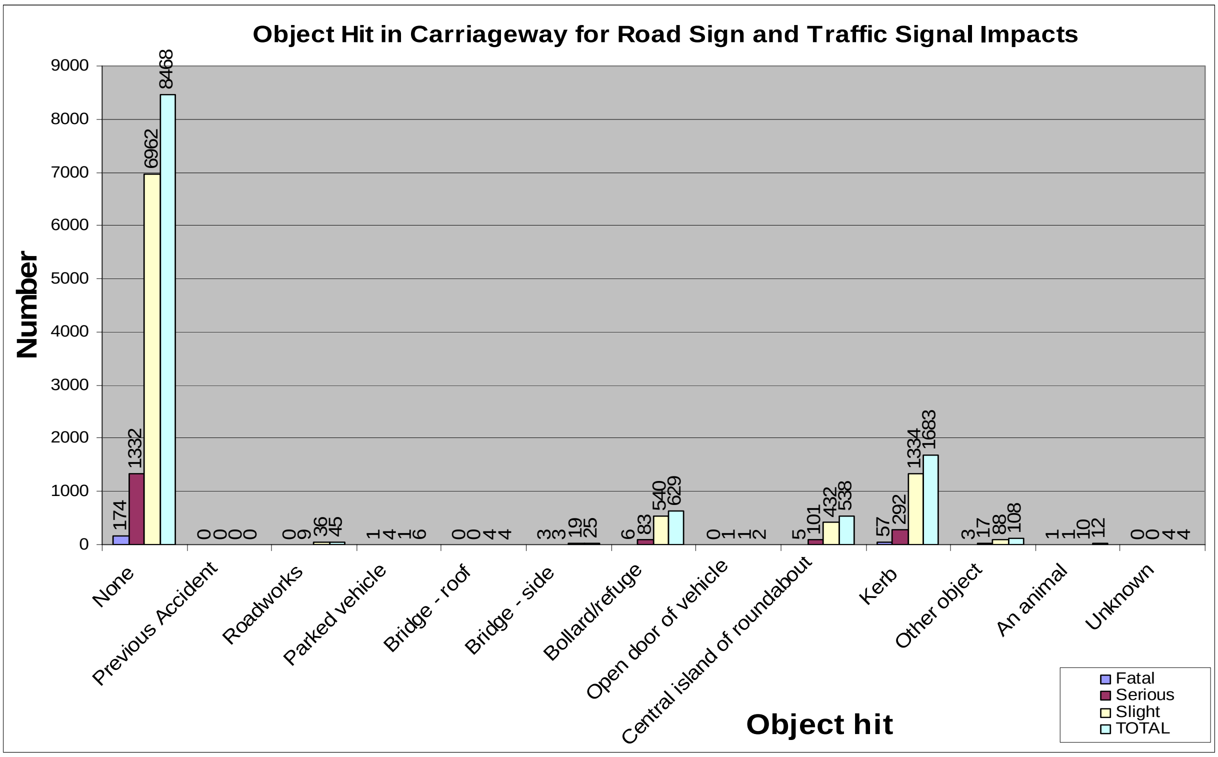

lamp Post Impacts: Road Class
Fatal
Serious
Slight
TOTAL
Number of Impacts
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
20
77
275
372
1
6
18
25
213
1547
6970
8730
47
362
1578
1987
31
217
1022
1270
94
785
3724
4603
Motorway
A(M)
A
B
C
Unclassified
Road Class

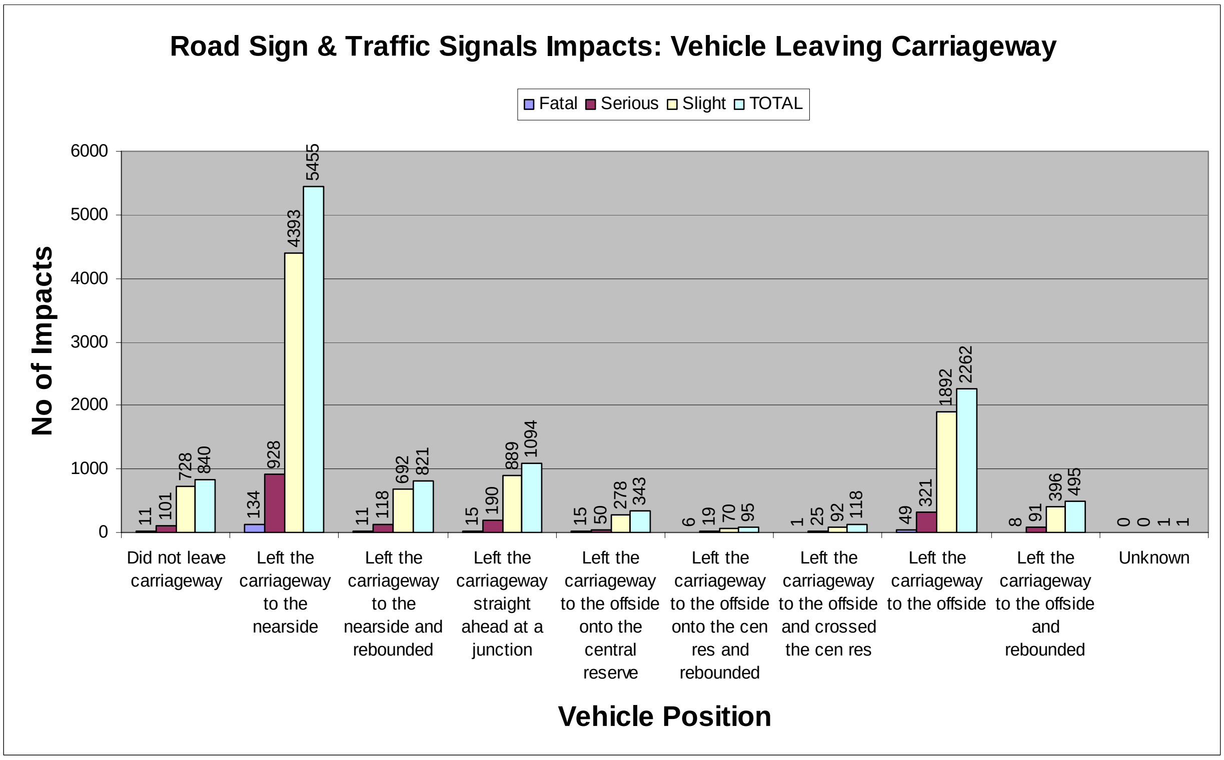

Lamp Post Impacts: Road Surface
Fatal
Serious
Slight
TOTAL
No of Impacts
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
257
1769
6880
8906
138
1110
5897
7145
1
19
123
143
7
80
579
666
3
8
36
47
0
8
51
59
0
0
16
16
0
0
5
5
Dry
Wet/damp
Snow
Frost/ice
Flood (3cm of water or deeper)
Oil or diesel
Mud
Unknown
Road Surface

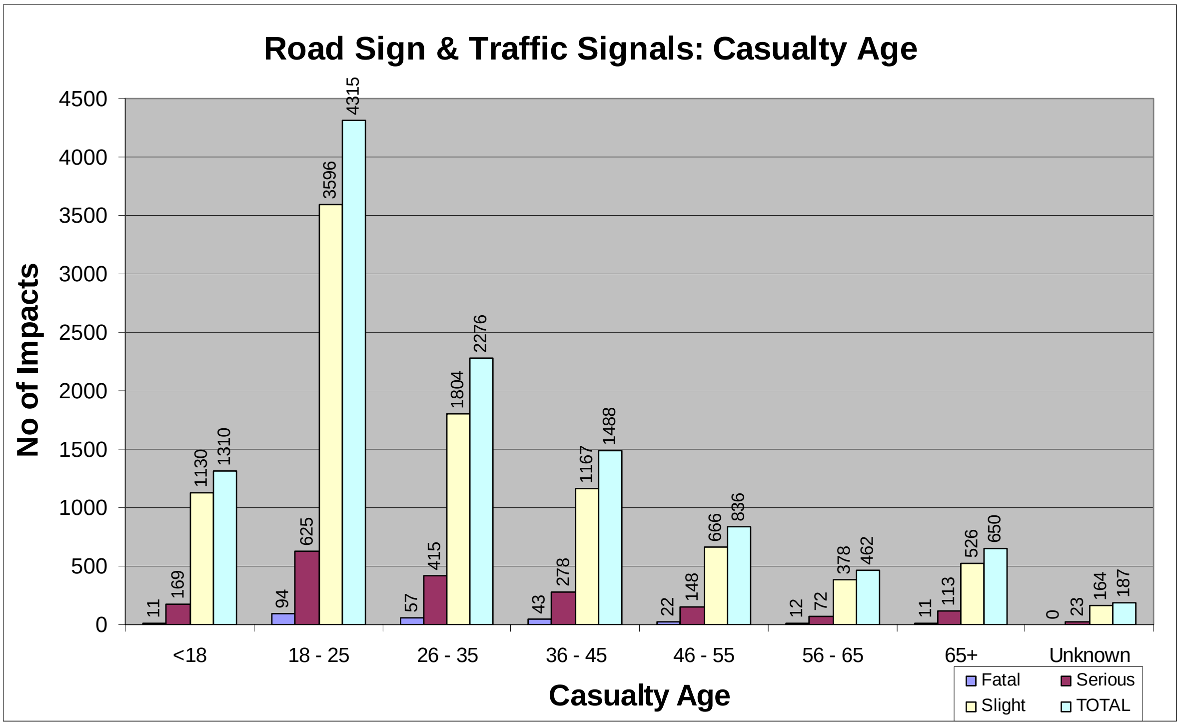

Lamp Post Impacts: Lighting
Fatal
Serious
Slight
TOTAL
No of Impacts
Lighting
Daylight; street lights present
Daylight; no street lights present
Daylight; street lights unknown
Darkness; street lights present and lit
Darkness; street lights present but unlit
Darkness; no street lights present
Darkness; street lights unknown
141 1081 5844 7066
8 75 431 514
2 19 122 143
243 1727 6747 8717
7 57 243 307
3 19 100 122
2 16 100 118


