

LED Roadway Lighting Benefits and Costs Collaboration

Final Report | Report Number 19-40 | October 2019

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Final Report

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle LED Roadway Lighting Benefits and Costs Collaboration		5. Report Date November 2019	
		6. Performing Organization Code:	
7. Author(s) J. D. Bullough, L. C. Radetsky and N. P. Skinner		8. Performing Organization Report No. 19-40	
9. Performing Organization Name and Address Lighting Research Center Rensselaer Polytechnic Institute 21 Union Street Troy, NY 12180		10. Work Unit No.	
		11. Contract or Grant No. Contract No. 83173	
12. Sponsoring Agency Name and Address New York State Energy Research and Development Authority 17 Columbia Circle Albany, NY 12203		13. Type of Report and Period Final Report (2016-2019)	
New York State Department of Transportation 50 Wolf Road Albany, NY 12232		14. Sponsoring Agency Code	
15. Supplementary Notes Patrick Bolton from NYSERDA and Owais Memon from NYSDOT served as project managers.			
16. Abstract <p>The use of light emitting diode (LED) roadway lighting is growing throughout New York State and the rest of the country, because of the potential for longer effective life and energy savings compared to high pressure sodium (HPS) lighting systems. While the technological feasibility of LED roadway lighting systems has been established, the impacts of LEDs on the economics of roadway lighting are situationally dependent. In many municipalities, roadway lighting is owned and maintained by the local electric utility. Entities such as the New York State Comptroller's Office have advocated for municipalities to purchase their roadway lighting systems from the utility, and economic analyses suggest a substantial cost savings can be achieved in this way. Utility-owned roadway lighting is still attractive, however, for many municipalities who are not prepared to purchase and maintain their lighting network. In the present project, LED luminaires were installed along a major arterial roadway by the local utility. The LED lighting was selected to improve the visual conditions while using less energy. Over 30% energy savings were realized, although utility costs were not reduced by the same amount. Subjective evaluations of the previous HPS and each type of LED, revealed that the LED lighting was judged to be an improvement over the HPS lighting conditions.</p>			
17. Key Words Solid state lighting; Light emitting diodes, Utility tariffs		18. Distribution Statement	
19. Security Classif. (of this report): Unclassified	20. Security Classif. (of this page): Unclassified	21. No. of Pages 59	22. Price

Form DOT F 1700.7 (8-72)

Reproduction of completed page authorized.

Acknowledgments

This project was sponsored by the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Transportation (NYSDOT) through Program Opportunity Notice (PON) 3090, Integrated Mobility Solutions for Smarter Cities and Communities. Patrick Bolton from NYSERDA and Owais Memon from NYSDOT served as project managers. Joseph Tario from NYSERDA is the former NYSERDA project manager. Many individuals and organizations collaborated on this project: Robert Terry, Mark Kennedy and Shawn Raymond from NYSDOT; Camille Kanga and Penny Eickemeyer from the Region 2 University Transportation Research Center (UTRC), which provided cost sharing; John Walter, Caeresa Richardson, Jennifer Kellish, Kevin George, Kristoffer Kiefer and James Klein from National Grid, which provided in-kind support; Sandra Misiewicz and Christian Bauer from the Capital District Transportation Committee (CDTC), which provided in-kind support; John Cunningham, Jack Spath and Judy Ekstrom from the Town of Colonie, which provided in-kind support; Mayor Frank Leak, Deputy Mayor Michael Aidala, Lester Decker, Henry DeCotis, Jamie Blot, Julianne Okun and Chris Bisognano from the Village of Colonie, which provided in-kind support; and Stephan Godlewski and Gregory Gibbons from Creighton Manning.

Preferred Citation

New York State Energy Research and Development Authority (NYSERDA). 2019. “LED Roadway Lighting Benefits and Costs Collaboration,” NYSERDA Report Number 19-40. Prepared by Lighting Research Center, Rensselaer Polytechnic Institute, Troy, NY. nyserdera.ny.gov/publications

Table of Contents

Notice.....	ii
New York State Department of Transportation Disclaimer	ii
Technical Report Documentation Page.....	iii
Acknowledgments	iv
Preferred Citation.....	iv
List of Figures	vi
Acronyms and Abbreviations	viii
Executive Summary.....	ES-1
1 Background.....	1
2 Previous Conditions	3
2.1 Energy and Economics.....	3
2.2 Lighting System Performance.....	4
2.3 Survey Questionnaire Evaluation.....	6
3 Selection of LED Luminaires.....	14
3.1 Photometric Performance	14
3.2 LED Luminaire Locations.....	15
3.3 Logistical Planning	16
4 New Conditions.....	18
4.1 Energy and Economics.....	18
4.2 Lighting System Performance.....	19
4.3 Survey Questionnaire Evaluation.....	20
5 Conclusions	47
5.1 Discussion.....	47
5.2 Statement on Implementation	48
6 References	49
Appendix A. Route 5 Crosswalk Lighting Analysis: Existing Lighting Values—Measured	A-1

List of Figures

Figure 1. HPS Luminaire Type	4
Figure 2. Central Avenue with HPS Lighting	5
Figure 3. Response to Survey Question 1—HPS	7
Figure 4. Response to Survey Question 2—HPS	7
Figure 5. Response to Survey Question 3—HPS	8
Figure 6. Response to Survey Question 4—HPS	8
Figure 7. Response to Survey Question 5—HPS	8
Figure 8. Response to Survey Question 6—HPS	9
Figure 9. Response to Survey Question 7—HPS	9
Figure 10. Response to Survey Question 8—HPS	9
Figure 11. Response to Survey Question 9—HPS	10
Figure 12. Response to Survey Question 10—HPS	10
Figure 13. Response to Survey Question 11—HPS	10
Figure 14. Response to Survey Question 12—HPS	11
Figure 15. Response to Survey Question 13—HPS	11
Figure 16. Response to Survey Question 14—HPS	11
Figure 17. Response to Survey Question 15—HPS	12
Figure 18. Response to Survey Question 16—HPS	12
Figure 19. Response to Survey Question 17—HPS	12
Figure 20. Response to Survey Question 18—HPS	13
Figure 21. LED and HPS Performance—Preliminary Analysis	14
Figure 22. LED Luminaire Locations	16
Figure 23. Central Avenue with LED Lighting	20
Figure 24. Response to Survey Question 1—LED A (3000 K).....	21
Figure 25. Response to Survey Question 2—LED A (3000 K).....	21
Figure 26. Response to Survey Question 3—LED A (3000 K).....	22
Figure 27. Response to Survey Question 4—LED A (3000 K).....	22
Figure 28. Response to Survey Question 5—LED A (3000 K).....	22
Figure 29. Response to Survey Question 6—LED A (3000 K).....	23
Figure 30. Response to Survey Question 7—LED A (3000 K).....	23
Figure 31. Response to Survey Question 8—LED A (3000 K).....	23
Figure 32. Response to Survey Question 9—LED A (3000 K).....	24
Figure 33. Response to Survey Question 10—LED A (3000 K).....	24
Figure 34. Response to Survey Question 11—LED A (3000 K).....	24
Figure 35. Response to Survey Question 12—LED A (3000 K).....	25
Figure 36. Response to Survey Question 13—LED A (3000 K).....	25
Figure 37. Response to Survey Question 14—LED A (3000 K).....	25
Figure 38. Response to Survey Question 15—LED A (3000 K).....	26
Figure 39. Response to Survey Question 16—LED A (3000 K).....	26
Figure 40. Response to Survey Question 17—LED A (3000 K).....	26
Figure 41. Response to Survey Question 18—LED A (3000 K).....	27
Figure 42. Response to Survey Question 1—LED A (4000 K), East and West Sections	27

Figure 43. Response to Survey Question 2—LED A (4000 K), East and West Sections	27
Figure 44. Response to Survey Question 3—LED A (4000 K), East and West Sections	28
Figure 45. Response to Survey Question 4—LED A (4000 K), East and West Sections	28
Figure 46. Response to Survey Question 5—LED A (4000 K), East and West Sections	28
Figure 47. Response to Survey Question 6—LED A (4000 K), East and West Sections	29
Figure 48. Response to Survey Question 7—LED A (4000 K), East and West Sections	29
Figure 49. Response to Survey Question 8—LED A (4000 K), East and West Sections	29
Figure 50. Response to Survey Question 9—LED A (4000 K), East and West Sections	30
Figure 51. Response to Survey Question 10—LED A (4000 K), East and West Sections	30
Figure 52. Response to Survey Question 11—LED A (4000 K), East and West Sections	30
Figure 53. Response to Survey Question 12—LED A (4000 K), East and West Sections	31
Figure 54. Response to Survey Question 13—LED A (4000 K), East and West Sections	31
Figure 55. Response to Survey Question 14—LED A (4000 K), East and West Sections	31
Figure 56. Response to Survey Question 15—LED A (4000 K), East and West Sections	32
Figure 57. Response to Survey Question 16—LED A (4000 K), East and West Sections	32
Figure 58. Response to Survey Question 17—LED A (4000 K), East and West Sections	32
Figure 59. Response to Survey Question 18—LED A (4000 K), East and West Sections	33
Figure 60. Response to Survey Question 1—LED B	33
Figure 61. Response to Survey Question 2—LED B	33
Figure 62. Response to Survey Question 3—LED B	34
Figure 63. Response to Survey Question 4—LED B	34
Figure 64. Response to Survey Question 5—LED B	34
Figure 65. Response to Survey Question 6—LED B	35
Figure 66. Response to Survey Question 7—LED B	35
Figure 67. Response to Survey Question 8—LED B	35
Figure 68. Response to Survey Question 9—LED B	36
Figure 69. Response to Survey Question 10—LED B	36
Figure 70. Response to Survey Question 11—LED B	36
Figure 71. Response to Survey Question 12—LED B	37
Figure 72. Response to Survey Question 13—LED B	37
Figure 73. Response to Survey Question 14—LED B	37
Figure 74. Response to Survey Question 15—LED B	38
Figure 75. Response to Survey Question 16—LED B	38
Figure 76. Response to Survey Question 17—LED B	38
Figure 77. Response to Survey Question 18—LED B	39
Figure 78. Response to Survey Question 1—LED C	39
Figure 79. Response to Survey Question 2—LED C	39
Figure 80. Response to Survey Question 3—LED C	40
Figure 81. Response to Survey Question 4—LED C	40
Figure 82. Response to Survey Question 5—LED C	40
Figure 83. Response to Survey Question 6—LED C	41
Figure 84. Response to Survey Question 7—LED C	41
Figure 85. Response to Survey Question 8—LED C	41
Figure 86. Response to Survey Question 9—LED C	42

Figure 87. Response to Survey Question 10—LED C	42
Figure 88. Response to Survey Question 11—LED C	42
Figure 89. Response to Survey Question 12—LED C	43
Figure 90. Response to Survey Question 13—LED C	43
Figure 91. Response to Survey Question 14—LED C	43
Figure 92. Response to Survey Question 15—LED C	44
Figure 93. Response to Survey Question 16—LED C	44
Figure 94. Response to Survey Question 17—LED C	44
Figure 95. Response to Survey Question 18—LED C	45

Acronyms and Abbreviations

CCT	correlated color temperature
CDTC	Capital District Transportation Committee
ft	feet
HPS	high pressure sodium
hr	hours
K	kelvins
kWh	kilowatt hours
LED	light emitting diode
LRC	Lighting Research Center
NYS	New York State
NYSDOT	New York State Department of Transportation
NYSERDA	New York State Energy Research and Development Authority
PON	Program Opportunity Notice
UTRC	University Transportation Research Center
W	watts

Executive Summary

The use of light emitting diode (LED) roadway lighting is growing throughout New York State and the rest of the country, because of the potential for longer effective life and reduced energy compared to high pressure sodium (HPS) lighting systems. While the technological feasibility of LED roadway lighting systems has been established, the impacts of LEDs on the economics of roadway lighting are situationally dependent. In many municipalities, roadway lighting is owned and maintained by the local electric utility. Entities such as the New York State Comptroller's Office have advocated for municipalities to purchase their roadway lighting systems from the utility, and economic analyses suggest a substantial cost savings can be achieved in this way. Utility-owned roadway lighting is still attractive, however, for many municipalities who are not prepared to purchase and maintain their lighting network. In the present project, LED luminaires were installed along a major arterial roadway by the local utility. The LED lighting was selected to improve the visual conditions while using less energy. Over 30% energy savings were realized, although utility costs were not reduced by the same amount. Subjective evaluations of the previous HPS and each type of LED revealed that the LED lighting was judged to be an improvement over the HPS lighting conditions.

1 Background

Presently, the majority of roadway lighting in the United States uses high pressure sodium (HPS) light source technology (Navigant Consulting 2012). The use of light emitting diode (LED) technology is growing rapidly for roadway lighting throughout the country, including among New York State's 1.4 million streetlights (Winner and Arnold 2015). Among the reasons for the rise of LED roadway lighting technology are increased useful life, higher luminous efficacy and potentially improved visual effectiveness. Published literature has shown consistent improvements in LED roadway luminaire performance since 2010 (Radetsky 2010, 2011; Bullough 2012; Bullough and Radetsky 2013; Bullough et al. 2015), and performance has exceeded that of HPS lighting systems.

One important barrier to more widespread installation of LED streetlights has been the lack of utility tariff structures facilitating this change. The majority of streetlighting systems in New York State are owned by the local electric utility and paid for through a flat tariff that includes installation and initial costs as well as the energy and maintenance costs. Under this type of tariff, the utility performs all of the installation and maintenance work on the lighting system. As an alternative, the municipality could purchase its streetlighting system from their local utility based on the present worth of the system, and then pay the utility only for energy and delivery charges, while performing its own maintenance and eventually purchasing and installing new lighting when the system reaches the end of its life. It has been pointed out that municipal ownership of streetlighting and conversion to a more efficient technology such as LED would result in substantial cost savings to NYS municipalities (NYS Office of the Comptroller 2012; Winner and Arnold 2015). Having the necessary funds up front to purchase the lighting system and the personnel required to perform the maintenance and installation has been a barrier for some municipalities.

More recently, utilities in the State have begun to issue tariffs for utility-owned LED streetlighting, which do not require municipalities to purchase, install, or maintain the lighting system, but provides the opportunity to reduce costs, although the cost savings are smaller than would be achievable through municipal ownership of the lighting because LED luminaires are still expensive in terms of initial costs, compared to HPS lighting systems.

In 2014–2015, the New York State Department of Transportation (NYSDOT) commissioned a study to investigate the feasibility of LED roadway lighting in retrofit scenarios (Bullough et al. 2015). Two roadway scenarios were evaluated, a freeway (Southern State Parkway on Long Island) and a major arterial roadway (NYS Route 5/Central Avenue in Colonie, NY). In general, it was found that LED retrofit luminaires could be used along both of these roadways to increase the light levels over the existing conditions (in both cases the existing lighting was designed in the 1970s and 1980s when traffic volumes on both roads were much lower than current traffic conditions), while still resulting in energy savings of 20% to 30% or more.

The Central Avenue location was of interest to NYSDOT because this was an area where a pedestrian safety study (Creighton Manning 2014) found that improved lighting, among other improvements, could help reduce the number of pedestrian crashes along this road. Building on this study and the NYSDOT study of retrofit LED lighting, the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute responded to a joint Program Opportunity Notice (PON) from the New York State Energy Research and Development Authority (NYSERDA) and NYSDOT. The objective of the PON was to replace HPS streetlights between Madison Avenue and Reber Street in the Town and Village of Colonie with several types of LED luminaires in cooperation with National Grid, Creighton Manning, the Town and Village of Colonie, and the Capital District Transportation Committee (CDTC). In-kind support was provided by many of these organizations and cost-sharing was provided by the Region 2 University Transportation Research Center (UTRC) at City University of New York.

