Street Lighting and Crime in Madison, WI

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Abstract

Much academic literature exists which suggests streetlighting acts to deter crime (Pease 1999). This analysis offers a GIS approach to the spatial relationships between person-on-person and person-on-property crime with street lighting in downtown Madison, Wisconsin. In this report, it is hypothesized that streets with higher densities of street lighting will correspond with lower crime density. By combining calls for service to the Madison Police Department with city-maintained street light shapefiles, the densities of crime and lighting per 200 ft along streets were calculated, and their relationships examined. In doing, a moderate correlation between high lighting density and high crime density is observed. We believe that because of data limitations, our site setting of the most heavily trafficked areas in Madison led to such a counterintuitive result.

The phrase “Walk on well lit streets” widely circulates in America as a public safety advice standard. For our project, “Street Lighting and Crime in Madison, WI” we investigated whether well-lit streets can actually deter crime in Madison, WI. The crimes of interest were those that take place at night (between certain hours and accounting for seasonal light differences) and are classified as person and property crimes by Madison Police Department. These crimes include sexual assault/rape, battery, personal theft, auto theft, weapons offense, bike theft, trespassing, burglary, and damaged property. During our research we collected data on luminosity, street lighting location, effective street lighting radius and person and property crimes in Madison and will utilize GIS and statistical analysis to verify our claims.

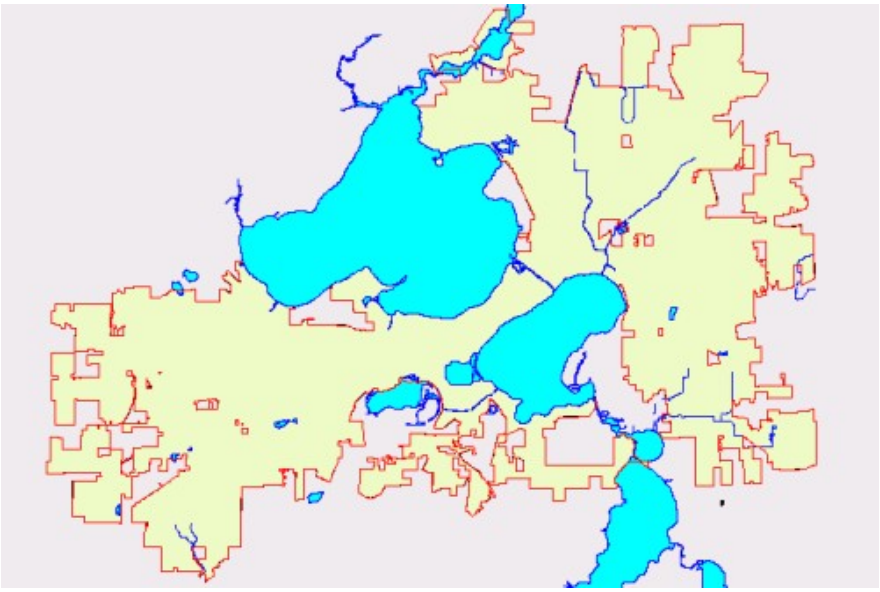
The core portion of the primary research involved gathering data on luminosity and crime. Datasets were not as readily available as we had originally planned and so our research plan changed considerably. We were able to adjust for the data available and statistically analyze the frequency of crimes occurring within a defined distance buffer of streetlights using ArcGIS.

Despite the straight forward nature of our research design, we still relied heavily upon historical and literature research. Street lighting and crime has been extensively researched in the past and so we had much prior data to draw upon. The major conclusion we drew from the literature was to avoid qualitative data as much as possible and focus on the quantifiable. What follows is an overview of our site setting and explanation of our primary research methodology, results and analysis.

Site Setting:

Our area of research is the downtown and campus areas of Madison. The boundaries of the City of Madison are defined by local government on the City of Madison website

(http://www.cityofmadison.com). Below is a screenshot of the GIS layer we used, provided by the Robinson Map Library. Given the lack of GIS data on street lights from the city, our analysis is further refined to the State/Langdon and campus neighborhoods.



The years we focused on in this project were 2012 to 2013. We wanted to provide a relevant analysis and were also limited by the amount of data that was available from the police department.

Introduction

There is a large volume of information regarding street lighting and crime which both benefitted our project and posed obstacles. On one hand, we had a huge amount of supplemental material that gave us direction and guidance during the research process, however, we had to comb through this literature and pull out the most vital and major ideas within a sea of relevant and pertinent research.

The interest for street lighting improvements spans the history of street lighting itself, but

in our research of the literature we have found that there is a particularly large boom in this subject around the late 1970s in Great Britain. A reason for this boom is described in the 1982 British Crime Survey where 34% of the population of England and Wales felt unsafe walking alone in the dark and half of women reported avoiding going out in the dark for reasons of crime and fear (Herbert and Moore 1991). These early experiments and research projects tended to focus on the qualitative side and more generally on what effect street lighting had on individuals, emotions and social cohesion.

With the increase in GIS technologies throughout the recent decades, we had an expectation for an increase in spatial statistic based research in the topic. However, we had found that this was not the case and that GIS based research was few and far between in the topic of street lighting and crime. Instead, there was a large amount of critique and refinement of older assumptions and techniques

With this in mind, we have aggregated what we feel is the most important and crucial research and experiments in street lighting and crime. These projects have been turned into subtopics. Below we will talk about these subtopics, their meaning, their relevance, how the researchers approached them and what it means for our research.

Definition of Crime

This is a topic that comes up in various research projects as a necessity whether talked about directly or laying in the background. Understandably, when talking about crime it becomes necessary to talk about what sorts of crimes you are focused on and how these crimes are defined. Being that these research projects cover such a large geographic area, definitions of

crime vary between them. We have found that crimes pertaining to street lighting generally fall into these categories: crimes against person vs. crimes against property and violent crimes vs. sexual crimes.

Our definition of crime will be similar to that of Kate Painter's, which looks primarily at personal and property crimes. These include incidents such as mugging, assault, theft, harassment, and disorderly behavior (Painter 1996). We feel that these incidents are more likely to be influenced by the presence of street lighting than crimes such as drunk driving, noise complaints, etc.

Fear of Crime

Fear of crime is an extensive topic in street lighting and crime. It has been broadly defined as the fear of a crime happening in regard to the probability of the crime actually occurring. Despite being frequently discussed, the topic is not often agreed upon. Some researchers tend to agree that the fear of crime is a major factor in the disposition of the public while others critique this emphasis.

In the Cardiff Project, fear of crime plays a major role in the research. To professors Herbert and Moore (1991), the fear of crime is a clear and defined problem in the area they are studying. To reinforce this, they did a series of interviews and surveys in the area to determine what people think of crime, what they are worried about and ultimately whether there is a fear of crime (Herbert and Moore 1991 p. 24).

The surveys and interviews for the Cardiff Project were done before and after a new lighting installment in Cardiff, England. Statistics were garnered from the various surveys, which

found that there was indeed a fear of crime in the area and this fear of crime was largely alleviated by greater distribution of street lighting. More minor statistics included that people above the age of 36 tended to be more anxious about crime and the fear of burglary was largest among fear of crime (Herbert and Moore 1991 p. 43). However, because of the methodologies chosen, one might find that the idea of fear was given to the research subjects instead of produced naturally.