Lamp Post Impacts: Weather
Fatal
Serious
Slight
TOTAL
No of Impacts
Weather
Fine without high winds
Raining without high winds
Snowing without high winds
Fine with high winds
Raining with high winds
Snowing with high winds
Fog or mist
Other
Unknown
333 2364 9860 12557
38 427 2529 2994
3 16 131 150
8 35 149 192
12 32 215 259
0 4 31 35
1 26 125 152
10 80 462 552
1 10 85 96

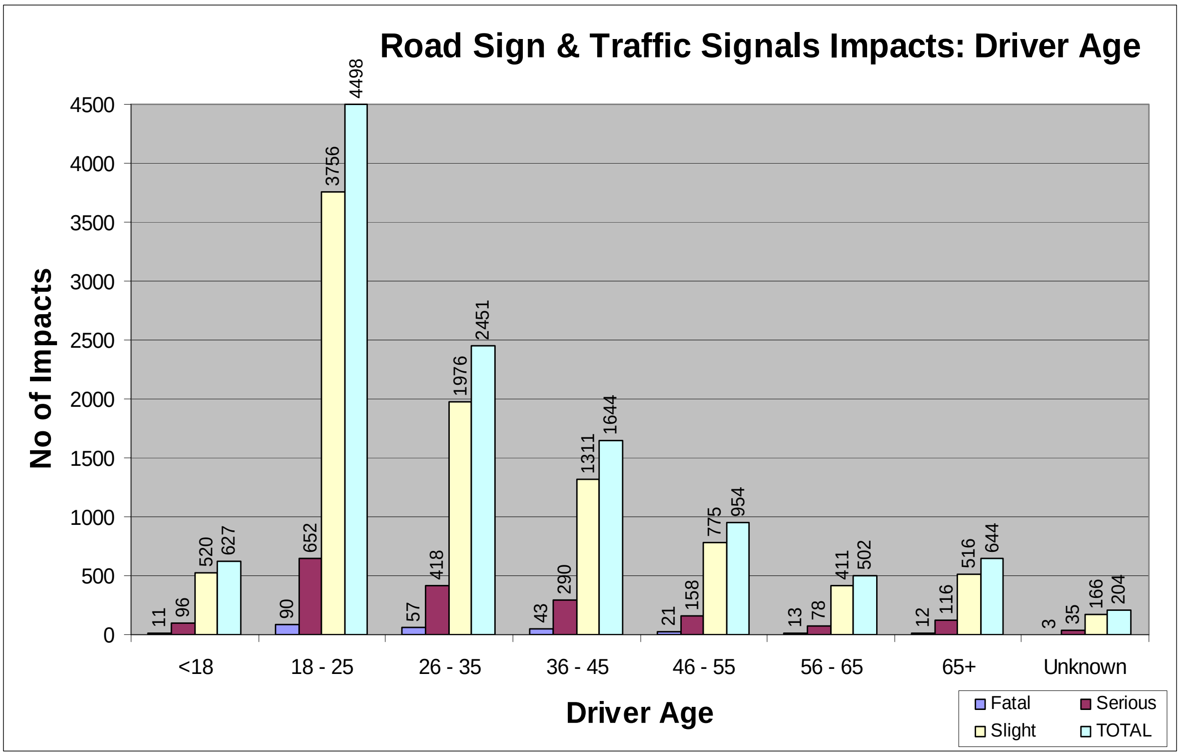
Appendix D Signpost / Traffic Signal Impacts - Graphs