2 Previous Conditions

This section of the report describes the previous lighting conditions along Central Avenue, before installation of LED luminaires.

2.1 Energy and Economics

The section of Central Avenue under evaluation was a 3.4-mile stretch from Madison Avenue to Reber Street, illuminated by a mix of 151 HPS cobrahead style luminaires (Figure 1) containing a range of lamp wattages (in conjunction with ballast power to operate the lamps, the total power is also listed), as follows:

- 70 W HPS (86 W total): 1
- 100 W HPS (118 W total): 18
- 150 W HPS (173 W total): 58
- 250 W HPS (304 W total): 62
- 400 W HPS (470 W total): 12

Assuming an average use of 12 hour (hr) per day over the year, the annual energy use for the HPS lighting system along this segment of Central Avenue was 153,172 kilowatt-hour (kW) per year.

The annual cost for the utility-owned streetlights was \$30,772 (annual equipment costs of \$57.36 for 150 watt (W) and lower luminaires or \$74.64 for 250 W and higher, and \$0.136/kWh for energy and delivery charges).

2.2 Lighting System Performance

Figure 1. HPS Luminaire Type

Photograph of an HPS luminaire mounted on a utility pole along Central Avenue.



The luminaires were mounted on existing utility poles along both sides of the roadway, with a 2-foot (ft) setback from the road edge and an approximately 8 ft mast arm length. Because of the presence of many driveways for the extensive commercial development along this section of Central Avenue, the utility pole spacing is irregular, and luminaires are not mounted to every pole. A typical spacing between luminaires along the same side of the road is 200 ft, but luminaires can be farther or closer apart in distance.

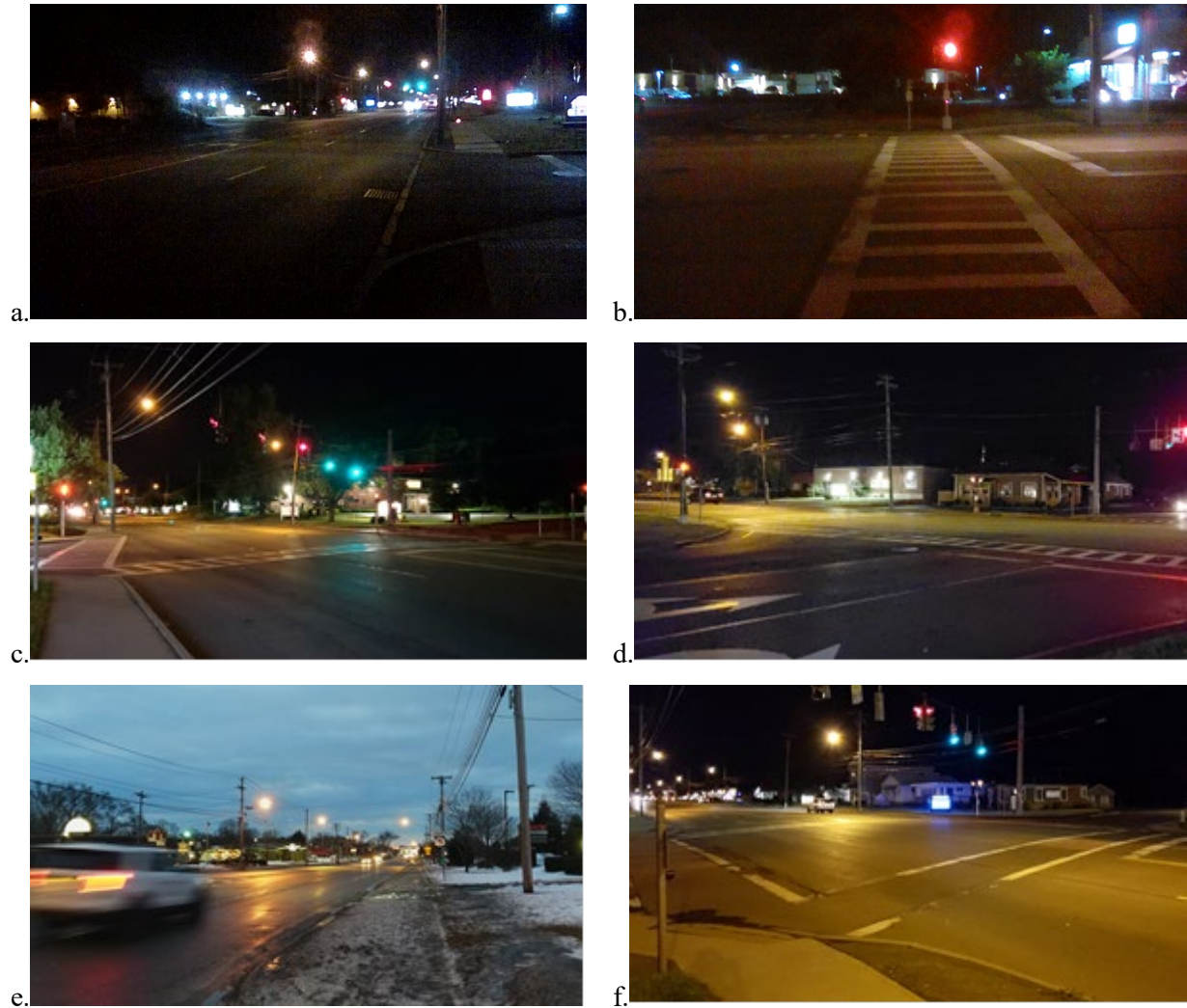
Along this section, Central Avenue contains two lanes of traffic in each direction with a turn lane in the center, along with several traffic signal-controlled intersections containing multiple signal-controlled crosswalks. The section of the road travels through both the Village and the Town of Colonie. Each municipality pays the utility bill associated with the luminaires within its boundaries, and the streetlights were owned and maintained by the local electric utility, National Grid.

Several photographs of Central Avenue with the HPS lighting are shown in Figure 2.

Figure 2. Central Avenue with HPS Lighting

Photographs of several locations along the relevant part of Central Avenue illuminated by HPS lighting at night.

Sources: Sandra Misiewicz, Capital District Transportation Committee (c, d, f); Owais Memon, NYSDOT (e).



The Visual Roadway Tool (Acuity Brands) was used to perform calculations of the approximate light levels along Central Avenue with the HPS lighting. A luminaire spacing of 200 ft in a staggered formation was assumed for these calculations as an approximation of their irregular layout. Calculations of the average horizontal illuminance on the roadway were made assuming each of the lamp wattages listed in section 2.1 and were as follows:

- 70 W HPS: 4 lux average
- 100 W HPS: 5 lux average
- 150 W HPS: 9 lux average
- 250 W HPS: 16 lux average
- 400 W HPS: 29 lux average

Taking the number of luminaires of each wattage into account, the average illuminance along Central Avenue was estimated to be 13 lux. In general, the higher HPS wattages tended to be located closer to the junctions between Central Avenue, and Interstate 87 and Wolf Road, in the eastern portion of this segment of Central Avenue, where a large shopping mall was located, so that the average illuminances were likely higher than 13 lux near this location, and lower in the western portion of the segment.

In addition, light levels along crosswalks and sidewalks were measured in selected locations. In crosswalks, the average horizontal illuminance was 9 lux (see appendix A). On sidewalks near Reber Street and near Nicholas Drive, the average horizontal illuminances were 4 lux and 9 lux, respectively.

2.3 Survey Questionnaire Evaluation

Following the project kickoff, the project team developed a questionnaire geared for members of the public as a way to gather input about how the roadway lighting was perceived along this section of Central Avenue. The survey included the following numbered statements with which respondents were asked to record their level of agreement or disagreement:

- Overall:
 1. I like the lighting.
 2. The lighting is comfortable.
 3. The street looks bright.
 4. The street looks gloomy.
 5. The streetlights are too bright.
 6. Colors of traffic signs appear clear.
 7. Colors of vegetation look natural.
 8. The lighting is too warm in color for a street.
 9. The lighting is too cool in color for a street.
 10. The lighting looks better than other streets.
- As a driver:
 1. I can see the roadway pavement clearly.
 2. I can see other vehicles clearly.
 3. I can see pedestrians approaching clearly.
 4. I feel safe when driving on this street.

- As a pedestrian:
 1. I can see other pedestrians approaching clearly.
 2. I can see faces of other pedestrians clearly.
 3. I can see vehicles approaching clearly.
 4. I feel secure while walking along this street.

Notice of the survey was published in the weekly newspaper *Pennysaver*, distributed by the town and village to residents, and shared on Facebook pages by several community organizations in the Town and Village of Colonie. A total of 30 people responded to the survey. Since some questions were specific to opinions about the lighting from the perspective of a driver or of a pedestrian, not all respondents answered all questions. Figures 3 through 20 show the distribution of responses to each statement. In general, the HPS lighting system along this segment of Central Avenue was not judged positively.

Figure 3. Response to Survey Question 1—HPS

I like the lighting.

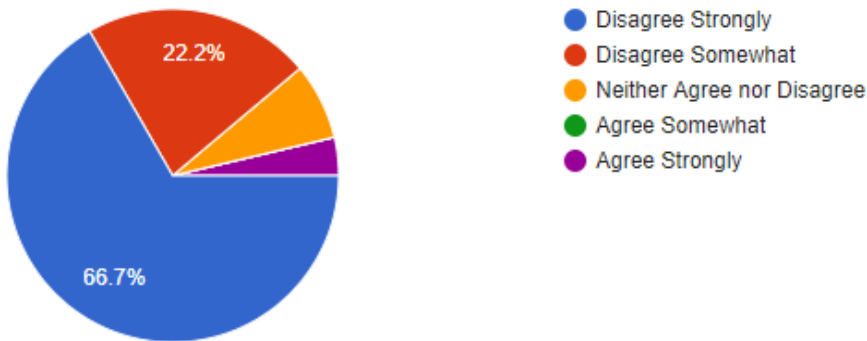


Figure 4. Response to Survey Question 2—HPS

The lighting is comfortable.

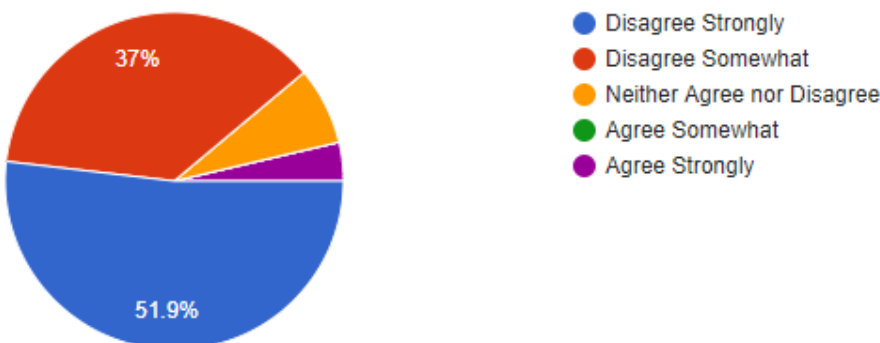


Figure 5. Response to Survey Question 3—HPS

The street looks bright.

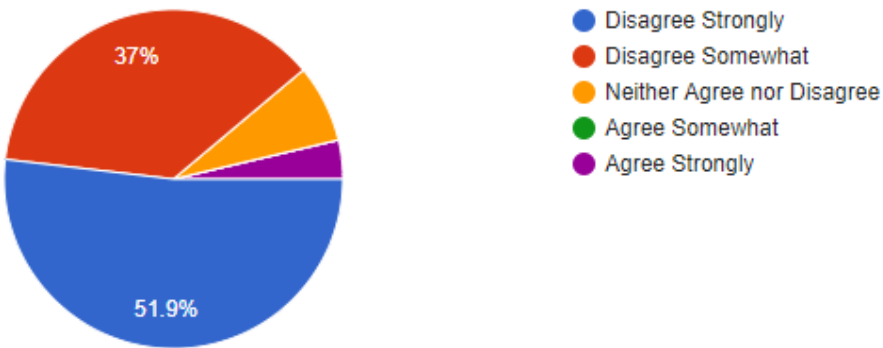


Figure 6. Response to Survey Question 4—HPS

The street looks gloomy.

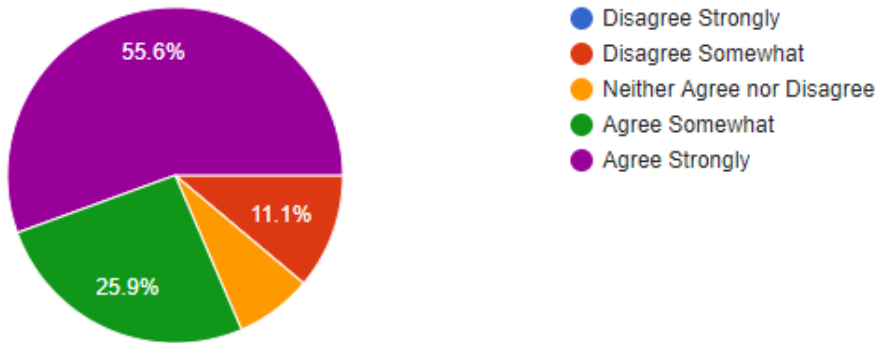


Figure 7. Response to Survey Question 5—HPS

The streetlights are too bright.

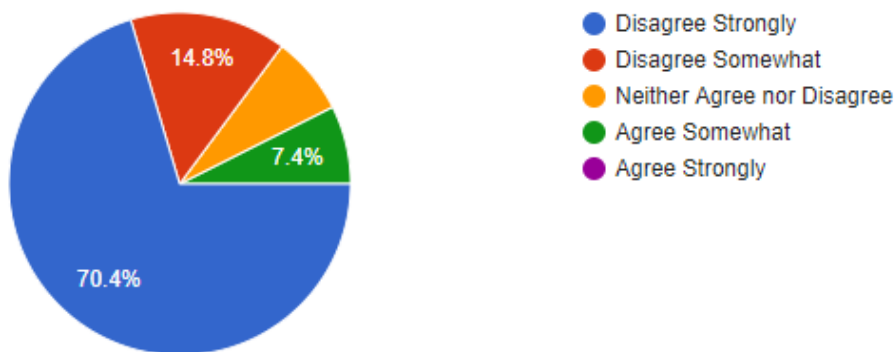


Figure 8. Response to Survey Question 6—HPS

Colors of traffic signs appear clear.

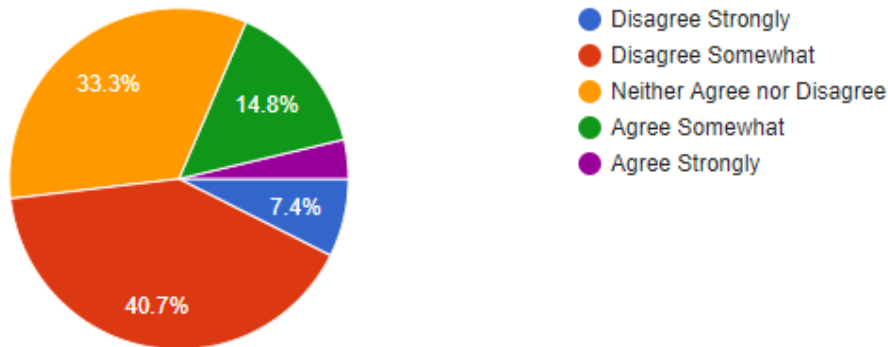


Figure 9. Response to Survey Question 7—HPS

Colors of vegetation look natural.

