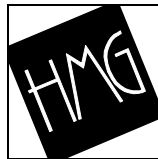


Outdoor Lighting and Security: Literature Review

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Executive Summary

This literature review is intended to inform Pacific Gas and Electric Company (PG&E) about the existing research literature relating to any relationship between night-time outdoor lighting and security. This report reviews ten original research papers and three previous literature reviews. It sets out to answer the following questions:

1. Does the presence of nighttime lighting around commercial and residential buildings, parking lots and walkways influence crime or the fear of crime?
2. Does the quantity or quality of nighttime lighting influence crime or the fear of crime?
3. Is there a causal relationship between nighttime lighting and crime or the fear of crime?

None of the papers reviewed presents sufficient evidence to demonstrate a causal link between night-time lighting and crime. The available results show a mixed picture of positive and negative effects of lighting on crime, most of which are not statistically significant. This suggests either that there is no link between lighting and crime, or that any link is too subtle or complex to have been evident in the data, given the limited size of the studies undertaken.

Several studies showed a significant relationship between lighting and the *fear* of crime, i.e. that people feel safer in lit areas. The amount of light required to reduce the fear of crime appears to be in the range of 10 horizontal lux (1 footcandle), with little increase in perceived safety above that level.

Introduction

This literature review is intended to inform Pacific Gas and Electric Company (PG&E) about the existing research literature relating to any relationship between night-time outdoor lighting and security. PG&E supports the California Energy Commission in its responsibility for setting requirements for outdoor lighting in California; these requirements may include but are not limited to maximum wattage, maximum lighting power density, and allowable control options.

Throughout the review we will use the term “night-time lighting” instead of “security lighting” because the latter presupposes a link between lighting and security. We also discuss “crime” or “fear of crime” rather than “security”. “Security” is a rather broad and loosely defined term, which can include both specific steps taken to prevent danger or injury, along with the psychological state avoiding anxiety or fear. The first two definitions offered in Merriam Webster’s dictionary are most applicable here:

***Security:** 1: the quality or state of being secure, as a freedom from danger. 2: freedom from fear or anxiety.*

Wordnet from Princeton University offers further definitions:

***Security:** freedom from anxiety or fear; "the watch dog gave her a feeling of security"*

***Security:** the state of being free from danger or injury; "we support the armed services in the name of national security".*

The available literature that we reviewed did not address the broader term “security” per se, but rather the more specific topics of crime, and/or fear of crime. “Crime” is typically taken to be publicly reported events, thus a neutral source of data for the study was available for analysis. “Fear of Crime” is typically based on respondents’ perceptions recorded during study interviews.

Further more, we do not report on studies of the relationship between accidents, such as trips and falls, or vehicular accidents, as that literature relates more to specific task visibility and risk of physical hazards, rather than more general purpose nighttime lighting intended to produce a sense of security..

Questions

This literature review set out to answer the following questions:

4. Does the presence of nighttime lighting around commercial and residential buildings, parking lots and walkways influence crime or the fear of crime?
5. Does the quantity or quality of nighttime lighting influence crime or the fear of crime?
6. Is there a causal relationship between nighttime lighting and crime or the fear of crime?

Background – Outdoor Lighting Standards and Energy Use

Arguments have been made both for and against outdoor lighting for a wide variety of reasons. The most common arguments in favor of outdoor lighting are to prevent accidents (both vehicular accidents, and trips and falls), and to reduce crime and/or the fear of crime. Social factors such as encouraging retail purchasing, and bringing people out on to the streets have also been put forward. The most common arguments against outdoor lighting are the increase in electricity use the creation of “light pollution” that obscures the view of night sky and may have a variety of adverse ecological consequences (Rich and Longcore 2005). Other factors such as “light trespass” (or “obtrusive light” providing unwanted light in areas beyond the immediate lit property) and a probable link between night-time light and the formation of cancers have also been advanced (Davis 2001, Baldwin et al 1998, Dauchy et al. 1997, Feychting et al. 1998)

California Standards

In response to the California energy crisis, on February 1, 2001 Governor Gray Davis issued Executive Order D-19-01 that required retail business to substantially reduce unnecessary outdoor lighting energy use during non-business hours.

In April of 2001 the California Legislature and Governor Davis passed and signed Senate Bill 5X. This bill established authority¹ for the California Energy Commission to adopt lighting standards for outdoor lighting. The first round of Outdoor Lighting Standards were adopted in the 2005 revision of California’s lighting standard (Title 24²).

The definition of outdoor lighting is taken from Title 24 2005 section 147, and includes:

“all outdoor lighting, whether attached to buildings, poles, structures or self supporting, including but not limited to: hardscape areas including parking lots; lighting for building entrances; sales and non-sales canopies; lighting for all outdoor sales areas; and lighting for building facades.

EXCEPTIONS to Section 147:

- 1. Temporary outdoor lighting.*
- 2. Lighting required and regulated by the Federal Aviation Administration and the Coast Guard.*
- 3. Lighting for public streets, roadways, highways, and traffic signage lighting, including lighting for driveway entrances occurring in the public right-of-way.*
- 4. Lighting for sports and athletic fields, and children’s playgrounds.*
- 5. Lighting for industrial sites, including but not limited to, rail yards, maritime shipyards and docks, piers and marinas, chemical and petroleum processing plants, and aviation facilities.*
- 6. Automated Teller Machine lighting.*

¹ This authority is established in the Public Resources Code section 25402.5 (3) (c)

² Section 147(c)1B

7. Lighting of public monuments.
8. Internally illuminated, externally illuminated, and unfiltered signs.
9. Lighting used in or around swimming pools, water features, or other locations subject to Article 680 of the California Electrical Code.
10. Lighting of tunnels, bridges, stairs, and ramps.
11. Landscape lighting.”

Title 24 “Security Lighting” Provisions

The issue of “security” lighting is of particular interest in California because Title 24 allows designers to increase lighting power densities in areas with “special security requirements”. The multipliers are shown in Figure 1; this list is exhaustive, i.e. no other places are allowed to be designated as having special security requirements. However, “security lighting” or “special security requirements” are not further defined or referenced Title 24.

Function	Multiplier
Retail parking lots in lighting zones 1, 2 and 3	1.25
Hardscape areas within 100 feet of the entrance of senior housing facilities in lighting zones 1, 2, and 3	1.25
Parking lots and walkways within 60 feet of entrances to the building for law enforcement, fire, ambulance and emergency vehicle facilities	2.00

Figure 1 – Title 24 multipliers for lighting power density for “special security requirements” (TABLE 147-D).

Why Street Lighting is Included in this Review

The definition of “outdoor lighting” covered in Title 24 specifically does *not* include street lighting, since the California Energy Commission does not have jurisdiction over the energy use of public streets. Nevertheless, this review includes studies of street lighting, because most published studies involving lighting and crime have been based on street lighting.

Recent Growth in Commercial Outdoor Lighting

Lawrence Berkeley Laboratory (2002) estimated that in 1999 *commercial* outdoor lighting accounted for 5 TWh of electricity consumption in California, or 2% of total electricity use (5.6% of commercial electricity use). This value was unchanged from the 1997 figure given by the California Energy Commission (1998). The California Outdoor Lighting Baseline Assessment (CEC 2003) found a slightly lower figure of 3.07 TWh for commercial outdoor lighting energy use, with a peak demand of 809 MW in the winter between 7pm and 8pm.

CEC 2004 estimates that security lighting represents about 47% of commercial outdoor lighting by wattage³; CEC 2003 estimates that the parking represents 31.5% of wattage, pedestrian and walkway lighting represents 22.4%, and specific “security” lighting only 6.8%. These differing estimates likely reflect different definitions of security lighting, i.e., CEC 2004 may include parking lot and/or pedestrian lighting in its estimate.

Although none of the reports cited gives information about whether outdoor lighting energy use has increased or decreased over time, there is a widespread belief (evidenced by manufacturer’s literature and magazine articles) that commercial outdoor lighting has experienced rapid growth in recent years. According to the National Electrical Manufacturers’ Association, the market for “roadway”-style lighting fixtures is growing at 5-6% per year by value⁴.

Background – Times and Places at which Crimes are Committed

Later in this report, the research evidence for links between lighting and crime is discussed. An important background to this discussion is to note two things: first that the majority of crime is committed during daylight, and so is unlikely to be influenced by the presence or absence of electric lighting, and second that only a small percentage of crimes are committed in places that have (or could have) commercial outdoor lighting. These two pieces of information help to establish the potential magnitude of the effect of outdoor lighting on crime.