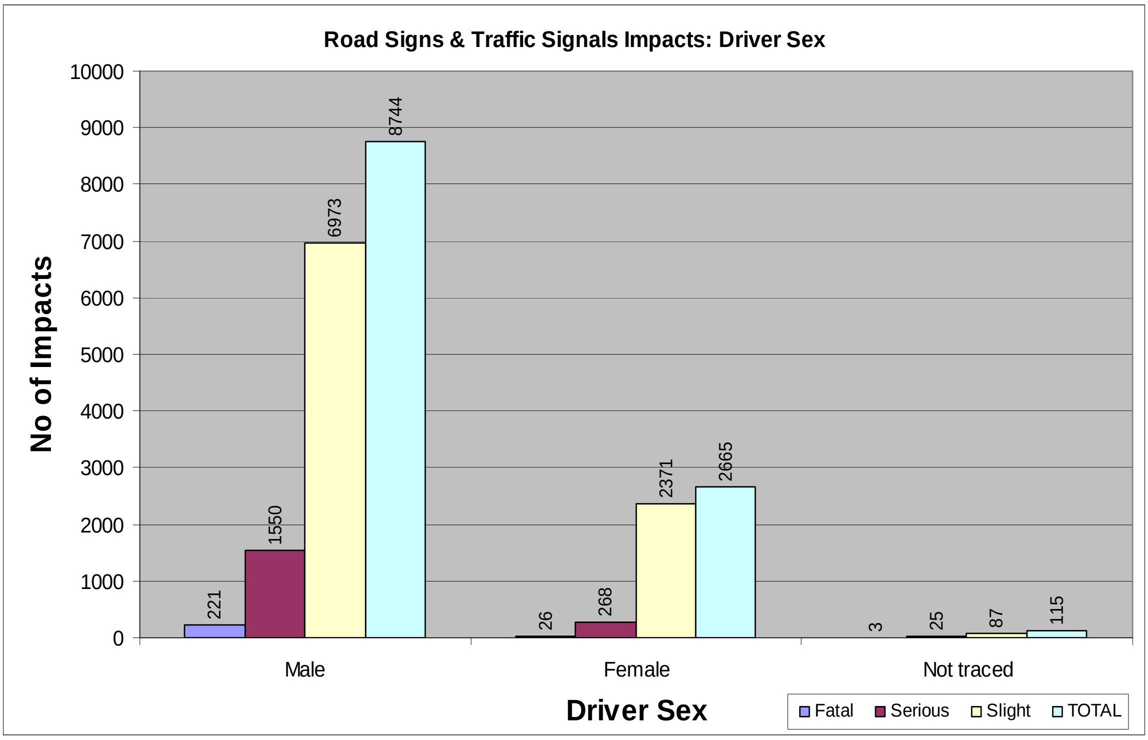


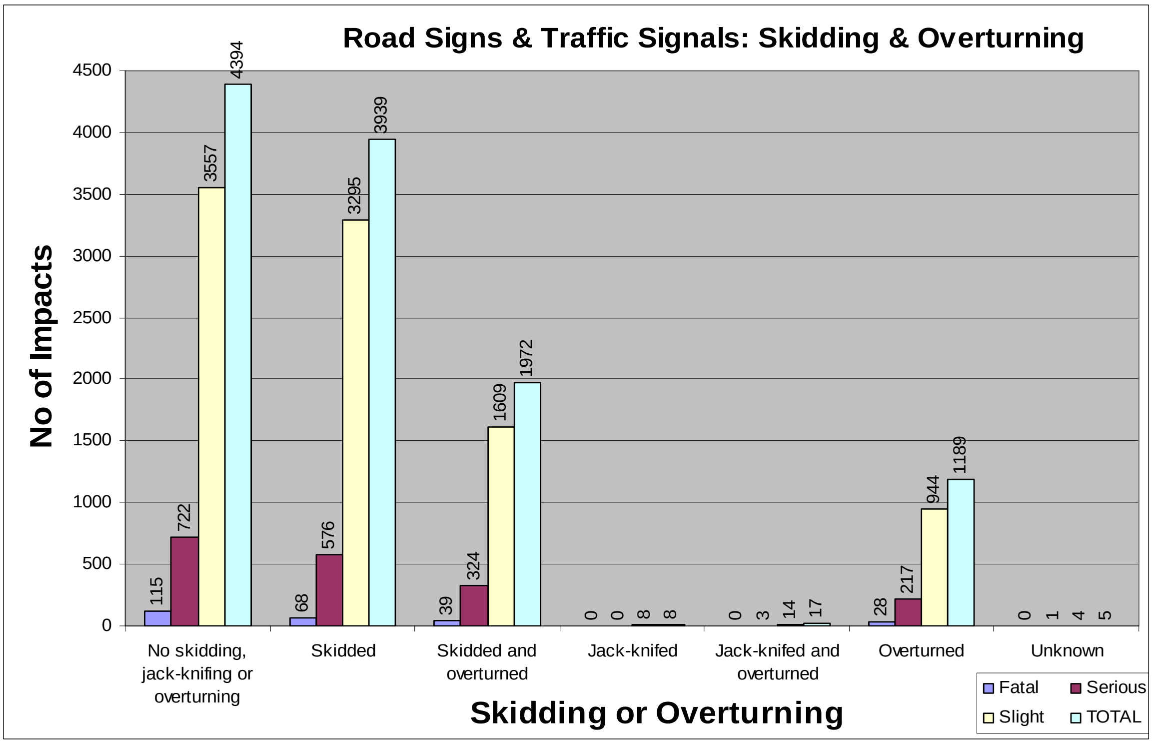


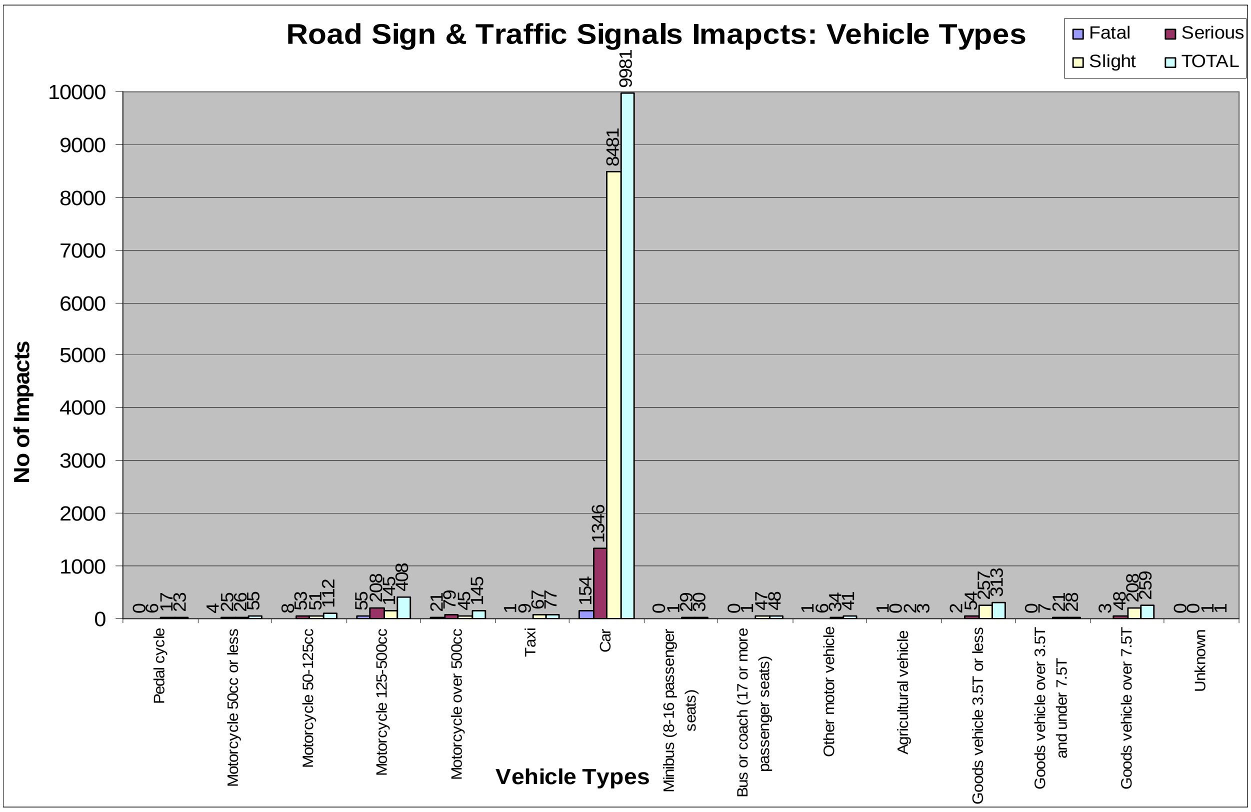
Road Sign & Traffic Signals: Casualty Age
No of Impacts
Casualty Age
<18
18 - 25
26 - 35
36 - 45
46 - 55
56 - 65
65+
Unknown
Fatal
Serious
Slight
TOTAL

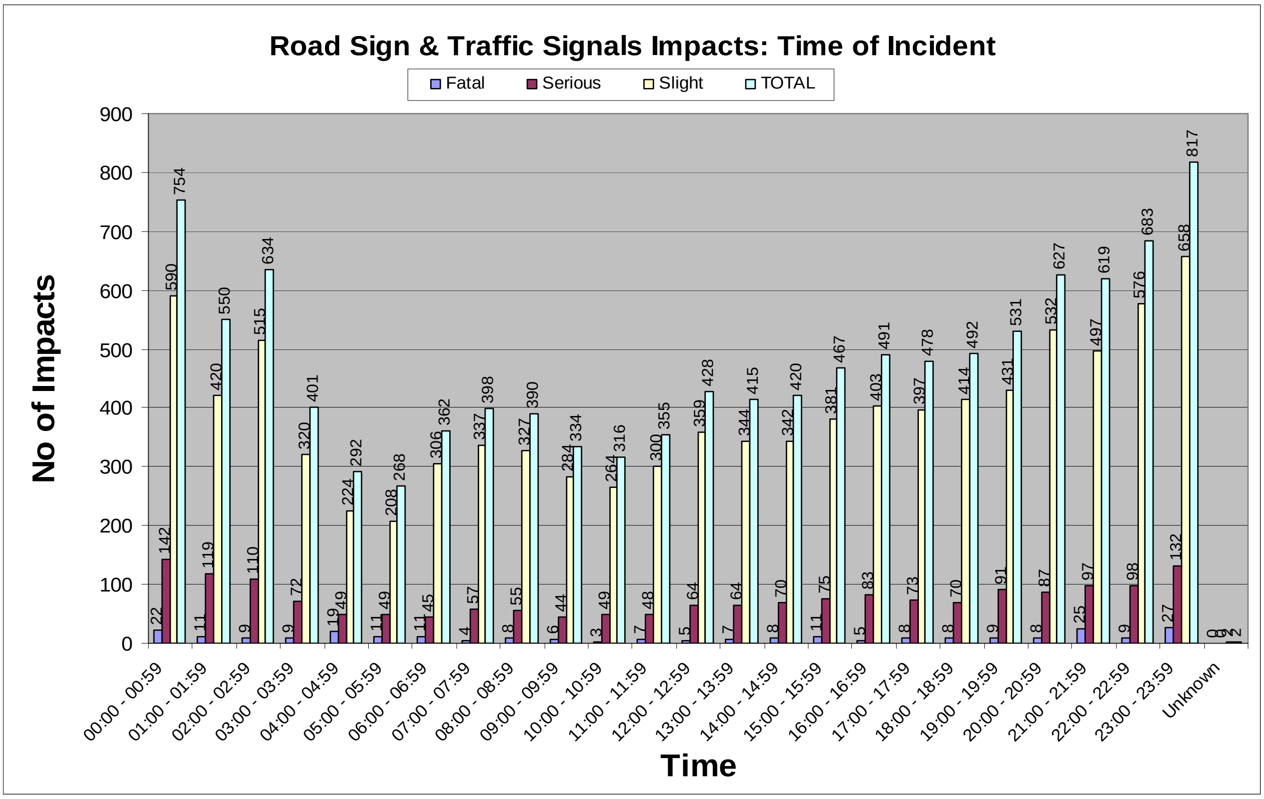


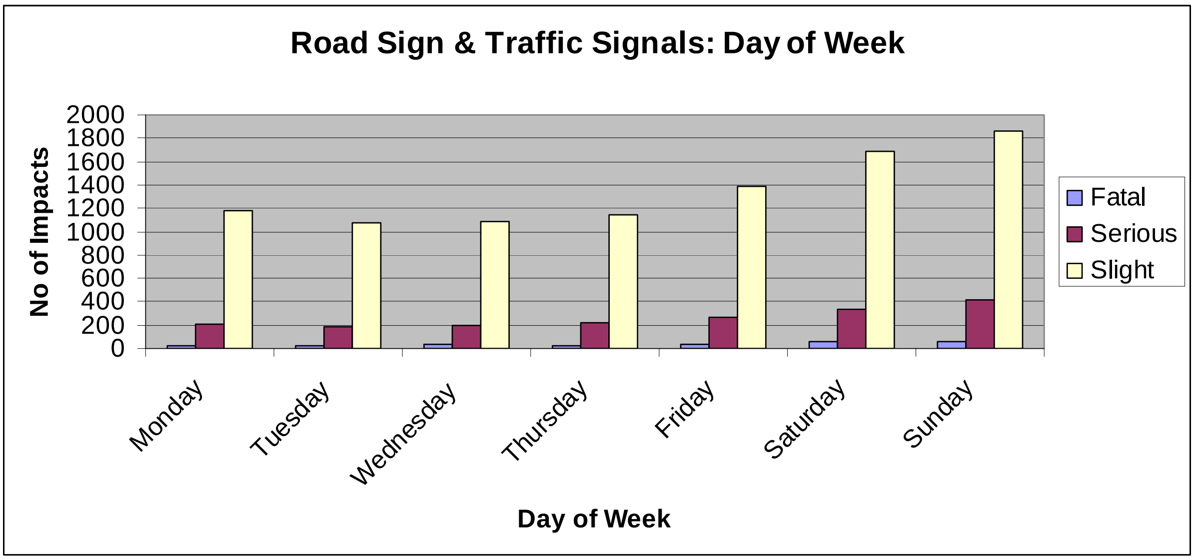
Road Sign & Traffic Signals Impacts: Driver Age
No of Impacts
Driver Age
<18
18 - 25
26 - 35
36 - 45
46 - 55
56 - 65
65+
Unknown
Fatal
Serious
Slight
TOTAL


Road Signs & Traffic Signals Impacts: Driver Sex
No of Impacts
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
221
1550
6973
8744
26
268
2371
2665
3
25
87
115
Male
Female
Not traced
Driver Sex
Fatal
Serious
Slight
TOTAL