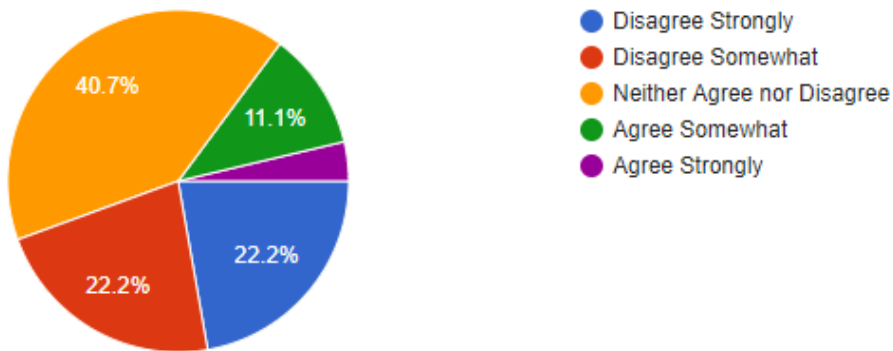


Figure 10. Response to Survey Question 8—HPS

The lighting is too warm in color for a street.

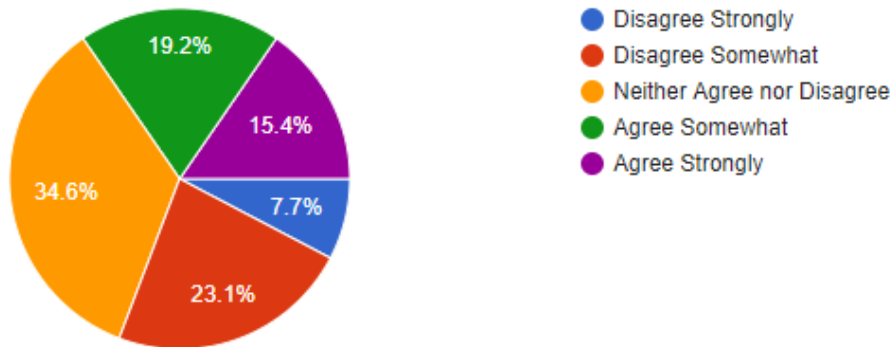


Figure 11. Response to Survey Question 9—HPS

The lighting is too cool in color for a street.

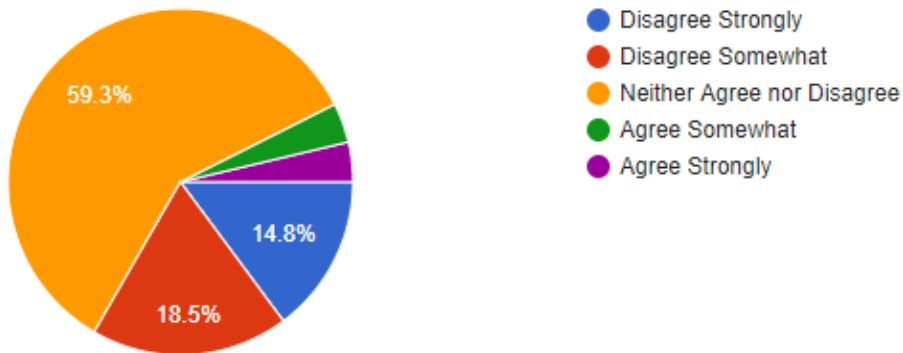


Figure 12. Response to Survey Question 10—HPS

The lighting looks better than other streets.

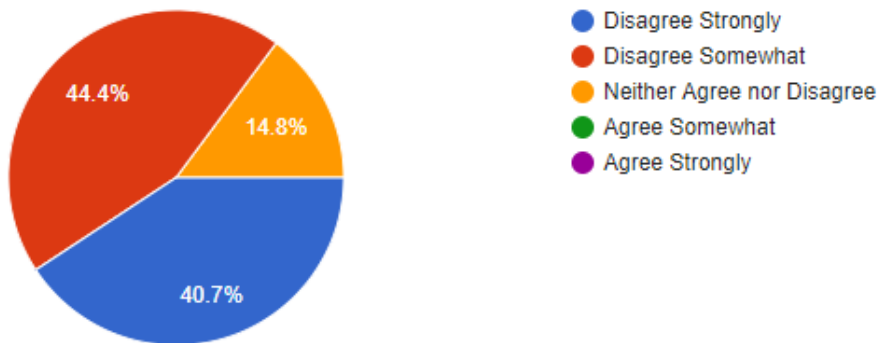


Figure 13. Response to Survey Question 11—HPS

As a driver, I can see the roadway pavement clearly.

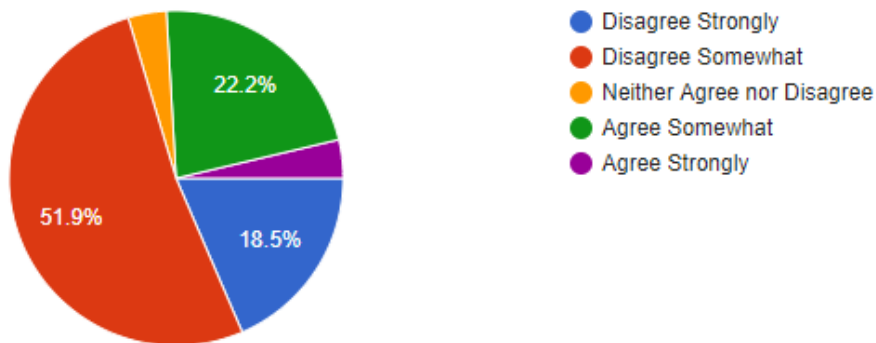


Figure 14. Response to Survey Question 12—HPS

As a driver, I can see other vehicles approaching clearly.

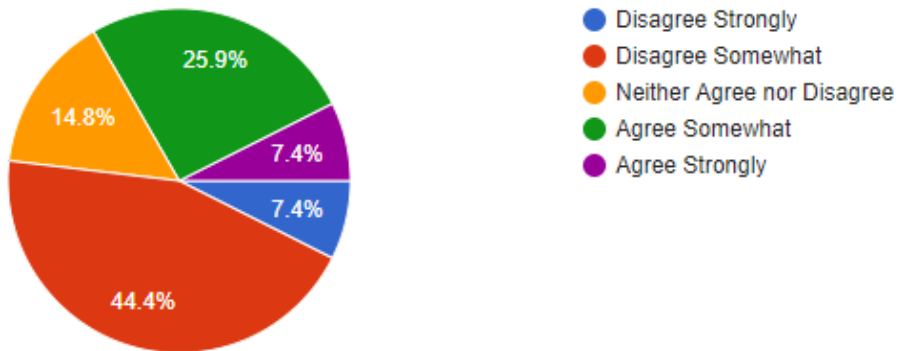


Figure 15. Response to Survey Question 13—HPS

As a driver, I can see pedestrians approaching clearly.

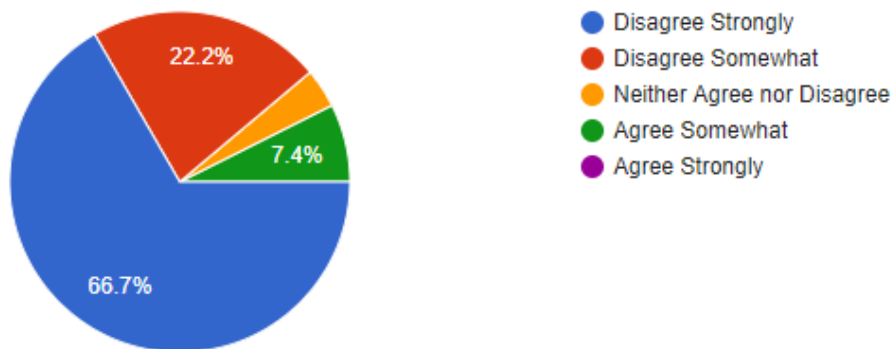


Figure 16. Response to Survey Question 14—HPS

As a driver, I feel safe when driving.

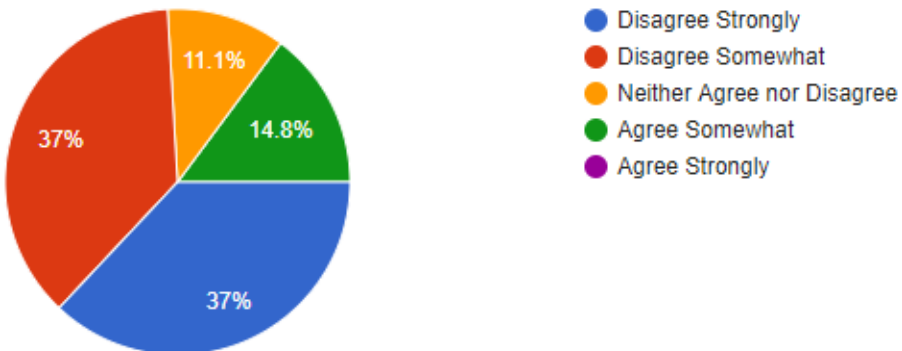


Figure 17. Response to Survey Question 15—HPS

As a pedestrian, I can see other pedestrians approaching clearly.

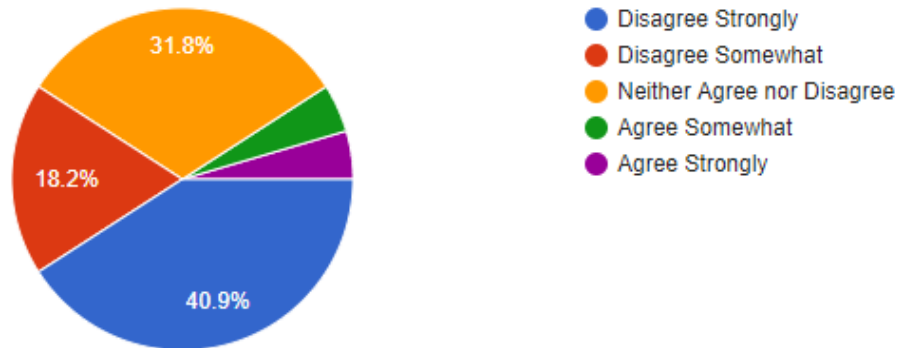


Figure 18. Response to Survey Question 16—HPS

As a pedestrian, I can see faces of other pedestrians clearly.

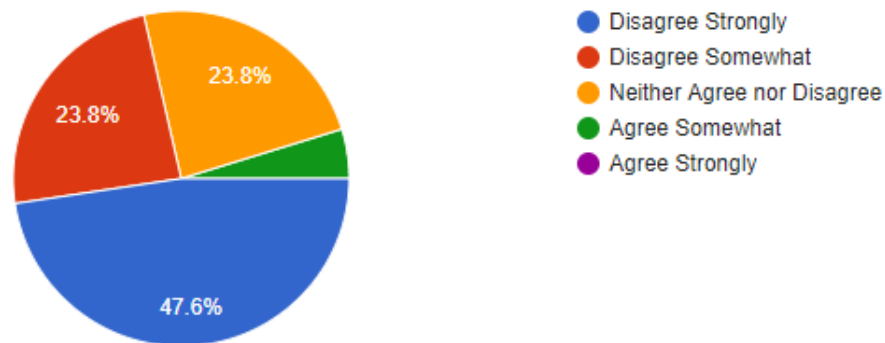


Figure 19. Response to Survey Question 17—HPS

As a pedestrian, I can see vehicles approaching clearly.

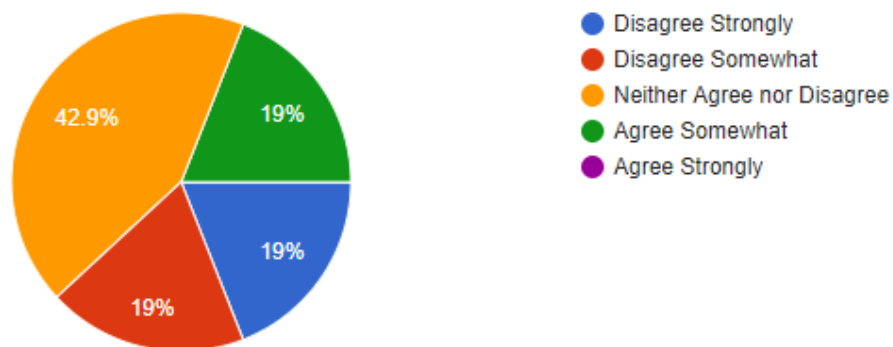
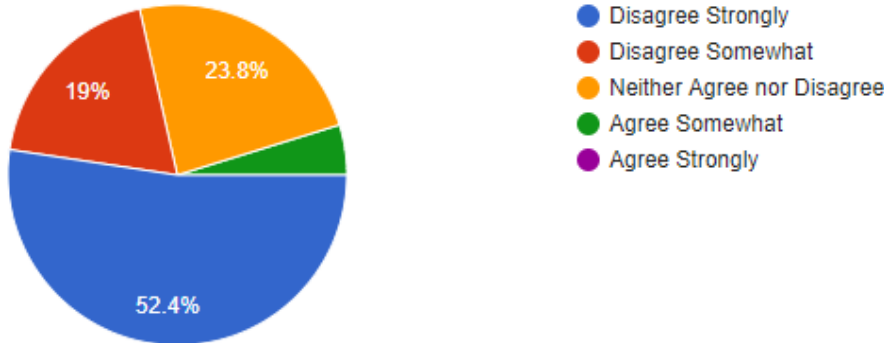


Figure 20. Response to Survey Question 18—HPS

As a pedestrian, I feel secure while walking along this street



3 Selection of LED Luminaires

The project team had two primary objectives in selecting LED luminaires to replace the existing HPS lighting system on the section of Central Avenue:

- Increase light levels over the existing conditions
- Use less energy than was being used by the HPS lighting system

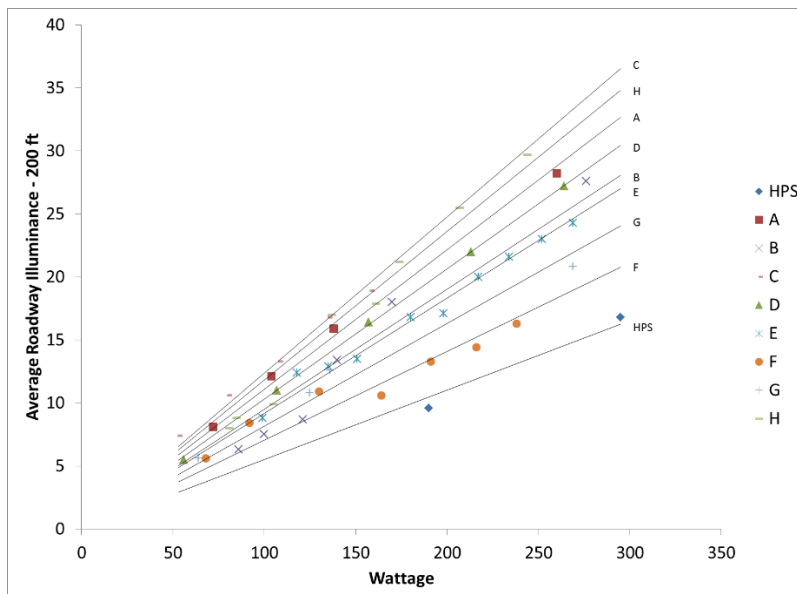
3.1 Photometric Performance

Photometric data for a range of LED luminaire wattages from about 50 W to 250 W, and for HPS cobrahead style luminaires using 150 W and 250 W HPS lamps, were obtained from the websites of streetlight manufacturers. Eight LED products were identified in this preliminary stage, denoted A through H. In order to compare their performance, the average horizontal roadway illuminance was calculated using the Visual Roadway Tool for each wattage from each manufacturer, assuming a staggered layout and a pole spacing of 200 ft on each side of the roadway.

Not surprisingly, the average illuminance increased approximately linearly as a function of wattage for each luminaire manufacturer (Figure 21). All eight of the luminaires outperformed the HPS systems by providing higher average illuminances for the same or lower power.