There are those that doubt the conventional importance and methodology of fear of crime. In the article, "Road lighting and pedestrian reassurance after dark" Fotios et al (2014) had this to say about fear of crime,

> "Poor question wording, the desire to cooperate with surveys, and media and political interests in the fear of crime have contributed to a scenario in which the fear is continually recreated both socially as a topic for debate and at the individual level: Surveys in this situation may not merely measure fear, and they may actually create and recreate it."

The general belief that the fear of crime is widely overemphasized and can be detrimental to research is held by a few researchers. In this vein of thought, the fear of crime and the discussion of it can raise problems that are otherwise non-existent. For example, statistics are often highly fabricated because the test subjects are given the context before they answer, thus they produce answers without actually having been worried about them prior (Fotios et al. 2014

p. 9).

A more modern approach to this was given by Fotios et al (2014). Instead of pre-disposing their test subjects with the ideas of street lighting and crime, they were to give their reasons for being afraid on their own. In this way, the researchers found that people did mention street lighting as a reason for feeling "reassured", but mentioned it less often as a direct reason for crime (Fotios et al. 2014).

This style of critique from newer generations to older generations is common. The earlier research tends to be highly qualitative until it is critiqued and re-defined to remove as much bias as possible. As seen in the Cardiff Project, many statistics can be produced from surveys, but there is a question of whether these statistics are produced from primary methodology that encourages certain results and as such, and whether those statistics are exaggerated. Fotios et al (2014) addressed this problem of exaggerated statistics by using refined methodologies which would remove bias from research subjects. Ultimately, our research aims to remove this bias entirely by looking primarily at quantitative data and drawing statistics from that, reducing the possibility of human emotions and bias.

Lighting as a Deterrent

While the influence of street lighting is thought to have crime prevention benefits, it is neither a physical barrier nor a solution to the problem of criminal activity (Farrington and Welsh 2002, 42). Many studies found that street lighting is largely ineffective in stopping offenders from committing criminal acts. A study by Quinet and Nunn yielded very ambiguous results about the effect of street lighting as a crime deterrent on its own. This study analyzed the

amount of reported crime before and 12 months after the installation of new street lighting based on calls for service (CFS). Crimes were categorized into tested areas and control areas, and irrelevant complaints, duplicate complaints, and complaints occurring during the daytime were eliminated from the data. The results showed that lighting deterred crime, but in some areas crime remained unchanged in comparison to the control area or increased, which was counter to expectations (Quinet and Nunn 1998).

Ramsey and Newton looked to identify the offenders' views of street lighting by reviewing interviews of experienced offenders, specifically burglars. Most offenders identified signs of occupancy, rather than street lighting, as the primary deterrent. This helps explain the phenomenon of crime rising with improved street lighting. Ramsey and Newton re-evaluated the Edmonton Study, which found that after the implementation of street light improvements, people's reports of incidents decreased, though these incidents referred mostly to incivilities rather than crimes. Additionally, the study's methodology was flawed as many people could not pinpoint whether incidents happened within a 6-week period. There was still debate whether street lighting deterred crime or created better lighting for identifying possible targets, which was the opposite of the intended effect (Ramsey and Newton 1991). Thus, we may conclude that street lighting alone may not be effective in deterring crime. These reviews are helpful for our research question because we do not have the means or time to collect data based on the installation of new street lighting. We are evaluating street lighting that is not new to the area and comparing it to areas where street lighting is not present, therefore these reviews give us information that would not otherwise be available through our own primary data collection.

Street lighting may, however, affect crime indirectly. Herbert and Davidson (1994) discuss a study in which surveys were given to the public 6 weeks before and after an improvement in street lighting. The topics covered included crime, feelings of fear, victimization and attitudes of public safety and change. In this study, women and elderly citizens were shown to experience more fear from poorly lit streets. The biggest shift in both of the cities was the attitudes of women and the elderly who reported feeling more at ease walking at night after the lighting improvements. Residents could recognize faces at night as a result of the brighter lighting schemes (Herbert and Davidson 1994).

It seems that the presence of street lighting is most effective in changing the psychological state and behaviors of the public. Kate Painter assess this in a series of surveys given to the public 6 weeks before and after the installation of new lighting. The responses she received back showed that the public felt much safer walking alone at night, a phenomenon which led to an increase in public street use. This shift in behavior had several benefits to the community, such as the constant informal surveillance that occurs when the community is able to see what is happening along the street. The newfound ability to see crime as it happens meant that the likelihood of someone intervening on a crime in progress is much greater. This would deter crime as an offender would feel they were much more easily identified and apprehended. Painter concludes that while street lighting is neither a physical barrier to crime nor a solution, the indirect changes in the public's mindset caused a series of benefits that created a safer environment (Painter 1996 p. 195). This lets us know that while street lighting may not directly stop a crime from occurring, there are various benefits that may be gleaned from the community

believing that their neighborhood is safer.

Social Cohesion

One of the indirect benefits of street lighting is the improvement in a community's social cohesion. Doran and Lees (2005) introduced the "broken window theory" in effort to explain how this concept functions. If a window is broken and is not fixed in any hurry, other people in the environment will soon take this to mean that the community does not care about the windows and consequently more windows will be broken. This applies to crime and fear of crime because should disorderly behavior remain unattended to, it will gradually develop into more severe cases of criminal activity. If disorder in an area is on the rise, people will avoid the area out of fear of becoming a victim. What then develops is a positive feedback loop in which public avoidance of an area due to presence of incivilities will invite more serious criminal activities into the area, thus contributing further to public fear and avoidance. So, despite the lack of a direct connection between disorder and crime, the two can be linked indirectly through the downward spiral of community stability (Doran and Lees 2005).

Quantified with readily accessible census data including percentage of crimes committed by juveniles (Bowers et. al. 1997), social cohesion helps offer further insight into traditionally investigated statistics about crime to identify places at higher risk for crime. If attempts are made to deter crime in a particular location, this is perceived as the city making efforts to increase security. If the city chooses to install improved street lighting, the community will feel pride and a sense of responsibility to keep their neighborhood safe. The installation of well functioning

street lighting may well decrease fear and stimulate public street use and natural surveillance of an area. Ken Pease discusses Situational Crime Prevention (SCP), which works to make crime more difficult, with more risk and less reward (Pease 1999). Improved social cohesion works to deter crime, as offenders may notice the efforts being made to reduce crime and assess the area as too risky to take advantage of. We may find that areas experiencing interconnectivity and community pride will have lower crime rates than those that put little effort into deterring crime.

Lighting Type and Efficiency

Lighting efficiency has been an important factor in lighting projects since at least 1973 with Roger Wright et. al.'s "The Impact of Street Lighting on Street Crime". Without a doubt, a major factor in any real-life decisions is how much money it will cost, but often with academic ventures such as ours, resources and practicality are a low consideration. However, in street lighting and crime with its connection to real life applications, efficiency becomes paramount.

In "The Impact of Street Lighting on Street Crime", research was done after a large scale replacement of incandescent street lighting for mercury and sodium vapor street lighting in Kansas City, Missouri. The stated motivation for change was energy and gas crisis of the time. Roger Wright et al estimate that with 12.4 million street lights in 1973 and an average yearly wattage per light at 325, there was a necessary 1,240,000 gallons of gas used on street lighting each year. Compounded with the statistic from General Electric that 80% of all lighting energy consumption is allocated to street and highway lighting, the benefit to changing to more efficient street lighting is clearly defined in the paper (Wright et al. 1973).