Time at Which Crimes are Committed

Data from the U.S. Department of Justice (1994) shows that a narrow majority of crimes are committed during the daytime (defined as 6 a.m. to 6 p.m. irrespective of season and location). Data specifically on *urban* crime by time of day is given by Spencer, Austin and Chainey (2001) for the London Borough of Harrow; this data shows that crime peaks at around 3 p.m. and remains high until around midnight.

If lighting has an effect on crime because of the increased likelihood of the crime being witnessed by police or civilians, then this effect is most likely to occur during the period 6 p.m. to midnight. This is the period during which people are most likely to be out in public spaces (both civilians and police are much less likely to be on the streets from midnight to 6 a.m.).

Note that the crimes that have the highest percentage of incidents from 6 p.m. to midnight (see below) are violent crimes against the person, so any effect due to outdoor lighting should be most noticeable in the data on violent crime.

- Robbery (43% of all robberies are committed between 6 p.m. and midnight)
- Rape/sexual assault (37%)

³ “Any parking lights or general area lighting which are operated on a separate meter would not be included. Consequently, we do not know very much about parking lighting in shopping centers or other large complexes from this data.”

⁴ Bremer, D. *The Latest in Transportation Project Lighting*. Electrical Contractor Magazine July 2005. http://www.ecmag.com/editorial_detail.aspx?id=1795

- Assault (34%)

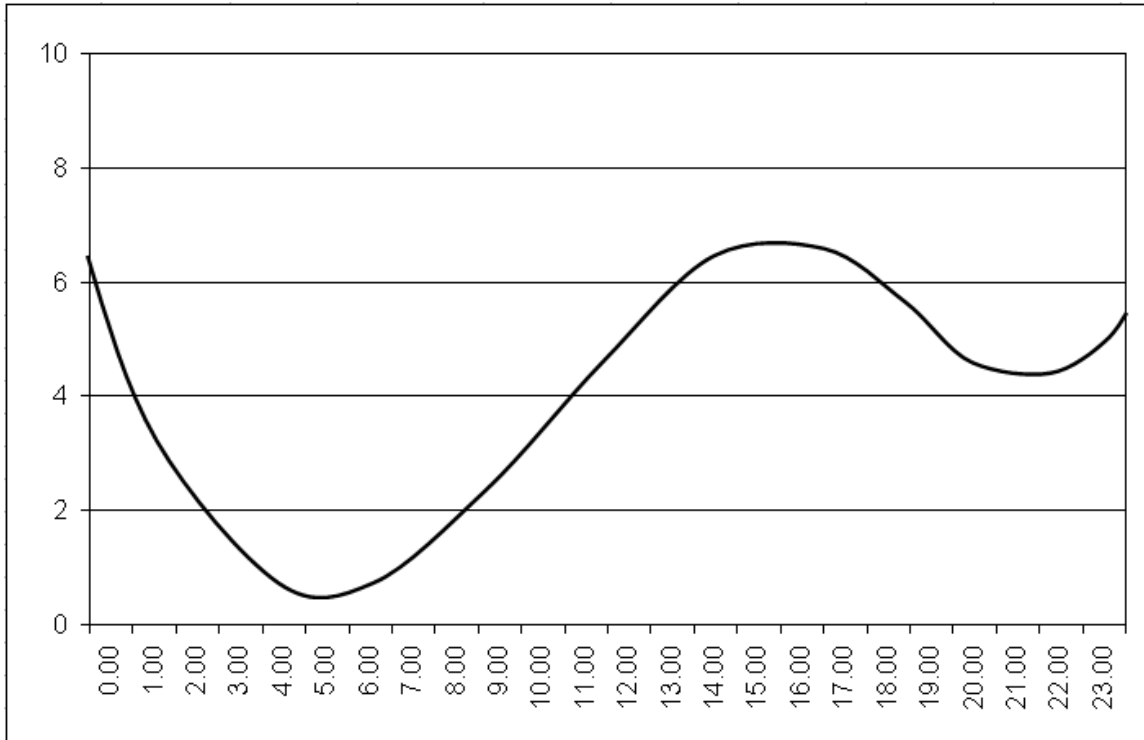


Figure 2 – Percentage of All Crimes Committed by Hour of the Day, London Borough of Harrow

	Daytime	Nighttime		Not known
	6 a.m.- 6 p.m.	6 p.m.- midnight	Midnight - 6 a.m.	
Crimes of violence (9.8M crimes)	52.2%	34.4%	11.7%	1.6%
Property crimes including motor vehicle theft (31M)	37.1%	15.1%	14.0%	33.7%
Motor vehicle theft (1.8M)	25.0%	19.6%	29.4%	26%

Figure 3 – Times at Which Crimes are Committed⁵

Places at Which Violent Crimes are Committed

Data from the U.S. Department of Justice (1994) shows that the percentage of violent crimes committed in places that have *commercial* outdoor lighting is somewhere between 8% and 19% (including all crimes committed in parking lots and garages, and some proportion of crimes committed in “parks”, “inside stations”, and “other”; crimes committed on the street are excluded because they are under street lighting)

⁵ Adapted from U.S. Department of Justice, <http://www.ojp.usdoj.gov/bjs/pub/pdf/cvius94.pdf>,

Location of crime	Percentage of crimes
At or near respondent's home	14.4 %
Near home	8.3 %
On the street near home	3.2 %
At, in, or near a friend's, relative's or neighbor's home	7.5 %
Inside a restaurant, bar or nightclub	4.9 %
Inside another commercial building	8.2 %
Parking lot or garage	7.7 %
Inside a school building or on school property	13.1 %
In apartment yard, park, field or playground	2.8 %
On street other than near own home	19.8 %
On public transportation or inside station	1.1 %
Other	8.9 %

Figure 4 – Locations at Which Violent Crimes are Committed⁶

⁶ Adapted from U.S. Department of Justice, <http://www.ojp.usdoj.gov/bjs/pub/pdf/cvius94.pdf>

Literature Review

Research on a possible link between lighting and crime began in earnest in the 1960s in the US, following a dramatic rise in city-center crime (Painter 1997) and during the period when highway construction and street lighting installations started growing dramatically. Beginning in the 1990s concern about global warming has caused many countries and research institutions to more critically review the need for night-time lighting, and in recent years the emerging fields of photobiology and photoecology have also identified potential adverse effects. The falling cost of closed-circuit television (CCTV) monitoring in the 1990s led municipalities to consider whether their resources would better be spent on lighting or on CCTV; the adoption of CCTV has varied between countries, and is currently much more widespread some countries (for instance in the UK) than in the US.

These issues, along with the emerging opposition to night-time lighting from astronomers and others who value the view of the night sky, have led to several thoroughly-argued reviews and meta-analyses that have drawn widely differing conclusions. Several papers (e.g., Painter 1999) have been the subject of heated argument, and several reviewers (e.g., Clark 2002) have sought to discredit or reappraise the work of other researchers.

This thorough debate has arisen despite, or perhaps because of, a scarcity of actual data. There are very few papers that specifically address the link between lighting and crime, and even fewer (as noted by Painter (1999b)) that use analytical methods suitable for the problem.

As noted above, the term “security lighting” itself presupposes a link between lighting and security; the frequent use of this term not only by fixture manufacturers but also by researchers supports the view (Clark 2002) that there may be a research bias in favor of a link between lighting and security. Clark (2002) provides a review of the usage of this term by various researchers.

Many of the studies reviewed in this report were conducted outside the U.S. The amount and type of crime varies by region and over time both within the U.S. and in other countries, but we do not believe that there is any basis on which to preclude data from outside the U.S. from this report.

Method of Review

The purpose of this literature review is to describe and to evaluate the available research, and to arrive at conclusions about what is currently known and not known about any possible relationship between crime and outdoor lighting.

From the available literature, we identified several key research issues. In assessing each research study we have given consideration to whether the researchers understand and address each issue, and discuss whether their conclusions are supported by their data.

The quality of the papers themselves (i.e. the quality of the writing, the authors’ demonstrated awareness of previous research, and the quality of study methodologies) is also an important factor. The quality of the papers reviewed is, in general, very high;

most of the papers reviewed have been published in peer-reviewed journals and cited by others.

Because the arguments for and against outdoor lighting are sometimes polarized, we have also noted each author's affiliations or biases where appropriate and known.

Research Issues

Several recurring issues emerge from the papers reviewed for this study. Rather than addressing them in the discussion of each individual paper, we have summarized the issues under the following headings.