Figure 21. LED and HPS Performance—Preliminary Analysis

Symbols and best fitting lines show the average horizontal illuminance in the roadway as a function of wattage.



Based on these results, the project team began to investigate availability and pricing for LED luminaires with the best performance. It was also decided in conjunction with project partners that one of the LED options should be the LED luminaire type selected by the local electric utility for utility-owned municipal streetlighting. In addition, the project team decided to select this luminaire type but with two correlated color temperatures (CCTs), 3000 K and 4000 K. This was chosen to determine whether these CCT options differed substantially in terms of their performance and in terms of subjective impressions after they were installed.

The three LED luminaire types that were selected for subsequent installation were types A, B and C. Type A was from American Electric and was used in 3000 K and 4000 K CCTs. Type B was from Cree, and type C was from LED Roadway Lighting. The LED luminaires for types B and C all had CCTs of 4000 K.

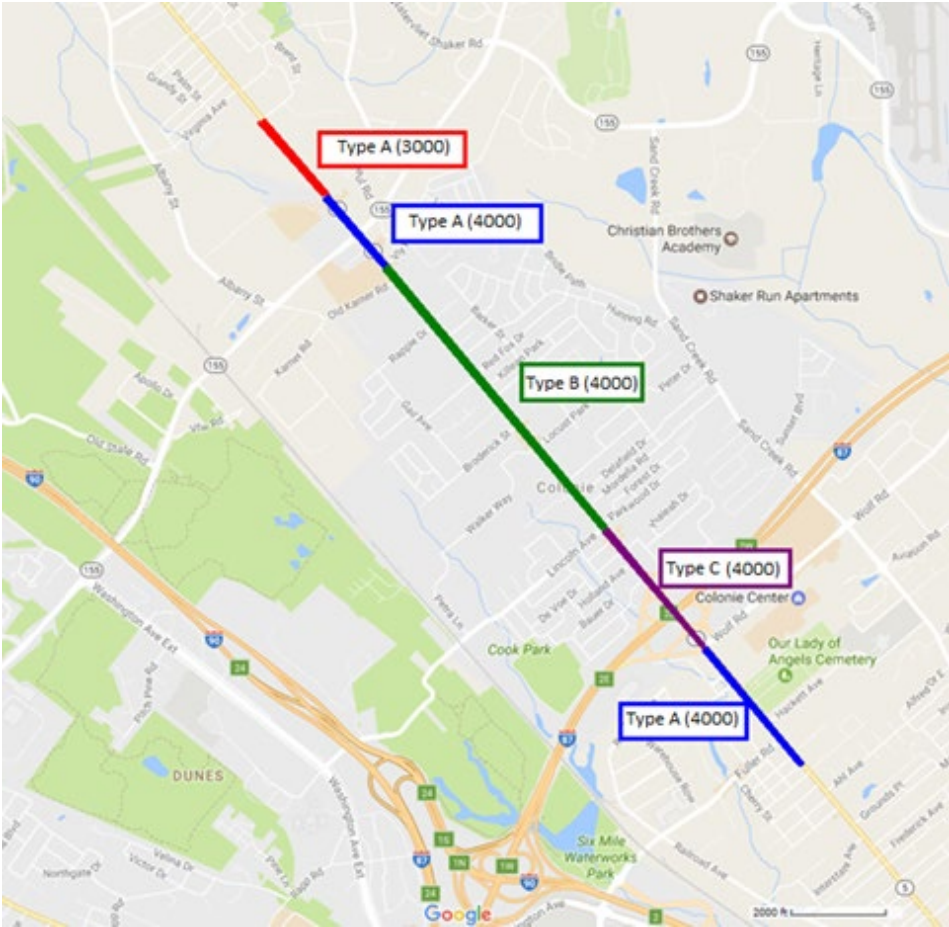
3.2 LED Luminaire Locations

The part of Central Avenue under investigation was divided into five segments, with a different LED luminaire type assigned to each segment as follows (from west to east, as illustrated in Figure 22):

- Reber Street to the entrance of Colonie Plaza: LED type A (3000 K)
- Colonie Plaza entrance to Vly Road: LED type A (4000 K)
- Vly Road to Lincoln Avenue: LED type B (4000 K)
- Lincoln Avenue to Wolf Road: LED type C (4000 K)
- Wolf Road to Madison Avenue: LED type A (4000 K)
- Figure 22. LED Luminaire Locations
- Colored portions of Central Avenue show the locations where each type (and CCT) of LED luminaire was installed.

Figure 22. LED Luminaire Locations

Colored portions of Central Avenue show the locations where each type (and CCT) of LED luminaire was installed.



3.3 Logistical Planning

Before the LED systems could be purchased, NYSDOT radio engineers expressed concern that some LED luminaires might produce electromagnetic noise that could interfere with the use of older radio equipment on NYSDOT highway maintenance vehicles, even if they conformed to Federal Communications Commission requirements for radio interference. Snow removal and other maintenance activities are performed by NYSDOT on Central Avenue, and NYSDOT radio communications are critical to operation on this arterial. Sample luminaires from each of the manufacturers were obtained by the project team and were tested for radio interference by personnel from NYSDOT, who confirmed that the luminaires to be installed did not produce excessive interference.

In addition to radio interference, several issues needed to be worked out among the LRC team members, the local electric utility, and the two municipalities involved, the Town and Village of Colonie. Ordinarily, when a municipality wishes to convert its utility-owned streetlighting system from HPS to LED, it is required to reimburse the utility for the nondepreciated value of the HPS system. For the streetlights along this part of Central Avenue, the amount was approximately \$24,000, which was paid for with project funds rather than by the town and village. Project funds in the amount of approximately \$12,000 were also used for the cost of traffic control required by NYSDOT for the eventual installation of the LEDs along this State highway.

Because the local utility only offers LED luminaires from one manufacturer (type A) as part of its tariff for utility-owned LED streetlighting, the utility agreed to purchase the LED luminaires from manufacturers B and C as part of the project. For billing purposes, the utility agreed with the town and village that the utility would bill the luminaires from manufacturers B and C based on the closest wattage for the LED luminaires from manufacturer A.

One of the tasks in the project that took the longest was in making these arrangements. Negotiations among the project partners took approximately a year to complete before the LED luminaires could be installed.

4 New Conditions

This section describes the performance of the LED lighting systems installed to replace the HPS luminaires along Central Avenue.

4.1 Energy and Economics

For each HPS wattage along Central Avenue, LED wattages from manufacturers A, B and C were selected, as listed below (wattages do not always match the wattages used to develop Figure 21 because some manufacturers released new products between the preliminary analysis and procurement):

- 70 W HPS: Type A—47 W; Type B—100 W; Type C—80 W
- 100 W HPS: Type A—95 W; Type B—100 W; Type C—80 W
- 150 W HPS: Type A—95 W; Type B—136 W; Type C—116 W
- 250 W HPS: Type A—209 W; Type B—163 W; Type C—158 W
- 400 W HPS: Type A—209 W; Type B—274 W; Type C—158 W

Annual operating costs for each of these luminaires are determined based on the tariff for utility-owned streetlighting as follows for each LED luminaire wattage:

- 47 W LED: \$88.68/year for luminaire; \$27.22/year for energy and delivery
- 80 W, 95 W, 100 W, 116 W, 136 W LED: \$110.28/year for luminaire; \$54.44/year for energy and delivery
- 158 W, 163 W, 209 W, 274 W LED: \$119.16/year for luminaire; \$119.10/year for energy and delivery

In total, the following numbers of LED luminaires of each type were installed to replace the existing HPS lighting system:

- Type A (3000 K), 95 W: 24 luminaires
- Type A (4000 K), 95 W: 8 luminaires
- Type A (4000 K), 209 W: 39 luminaires
- Type B, 100 W: 12 luminaires
- Type B, 136 W: 31 luminaires
- Type B, 163 W: 7 luminaires
- Type B, 274 W: 2 luminaires
- Type C, 116 W: 2 luminaires
- Type C, 158 W: 28 luminaires

Altogether, the LED luminaires along this part of Central Avenue will use 100,530 kWh/yr, a reduction of 34% from the amount of energy used by the HPS lighting. The total annual operating cost (including equipment, energy, and delivery) is \$30,315, a reduction of \$457 from the annual cost of the previous lighting system.

4.2 Lighting System Performance

In order to estimate the performance of the LED luminaires selected for the retrofit installation, photometric analyses of the average horizontal illuminance on the roadway were performed using the Visual Roadway Tool. Assuming a staggered layout with a 200-ft spacing on each side of the road, each luminaire type and wattage would be expected to produce the following average illuminances:

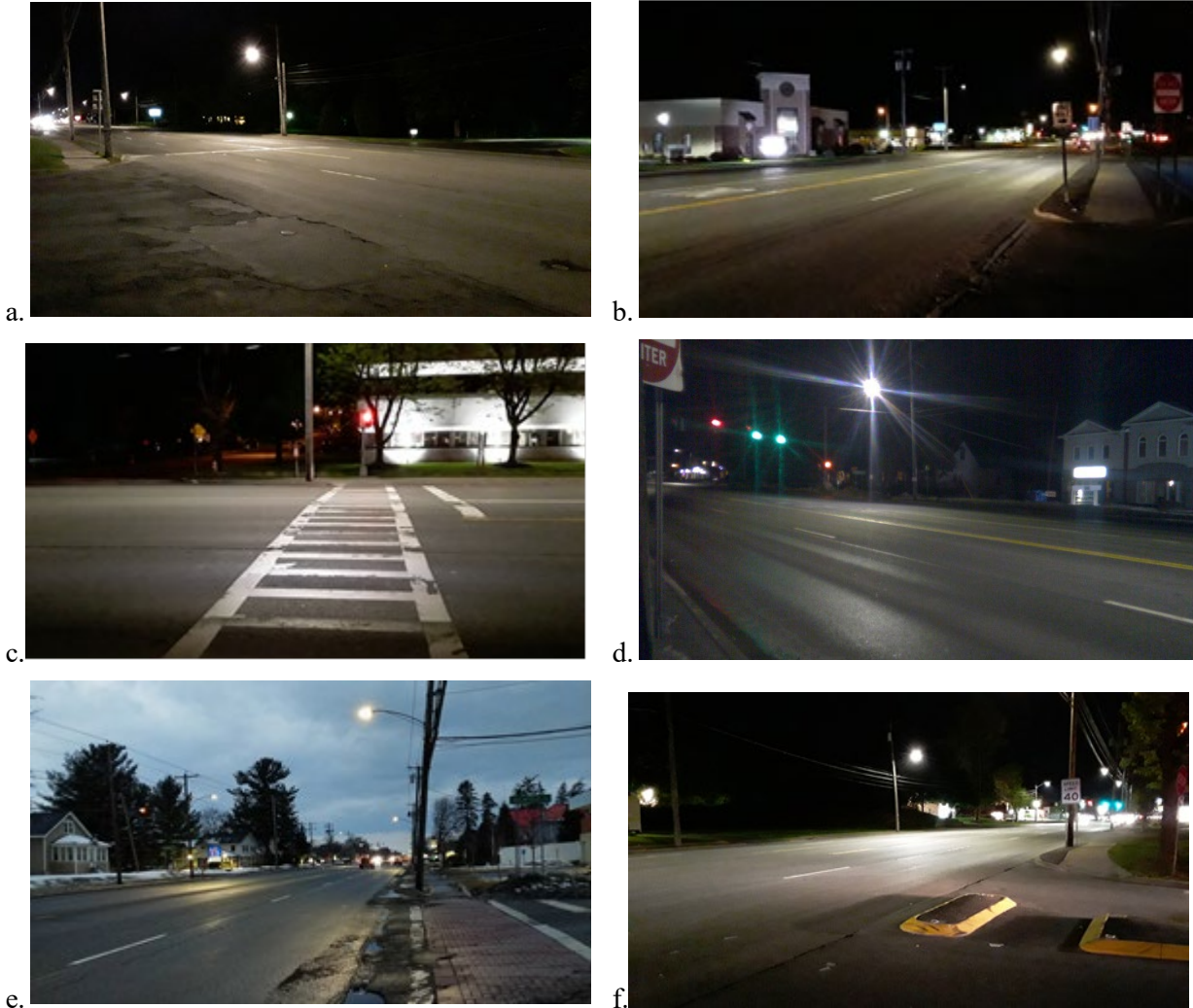
- Type A, 95 W: 14 lux
- Type A, 209 W: 25 lux
- Type B, 100 W: 8 lux
- Type B, 136 W: 17 lux
- Type B, 163 W: 21 lux
- Type B, 274 W: 32 lux
- Type C, 116 W: 18 lux
- Type C, 158 W: 22 lux

Taking into account the number of LED luminaires of each type and wattage, the average illuminance with the LED luminaires along this part of Central Avenue is estimated to be 19 lux, an increase over the HPS illuminance of 13 lux by over 40%. Figure 23 shows several photographs of Central Avenue with the LED lighting. Anecdotally, however, LED luminaires have often been claimed to have “tighter” optical distributions that focuses more light onto the road surface of the road and less on adjacent surfaces (such as sidewalks). This narrower distribution might also impact light levels in crosswalks at intersections where the orientation of luminaires might differ from their orientation along segments between intersections. Field measurements along crosswalks and sidewalks were made after the LED installation in the same locations that were measured with the HPS lighting. The average illuminance in crosswalks exceeded 10 lux, and on average, the illuminances exceeded the HPS levels by 15% (see appendix A). The average illuminance along the sidewalk near Reber Street was 5 lux, a 25% increase from the illuminance with HPS, and the average illuminance on the sidewalk near Nicholas Drive was 11 lux, a 16% increase from the HPS level. The smaller increases in illuminance for crosswalks and sidewalks compared to the increase within the roadway is consistent with the anecdotal notion that LED streetlighting luminaire distributions are narrower than those of HPS luminaires.

Figure 23. Central Avenue with LED Lighting

Photographs of several locations along Central Avenue illuminated by LED lighting at night.

Source(s): Owais Memon, NYSDOT (e).



4.3 Survey Questionnaire Evaluation

Following the installation, the project team developed a second questionnaire in order to obtain information about the newly installed LED lighting along each section of Central Avenue. The questions in the survey were the same as for the initial survey. A separate set of questions was included for each section containing a different type of LED luminaires. As with the previous survey, an online version of the questionnaire was prepared using Google Forms and a link to the survey was published in the weekly newspaper *LocalFirst* (formerly *Pennysaver*), posted on Facebook by several community groups, shared with Colonie residents by the town and village.

On May 22, 2019, several individuals participated in an evening session to visit sections of Central Avenue illuminated by each LED luminaire type and to complete a printed version of the same survey questions. A total of 26 individuals participated in the survey. Figures 24 through 41 show the distributions of responses for the LED type A (3000 K) lighting, Figures 42 through 59 for the LED Type A (4000 K) lighting, Figures 60 through 77 for the LED Type B lighting, and Figures 78 through 95 for the LED Type C lighting.

Figure 24. Response to Survey Question 1—LED A (3000 K)

I like the lighting.

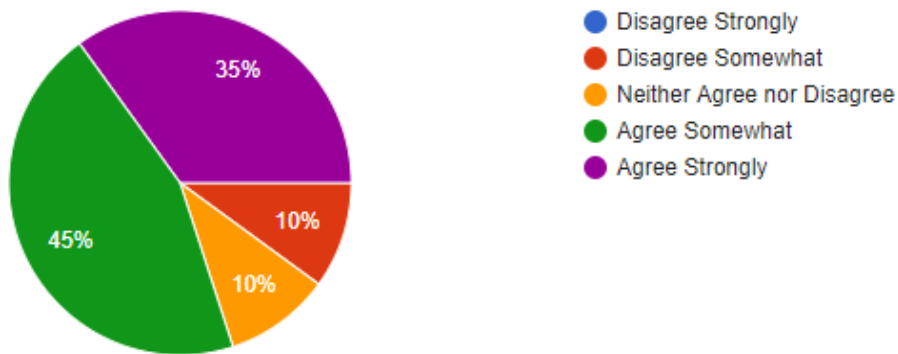


Figure 25. Response to Survey Question 2—LED A (3000 K)

The lighting is comfortable.