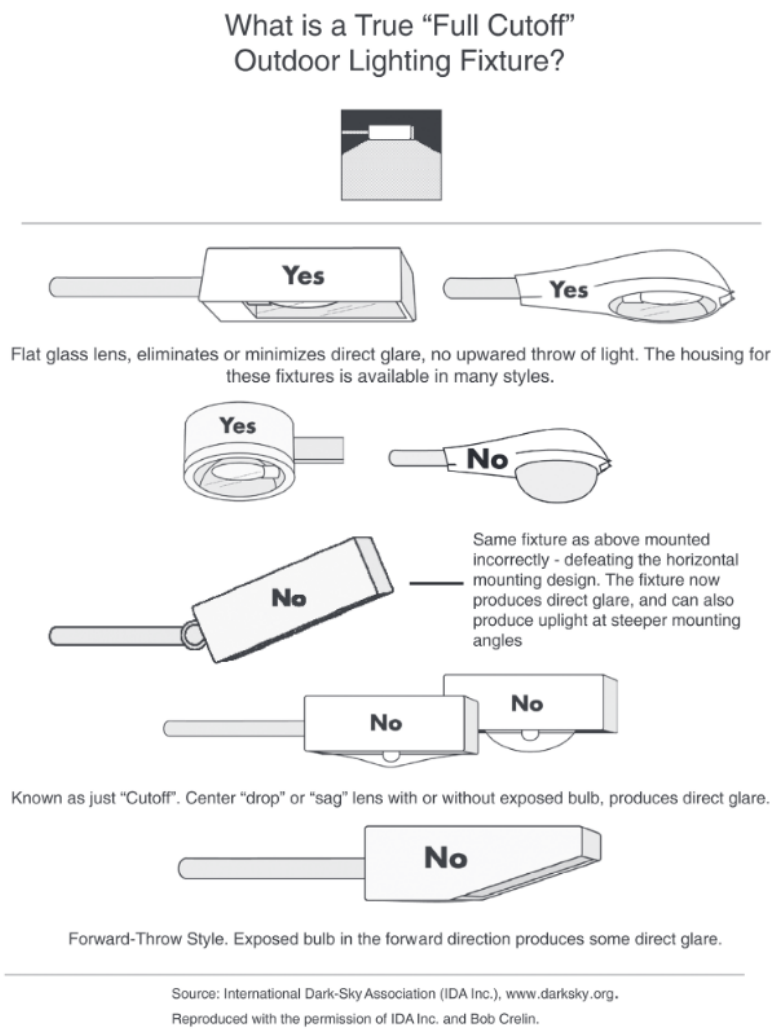
"In terms of efficiency of utilization of energy, different types of lights are differentially

efficient." (Wright et al. 1973). The researchers go on to list the approximate energy efficiency of each lighting type. In short, incandescent lights produce an average of 22 lumens per watt, mercury lights produce an average of 50 lumens per watt and sodium lights produce an average of 115 lumens per watt. Despite this, 20% of street lighting remained incandescent and only 5% was sodium based.

The preface efficiency concern and the statistics given in this paper give proper motivation and reason behind the research. Research results aside, Wright et al have provided clear evidence that efficiency in 1973 was lacking and the potential for improvement was massive, and because of this, change was made. This type of data and information becomes useful in all occupations, but especially for those in crime-prevention.

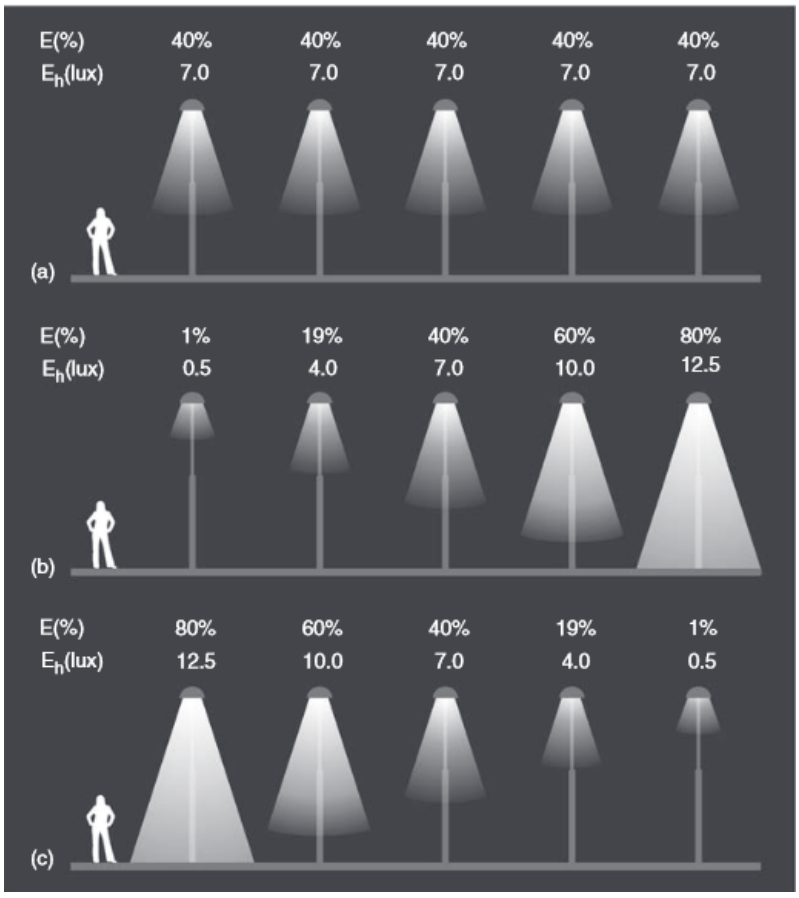
In part of a police manual titled "Problem-Oriented Guides for Police", Ronald Clarke (2008) looks at recent research in crime and street lighting and applies it for police officers to use in starting their own lighting projects. One of the more important considerations for the manual was how much street lights cost. In one example, a street lighting project in Workington, West Cumbria, United Kingdom showed that a particular street had a serious theft problem. A lighting project was bid for by the government at around $24,500 and the crime was reduced from $9000 in theft to $1,500 (Clarke 2008 p. 15).

In addition to cost, the manual goes over the different types of street lighting, what their pros and cons are, and the optimal position for luminosity. The six main kinds of street lighting from least efficient to most efficient are: incandescent, mercury vapor, high-pressure sodium, low-pressure sodium, metal halide and fluorescent (Clarke 2008). In the figure shown below, Ronald Clarke reviews positions of a street light and shows the optimal positions.



Even in more academic levels of research, the need to explain reason and practicality are clear. In a 2014 lighting journal article, "Road lighting and pedestrian reassurance after dark: A Review", Fotios et al (2014) explain that higher luminosity leads to higher reassurance and lower fear of crime, but luminosity is perceived to be higher with better horizontal illumination. This means that while luminosity is needed to reduce fear, it is also second to the cost of street lighting so it is important for the researchers to find alternate and more efficient ways of lighting

the streets. In the figure below, various methods of light distribution are shown with their respective percentage of maximum output (Fotios et al. 2014).



