The Impact of Street Lighting on Night-Time Road Casualties

G I Crabb and L Crinson

Transport Research Laboratory

ABSTRACT

TRL Ltd was commissioned by the Department for Transport to carry out an investigation into the impact of street lighting on night-time road casualties. The overall aim is to provide highway authorities with a robust methodology for preparing cost benefit analyses of new, and refurbishment or replacement of old, road lighting schemes, in terms of their impact on road safety. Current guidance on lighting installations, is based mainly on research by TRL between the 1950's and the 1970's since when significant changes have occurred in terms of greater efficiency of modern lighting, developments in vehicle design and increases in traffic levels.

TRL worked with Local Authorities in Great Britain and made use of the national road accident database ('STATS19'), which provides a record of all vehicle accidents attended by the Police and which involve personal injury.

Night-time accident data was studied and correlated with the lighting systems in use, in order to determine the relationships between the presence of lighting, and the frequency and/or severity of accidents on different classes of road.

The findings of the study to date have shown that there are many interacting variables affecting accident rates, making the separation of the effect of street lighting difficult. The analysis carried out so far shows an apparent benefit in accident savings due to lighting, but confidence in the size of the benefit is low and should be improved by completion of the work. Any resulting changes necessary to update the current lighting provision will be published in a guidance document.

1. INTRODUCTION

TRL Ltd was commissioned by the Department for Transport (DfT) to carry out an investigation into the impact of street lighting on night-time road casualties. There was a perception that existing guidance on the beneficial effects of street lighting is out of date, being largely based on research carried out in the 1950s to the 1970's. Most cost-benefit analysis has been based on an expectation that good street lighting causes a 30% reduction in night-time road casualties compared with poor or no street lighting. This figure, however, is at best an average over different types of roads, road layouts and traffic types, densities and speeds and is most applicable to rates on urban roads with low speed limits. In reality the benefits are likely to depend on other factors as well as these and will therefore be variable over a considerable range. Street lighting, vehicle lighting, road use and pedestrian behaviour have changed considerably since much of this research was carried out. Lighting may also be installed for other reasons than road safety, such as to reduce crime or the fear of crime. The research set out to provide robust evidence for the contribution of street lighting to road casualty reduction by statistical investigation of the relationship between street lighting level and casualty rates, over the most recent period of four years for which accident data was available. The results would be used to define a methodology for preparing cost-benefit analyses for lighting schemes and provide guidance on its use. Such analyses would ensure that lighting is only installed or replaced where justified and of benefit to road safety and that lighting levels for different classes of road are both consistent with safety levels and minimise unnecessary use of light and energy. In this paper the term "accidents" means "personal injury accidents" (PIAs).

The specified stages of the project were:

- A literature review
- Initial analyses of STATS19 casualty data for the whole of the UK to find if street lighting appeared as a significant factor in accident rates.
- Collection of street lighting inventory, traffic flow and digital network mapping data for as large a proportion of the network as practicable from local and other authorities.
- Statistical analyses of the acquired data to determine the contribution of street lighting to night-time casualty reduction for each identified category of road.
- Application of the relationships found to the development of cost/benefit modelling of new or replacement lighting for these categories of road.

2. LITERATURE

Although a number of studies have shown that the provision of street lighting can reduce accident rates (for example Tanner, 1958; Scott, 1980; Cobb, 1987; CIE, 1992; Schreuder, 1998), these studies individually are applicable to limited circumstances, for example one type of road or one speed limit. The relationship between street lighting level and accident rate remains ill-defined. In the UK the Highways Agency (HA), has until recently installed lighting on trunk roads and motorways on the assumption that it reduces night-time accident rates by an average of 30 per cent. However the HA has recently has recently issued a new advice note TA49/07 (HA, 2007) which recommends, for the appraisal of lighting schemes on motorway and "all purpose" dual carriageway "links" (a link is a section of road connecting two consecutive junctions, ignoring minor accesses), a 10% saving in personal injury accidents. For single carriageway all-purpose links the figure is 12.5%. This represents a significant reduction in the expected savings of personal injury accidents on links compared with previous recommendations. For most types of junctions the document advises that clear statistical indications of PIAs likely to be saved by lighting are not available.

While there are many studies published comparing accident levels on lit and unlit roads, there is little published information on the effects of different lighting levels or the degree of correlation between traffic flow rates, lighting levels and accidents.

Since much of the research reviewed was carried out significant changes have taken place in highway design, traffic flows, vehicle lighting and street lighting technology. These changes may have invalidated the applicability of some of the earlier research findings to the current conditions. One notable change in recent years is the steady replacement of low pressure sodium lamps (LPS) in very inefficient luminaires with the much smaller high pressure sodium (HPS) and metal halide (MH) lamps in much more efficient, optically designed, luminaires.

There are many potential interactions between the variables involved, which make the separation of the effect of lighting from other effects extremely difficult. For example, several researchers have pointed out that in studies comparing accidents on lit and unlit roads, the accident rate and the presence of lighting are not independent variables, because lighting is likely to have been installed preferentially where traffic flows and/or accident rates are high. Also, the number of accidents in any one study is generally not large enough to determine statistically significant changes in accident rates. As a result the relative effects of many of the variables which influence accident rates are not clearly defined. Currently no models exist which can be applied to the circumstances of individual sites, but only to the average which is expected from a large number of similar sites and about which the scatter will be large.

Some broad inferences have been drawn from the studies in the literature reviewed.