Models of Criminal Behavior

Criminologists have developed sophisticated models of criminal behavior that predict the location, timing and types of crimes likely to be committed. These models include *routine activity theory* (Cohen and Felson 1979) and *offender search theory* (Brantingham and Brantingham 1981). The theory that criminal behavior can be reduced by altering the physical characteristics of places is known as *situational crime prevention*; an extensive list of these techniques can be found in IES (2003); the ones most relevant to lighting are *formal surveillance*, *surveillance by employees*, and *natural surveillance*.

Research involving convicted criminals has identified several conditions that criminals prefer in order to commit a crime. For instance they prefer to have a clear escape route, and they prefer to be able to observe the scene from a secluded place (Eck 1997). Removing these conditions, or "hardening" the target, is known as *opportunity blocking*; this has been advanced as a hypothesis for why lighting may reduce crime.

Conversely however, criminals may also make use of lighting to help them in their pre-crime surveillance: i.e. to identify potential targets and to assess their current level of risk. Thus, in many cases it's not clear whether lighting helps or hinders the criminal. Some evidence indicates that, for certain types of crime (such as thefts from cars) criminals perceive such a low threat of being impeded, identified or apprehended that situational factors play an insignificant role (Eck 1997, p.36).

Displacement vs. Diffusion of Benefits

If a crime-prevention measure appears to be successful in one location, researchers need to show that the crime hasn't simply been displaced to another location (or to another time of day, for instance from night-time to day-time). This is known as "displacement". Alternatively, successful crime reduction in one location may deter criminals from committing crimes in other locations too (Clarke and Weisburd 1994), an effect known as "diffusion of benefits". A review of 55 crime prevention projects found 33 cases of displacement and 6 of diffusion of benefits (Hesseling 1994), though this issue remains a subject of debate.

To identify whether either of these effects is occurring, researchers need to monitor crime levels in areas adjacent to the experimental area, during both the day and the night.

Ideally the control areas should have a similar physical and demographic character to the experimental area.

Experimental Controls and Level of Significance

Crime rates often vary significantly over short periods of time due to factors such as climate and economics. Therefore “before and after” studies (the majority of the papers reviewed) must use matched control areas and time periods to determine whether, for instance, a city-wide increase or decrease in crime occurred at the same time as an increase or decrease in crime in the experimental area, and also that a reduction in crime “after” an intervention was not just a normal cycle or random variation. Designing this kind of experimental control is not an exact science for field studies; most researchers attempt to find “matched” areas of the city and use these as controls, while others use city-wide crime rates.

Even with a well-designed experimental control, the “natural” variation in crime rates can be high enough to make the statistical analysis of available datasets useless. The greater the variation in the data, the larger the number of data points needed to determine statistical significance. Clark (2002) conducted a “quasi-experiment” that showed that statistically significant effects can be expected to exist even in the *absence* of anti-crime measures. He used crime rate data for the 21 counties in New Jersey; and grouped the counties into matched pairs (adjacent counties with similar crime rates) and compared their crime rates in consecutive years (1999 and 2000). Five of the ten pairs showed a statistically significant change in crime rate even though no (known) interventions had been made.

It should be noted that the type of analysis used by Clark (chi-squared analysis assuming normal distribution⁷) gives a result based on the assumption that the variable (crime rate) has a normal (bell-shaped) distribution. However, it can reasonably be assumed that crime rates do not have a normal distribution, since most areas have no crimes and a few areas have a very high number of crimes. This means that there may be an inherent shortcoming in the statistical methods used to evaluate crime rates.

Confounds

The primary confounds commonly identified by researchers are police intervention, closed-circuit television and regression to the mean⁸. These confounds occur because street lighting is often installed as a crime-reduction measure in areas that already have high crime rates. Municipalities often use multiple measures to address areas of high crime, for instance street lighting in conjunction with additional policing or CCTV.

⁷ “The chi-square test...is used to test if a sample of data came from a population with a specific distribution.” NIST/SEMATECH e-Handbook of Statistical Methods, section 1.3.5.15.
<http://www.itl.nist.gov/div898/handbook>

⁸ “Regression toward the mean...is a principle that states that if you take a pair of independent measurements from the same distribution, samples far from the mean on the first set will tend to be closer to the mean on the second set, and the farther from the mean on the first measurement, the stronger the effect... any measurement of any variable that is affected by random variance *must* show regression to the mean.” http://en.wikipedia.org/wiki/Regression_to_the_mean

Researchers cannot then isolate the effect of lighting from the effect of the other measures. Regardless of any intervention, any area of high crime is likely to decrease towards the mean crime rate for that city over a long enough period of time. This “natural” regression to the mean is a well known statistical phenomenon, and is a confounding factor in the majority of the research papers.

Study Populations

As observed by Eck (1997, p.1) “Most places have no crimes”, and 10 percent of places are the sites for around 60 percent of crimes. Therefore researchers must conduct their experiments in areas that have high crime rates if they want to achieve statistical significance in their results. Even in those places, the number of recorded crimes can be too low for analysis, and many researchers therefore use self-reports⁹ of crimes, or police *calls for service*¹⁰ as proxy variables, i.e. variables that give an idea of how many crimes were probably committed. Self-reports are more open to bias from the interviewer, or from the interviewees’ perception that crime *must* have decreased because the areas had been relit. In many of the papers reviewed, the sample size (n) is a limiting factor in the significance of the results.

Types of Crime

Most researchers quote a figure for “total number of crimes” or “total number of calls for service” irrespective of the type, i.e. they do not analyze, for instance, crimes against the person separately from crimes against property, even though it’s reasonable to believe that these types may be differently affected by the presence of lighting.

A few researchers (e.g. Quinet and Nunn 1998) disregard certain types of crime (domestic disturbance, traffic crimes) that they regard as not being influenced by lighting. Other researchers do not give details of what types of crime are included in their analysis. None of the papers reviewed for this study gives evidence or a causal explanation for why one type of crime or another may or may not be affected by lighting. Therefore we believe that existing theories of criminal behavior do not provide clarity in this area.

Photometry

Most of the papers are not precise in their photometric descriptions of lighting; they refer only to “improved” lighting without giving technical details about the changes that were made. Without precise descriptions of the changes in lighting quantity and/or quality achieved by an intervention, it is difficult to assess the meaning of any finding relating lighting to security.

The key aspects of photometry that may affect security are summarized by the Illuminating Engineering Society of North America (2003) as follows; “*vertical and horizontal illuminances, the uniformity of the illuminance distribution, the effect of*

⁹ Self-reports are reports of crime made by survey participants to the surveyor, in response to a question about whether they have been a victim of crime or have witnessed a crime.

¹⁰ Police calls for service are emergency calls made to the police, and are usually analyzed by the location from which the call originated, and/or the type of crime reported. In the US, these are “911” calls.

obstructions, the reflectance of surfaces, background contrast, degree of glare, spectral power distribution of the light source.”

“Vertical and horizontal illuminances” are important because human visual discrimination is logarithmically related to the luminance of the viewed object, and luminance (reflected light) increases as a direct consequence of illuminance (incident light). Vertical illuminance is usually cited as the most relevant metric for identification of faces and feeling of security e.g. by Van Bommel and Caminada (1982). Uniformity is the ratio of minimum to average illuminance over a given area.

The “effect of obstructions” is due to cast shadows that can prevent viewers from recognizing faces or objects; the “reflectance of surfaces” is important because reflected, ambient light fills in shadows and makes object recognition easier. “Background contrast” and “degree of glare” can hinder object identification by causing optical scatter in the eye that obscures objects. “Spectral distribution” is an issue for two reasons: first, good rendering of colors helps viewers to identify objects; and second because the SI definition of the lumen is based on photopic conditions ($>3\text{cd/m}^2$) which are sometimes not met at night; sources that emit a lot of short-wavelength visible light are underrated by conventional photometry in very dark conditions.

Previous Literature Reviews

There have been several literature reviews on the subject of lighting and crime, but only Clark (2002), Eck (1997) and IES (2003) are discussed here, mostly because the other relevant reviews (e.g. Tien et al. 1977) were published before the important papers by Painter and Farrington, but also because, as reported by Eck “*Not much has changed since Tien and his colleagues gave their critical assessment of the impact of lighting on crime.*” Further, the reviews by Clark and Eck are extensive and methodical, and provide sufficient overview of the subject area.

Taken together, these reviews confirm a paucity of research on the subject, and a wide range of important methodological concerns about those studies that do exist.