The above image also appears in a study from Dutch researchers Haans and de Kort (2012). In attempts to modernize cities, reduce waste, all while preserving or improving citizens' experiences, "smart" technologies are expected to emerge throughout the globe. Smart here refers to technologies such as street lighting with the ability to wirelessly communicate and optimize their use. In developing dynamic, smart street lighting, light post will be able to sense movement, communicate the presence of a pedestrian to nearby light fixtures, and adjust luminosity to accomodate. Haans and de Kort found that the setup expressed by the person at position (c) in the above figure best resonated with feelings of safety. They attributed this to the

perception of safety in light, that being in a strongly lit immediate area gives a stronger perception of safety than in a uniformly-lit area.

The need to understand lighting types and discuss street lighting efficiency is seen as vital within almost all sources. Street lighting takes up a majority of the cost of lighting in the United States and since 1973 has seen major improvements in efficiency (Wright et al. 1973). Police departments have applications for research done in street lighting and crime where efficiency and cost of lighting is vital to pitching lighting projects to local governments (Clarke 2008). Current researchers understand the importance of finding the most optimal and efficient ways of lighting streets (Fotios et al. 2014). The projects shown above give additional reason and use for our own research: a validation for lighting projects within Madison, WI to decrease crime.

Displacement

In developing, implementing, and investigating improvement projects in neighborhoods, including lighting projects, there has been surmountable evidence for the diffusion of benefits. Diffusion is defined by Farrington and Painter as "the spread of beneficial influence of an intervention beyond the places which are directly targeted, the individuals who are the subject of control, the crimes which are the focus of the intervention, or the time periods in which an intervention is brought." (Farrington et. al. 1990). Other have referred to this as a "free-rider" or "bonus" effect. In addressing one type of crime, such as over-the-counter robberies via implementing bullet-proof windows to the counter space, criminals may incorrectly assume that

other types of crime are more difficult to be pulled in that area, forcing them to reevaluate their decision to attempt the crimes.

In addition to influencing other types of crimes, benefits of improvement often diffuse geographically, presenting researchers with a bit of a paradox. In most research designs, the area of benefit will often be compared to an area nearby which did not receive said benefit: this is to define a control space with conditions nearly exactly like the experimental. Should diffusion of benefits occur, as it often does, the success of a development program will not appear as glamorous compared to its neighboring control area. It is therefore imperative to keep this effect in mind when conducting neighborhood improvement research, that is, to define control areas both near and far removed from an experimental one.

Source of Bias

While there have been several mentioned benefits of street lighting, including psychological improvements of community residents and a decrease in overall crime rates, it is responsible to consider effective and practical limitations to lighting. Light pollution for one is a large concern of urban planners; residents would like minimal obstruction when viewing the nighttime sky. At the same, said residents would like to keep their residences safe, to which infinite amounts of lighting are no solution. Finding the nexus of lighting for safety and aesthetically pleasing locales is not well-researched and presents the opportunity for additional research topics.

Also worth considering are ecological influences urban lights have. Humans' ability to extend their activity further into the night with lights directly affects those animals whose active periods begin upon sunset. One investigation of bat species *R. hipposideros* concluded that typical city luminosities can drastically disrupt the timing of the bat's activity and typical travel patterns in ways which may cause it to miss its feeding window, leading to the species' demise (Harris et. al. 2009). Just one example, it is not unreasonable to extrapolate these results to other nocturnal species, presenting the risk of severe ecological balance disruptions.

Methodologies

Research on street lighting has taken both qualitative and quantitative forms. Typically, qualitative research invokes interviews of perceived safety or risk of victimization. Conversely, quantitative research methods often use GIS analysis of crime data.

In the past, there was a tendency to rely on qualitative information in street lighting and crime. This is of little surprise as GIS was an emerging field in the 1970s and 1980s. The oldest paper in our literary review utilized a combination of post lighting project crime analysis with city history context and interviews (Wright 1973). The Cardiff project used a large amount of interviews and surveys to supplement post lighting project findings (Herbert and Moore 1991). In addition to the Cardiff project, a research done by Barry Poyner utilized a ranking system and a review of past research to rank crime preventions methods (Poyner 1987). These three projects exemplify the typical qualitative style of the earlier era of street lighting and crime research.

Today, GIS has been used extensively as a tool to monitor crime activity. Sites like crimereports.com involve a user-friendly interface by which to visually represent crime activity

to the public. GIS' ability to represent data like crime both visually and statistically can "support a fuller analysis of the 'what, when, and who' aspects of crime-and-disorder data. (Gill et al. 2006).

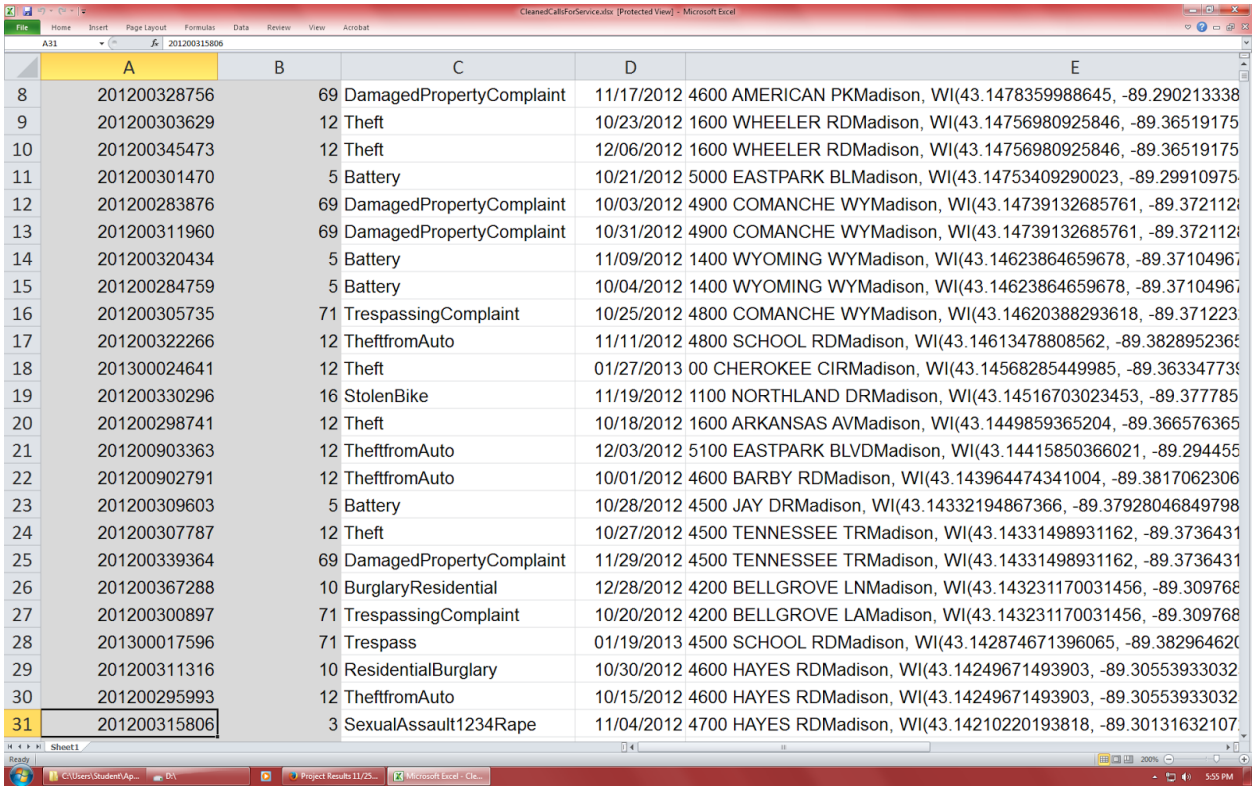
Gill et al. (2006) qualified the bridging of the gap between these approaches in their study in Northumberland, England. By utilizing GIS, the group was able to better evaluate a potential site of improvement. Augmenting crime and streetlight coverage with residents' evaluations and interviews about perceived safety and impacts of lighting gave further insight to the specific needs of a developmental project, or as they put it, "qualification of the 'when', 'if', and 'but'" of these projects (Gill et al. 2006 p. 2060).