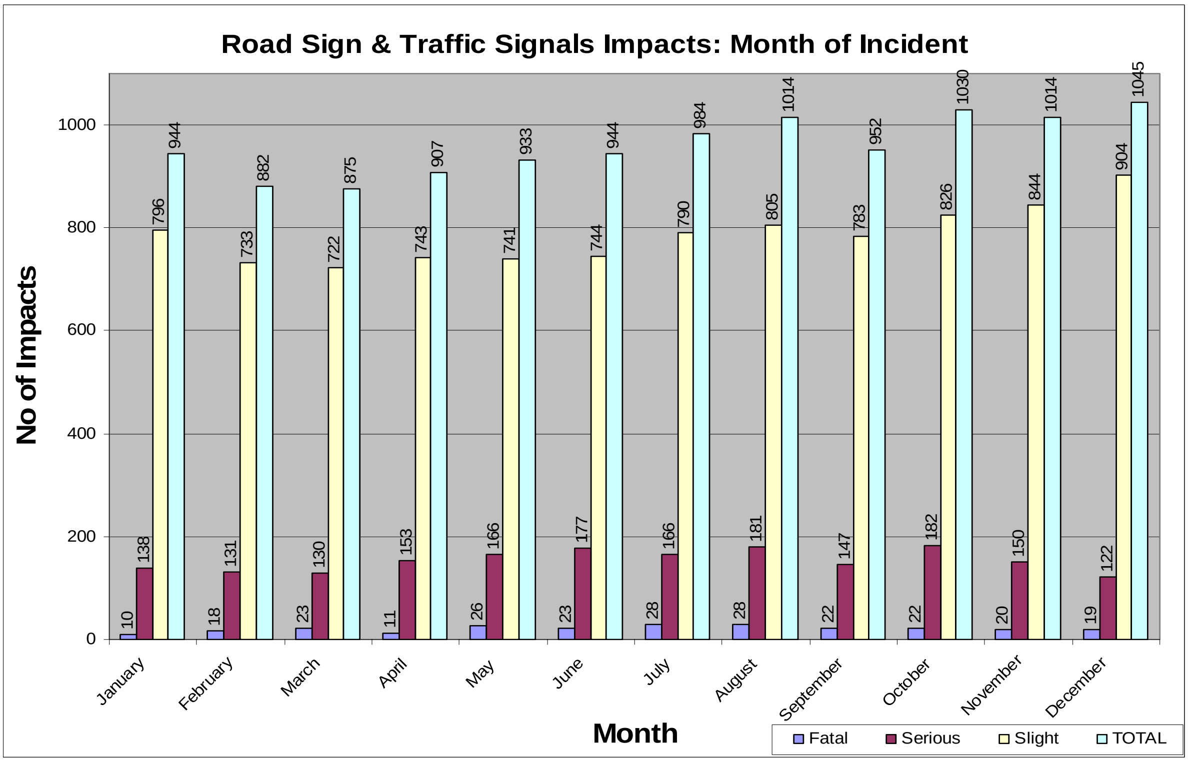

Road Signs & Traffic Signals: Skidding & Overturning
No of Impacts
4500
4000
3500
3000
2500
2000
1500
1000
500
0
115
722
3557
4394
68
576
3295
3939
39
324
1609
1972
0
0
8
8
0
3
14
17
28
217
944
1189
0
1
4
5
No skidding, jack-knifing or overturning
Skidded
Skidded and overturned
Jack-knifed
Jack-knifed and overturned
Overturned
Unknown
Skidding or Overturning
Fatal
Serious
Slight
TOTAL


Road Sign & Traffic Signals Imapcts: Vehicle Types
Fatal
Serious
Slight
TOTAL
No of Impacts
Vehicle Types
Pedal cycle
Motorcycle 50cc or less
Motorcycle 50-125cc
Motorcycle 125-500cc
Motorcycle over 500cc
Taxi
Car
Minibus (8-16 passenger seats)
Bus or coach (17 or more passenger seats)
Other motor vehicle
Agricultural vehicle
Goods vehicle 3.5T or less
Goods vehicle over 3.5T and under 7.5T
Goods vehicle over 7.5T
Unknown

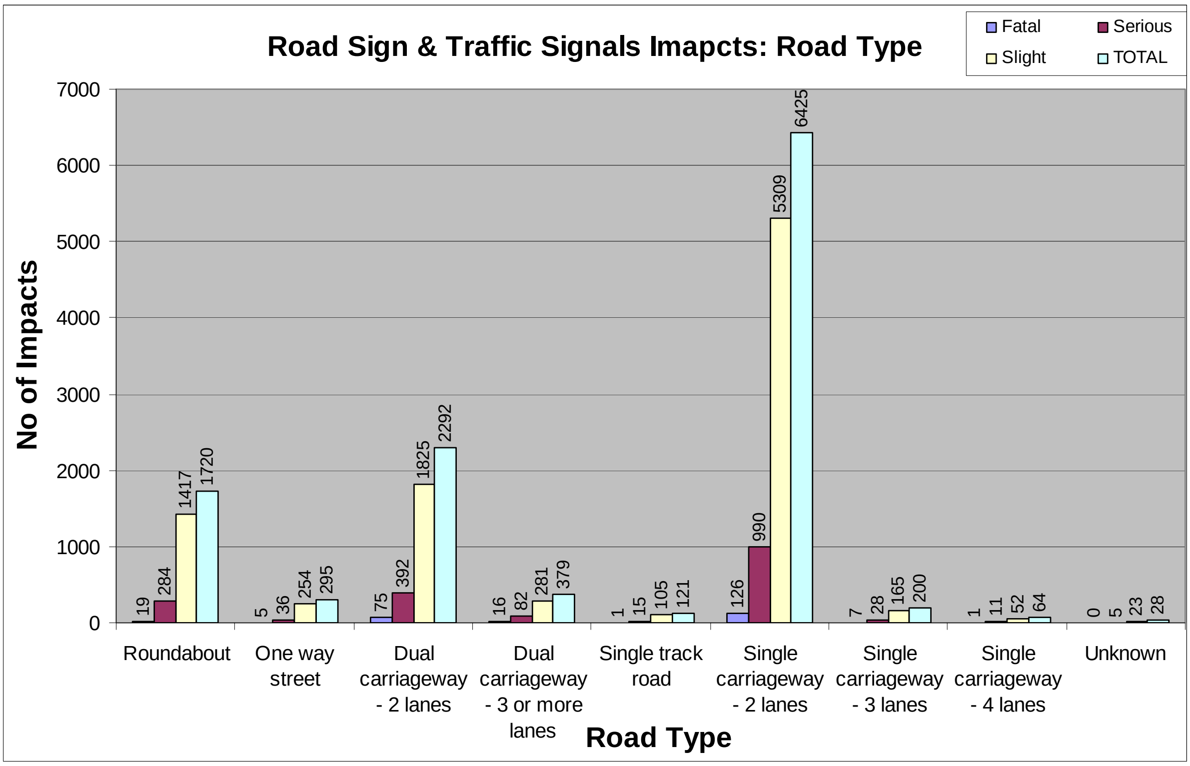

Road Sign & Traffic Signals Impacts: Time of Incident
Fatal
Serious
Slight
TOTAL
No of Impacts
Time
Unknown