- Where a network of (generally urban) roads was previously unlit an average reduction in accident levels of about 30% may be achieved where lighting is installed. However, this is a global average and the scatter in the data is large.
- The benefit at any particular site will depend on a large number of factors, including the type and geometry of road, pedestrian flows and facilities, the presence/absence of junctions, and the type, speed and density of traffic.
- Road lighting appears to have a bigger reducing effect on the number of fatal accidents than injury and slight accidents (i.e. accident severity is reduced by lighting).
- Road lighting also appears to have a bigger effect on reducing accidents involving pedestrian casualties (vulnerable road users) than vehicle occupants.
- Road lighting may have a larger effect on reducing accidents at junctions than on carriageway without junctions.
- Accident rates drop with increasing lighting level. However, the improvement is not linear. Some research suggests that there is little benefit in exceeding a threshold level, beyond which the rate of accident reduction is low. Unfortunately, studies have failed to clearly define this threshold. There is however a suggestion that the threshold may be comfortably exceeded by most of the classes defined by the current lighting standards.
- There may be risk-compensation effects in which lighting may lead to increased speeds and reduced concentration, but these effects are likely to be small.
- The age and ability distributions of the groups driving at night are different from those driving during the day. For example, visually impaired older people often avoid night driving, while there may be more road users impaired by alcohol, drugs or tiredness at night. Average speeds also tend to be higher at night, in part because there is less traffic.

- The introduction of lighting columns presents an additional hazard and they are involved in significant number of injury accidents. (This hazard can be mitigated by using passively safe columns but very few of the current inventory on the UK road network are of this type.)

Implications for the current project were that in the initial analysis involving the whole of the accident database there would be a large number of accidents, but also a large number of confounding variables, which would mask the effect of street lighting on accidents. These results would need to be interpreted with caution and used to help design a second phase of analyses which would necessarily be restricted to smaller parts of the network about which more information on traffic flows, road type and lighting could be obtained. It was important to include in the analysis the largest number of accidents possible in order to achieve statistical significance in the findings. Where there are only a small number of accidents in an analysis period very large differences in the number of accidents for different lighting conditions are needed to establish significant relationships.

3. INITIAL ANALYSIS OF STATS19 DATA

The objective of the initial analysis was to provide an overview, over the whole of the road network in Great Britain, of the characteristics of the road network, numbers of accidents in darkness and daylight, whether these accidents were on lit or unlit sections and their distribution over the different classes of road.

The data used for this study were the national STATS19 personal injury accident (PIA) data for 2001 to 2005. This is a database of all recorded PIAs on all public roads in Great Britain, compiled and published annually by the DfT. Accidents in the database are classified by severity as “Fatal” “Serious” or “Slight”.

3.1 CHARACTERISTICS OF THE NETWORK

Table 1 shows traffic flows in terms of annual average daily traffic (AADT) and average annual traffic; total length of each category; total accidents in the study period and corresponding accident densities and rates for each category of road, broken down into urban and rural lengths. The total network length is 388,009km, of which 57% is unclassified road, and B and C class roads combined account for 30%. Motorways and trunk A-roads account for 3% of the length, and non-trunk A-roads make up the remaining 10%. The majority of the A, B and C-road networks are in rural areas, whereas about half the total length of unclassified roads is in urban areas.

It can be seen that while minor roads (B, C and unclassified) accounted for 87% of road length, they only carried 25% of the total traffic. Motorways carried 13% and trunk A-roads carried 9% of total traffic.

Table 1 also shows accident densities and accident rates, which give measures of accident risks. The highest accident rate is on principal A-roads in urban areas, and the lowest is on motorways. For all road classes, urban roads have a higher accident rate than rural roads. The accident density is also shown, which is the number of accidents per kilometre. This shows that urban A-roads have the highest accident density. The motorway accident density is also high, but this is due to the large volume of traffic using these routes. For rural and urban minor roads together, the accident density is lower than the average for all roads, but the accident rate is higher due to these routes having lower traffic flows.

Road type		AADT (thousand vehicles per day)	Average annual traffic (billion veh-km)	Length (km)	Accidents (2001-2005)	Accident density (accidents per km per year)	Accident rate (accidents per billion veh-km per year)
Motorways		75.5	97.0	3,520	44,507	2.53	91.7
A - trunk	Rural	19.3	58.0	8,239	39,699	0.96	136.8
	Urban	33.9	5.5	444	8,499	3.83	307.1
	Total	20.1	63.6	8,683	48,309	1.11	152.0
A - principal	Rural	8.4	83.3	27,312	139,582	1.02	335.1
	Urban	19.6	76.2	10,663	300,648	5.64	789.0
	Total	11.5	159.5	37,975	441,081	2.32	553.0
Minor	Rural	0.9	66.8	207,646	152,711	0.15	457.2
	Urban	2.4	112.5	130,185	383,039	0.59	681.1
	Total	1.5	179.3	337,831	537,042	0.32	599.1
Total		3.5	499	388,009	1,070,939	0.55	428.9

Table 1 Accidents in Great Britain by road type and rural or urban

3.2 ACCIDENTS IN WITH AND WITHOUT STREET LIGHTING

Table 2 shows overall figures for the numbers of all PIAs under each lighting condition in the five year period. Of the total of over one million PIAs, 28% occurred during the hours of darkness. Of these one fifth (6% of all PIAs) occurred where no street lighting was present.

