INNOVATIONS IN LIGHTING FOR PEDESTRIAN SAFETY AND WALKABILITY

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INTRODUCTION AND SUMMARY

Street lighting is increasingly recognized as a critical factor in the quality of the nighttime pedestrian environment. Advances in technology and planning techniques will enhance the impact of lighting improvements on pedestrian safety, security, and comfort.

"Smart" or adaptive street lighting adjusts illumination to increase pedestrian visibility, while potentially reducing the costs and environmental impact of street lights. LED (light emitting diode) lights reduce maintenance and power costs, while offering better illumination of pedestrians. Pedestrian-scale lighting enhances sidewalk and crossing safety and security. Lighting can be an important streetscape or public art element, such as historic light fixtures in urban tourist districts and programmable lighting for artistic displays. Lighting fixtures will increasingly communicate in networks and with nearby devices to improve lighting central control, maintenance, and citizen information.

This paper primarily addresses lighting from the transportation planning perspective, rather than from the lighting designer's viewpoint. It summarizes the potential benefits, costs, and issues related to selected technological advances. It also addresses planning techniques for prioritizing and funding lighting improvements for pedestrian safety and walkability.

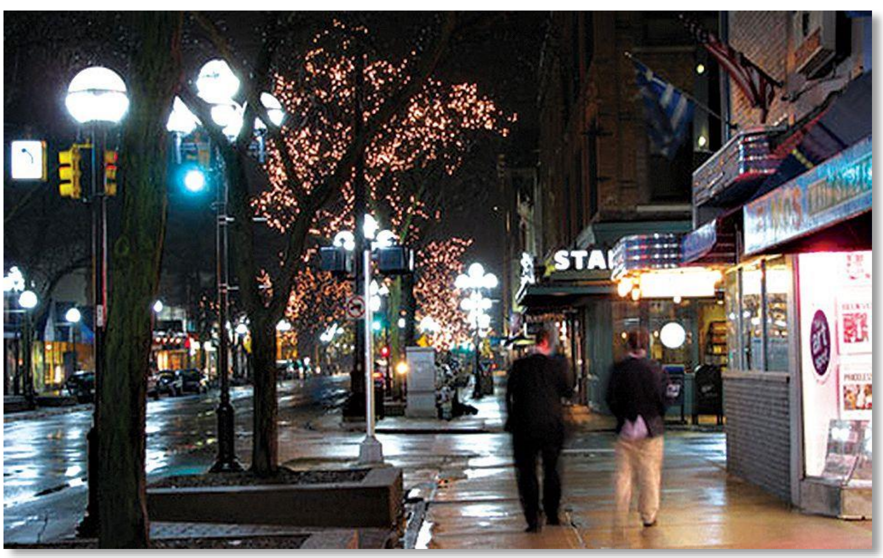


Photo credit: NACTO website (https://nacto.org/wp-content/themes/sink_nacto/views/design-guides/retrofit/urban-street-design-guide/images/visibility-sight-distance/carousel/pedestrian-scale-lighting.jpg)

LIGHTING SAFETY BENEFITS AND COSTS

The literature on lighting's benefits shows that lighting improves pedestrian safety. Studies have demonstrated that lighting can substantially improve the nighttime pedestrian environment by reducing injures from collisions, reducing crime, and improving perceived walking comfort. Despite the clear benefits of lighting improvements, these can be expensive, especially when compared to other pedestrian safety improvements.

SAFETY BENEFITS

About two-thirds of pedestrian fatalities in the U.S. occur at night or under low-light conditions. Pedestrian fatalities are 3 to 6.75 times more likely at night, taking into account pedestrian volumes (Sullivan and Flanagan, 1999). Several studies have found that pedestrian injuries at nighttime are typically reduced by roughly half by illumination (Schwab et al., 1982, Elvik, 1995, Commission Internationale de l'Eclairage, 1992).

San Francisco's innovative WalkFirst project ranked roadway lighting improvements as highly effective at improving pedestrian safety, medium cost, and long time frame (San Francisco City and County, 2014). The project's toolkit webpage suggested that lighting improvements should be targeted especially to locations with a high nighttime crash profile and to complex intersections.

A comprehensive review of 13 studies concluded that improved street lighting also significantly reduces crime (Welsh and Farrington, 2008). Enhanced lighting may improve daytime personal security on affected blocks, perhaps by communicating to potential criminals that there is greater public attention to the location.

Lighting is also a major factor in perceived walking comfort. "Low lighting" was one of the primary barriers Seattle residents cited as discouraging walking after dark (Seattle, 2012).