As we have discovered that a large amount of inflated statistics and flawed data have come from qualitative bias in past research of street lighting and crime, our primary goal in our methodology was to avoid this. We feel we have removed the largest amount of bias by keeping our primary research mostly quantitative. A second method for avoiding this bias was to tread lightly and/or nearly avoid topics such as fear of crime, social cohesion and displacement. While we had discovered it is possible to deal with these topics, our time constraints and limited research area make it quite difficult to address them accurately and completely.

We began our primary research by obtaining basic GIS layers from Jaime Stoltenberg at the UW Robinson Map Library. The data was readily available and allowed us to get a basemap for our area of study as well as a basic visual of our study area. Our selected layers were: impervious areas, lakes/rivers, street names, street centerlines, city fill, and ramps. These were selected on the basis of what is visible from the street and thus what is relevant to our study. We later refined these layers to just the streets, city fill and lakes to make a cleaner and more

accessible map.

We contacted the Madison Police Department to obtain any GIS-accessible files on crime in Madison. Upon learning that the city does not directly maintain GIS files on crime, we were instead left with static Excel data for calls for service. Upon filtering out crimes to include only person-on-person crimes, GPS coordinates of crime locations were extracted, allowing the data to be imported into ArcMap. The relevant crimes investigated include sexual assault/rape, battery, personal theft, auto theft, weapons offense, bike theft, trespassing, burglary, and damaged property (Fig. 1).



	A	B	C	D	E
8	201200328756	69	DamagedPropertyComplaint	11/17/2012	4600 AMERICAN PKMadison, WI(43.1478359988645, -89.290213338
9	201200303629	12	Theft	10/23/2012	1600 WHEELER RDMadison, WI(43.14756980925846, -89.36519175
10	201200345473	12	Theft	12/06/2012	1600 WHEELER RDMadison, WI(43.14756980925846, -89.36519175
11	201200301470	5	Battery	10/21/2012	5000 EASTPARK BLMadison, WI(43.14753409290023, -89.29910975
12	201200283876	69	DamagedPropertyComplaint	10/03/2012	4900 COMANCHE WYMadison, WI(43.14739132685761, -89.372112
13	201200311960	69	DamagedPropertyComplaint	10/31/2012	4900 COMANCHE WYMadison, WI(43.14739132685761, -89.372112
14	201200320434	5	Battery	11/09/2012	1400 WYOMING WYMadison, WI(43.14623864659678, -89.3710496
15	201200284759	5	Battery	10/04/2012	1400 WYOMING WYMadison, WI(43.14623864659678, -89.3710496
16	201200305735	71	TrespassingComplaint	10/25/2012	4800 COMANCHE WYMadison, WI(43.14620388293618, -89.371223
17	201200322266	12	TheftfromAuto	11/11/2012	4800 SCHOOL RDMadison, WI(43.14613478808562, -89.382895236
18	201300024641	12	Theft	01/27/2013	00 CHEROKEE CIRMadison, WI(43.14568285449985, -89.363347739
19	201200330296	16	StolenBike	11/19/2012	1100 NORTHLAND DRMadison, WI(43.14516703023453, -89.377785
20	201200298741	12	Theft	10/18/2012	1600 ARKANSAS AVMadison, WI(43.1449859365204, -89.366576365
21	201200903363	12	TheftfromAuto	12/03/2012	5100 EASTPARK BLVDMadison, WI(43.14415850366021, -89.294455
22	201200902791	12	TheftfromAuto	10/01/2012	4600 BARBY RDMadison, WI(43.143964474341004, -89.3817062306
23	201200309603	5	Battery	10/28/2012	4500 JAY DRMadison, WI(43.14332194867366, -89.37928046849798
24	201200307787	12	Theft	10/27/2012	4500 TENNESSEE TRMadison, WI(43.14331498931162, -89.3736431
25	201200339364	69	DamagedPropertyComplaint	11/29/2012	4500 TENNESSEE TRMadison, WI(43.14331498931162, -89.3736431
26	201200367288	10	BurglaryResidential	12/28/2012	4200 BELLGROVE LNMadison, WI(43.143231170031456, -89.309768
27	201200300897	71	TrespassingComplaint	10/20/2012	4200 BELLGROVE LAMadison, WI(43.143231170031456, -89.309768
28	201300017596	71	Trespass	01/19/2013	4500 SCHOOL RDMadison, WI(43.142874671396065, -89.38296462(
29	201200311316	10	ResidentialBurglary	10/30/2012	4600 HAYES RDMadison, WI(43.14249671493903, -89.30553933032
30	201200295993	12	TheftfromAuto	10/15/2012	4600 HAYES RDMadison, WI(43.14249671493903, -89.30553933032
31	201200315806	3	SexualAssault1234Rape	11/04/2012	4700 HAYES RDMadison, WI(43.14210220193818, -89.30131632107

Figure 1. Excel document of calls for service within the city of Madison provided by the MPD. Source: http://www.cityofmadison.com/police/data/callsforservice.cfm

Street light data obtained from City of Madison engineers was not GIS-ready and was preserved only in static maps as pdf files. Given this restriction, we elected to manually create layers in ArcMap using the relative positions on the pdf maps. This lengthy process limited our project's scope from all of Madison to the campus and State/Langdon neighborhoods. From there, an effective radius of 50 feet per light post was chosen. Crimes that occur greater than 50 feet from a street light are considered to have been unaffected by the presence of light. These layers will be overlayed in Arc and making use of the "Near" function in ArcMap returned the distance from all crimes to their nearest streetlight (Fig. 2).

