NIHR Public Health Research programme

NHS National Institute for Health Research

PHR Protocol - project ref: 11/3004/02
Version: 1.0
Date: *1 January 2013*

What is the effect of reduced street lighting on crime and road traffic accidents at night? A mixed methods study.

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Sponsor	London School of Hygiene & Tropical Medicine
Funder	NIHR PHR Programme
NIHR Portfolio number	N/A
ISRCTN registration (if applicable)	N/A

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1. Aims/Objectives:

1.1. To conduct a nationwide analysis of street-level data for all local authorities where street lighting reduction schemes have been introduced by 2012; and to quantify (with adequate power and precision) the impact of these schemes on the incidence of road traffic injuries and crimes.

1.2. To use a rapid appraisal to identify: articulated public views about street lighting reduction schemes and their unforeseen consequences or benefits; the role these views have played in local decision making; and less explicit concerns evidenced in accounts of the impact of reduced street lighting.

1.3. To develop an inventory of all quantified costs and benefits of street lighting reduction schemes and to examine variation in the costs and benefits of schemes.

1.4. To convene a workshop with representatives of key stakeholder groups in order to maximise knowledge transfer.

2. Background:

Many local authorities of England and Wales are considering reducing, or have reduced, some street lighting provision, in part to reduce costs, but also with considerations of contributing towards climate change mitigation and reducing environmental light pollution (Royal Commission 2009). To date, many proposals to reduce street lighting, particularly in urban areas, have attracted considerable public and media concern. Expressed concerns have centred on crime, public perceptions of safety, and road safety. However, potential positive impacts of reduced lighting have also been noted, in particular for amateur astronomy (House of Commons CoSaT 2003), and reductions might, in theory, mitigate the negative health impacts some have claimed from 'light at night' such as disrupted sleep (Navara, 2007). To date, there is little robust evidence on which to judge whether these concerns are well-founded (Welsh and Farrington, 2008; Beyer and Ker, 2010; DeFRA, 2011). There are therefore policy imperatives to generate good quality evidence on whether reductions in street lighting provision are associated with public health effects. Robust assessment of two key public health outcomes– road safety and crime – is possible using existing routine data sources, and generating good quality evidence on these is the primary aim of this project.

Other potential impacts, such as improved sleep or increased fear of crime, are more challenging, given the lack of existing baseline data with sufficient coverage to assess changes using a retrospective study design, and the large costs and methodological difficulties that would prohibit prospective trial designs. However, only assessing those impacts which can be easily quantified can risk generating data that are less useful for policy, and which do not resonate with public concerns. A secondary aim of this study is therefore to map the range of public concerns about the health effects of reduced street lighting, and

to provide some exploratory assessment of those impacts for public health that cannot, currently, be quantified.

The cultural context of public concern is likely to be broader than a focus on crime and road safety only. Although expressed public concern has explicitly focused on impacts on safety, it also perhaps reflects the wider cultural significance of 'bright lights' as a marker of modern, affluent and well administered cityscapes. Permanent and abundant lighting is a feature of such spaces as 24-hour supermarkets or motorway service stations - the paradigmatic 'non-places of supermodernity' (Augé 1995). In contrast to Victorian or low-income cities, contemporary modern cities are expected to be well-lit, with streets and inhabitants made visible day and night by widespread electric lighting (Otter 2002, Brox 2010). Such abundant lighting requires not just resources, but also good governance: by implication, perhaps, any lack or reduction in lighting undermines our faith in the ability of administrations to maintain social order. Street lights are thus a component of the citizen's sense of security in their governance, as well as their personal safety: taken-for-granted until threatened. The impact of street lighting on well-being is, therefore, potentially wide ranging. Permanently well-lit streets evoke more than a (presumed) safer place to walk or drive, but also indicate good governance, affluence and a taken-for-granted location in the 'modern'. The 'lights going out' and a return to darkness is a recurrent metaphor for terror and apocalyptic futures (Virilio 1993).

Understanding public views relating to health impacts, and the ways in which those public views are incorporated into local decision making, will therefore be essential for a broader and policy relevant understanding of the effect of reduced street lighting on the public health. Local decision making is done in complex policy environments in which policy makers have to balance competing agenda (Green & Edwards 2008). As many local authorities have undertaken public consultation on street lighting proposals, and have recorded the results of this, there is already a large amount of material in the public domain on *expressed* public opinion, particularly on anticipated implications of reduced street lighting. What is not known is how this is taken into account in local decisions, and whether different forms of public consultation (e.g. public meetings, residents' surveys) generate different sorts of knowledge about public views, or are utilised differently by local policy makers. Additionally, rather less is known on more considered public views. How, for instance, do expressed opinions reflect the (rather less easily articulated) cultural concerns, above, about the implications of 'darkness'? Understanding the extent to which expressed concerns reflect calculable assessments of risk, and how far they are shaped by deeper anxieties about lighting, as above, is crucial for both framing findings for public dissemination, and for furthering our understanding of the role of public health evidence in policy decision making.

2.1. Existing research

Street lighting and crime

In the most recent systematic review of the effects of street lighting (Welsh & Farrington, 2008) on levels of crime, in 9 of the 13 controlled before and after studies included, there was a reduction in crime for both hours of daylight and for hours of darkness. In studies that examined crime occurring during night-time alone there was no impact of the intervention. At the very least, this suggests that effects of street lighting are not straightforward. In the extreme, it may be that changes in levels of illumination do not impact upon levels of crime. However, this is yet to be examined as studies concerning the impact of street lighting on

crime have only tested the hypothesis that *increasing* levels of illumination are associated with reductions in crime. Despite the (arguable) ease with which lighting can be turned on and off, no study of which we are aware has tested the associated prediction that reductions in levels of illumination will be associated with an increase in crime levels (for a more general discussion of why this is important, see Mayo, 1949). A major limitation of the studies included in the systematic review was the use of inadequate control areas (only two studies that used multiple control areas also included non-adjacent areas). Also, the review authors could not interpret data from one evaluation (Shaftoe 1994) because the street lighting was improved gradually over time in different locations across the city (Bristol, UK). The review authors recommend high quality evaluations with long-term follow up.