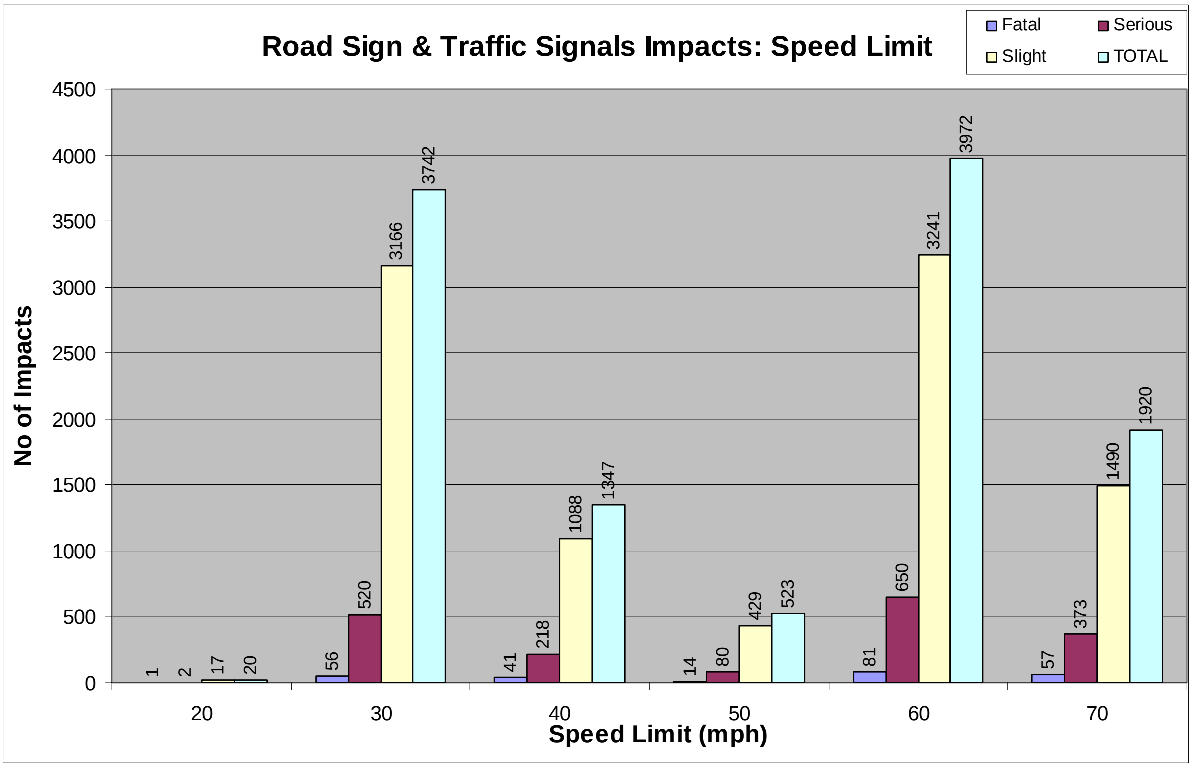


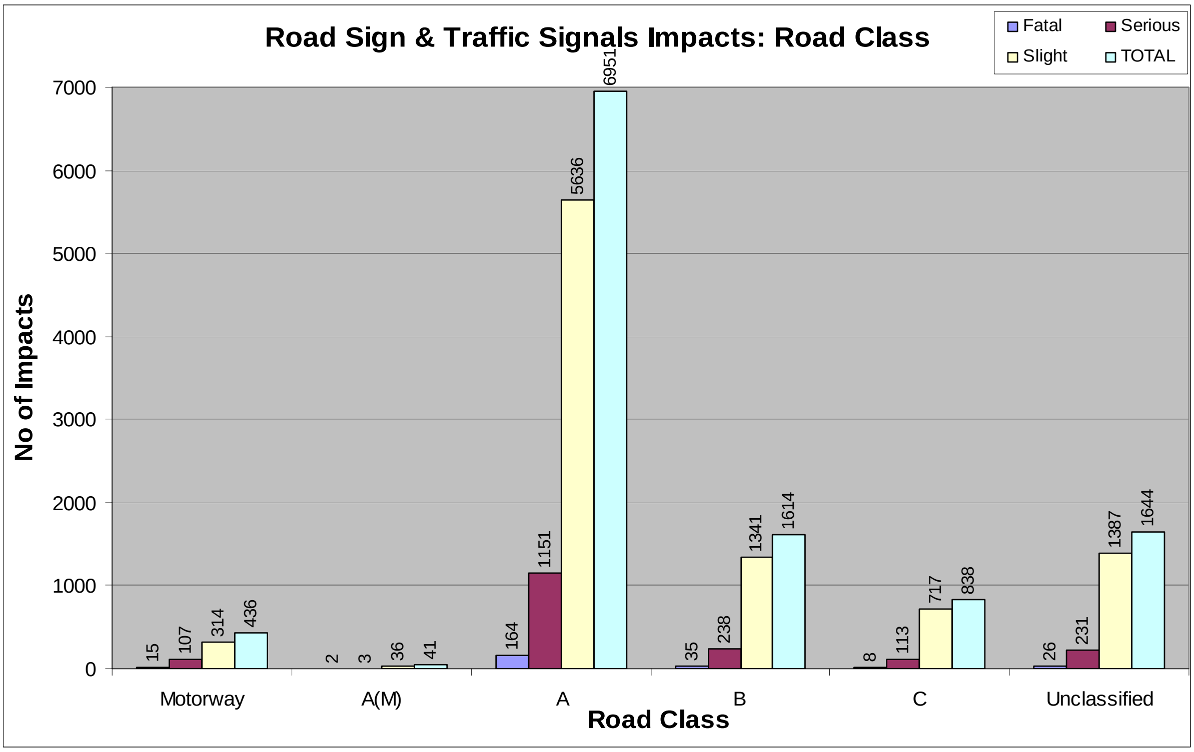
Road Sign & Traffic Signals: Day of Week
No of Impacts
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Day of Week
Fatal
Serious
Slight

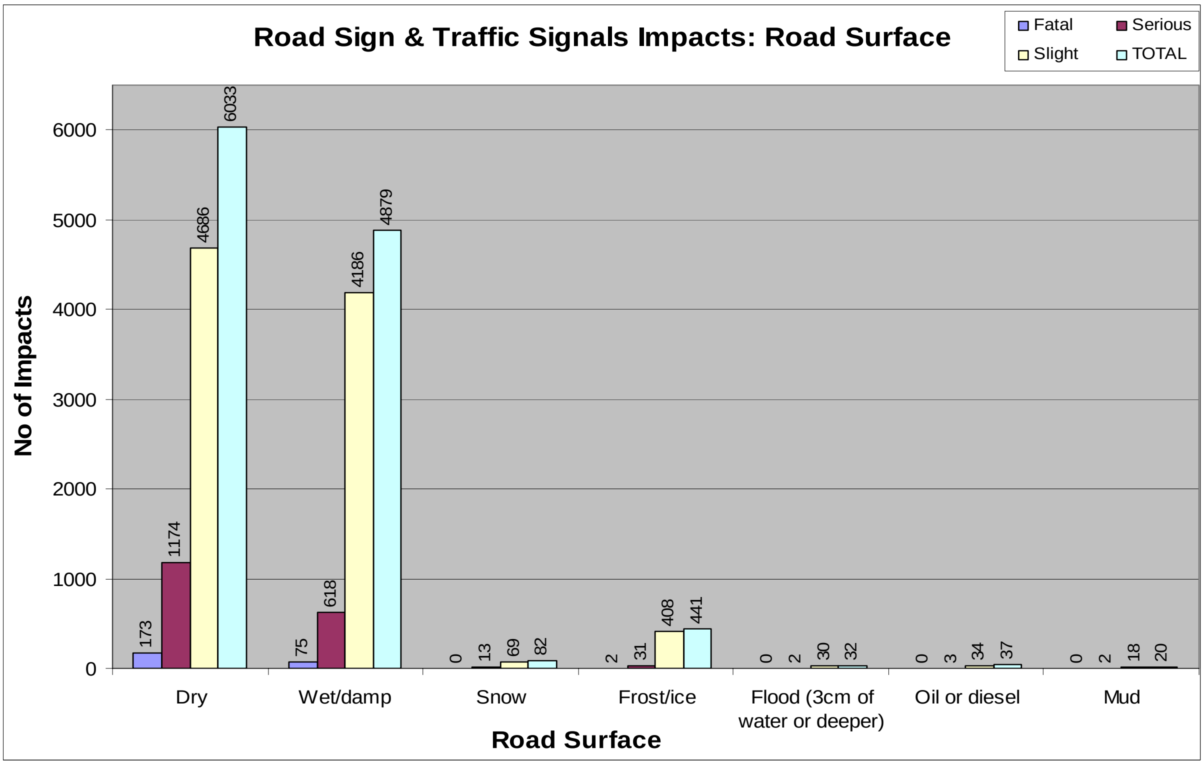


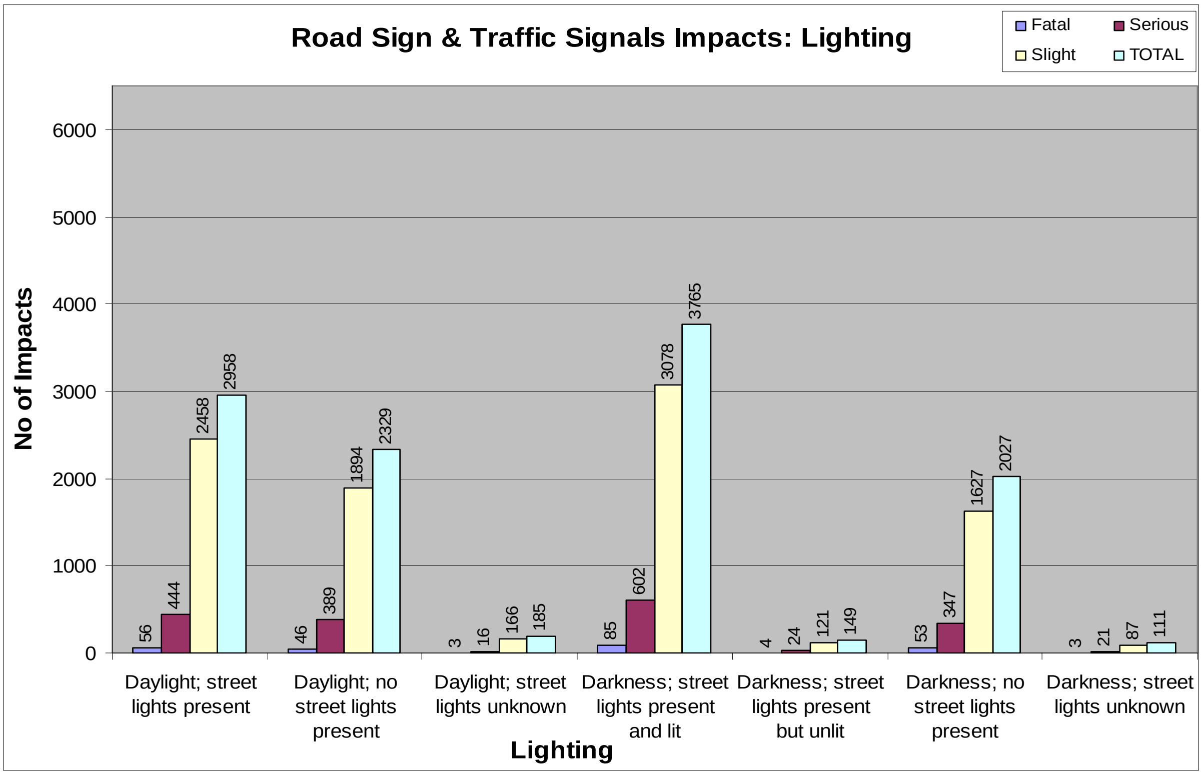
Road Sign & Traffic Signals Impacts: Month of Incident
No of Impacts
1000
800
600
400
200
0
10 138 796 944
18 131 733 882
23 130 722 875
11 153 743 907
26 166 741 933
23 177 744 944
28 166 790 984
28 181 805 1014
22 147 783 952
22 182 826 1030
20 150 844 1014
19 122 904 1045
January
February
March
April
May
June
July
August
September
October
November
December
Month
Fatal
Serious
Slight
TOTAL