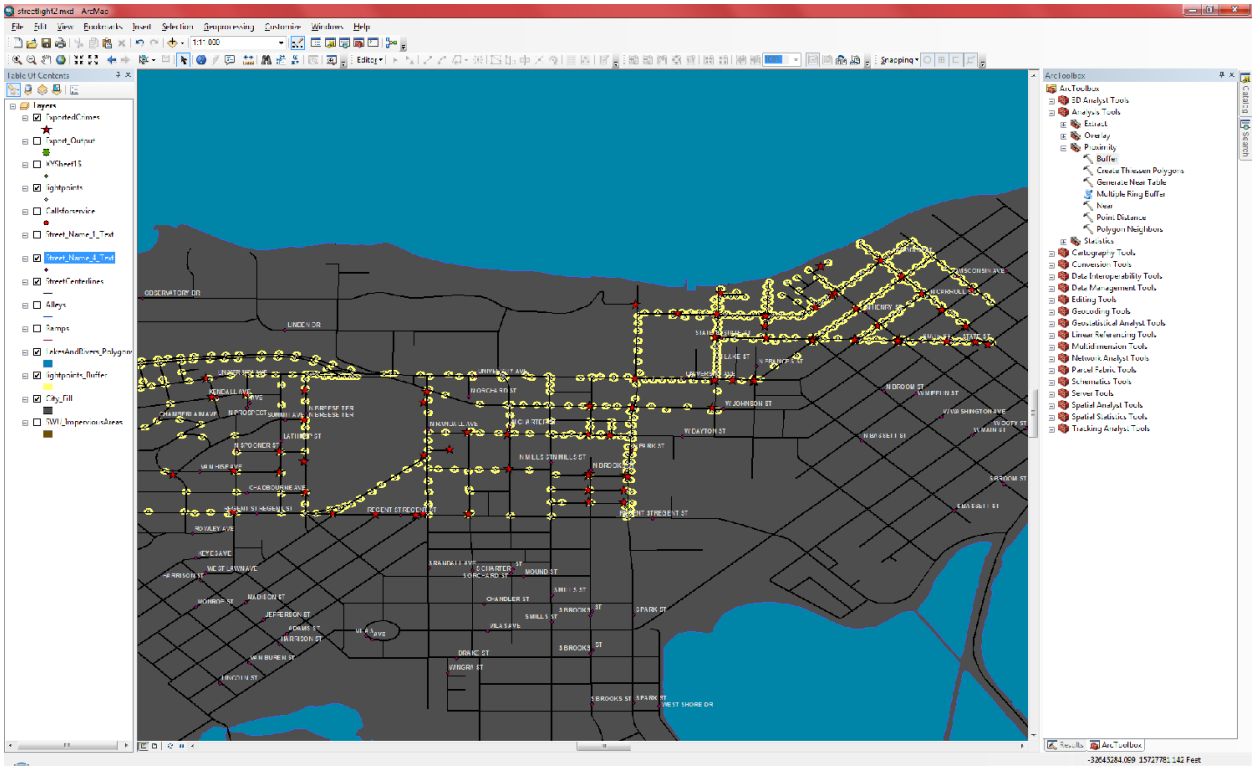
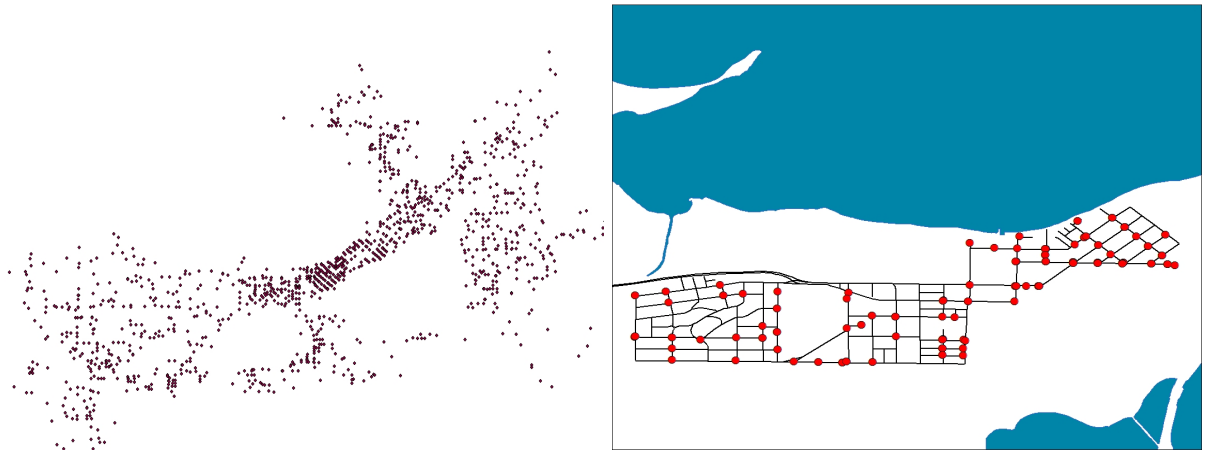


Figure 2. ArcMap screenshot showing crime shapefile overlayed with street light shapefile.

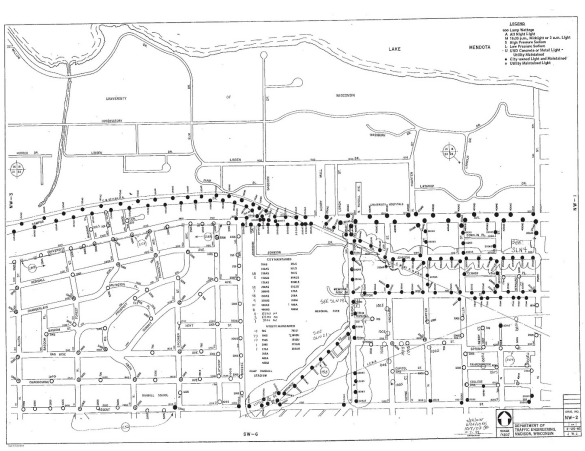
Below is a series of images taken from ArcMap and Adobe Illustrator to give a sequential and clearer idea of what was done in creation of our data layers and maps.

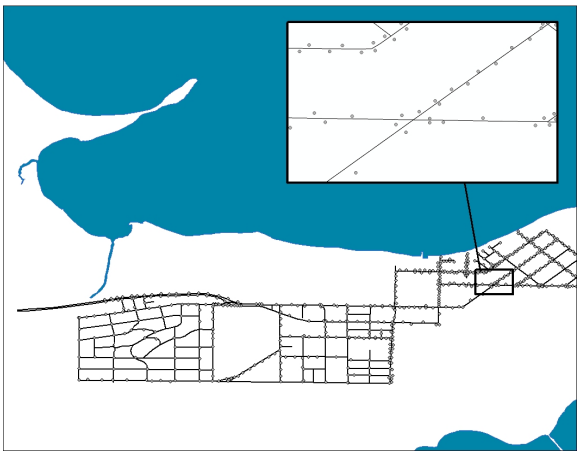
Site setting limited by availability of street light data:

Crime points georeferenced and “selected by location” of our street layer:

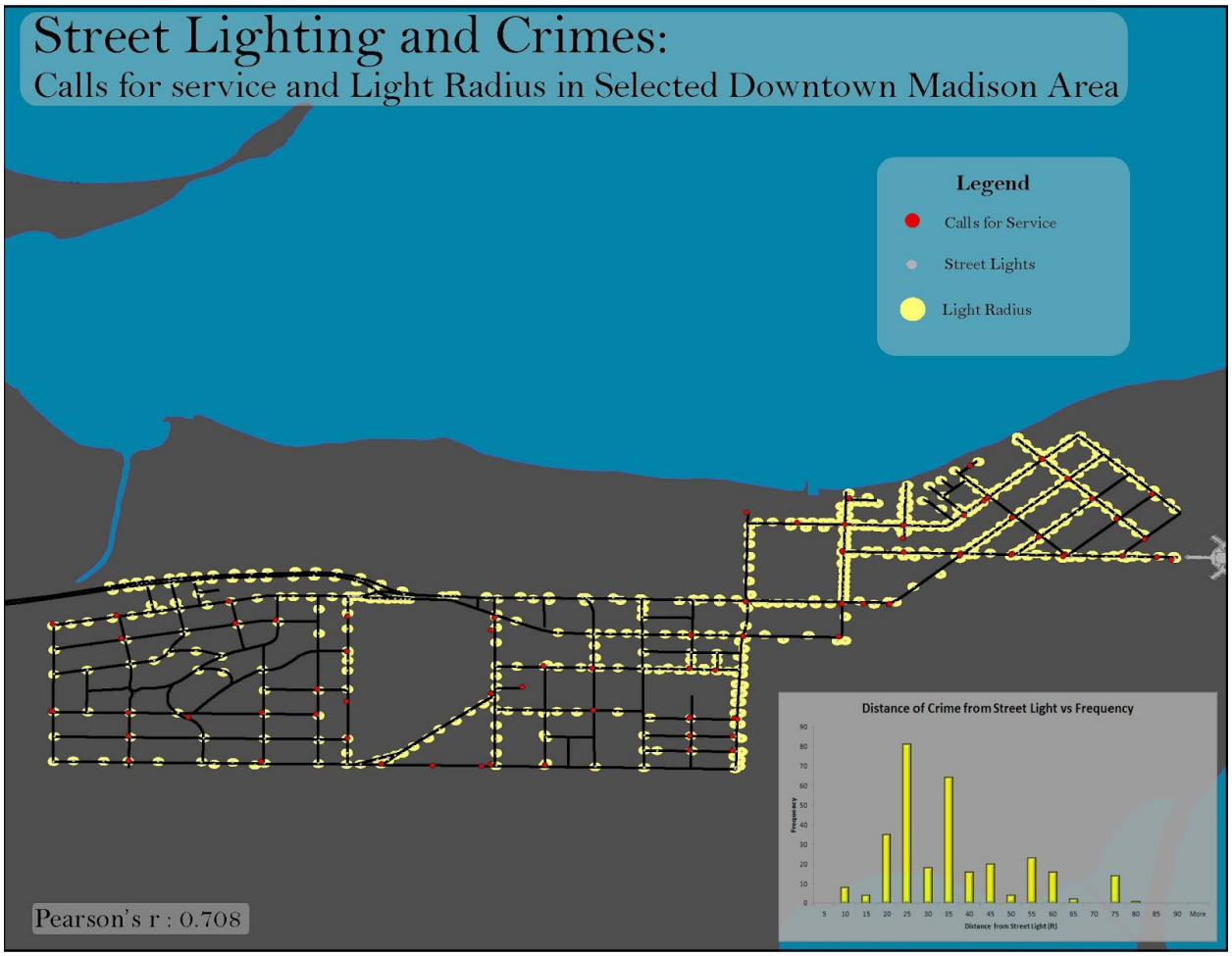


An example of a PDF map which was manually transferred to ArcMap via markers and shapefile creation:





A final product which gives a sense of how light interacts with crime in downtown Madison:



Statistical Analysis:

Our first goal with analysis was to do brief descriptive statistics. We wanted to find generally: What does crime look like spatially in Madison? Where are large and small clusters of light and crime? What type of crimes occur in which locations? What is the strength of the relationship between street lighting and crime? Figure 3 shows a histogram of crime distances from street lights. It is apparent that the majority of crimes happen between 20 and 40 feet (54%). Yet the graph also shows a left-skew, with a value of 4.2, with a noticeable amount of crimes occurring at further distances. Further analysis will show that this crime would not likely have been deterred with additional lighting.

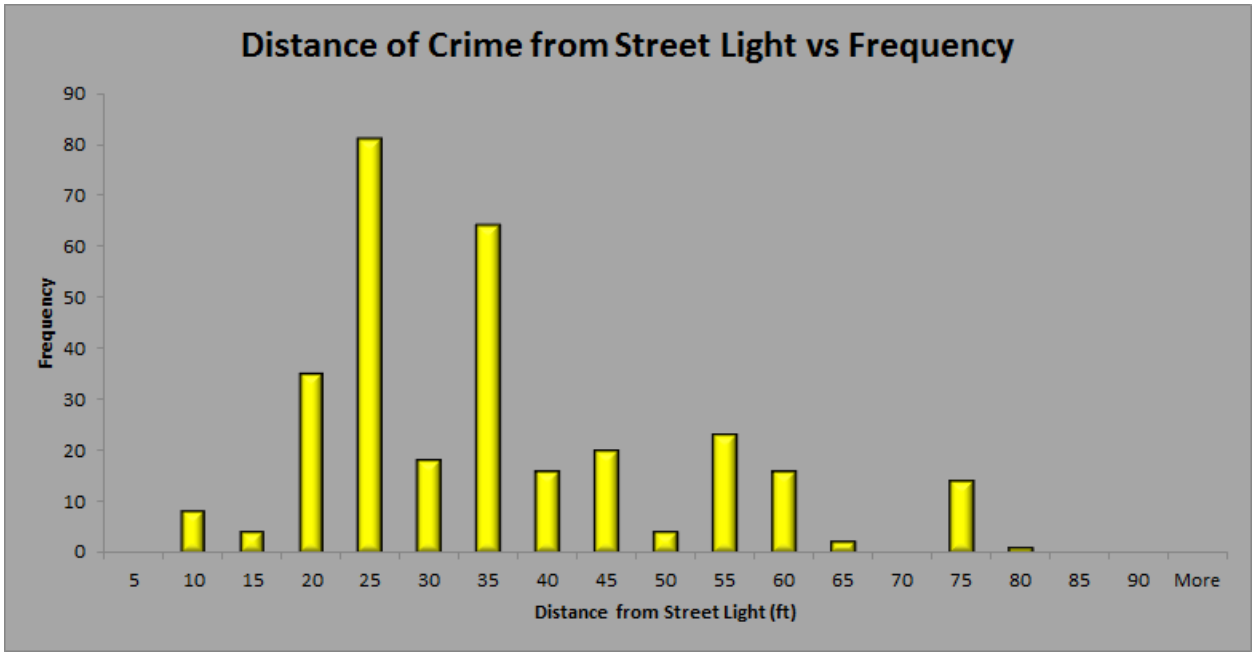


Figure 3: Histogram of crime distance from street lighting.

Although individual street lights are not distributed randomly throughout downtown Madison, the density of street lighting per unit of area varies. Aggregation of the street lighting and crime data into linear enumeration units (per 200 feet) allowed us to assess the strength of the relationship between street light density and crime density in our study area. Comparing the two densities yielded a Pearson's r value of .708- a moderately higher than expected correlation to say the least.