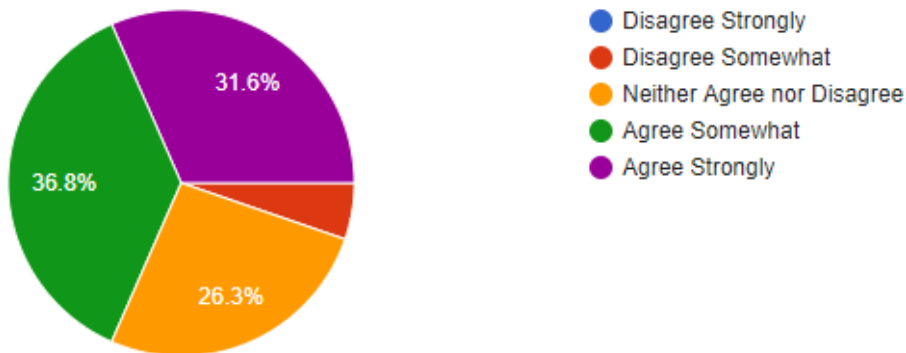


Figure 26. Response to Survey Question 3—LED A (3000 K)

The street looks bright.

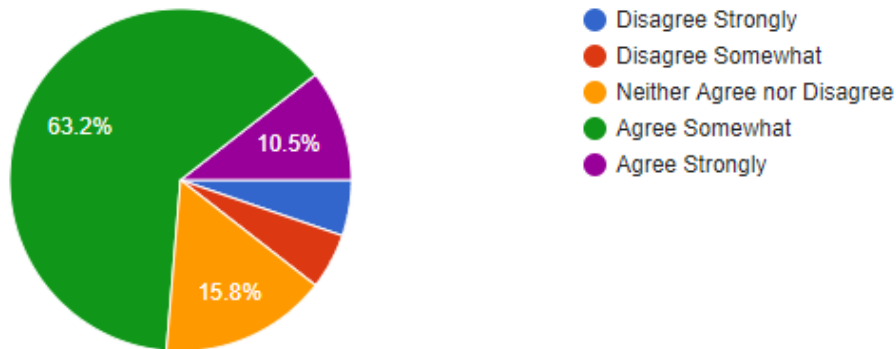


Figure 27. Response to Survey Question 4—LED A (3000 K)

The street looks gloomy.

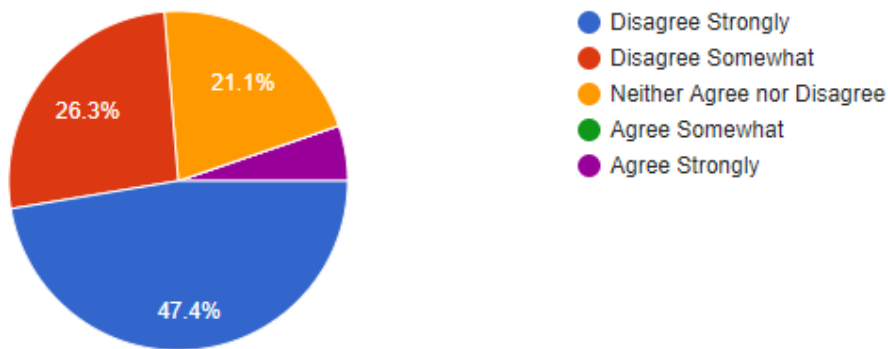


Figure 28. Response to Survey Question 5—LED A (3000 K)

The streetlights are too bright.

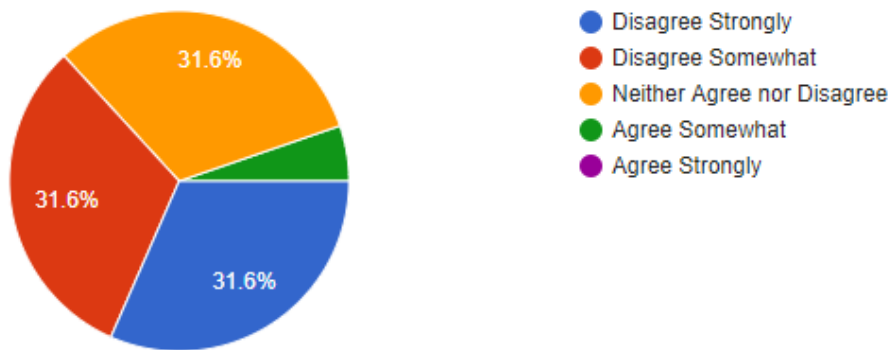


Figure 29. Response to Survey Question 6—LED A (3000 K)

Colors of traffic signs appear clear.

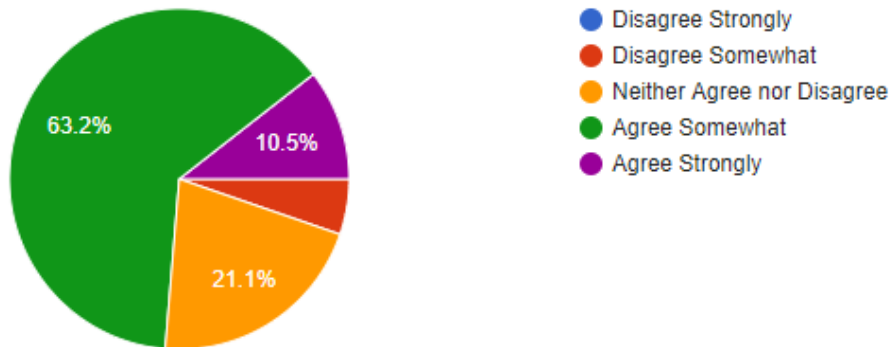


Figure 30. Response to Survey Question 7—LED A (3000 K)

Colors of vegetation look natural.

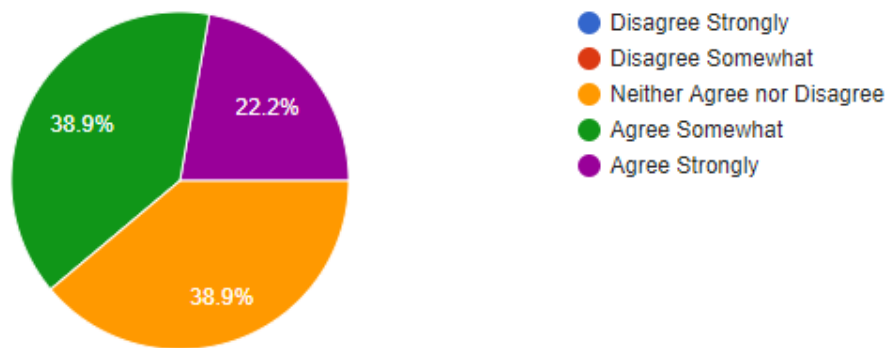


Figure 31. Response to Survey Question 8—LED A (3000 K)

The lighting is too warm in color for a street.

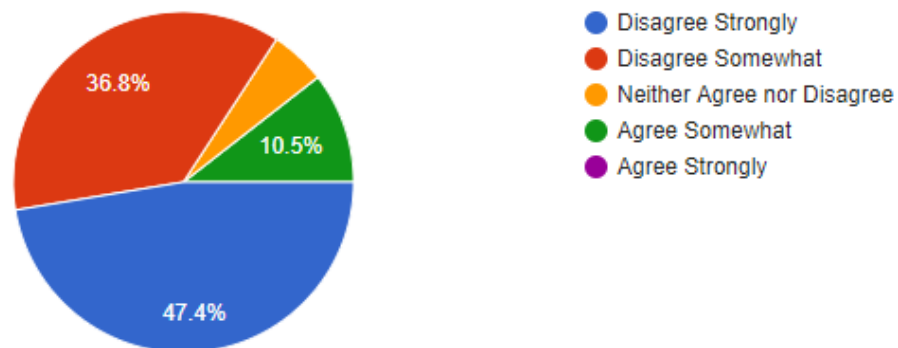


Figure 32. Response to Survey Question 9—LED A (3000 K)

The lighting is too cool in color for a street.

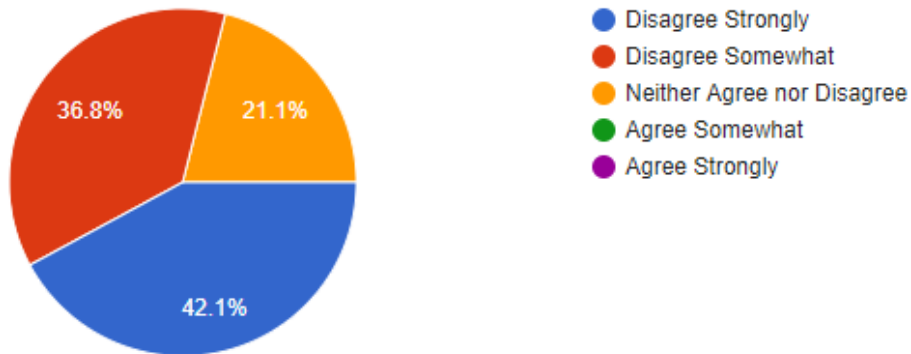


Figure 33. Response to Survey Question 10—LED A (3000 K)

The lighting looks better than other streets.

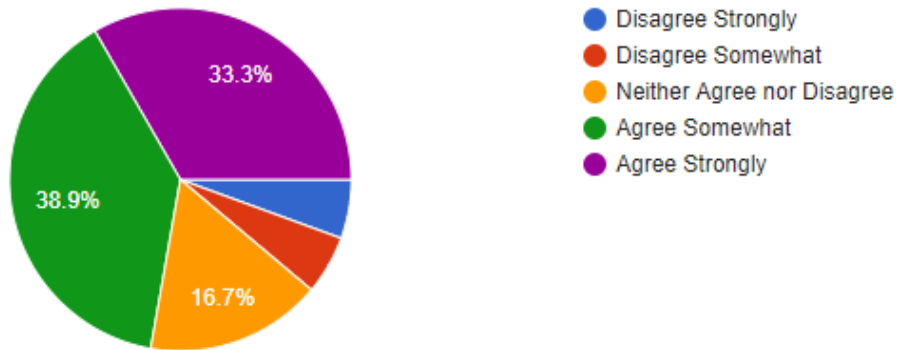


Figure 34. Response to Survey Question 11—LED A (3000 K)

As a driver, I can see the roadway pavement clearly.

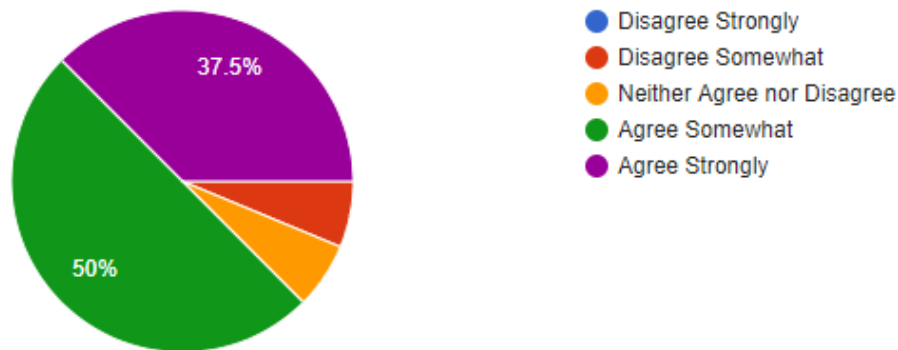


Figure 35. Response to Survey Question 12—LED A (3000 K)

As a driver, I can see other vehicles approaching clearly.

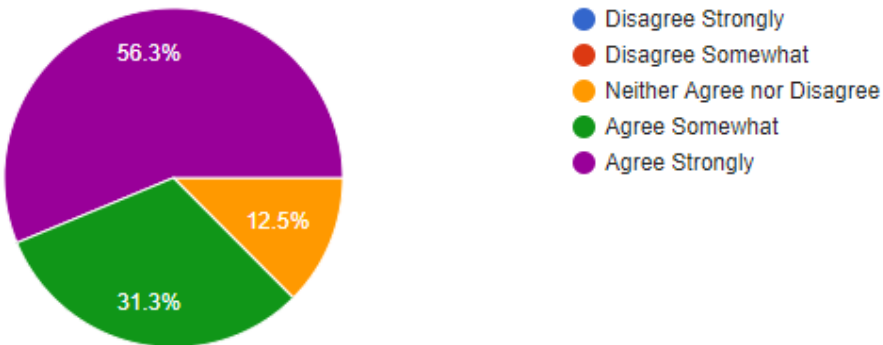


Figure 36. Response to Survey Question 13—LED A (3000 K)

As a driver, I can see pedestrians approaching clearly.

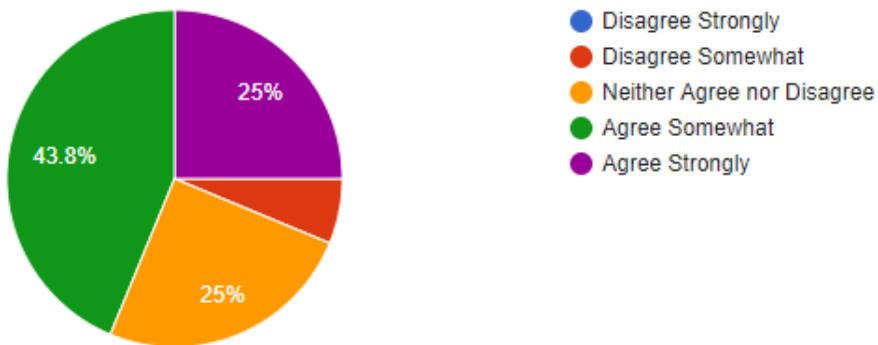


Figure 37. Response to Survey Question 14—LED A (3000 K)

As a driver, I feel safe when driving.

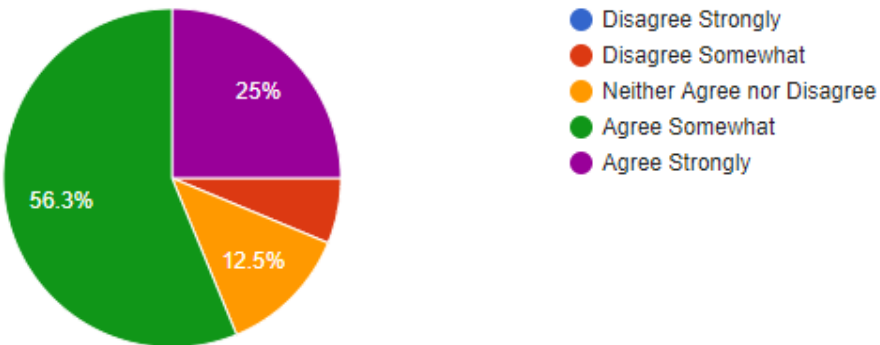


Figure 38. Response to Survey Question 15—LED A (3000 K)

As a pedestrian, I can see other pedestrians approaching clearly.