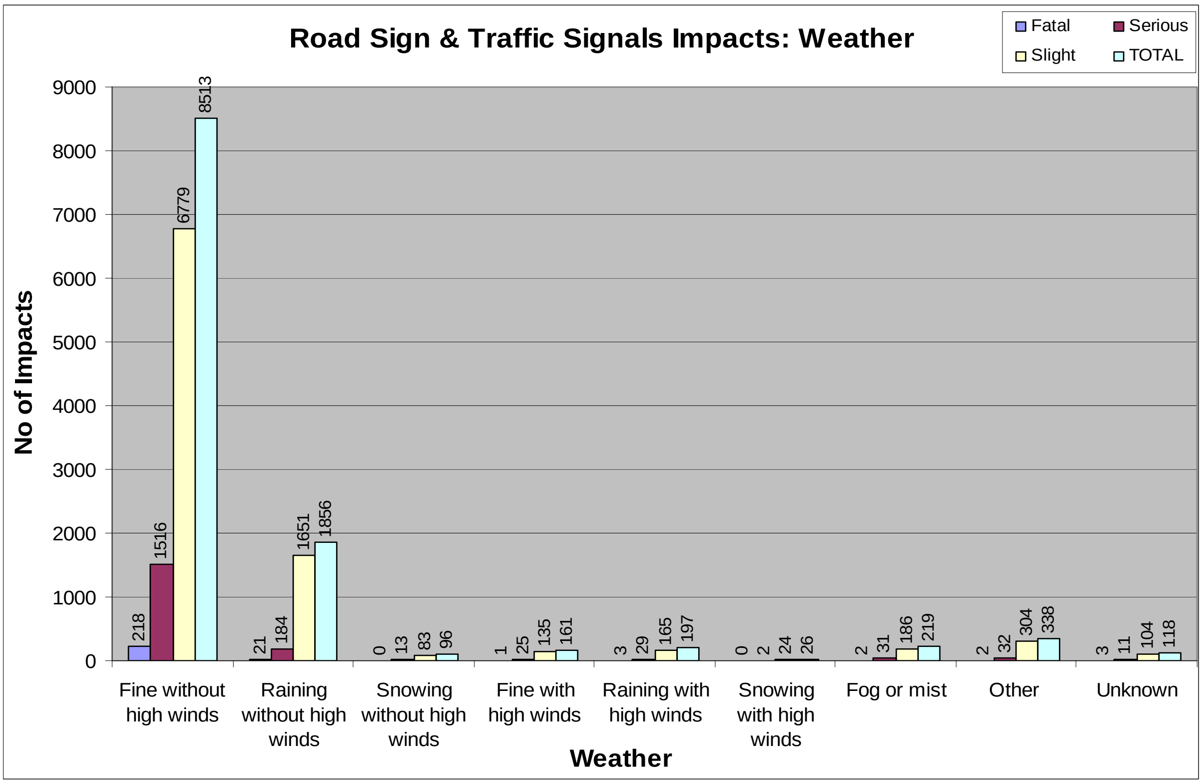

Road Sign & Traffic Signals Imapcts: Road Type
Fatal
Serious
Slight
TOTAL
No of Impacts
7000
6000
5000
4000
3000
2000
1000
0
19 284 1417 1720
5 36 254 295
75 392 1825 2292
16 82 281 379
1 15 105 121
126 990 5309 6425
7 28 165 200
1 11 52 64
0 5 23 28
Roundabout
One way street
Dual carriageway - 2 lanes
Dual carriageway - 3 or more lanes
Single track road
Single carriageway - 2 lanes
Single carriageway - 3 lanes
Single carriageway - 4 lanes
Unknown
Road Type


Road Sign & Traffic Signals Impacts: Speed Limit
Fatal
Serious
Slight
TOTAL
No of Impacts
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1 2 17 20
56 520 3166 3742
41 218 1088 1347
14 80 429 523
81 650 3241 3972
57 373 1490 1920
20
30
40
50
60
70
Speed Limit (mph)


Road Sign & Traffic Signals Impacts: Road Class
Fatal
Serious
Slight
TOTAL
No of Impacts
7000
6000
5000
4000
3000
2000
1000
0
15
107
314
436
2
3
36
41
164
1151
5636
6951
35
238
1341
1614
8
113
717
838
26
231
1387
1644
Motorway
A(M)
A
B
C
Unclassified
Road Class


Road Sign & Traffic Signals Impacts: Road Surface
Fatal
Serious
Slight
TOTAL
No of Impacts
6000
5000
4000
3000
2000
1000
0
173
1174
4686
6033
75
618
4186
4879
0
13
69
82
2
31
408
441
0
2
30
32
0
3
34
37
0
2
18
20
Dry
Wet/damp
Snow
Frost/ice
Flood (3cm of water or deeper)
Oil or diesel
Mud
Road Surface


Road Sign & Traffic Signals Impacts: Lighting
Fatal
Serious
Slight
TOTAL
No of Impacts
0
1000
2000
3000
4000
5000
6000
56
444
2458
2958
46
389
1894
2329
3
16
166
185
85
602
3078
3765
4
24
121
149
53
347
1627
2027
3
21
87
111
Daylight; street lights present
Daylight; no street lights present
Daylight; street lights unknown
Darkness; street lights present and lit
Darkness; street lights present but unlit
Darkness; no street lights present
Darkness; street lights unknown
Lighting


Road Sign & Traffic Signals Impacts: Weather
Fatal
Serious
Slight
TOTAL
No of Impacts
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
218
1516
6779
8513
21
184
1651
1856
0
13
83
96
1
25
135
161
3
29
165
197
0
2
24
26
2
31
186
219
2
32
304
338
3
11
104
118
Fine without high winds
Raining without high winds
Snowing without high winds
Fine with high winds
Raining with high winds
Snowing with high winds
Fog or mist
Other
Unknown
Weather

Appendix E Risk Assessment for a Vehicle Striking a Passively Safe Lighting Column or Signpost

E1. Introduction

The risk assessment of a vehicle hitting a passively safe lighting column or signpost is outlined here for the case of a lighting column on a single carriageway rural road. It uses estimates based on the Road Restraint Risk Assessment Process (RRRAP) that is part of the Road Restraint Standard TD 19/06 (DMRB Section 2.2.8). In the RRRAP model, the risk of an errant vehicle hitting a post (whether passively safe or conventional) can be divided into three individual components:

1. Probability of leaving the carriageway;
2. Probability of reaching the post ;
3. Consequences of hitting the post.

The probability of leaving the carriageway will depend on a number of factors e.g.

Road type;

Vehicle flow;

Road alignment (horizontal and vertical);

Presence of any specific local hazards (e.g. junctions).

The probability of reaching the object will depend on factors such as:

Speed of errant vehicle;

Dimensions of post;

Offset of post;

Presence and width of hard strip;

Type of intervening ground;

Length and containment level of restraint system, if used.

The extent to which drivers are likely to take evasive action when their vehicles leave the carriageway also needs to be taken into consideration.

The consequences of hitting a lighting column or post are twofold, i.e. those affecting the errant vehicle and those affecting other road users or third parties. For the errant vehicle, it is the speed on reaching the object and the aggressiveness of the object that are the key parameters. In the case of a passively safe lighting column or signpost, the consequences for other road users need to be investigated as it is more likely that the post will fall and the vehicle will continue at high speed.

In the RRRAP model, risk is expressed in terms of equivalent fatalities per 100 million veh-km, and it is assumed that 10 serious casualties or 100 slight casualties are equivalent to one fatality, these ratios being broadly in line with the Highways Economic Note (HEN1) (DfT, 2006) costs.

E2. Risk to Occupants of Errant Vehicle Hitting a Lighting Column or Post

The risk of injury to the occupants of an errant vehicle is based on the RRRAP model and its background calculations. Design choices within the model include the offset of the column or post, and the length and level of containment of safety barrier installed, if used. The resistance of the post to impact (and thus its likely effect on occupant casualties) is expressed through an aggressiveness factor.

The aggressiveness factors currently used in the RRRAP model are as shown in Table E1. These values are intended to be realistic in relation to each other, based on the calibration of an assumed errant vehicle rate and the actual number of casualties resulting from run-offs. If the structure is passively safe, then injury to vehicle occupants should be minimal.

Table E1: Aggressiveness factors[1]

Object	Basic value assumed
Safety barrier (N2)	0.3 per m
Non-passively safe lighting column	1.7
Passively safe lighting column	0.25
Large tree	2.0
Non-passively safe signpost	1.8
Passively safe signpost	0.2

[1] *taken from RRRAP v1.3*

In the RRRAP software, the injury outcome, in terms of fatal, serious and slight injuries, is estimated by multiplying a standard matrix of injury severities (dependant on the speed of impact), by the aggressiveness factor. Hence an object with an aggressiveness of 1 will result in the proportion of injuries shown in the standard matrix whereas an object with an aggressiveness of 0.1 will result in one tenth of these casualties. There is a different standard injury matrix for car occupants and for heavy goods vehicle occupants as the latter will be afforded better protected by their vehicle.

