Case Study Analysis for the Strategic Implementation of Smart Street Lighting in the Linden Neighborhood of Columbus, Ohio

Photo courtesy of Smart Columbus, 2016

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EXECUTIVE SUMMARY

As part of the Smart Cities grant, the City of Columbus is exploring the prospect of implementing a smart street lighting pilot project in the Linden neighborhood. Smart street lighting infrastructure has the ability to save energy through LED bulbs, add utility to neighborhoods through selected technological add-ons, and provide a way for lights to communicate through a centralized control system. At minimum, the smart street lights implemented in Linden would be outfitted with LED bulbs but would also have the capacity to add other capabilities such as 5G technology, security features, air quality monitors, electric vehicle charging infrastructure and more.

To help the City plan and complete this project with maximum efficiency, we examined several case studies. We identified industry leaders in smart street lighting technology and researched capabilities of this technology beyond LED lights. After careful consideration, we selected Detroit, Michigan; Los Angeles, California; San Diego, California; and San Francisco, California as our model cities. In addition to our case study research, we also studied Linden's demographics and amenities, as benefitting the community was an extremely important aspect of the project.

We found that each of our model cities gave us extensive insight to different aspects of the proposed Columbus project. These cities have experiential information on LED implementation in low-income neighborhoods (Detroit), the feasibility of public Wi-Fi (Los Angeles), community feedback measures (San Diego), and central management systems (San Francisco). From these data points, our team was able to make strategic recommendations that will assist the City of Columbus as it moves forward with the Linden smart street lighting project. Involving the Linden community in decision-making, including central management

system technology, and working with reliable vendors like General Electric (GE) are all-encompassing recommendations that best summarize the findings of our research. Overall, we believe the City of Columbus has an opportunity to be a change agent, and if carried out successfully, this pilot project could be a national example of community development and smart street lighting partnerships.

INTRODUCTION

For our capstone project, our main objective was to conduct a case study analysis on smart street lighting technology in order to make strategic recommendations for a pilot project in Columbus's Linden neighborhood. Our research goals were the following:

1) Identify and analyze several smart street lighting case studies

a. Identify industry leaders in smart street lighting technology

b. Research capabilities of smart street lighting systems beyond LED lights

2) Understand the needs of the Linden community

The implementation of smart street lighting would fulfill a number of Smart City goals by providing safer streets for Linden residents, as well as improving Columbus's technology infrastructure through installing self-communicating lights.

During our initial research, we found four cities to be most relevant to the Linden pilot project. These cities offered information regarding the planning phases, budgeting, implementation phases, energy savings, and other valuable data. We believe the following recommendations will help make this pilot project successful: (1) work with a reliable vendor, (2) make all lights "smart-ready," (3) explore a partnership with AT&T for 5G technology (based on their preliminary meetings with the City), (4) include a central management system (CMS), and (5) gather community input.

The majority of our case studies capture smart street lighting projects in affluent commercial districts of West Coast cities, but the Linden neighborhood is a low-income residential area in the Midwest. These disparities do not mean that these case studies are not applicable. Instead, it means that understanding the unique culture, needs, and assets of Linden will be pivotal to the success of the project.

METHODS

We began our project by meeting with James Gross and Kristian Fenner from the City of Columbus Division of Power in late January where we learned the City's main goal for the project was LED implementation and potential technological add-ons (Gross & Fenner, personal communication, January 27, 2017). We then attended the community meeting in the Linden neighborhood in February to speak directly with Linden residents and Smart City officials to get their input. Once we had baseline information from Columbus officials and guiding principles from Linden residents, we began researching our chosen cities and gathering public reports. We spoke to street lighting staff members from each city over the month of March. These conference calls gave us personal accounts of the planning and implementation processes as well as feedback on what worked well and what did not. These interviews provided the best data for the project since they gave a comprehensive view of the project, as opposed to what the cities chose to be transparent about in their public reports.

Throughout the research stage, we strove to obtain information on the following topics from each city: background and planning phases, smart capabilities implemented, any partnerships created, resulting implementation process, community feedback, positive and/or negative project impacts, and related takeaways for the Linden pilot project. We also collected information on budgeting and greenhouse gas emission reductions for each city.

We reviewed our data, created recommendations, and assessed feasibility of specific innovations based on Linden's wants and needs. Not all project aspects of our researched cities were in fact feasible, and not everything was something that we felt was beneficial for the Linden pilot.

RESULTS

Linden Community Needs

The neighborhoods of North and South Linden cover a total area of 5.93 square miles, are populated by 36,000 people (City-Data, 2017), and enjoy "rich racial, ethnic and socioeconomic diversity" (Momenee, 2016). With Hudson Street as the dividing boundary, South Linden is much smaller with almost twice the rate of poverty—North Linden with 26.1% of the population below the poverty level and South Linden with 42.2% of the population below the poverty level (City-Data, 2017). In the 2015 St. Stephen's Community House Canvass Report, it was reported that crime, safety and transportation are residents' biggest concerns (Momenee, 2016).

Members of our team attended the "Smart Columbus Connects Linden" community meeting. Community input gathered here showed that residents had mixed feedback regarding Wi-Fi implementation through street lighting (Smart Columbus, 2017). The City of Columbus has already partnered with Neighborhood Design Center to continue collecting data and community input and plans to create a Linden Master Plan (L. Snyder, personal communication, March 9, 2017).

Case Study Analysis

Table 1: Summary of Case Study Key Characteristics

City	Los Angeles, California	Detroit, Michigan	San Diego, California	San Francisco, California
LED Conversion	x	x	x	x
Public Wifi provided through street lights				
Has remote monitoring system or equivalent	x		x	x*
Gunshot detection			x	
EV charging stations	x			
Public input collected before implementation	x	x	x	x
Negative feedback from residents was not a major problem	x	x	x	x
Experienced cost savings through LED conversion	x	x	x	x
Experienced GHG emissions reductions through LED conversion	x	x	x	x**
Crime/safety has noticeably improved	x	x		

Data Source: See Dataset #1 in Appendix D
**San Francisco did an extensive pilot of their central control system, but did not end up moving forward with the technology after the pilot.*
***San Francisco did experience energy savings through LED conversion, but because 100% of the City's energy comes from renewable sources, it is not possible for carbon emissions to be reduced.*

Table 1 provides a brief overview of each case study city and the general characteristics of each project. As can be seen in the table, all four cities went through an LED conversion. Additionally, all four cities collected public input before the project, and none of them had major issues with negative public feedback. All cities also experienced cost savings and most experienced greenhouse gas emissions (GHG) reductions from LED conversion. Los Angeles, San Diego, and San Francisco all implemented some form of central control system; San Diego implemented gunshot detection. Los Angeles was the only city to implement electrical vehicle (EV) charging stations on its street lights. In Detroit and Los Angeles, crime and safety noticeably improved after LED conversion. Notably, none of the cities implemented public Wi-Fi through street lights.

Detroit, Michigan

Introduction to Project

Detroit, Michigan is a strong case study to analyze as its proximity and city attributes most closely match those of Columbus, Ohio. Only 207 miles away, this is the only case study from the Midwest (due to overall lack of smart lighting infrastructure in this region) (Google Maps, 2017). Detroit previously faced issues with both theft and broken infrastructure, which brought about the decision to begin the processes of upgrading street lights (Public Lighting Authority, 2015). The Public Lighting Authority has a clear mission to "improve, modernize, and maintain all street lights in the City of Detroit with brighter, more reliable, more energy-efficient lights" (Public Lighting Authority, 2015). The project began in the Summer 2013 with surveying neighborhoods to determine the status of the City's lights, specifically the lights that needed to be replaced (B. Berg, personal communication, March 17, 2017). The project came in $2 million under budget for a total project cost of $183 million (B. Berg, personal communication, March 17, 2017).

Smart Capabilities Implemented

A few smart capabilities were installed in the new and improved lighting system in Detroit. The first upgrade was a new circuit system that involves a multiple series circuit, which allows all of the lights to stay on even if one goes out (Public Lighting Authority, 2015). LED bulbs were another upgrade from the high-pressure sodium lights that were previously used, providing double the light and higher energy efficiency, leading to monetary savings (Public Lighting Authority, 2015).

Partnerships

According to the partners listed by the Public Lighting Authority, there were dozens of smaller contributors to this project in terms of engineering, marketing, and installation. The Public Lighting Authority also used bonds sold by the Michigan Finance Authority (Public Lighting Authority, 2015). These bonds allowed for an additional 10,000 street lights to be installed, creating more spending opportunities for Detroit (Public Lighting Authority, 2015).