Street lighting and road traffic injury

Beyer and Ker (2010) conducted a systematic review of the effects of increased street lighting on road traffic injuries. Their review included 17 controlled before-after studies; seven studies included a designated control site, the other 10 studies collected data at one site only and used day-time data as the control. Pooled results of studies that used control areas provided some evidence for a protective effect of increased street lighting on reducing road injury (Risk Ratio 0.78; 95% confidence interval 0.63 to 0.97). The pooled results of studies that used day-time data as the control also provided evidence for a stronger protective effect (RR 0.68; 95% CI 0.61 to 0.77). However, it should be noted that the methodological quality of the included studies was considered to be poor and the risk of bias therefore high. The review authors recommend high quality evaluations that will adequately determine the effectiveness of street lighting on the incidence of road traffic injury.

Street lighting and other outcomes

There is less research addressing the effects of street lighting on outcomes such as sleep, or fear of crime. Drawing on animal studies (Shuboni, 2010) and studies of shift workers, concerns have been expressed at the impact of 'light at night' on circadian rhythms via interrupted endocrine processes, potentially affecting outcomes such as sleep, anxiety, depression and cancer incidence (Navara 2007; Fonken et al., 2009; Pauley, 2004). However, to our knowledge, there is little robust evidence of the effects of light at night on human health outcomes, and no studies which have directly investigated the impact of reducing street lighting on these outcomes. On fear of crime, one study utilising a re-lighting programme in London to identify changes in public perception found mixed perceptions: women were more likely to report feeling secure and elderly residents were more likely to be concerned about vandalism to cars after lighting improvements, and little difference to after dark travel behavior (Atkins et al., 1991). In a controlled before and after study in the West Midlands, the results were mixed on a range of measures of fear of crime, but showed a reduction in the perception of risks for women after dark in the experimental area where lighting had been increased (Painter and Farrington, 1997).

2.2. Risks and benefits

Our proposed quantitative analysis will utilise existing data sets and will be based on the anonymised records of individuals and events (collisions and crimes). Our proposed qualitative study will use interviews with key policy actors and members of the public. There are therefore no expected risks for any individuals involved in the study.

2.3. Rationale for current study

Local authorities (LAs) in England & Wales are switching off street lights during the night in areas where there is low risk of crime or traffic accidents. These street lighting reductions potentially save energy costs for councils, reduce light pollution, and contribute to a reduction in greenhouse gases (Royal Commission 2009). However, implemented and proposed plans have attracted considerable public concern. These concerns centre on crime, road safety and perceptions of public safety. Street lighting reduction schemes tend to be implemented in rural areas while street lights are kept on all night on roads in town centres, those with heavy traffic use after midnight, and in areas with high rates of reported crime or road traffic collisions. Additionally (or alternatively) some LAs have implemented reduced illumination by dimming, whereby high wattage bulbs are "dimmed" at night until the early hours of the morning at times when traffic flows tend to be lighter and lower levels of lighting are not expected to affect road safety. Some schemes have already been implemented (e.g. Buckinghamshire Council introduced its scheme in February 2007) whereas others are planned to start in 2012. A recent review (DeFRA, 2011) identified 25 current schemes in England and Wales, including some small scale trials of temporary schemes.

As outlined above, systematic reviews have not identified robust evidence for, or against, the impact of reduced street lighting on road safety (Welsh and Farrington, 2008; Beyer and Ker, 2010), and the implementation of street lighting reduction schemes continues to cause considerable public debate. Welsh and Farrington (2008) conclude that:

> *"Future research should ideally include several experimental areas and several comparable adjacent and control areas... Adjacent areas are needed to test hypotheses about displacement and diffusion of benefits... The use of several areas would make it possible to establish boundary conditions under which improved lighting had greater or lesser effects... It is unfortunate that in many existing evaluations the control area was adjacent to the experimental area."*

Our proposed analysis is a high quality evaluation using all nationally available data and responds well to the recommendations made by the authors of the two systematic reviews. It will thus aim to contribute robust evidence to public debates and local authority decision-making about whether or not street lighting affects risk of road injury and crime. Furthermore, unlike previous analysis (e.g., Shaftoe 1994) our proposed controlled interrupted time series analysis will account for changes in street lighting provision that are introduced at street level over time. Using all existing data sets available nationally, our study will produce the most robust evidence to date for the relationship between reduced street lighting and the risks of crime and road traffic injuries. In particular, we will assess evidence for effects on injuries and crimes in areas adjacent to street lighting reduction schemes, and to inequalities in injuries and crimes according to level of deprivation of the areas.

Additionally, we will use qualitative methods to map the range of other possible positive and negative impacts of reduced street lighting on public health that cannot easily be quantified. These include potential direct impacts on, for instance, sleep quality, and also those that might impact less directly through, for instance, increased fear of crime and consequent anxiety or reduced willingness to travel after dark. Further, there are good grounds for hypothesising that concern about reduced street lighting might reflect deeper seated concerns about 'security' and the governance of public space. To ensure that our assessment of impacts that can be quantified is conducted in the context of a more wide-

ranging review, we will conduct a rapid appraisal of public views in local authority areas where schemes have been implemented, or proposed, in order to identify issues raised by the public (in both local authority consultations and in interviews) that are not quantified (e.g. trip avoidance; risk compensation behaviour) and to identify through ethnographic interviews the salience and meaning of those concerns.
Finally, decisions about street lighting reductions, in common with many policies that potentially affect the public health, are largely taken outside the health sector. Our experience to date is that sources of evidence generated by public health researchers may be invisible or inappropriately framed for those in LA settings. There is therefore a need to work closely with LA partners, to explore through this research how different sources of 'evidence' are currently utilised to make decisions that potentially impact on the public health, and to identify the most useful methods for dissemination and knowledge transfer.