Risk has been assessed for both conventional and passively safe lighting columns and signposts. In the case of conventional posts, risk is shown with and without 30m of 'normal containment' safety barrier in front of the column or post. For protected objects, therefore, the risk is that of a vehicle hitting the barrier or its ramped end (full height terminals are not currently considered in RRRAP), breaching the barrier or getting behind it.

The results for a rural single carriageway are given in Table E2, and illustrated in Figure E1.

Table E2: Risk to occupants of errant vehicle hitting object at 2.5m offset on a rural single carriageway road

Object	Risk
Conventional post	0.0243
Conventional post with 30m barrier	0.00578
Passively safe post	0.0027
Conventional lighting column	0.0146
Conventional lighting column with 30m barrier	0.00364
Passively safe lighting column	0.00172

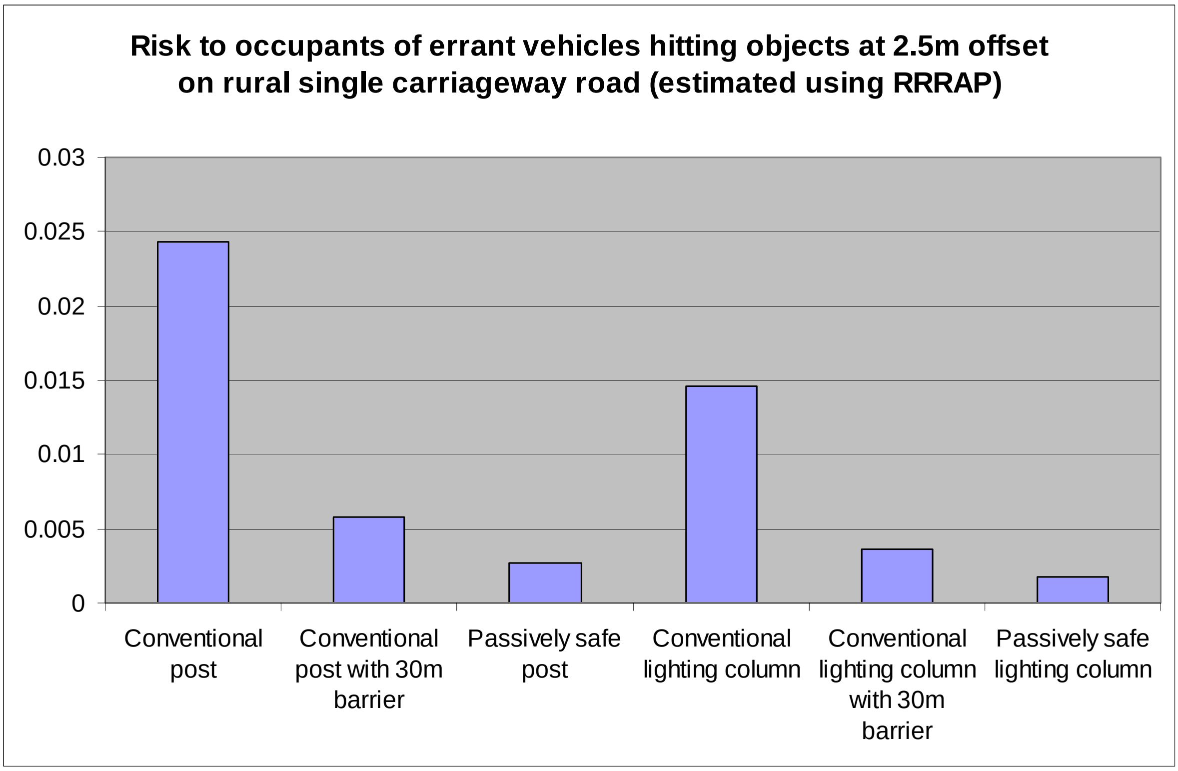


Figure E1: Risk to errant vehicle occupants hitting a lighting column or post at 2.5m offset on a rural single carriageway road

E2.1. Risk to occupants of vehicle hit by falling lighting column on a rural single carriageway

The risk to road users of being hit by a falling post or debris requires an understanding of what might happen following an impact with a passively safe lighting column or signpost. This is likely to depend on:

- Form of collapse (which might depend on whether the post is LE or NE);
- Weight, size and aggressiveness of any debris;
- Location of debris.

The probability of injury from the post or debris will then be

Probability of collapse

Multiplied by probability of other vehicles being in a location where they might be hit

Multiplied by probability of impact resulting in fatal, serious or slight injury.

Probability of collapse

A passively safe lighting column or signpost would almost certainly collapse if hit by an errant vehicle at a speed of more than 5mph, whereas a conventional one would be less likely to do so, particularly if the errant vehicle was a car. Table E3 shows the probability of collapse values assumed and a suitable range of values for each parameter.

Table E3: Probability of collapse given that a post is struck by an errant vehicle

Event	Basic value assumed	Range to assess
Probability of collapse if passively safe object hit	0.95	0.9 to 1.0
Probability of collapse if conventional object hit	0.05	0 to 0.1

Probability of other vehicles being in a location where they might be hit

Vehicle occupants may be hit by the falling column or post or by its components e.g. luminaires which become detached due to the shock loading transmitted following the errant vehicle impact with the support. A probability of 0.5 has been adopted for the likelihood of a lighting column or component of substantial weight landing in the road. The corresponding value for a signpost is 0.2. The lower value was adopted because the signpost is smaller than a lighting column and the sign is likely to fall close to its original position.

Probability of impact resulting in fatal, serious or slight injury

Injury through being hit by a falling column or post will only occur if there are other vehicles in the vicinity at the same time. For the probability of this happening, it is necessary to rely largely on theoretical calculations based on traffic speeds and densities. For example, suppose that for a typical single carriageway flow (two-way AADT of 15,000) the average flow per direction is 750 vehicles per hour and the mean speed is 80 kph. The mean spacing of vehicles is then approximately 100m. The probability of a falling object hitting a 3m long car is about 1/30 and of hitting the 1m front compartment is about 1/100. The severity of the outcome could potentially be serious.

On a dual-carriageway, a similar number of drivers would be at risk of a direct hit, if it is assumed that only the nearside lane would be affected.

Summary

An estimate of the probability of the equivalent fatalities resulting from an errant vehicle hitting a passively safe lighting column on a rural single carriageway is illustrated in Table E4. The figure for the number of run-off collisions per site per year is based on an average site with two-way Annual Average Daily Traffic flow of 15,000 and a lighting column with dimensions of 0.2m x 0.2m at an offset of 2.5m from the running lanes.

Table E4: Risk to occupants of vehicle hit by falling lighting column on a rural single carriageway

		Cumulative estimate of probability of injury collision per site per year
No of run off collisions per site per year that hit lighting column	0.092	
Proportion in which lighting column collapses	0.95	0.0874
Probability that column falls in carriageway	0.5	0.0437
Probability of falling post hitting other vehicle	0.01	0.000437
Number of vehicles in vicinity	1	0.000437
		No of fatal equivalents per site per year
Number of equivalent fatalities if vehicle hit by falling column	0.2	0.0000874

A similar calculation can be made for a signpost and for lighting columns, and signposts on dual-carriageway roads.

E2.2. Risk to other road users of running into fallen post or other debris

The risk assessment needs to include the risk of vehicles running into a fallen lighting column / post or other debris if the driver fails to take evasive action. How drivers will react when faced with debris in the road might depend on:

- Traffic and weather conditions at the time;
- Location of the fallen post or debris;
- Distance within which drivers can stop before reaching debris or reduce speed to reduce injury consequences from impact;
- Avoiding actions considered by drivers;
- Conspicuity of objects on the carriageway.

The Probability of injury from this risk will then be:

Probability of vehicles (not hit by debris) running into fallen post or other debris

Multiplied by probability of impact resulting in fatal, serious or slight injury.

It is again largely necessary to rely on theoretical calculations based on traffic speeds and densities. If vehicles were at 100m spacing, the next driver may be able to halt his vehicle or reduce speed substantially before reaching the object. Thus only the lead vehicle is likely to hit the fallen column or post, although others might impact this vehicle as a rear shunt (this latter possibility being discussed below).

The impact test of a car hitting a fallen gantry at a speed described in Section 2 suggests that the likelihood of serious injury to the car occupants would be low. Table E5 shows the estimates of equivalent fatalities to road users hitting a fallen lighting column.

Table E5: Estimate of equivalent fatalities to occupants of vehicle hitting a fallen passively safe lighting column on a rural single carriageway

		Cumulative estimate of probability of injury collision per site per year
No of run off collisions per site per year that hit post	0.092	
Proportion in which post collapses	0.95	0.0874
Proportion in which debris lands on road	0.5	0.0437
Probability of vehicle hitting fallen post	0.3	0.0131
Number of vehicles exposed	1	0.0131
		No of fatal equivalents per site per year
Number of equivalent fatalities if vehicle hits fallen post	0.01	0.000131

E2.3. Risk of secondary collisions resulting from vehicles taking action to avoid debris

The results of the simulator tests of driver behaviour when a gantry collapses described in Section 6.2.3 form the basis of the assumptions of driver reaction to a fallen post or other debris, and the likelihood of secondary collisions due to evasive action.