Implementation Process

The project was installed in various phases, including a preliminary pilot and a downtown portion (Public Lighting Authority, 2015). The process began after many years of having infrastructure issues with the City's lighting system, including broken bulbs and stolen copper wires (Public Lighting Authority, 2015). The first lights were installed in February 2014 in a pilot project located on the east and northwest sides of the City (Public Lighting Authority, 2015). Detroit's pilot project took about two years to implement all 59,000 LED lights (B. Berg, personal communication, March 17, 2017). Due to the success of the pilots, LED lights were installed downtown in 2015 for a total of 65,000 lights throughout Greater Detroit (B. Berg, personal communication, March 17, 2017).

Community Feedback

Community input was gathered toward the end of the project regarding safety in the City and reception to the lights (Public Lighting Authority, 2015). Many people responded that safety has increased; business revenues after 5:00 PM alone have gone up 15% since the LED retrofit (B. Berg, personal communication, March 17, 2017).

Feedback also noted that some historic neighborhoods want light poles that better fit the community's aesthetic and style, and the City has agreed to install these light poles if the neighborhoods pay the difference (Public Lighting Authority, 2015). By making this compromise, the neighborhoods get the benefits of efficient lighting, while also maintaining their original charm and character.

Positive Impacts from Project

By replacing the lights in Detroit with LEDs, there have been many positive impacts throughout the City. Detroit has used aluminum wiring instead of copper, which used to be stolen and resold (B. Berg, personal communication, March 17, 2017). Because of the LEDs, carbon emissions decreased by 40,000 tons (36,287.39 metric tons) a year, which is the equivalent of taking 11,000 cars off the road (Kimmelman, 2017). Additionally, the LEDs save the City about $2.5 million per year in electric bills (B. Berg, personal communication, March 17, 2017). As stated previously, there has also been a 15% increase in business revenues after 5:00 PM.

Social benefits have been a large byproduct of this citywide upgrade. About 5,400 lights have been installed near school routes, which enforces safety for children walking to and from school both in the early morning and in the evening (Public Lighting Authority, 2015).

Table 2: Detroit Estimated Benefit Transfer

	Detroit	Columbus (per unit)
Estimated cost of project	$183,000,000 (65,000 fixtures)	$2,815.38
Annual energy savings ($)	$2,500,000 (65,000 fixtures)	$38.46
Annual carbon emissions reductions	36,287.39 metric tons (65,000 fixtures)	.55827 metric tons

Columbus per unit numbers were calculated by dividing estimated cost of project, annual energy savings, and annual carbon emissions reductions by the number of light fixtures associated with each value. The per unit numbers can be multiplied by the number of lights in the Linden pilot (once determined) to get the total benefit transfer (Data sources: See Dataset #2 in Appendix D)

Table 2 displays some benefits of the Public Lighting Authority's project in Detroit that may be transferrable to Columbus. Based on Detroit's project cost of $183 million, the per-unit cost Columbus could incur would be $2,815.38 per fixture (B. Berg, personal communication, March 17, 2017). The price per unit in Detroit includes a new pole as well as the light bulb, which explains the high cost as compared to the following case study cities (B. Berg, personal communication, March 17, 2017). One conversion factor to be aware of is the annual carbon emissions reductions data reported in tons has been converted to metric tons.

The overall cost is something to consider when looking at the implementation of the project in Detroit versus planning a project for Columbus. Not only did Detroit install LEDs, it also installed new standard light poles around the City. If Columbus is only looking to retrofit the lights, its project would not be as expensive as Detroit's due to the presence of the existing infrastructure. Based on Detroit's energy cost and emission savings, Columbus could potentially save around $38.46 per fixture per year in energy costs and reduce carbon emissions by .55827 metric tons per fixture per year.

Main Takeaways for Linden

The main takeaways from Detroit's project are improved neighborhood safety and financial savings. Linden faces similar issues to Detroit, and has the same opportunities as the case study to improve business and social bases after dark (Kimmelman, 2017).

Likewise, Detroit saves about $2.5 million annually in energy costs by using the highly efficient LED bulbs (B. Berg, personal communication, March 17, 2017). Linden and Greater Columbus could reap similar savings by installing LED technology.

Los Angeles, California

Introduction to Project

The City of Los Angeles started its smart street lighting initiatives with an LED replacement program. The City planned to retrofit 140,000 of Los Angeles's over 209,000 fixtures, making it the largest LED retrofit project of its time (Clinton Climate Initiative, 2009). The project began in July 2009 and was estimated to last five years and cost $57 million (Clinton Climate Initiative, 2009). The City's old high-pressure sodium cobrahead fixtures were to be replaced with LED fixtures, and a remote monitoring system was to be implemented (Clinton Climate Initiative, 2009).

Smart Capabilities Implemented

Los Angeles implemented a "soft light" which is about 4,000 Kelvin and characterized as "the color temperature of the moon" (E. Ebrahimian, personal communication, March 7, 2017). In addition to its LED retrofit, Los Angeles went a step further by implementing remote monitoring nodes, EV charging stations, solar panels that feed into the electric grid, Gas Company Smart Meter communication, and security cameras on a select number of fixtures (City of Los Angeles, 2017b). The City has also created an "LA Lights" app where citizens can report problems from their smartphone (City of Los Angeles, 2017b). In addition, it implemented SmartPole street lights, which not only have LED technology, but also 4G LTE wireless technology (City of Los Angeles, 2017b). These poles help improve cell phone coverage in the Los Angeles area through small cell technology (Maddox, 2016). They also help increase revenues for the City because the installation of each pole is paid for by the cell phone carrier who then pays the City $1,000 annually to lease it (Maddox, 2016).

Currently, Los Angeles is not exploring implementing Wi-Fi through street lights (E. Ebrahimian, personal communication, March 7, 2017). Ed Ebrahimian, the director of the Los Angeles Bureau of Street Lighting, believes Wi-Fi works well in smaller, localized areas but is skeptical about Wi-Fi being implemented citywide through street lights (E. Ebrahimian, personal communication, March 7, 2017).

Partnerships

One thing that sets Los Angeles apart from other case study cities is that the City did not partner with any business for its LED replacement project. At the time Los Angeles began its LED replacement program, the technology was so new that the City did not want to partner with a single business, ensuring it would always get the best technology at the best price and stay on the forefront of the new technology (E. Ebrahimian, personal communication, March 7, 2017).

Implementation Process

The timeline for this project was five years (Clinton Climate Initiative, 2009). Los Angeles first identified potential manufacturers of LED street light fixtures and invited them to send four fixtures to the City for testing (Clinton Climate Initiative, 2009). The testing occurred on residential streets and not only focused on performance of the lights, but also on gathering feedback from residents through surveys (Clinton Climate Initiative, 2009). Based on the tests, the City planned to select the best option for the first stage of installation (Clinton Climate Initiative, 2009). After a few months, they planned to re-evaluate to ensure they were getting the best technology for the next phase of installation (Clinton Climate Initiative, 2009). The City planned to retrofit 20,000 fixtures in the first year and 30,000 in each of the four following years (Clinton Climate Initiative, 2009).

Community Feedback

Ed Ebrahimian, the Director of the Los Angeles Bureau of Street Lighting stated, "Angelinos have embraced the new white LED Light" (City of Los Angeles, 2017a). Additionally, he noted that the City has received close to 50 calls relating to the LED lights (E. Ebrahimian, personal communication, March 7, 2017). Most of these calls were because light was reaching into residences, and this issue was resolved quickly by the City (E. Ebrahimian, personal communication, March 7, 2017).

Positive Impacts from Project

As of January 10, 2017, the City had installed 173,634 LED fixtures, experienced 63.7% energy savings, reduced carbon dioxide emissions by 62,000 metric tons annually, and experienced $9,320,159 in annual energy savings (City of Los Angeles Department of Public Works Bureau of Street Lighting, 2017). Additionally, the City stated, "This proposal has generated savings in energy and maintenance costs that will pay for the estimated loan amount in seven years with no adverse impact to the General Fund" (City of Los Angeles, 2017a). Regarding social benefits, Ed Ebrahimian reported that residents have said the white light makes them feel safer (City of Los Angeles Bureau of Street Lighting, 2014). Additionally, from 2009 to 2011, night crime (7 p.m. to 7 a.m.) decreased by 10.5% (City of Los Angeles Bureau of Street Lighting, 2014). Ed Ebrahimian noted that the police department has played a major role in safety but that the role of lighting also cannot be denied (City of Los Angeles Bureau of Street Lighting, 2014).