3. Research design

Objective 1

Design: Controlled interrupted time series analysis.
Setting: All local authorities of England & Wales.
Target population: People who were victims of road traffic collisions or street crime.
Intervention being evaluated: Any street lighting reduction schemes (to include switching selected street lights off permanently; switching selected street lights off for part of the night; 'trimming' the period where lights are switched on; dimming the lighting level (brightness) in the evening and during the early hours of morning). We shall classify each road according to the type of lighting change implemented.
Measurement of outcomes and duration of follow up: STATS19 road traffic injury data will be obtained for the period 2000 to 2012. These data include date, time, location of collision, by type of casualty (pedestrian, car occupant, etc.). Crime incident data will be obtained for the period up to 2012 from police.uk including the month, location and type of crime.
Geographical Information System (GIS) methods: We will link data sets to a road segment database including the characteristics of all roads in England & Wales. We will classify each road segment according to road type, type of street lighting reduction scheme (e.g. part-night switch-off; 'dimming'), the period at night when lighting is reduced, and the Lower Super Output Area in which it is located.
Sample size: We propose to assemble and analyse data for all LAs in England & Wales that have implemented sizeable street lighting reduction schemes by 2012. This will enable reasonably precise quantification of the impact of such schemes on road injuries and crimes. *See Section 6 (Proposed sample size) below for details of sample size and power calculations.*
Planned analyses: Analyses will adapt methods previously applied by the applicants to quantify the effect of 20mph zones on road injuries (Grundy et al. 2009; Steinbach et al. 2010). *See Section 7 (Statistical analysis) below for further details.*

Objective 2

The design of this component utilises elements of ethnographic rapid appraisal, traditionally developed for research with rural populations in low income settings, but increasingly used as a complement to quantitative epidemiological methods in high income urban settings when more focused qualitative data are required on topics for which good quality epidemiological data do not exist (Trotter, 2001).
Rapid appraisal: Using the review of proposed lighting reduction schemes (DeFRA 2011) and

our contacts with all LAs of England & Wales (for Objective 1), we will identify a purposive sample of eight LAs to provide a range of rural & part-urban settings across England, with lighting reduction schemes in place, or proposed. The rapid appraisal will generate data from web searches, phone/email interviews and a 2-3 day site visits as follows:

- First, a rapid survey of web and public sources (e.g. LA websites, local news media, and minutes of committee meetings) will identify: LAs where lighting has been/ is to be reduced; public consultations on street lighting to identify methods used and the content of concerns expressed; and contact details for key informants in each locality.
- Key informant interviews to identify local consultation processes to date; local stakeholders' views of public concerns; how concerns are incorporated into policy decisions; other factors that influence policy decisions around street lighting. These key informants will help to identify sites for survey interviews with residents and for ethnographic interviews, and to provide data for Objective 3 (below). In each area we aim to include: councillors, local MPs, LA Engineers Departments, Police Community Liaison Officers, and other local actors identified in interviews.
- Door-to-door interviews in two contrasting sets of affected streets in each area. Based on our prior experience of household surveys, by sending an introductory letter about our study to around 80 households one week in advance of calling, a sample of 20 people will be achieved in streets where street lighting has been, or is proposed to be reduced. Interviews will cover: views of current street lighting levels, preferences for more/less lighting, impacts of any changes noticed. Using data on area deprivation (in the GIS) the streets will be selected to include contrasting areas of socio-economic status.
- Ethnographic interviews and observations using natural groups where possible (e.g. groups encountered in cafés, community meetings suggested by local key informants). These interviews will be used to generate more narrative talk about street lighting and possible reductions, and the impact of this on health and wellbeing.

Analysis: Data from key informant interviews will be thematically analysed to identify the range of ways public consultations are incorporated into decision making and how public health evidence (of the type generated in Objective 1) could, or would, be utilised. Resident survey interviews will be analysed using descriptive statistics, comparing views in areas where lighting has been reduced to those changes are proposed, and comparing higher and lower socio-economic settings. Key informant and ethnographic interviews will be analysed thematically, using both deductive methods (i.e. identifying how far issues such as sleep, anxiety, fear of going out after dark are expressed) and a more inductive analysis to identify the meaning and salience of street lighting for residents and other road users in terms of impact on health and wellbeing. Key issues for data analysis will include salience of concerns; comparisons of views before and after changes; comparison of concerns expressed in public consultations, survey interviews and ethnographic interviews.

Objective 3

We will assemble evidence from objectives 1 and 2 (above) of all costs and benefits. We will assemble data from local authorities on the costs of providing types of street lighting (i.e. infrastructure cost, maintenance costs, energy consumption). We will also assemble data on the monetary values (i.e. economic and societal costs) of road traffic casualties by level of severity and the economic, and societal costs of crimes by type of crime using Home Office definitions (Home Office, 2005). We will then compare societal costs of street lighting

schemes against the societal benefits in a cost-benefit analysis framework. We will assess the impacts of street lighting schemes on inequalities by conducting stratified analyses (e.g. by: area deprivation, resident population density, crime and traffic injury rates pre-implementation of schemes). Using sensitivity analyses we also propose to examine the impact on our results of the uncertainty in our effect estimates (to derive credible limits of the estimated societal costs and benefits of street lighting reduction schemes).

Objective 4

We will convene a workshop with representatives of key stakeholder groups in order to maximise knowledge transfer. Our findings from objectives 1-3 above would be presented and discussed with those from LAs involved in the study, other LAs, 3rd sector organisations such as Campaign for Dark Skies, Campaign to Protect Rural England, Automobile Association, and Living Streets. The aims of the workshop would be to identify: (i) how public health evidence is most likely to be utilised by LA partners; and (ii) how best to disseminate our findings to partners outside health.