Clark (2002)

This literature review was a public submission to a parliamentary commission on drugs and crime in the state of Victoria, Australia. The review was subsequently published on the website of the Astronomical Society of Victoria. Clark’s central finding is summarized by the title of the paper: “Little or No Benefit”. He discusses several papers in detail and finds a variety of methodological errors and instances in which the researchers may have biased their studies. He finds also that the reported effects are evenly split between a positive and negative effect of lighting on crime.

The fact that Clark is the only named author, that the review has not been submitted to a peer-reviewed journal, and that Clark does not list an affiliation with any research institution, may lessen the standing of the work. Clark describes his professional standing as being “*a consultant in optics, visual optics and lighting*”; he also holds a doctoral degree in engineering.

Clark's method of review is to concentrate closely on what he considers to be the most relevant papers, and to thoroughly discuss their methodology, results, and any confounds. His discussion of Painter's papers is particularly thorough; something that may be explained by his affiliation with the Astronomical Society of Victoria, a group that opposes night-time lighting because of the detrimental effect of "sky glow" on astronomical observations. Clark acknowledges that his affiliation with various astronomical societies as a conflict of interest at the end of his second paper (2003), in which he describes his "*concern about the undesirable scientific, social and environmental effects of excessive and wasteful outdoor artificial lighting.*"

Clark also discusses the potential biases of experimenters, and makes several observations regarding the language used by experimenters, reviewers and industry. He points out several instances in which experimenters' language presupposes their results, and several commonly-used phrases (e.g., "security lighting") that presuppose a link between lighting and security.

As well as reviewing the literature, Clark includes what he calls a "quasi-experiment", in which crime rates from the 21 counties of New Jersey were compared over two consecutive years from 1999 to 2000. The counties were divided into matched pairs as follows:

The total number of crimes for each county was converted to a crime rate per 100,000 of the county population, and the 21 counties were sorted in order of ascending crime rate for 1999. Pairs of counties were identified in which the crime rates matched within 10% of the larger crime rate of the pair. (p.14)

The "quasi-experiment" analysis is summarized as follows:

The idea is to consider each pair as a quasi-experiment in which a treatment is applied to one of the pair at the end of 1999. Here the first member in each case was selected as the experimental or treated county and the other is the control... The crime figures after the treatment are the actual values for 2000. Of course, there was no deliberate treatment with lighting or anything else, i.e., null treatment. (p.15)

The matched pairs were then analyzed using a standard chi-squared test, which showed that five of the ten matched pairs showed a statistically significant difference, i.e. the statistical analysis showed an effect due to a "treatment" that did not exist.

Clark's finding indicates that the patchy and sporadic nature of crime, along with outside influences such as economics and demographics makes it very likely that experimenters will find statistically significant results even if there is no effect due to lighting. Crime data shows large variations over time even on a very large (statewide) scale, and so should not be treated as random data for the purposes of statistical analysis.

Clark's result indicates that very large samples are required to demonstrate statistical significance for crime data, and so the mostly small-scale studies performed on the link between lighting and crime do not achieve sufficient statistical certainty. However, large-scale studies create another inevitable confound, which is that crime varies from place to place and over time in ways that cannot be controlled for in the analysis.

Eck (1997)

Eck's review, similar to Clark's, was prepared as a report to the U.S. Congress, although Eck's review was funded (by the National Institute of Justice) rather than a volunteer effort. The scope of Eck's review is broader than Clark's, and includes every variety of "situational crime prevention" techniques, not just outdoor lighting.

Eck classifies each technique into one of four categories: "works", "does not work", "promising", and "unknown"¹¹. In a 2002 revision to his original 1997 review, commenting specifically on Painter's work, he writes:

"Lighting appears to work in public areas, especially residential communities. Generalizing beyond these types of settings is highly speculative... Lighting may be effective in some places, ineffective in others and counter-productive in still other circumstances." (Cited in Clark (2002), p.9)

His method is to review a very large number of papers, to assign each a score from 1 to 5 on the "scientific methods scale", and then to discuss the findings of each paper, giving more weight to those with higher scores. He stops short of a formal statistical meta-analysis, perhaps because most of the papers he reviews have low scores on the methods scale.

Eck complains that "*the limited research on lighting continues to use weak designs (typically without control areas)*". He continues "*The problematic relationship between lighting and crime increases when one considers that offenders need lighting to detect potential targets and low-risk situations... [thus] who the lighting serves is unclear.*"

At the very beginning of Eck's review, he states "Most places have no crimes and most crime is highly concentrated in and around a small number of places." This observation provides both a rationale and a limitation for situation crime prevention, i.e., it may be cost-effective because only a few places need to be treated, and therefore the technique should be limited to only those places that require it.

IES (2003)

The *Illuminating Engineering Society of North America's Guideline for Security Lighting for People, Property and Public Spaces* provides guidance on how to maximize the performance of lighting in terms of metrics such as visibility, glare, uniformity, color rendering and the reduction of shadows.

The Guideline contains a brief summary of previous work; this summary is not strictly a literature review, but it has value because it indicates the collective view and awareness of the relevant IES committee at the time. The summary states, in regard to studies prior to Painter (1997), that "there was no statistical evidence that improved street lighting influenced the level of street crime." Painter's study is described, and the summary concludes by saying that "The results of all these studies indicate that lighting has a place to play [sic] in crime prevention."

¹¹ Eck classifies only one measure as "works"; none as "does not work", five as "promising"; and 31 as "unknown"

The Guideline defines “*when security is an issue*”, i.e. it provides a possible source of guidance on when the security lighting multiplier in Title 24 might justifiably be used (though neither document refers specifically to the other). These include¹²:

- The property has a history of relevant crime or increases in crime.
- Crime in the surrounding area is high compared to other political subdivisions, parts of the city or county.
- The results of a physical security survey or threat analysis indicate a problem
- Obvious physical signs of antisocial behavior near or on the property such as graffiti, vagrants, broken windows, trash buildup, trespass, or poorly maintained properties.
- There are recurring resident or customer complaints or reasonable concerns about security or fear of crime.
- High profile or troublesome areas exist such as bars, nightclubs, gambling halls, gang or teen gathering spots.
- There are industrial or commercial applications where persons or property are prone to attack, such as ATM and night depositories, convenience stores, and railway yards.

Reviewed Papers

The central argument about lighting and crime is whether nighttime lighting 1.) deters criminals because they’re more visible to passers-by, police, potential victims and video cameras; 2.) increases a sense of security while not necessarily deterring actual crime, or 3.) aids criminals in their work by illuminating their task and/or assisting their surveillance. There are a number of other subtle considerations: first, lighting may simply shift crime from well-lit to poorly-lit neighborhoods, and this may not be a socially desirable outcome; second; lighting may serve to reduce the fear of crime and thereby encourage more people on to the streets at night, thereby reducing crime or alternatively increasing the opportunity for crime; third, lighting may differentially attract the attention of police and security guards, resulting in more official reports initiated in well lit areas.

The papers reviewed in this report are the ones that arose most frequently in bibliographies, and the ones that are most readily available. The field of crime research is highly developed, but in many instances papers have been published in journals that no longer exist; or have been published in magazines that cannot be traced within the budget and resources of this study. The bibliography contains references to some of these papers. All the papers referenced study crime in public places as their primary focus. However, we found no studies of lighting and crime (or security) around specific building types such as retail establishments, police stations, hospitals, or prisons.

¹² This is not a complete list; some of the conditions are too vague to provide a basis for establishing whether security is an issue.

The following papers are reviewed in alphabetic order:

Atkins, Husain and Story (1985)

This study looked at reported crime in the central-London Borough of Wandsworth, one year before and after a 1985 street lighting retrofit. The study area included 3,500 retrofitted streetlights, and the database of crimes included over 100,000 reported incidents.

This study differs in two important ways from the other studies reported in this review: first, the relighting did not occur because of high crimes rates, it occurred because the municipality judged that mass replacement of old street lighting would be cheaper than a spot-replacement approach; therefore “regression to the mean” is less likely to be present. Wandsworth did not have particularly high crime rates at the time of the study. Second, the authors’ primary metric is the relative change between nighttime and daytime crime; they hypothesize that daytime crime could not be affected by lighting, so they use daytime crime rates as the control.

“Hence, the basic hypothesis to be tested was whether considerably improved street lighting had reduced likely types of crime after dark in the treated areas” [authors’ emphasis]

The authors divided reported crime into three categories, according to how likely they believed the crime was to be affected by lighting. “Likely” crimes included violent crimes, theft from outdoor locations, criminal damage and non-residential burglary.