It was anticipated that driver response might involve:

- Braking in an attempt to stop in front of the debris;
- Changing lane (or at least shifting laterally) to avoid debris;
- Both lane changing and braking.

Harsh braking may result in following vehicles failing to brake as quickly resulting in shunt collisions. A lane change might result in side impacts with other vehicles occupying an adjacent lane in the same direction on a dual-carriageway, or a head-on impact on a single-carriageway road. Both the initial response, and the outcome in terms of number of casualties, might differ according to the lateral position of the driver when the event occurs and the density of traffic in the adjacent lane.

Probability of injury from shunt collisions will be:

	Probability of leading driver braking harshly
Multiplied by	probability of following driver failing to stop without rear impact
Multiplied by	probability of injury resulting from shunt collision.

Probability of injury from side impacts will be:

	Probability of lane change
Multiplied by	probability of driver impacting vehicle during lane change
Multiplied by	probability of injury resulting from side impact.

It is assumed that the likelihood of a collision and the level of injury are likely to be similar to any collision where abrupt braking causes a potential shunt sequence, except that vehicles at the front of the queue which might otherwise have stopped could be shunted into the fallen column or post. However this secondary impact is unlikely to produce any significant additional injuries in the case of a passively safe object.

The simulator trial assessed the situation where drivers were faced with the partial collapse of a gantry. The range of responses observed is shown in Figure 13 in Section 6. These outcomes are summarised in Table E6. It is assumed that the same figures would apply to a lighting column / post or other major debris.

Table E6: Drivers' responses to falling debris

Response	Basic assumption	Range of values
Probability of continuing	0.6	0.4 to 0.8
Probability of harsh braking	0.4	0.2 to 0.7
Probability of changing lane	0.5	0.2 to 0.7

The probabilities assumed for a secondary collision (shunt or lane-changing) are shown in Table E7.

Table E7: Probability of secondary collision

	Basic assumption	Range of values
Probability of shunt if brake harshly	0.1	0.05 to 0.3
Probability of side impact if change lane	0.2	0.1 to 0.5

For motorways, it has been shown within STATS19 data that in collisions involving a shunt or a lane change, there are on average 0.01 fatalities when only two vehicles are involved and 0.02 when more than two vehicles are involved. There were roughly twice as many of the former collisions as the latter. These data are summarised in Table E8. Although strictly they are applicable only to motorways, they have been assumed to apply to other roads in the following analysis.

Table E8: Casualties from secondary collision

	Casualties per collision			Equivalent fatalities
	Fatal	Serious	Slight	
Probability of injury from shunt	0.014	0.123	1.619	0.043
Probability of injury from side impact	0.013	0.126	1.387	0.040

At most, one or two drivers will respond directly to the collapse of a post by braking or changing lanes unexpectedly. Following drivers may react to their response or make a separate decision to brake or change lanes. For the basic evaluation, it was assumed that one vehicle on a single carriageway and two on a dual carriageway would make an initial response.

Estimates of the number of equivalent fatalities from shunt and lane changing collisions following the collapse of a passively safe lighting column on a single carriageway road are shown in Tables E9 and E10.

Table E9: Estimate of equivalent fatalities from shunt collisions following impact with a passively safe lighting column on a rural single carriageway

		Cumulative estimate of probability of injury collisions per year
No of run off collisions per year that hit lighting column	0.092	
Probability that lighting column collapses	0.95	0.0874
Probability that debris lands in the road	0.5	0.0437
Probability of harsh braking per vehicle exposed	0.4	0.0175
Probability of shunt collision when harsh braking	0.1	0.00175
Number of vehicles exposed	1	0.0035
		Equivalent fatalities per year
Equivalent fatalities per year from shunt collision	0.043	0.000075

Table E10: Estimate of equivalent fatalities from lane change collisions following impact with a passively safe lighting column on a rural single carriageway

		Cumulative estimate of probability of injury collision per site per year
No of run off collisions per year that hit lighting column	0.092	
Probability that lighting column collapses	0.95	0.0874
Probability that debris lands in the road	0.5	0.0437
Probability of lane change per vehicle exposed	0.5	0.0219
Probability of injury collision following lane change	0.2	0.00437
Number of vehicles exposed	1	0.00437
		No of equivalent fatalities per site per year
Equivalent fatalities per year from lane change collision	0.04	0.000175

E2.4. Risk to third parties of being hit by falling debris

The main areas where a falling lighting column / post or debris is likely to expose members of the public (who are not road users) to risk are the verge or footway in the vicinity of the column / post or on public or private land close to the road.

Probability of injury from this risk will be:

Probability of debris falling where pedestrians might be exposed

Multiplied by probability of pedestrians being at the site at the time

Multiplied by probability of impact resulting in fatal, serious or slight injury.

This risk should be considered separately from that to road users, so that it can be compared with risks to third parties elsewhere on the network. For the same reason, risk is in fatalities rather than equivalent fatalities. The calculation is shown in Table E11.

Table E11: Example of calculation for estimating number of fatalities per year for pedestrians when a passively safe lighting column is hit

		Cumulative estimate of probability of injury collision per site per year
No. of run-off collisions per year that hit lighting column	0.092	
Probability that lighting column collapses	0.95	0.0874
Probability that debris lands on public area	0.3	0.0262
Probability of pedestrian being at this location	0.01	0.000262
		No of **fatalities** per year for pedestrians
Probability per year of **fatal injury** to pedestrian present on 30 days per year	0.25	0.00007
Number of years between fatal injuries		15,256

The risk is therefore low whilst concentrations of pedestrians are low, but would be much higher if there were significant numbers of pedestrians. However, the risk of being hit by an errant vehicle is greater than that arising from debris, because of the increased probability of serious or fatal injury. It will therefore be more important to locate the footway or other public area so as to minimise the likelihood of pedestrians being hit by errant vehicles than to be overly concerned about debris from a collapsing post. At the same time, it is clear that a conventional column / post would slow the vehicle more than a passively safe one and that a barrier would also protect any pedestrians in the vicinity.

E2.5. Sensitivity

The sensitivity of the results was investigated using sensitivity factors. These factors were calculated by considering the upper values suggested for each parameter in Tables E3, E6 and E7. The factor is the ratio of the risk estimate using the upper values divided by the risk estimate using the basic value. In each case the worst combination, i.e. using all upper values together, is considered.

As an example, the basic calculation of risk from shunt collisions following an impact with a passively safe lighting column on a rural single carriageway road assumed 0.95 for the probability of the lighting column collapsing, 0.5 for the probability of the column falling in the carriageway, 0.4 for the probability of harsh braking and 0.1 for the probability of an injury collision then occurring, i.e. a combined probability of these events of 0.95 x 0.5 x 0.4 x 0.1 = 0.019.

An upper value calculation of the risk of shunt collisions might then assume 1 for the probability of collapse, 0.8 for the probability of the column falling into the road, 0.7 for the probability of harsh braking occurring and 0.2 for the probability of an injury collision resulting, giving a combined probability of these events of 1 x 0.8 x 0.7 x 0.2 = 0.112. This value is 5.9 times higher than the basic estimate of 0.019 above.

Table E12 shows the factors calculated for each collision type if upper values are used instead of the basic factors assumed. Using all these factors together results in an overall risk estimate for the passively safe lighting column which is 1.8 times greater than the estimate with the basic input values, but this is still less than that of a conventional column protected by a safety barrier.

Table E12: Sensitivity to different input values of estimates of equivalent fatalities per year for a passively safe lighting column on single carriageway

<table>
<tr><th rowspan="3">Option</th><th colspan="6">Number of equivalent fatalities per year</th></tr>
<tr><th rowspan="2">Errant vehicle occupants</th><th colspan="4">Other road users</th><th rowspan="2">All road users</th></tr>
<tr><th>Hit by falling column</th><th>Run into fallen column</th><th>Shunt collision</th><th>Lane change collision</th></tr>
<tr><td>With basic values for input variables</td><td>0.0027</td><td>0.000087</td><td>0.00013</td><td>0.000075</td><td>0.00017</td><td>0.0032</td></tr>
<tr><td>With upper range values</td><td>0.0027</td><td>0.00029</td><td>0.00037</td><td>0.00044</td><td>0.00094</td><td>0.0047</td></tr>
<tr><td>Factor if use upper range of values for input variables</td><td>1</td><td>3</td><td>3</td><td>6</td><td>5</td><td>1.8</td></tr>
</table>

The use of passively safe signposts and lighting columns

The use of passively safe lighting columns and signposts is becoming increasingly common on both Highways Agency and local authority rural roads. They are particularly suitable where it would be difficult to use a safety barrier, or where the safety barrier itself could pose a hazard, for example at a nosing or on a roundabout splitter island. They have, to date, mainly been constructed of aluminium although more recently, steel and fibre reinforced composite posts have also become available.

TRL has been commissioned by Transport for London (TfL) to investigate the use of passively safe lighting columns and signposts on local roads, the research being initiated by the CSS Street Lighting Group. This report seeks to develop an understanding of any changes in safety risk that might result from introducing passively safe lighting columns and signposts in such areas.

The report recommends that passively safe lighting columns continue to be used in accordance with the National Annex to BS EN 12767. Furthermore, passively safe lighting columns should be used on major urban roads where there is little likelihood of their falling onto the carriageway or where there might be pedestrians. Since most of the run-off collisions occur at night, the latter will not be an issue in many locations. Where speeds are low, for example, in 20 mph zones, or on housing estates, there is little if any advantage in using passively signposts and lighting columns.

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