Lighting condition		2001	2002	2003	2004	2005	2001-05
Daylight	Street lights present	119,251	113,098	110,270	104,599	101,767	548,985
	No street lighting	37,670	36,794	36,541	36,937	36,560	184,502
	Street lighting unknown	8,561	8,261	7,938	7,617	5,352	37,729
Daylight Total		165,482	158,153	154,749	149,153	143,679	771,216
Darkness	Street lights present	49,272	49,268	45,558	44,261	41,608	229,967
	No street lighting	12,507	12,476	12,062	12,428	11,924	61,397
	Street lighting unknown	1,752	1,854	1,661	1,568	1,524	8,359
Darkness total		63,531	63,598	59,281	58,257	55,056	299,723
Total		229,013	221,751	214,030	207,410	198,735	1,070,939

Table 2 Number of accidents by lighting condition and year

Overall, accidents in the darkness were more severe than are those in the daylight. Figure 1 shows the severity ratio (or % KSI; the percentage of accidents that resulted in killed or seriously injured casualties) for each lighting condition. Accidents in areas without street lights were more severe than are those with street lights. However, this cannot be taken to show that if street lights were installed, the severity of accidents would necessarily decrease.

The difference in severity is influenced by differences in other factors such as road and traffic type, density and speed. This is emphasised by Figure 1 which shows that on roads without street lighting the severity ratio is higher during daylight as well as during darkness.

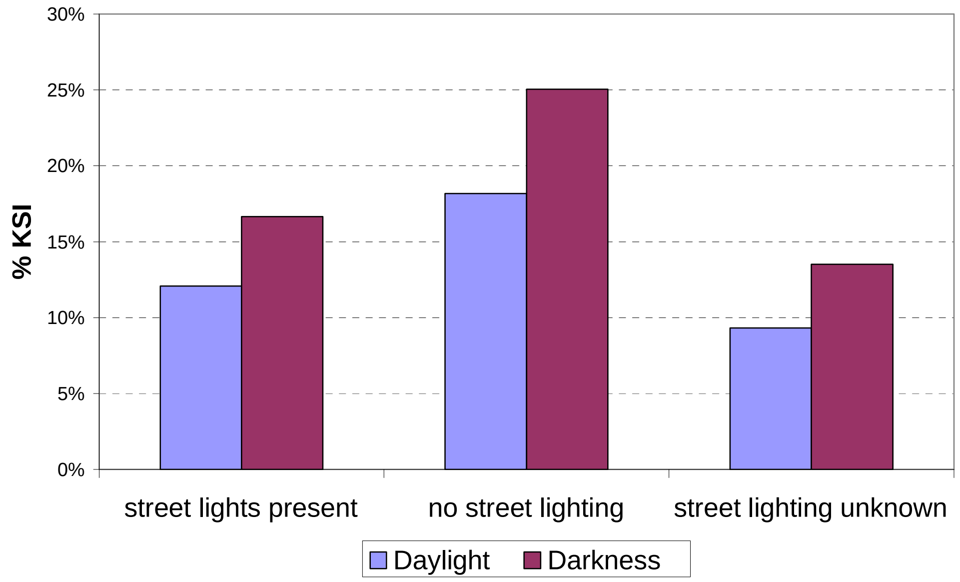

Figure 1 Severity ratio (%KSI) by lighting condition

Analyses of accidents in different road environments (e.g. urban/rural and speed limit) in daylight and in darkness, with and without street lights, showed many differences in the proportions of accidents in the darkness. Some of these analyses showed accident reductions and some increases, apparently due to street lighting. All of these differences are likely to be influenced by the daytime and darkness traffic patterns and other characteristics of routes as well as the presence or absence of lighting. It is also likely that sites or routes with potentially high night-time accident rates or high night-time traffic flows have already had street lighting installed.

This is demonstrated, for example, by Figure 2 which shows the proportion of accidents that occurred during darkness for lit and unlit conditions for the range of road categories in Great Britain. The strategic routes and motorways show a similar pattern, with a greater percentage of accidents in darkness on routes with no street lighting, whereas the pattern is reversed for the other road types.

The literature includes several studies that have taken the ratios of accident numbers in daylight and darkness, separately for lit and unlit sections of road and then found the ratio of these day-to-dark accident ratios to assess the apparent accident saving due to lighting. This is an attempt to normalise the data for differences between the lit and unlit sections, such as traffic flows. A lit-to-unlit ratio equal to one would suggest that there is no saving in accidents due to lighting, a ratio less than one suggests an accident saving, and a ratio greater than one suggests an increase in accidents due to lighting.

These ratios for each of the road classes have been calculated for this study and are presented in Table 3. This suggests an *apparent* accident reduction due to lighting for strategic routes is 17%, compared with an *apparent* increase in accidents of 42% for main distributor routes. However, these apparent changes are based on an assumption that, for example, the day to night traffic flow ratios are the same for the lit and unlit sections. The method may also not fully account for other differences than lighting condition which affect accident rates, between the lit and unlit sections, for example the speed limit, traffic mix and traffic volume. Different age groups using the roads at different times of the day and night may also have a bearing on accident rates. This is demonstrated by Figure 3 which shows that the casualty-age profiles for daylight and darkness are very different, with a much narrower casualty-age distribution at night.