4. Socio-economic position and inequalities

Using similar methods previously used by the applicants (Steinbach et al 2010) the quantitative component of the project will include analyses stratified by quintile of deprivation of the areas in which roads are located. Using a Geographic Information System database we will assign each road segment a deprivation score and deprivation quintile based on the Index of Multiple Deprivation (IMD) 2010 of the Lower Super Output Area in which it is located. Analyses will compare the pre-post change in the outcomes (injury and crime counts) on roads affected by reduced street lighting relative to the change seen on other roads within each deprivation quintile. To test statistically whether the effects of reducing street lighting on crimes and injuries differ by deprivation quintile, we will fit Poisson regression models (see *7.Statistical analysis, below for further details*) that include interaction terms for deprivation quintile and road lighting status. We will also examine the distributions of implemented (and planned) reduced street lighting schemes by deprivation quintile. The qualitative component will purposively sample from contrasting areas of socio-economic status, enabling a comparison of key concerns by area. Interview data will be explored for issues that may relate to potential inequalities in impacts (e.g. on particular kinds of workers, such as shift workers, who are likely to be from lower income groups) or concerns.

5. Proposed outcome measures

For the quantitative components the proposed outcome measures will be road traffic injuries and crimes affecting the population living in, visiting, or passing through roads under the control of the LAs included in the study. For road traffic injuries we will obtain STATS19 data for the period 2000 to 2012 covering all LAs included in the study. The STATS19 data include date, time of day, location (easting and northing of location of the road traffic collision), severity (slight injury, serious injury, fatal injury) by type of casualty (pedestrian, cyclist, car occupant, powered two-wheeler) for all road collisions. Publicly available data on crime will be obtained for the whole of the UK from the police.uk website. Available from December 2010 onwards, these data contain: month, policy constabulary, name of road where the incident occurred (or near to), type of crime, and geographic co-ordinate of the

offence. For the cost-benefit analysis we will obtain monetary values of street lighting provision, crimes and road traffic collisions prevented. For the qualitative component, the outcomes will be a qualitative map of issues raised by policy stakeholders and the public (from the rapid assessment); comparison of concerns about street lighting levels before and after implementation of schemes (from street intercept and ethnographic interviews), an understanding of the comparative salience of those issues we can quantify (road injury, crime), and other expressed concerns for the public.

For the crime data, the geographic coordinates do not reference the exact location of offences; this partly reflects the fact that the precise location will likely be unknown for crimes which occur on the street, as victims may only be able to provide a description of (say) the street segment on which an offence occurred. Moreover, to preserve the anonymity of victims, the police data are processed as follows: "*Each dot marks the approximate location of an incident of crime or anti-social behaviour and it will usually appear on a street with 8 or more postal addresses. We have purposely used radar-style icons to demonstrate this and also clearly state at each dot that the incident is 'on or near.'" (http://www.police.uk/help?).*

Considering the crime categories, these were initially classified as being: burglary, anti-social behaviour, vehicle crime, violent crime, or belonging to a collection of "other" offence types. As a consequence of public feedback, from October 2011, the "other" category has been disaggregated so that offences can be differentiated as: Burglary, Anti-social behaviour, Robbery, Vehicle crime, Violent crime, Public disorder and possession of weapons, Shoplifting, Criminal damage and arson, Other theft, Drugs, and "Other" crime. Data for the period December 2010 to September 2011 have not been reclassified, but the above can be aggregated to form the "other" category previously used.

The benefit of using these data is that they provide complete coverage for the UK, the data are available in a standard format, and the data allow for monthly counts of offences to be computed. Moreover, acquiring data from individual police forces is notoriously difficult, even for government funded research. The disadvantages of the data are that: 1) geo-codes associated with offences may not reflect the crime locations as recorded in the police data (as discussed above); and 2) the time of day that offences occurred is not included in the data. On the one hand, this latter point is a concern as one would expect the effects of street lighting to be most apparent during hours of darkness. On the other, the Farrington & Welsh (2008) systematic review suggested that lighting does not differentially impact upon levels of crime during the night.

For the reasons discussed above, and to allow us to assess the reliability of inferences drawn using the (nationally available) police.uk data, police recorded crime data will be obtained from a sample of four police forces. The data requested will include the following fields of information:

- exact date *and* time of each offence
- text address of the offence
- geo-coordinates of the offence
- type of crime.

For comparison with previous research on this topic (see Welsh and Farrington, 2008), data will be requested for the types of crime most commonly considered in studies of this kind, as follows: Assault, Burglary, Robbery, theft *from* and theft *of* vehicle, theft from the person,

and anti-social behaviour. With respect to theft, we intend to use both an aggregate category and also to disaggregate to allow us to focus on (for example) trends in the theft of pedal cycles (one of the few types of crime to have increased over time), as the theft of cycles is known to impede cycle usage (as cyclists often will not replace stolen bikes which is counterproductive in terms of the sustainable transportation agenda (see, Johnson, Sidebottom, & Thorpe, 2008). In addition, we propose to examine trends in criminal damage as signs of decay in a neighbourhood can have impacts beyond the intended target, can impact upon fear of crime, and the perception of an area more generally.

Data security - For the purposes of data protection and security, crime data obtained from police forces will initially be stored in the UCL JDI data lab. The data lab is a new UCL facility, which is part of the UCL Jill Dando Institute of Crime Science, that will be accredited against national standards for the handling of data up to the level of 'confidential' and will provide a secure environment in which to store and analyse data. There are 15 thin client terminals within the lab through which to access data. The lab will be operational summer 2012. The point level data will then be processed within the lab and events aggregated to the street segment level, thereby anonymising the data to a level suitable for sharing with research team for analysis. For added security, all crime data will be stored on encrypted computers.

6. Proposed sample size

For our quantitative objectives, we propose to assemble and analyse data for all LAs in England & Wales that have implemented sizeable reduced street lighting schemes by 2012. This will enable reasonably precise quantification of the impact of street lighting changes on road injuries and crimes. For our power and sample size calculations below we have assumed that lighting reduction schemes have been implemented on streets on which only 1% of pre-intervention events occurred.

Road traffic injury: For night-time road injuries we will maximize power by using data for at least 10 years before changes were implemented. Using STATS19 casualty data for 2010 (table 1), we estimate that across all study areas the expected number of night-time injuries on intervention roads will be around 150 (i.e. 1% of 15,419 casualties) per year. If we expect 1,500 casualties on intervention roads during 10 years before lighting reduction, and 150 casualties one year after, we will have 90% power to detect an increase of 32% above pre-intervention casualty levels.