Table 3: Los Angeles Estimated Benefit Transfer

	Los Angeles	Columbus (per unit)
Estimated cost of project	$57,000,000 (140,000 fixtures)	$407.14
Annual energy savings ($)	$9,320,159 (173,634 fixtures)	$53.68
Annual carbon emissions reductions	62,000 metric tons (173,634 fixtures)	.35707 metric tons

Columbus per unit numbers were calculated by dividing estimated cost of project, annual energy savings, and annual carbon emissions reductions by the number of light fixtures associated with each value. The per unit numbers can be multiplied by the number of lights in the Linden pilot (once determined) to get the total benefit transfer (Data source: See Dataset #3 in Appendix D)

Table 3 shows how some of the benefits of Los Angeles's LED conversion might transfer to Columbus. Based on Los Angeles's project cost of $57 million (Clinton Climate Initiative, 2009), the per unit cost Columbus could incur would be $407.14 per fixture. There are a few aspects about the estimated cost that might be different in Columbus. First, this cost includes not only LED conversion of 140,000 lights but also the implementation of a remote monitoring system. Second, because Los Angeles began its LED replacement in 2009, costs of LED technology have likely decreased since then. Third, the per unit cost from the Los Angeles case study is much lower than that of the San Diego and Detroit case studies. There are two main reasons this might be the case. First, the Los Angeles cost only included LED conversion and implementation of a remote monitoring system, whereas Detroit replaced a large amount of street lighting infrastructure and San Diego implemented several smart capabilities. Second, Los Angeles' project was much larger than the other two projects, which likely led to decreased per unit costs. Based on Los Angeles's annual energy savings and carbon emissions reductions, the City of Columbus could potentially experience energy savings of $53.68 and carbon emissions reductions of .35707 metric tons per fixture per year.

Main Takeaways for Linden

A key takeaway from Los Angeles's project is that the City had little negative feedback. This is likely because the City put significant effort into gathering community input beforehand. This will be important in Linden to ensure that residents are satisfied with the quality of lighting.

Smart Pole technology is interesting to consider, but it is dependent on residents having smartphones with data plans. More information about data plans and smartphone usage in Linden would need to be collected to assess whether this technology would be beneficial to residents. Regarding implementation of Wi-Fi through street lights, it may not make sense to invest in providing free public Wi-Fi now considering the current shift toward cell phone technology.

San Diego, California

Introduction to Project

San Diego began the implementation process for smart street lighting in 2013. Partnering with GE early on, the City worked with the company to design and install custom-designed decorative LED lights that came with adaptive controls and could be later fitted with sensors (L. Cosio-Azar, personal communication, March 2, 2017). With an iterative piloting process, the City systematically gathered community feedback along the way and tested its options. Moving from a 40-fixture pilot to a 3,600-fixture pilot in three years, San Diego is now preparing for a 14,000-fixture pilot that will be deployed citywide (L. Cosio-Azar, personal communication, March 2, 2017). This pilot includes 3,200 smart sensors to collect data for parking optimization, traffic safety, and environmental monitoring (L. Cosio-Azar, personal communication, March 2, 2017). Data from the sensors could be used by software developers and first responders during emergencies. The City continues to receive positive feedback from community members and has seen significant cost and energy savings, according to Lorie Cosio-Azar, Program Manager for City of San Diego Environmental Services Department (L. Cosio-Azar, personal communication, March 2, 2017).

Smart Capabilities Implemented

The adaptive control system (a node on top of the light) serves as an inventory management tool with a live map showing maintenance needs for each fixture. This also controls dimming levels and schedules (manually/automatically) and will eventually allow for a metered rate with the local utility, San Diego Gas & Electricity (L. Cosio-Azar, personal communication, March 2, 2017).

The smart sensors are equipped with cameras (without facial recognition), microphones, and “internet of things” connectivity through AT&T at the data carrier, offering a highly secure network (Dent, 2017). Their capabilities include monitoring air quality, weather alerts, tracking carbon emissions, gunshot detection, monitoring traffic/identifying intersections to improve pedestrian and cyclist safety, and directing first responders during emergencies. San Diego chose not to implement public Wi-Fi simply because when community input was gathered at different stages of piloting, there was no real demand for this capability (L. Cosio-Azar, personal communication, March 2, 2017).

Partnerships

Early on in the piloting, San Diego partnered with General Electric (GE). The City chose GE for the company’s reliability and because they had partnered on previous projects. The company was willing to be flexible and customize decorative fixtures, designing sensor nodes to look aesthetically pleasing and offer 360 degree views. Cosio-Azar stated that GE was “willing to appear to be a small company in a large body, and that was critical for us, because you can’t do this innovative work if you’re not able to think progressively” (L. Cosio-Azar, personal communication, March 2, 2017). For the smart sensors, San Diego has partnered with AT&T to be the data carrier (Dent, 2017).

In order for us to review GE’s technology further and opportunities for Linden, Lorie set our team up with Steve West, a GE contact based in Ohio. We spoke with Steve on a conference call, along with Jamie Sullivan, a representative from AT&T, where we learned that public Wi-Fi might not be optimal in Linden based on the growing popularity of smartphone technology (Sullivan & West, personal communication, April 7, 2017). AT&T is looking to implement 5G data streaming throughout the Linden neighborhood, a current step up from the nationwide 4G

LTE systems (Sullivan & West, personal communication, April 7, 2017). AT&T is also working with GE to implement First Net, a public safety broadband network (Sullivan & West, personal communication, April 7, 2017).

Implementation Process

San Diego began a three-year piloting process for LED lights and adaptive controls in 2013. In the first year, six manufacturers were tested, as well as different LED light temperatures (L. Cosio-Azar, personal communication, March 2, 2017). The City made strong efforts to gather community input about the "look" and "feel" of these lights through public surveys, work groups, and even interactive block parties. Input was gathered before, during, and after each new pilot (L. Cosio-Azar, personal communication, March 2, 2017). Adaptive controls were then tested for six months with a 40-fixture pilot downtown, where the City found that they reduced maintenance costs. After deployment of 3,600 LED street lights downtown with adaptive controls, testing began in Autumn 2015 for sensors for parking infrastructure assistance. (L. Cosio-Azar, personal communication, March 2, 2017).

The next step in the implementation process is to deploy 14,000 more LED fixtures citywide. These lights will mostly be downtown but will include residential areas downtown and elsewhere (L. Cosio-Azar, personal communication, March 2, 2017). Out of these 14,000 fixtures, only 3,200 will have sensors. These sensors will be put in areas of high crime, according to a map from the chief of police, in order to gather data. (L. Cosio-Azar, personal communication, March 2, 2017).

Community Feedback

San Diego was thorough and systematic about gathering community input throughout piloting and testing processes. It formulated working groups that were a part of planning throughout the project. The City also organized town hall meetings to collect information and asked for feedback on its website and public forum (L. Cosio-Azar, personal communication, March 2, 2017). It was stressed that outreach was needed to each and every community in which the pilot would be deployed. For even further interactive outreach, San Diego also organized a street light block party downtown for community members to see the new lights and write ideas and feedback on a giant board. “This was before social media was as popular,” said Cosio-Azar, “so you could utilize that a lot more now—that would be a great tool,” (L. Cosio-Azar, personal communication, March 2, 2017).

After its 3,600-fixture pilot, the City only received nine requests to dim down the lights—only in residential areas where residents preferred to not shut their blinds at night or where there were observatories (L. Cosio-Azar, personal communication, March 2, 2017). San Diego is anticipating feedback from residents about the sensors related to concerns about privacy or being watched. Its plan is to mitigate the messaging and be clear about the technology (no facial recognition, no streaming, just metadata saved for 7 days on an analytical platform) (L. Cosio-Azar, personal communication, March 2, 2017).