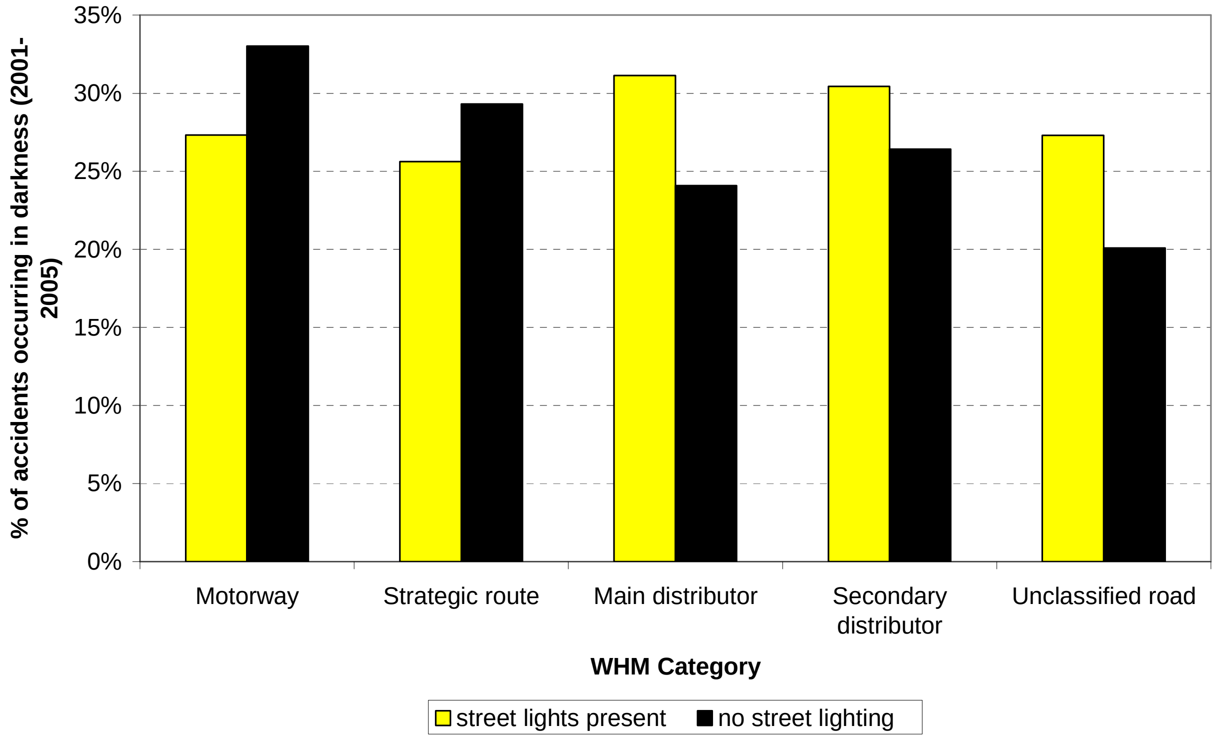

Figure 2 Road category and lighting condition

Accident ratio	Motorway	Strategic route	Main distributor	Secondary distributor	Unclassified road
Lit dark/daylight	0.38	0.34	0.45	0.44	0.38
Unlit dark/daylight	0.49	0.41	0.32	0.36	0.25
Lit/unlit	0.76	0.83	1.42	1.22	1.49
Apparent saving	24%	17%	-42%	-22%	-49%

Table 3 Street lighting accident ratios by road category

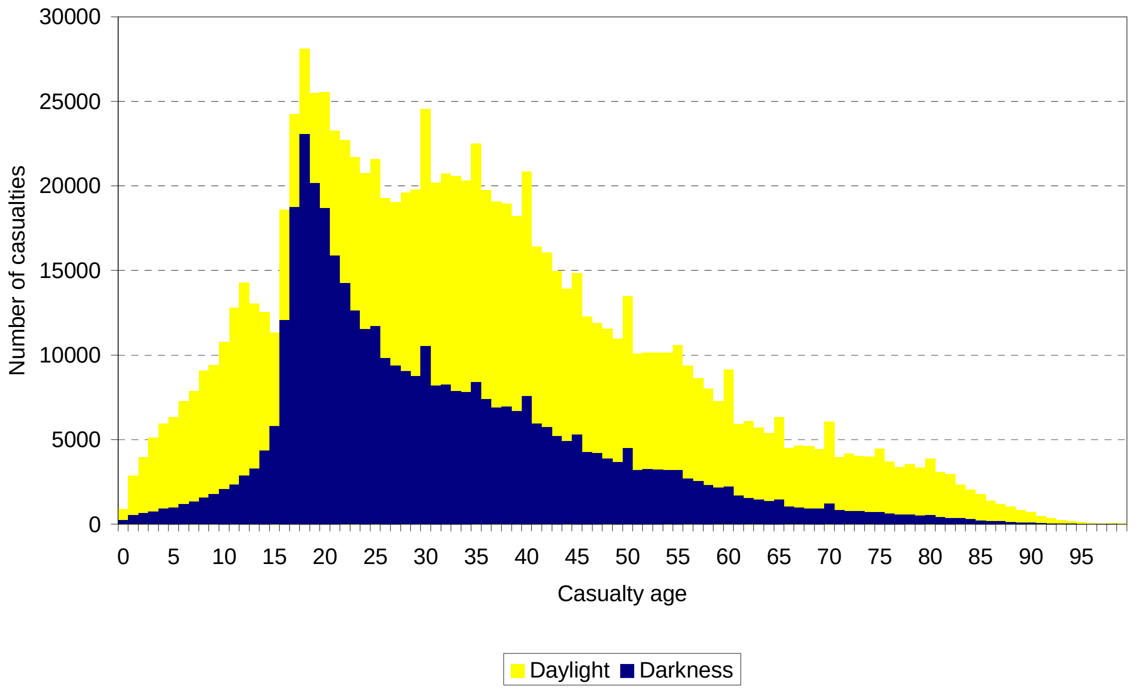

Figure 3 Number of casualties by age in daylight and darkness (2001-2005)

3.3 CONTRIBUTORY FACTORS

Contributory Factors to accidents have been recorded nationally in addition to the accident, vehicle and casualty details from the start of 2005. This data can help to indicate possible causes of accidents, and what might have prevented them. There are 77 different factors, and up to six factors can be recorded for each accident. The contributory factors are related to the road environment or the behaviour or actions of a driver, rider or pedestrian. Table 4 shows the most common ten factors (highlighted in yellow) in each of the lighting conditions, ordered by the occurrence in all accidents.