COSTS

Lighting improvements tend to be relatively expensive compared to other typical pedestrian improvements. For example, in San Francisco, pedestrian-scale lighting was estimated to cost $610,000 to furnish and install 34 poles spaced about 50 feet apart around a rail station (SFMTA, 2015). By comparison, in San Francisco, converting a crosswalk to more visible continental striping costs roughly $5,000, signal timing/phasing changes cost roughly $4,000 to $11,000 per intersection, curb bulb-outs are approximately $100,000 per corner, and installing a traffic signal is typically close to $400,000 per intersection (SFMTA, 2015a). (These comparison costs include soft costs like planning, design, and permits.)

LIGHTING TECHNOLOGIES

"SMART LIGHTING"

"Smart" (or adaptive) lighting has promise for safety and energy benefits based on limited studies. University of Nevada, Las Vegas, researchers found a statistically significant increase in driver yielding by using supplemental lighting for a crosswalk, triggered by automated detection of pedestrians. The University of California, Davis, cut energy costs by 50-60% by using lighting on campus paths that adapts illumination levels to pedestrian activity (UC Davis, 2013).

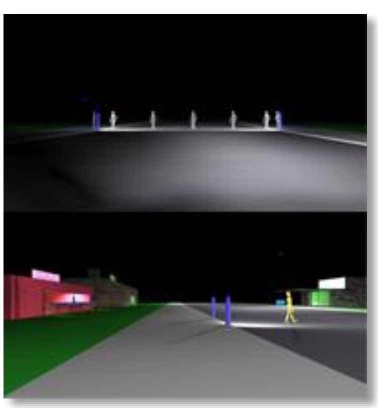
Left: Supplemental crosswalk lighting triggered by pedestrian video detection. (Image credit: https://safety.fhwa.dot.gov/ped_bike/tools_solve/ped_scdproj/webinar052809/las_vegas/) Right: Michael Siminovitch, director of UC Davis' California Lighting Technology Center, demonstrates how the lights switch from low power to high power when someone is detected walking or driving nearby. (Karen Higgins/UC Davis photo)

LED LIGHTING

LED benefits, by contrast to Smart Lighting, have been proven in large-scale implementation efforts. The City of Los Angeles street lighting cut energy usage, saving $9 million annually, by replacing incandescent with LED lighting (Gerdes, 2013). LED lights also offer a better color rendition, and last three times longer than High Pressure Sodium (HPS), but can have greater glare impacts. Vancouver, BC, prioritized LED installation at 44 locations based on pedestrian safety considerations (Luba, 2014).

BOLLARD LIGHTING

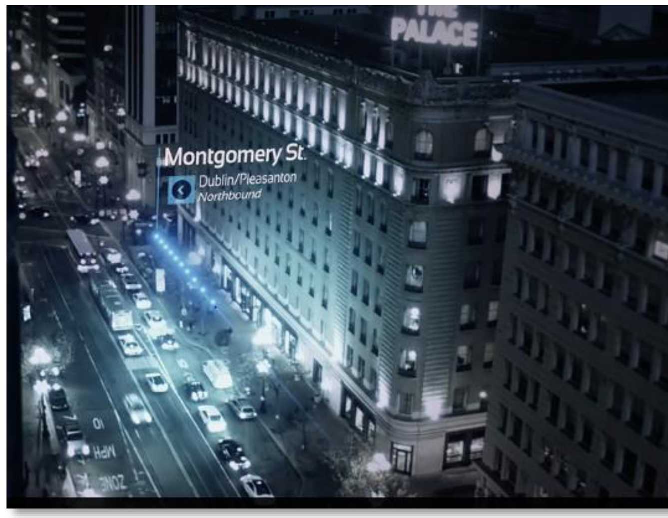
Rensselaer Polytechnic University's Lighting Research Center concluded that a bollard-based fluorescent lighting system mounted at the ends of a crosswalk "could be a feasible approach with reduced costs to improving pedestrian visibility" (Bullough et al., 2009). A pilot demonstration found vertical illumination of 40-50 lux at the ends of the crosswalk and 10 lux in the center of the crosswalk, which observers found significantly brighter and higher contrast, but also more glare-producing, than standard high pressure sodium overhead lighting. An economic analysis suggested this system would have lower initial and operating costs than several alternatives.



Bollard lighting. Image credit: RPI website.