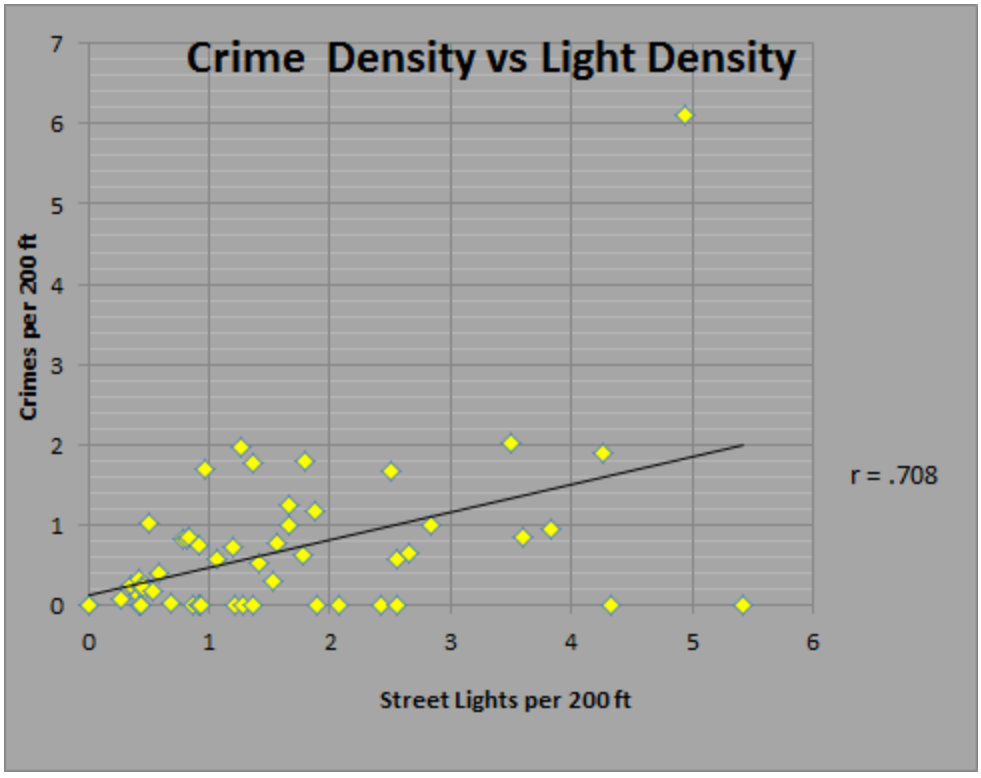


Figure 4: Scatter plot of street light density and crime density with added trendline.

Table 1 shows a breakdown of average distance to street light by crime type. Though the intent was to analyze our data on a crime-type basis, due to small sample sizes we did not feel that we would have statistically meaningful results. For this reason we recommend future researchers to implore Chi-Square goodness of fit tests to see which types of crimes can be further deterred with more street lights. This data would be invaluable in cost-savings calculations for urban planners.

Crime	Number of Crimes	Average Distance
Sexual assault	1	50.468
Armed Robbery	3	6.233352
Battery	29	9.827114
Weapon Offense	4	9.071645
Robbery Strong Armed	2	8.234
Residential Burglary	36	12.842054
Non-Residential Burglary	2	7.712796
Theft	91	10.980157
Stolen Auto	3	11.467609
Stolen Other Vehicle	1	4.290992
Stolen Bike	22	14.069921
Misc Sex Offense	1	45.818626
Aggravated Battery	9	13.010155
Person with Gun	1	56.484205
Damaged Property	46	10.137135
Trespassing	71	9.394262

Table 1: Average distance to street lighting and frequency of crimes in study area

Discussion:

A Pearson's r of .708 indicates that high density crime areas also tend to be high density light areas. Much of our premise is built around the opposite of this finding and much of our literary review disagrees with this finding as well. However, there are many possible explanations for this finding examined below.

1. Site Setting:

Our site setting was heavily limited by the data we could acquire. The final site setting is a heavy traffic area from both pedestrians and automobiles. As this area is the center of nightlife and tourism in Madison, an area filled with many bars, high-rise apartments, and concert venues, it is to be expected that the area is very bright at night to accommodate the vibrant entertainment and leisure offered in the area. It is not unreasonable to assume the sheer volume of people would lead to more crime in an area, no matter how well-lit an area is. Thus, this points to the idea of street lighting as a deterrent to crime, and not a guaranteed solution.

2. Sample Size:

Like our site setting, our sample size was much lower than we had desired because of a limitation of data availability. Our sample size for crimes of 306 incidents occurred between 2012 and 2013 while our street light sample is up-to-date. Both of these sample sizes incur certain disadvantages and difficulties.

A sample size of 306 allows for statistical analysis on an aggregated level, but once you split the sample size into individual crime types, most of the crime types are too small of sample

sizes to make any statistical claims. If a larger sample size of crimes were available, we might find that there is a great disparity between where highly violent crimes occur and where petty crimes occur. However, because of our low sample size, it is not possible to verify that idea.

Our street light sample is problematic because it does not give us a change of lighting over time. Other researchers found that with the installation of new lighting, there was a lowering of crime in that area (Wright 1973; Herbert et al. 1991). With only current street lighting data, we were unable to do a statistical analysis of change and thus were unable to make the claim that lighting deterred crime as it was added.

3. Property Crime Skew:

A look at our individual crime types will reveal that the greatest amount of our sample crimes are property crimes. Property crimes and person crimes are different by nature and should be expected to have different spatial distributions. Since property crimes by definition happen near a house, an automobile or a bicycle, it is expected that these crimes will occur near street lights and skew our results towards a positive r.

4. Light facilitating crime:

There is certainly some logic in the idea that light may facilitate certain crimes. Thieves require light to identify the object to be stolen and trespassers require light in order to access areas that are off-limits. Given that this is true, we would expect to find crimes that need light to be occurring near lighting sources. Further research could investigate the possible relationship between certain crimes and light to determine whether or not light can facilitate crimes. For now,

we offer this as a possible explanation for our high positive skew from property crimes.

5. Modifiable areal unit problem:

A final minor consideration to our correlation finding is the common problem in geography MAUP, or modifiable areal unit problem. A basic summary of this problem is as follows: different aggregation units can have an effect on the outcome of certain statistics and findings. In our case, our aggregation unit of 200 feet may have a minor effect on our correlation of .708. However, we feel this problem would only have a very miniscule sway on the overall findings as the crime points tended to be aggregated together on street intersections as result of generalization and lack of data from the police department.

Conclusion and Further Research

Though the result of our analysis differed strongly from our literature based hypothesis that crime would be less frequent in areas of more dense street lighting, we were able to qualitatively address the source of our findings. None of these suggested serious error in the methods chosen. Therefore, while this one particular site setting yielded a counterintuitive result, the procedure described offers a simple quantitative approach to better understanding the complex relationships between society and crime. Application of these methods and their data to studies with more readily available data can prove invaluable to urban developers in determining cost-benefits as well as community planners interested in the well-being of their respective residents.

As previously mentioned, higher volumes of data would allow for more comprehensive analyses of crime and street lighting. More specifically, with large enough sample sizes, additional statistics such as the Chi-Square test may be utilized to investigate which types of crimes are affected by the presence of light, if any. A higher sample of person's crime, a category of crime which we severely lacked, would be able to give a better idea of the relationship between violent crimes and light. Additionally, with street lighting data over time, it would be possible to ascertain the effect new street lights have on crime and if street lights do lower crime as they are added.

A final area of research would be to attach luminosity physics to data layers. Since there is a wealth of knowledge about the way light interacts with the physical world, it would be possible to apply light physics to layers in ArcMap and get a sense of to what extent light permeates through the city and what effect this has on color rendering and other optical phenomenon. With a more data and time, streetlight types like metal halide, sodium vapor and LED could be added to our pre-existing layers and the buffers could be modified to better fit their real life luminosity properties. Concepts like lighting efficiency and cost could be examined against their benefits to crime reduction. This further research, in addition to our project's groundwork, would provide statistical descriptions and quantifiable truths to the fundamental problem of crime that plagues all human societies.

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