Table 4: San Diego Estimated Benefit Transfer

	San Diego	Columbus (per unit)
Estimated cost of project	$30,000,000 (14,000 fixtures)	$2,142.86
Annual energy savings ($)	$2,400,000 (14,000 fixtures)	$171.43
Annual carbon emissions reductions	3261.7 tons (14,000 fixtures)	.23298 tons

Columbus per unit numbers were calculated by dividing estimated cost of project, annual energy savings, and annual carbon emissions reductions by the number of light fixtures associated with each value. The per unit numbers can be multiplied by the number of lights in the Linden pilot (once determined) to get the total benefit transfer (Data source: see Dataset #4 in Appendix D)

Table 4 shows how the costs and benefits of San Diego’s next deployment of 14,000 LED lights with 3,2000 sensors could transfer to the Linden pilot in Columbus. San Diego shows significantly higher energy savings than other cities; this is due to the higher cost of energy in the region (L. Cosio-Azar, personal communication, March 2, 2017). Data for annual carbon emissions reductions from this interview were given in megawatt hour units (11,600 mwh). Using a conversion rate of 619.9 pounds of carbon emissions per mwh from the U.S. EPA (United States Environmental Protection Agency, January 13, 2017), this data was converted to pounds and then tons of carbon emissions.

Main Takeaways for Linden

With the concerns for crime and safety in the Linden neighborhood, San Diego's smart street lights confirm that police and residents feel safer with the brightness and improved visibility of LED light (L. Cosio-Azar, personal communication, March 2, 2017). If the Linden pilot were to include sensors with either gunshot detection or cameras, it would be similarly important for the City to be clear in its messaging about these capabilities so that residents feel protected and not under surveillance.

Probably the most significant takeaway is the importance of community outreach and engagement. This was a major strength in San Diego's project, and the results were extremely low rates of complaints or pushback on the project, which was instead greeted with wide community support and excitement.

San Francisco, California

Introduction to Project

In 2013, the City of San Francisco underwent a five-month pilot project to evaluate three wireless monitoring and control systems from three different companies. The companies that participated in the project were InesoCompany (France), Lumewave (United States), and Telensa (United Kingdom) (Young et al., 2014). The control systems were utilized in three different locations around the City. Throughout the pilot, the San Francisco Public Utilities Commission (SFPUC) examined the features, the specific installation and commissioning process, and the usage of a dimming schedule as well motion sensors for each individual system (Young et al., 2014). Lastly, SFPUC collected vital residential feedback during the project regarding the effectiveness and quality of the LED lighting.

Smart Capabilities Implemented

San Francisco was an anomaly when compared to our other case studies because unlike the other cities, San Francisco has not implemented any smart capabilities for its street lights. The reason for this is the functionality of this technology. SFPUC Project Manager Mary Tienken stated that "the technology was still developing; in the future there would be greater functionality (for these control systems), and no product could successfully accomplish more than one task reliably," (M. Tienken, personal communication, March 7, 2017). Implementing this new technology is a big investment for a city, so being able to determine the right company to partner with can be arduous. By executing a pilot, San Francisco was able to identify numerous characteristics that needed review before beginning the implementation process.

However, even though the City hasn't taken steps to implement smart capabilities, it has made a concentrated effort in transitioning from older street lights to the LED retrofits in the last decade. According to Mary Tienken, "about five or six years ago there were small replacements made around the City, but in the past two years there has been approximately 1,800 retrofits" (M. Tienken, personal communication, March 7, 2017).

Partnerships

San Francisco has not deployed new street light technology other than LED retrofits. After the pilot project, Mary Tienken of SFPUC reported that the "U.K. company that participated in the pilot had a very reliable product, but the reason they did not implement Telensa's system was due to the market being relatively new and the lack of experience the company had on large-scale projects" (M. Tienken, personal communication, March 7, 2017).

Implementation Process

During the summer of 2012, San Francisco issued a Request for Proposals to determine vendors for its pilot project. The City chose eight vendors to participate, but due to various complications, only three vendors ended up taking part in the project (Young et al., 2014). In terms of installation and startup, SFPUC line workers were in charge of installing the controls for all three participant systems. The City then evaluated each vendor on the ease of installation for the fixtures, nodes, and motion sensors (Young et al., 2014).

Community Feedback

During the pilot, the SFPUC gathered community input from an online public survey as well as live demonstrations that took place during two months of the five-month pilot project. The feedback acquired was focused on "the perception of LED luminaires as well as the adaptive lighting" (Young et al., 2014). Since the adaptive lighting capability allows the LEDs to produce an output of 100% and 50%, the SFPUC compared the results of community input for both illumination settings (Young et al., 2014). The most noteworthy feedback was that the majority of people felt that the dimmed lights were just as effective as the light illuminated at full output (Young et al., 2014). The only areas of concern that correlated to the dimmed lighting was a decrease in satisfaction when it came to light quality. There was no conclusive evidence regarding why there was a decrease in satisfaction but when compared to the full output lighting, the community favored the LEDs at full output (Young et al., 2014). Additional public feedback results can be viewed in Appendix B.

Positive Impacts from Project

San Francisco and the SFPUC gained a great deal of information from completing the pilot. Focusing on a specific smart capability was extremely advantageous because the City was able to intensely evaluate a few systems, which not only helped pinpoint the best system for San Francisco, but it also gives other cities insight into determining which central management system (CMS) products to adopt. The majority of systems used in this project exemplified vigorous communications networks, the feasibility for large-scale implementation in city areas, and the ability to execute simple commands, which added increased value to the overall functionality. Furthermore to these abilities, “Telensa and Lumewave systems demonstrated the ability to successfully diagnose asset errors and failures, which can be extremely vital to the maintenance team and cutting costs for this area” (Young et al., 2014).

Monetary savings from this project came mostly from the dimming schedule and the motion sensors that were activated once the systems proved to successfully utilize the advanced lighting schedules. The dimming schedule allowed fixtures to reduce their output during hours when 100% illumination wasn’t needed. According to the SFPUC, “Applying this schedule yielded energy savings of approximately 25%, and if more aggressive scheduling was set for the street lights, the achievable savings would increase” (Young et al., 2014) (see Table 5 in Appendix C).

When the motion sensors were enabled to increase light output based on pedestrian and vehicular activity, the energy savings actually decreased due to the intensive need for energy. Figure 1 in Appendix C shows a visualization of the energy savings when comparing the scheduled dimming and sensor dimming adaptive lighting strategies.

In terms of energy reductions and the minimization of greenhouse gasses, the San Francisco pilot wasn't the best representation of this benefit. Impressively enough, San Francisco "generates 100% of their energy from renewable resources such as hydro, solar and wind" (M. Tienken, personal communication, March 07, 2017). As stated before, energy savings for the pilot were derived from the dimming schedule and motion sensor capabilities. These savings varied depending on which capability or capabilities were being used.

Main Takeaways for Linden

It is important for the City of Columbus to analyze the past experience of each possible vendor, as well as their strengths and weaknesses, in order to implement a successful project in Linden. Furthermore, it is important to determine how resilient the vendor and their system is in case the technology fails. In general, a CMS is a vital addition to LED streetlight installations. The abilities that come along with a CMS ensure improvements in lighting systems as well as decreasing operational costs over time. Implementing a dimming schedule to control the ability of adaptive lighting was the best tool for San Francisco in terms of increasing energy savings.

MAIN TAKEAWAYS

After we completed our conference calls and collected data, we shared thoughts of some of the main takeaways from our case studies. First and foremost, this project will require a significant investment from the City of Columbus based on the cost projections from other case studies. Second, we learned that most people involved with smart street lighting projects were relatively skeptical when it came to implementing public Wi-Fi through the infrastructure. This was something that seemed prevalent from the beginning of our research. As such, we factored this into our recommendations.

RECOMMENDATIONS

Work with a reliable vendor

We believe working with a reliable vendor who has extensive experience in smart street lighting technologies would be the best use of Columbus's Smart City grant. We have found that GE has been a great partner for the City of San Diego as it was committed to customizing the project to San Diego's needs.

Make sure all lights are "smart-ready"

There are a plethora of options for smart street lighting additions, but we believe that focusing on a few that would most benefit the Linden community would be the smartest approach. Specifically, we believe that safety technology, such as security cameras or motion sensors, may be the best additions to install based on the overall condition of the neighborhood and the survey results from St. Stephens House (Momenee, 2016). Making the lights "smart-ready," even if the City only implements LED technology initially, will ensure smooth transitions to smart technology should the City want to move forward with the pilot.

Explore a partnership with AT&T for 5G technology

Through our research, we discovered that city officials from around the United States doubted the capabilities of public Wi-Fi. Per a conference call with AT&T and GE (set up through our communication with The City of San Diego), we discovered that 5G technology might be a possibility for the Linden pilot project (Sullivan & West, personal communication, April 7, 2017). This cell phone data infrastructure would provide immediate, hyper-fast service to the ever-growing population of smartphone users. Because 5G cannot easily support computers and the educational benefits they provide, we would advise the City to look for alternative options for spreading Wi-Fi access, such as provider subsidies or enhanced programs through its library and public assets.