ARTISTIC, HISTORIC, AND PROGRAMMABLE LIGHTING

Artistic or historic lighting has been used for decades to provide a unique sense of place to such popular tourist locations as San Diego's Gaslamp District, Vancouver's Gastown, and San Francisco's Market Street Path of Gold. Technological advances provide additional options for using programmable lighting to enhance the identity and nighttime interest of such locations. For example, programmable lighting was used in Vancouver's False Creek as a major attraction for the 2010 Winter Olympics (CDm2, 2012). This provided both a lighting show and unusual aesthetics of the oversized light fixtures themselves. San Francisco uses colored lighting of City Hall's exterior for special occasions. Public arts group ILLUMINATE is raising funds for a "Lightrail" installation that will flash lights along San Francisco's Market Street in time with the trains in a subway underneath, plus providing the historic Path of Gold lighting with LED bulbs (ILLUMINATE, 2017).



Left: Vancouver's False Creek Olympic Plaza. Photo credit: DIALOG, Stephane Laroye (https://laroye.ca/). Right: ILLUMINATE's proposed San Francisco Lightrail project. Photo credit: ILLUMINATE (http://illuminatethearts.org/projects/)

THE INTERNET OF THINGS

Lighting fixtures can be tied into the municipal communications networks for purposes of central control of lighting, communicating lighting maintenance needs automatically, or sending messages to nearby devices. The City of San Jose, for example, has a pilot project to control lighting wirelessly (Philips, 2015). The German town of Wipperfurth is testing similar controls, plus use of LED luminaires to transmit civic announcements to Bluetooth-enabled devices (Halper, 2017).

PLANNING AND PRIORITIZING PEDESTRIAN LIGHTING FOR PEDESTRIANS

There are generally recognized engineering standards and guidelines for street lighting for illuminating the roadway (e.g., the Illuminating Engineering Society of North America, *American National Standard Practice for Roadway Lighting. Recommended Practice*, 2014). Procedures for assessing intersection lighting needs have also been proposed. The Transportation Association of Canada (2006) procedure develops a score based on geometric, operational, environmental, and crash factors. Key criteria are traffic volumes, nighttime crashes that may be attributed to the lack of illumination, presence of crosswalks, and the extent of raised medians. Higher scores indicate the need for full illumination (vs. partial or delineation illumination).

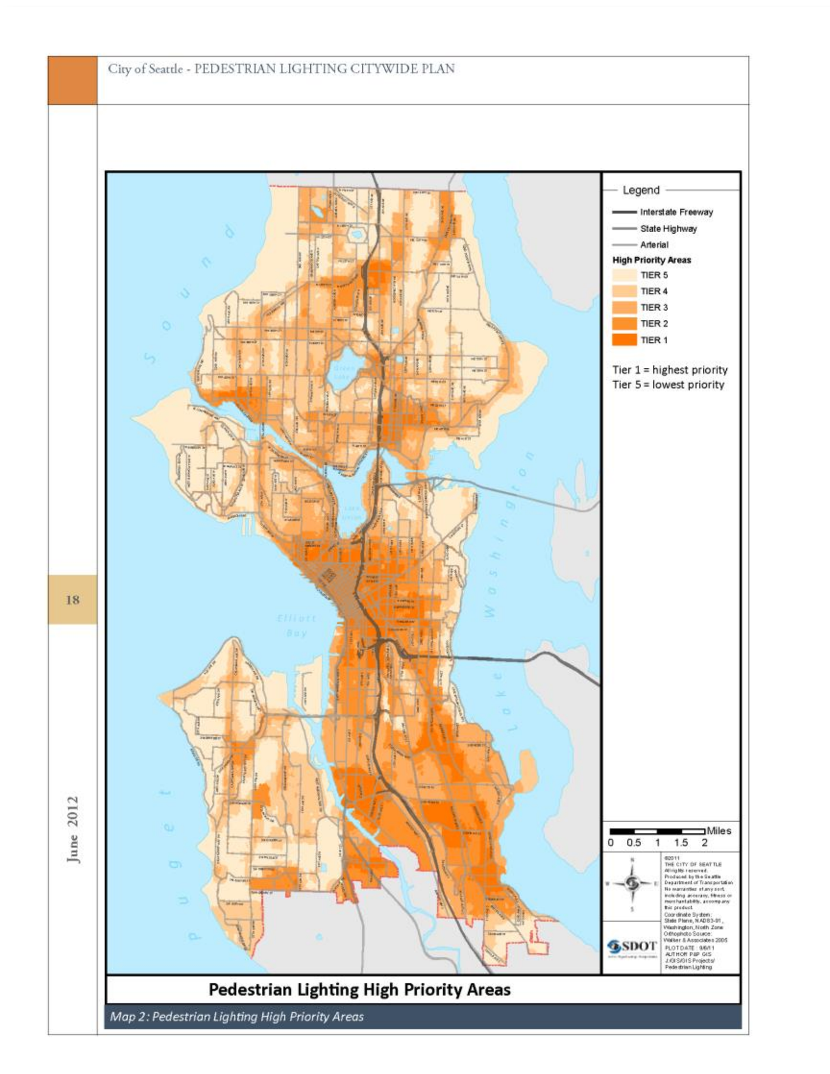
Donnell, Porter, and Shankar (2010) attempted to develop a framework for assessing the potential safety benefits of lighting improvements at a variety of intersection types and locations. They explored issues, such as availability of relevant data; the analytical framework related to different intersection classifications; and statistical model development. They found a much lower overall safety benefit from lighting than some published studies (with a crash reduction factor of 11.9%), but consistent with estimates included in Highway Safety Manual research.