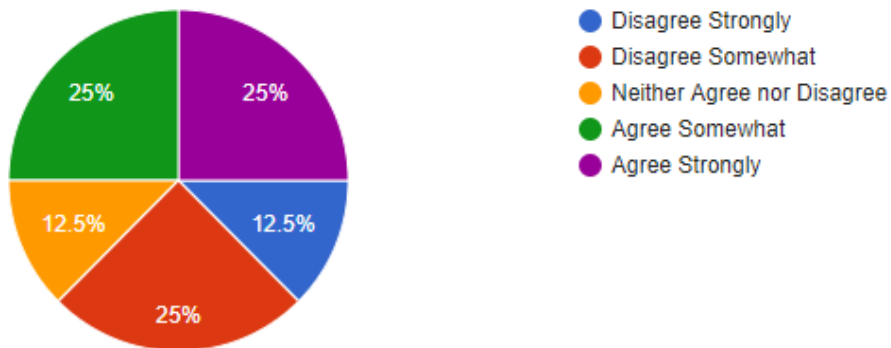


Figure 39. Response to Survey Question 16—LED A (3000 K)

As a pedestrian, I can see faces of other pedestrians clearly.

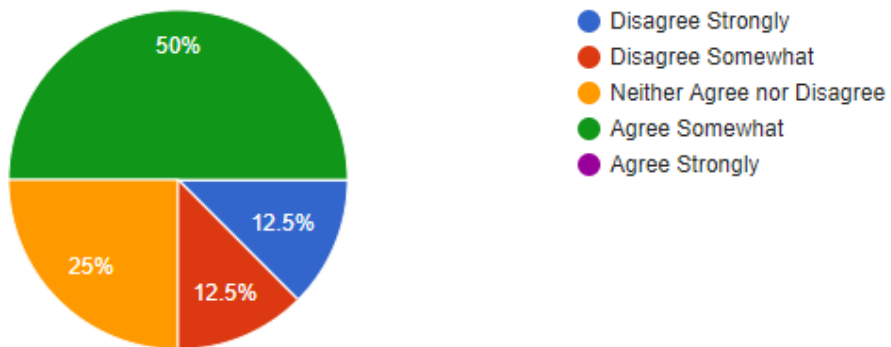


Figure 40. Response to Survey Question 17—LED A (3000 K)

As a pedestrian, I can see vehicles approaching clearly.

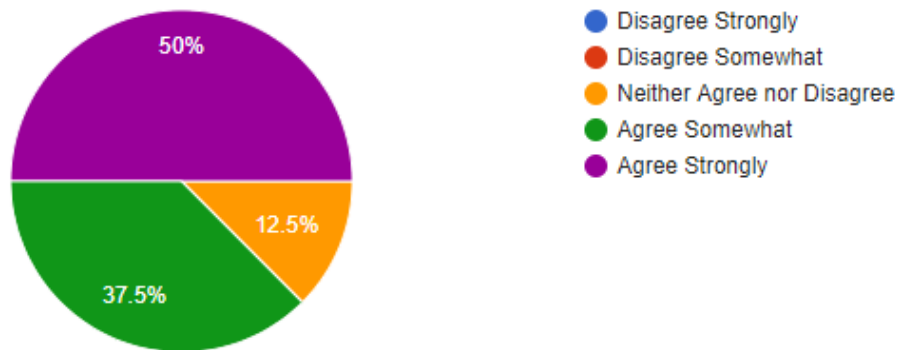


Figure 41. Response to Survey Question 18—LED A (3000 K)

As a pedestrian, I feel secure while walking along this street.

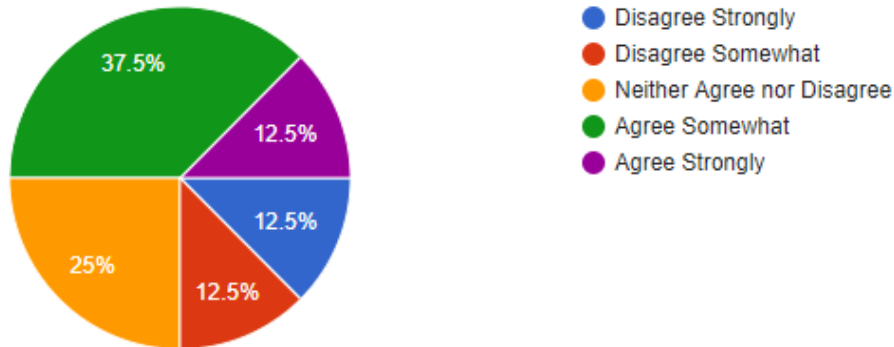
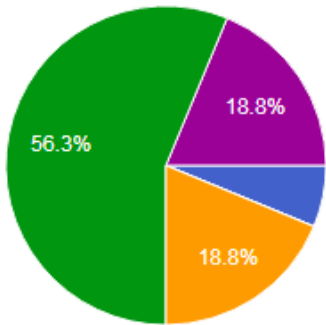


Figure 42. Response to Survey Question 1—LED A (4000 K), East and West Sections

I like the lighting.

East



West

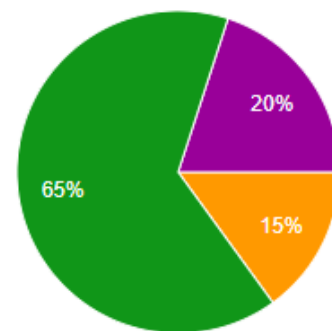
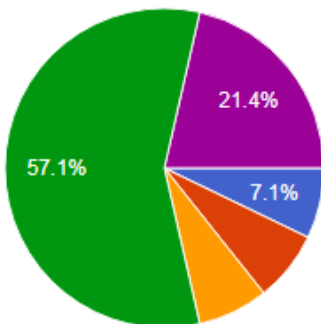


Figure 43. Response to Survey Question 2—LED A (4000 K), East and West Sections

The lighting is comfortable.

East



West

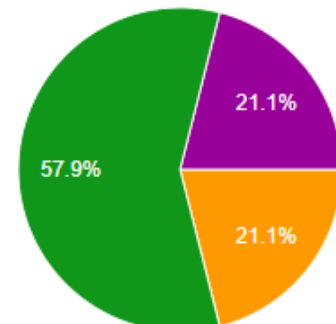
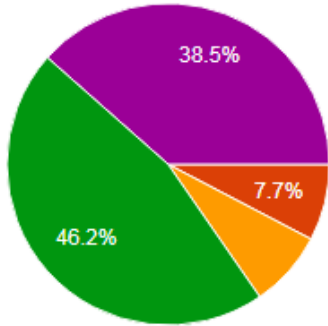


Figure 44. Response to Survey Question 3—LED A (4000 K), East and West Sections

The street looks bright.

East



West

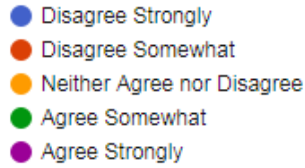
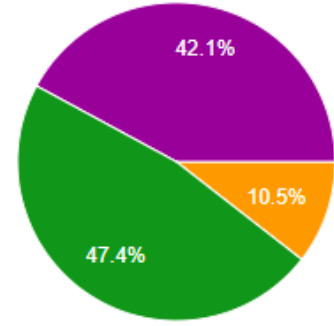
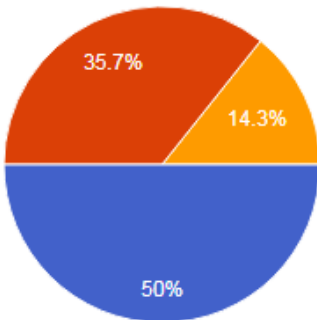


Figure 45. Response to Survey Question 4—LED A (4000 K), East and West Sections

The street looks gloomy.

East



West

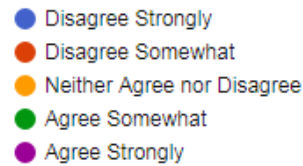
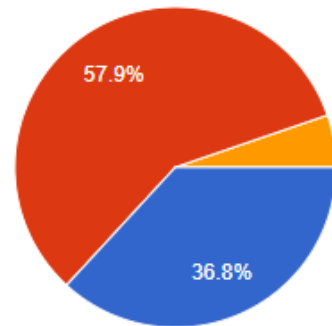
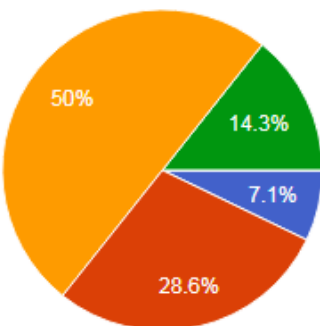


Figure 46. Response to Survey Question 5—LED A (4000 K), East and West Sections

The streetlights are too bright.

East



West

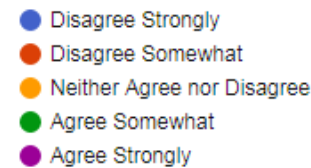
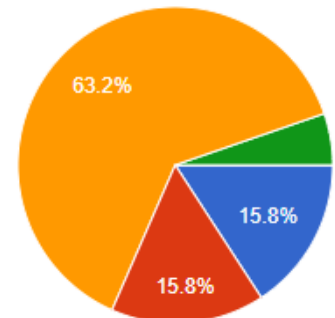
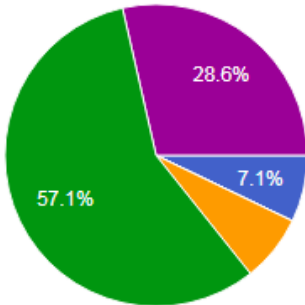


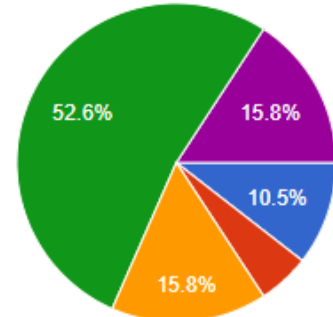
Figure 47. Response to Survey Question 6—LED A (4000 K), East and West Sections

Colors of traffic signs appear clear.

East



West

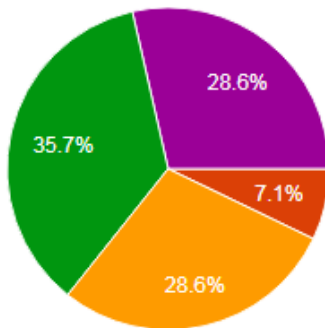


- Disagree Strongly
- Disagree Somewhat
- Neither Agree nor Disagree
- Agree Somewhat
- Agree Strongly

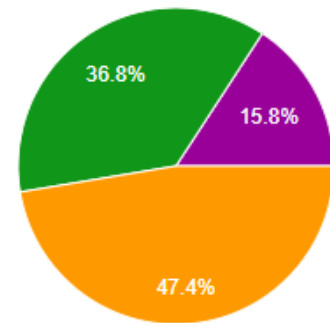
Figure 48. Response to Survey Question 7—LED A (4000 K), East and West Sections

Colors of vegetation look natural.

East



West

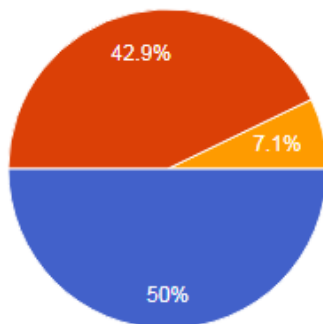


- Disagree Strongly
- Disagree Somewhat
- Neither Agree nor Disagree
- Agree Somewhat
- Agree Strongly

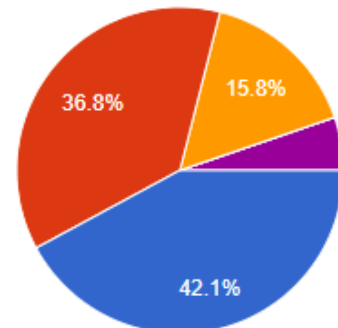
Figure 49. Response to Survey Question 8—LED A (4000 K), East and West Sections

The lighting is too warm in color for a street.

East



West

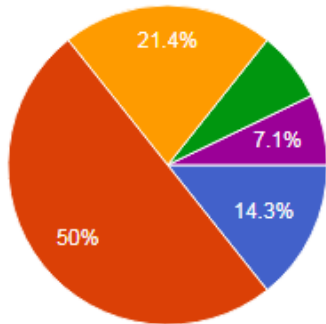


- Disagree Strongly
- Disagree Somewhat
- Neither Agree nor Disagree
- Agree Somewhat
- Agree Strongly

Figure 50. Response to Survey Question 9—LED A (4000 K), East and West Sections

The lighting is too cool in color for a street.

East



West

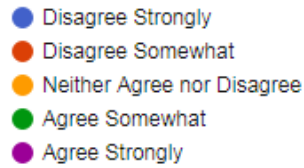
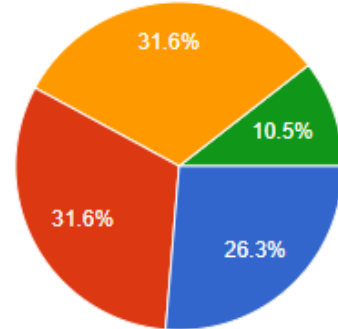
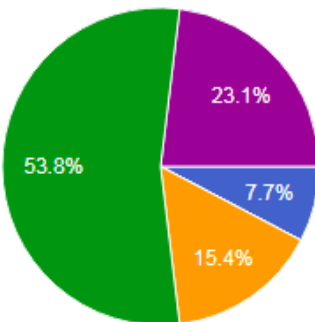


Figure 51. Response to Survey Question 10—LED A (4000 K), East and West Sections

The lighting looks better than other streets.

East



West

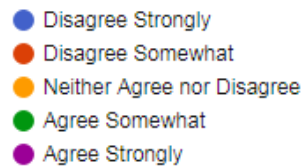
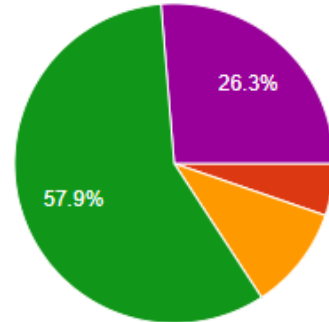
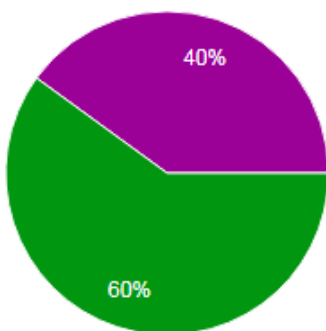


Figure 52. Response to Survey Question 11—LED A (4000 K), East and West Sections

As a driver, I can see the roadway pavement clearly.

East



West

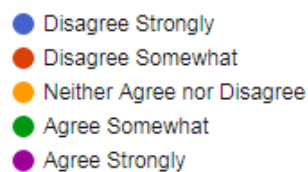
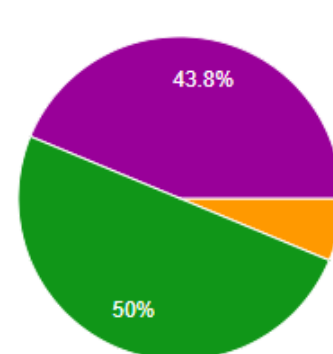
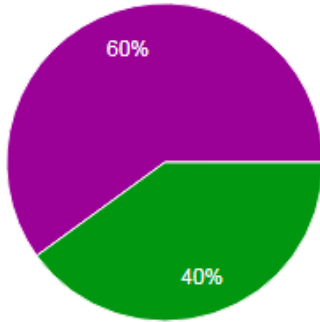


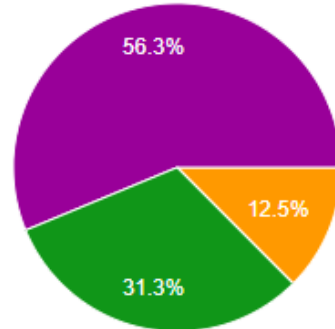
Figure 53. Response to Survey Question 12—LED A (4000 K), East and West Sections

As a driver, I can see other vehicles approaching clearly.