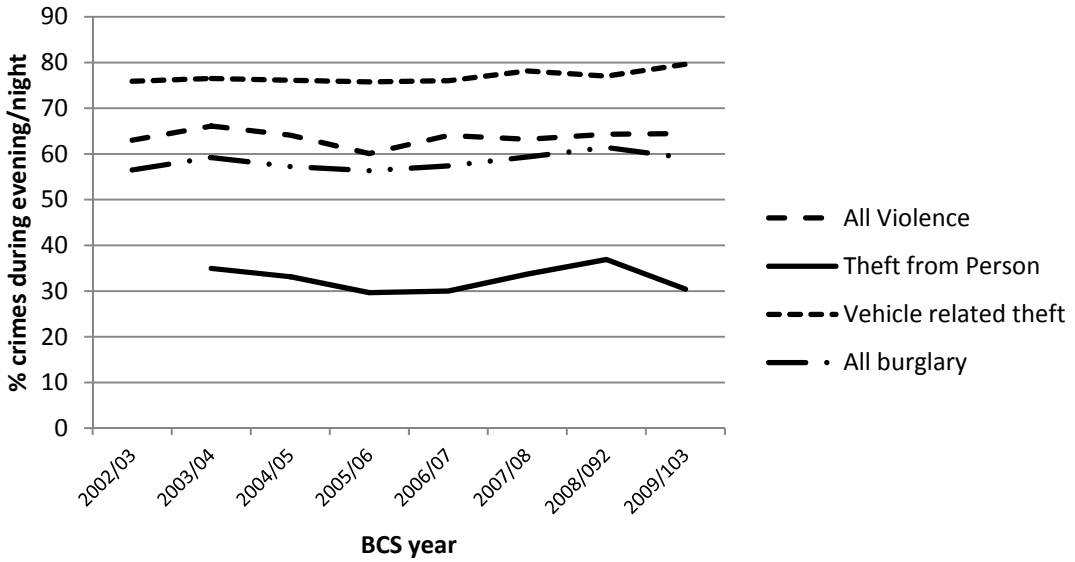
Table 1 Road traffic casualties (England & Wales 2010)

Road user category	Total casualties	Casualties 7am-midnight	Casualties midnight-7am	% midnight - 7am
Pedestrian	25,845	24,156	1,689	7%
Cyclist	17,185	16,391	794	5%
Powered 2-wheeler	10,965	10,409	556	5%
Car occupant	132,623	121,601	11,022	8%
Other	22,030	20,672	1,358	6%
Total	208,648	193,229	15,419	7%

Crimes: In the absence of police data on the time and location of crimes at the present time, it is not possible to calculate how many crimes occur on roads affected by street lighting, or during the hours of darkness. Our analysis of national crime data from December 2010 from

police.uk will quantify the impact of street lighting reduction schemes on *day-time and night-time crimes combined* (no time of day for these data). There were 1,936,425 Police recorded crimes in England & Wales during 2009/10 (table 2 below). We therefore estimate that across all study areas the expected number of all (day and night-time) crimes on intervention roads will be around 20,000 (i.e. 1% of 1,936,425 crimes) per year. This number will provide 90% power to detect a 5% increase in all (day and night-time) crimes above pre-intervention levels (equivalent to a 20% increase in night-time crimes alone), and for major sub-categories such as burglary, we will have 90% power to detect increases of about 10% in all (day and night-time) crimes.

Crime at night: Data from the British Crime Survey (BCS) are instructive with respect to the time of day that offences occur. The figure below shows the fraction of crimes that occur either during the evening (6pm-midnight) or night-time (midnight-6am) for offence types commonly examined when evaluating the effectiveness of street lighting. A non-trivial percentage occurs during the hours of darkness for all offences considered, and with the exception of 'Theft from Person' more than half of offences tend to occur during the 12-hour window that encapsulates the evening and night-time.



In terms of where such crimes occur at the micro level (e.g. the type of street), we are unaware of such an analysis at the national level. However, a large-scale study by Johnson & Bowers (2010) found that, after controlling for area level influences, the risk of burglary was highest on street segments that were part of major roads (being lowest on cul-de-sacs and private roads) and those that are more connected to others (particularly those connected to other major roads), the types of roads that are most likely to have enhanced street lighting. Thus, it seems reasonable to suggest that for burglary at least (for a similar conclusion, but for an aggregate analysis of other crimes, see Armitage et al., 2011), there should be a disproportionate amount of crimes on roads where improved street lighting exists, and during the hours of darkness.

The table below shows the number of recorded crimes during 2009/10 by Home Office category. The table also shows the number of night-time crimes estimated using the BCS data above, and assuming that one third of evening or night-crime occurs during the night-time (midnight-6am).

Table 2 Police recorded crime (England & Wales 2009/10)

	Total counts	Estimated % night-time (midnight-6am)	Estimated crimes (midnight-6am)
Violence against the person	871,712	25%	217,928
Robbery	75,101	10%	7,510
Burglary	540,655	15%	81,098
Theft from motor vehicle	339,140	20%	67,828
Theft of motor vehicle	109,817	20%	21,963
Total	1,936,425	20%	396,328

http://www.homeoffice.gov.uk/science-research/research-statistics/crime/crime-statistics/police-recorded-crime/

For the crimes listed, the estimated number of pre-intervention night-time crimes, on intervention roads, will be around 4,000 (1% of 396,328 crimes). By obtaining data from a sample of four police forces (one tenth of all forces) we can expect 400 detailed night-time crime events per year. Using data for one year before lighting reduction and one year after, we will have 90% power to detect a 26% increase in crimes above pre-intervention levels. There will be similar power to detect increases of 40% in major sub-categories of crime (e.g. violence against the person).

For our qualitative investigation, we estimate that up to eight LAs chosen purposively to include a range of geographical areas where schemes have been implemented, or are proposed, will be sufficient to assess the variability in public concerns. Within each LA area selected, interviews will be conducted with all identified key informants. The sample size of 20 household interviews is typical for similar exercises (Trotter, 2001), generating sufficient data to map variability of views. We will sample systematically (i.e. every n^{th} house) within sites (e.g. a street with reduced lighting) where there is a choice of households. Three to four ethnographic interviews in each setting will generate a sufficient sample size of narrative interviews for more detailed inductive analysis.