The results show that “likely” crimes were 2.7% less likely to be committed in the dark after the relighting; this result supports the hypothesis that lighting may have reduced crime. However, “unlikely” crimes were 24% less likely to be committed in the dark after the relighting, which was contrary to the authors’ hypothesis. Also, neither value is statistically significant. Therefore, the authors reject the principal hypothesis that increased levels of street lighting reduce crime.

The study also involved a survey of residents’ attitudes and behavior, and their experience of crime not reported to the police. The perceived safety of women walking alone after dark in the re-lit area was improved, but few other effects were statistically significant. There was no change in un-reported crime, harassment or travel behavior.

Boyce and Bruno (1999)

In this laboratory experiment conducted in a parking lot, 15 observers were asked to identify a range of small hand-held objects (including weapons, tools, containers) at night under a variety of typical parking lot lighting conditions. The objects were held in the hand of a research volunteer who walked across the line of sight of a seated subject at a range of 45’. The main variable of interest was pavement illuminance, although the lighting also conditions also varied in terms of spectral distribution (high-pressure sodium vs. metal halide), uniformity and glare. These variables were all within the bounds of normal lighting practice.

The results show a positive correlation between the number of objects correctly identified and the illuminance measured at the pavement surface, over the range of illuminances

tested (1 to 20 lux), as predicted by the literature on visual acuity. The level of statistical significance is not given in the paper, but the result is clearly significant. A similar correlation was found for an on-axis visual search task, although for a 10-degree off-axis detection task and a color-identification task there was no correlation.

The study also asked which of the lighting conditions the subjects considered “most secure” to leave a new car parked under for a week; their choices showed a close positive correlation with higher illuminance levels.

One possible objection to the method of this study is that subjects wore dark wrap-around sunglasses to simulate the effect of reduced illuminance, and that their judgments may have been affected by this differently than by a *real* reduction in average illuminance, where visual adaptation might be different given that the brightness of light sources would not be reduced proportionately to surrounding illuminance. Wearing the sunglasses also “gave away” the purpose of the study, so subjects’ reactions may have been affected by a desire to give the “correct” answer – this is widely recognized as poor experimental practice. This study did not attempt to quantify the effect of shadows or non-uniformity on visual detection tasks, but it would be reasonable to believe that both shadows and non-uniformity would result in poorer visual performance. The study also did not attempt to isolate the effect of spectral distribution or glare.

Boyce et al. (2000)

This field study involved subjects making judgments about the lighting of real parking lots at night and in the daytime, in urban, suburban and rural areas of New York State. 20-23 subjects (depending on the site) stood in a predefined location at each site and made judgments on standard semantic differential scales - “bright-dark”, “glaring-not glaring” etc. In the first and second set of experiments they were asked whether they agreed with the statement “This is a good example of security lighting”; but subjects’ response to this question would clearly be confounded with their preconceptions about what good lighting is, and about what security lighting is. Unfortunately the way the question was phrased is not relevant to the main issue of interest – their fear of crime of their judgment of whether crime is likely to be committed.

In a third experiment subjects were asked “How risky would it be to walk here at night?” They were asked this question both by day and by night in the same parking lots. Their fear of crime was significantly higher at night than during the day, and the *difference* between their daytime and night-time response was significantly negatively correlated with the average illuminance in the parking lots. This correlation showed that when the illuminance was less than 10 lux people perceived a difference in safety between daytime and nighttime, but they perceived no difference when the illuminance was above 10 lux.

Unfortunately no measurements of ambient light (i.e. light from surrounding buildings, street lighting) were taken, so it can’t be determined whether this variable had a significant effect. Also, for the third experiment, no data is given about the subjects. In the first and second experiments the subjects were a mix of people who could be expected to have a bias in favor of higher lighting levels (utility staff, business development groups, and students from the Lighting Research Center) and those who

might not have (people recruited from a temporary employment agency). Boyce et al do not discuss whether differences in response existed between these two groups.

One significant confound that is not addressed in the paper is the type of lighting fixture. It is possible, for instance, that the places with lower illuminances had a particular type of lighting (such as wall packs or non-cutoff fixtures) while the places with higher illuminances had another. The differences in light distribution between these types could plausibly account for differences in fear of crime, due to factors such as contrast, glare, vertical illuminance levels and/or silhouetting.

Boyce et al. (2001)

This study involved a before-and-after comparison of three canopy lighting installations at the same gas station over a period of weeks. Customers were surveyed at random to determine their opinions about the lighting in terms of perceived safety, and records were kept of the number of customers who turned in to the gas station (between 41 and 59 customers during the 210-minute recording period). The rationale used by the researchers is that customers are more likely to use a gas station that looks safer.

All three lighting installations used the same amount of lighting power and the same lamps (320W metal halide), but had different luminaires and therefore different light distributions. The original luminaires shone a significant amount of light sideways, whereas the two new installations concentrated the light downward more; one of the new installations retained a degree of “sparkle” by using a prismatic controller, whereas the other had no sparkle.

There were no statistically significant differences between the three installations, which was partly due to the small number of surveys conducted (109 in total between the three installations). Noteworthy differences (none significant) included those shown in Figure 5. All three installations had very high lux levels (320-800 lux), but over this range of illuminances the light level did not correlate with customers’ feelings of safety or the degree to which the lighting had “attracted them in to the gas station”. Across all three installations, 13% of people thought that the lighting was too bright, whereas 8% thought it was too dim.

Question	Original installation (320 lux)	New installation without sparkle (800 lux)	New installation with sparkle (740 lux)
The lighting at this gas station attracted me to pull in	62%	37%	57%
The lighting at the gas station makes me feel safe	88%	93%	96%
The lighting is too bright for pumping gas and checking my car	15%	10%	13%

Figure 5 – Customer Responses to Three Gas Station Canopy Lighting Installations

Clark (2003)

Clark’s second study, unlike his first, is a research paper rather than a review, although the research is based on historical data rather than experimental data.

Clark's method is to compare changes in crime rates over long periods of time, and from one place to another, and then to correlate these with changes in the amount or brightness of street lighting. It should be noted that this method has the lowest possible score (1/5) on Eck's (1997) scientific methods scale, due to its extreme susceptibility to confounding factors.

Clark hypothesizes that "*Excessive outdoor lighting appears to facilitate some of the social factors that lead to crime.*" He proposes the following series of events:

Commercial and retail centres provide lots of light to attract people after daylight hours. One effect of the light is to make people feel safer. Commercial success is assisted by the presence of more people. In turn, this allows more goods and services to be offered. There is more money about. Part of any extra profits may go into further development, including more lighting. Crime opportunities increase with the number of people. (p.ii)

Clark presents four types of evidence: 1.) a correlation over time between increases in street lighting and increases in crime; 2.) evidence that crime rates drop suddenly during periods of darkness such as blackouts; 3.) a correlation between the amount of upward light energy loss per person and the rate of crime in cities in the US, Canada, Australia and the UK; and 4.) evidence that vandalism and theft is reduced when lights are switched off at night on university and school campuses.

The confounding factors in the first and second sets of evidence are clear, and make the evidence very weak. For the third set, the most obvious confounding factors would be that larger cities emit more light, and also have higher crime rates; Clark shows that this confound is not significant by presenting a graph of light loss per unit *area* (large, dense cities score higher on this scale) against UCR crime rate¹³ and showing that there is no correlation ($R^2 < 0.01$).