Include a Central Management System within the Linden pilot project

Due to benefits of CMS demonstrated in the San Francisco pilot project, we recommend installing a similar system in the Linden pilot project. A CMS will enable all the lights to communicate with one another, as well as communicate potential outages or problems to public power officials. This system will ensure crews will be able to respond to broken lights more quickly, restoring full LED capabilities and ensuring a safer neighborhood. Also, CMS technologies have the ability to dim the LED lights during hours of low traffic (mainly in the early morning) to save energy costs and greenhouse gas emissions.

Engage the Linden community

This is one of the most, if not the most, important recommendation. We believe that involving the community in the decision-making process for the smart street lighting pilot is imperative. Without adequate community involvement, the pilot will not be as successful. Getting community input will ensure that the lights will not only benefit the City of Columbus, but they will also benefit a neighborhood that needs a safer environment for its younger generation to grow and thrive.

CONCLUSION

Upon researching multiple case study cities in depth and conducting conference calls, we developed recommendations for the City of Columbus to guide it in implementing a smart street lighting pilot project in the Linden neighborhood. These recommendations include working with a reliable lighting vendor, making sure the lights are “smart-ready,” exploring a 5G partnership with AT&T, including a central management system, and engaging the community to implement best practices.

Our team realizes the case study analysis and recommendations contain gaps in knowledge. First, we have not correctly surveyed the Linden population to get statistically significant data for its opinions on smart street lighting infrastructure. Second, we realize that not all residents in Linden may have data plans to support 5G technology; to find these numbers, the City of Columbus would have to do extensive research. These are both huge obstacles to creating the perfect set of solutions, but we believe the City can feasibly gather both data sets and move forward with the project.

If these recommendations are taken into consideration as the pilot is planned and implemented, we believe the project will amass the greatest benefit to both the City of Columbus and the community of Linden. These lights will bring security and increased connection to the neighborhood, as well as significant cost savings to the City. Smart street lighting through the Linden pilot is one step toward a more connected, safer, energy-conscious Columbus.

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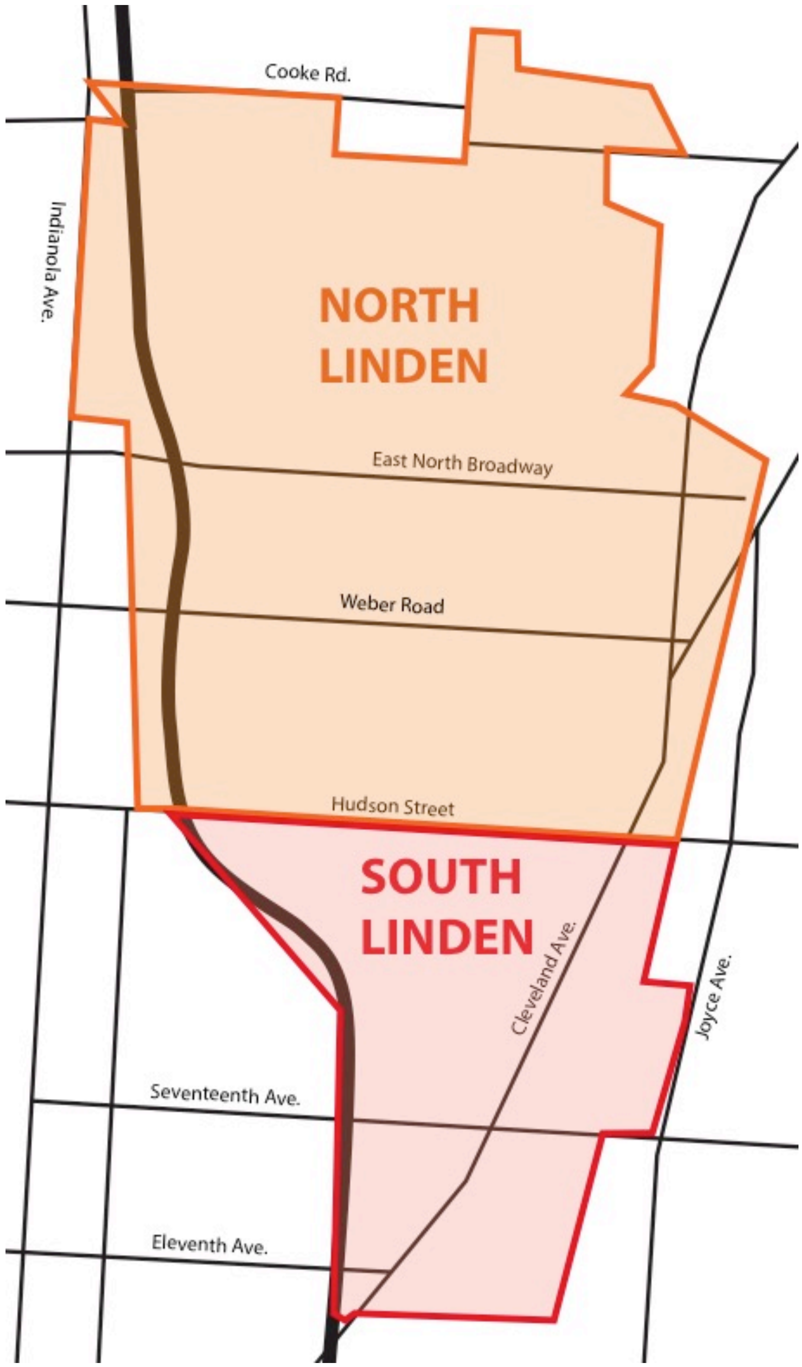
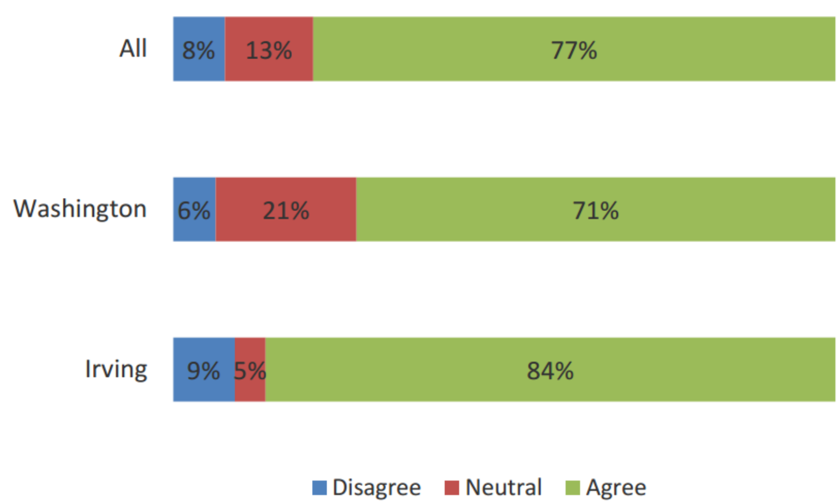
APPENDIX A: MAP OF LINDEN



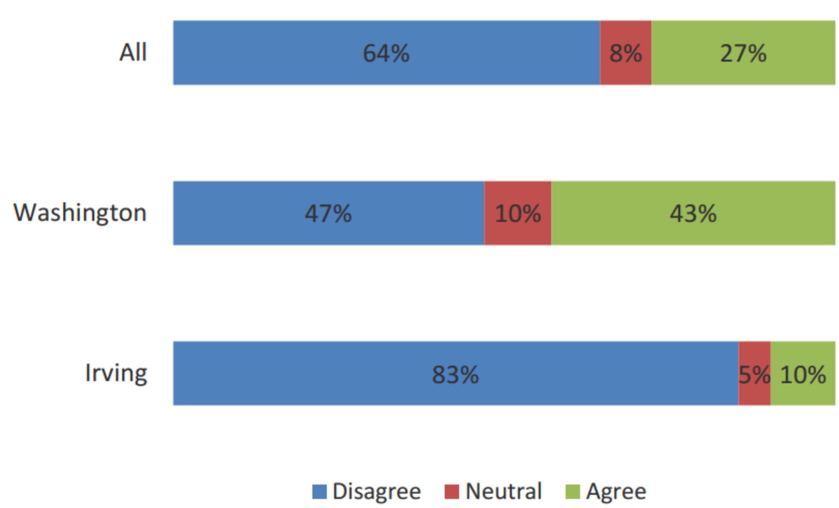
Data Source: See Dataset #11 in Appendix D