7. Statistical analysis

Analyses will use an adaptation of the controlled interrupted time-series methods previously applied by the applicants to quantify the effects of 20 mph zones on road traffic injuries (Grundy, 2009):

Geographical Information System (GIS) methods: Using GIS we will link all data sets to a road segment database that will include the characteristics of all classified and unclassified roads (see Figure 1 for worked example). We will classify each road segment according to the type of street lighting reduction scheme (e.g. part-night switch-off; 'dimming'; etc.) and by the Lower Super Output Area within which it is located. GIS will also be used to generate *adjacent* areas around streets (i.e. streets that are not part of lighting reduction schemes but which are adjacent to streets that are).

Figure 1a Example showing GIS used to map STATS19 road injury data (dark stars) and Police.uk crime incidents (circles showing numbers of crimes in the street) to road segments.

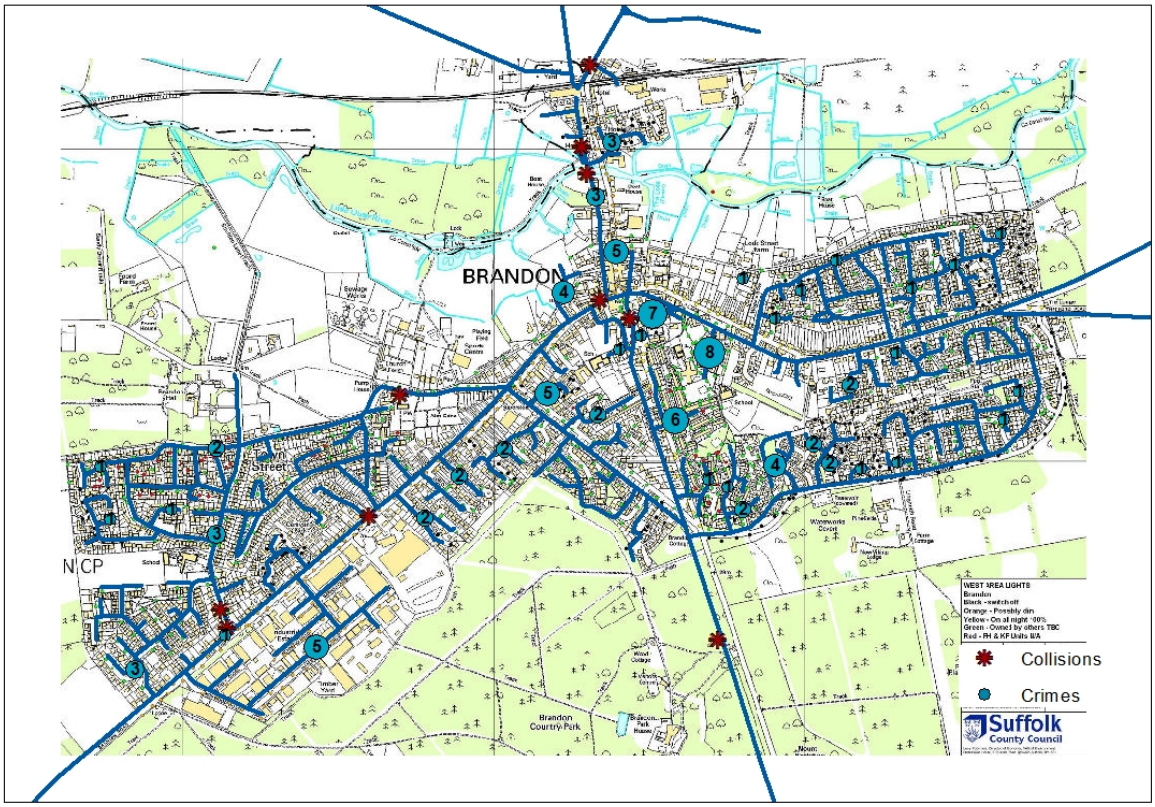
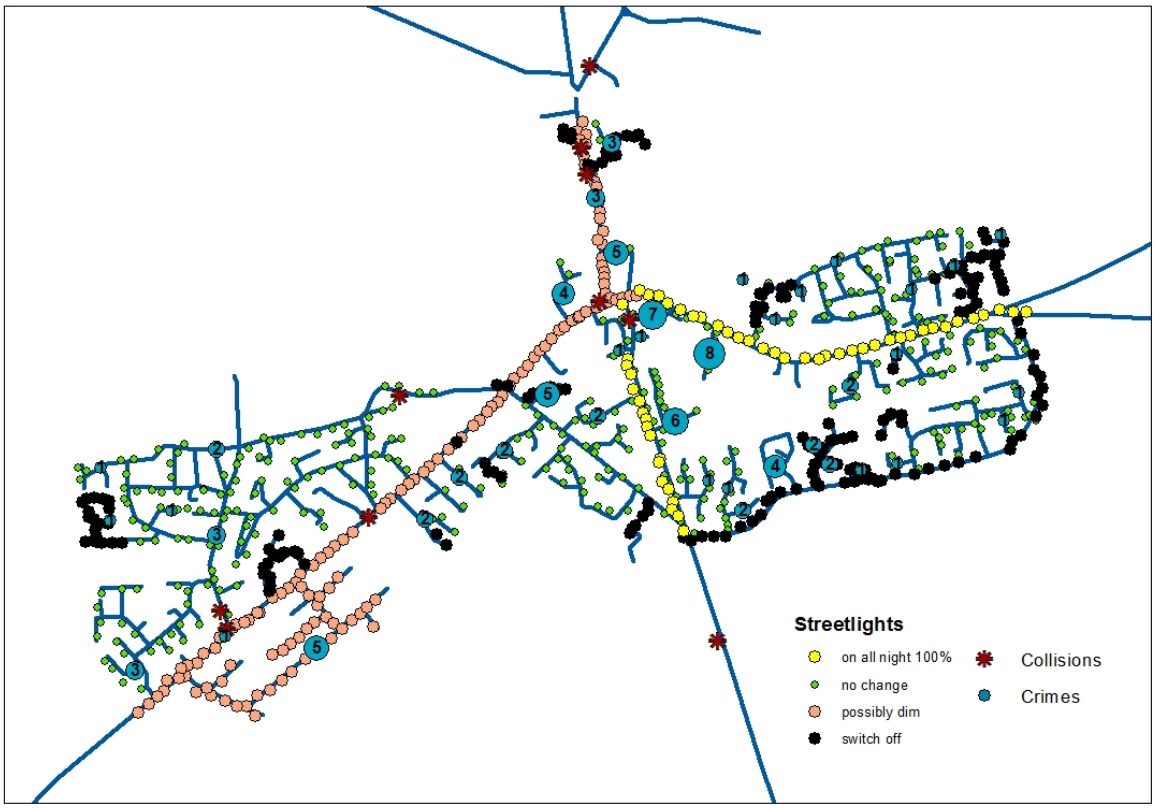