There are several differences between the contributory factors of accidents occurring in the daylight and darkness, with and without street lights. Overall, the most common contributory factor was ‘failed to look properly’, and this was the most common in all of the lighting conditions except for darkness with no street lighting, where ‘loss of control’ was most common.

Differences between contributory factors for accidents with and without street lights are influenced by the nature of the roads and type of accident. For example ‘loss of control’ is more common on roads without street lights in daylight as well as darkness. Some of the differences between factors in the daylight and darkness are as expected, for example ‘dazzling headlights’ (a minor cause, not in the top 10 shown in Table 4), which would not be expected to be a factor in the daylight.

In pedestrian accidents that occurred in darkness, ‘pedestrian impaired by alcohol’ was more common for accidents in areas without street lights than in those with street lights. It is interesting to note that for both ’Failed to look properly‘ and ’Failed to judge other person's path or speed‘, both factors which might be thought to be strongly influenced by the lighting condition, smaller proportions of the accidents in darkness than in the daylight were where there was no lighting.

Factor	Daylight		Darkness		Total
	Street lights	No lights	Street lights lit	No lights	
Failed to look properly	38.5%	26.4%	32.9%	12.3%	33.4%
Failed to judge other person's path or speed	20.0%	18.9%	16.5%	11.2%	18.5%
Careless, reckless or in a hurry	16.6%	14.9%	18.8%	15.7%	16.6%
Poor turn or manoeuvre	16.2%	13.3%	15.3%	10.1%	15.0%
Loss of control	7.8%	19.3%	12.7%	32.6%	12.5%
Travelling too fast for conditions	8.8%	14.0%	12.1%	19.3%	11.0%
Pedestrian failed to look properly	11.5%	3.8%	10.3%	1.1%	9.1%
Slippery road (due to weather)	5.2%	15.0%	8.1%	20.5%	8.7%
Following too close	9.5%	8.0%	6.9%	3.7%	8.3%
Sudden braking	6.9%	10.0%	4.8%	6.5%	7.0%
Impaired by alcohol	1.9%	2.3%	11.3%	13.2%	4.6%
Exceeding speed limit	3.4%	4.4%	7.2%	6.9%	4.6%
Learner or inexperienced driver/rider	3.8%	5.4%	4.7%	8.6%	4.6%
Swerved	2.5%	5.0%	3.2%	7.1%	3.4%
Road layout	1.4%	6.5%	1.1%	6.3%	2.6%
All accidents with at least 1 factor (100%)	92,419	33,877	36,626	10,923	180,401

Table 4 Most common contributory factors in all accidents
(the top ten in each column are highlighted)

3.4 MULTIVARIATE ANALYSIS

As has been discussed, several of the variables investigated; road hierarchy, urban/rural, road surface condition, and lighting, are related. For example, urban roads are much more likely to be lit than rural roads. A multivariate analysis has been carried out to take account of some of the interrelations within the sample.

The analysis was carried out with the 2005 data for killed and seriously injured casualties (over 31,000 casualties in total). A larger selection of data, (for example, more years or including slight casualties) made the data set too large for this method to distinguish useful results. Even with the smaller subset the interpretation of the results is not straightforward. The variables which were believed to be related to lighting condition, when counting casualties, were included in the analysis. The selection was based on the results of the preliminary analysis, results and expert judgement. Each variable was grouped as far as sensibly possible in order to reduce the number of combinations. The groupings used are given in Table 5.

Variable	Values
Urban/Rural	Urban, rural
Road category	1, 2, 3a, 3b, 4
Vehicle	Car, motorcycle, other
Driver age	17-25, 26-59, 60+
Speed limit	<=30, 40-50, 60, 70
Road surface	Dry, not dry
Lighting	daylight with street lighting, daylight without street lighting, dark with lights on, dark without lights

Table 5 Variable groups in multivariate analysis

The multivariate analysis confirmed that there are complex interactions between the variables and emphasised a lack of exposure (traffic volume) data, which made it difficult to distinguish the effect of street lighting on the distribution of casualties. For example, the distribution of counts of killed and seriously injured casualties, on roads with different lighting conditions is shown to be dependent on each of the other six groups of variables in the analysis.

This initial analysis showed that for a better understanding of the effect of street lighting on accidents, it was vital to carry out analysis on a sample of routes, with and without street lighting, for which more comprehensive data on, in particular, traffic flows and lighting conditions could be obtained.