¹³ UCR refers to the annual FBI Uniform Crime Report

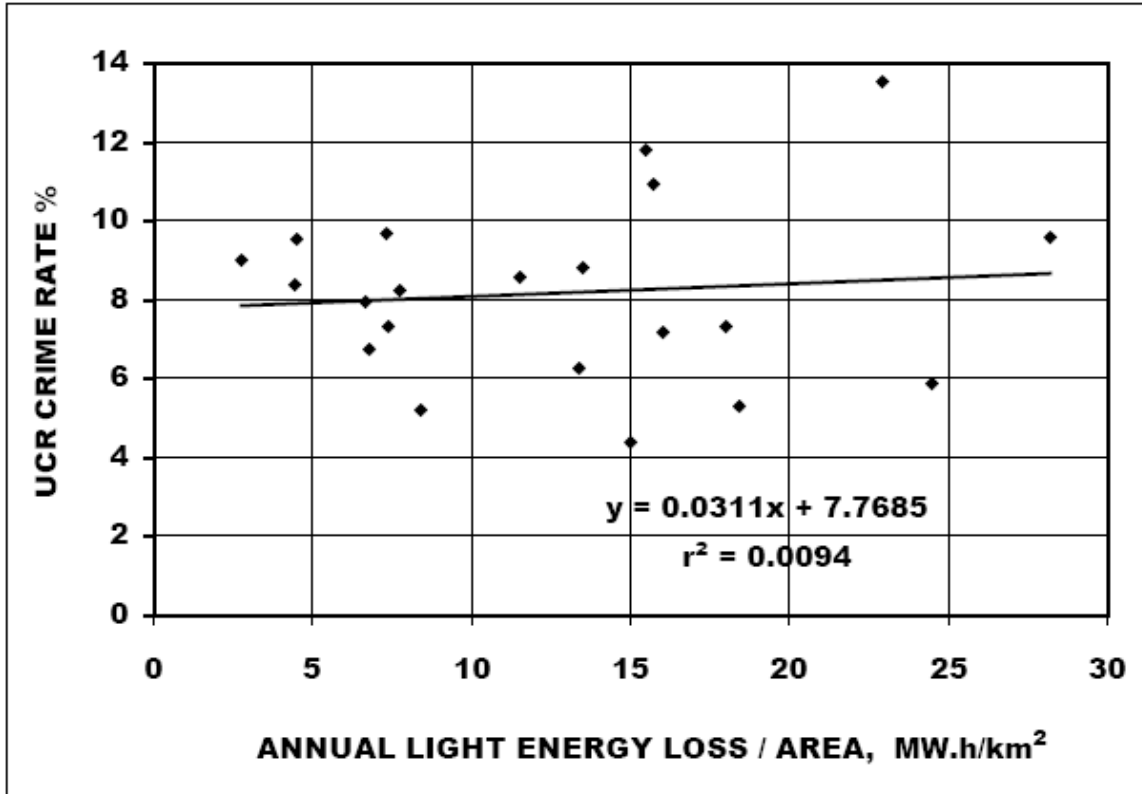


Figure 6 – UCR Crime Rate and Upward Light Energy Loss in USA Cities (from Clark 2003), showing no correlation between lighting density and crime

However, there is a stronger correlation between light energy loss per *person* (i.e., taking into account population density rather than just area), and crime rate. This correlation holds both when crime is measured using the UCR scale ($R^2=0.46$, see Figure 7) and the Morgan Quitno Crime Score ($R^2=0.56$). These correlations also hold for Canadian cities ($R^2=0.31$, $R^2=0.22$). These correlations support Clark’s hypothesis, although they may well be due to other unknown confounds, so the evidence is still weak. One important variable that strongly influences the data is where the boundary of each city is taken to be; Clark does not give details of this definition.

Clark’s fourth set of evidence attempts to show that vandalism is reduced when campus lighting is switched off. Clark’s hypothesis for this is that “*vandals...need or like to see the damage they cause.*” Only anecdotal evidence is presented (for instance, quotations from maintenance staff and police, personal observations, magazine articles). Nine sources are quoted as supporting Clark’s hypothesis, while one refutes it.

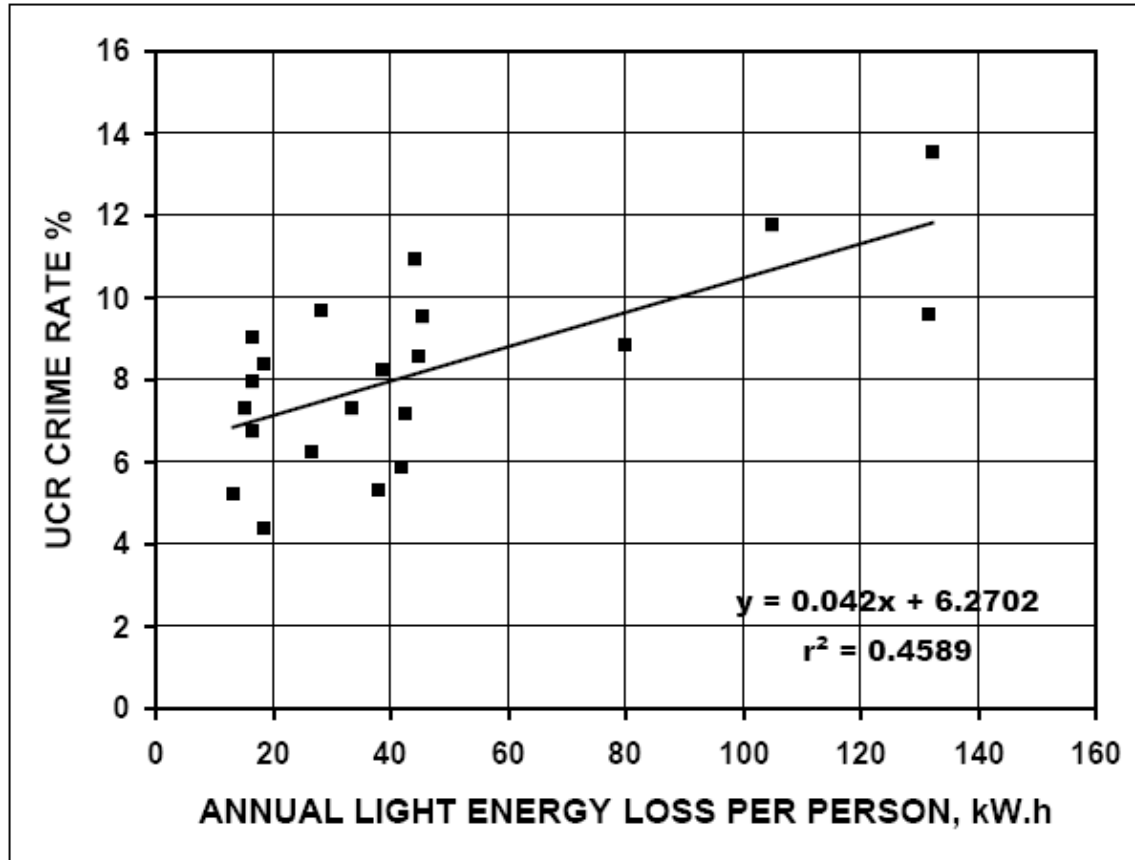


Figure 7 - UCR Crime and Upward Light Energy Loss per Person in USA Cities (from Clark 2003)

Hendricks et al. (1999)

This was an extensive field survey that linked environmental variables with robbery statistics, for 400 convenience store robberies in Virginia. The sample consisted of 258 stores where robberies had been committed and 1201 control stores where no robberies had been committed. The authors collected data for 14 environmental variables, and controlled for demographic, crime, transportation and land-use variables.

They found that many of environmental variables were correlated with the likelihood of robbery, however, the only variable which they considered that was relevant to lighting was “visibility from outside to inside of store.”, i.e., whether it was possible to see into the store from outside. Higher visibility was significantly ($p < 0.01$) correlated with *fewer* robberies, suggesting that robbers may choose their targets based on the likelihood of the robbery being witnessed from outside the store. This suggests that a higher difference in illumination between inside and outside is beneficial, i.e. that *darker* street lighting or parking lot lighting might reduce robberies.

Concurrently, there is a need for clerks inside gas stations to be able to see out through the windows, in case drivers leave without paying or in case patrons are robbed on the forecourt. These dual requirements suggest that lighting levels on the forecourt can be lower, but not a lot lower than light levels inside the building.

Hendricks et al found a total of nineteen variables (out of 42 considered) that predicted the number of robberies with $p < 0.05$; these variables included a wide range of environmental, demographic and procedural factors such as the “distance to nearest graffiti (miles)” and “cash handling method”. The visibility variable was one of eight significant predictors that the authors termed “crime prevention” variables.

Hendricks et al. cite previous studies that show the robbers target stores “within a 2- to 3-mile radius [of each other] on the basis of various situational crime prevention factors”. This suggests that for this type of crime, prevention measures are likely to displace crime to nearby stores.