APPENDIX B: SAN FRANCISCO COMMUNITY INPUT

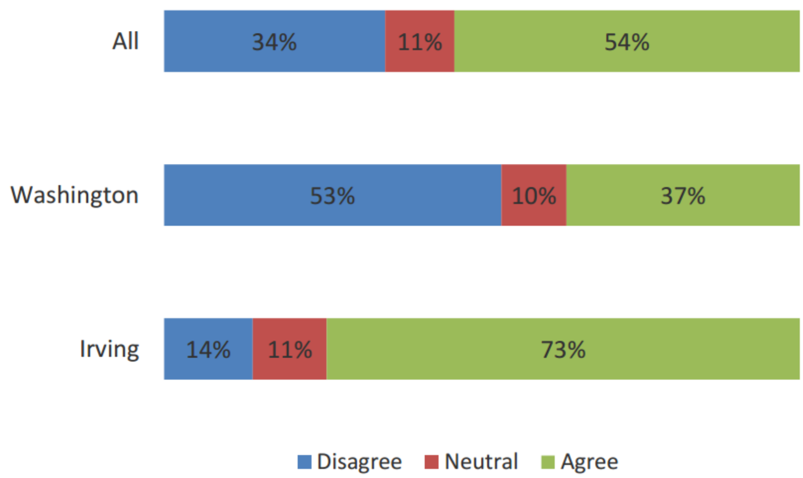
1. It would be safe to walk here, alone, during darkness hours.



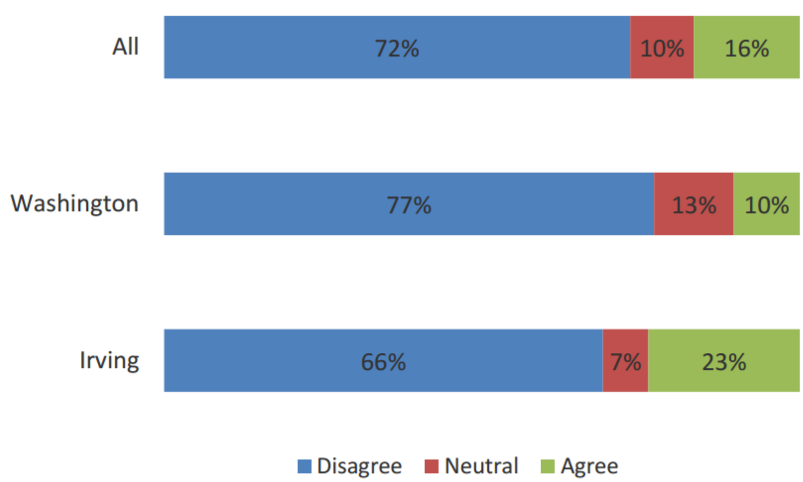
2. There is too much light on the street.



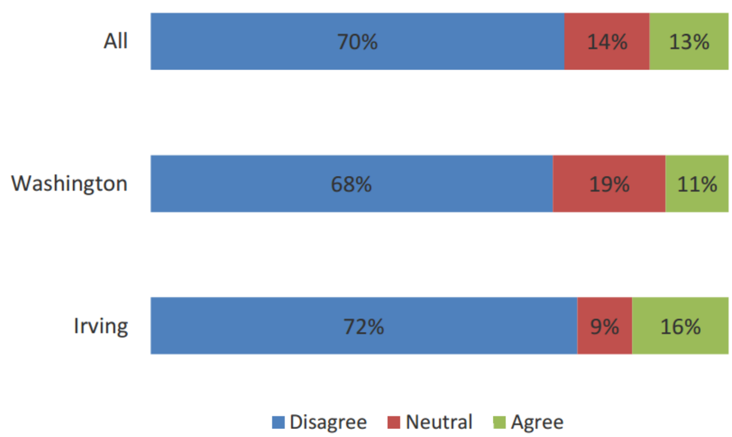
3. The lighting is comfortable.



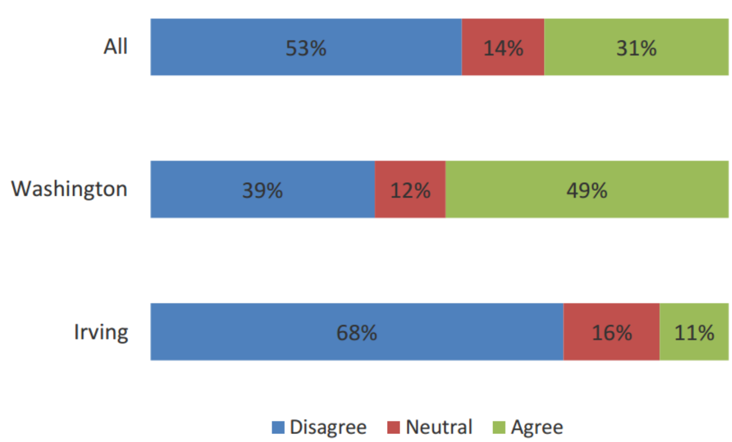
4. There is not enough light on the street.



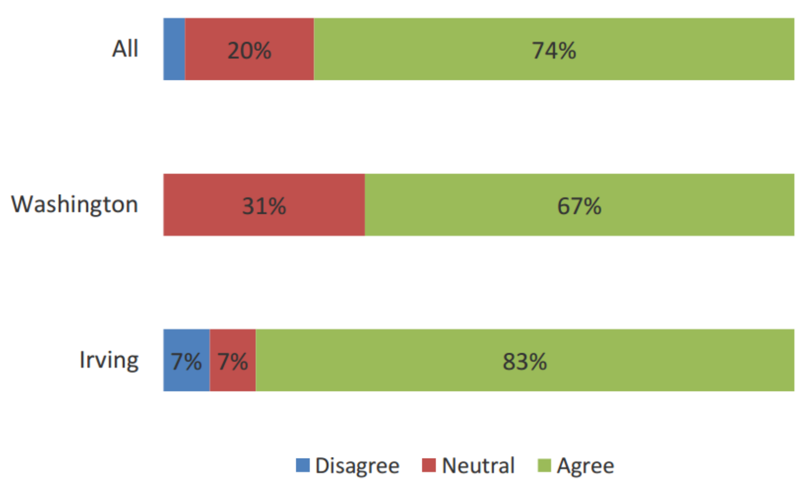
5. The light is uneven (patchy).



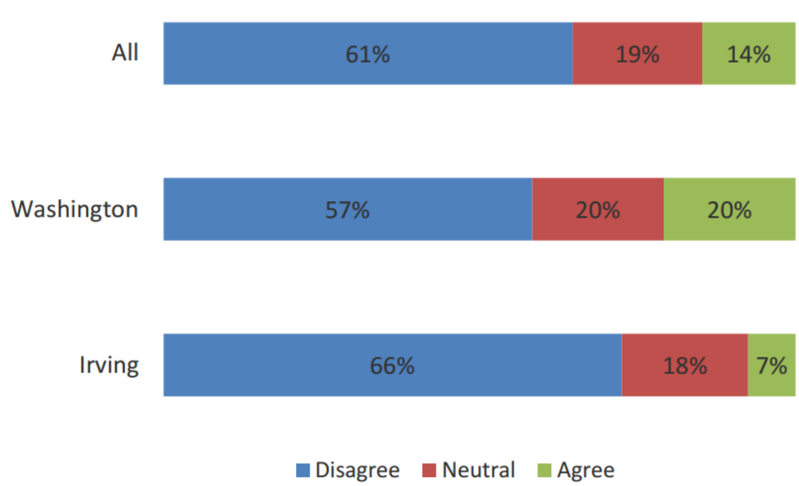
6. The light sources are glaring. (Please give us your impression without looking directly at the lights.)