4. DATA COLLECTION

A list of potential contacts in local authority lighting departments and other organisations was provided by the project steering group. This list was used to distribute an initial request for data about these authorities' street-lighting inventories, data on traffic flows and categorisation of routes, preferably using the hierarchy given in "Well Maintained Highways" (Roads Liaison Group, 2005). It was expected that a number of the authorities approached would hold the required data in computer-based databases and geographical information systems and that it would be straightforward for them to extract the data required and provide it as Excel or Excel compatible (CSV) text, Access or GIS format files. Authorities were asked to provide this information for the whole of their road networks if possible. The following list numbers and types of authority were contacted:

- 17 Counties
- 7 London boroughs
- 8 other English cities or boroughs
- 2 Welsh cities or boroughs
- Welsh Assembly
- 1 Scottish region
- 1 Scottish city
- TfL
- Northern Ireland

- 2 Highways Agency area agents

Six authorities provided lighting inventory and traffic flow data for their complete networks. For some authority areas where the data is held on behalf of the authority by an agent organisation, it was not found practicable to acquire traffic flow data.

In addition, the traffic flow information for all census points on main roads and some minor roads was available in a national DfT traffic flows database. This left some gaps in the local authority data for roads without DfT data, where the lighting inventory had been provided by the LA but not the traffic flows.

For the national data, the traffic flow information for census points on motorways, A-roads and B-roads was used in conjunction with a GIS map layer of the routes to assign accidents to sections of roads. No lighting inventory was available for these data sets, and hence the recording of the lighting condition in STATS19 was used to determine whether each link was lit. The lighting condition could not be determined on links with no accidents in the 5-year period or for those sections where the lighting condition was unclear from STATS19 accident data. These sections were therefore not included in the analysis.

Where both a road network, traffic flows and a lighting inventory was available for a local authority, these data were prepared for analysis by selecting the accidents, traffic value and lighting columns on each route. Figure 4 shows an example map of accidents and street lights.

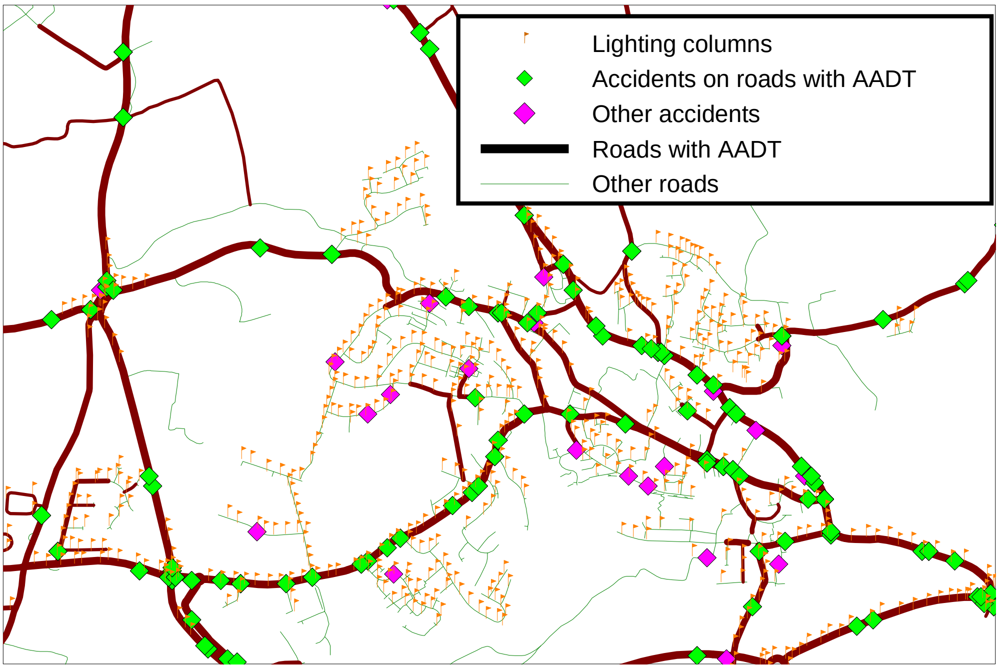

Figure 4 Example plot of street lighting inventory and accident data

Some or all of the following data was available for each of the data sets in the analysis:

- Lit or unlit (either from accident data or lighting inventory)
- AADT
- Length
- Road class
- Rural or urban
- Speed limit

- Route Hierarchy
- Number of lanes

5. ANALYSIS OF COLLECTED DATA

5.1 SUMMARY STATISTICS

The average AADT for each type of road for each data set was calculated, and an example for one of the data sets is shown below.