Figure 1b The same map (as Fig 1a above) showing locations of street lights where street lighting reduction scheme has been implemented.



Statistical methods: From the combined dataset, we will generate counts of crimes and road

traffic injuries for each road segment by year. The road segments will allow stratification of results by area deprivation (i.e. based on IMD of areas) and whether they are adjacent to streets where lighting has been reduced. Our primary focus will be to quantify the effect of decreased street lighting on crimes and road injuries on roads after allowing for underlying trends over time. As it is difficult to define appropriate population denominators to estimate rates on individual road segments, analyses will be based on change in counts within each road segment. Therefore for optimal control of confounding, the proposed analysis will compare change in counts of crimes and traffic injuries in the street before and after lighting is reduced, relative to trends seen on other roads. The estimated effect is therefore specific to roads with decreased lighting compared with other roads.

We will use conditional fixed effects Poisson models (xtpoisson, fe) in STATA statistical software.‡ Over dispersion is an issue when modelling units with zero events and use of a negative binomial model in place of a Poisson model is often recommended to address this. However there is technical issue with the model implemented by STATA, where the conditional negative binomial model (xtnbreg, fe) fits a different dispersion parameter for each road. We expect few events in most roads, and so such stratum-specific dispersion estimates are likely to be very imprecise, and thus give a far from optimal basis from which to estimate the parameter of interest (street light reduction effect). To overcome this, we intend to implement an over-dispersed Poisson version of the STATA conditional Poisson model command (xtpoisson, fe) which estimates scale dispersion for all roads combined (from the Pearson chi-square). The number of casualties (or crimes) $Y_{s,t}$ in road segment *s* in year *t* is therefore modeled as follows:

$$Y_{s,t} \sim \text{Poisson}(\mu_{s,t})$$

$$\log(\mu_{s,t}) = \alpha_s + S(t,z_s) + ßx_{s.t}$$

where α_s is the road segment effect, $S(t,z_s)$ is a function of year to allow for nationwide trends in casualties and crime incidents, dependent on road segment characteristics z_s, $x_{s.t}$ is a vector of indicator (0,1) variables identifying road segments with 'reduced lighting' and (separately) adjacent areas, after the lighting reduction had been implemented, and ß is a vector of coefficients representing the effect of decreased street lighting and adjacent areas on casualties and crime incidents. The α_s nuisance parameters are "conditioned out" in the conditional fixed effects Poisson model, allowing models to be based on annual counts of casualties and crime incidents within each road segment. For transparency, we will fit the underlying trends in casualties and crime incidents $S(t,z_s)$ with linear terms.

The conditional Poisson models will be applied to road injuries and crimes for every individual road segment across the study areas nationwide (over 100,000 road segments in total). Comparisons will be made of the change in events on roads before and after the street lighting changes, controlling for: (i) changes over time in day-time road injuries and all crimes on the same road segments (i.e. 'within-roads' comparisons); and (ii) year-to-year trends in night-time road injuries and all crimes on all other roads of a similar kind (i.e. 'between-roads' comparisons).

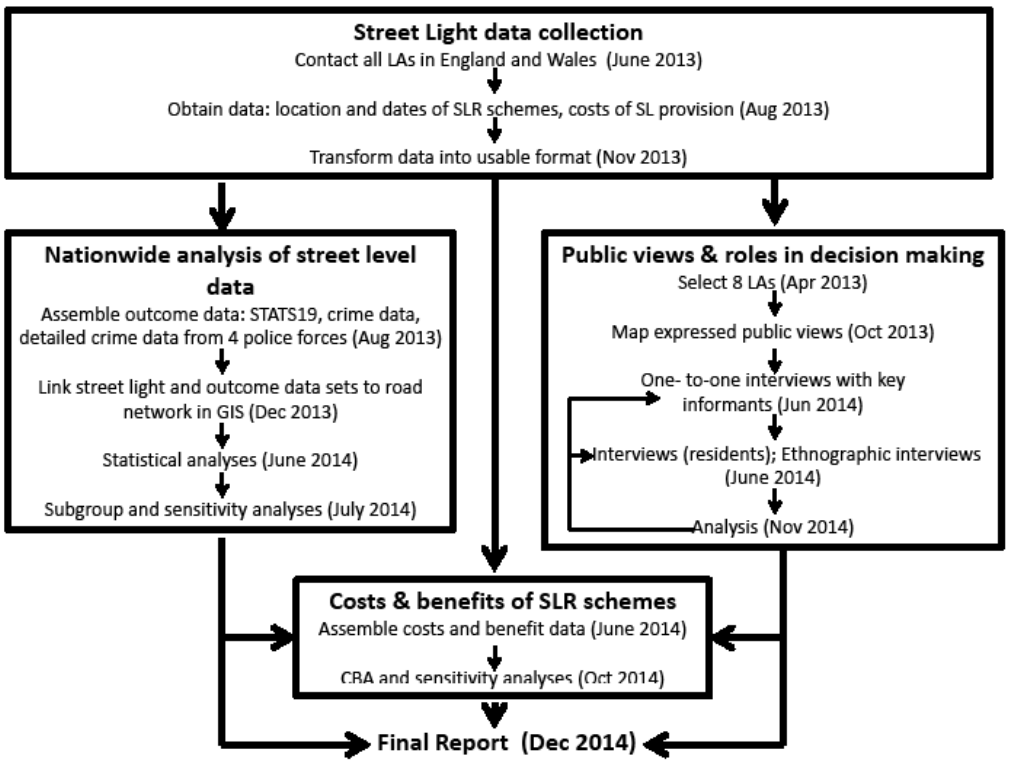
Additional analyses will examine potential biases relating to 'regression to the mean' (arising from the fact that low numbers of traffic injuries and crimes may be factors in the decision to reduce street lighting in some areas). For this, we will repeat the analyses excluding data for periods of one and two years before the change to street lighting. We will also