East



West

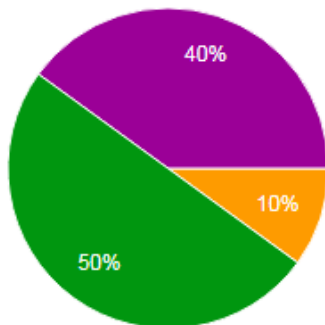


- Disagree Strongly
- Disagree Somewhat
- Neither Agree nor Disagree
- Agree Somewhat
- Agree Strongly

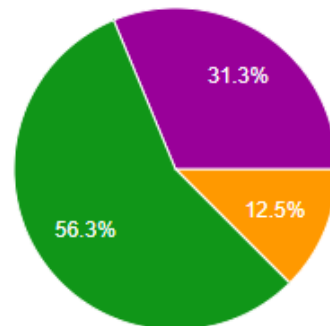
Figure 54. Response to Survey Question 13—LED A (4000 K), East and West Sections

As a driver, I can see pedestrians approaching clearly.

East



West

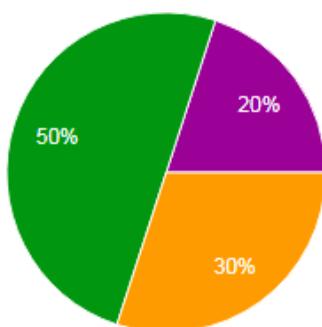


- Disagree Strongly
- Disagree Somewhat
- Neither Agree nor Disagree
- Agree Somewhat
- Agree Strongly

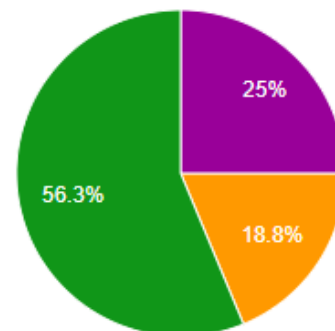
Figure 55. Response to Survey Question 14—LED A (4000 K), East and West Sections

As a driver, I feel safe when driving.

East



West

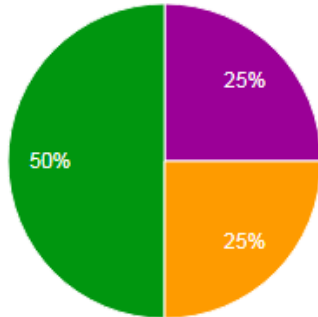


- Disagree Strongly
- Disagree Somewhat
- Neither Agree nor Disagree
- Agree Somewhat
- Agree Strongly

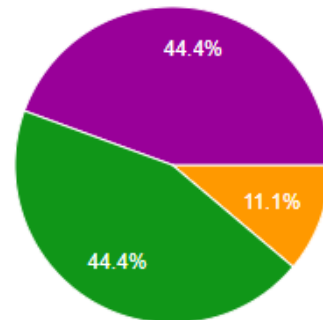
Figure 56. Response to Survey Question 15—LED A (4000 K), East and West Sections

As a pedestrian, I can see other pedestrians approaching clearly.

East



West

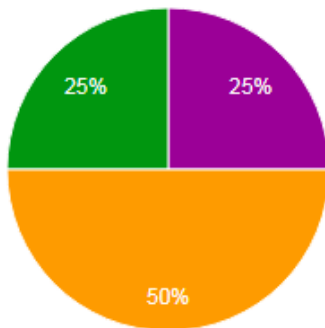


- Disagree Strongly
- Disagree Somewhat
- Neither Agree nor Disagree
- Agree Somewhat
- Agree Strongly

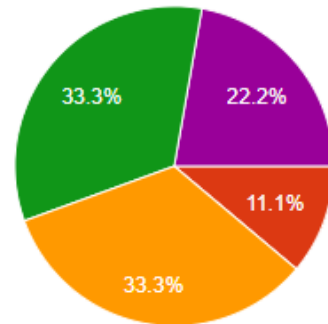
Figure 57. Response to Survey Question 16—LED A (4000 K), East and West Sections

As a pedestrian, I can see faces of other pedestrians clearly.

East



West

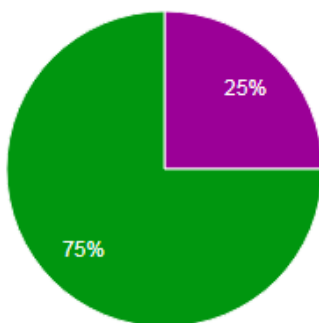


- Disagree Strongly
- Disagree Somewhat
- Neither Agree nor Disagree
- Agree Somewhat
- Agree Strongly

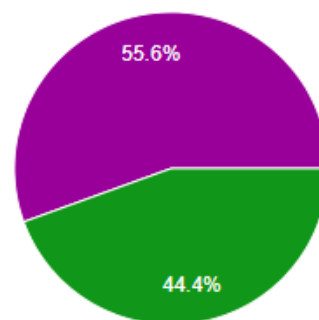
Figure 58. Response to Survey Question 17—LED A (4000 K), East and West Sections

As a pedestrian, I can see vehicles approaching clearly.

East



West

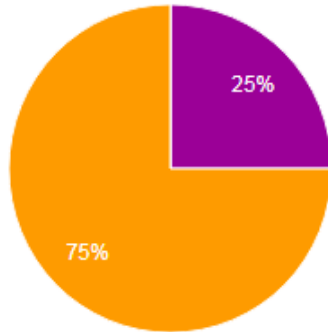


- Disagree Strongly
- Disagree Somewhat
- Neither Agree nor Disagree
- Agree Somewhat
- Agree Strongly

Figure 59. Response to Survey Question 18—LED A (4000 K), East and West Sections

As a pedestrian, I feel secure while walking along this street.

East



West

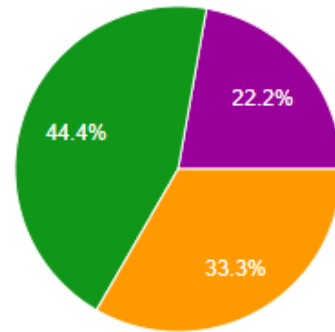
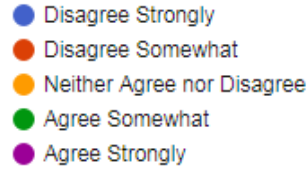


Figure 60. Response to Survey Question 1—LED B

I like the lighting.

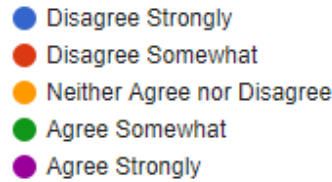
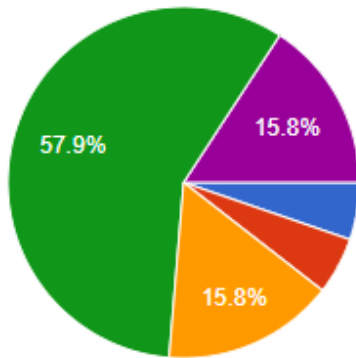


Figure 61. Response to Survey Question 2—LED B

The lighting is comfortable.

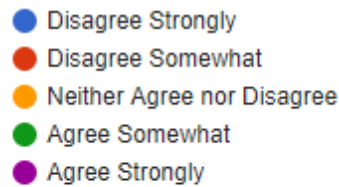
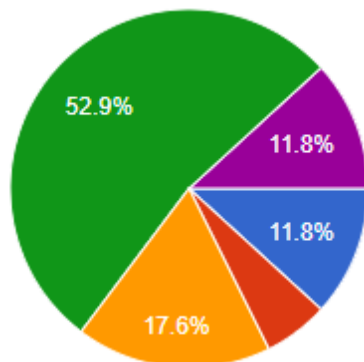


Figure 62. Response to Survey Question 3—LED B

The street looks bright.

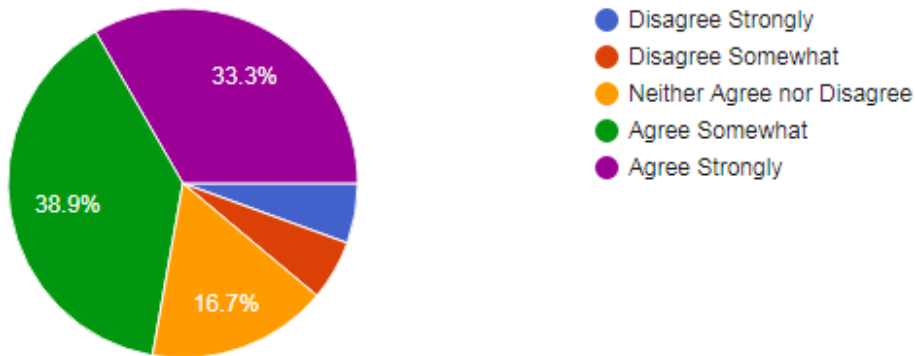


Figure 63. Response to Survey Question 4—LED B

The street looks gloomy.

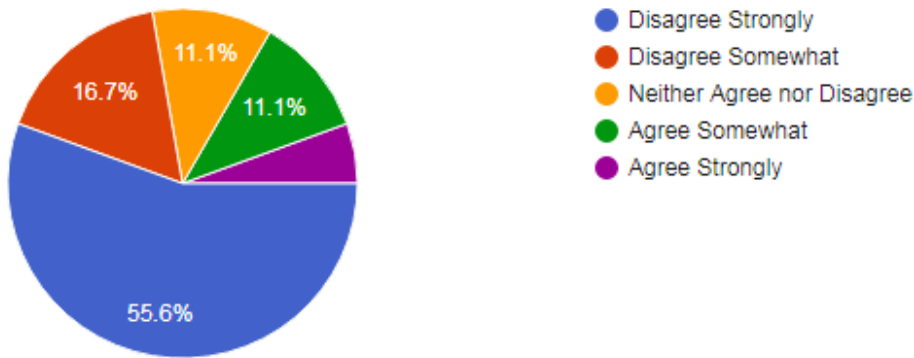


Figure 64. Response to Survey Question 5—LED B

The streetlights are too bright.

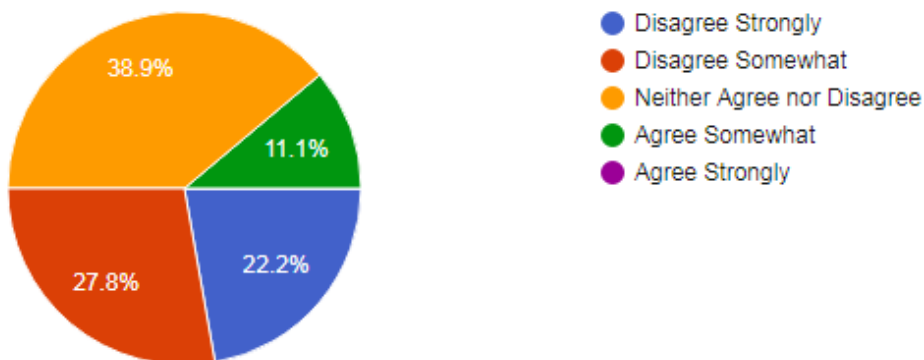


Figure 65. Response to Survey Question 6—LED B

Colors of traffic signs appear clear.

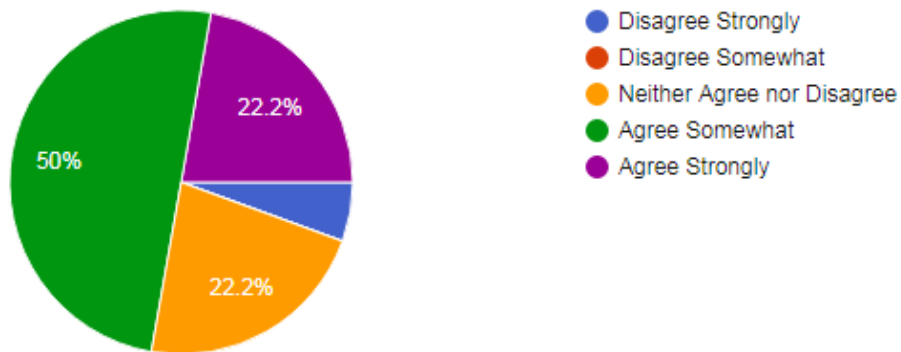


Figure 66. Response to Survey Question 7—LED B

Colors of vegetation look natural.

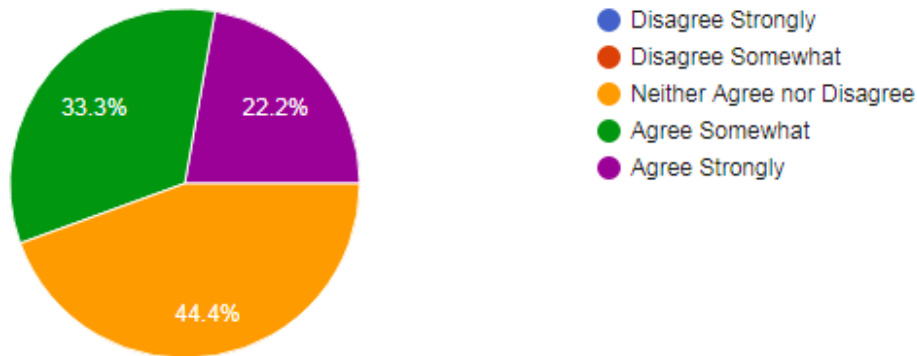


Figure 67. Response to Survey Question 8—LED B

The lighting is too warm in color for a street.

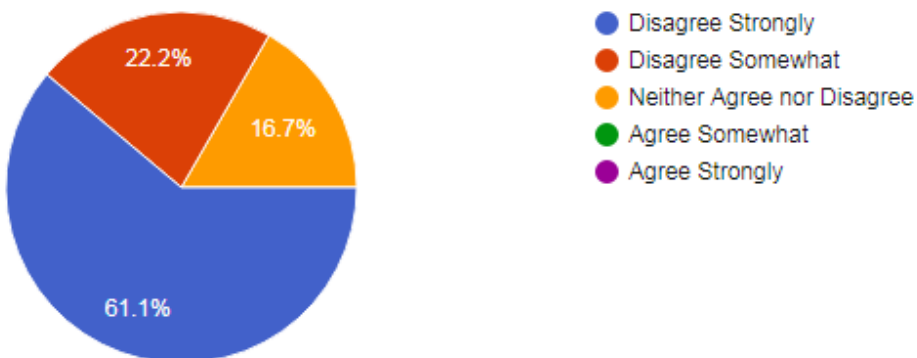


Figure 68. Response to Survey Question 9—LED B

The lighting is too cool in color for a street.

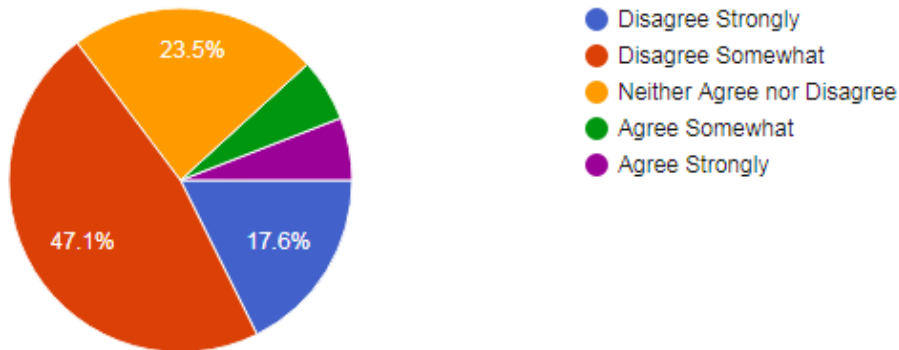


Figure 69. Response to Survey Question 10—LED B

The lighting looks better than other streets.