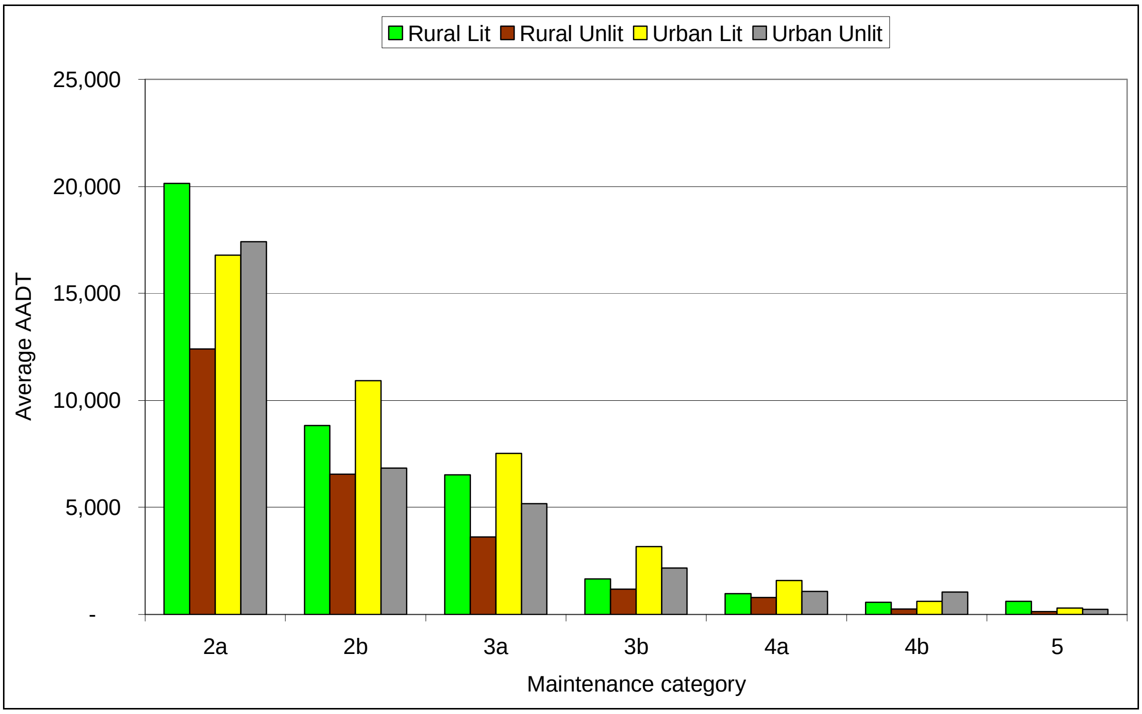

Figure 5 Average AADT by road maintenance category for one data set

Major roads have a higher AADT (maintenance category 2a and 2b), with lower AADT for more minor roads. For most of the maintenance categories, lit roads have a higher AADT than unlit roads. This pattern was similar for other data sets.

Figure 6 shows the average accident rate (accidents per 100 million vehicle-km) for roads in one data set, by maintenance category.

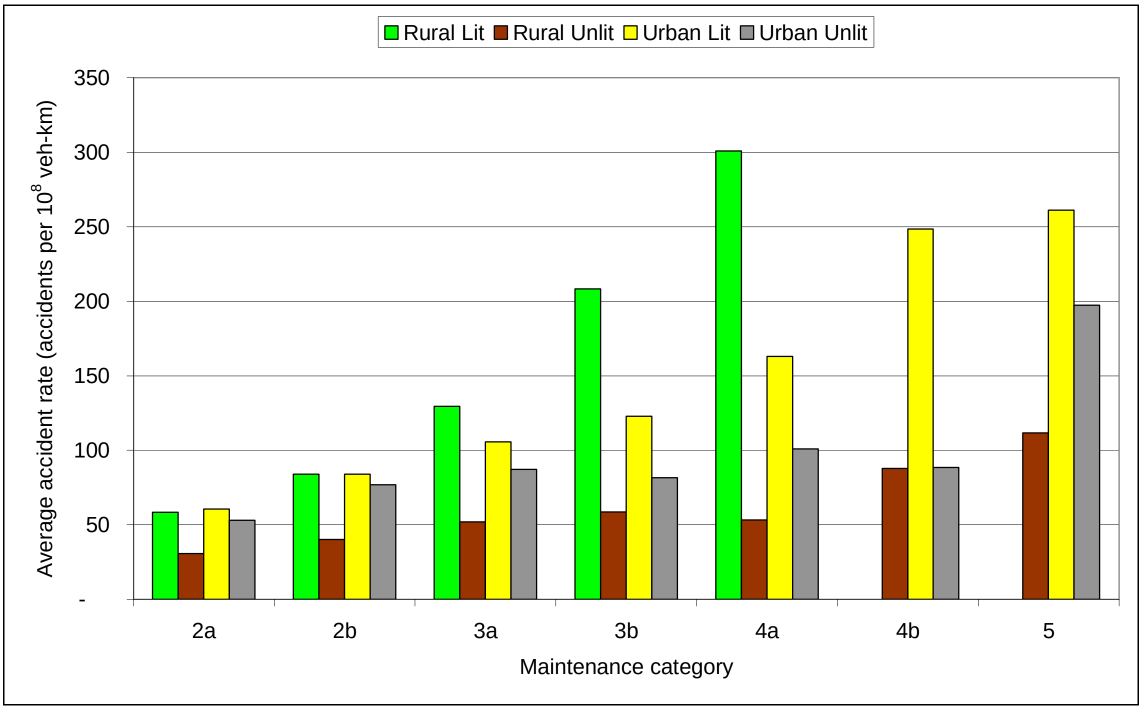

Figure 6 Average accident rate by road maintenance category for one data set

Major roads are designed to a higher standard and therefore have a lower accident rate than more minor roads. For all of the maintenance categories the lit roads had a higher average accident rate than the unlit roads. This factor tends to mask the effect of the lighting on accidents.

These differences in AADT and accident rate are due to the type of roads that have been selected for street lighting, with roads with a high accident rate and high traffic having street lighting installed. This does not mean that the installation of lighting would increase the AADT or increase the accident rate.

5.2 MULTIVARIATE ANALYSIS

The aim of the multivariate analysis was to determine the change in the number of accidents due to street lighting, taking into account other factors such as AADT and road type.

The method of analysis used was General Linear Modelling, a technique used to model accidents due to their non-normal nature. The number of accidents is standardised here by length (accident density or accidents per km) rather than traffic (accident rate or accidents per vehicle-km) as length and AADT should be treated independently in the model. In fact whereas length is included in the model for all of the data sets, AADT does not contribute significantly to the model for all data sets. However, where AADT is significant in the model, this is taken account in the estimates. For each data set two statistical models were created:

1. Using all of the available variables apart from lighting to determine which variables were significant explanatory variables.
2. Using the variables from (1) that were statistically significant to determine the effect of street lighting.