OSHA (1998)

OSHA developed this document for use by the late-night retail industry, especially for owners of convenience stores, liquor stores, and gasoline stations. The document helps employers to design, select, and implement prevention programs based on the specific risk factors they identify in their particular workplaces. The document was based on a literature review, and a working panel of researchers, educators, representatives from victims’ groups, industry, and law enforcement professionals. It does not cite any authoritative sources as the basis for its recommendations. It gives the following recommendations under “Engineering Controls and Workplace Adaptation”:

Improve visibility as visibility is important in preventing robbery in two respects: First, employees should be able see their surroundings, and second, persons outside the store, including police on patrol, should be able to see into the store. Employees in the store should have an unobstructed view of the street, clear of shrubbery, trees or any form of clutter that a criminal could use to hide...Maintain adequate lighting within and outside the establishment to make the store less appealing to a potential robber by making detection more likely. The parking area and the approach to the retail establishment should be well lit during nighttime hours of operation. Exterior illumination may need upgrading in order to allow employees to see what is occurring outside the store.

There are several ways to meet this guideline while maintaining a reasonably low level of outdoor lighting; for instance low-reflectance or angled glass, or specular (low-glare) luminaires can be installed both inside and outside the store to ensure that employees can see out more clearly. This guideline could reasonably be met by providing an outdoor illuminance of the order of one-quarter to one-half of the indoor illuminance level.

OSHA’s interest in crimes against employees in the late-night retail industry stems from the fact that, from 1980 to 1992, its overall rate of homicide was 1.6 per 100,000 workers per year, compared with a national average of 0.70 per 100,000 workers (NIOSH, 1996). Late-night retail stores are therefore both an important subject and an ideal laboratory for research into the possible effect of outdoor lighting on crime. From 1990 to 1992, the highest annual homicide risks among retail industries were as follows:

Retail Type	Rate of homicide per 100,000 workers
Liquor stores	7.5
Gasoline service stations	4.8
Jewelry stores	4.7
Grocery stores (including convenience stores)	3.8
Eating and drinking places	1.5

Figure 8 – Rates of Homicide for Various Retail Industries (NIOSH, 1996).

Painter (1997)

This study (the “Dudley Study”) uses self-reports to measure the incidence and prevalence of crime before and after the installation of new lighting in experimental and control areas. The experimental area and control area were adjacent “local authority housing estates” in the UK dating from the mid-1930s, within similar housing (rows of four two-story houses with yards front and back) and demographics. The experimental area was relit to an average illuminance of 6 lux with high-pressure sodium lamps, while the control area remained at the previous level of 3 lux, lit mainly by incandescent lamps.

The researchers carried out before-and-after surveys of 743 households in the relit area, and those households reported a total of 343 crimes although many of those are likely to be multiple reports of the same crime.

Figure 9 shows that the prevalence of crime in the experimental area decreased more than crime in the control area. The fear of crime also improved in the experimental area on five out of seven measures, while in the control area it became worse on five out of seven.

Prevalence (percentage of people reporting having been victims of crime) for both daytime and nighttime events	Before	After
Experimental Area	42%	32%
Control Area	39%	38%

Figure 9 – Prevalence of Crime Before and After Relighting, Dudley

The “before” and “after” surveys were carried out one year apart, and each asked questions about crimes that had occurred during the previous 12 months. The authors acknowledge that this method is subject to at least two sources of accuracy; first, the interviewee may forget less recent events and second, the interviewer may believe that events that occurred a long time ago occurred more recently (this is known as “telescoping”). The magnitude of these effects is not known, but may have been significant.

This survey avoids one potential confound, because it measures both daytime and nighttime crime to determine whether displacement or diffusion effects exist. However,

this result is problematic because it shows that crime was no less likely to be committed **after dark** after the street lighting was installed. It is difficult to explain how street lighting could affect daytime crime rates just as much as nighttime crime rates.

However, several confounds were still present. First, there were fewer police patrols in the experimental area than in the control area before the lighting was installed, and more afterward. Second, regression to the mean may have occurred (the experimental area had higher crime rates than the control area before the study, and street lighting was installed as a crime-reduction measure). Third, the “control” area was adjacent to the experimental area; there was no separate matched control area. A fourth confound noted by Clark (2002) is that the study team was involved in community planning and development meetings prior to the relighting.

Painter 1999

This study (the “Stoke Study”) uses the same experimental method as the Dudley study, but with the addition of a true control area, in addition to the adjacent area; this allows the measurement of displacement and diffusion effects. The experimental area contained UK housing from the 1950s, including both row houses and duplexes, both with front and rear yards. The relighting involved high-pressure sodium lamps that increased the average illuminance by a factor of five compared with the original tungsten lamps (actual illuminance levels are not given).

Figure 10 shows that crime rates (both day and night) decreased in the experimental area after relighting; rates in the adjacent area decreased by almost exactly the same amount, whereas rates in the control area remained the same. The authors hypothesize that this is due to a diffusion of benefits, i.e. *“the improved lighting in the experimental area deterred potential offenders not only in this area but in the adjacent area as well.”*

Similar to the Dudley study, crime rates during the daytime changed in exactly the same way as crime rates during the nighttime, so again the authors hypothesize that there was a diffusion of benefits, whereby *“improved street lighting led to increased community pride, increased community cohesion and increased informal social control, which deterred potential [daytime] offenders.”*

The authors claim that the *“most plausible explanation of all the results is that improved street lighting caused a decrease in crime in the experimental area”*, yet they don’t consider the much simpler explanation that the lighting had no effect at all, or that the planning process increased social cohesion and vigilance, regardless of the measures initiated—a kind of “Hawthorne effect”. This alternative explanation would account for the identical change in crime rates in the experimental and control areas, and for the fact that nighttime crime did not reduce relative to daytime crime. Under this alternative explanation the decrease in crime in both the experimental and control areas is explained by regression to the mean, and the absence of change in the control area supports this explanation.

	Before	After
Prevalence (percentage of people reporting having been victims of crime) in both day and nighttime		
Experimental Area	57.7	42.8
Adjacent Area	55.6	43.8
Control Area	34.1	38.3
Incidence (number of crimes per 100 households)		
Experimental Area	173.8	99.3
Adjacent Area	180.0	98.3
Control Area	69.3	67.9

Figure 10 - Prevalence and Incidence of Crime Before and After Relighting, Stoke

Despite the ambiguity of the results, this study represents the best experimental design to date in the field of lighting and crime, and this has been recognized by commentators.

Quinet and Nunn (1998)

This study analyzes *calls for service* (CFS) made to the police department by citizens before and after the installation of new street lighting in a crime-ridden area of Indianapolis. Two experimental areas were matched with two control areas that did not have lighting installed and were “*close to our lighting intervention areas [and] had similar crime rates and similar sociodemographic characteristics.*” The exact location and proximity of the areas is not described. The experimental and control areas contained a total of 100 street lights and there were 583 calls for service during the pre- and post-installation monitored periods.

The new street lighting was funded and installed in a joint effort by the electrical utility and neighborhood associations; the study was funded by the Indiana Electric Association.

Following the installation of new lighting, CFS increased in both experimental areas; it decreased in one of the control areas and rose in another. No analysis of statistical significance is given in the paper. The authors report that “*Overall, the findings of this study are consistent with the mixed reports of other previous work on...lighting.*”

This paper exhibits many of the methodological shortcomings identified in this review. First, the experimental areas were being re-lit because they had high crime rates, and so regression to the mean would be a plausible explanation for any decrease in crime; this problem was exacerbated by the authors who then selected the areas with the highest crime rates for study. Second, the study does not include “adjacent” areas, so cannot determine the effects of displacement or diffusion. Third, it does not include daytime measures of crime, so temporal displacement or diffusion cannot be determined. Fourth, a confounding factor was present because the Indiana Police Department (IPD) conducted several targeted operations in the experimental areas during the experiment, which the authors argue could have resulted in increases in CFS in the experimental areas (no evidence is given for this).

Conclusions

General Conclusions

The available results show a mixed picture of positive and negative effects of lighting on crime, most of which are not statistically significant. This suggests either that there is no link between lighting and crime, or that any link is too subtle or complex to have been evident in the data, given the limited size of the studies undertaken. It is possible that future more targeted studies may be justified to further investigate a possible link, given the potentially high cost-benefit ratio of lighting as a crime-reduction measure.

Experimental work in this area is subject to a great many confounding factors. The quality of research has steadily improved over time, as authors have improved on the methodological shortcomings of previous studies. The most robust method is the one used by Painter (1999), and yet even this study has several methodological flaws.

Of those few studies that did show a significant relationship between lighting and fear of crime, the range of effective lighting levels are rather low, at 1 footcandle or less.