7. It would be safe to walk on the sidewalk here at night.



8. I cannot tell the colors of things due to the lighting.



Data Source: All community input figures in Appendix B obtained from Young et al., 2014

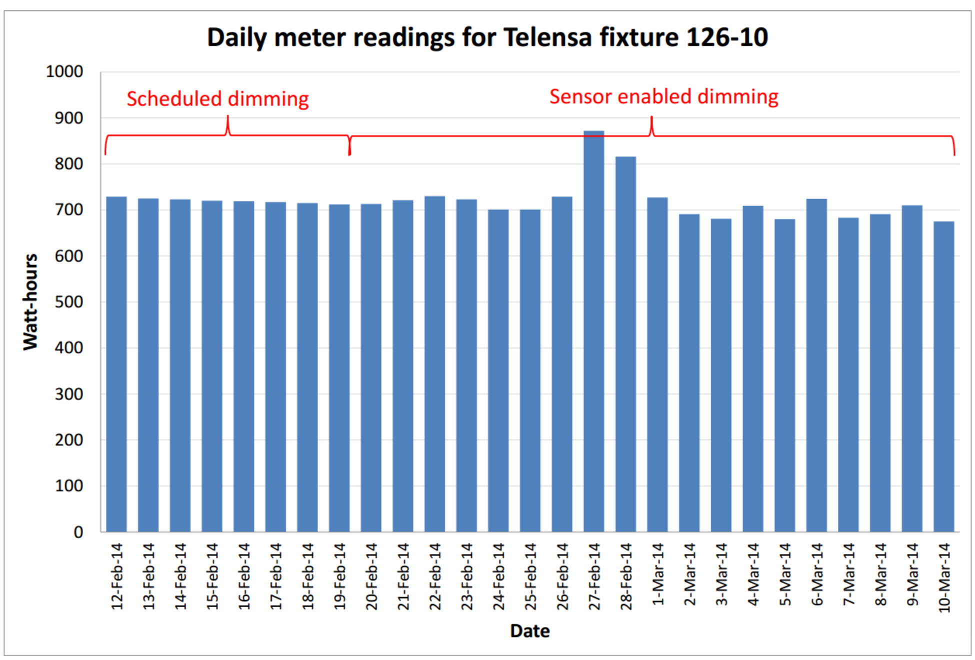
APPENDIX C: SAN FRANCISCO DIMMING BENEFITS

Table 5: Comparison of duty cycle and power draw of fixtures operated with and without a dimming schedule

Time Period	Duration (hours)*	Fixture Power (no dimming)	Fixture Power (with dimming)
30 minutes before sunset - 10 PM	~2.5	100%	100%
10 PM - 1 AM	3	100%	75%
1 AM - 5 AM	4	100%	50%
5 AM - 6 AM	1	100%	75%
6 AM - 30 minutes after sunrise	~1.5	100%	100%
Total operating hours and weighted avg. fixture power	**12**	100%	**75%**

Data Sources: See Dataset #5 in Appendix D
*Sunset and sunrise times vary throughout the year. For the purposes of calculating expected nightly energy savings, rough estimates were chosen to represent annual average values

Figure 1: Graph of daily energy use for Telensa fixture, from February 12-March 10, 2014



Data Source: Young et al., 2014 for energy savings for both the dimming schedule and the motion sensor technology.

APPENDIX D: METADATA

Dataset #1: Summary and Benefit Transfer Tables.xlsx (Summary Table tab)
Sources: Data sources for each cell can be seen in the table below:

Corresponding data sources	
City	**Los Angeles, California**
LED Conversion	http://www.dvrpc.org/energyclimate/eetrafficstreetlighting/pdf/CCI_Los_Angeles_LED_Streetlighting_Retrofit_Program_Report.pdf
Public Wifi provided through street lights	E. Ebrahimian, personal communication, March 7, 2017
Has remote monitoring system or equivalent	http://www.dvrpc.org/energyclimate/eetrafficstreetlighting/pdf/CCI_Los_Angeles_LED_Streetlighting_Retrofit_Program_Report.pdf
Gunshot detection	
EV charging stations	http://bsl.lacity.org/smartcity.html
Public input collected before implementation	E. Ebrahimian, personal communication, March 7, 2017
Negative feedback from residents was not a major problem	E. Ebrahimian, personal communication, March 7, 2017
Experienced cost savings through LED conversion	http://bsl.lacity.org/downloads/led/LED_Energy_Savings_011017.pdf
Experienced GHG emissions reductions through LED conversion	http://bsl.lacity.org/downloads/led/LED_Energy_Savings_011017.pdf
Crime/safety has noticeably improved	https://www.youtube.com/watch?v=i04MjLK8qvE
City	**Detroit, Michigan**
LED Conversion	B. Berg, personal communication, March 17, 2017
Public Wifi provided through street lights	B. Berg, personal communication, March 17, 2017
Has remote monitoring system or equivalent	B. Berg, personal communication, March 17, 2017
Gunshot detection	
EV charging stations	
Public input collected before implementation	
Negative feedback from residents was not a major problem	B. Berg, personal communication, March 17, 2017
Experienced cost savings through LED conversion	https://www.nytimes.com/2017/01/10/arts/the-lights-are-on-in-detroit.html?_r=1
Experienced GHG emissions reductions through LED conversion	https://www.nytimes.com/2017/01/10/arts/the-lights-are-on-in-detroit.html?_r=1
Crime/safety has noticeably improved	https://www.nytimes.com/2017/01/10/arts/the-lights-are-on-in-detroit.html?_r=1
City	**San Diego, California**
LED Conversion	L. Cosio-Azar, personal communication, March 2, 2017
Public Wifi provided through street lights	L. Cosio-Azar, personal communication, March 2, 2017
Has remote monitoring system or equivalent	L. Cosio-Azar, personal communication, March 2, 2017
Gunshot detection	L. Cosio-Azar, personal communication, March 2, 2017
EV charging stations	
Public input collected before implementation	L. Cosio-Azar, personal communication, March 2, 2017
Negative feedback from residents was not a major problem	L. Cosio-Azar, personal communication, March 2, 2017
Experienced cost savings through LED conversion	L. Cosio-Azar, personal communication, March 2, 2017
Experienced GHG emissions reductions through LED conversion	L. Cosio-Azar, personal communication, March 2, 2017
Crime/safety has noticeably improved	
City	**San Francisco, California**
LED Conversion	M. Tienken, personal communication, March 7, 2017
Public Wifi provided through street lights	
Has remote monitoring system or equivalent	https://sfwater.org/modules/showdocument.aspx?documentid=5972
Gunshot detection	
EV charging stations	https://sfwater.org/modules/showdocument.aspx?documentid=5972
Public input collected before implementation	https://sfwater.org/modules/showdocument.aspx?documentid=5973
Negative feedback from residents was not a major problem	https://sfwater.org/modules/showdocument.aspx?documentid=5974
Experienced cost savings through LED conversion	M. Tienken, personal communication, March 7, 2017
Experienced GHG emissions reductions through LED conversion	M. Tienken, personal communication, March 7, 2018
Crime/safety has noticeably improved	

Description: This data set contains the links for each reference that corresponds to the summary table (Table 1). These links provide the data to back up the "x" in each cell.

Dataset #2: Summary and Benefit Transfer Tables.xlsx (Benefit Transfer tab - Detroit data)
Sources: Berg, B. (2017, March 17). Phone Interview.
Kimmelman, Michael. "The Lights Are On in Detroit." *The New York Times*. The New York Times, 10 Jan. 2017. Web. 24 Mar. 2017.
Description: This data set includes estimated cost of project, annual energy savings ($) and annual carbon emissions reductions which were all obtained from Bob Berg, a consultant to the PLA project and the New York Times' story "The Lights are on in Detroit" (both are cited in the references). This data was used to create Table 2 in the report. The numbers for estimated cost of project, annual energy savings, and annual carbon emissions reductions were divided by the number of fixtures to calculate per unit cost/savings.

Dataset #3: Summary and Benefit Transfer Tables.xlsx (Benefit Transfer tab - Los Angeles data)
Sources:
Clinton Climate Initiative Case Study:
http://www.dvrpc.org/energyclimate/eetrafficstreetlighting/pdf/CCI_Los_Angeles_LED_Streetlighting_Retrofit_Program_Report.pdf
City of Los Angeles Department of Public Works Bureau of Street Lighting PDF:
http://bsl.laCity.org/downloads/led/LED_Energy_Savings_011017.pdf
Description: This data set includes estimated cost of project, which was obtained from the Clinton Climate Initiative Source, as well as annual energy savings ($) and annual carbon emissions reductions which were both obtained from the City of Los Angeles Department of Public Works Bureau of Street Lighting source. This data was used to create Table 3 in the report. The numbers for estimated cost of project, annual energy savings, and annual carbon emissions reductions were divided by the number of fixtures to calculate per unit cost/savings.