The accidents were split into those that occurred at night and during the day. This was based on an 8-hour time period for night-time (10pm-6am), which was constant throughout the year. The 12-hour day-time accident density was also modelled.

Table 6 shows some preliminary results from the analysis, which was incomplete at the time of writing. For each data set, the percentage difference in the accident density from the unlit roads is shown, for both daylight and darkness periods. A negative value shows an increase in the accident density for roads with street lighting. If the statistical model was perfect it would be expected to remove all the difference in accident density between the lit and unlit roads during daylight. The significance shows whether the accident densities for the lit and unlit roads were significantly different.

Data set	Authority	Road types	8hr night		12hr day	
			% difference	Significant?	% difference	Significant?
1	County 1	all	-13%	n	-71%	y
2	County 1	C-roads	-23%	n	-40%	y
3	County 2*	all	26%	n	15%	y
4	National	B-roads	62%	y	59%	y
5	National	30mph B-roads	73%	y	71%	y

*provisional data ‘y’ or ’n’ = significant or not at the 5% level

Table 6 Effect of street lighting from statistical analysis for 5 data sets

For Data Set 1 (County 1, all roads), the accident density during the day-time was 71% higher on the lit routes compared with the unlit routes. This suggests that there are other differences than lighting between the routes with and without street lighting, having an effect on accidents. This difference was reduced to 13% for the accident density at night-time, suggesting that the street lighting has a safety benefit. The result for Data Set 2 is similar, but this is a subset of Data Set 1

For Data Set 3 (County 2, provisional), the accident density during the daytime was 15% higher for the routes without street lighting compared to those with street lighting, and this difference increased to 26% for the accident density at night. This again shows that there are other differences between the routes, with and without street lighting, which have not been taken account of by the analysis, but it does suggest that street lighting may have a safety benefit.

Data Sets 4 and 5 showed a similar pattern, with a larger difference between the accident densities on unlit and lit roads at night, compared with during the day. This suggests a small safety benefit of street lighting.

These results showed that for some of the data sets there was a higher accident density for lit roads, both during the day and the night, whilst for other data sets the accident density was higher for unlit roads, both during the day and the night. However, all of these data sets showed that the lit roads had a relatively lower night-time accident density than the unlit roads, suggesting that there may be a safety benefit of street lighting. There was variation between the different data sets, with some showing larger apparent reductions than others. This could be due to the following:

- Street lighting has different effects for different network locations and road types
- There are more variables influencing accident density differences between roads with and without street lighting, than it has been possible to include in the analysis

There is evidence to support the latter of these, showing that for some of the data sets, the daytime accident density is significantly different for the lit and unlit roads suggesting that these differences in accident density are not due to the lighting, but other unmeasured or un-measurable factors. Examples of these influencing factors might be pedestrian flow or any of the contributory factors listed in Table 4. If the statistical model included all these influencing factors it would be expected to remove all the difference in accident density between the lit and unlit roads during daylight. There are factors other than lighting included in the model, which have an effect on accident rates. The model assumes that these factors are similar during the day and the night, which may not be the case. For example, this is unlikely to be the case for AADT and pedestrian flow.

6. CONCLUSIONS

The literature review identified that previous research had tended to a figure of 30% reduction in accidents (PIAs) due to lighting as a global average, but that there is considerable scatter in the results and that there are likely to be considerable differences between different road and traffic situations. It is clear that there are a large number of interacting variables which affect accident rates, making it difficult to determine the effect of street lighting. In any practical study the analysis period and the length of network are limited, which restricts the number of accidents available for analysis and makes it difficult to achieve statistical significance in any differences found. However a number of general trends were identified in the effects of different situations (detailed in Section 2.).

It was also clear from the literature that the initial analysis of the STATS19 data for the whole of Great Britain would include a large number of accidents, but also a large number of confounding variables. For the second stage of analysis, using more comprehensive data acquired from smaller parts of the network, it would be important to include the largest possible network length and therefore accident numbers to provide statistical significance in the effect of street lighting on accident rates.

The initial analysis provided an overview of the numbers of accidents in daylight and darkness on lit and unlit roads in each category. The results largely corroborated many of the findings of the literature review and emphasised the importance of analysing more comprehensive data accounting for a wider range of the interacting variables affecting accidents.

Multivariate analysis of some of the data from local authorities has been carried out. This used the available data from local authorities and from the DfT. This analysis assumed that the characteristics of routes were the same for the daytime and night-time.

The results showed that while there were large differences between the authority areas studied, in whether roads with street lights had a higher or lower accident rate in the daytime than those with no street lighting, all of the data sets analysed so far showed an apparent benefit in accident savings due to lighting. At this stage it is not possible to determine with confidence the size of any benefit. The work described in this paper is incomplete at the time of writing.

Future work on the project may include:

- Further analysis of existing data sets, such as refining the definition of day-time and night-time
- Multivariate analysis of additional data sets
- If statistical significance can be achieved, determination of the accident reductions due to lighting on different categories of road.
- A cost benefit methodology for the appraisal of lighting schemes based on the accident reduction rates identified.

The full findings of the project will be presented in a published report (Crabb et al, 2008).

It is also intended to publish a guidance note for practitioners on the application of the results of the project to the specification of new or replacement street lighting schemes.

7. REFERENCES

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