In addition, the available literature does allow a number of important conclusions to be drawn, as follows:

Insufficient Statistical Power

The main conclusion to be drawn from the available evidence is that the variance in rates of crime is very high; crimes rates vary greatly over time both over the long and short term, and they vary from one place to another. This can be seen in the magnitude of variation between “experimental” and “control” areas in the reviewed papers, and most compellingly in Clark’s (2002) “quasi-experiment”. This high variation means that a very extensive study, both in number of subjects and time period, would be required to establish a link between lighting and crime, while controlling for other possible confounds or influences. No such study has yet been conducted.

Significant Results are Likely to be False Positives

Crime rates are highly variable due to a number of factors such as economic conditions, demographics, police and municipal initiatives, and the unpredictable behavior of criminals themselves. The “noise” created by these factors (as shown by Clark 2002) is large enough to create effects that could mistakenly be attributed to lighting, unless these other factors are somehow controlled. On the other hand, any real effects of a lighting program could be swamped by the variation due to these other factors. Without the ability to control for other influences, any real effects of the program would not reach acceptable levels of statistical significance.

Clark’s data was assembled over a two-year period (typical of the studies cited in this review) and over a very large geographical area (the state of New Jersey), which suggests that even in large study areas these confounding factors can be significant. They would be even more so in smaller areas where monthly crime data may be more volatile since the total can be more greatly affected by the behavior of a single criminal.

Several of the papers claim that accurate models exist that predict crime on the basis of economic, demographic and environmental factors. These models could potentially be used to explain some of this variation and to isolate the effect of lighting, if all of this information were available and assuming the effect of the lighting program were sufficiently large.

Since controlled experiments are nearly impossible in the field of crime studies, the next best alternative is very large studies, in terms of geographical area covered, time period, number of crimes recorded, and information on other explanatory variables.

Extensive Confounds in the Experimental Data

The two largest confounds in the data are “regression to the mean” and the effects of increased policing after the installation of the lighting. Both these effects occur because relighting is often carried out in high-crime areas. Future studies should attempt to isolate these two variables.

Most Places have no Crime

Eck (1997) quotes sources that show that crime is concentrated in only a few places, and that most places have no crime at all. Therefore lighting, as a place-specific measure, would be most cost-effective when used only in a targeted way, assuming that the crime would not simply be displaced to adjacent areas.

Displacement Effects Observed, but not very Certain

“Displacement” of crime from one area to another has been observed in several of the studies. The likelihood of displacement varies by the type of crime, but a study of displacement (Hesseling 1994) showed that most crimes undergo displacement. Some crimes such as convenience store robberies are known to undergo displacement because criminals search for the easiest target in a small geographic area. It is therefore likely that a successful attempt to reduce crime in one area would cause crime to increase in adjacent areas. However, it should be noted that many of the observed “displacements” could simply be due to “natural” variations in crime rates.

Little Theoretical Basis for Why Lighting would affect Crime

The most commonly-cited theoretical basis for why lighting would influence crime is that “informal social surveillance” increases. However, none of the studies were able to identify or quantify such an effect, so it remains hypothetical. Further, it is known (Clark 2003) that some criminals are not deterred by informal surveillance because they are confident that they won’t be interrupted or identified while committing their crimes. Similarly, if lighting deterred outdoor crime, one would expect to see much lower rates of certain crimes during the daytime than night. A more thorough understanding of criminal behavior (specific to particular types of crime) is required before the effect of lighting, if any, can be explained.

Higher Illuminances Reduce the Fear of Crime

Several of the studies reviewed found that people’s subjective fear of crime is reduced when “improved” lighting is installed, or when illuminances increase. The clearest and

most applicable result is that found by Boyce et al. (2000) that 8-10 lux in parking lots was sufficient to reduce the difference between daytime and nighttime appraisals to less than one point on a 1-7 scale.

It is important to note that different populations require different levels of illuminance; some functions show little change with age (e.g., high contrast visual acuity), whereas low-contrast visual acuity under glare, and facial recognition are up to 18 times worse among the oldest (>90 years) age group than among young observers (Haegerstrom-Portnoy 2005). Glare should therefore be seen as a critical factor in improving visibility and sense of security under outdoor lighting, but has not yet been extensively researched.

Illuminance from Outdoor Lighting aids in the Recognition of Objects and Faces

People's ability to identify faces and to identify held objects at night may be a determining factor in their perceptions of safety, although this has not yet specifically been proven by research. People find it easier to recognize objects and faces under higher levels of illuminance. Van Bommel and Caminada (1982) found that 2.7 lux of vertical illuminance was required for facial recognition at 10m (30'), and Boyce and Bruno (1999) found that subjects were better able to identify hand-held objects under 20 lux (horizontal illuminance) than under 1 lux.

Higher Illuminances May Improve Professional Surveillance

Lighting may allow more effective surveillance of places by security guards or other employees (Boyce and Bruno 1999), and this provides a potential theoretical basis for establishing a link between lighting and crime. However, to establish a causal link, research would be required to gauge the magnitude of the effect of surveillance on crime; for instance to determine how much crime is detected or deterred because security guards spot hand-held weapons or tools.

Lighting May Encourage Behaviors that Lead to Crime

This hypothesis, advanced by Clark (2003) is the opposite of the hypothesis often put forward by those who believe lighting reduces crime. Clark notes that late-night activity is encouraged by lighting, and that criminals would logically be attracted to this activity in their search for opportunities. He presents evidence that cities with higher per-capita light levels also have higher crime rates, and gives anecdotal evidence of antisocial behavior such as petty vandalism and harassment being associated with street lighting.

Special Lighting No Longer Required for CCTV

Whereas closed-circuit television (CCTV) previously required especially high illumination levels, current CCTV cameras can function under very low light levels. Kukula and Elliot (2004) found that the "failure to enroll" rate for an automatic face-identification system was only 6.3% under 10 lux, compared with 3.2% under 410 lux. Vermeulem (1992) found that a CCTV camera with a "good quality lens" required 26 lux for "excellent picture quality". This value can be expected to have dropped very dramatically since 1992. Indeed, some modern infra-red CCTV cameras specifically require very *low* light levels for proper functioning.

Alternatives to Lighting

Increased policing is an obvious way to reduce crime; there is a well-researched relationship between increased policing and reductions in crime, and this literature is cited by several researchers including Clark (2002). Another alternative is closed-circuit television; Clark (2002) cites studies that show that CCTV assists police in getting convictions. CCTV is now extensively used in Great Britain both by the police, municipalities and private companies. Studies of CCTV and crime suffer from the same confounds as studies of lighting and crime. Other “environmental” means to reduce crime include improving sight-lines and reducing hiding places (OSHA 1998), increasing visibility of people and movement against high reflectance surfaces (both horizontal and vertical), and altering roadway design to impede circular driving patterns, which have been shown (Eck 1997) to be a common method by which criminals survey their targets.

Specific Conclusions

Does the presence of nighttime lighting around commercial and residential buildings, parking lots and walkways influence the *fear* of crime?

Several studies show that subjective fear of crime is reduced by the presence of lighting. This is true both for places that are familiar to the subject (e.g. Painter 1997) and for places that are not familiar (Boyce et al. 2000).

Does the presence of nighttime lighting around commercial and residential buildings, parking lots and walkways influence crime?

On balance, the studies cited show no net effect of night-time lighting on crime; some studies show statistically significant positive effects and some show significant negative effects; this is likely due to the inherently sporadic nature of crime itself. Studies on a larger scale (either in area or over time) are required to overcome the sporadic data.

Does the quantity or quality of nighttime lighting influence crime?

None of the studies that concerned crime looked at whether *more* lighting produced a *greater* effect on crime.

Of the papers reviewed, only the study by Hendricks et al. (1999) suggests a link between illuminance level and the likelihood of crime. Hendricks et al. found that high visibility from the outside to the inside of convenience stores made robberies less likely; this suggests that outdoor light levels should be substantially lower than indoor light levels, which they are in most circumstances.

Does the quantity or quality of nighttime lighting influence the *fear* of crime?

Boyce et al. (2000) found that *fear* of crime in parking lots is *reduced* when illuminance levels increase, and (as predicted by the lighting literature) an approximately logarithmic dose-response relationship exists, i.e., that the strength of the effect diminishes quickly for higher illuminances. The effect was significant up to 8-10 lux, with little additional improvement above 10 lux (1 footcandle).

This would suggest that any requirements or allowances for additional ambient lighting above that rather low level (1 footcandle) would not be likely to have the intended effect.

Is there a causal relationship between nighttime lighting and crime?

None of the papers reviewed presents sufficient evidence to demonstrate a causal link between night-time lighting and crime. However, people feel more secure and have a perception of greater safety in lit areas.

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