Guidance in planning and prioritizing the installation of lighting related specifically to pedestrians is limited. There are a handful of cities that have presented work in this area. Below are two examples.

SEATTLE

The City of Seattle is an unusual municipality in that it has established criteria for locating pedestrian-scale lighting. Its *Pedestrian Lighting Citywide Plan* (2012) includes maps with priority locations (including areas, arterial street segments, intersections, and trails) for pedestrian-scale lighting. Criteria include:

- Pedestrian demand (based on land uses);
- Socio-economic status (with traditionally under-served areas prioritized); and
- Street segment classification (importance in pedestrian network).



Pedestrian Lighting High Priority Areas. City of Seattle, Pedestrian Lighting Citywide Plan, 2012.

SAN JOSE

The City of San Jose Downtown Street and Pedestrian Lighting Master Plan was created in 2003 as part of its Downtown Streetscape Master Plan. The plan's primary goal is to create cohesive and consistent lighting design as incremental improvements are implemented in Downtown over the long-term. The Lighting Master Plan acknowledges the scarcity of funding, but address this through a variety of implementation strategies:

- Plan for long-term, incremental improvements— the lighting plan is updated every five years, includes new technologies as they emerge, and adds newly funded projects as budgets and funding priorities are updated;
- Re-use and retrofit existing infrastructure with newer technology;
- Identify first and second tier priority for planned projects;
- Take advantage of ongoing opportunities for lighting improvements in upcoming private and public developments by requiring new developments to meet Downtown Lighting Master Plan lighting levels and standards; and
- Improve maintenance practices by standardizing and streamlining maintenance procedures.

FRAMEWORK FOR IMPLEMENTING LIGHTING IMPROVMENTS

Given the inexperience on the part of many municipal governments in preparing and implementing pedestrian lighting plans, a system is needed that can be used for prioritizing and channeling investment funds to areas that would most benefit from lighting improvements for pedestrians. The following is a framework for developing a priority system, based on the City of Seattle and City of San Jose pedestrian-scale lighting prioritization procedure and more general pedestrian priority systems.

1. Inventory existing lighting fixtures
2. Analyze low-light crash patterns and locations
3. Assess citizen preferences for lighting fixtures and strategies, including field surveys at night
4. Inventory crash, road, and environmental data
5. Develop scoring system for determining lighting need
6. Map lighting needs by priority classification
7. Prepare benefit/cost analysis for alternative lighting strategies
8. Compare benefit/cost ratios for lighting improvements vs. other potential roadway improvements and compare on metrics such as ease of implementation, time frame, funding availability
9. Recommend a specific program of improvements
10. Develop a funding and implementation strategy

Potential priority factors for lighting need scores include the following:

- Transit proximity;
- Street classification;
- Land use classification;
- Crime levels;
- Collision record, particularly the time and type of collisions;
- Potential for coordination with other projects; and
- Citizen input (including complaints about specific locations and response to surveys).

This scoring system should weight locations expected to have the highest number of pedestrians and where nighttime pedestrian safety and crime levels are a concern. However, there should be minimum illumination levels, based on the IES standards.

NEXT STEPS

Other promising areas for lighting research include:

- Crash reduction potential of different lighting types and strategies;
- Pedestrian preferences for different lighting types;
- Cost-effectiveness of lighting improvements versus other pedestrian improvements; and
- Impact of lighting conditions on the effectiveness of vehicle-mounted crash avoidance technologies.

This research background could also be used in developing a manual for transportation engineers and planners on the use of lighting (both roadway lighting and pedestrian-scale lighting) to improve pedestrian safety, security, and the walking environment. FHWA (Lutkevich et al., 2012) has issued an extremely useful roadway lighting handbook, but with only limited material specifically for pedestrians. FHWA also prepared an informational report on crosswalk lighting focused on mid-block crosswalks (Gibbons et al., 2008). Neither reference covers prioritizing lighting improvements in the manner of the Seattle Plan.

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