investigate evidence for displacement of road accidents and crimes from better-lit nearby roads, and evidence for differences in effects on outcomes according to sub-groups (tentative only, due to limited study power) defined by the nature of the street lighting reduction (e.g. switching street lights off permanently; switching street lights off for part of the night; 'trimming' the period where lights are switched on; dimming the brightness of lights). We will examine evidence for a 'lag' effect of street lighting reduction by modelling change in effects on events by month since implementation of lighting reduction.

To examine the potential for the under-reporting of events to police to influence our estimates of effect and inequalities, we will separately analyse the effects of street lighting reduction on the *most reliably* reported events (i.e. severe/fatal injuries; crimes for which insurance claims require a crime report). The results for the 'street lighting reduction' effect might be interpreted as the before and after change in the number of injuries and crimes within road segments adjusted for the trends in crimes and casualties on other roads. Robust standard errors of our estimates will be obtained using 'jackknife' procedures, clustering on LA area.

≠We acknowledge that absence of existing software to implement the appropriate conditional negative binomial model is not an overwhelming reason not to pursue this, which we agree would be preferable in the event of over-dispersion. Thus, if there does appear to be over-dispersion we will develop the necessary software ourselves if we do not find an implementation and apply a conditional negative binomial model.

8. Plan of Investigation:



9. Project Management:

The multi-disciplinary team brings together a team from LSHTM's Transport & Health Group and UCL Department of Security and Crime Science. The LSHTM team has a well established collaboration for delivering mixed methods projects, familiarity with the road safety data sets needed for this project and a track record of both publishing high quality evaluations and disseminating broadly to public and other stakeholders. Specifically, this is the same team who conducted research that demonstrated that introducing 20mph zones in residential areas reduces road traffic injuries in London (Grundy et al. 2009; Steinbach et al. 2010), which developed methodologies for time series analyses using STATS 19 data. The UCL team has familiarity with the main crime data set needed for this project and has expertise in modeling crime patterns and the evaluation of crime prevention interventions, including the completion of two systematic reviews of what works in crime prevention. The expertise of our team is as follows:

Dr Phil Edwards, Senior Lecturer in Statistics and is a Chartered Statistician. He will manage the project and will be involved in each study component. He will be involved in all aspects of the study, including weekly meetings with the members of the project team at LSHTM and at UCL. He has specialist skills in follow-up, questionnaire design, data management and statistical analysis, and he will input in the following: devising methods of contact and follow-up with local authorities to ensure maximum response; creation of a study database for the storage and management of study data relating to contact with local authorities; development of statistical analysis plan and creation of statistical analysis programme. He will also provide input into the qualitative component by assisting with the design of the household interview schedule and by accompanying Prof Green during many of the field visits and interviews.
Professor Shane Johnson, Professor of Security and Crime Science will provide expertise in crime data and analysis; and contribute to writing the report.
Ms Rebecca Steinbach, Research Fellow has expertise in Geographic Information Systems, qualitative methods, and cost-benefit analyses.
Professor Judith Green, Professor in Sociology has expertise in the sociological research of the determinants of health and inequalities; she will design and supervise the rapid appraisal and contribute to writing the report.
Mrs Chloe Perkins, Research Assistant in GIS will obtain, collate, and assist with data preparation in GIS, and assist with the rapid appraisal.
Mr Chris Grundy, Lecturer in GIS will provide expert advice and input in data management in GIS.
Dr Lisa Wainer, Research Associate in Criminology, has experience in crime data and analysis; she will manage the crime data from the sample of Police forces.
Professor Paul Wilkinson, Professor of Environmental Epidemiology will provide expert advice in the quantitative component and contribute to writing the report.

10. Service users/public involvement:

The London School of Hygiene & Tropical Medicine will be sponsor of the study. We will appoint a Project Steering Group including representatives from two local authorities (lighting and highways) and one police force, with six-monthly Project Steering Group meetings. All data required for this research study are maintained by the local highways,

lighting and police authorities.

Local authorities (the lighting authorities and highways authorities) are going to be key partners, but at present we do not know exactly which ones we will be working with. English and Welsh local authorities known to have trialled, or implemented, schemes include: Essex, Derbyshire, Dorset, Southwark, Suffolk, Buckinghamshire, North Somerset and Bristol, Nottinghamshire, Powys, Gloucestershire, Bath and North East Somerset, Peterborough City Council, Shropshire, Devon, Rutland County, Telford and Wrekin, Leicestershire, Stockton-on-Tees Borough, South Gloucestershire, Bridgend, Blaenau Gwent, Conwy, Pembrokeshire, Isle of Anglesey, Carmarthenshire, Ceredigion, Newport, Torfaen, Durham, Central Bedfordshire, Borough of Poole, Cornwall, East Sussex, West Sussex, Wiltshire.

Police forces will also be key partners. We will work closely with four Police forces to obtain crime data including the exact date and time of each offence, the text address of the offence and the geo-coordinates of the offence. As with local authorities, we do not at present know which four police forces we will be working with.

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This protocol refers to independent research commissioned by the National Institute for Health Research (NIHR). Any views and opinions expressed therein are those of the authors and do not necessarily reflect those of the NHS, the NIHR, the PHR programme or the Department of Health.