Dataset #4: Summary and Benefit Transfer Tables.xlsx (Benefit Transfer tab - San Diego data)
Sources:
Personal communication from Lorie Cosio-Azar
United States Environmental Protection Agency:
https://www.epa.gov/sites/production/files/2015-10/documents/egrid2012_summarytables_0.pdf
Description: This data set includes estimated cost of project, annual energy savings ($) and annual carbon emissions reductions, which were all obtained from personal communication with Lorie Cosio-Azar. Data for carbon emissions reductions were converted from mwh to metric tons of carbon emissions using a conversion rate from United States Environmental Protection Agency (2017). This data was used to create Table 4 in the report. The numbers for estimated cost of project, annual energy savings, and annual carbon emissions reductions were divided by the number of fixtures to calculate per unit cost/savings.

Dataset #5: Summary and Benefit Transfer Tables.xlsx (Benefit Transfer tab - San Francisco Benefit Transfer tab)
Source:
San Francisco Public Utilities Commission Evaluation Report:
https://sfwater.org/modules/showdocument.aspx?documentid=5972
Description: This document outlines the outcomes registered with the implementation of a central management system in the San Francisco smart street lighting pilot project. The data for this table specifically comes from a dimming schedule table located on page 22 in the document and was used to create Table 5 in the Appendix C.

Dataset #6: DetroitInterview.docx
Source: Bob Berg, Co-Founder, of Counsel at VanDyke Horn Public Relations. Phone: (313) 872-2202. Website or other contact info: http://www.vandykehorn.com/bob-berg/
Description: Notes from conversation with Bob Berg regarding his involvement and knowledge of the Public Lighting Authority's project in Detroit. Phone conversation on March 17, 2017.
Questions included:

1. What were the realized energy savings (GHG reductions too, if possible) and cost savings as compared to the City's regular street lights?

2. Are the lights linked to a central control system? If so, has it worked out well having all the information in one place? If not, do you think it would be helpful to have one?
3. Are there plans in place to broaden the project into other parts of Michigan? Where do you see this project moving in the future?
4. How has safety and the perception of safety changed among the community? Has the installation of the new LEDs changed people's night behaviors?
5. In the NYT article, it was mentioned that the project came in under budget and faster than estimated. What were the original and actual budgets and timelines?

Dataset #7: LosAngelesInterview.docx
Sources: Ed Ebrahimian, Director of the Bureau of Street Lighting, City of Los Angeles. Bureau of Street Lighting email: bsl.streetlighting@laCity.org
Description: Notes from conversation with Ed Ebrahimian about the City of Los Angeles' smart street lighting projects. Phone conversation on March 7, 2017. Questions included:

1. It seemed like Los Angeles had a pretty good response from residents about the white light. Was there a period where you collected public input about the lights before implementation? Was there pushback from the public at any point?
2. What was the main driver for the implementation of smart street lighting in Los Angeles?
3. What vendor did you partner with? Why did you go with this company?
4. I've read that Los Angeles has implemented Smart Pole street lighting. Could you tell me a little more about this? What area were the 100 lights implemented in and why was it chosen?
5. Has Los Angeles considered providing public Wi-Fi through street lights?
6. Do you have any thoughts on the types of issues that a Midwestern City, like Columbus, might face when implementing smart street lighting that Los Angeles did not face?

Dataset #8: SanDiegoInterview.docx
Sources: Lorie Cosio-Azar, Program Manager, City of San Diego Environmental Services Department. Email: LCosioAzar@sandiego.gov
Description: Transcribed phone interview with Lorie Cosio-Azar about the City of San Diego's smart street lighting projects. Phone conversation on March 2, 2017. Questions included:

1. What were the planning and installation phases, and how long did each take?
2. What manufacturer did you use for the adaptive control system?
3. What are the next steps for implementation in 2017?
4. Are the sensors separate from the adaptive control note, or just an enhanced version?
5. Will the next installation have both sensors and adaptive controls?
6. Do you have numbers for carbon emissions reductions?
7. What other smart capabilities are included in the sensors?
8. Is there a reason San Diego did not implement Wi-Fi in the street lights?
9. How and when did you collect public input?
10. Would you need new infrastructure or another product from GE in order to implement Wi-Fi in your current fixtures?
11. Are any of your street lights in residential areas, or are they all downtown (commercial areas)?
12. Did you ever receive negative feedback or pushback from residents?

13. What challenges do you think might be presented in implementing smart street lighting in a totally different area (gave brief background about Linden – residential, low income, high crime)?
14. Do you have any other thoughts about how Wi-Fi, or other capabilities of smart street lighting, could present social opportunities in a low income residential neighborhood like Linden?
15. If and when you would receive negative feedback from the sensors, what will you do to mitigate those feelings?
16. Did GE have the option to offer facial recognition, or was that the only option for that sensor?
17. Did you ever get any negative feedback when you increased to the brighter light?
18. Can you give us information about the costs of this project?
19. What ratio of lights should have sensors?

Dataset #9: SanFranciscoInterview.docx
Sources: Mary Tienken, Project Manager for San Francisco Public Utilities Commission. Email: MTienken@sfwater.org
Description: Transcribed phone interview with Mary Tienken about the City of San Francisco's smart street lighting projects. Phone conversation on March 7, 2017. Questions included:

1. When did the City begin replacing their 2000+ street lights with LEDS?
2. Is there any projects/plans arising in regards to the City street lights?
3. Has the City looked into any other companies that offer a CMS or other capabilities since you didn't move forward with the three companies from the pilot?
4. Was there a focus or project regarding the employment of LEDs in the Tenderloin to increase safety? (I read about something like this in the news)
5. Any additional feedback/advice that would be essential for our research moving forward?
6. What were the social impacts of implementing LED street lights compared to the old street lights?

Dataset #10: AT&TGEInterview.docx
Sources: Jamie Sullivan, AT&T Digital Infrastructure Analyst, Email: js397p@att.net & Stephen West, GE Regional Sales Manager, Email: stephen.e.west@ge.com
Description: Transcribed phone interview with Jamie Sullivan (AT&T) and Stephen West (GE) about the feasibility of public Wi-Fi and other alternatives, as well as their plan of action for doing business with the City of Columbus. Phone conversation on April 7, 2017. Questions included:

1. With the cost savings and emissions reductions of LED lighting, what could be the hold up in other cities making this transition? (initial cost barrier? public perception? culture?)
2. What would be your estimates on cost per fixture if/when Columbus moves forward with a 100-200 light pilot in the Linden neighborhood?
3. What would be the cost and feasibility of implementing public Wi-Fi?
4. We know Los Angeles has invested in smart pole technology, are you familiar with this?
5. What is the future of Wi-Fi? Does it make sense to invest in public Wi-Fi with the future of cell phone technology (LTE)?

Dataset #11: Linden Map.pdf
Sources:
Google Maps:
https://www.google.com/maps/place/Linden,+Columbus,+OH+43211/@40.0200643,-82.9907471,14z/data=!4m5!3m4!1s0x88388be739c38be9:0x2a061f0ea62285b3!8m2!3d40.0200643!4d-82.9732376
City-Data (North Linden): http://www.City-data.com/neighborhood/North-Linden-Columbus-OH.html
City-Data (South Linden): http://www.City-data.com/neighborhood/South-Linden-Columbus-OH.html
Description: Map designating Linden neighborhood boundaries, created with data from Google Maps and City-Data. Created on April 10, 2017. This map can be found in Appendix A.

Dataset #12: LisaSnyderInterview.docx
Sources: Lisa Snyder, Neighborhood Design Center Project Manager
Description: Transcribed phone interview notes with Lisa Snyder about NDC's involvement with the Smart Columbus projects in Linden. Phone conversation on March 9, 2017. Question was:

1. Can you tell me about the research Neighborhood Design Center is doing in Linden related to the Smart Columbus project?

Dataset #13: Gross&FennerInterview.docx
Sources: James Gross and Kristian Fenner, Power Assistant Administrators (City of Columbus), Emails: jmgross@columbus.gov; kdfenner@columbus.gov
Description: Transcribed in-person interview notes with James Gross and Kristian Fenner to receive preliminary information about the Linden smart street lighting pilot project. In-person conversation at the Columbus Division of Power on January 27, 2017. Questions included:

1. What is the budget for the Linden pilot project?
2. What does the City want to see from our case study research?
3. What manufacturers have you looked at?
4. Where is the pilot project going to be located?
5. How many street lights are going to be implemented in the pilot?
6. How much work has been done regarding social justice benchmarking?