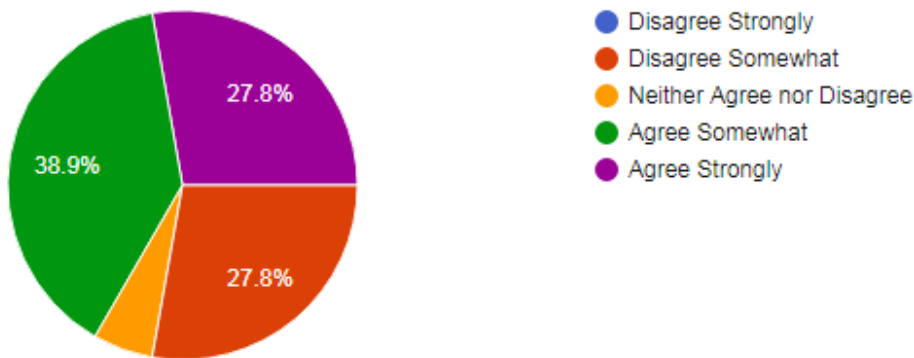


Figure 70. Response to Survey Question 11—LED B

As a driver, I can see the roadway pavement clearly.

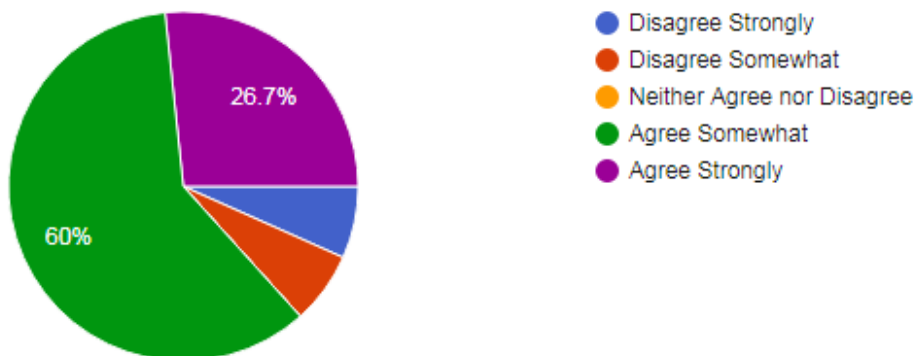


Figure 71. Response to Survey Question 12—LED B

As a driver, I can see other vehicles approaching clearly.

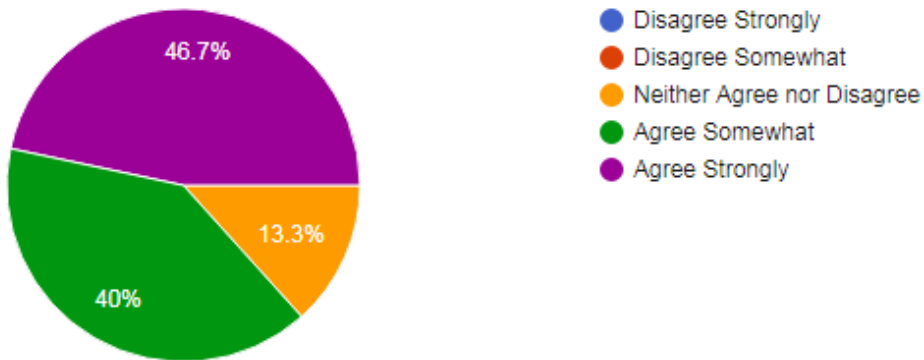


Figure 72. Response to Survey Question 13—LED B

As a driver, I can see pedestrians approaching clearly.

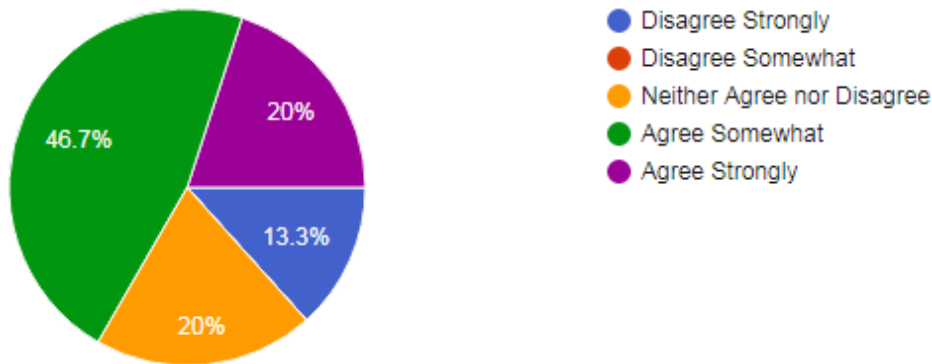


Figure 73. Response to Survey Question 14—LED B

As a driver, I feel safe when driving.

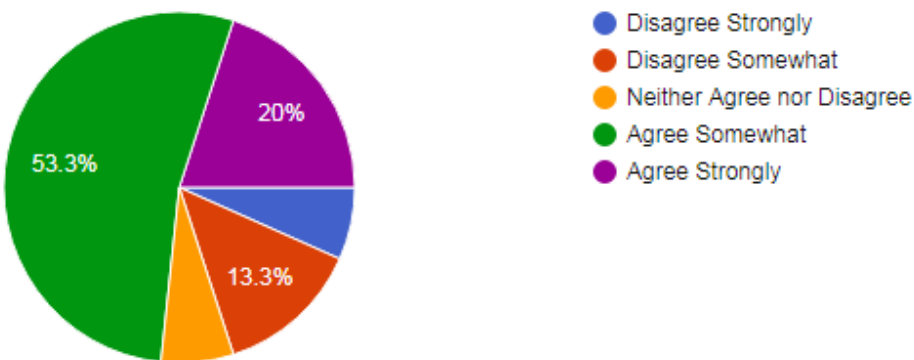


Figure 74. Response to Survey Question 15—LED B

As a pedestrian, I can see other pedestrians approaching clearly.

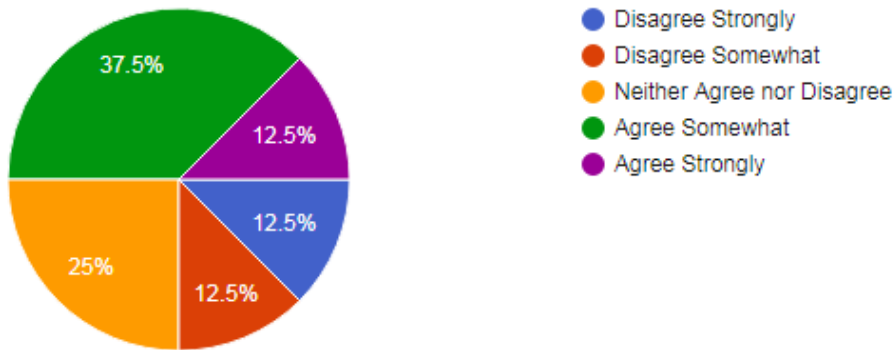


Figure 75. Response to Survey Question 16—LED B

As a pedestrian, I can see faces of other pedestrians clearly.

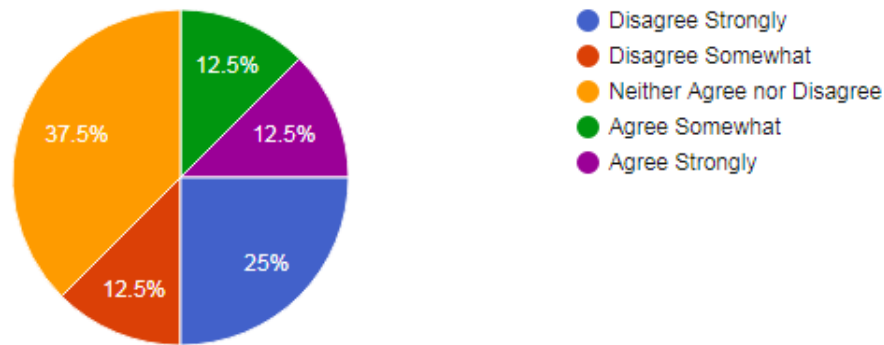


Figure 76. Response to Survey Question 17—LED B

As a pedestrian, I can see vehicles approaching clearly.

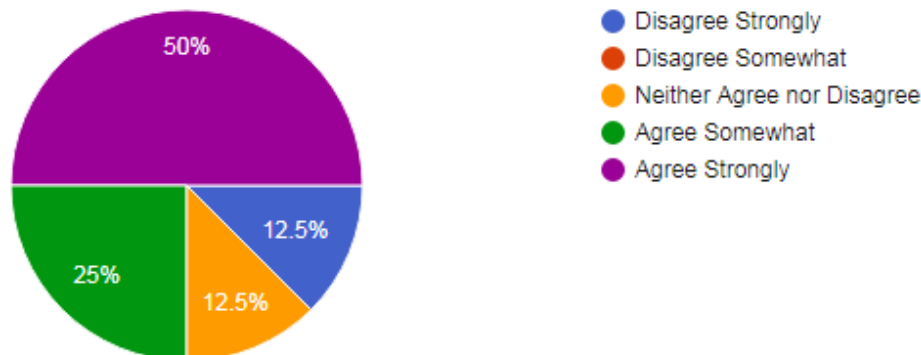


Figure 77. Response to Survey Question 18—LED B

As a pedestrian, I feel secure while walking along this street.

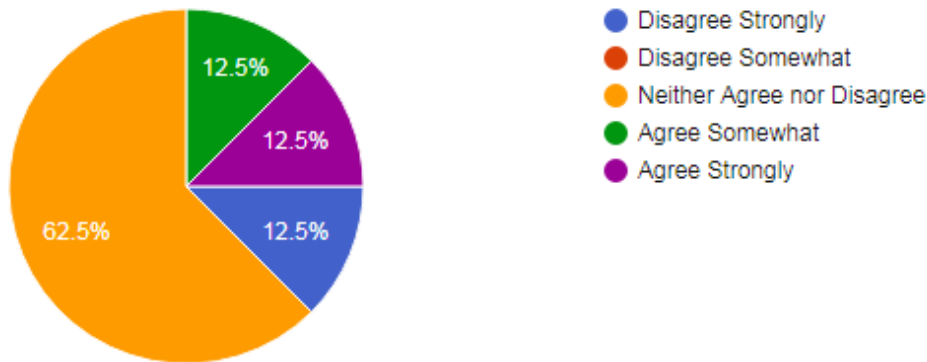


Figure 78. Response to Survey Question 1—LED C

I like the lighting.

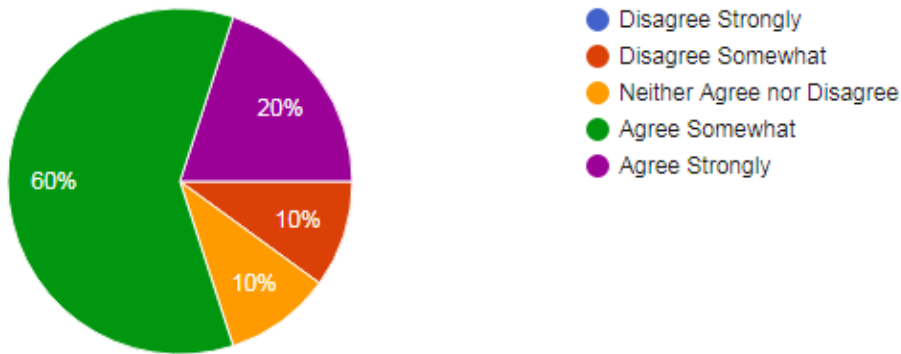


Figure 79. Response to Survey Question 2—LED C

The lighting is comfortable.

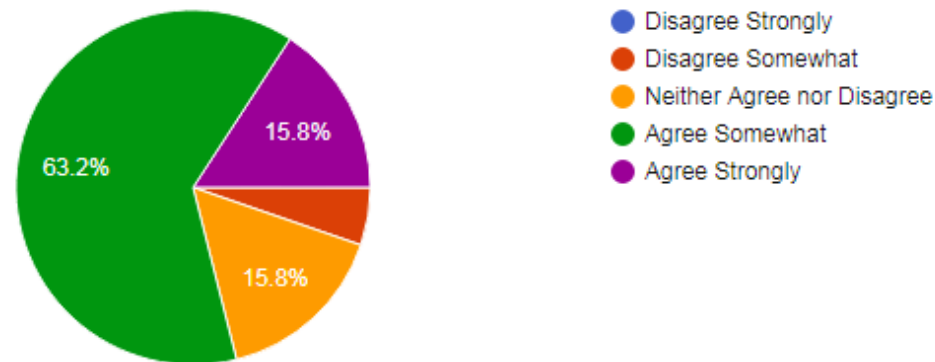


Figure 80. Response to Survey Question 3—LED C

The street looks bright.

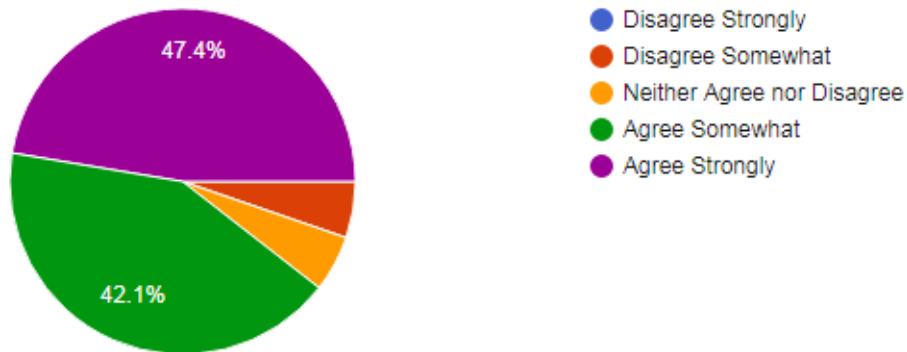


Figure 81. Response to Survey Question 4—LED C

The street looks gloomy.

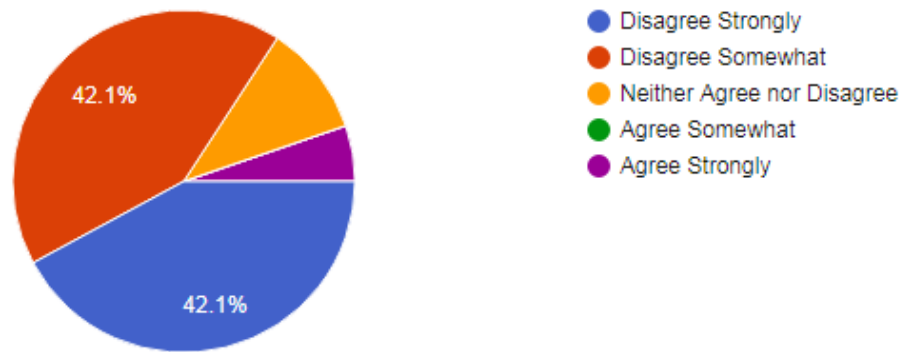


Figure 82. Response to Survey Question 5—LED C

The streetlights are too bright.

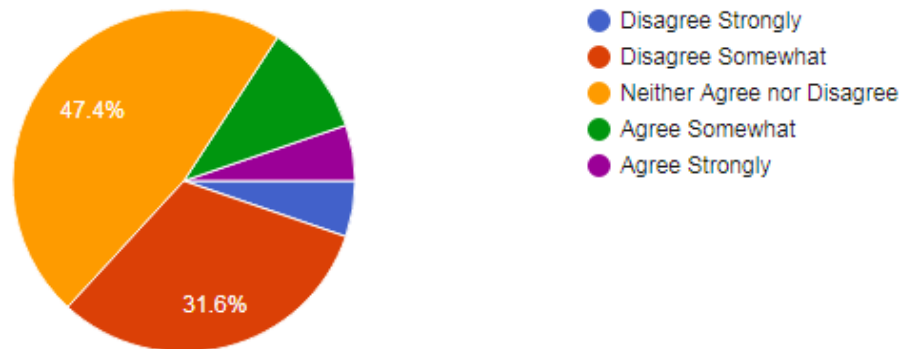


Figure 83. Response to Survey Question 6—LED C

Colors of traffic signs appear clear.

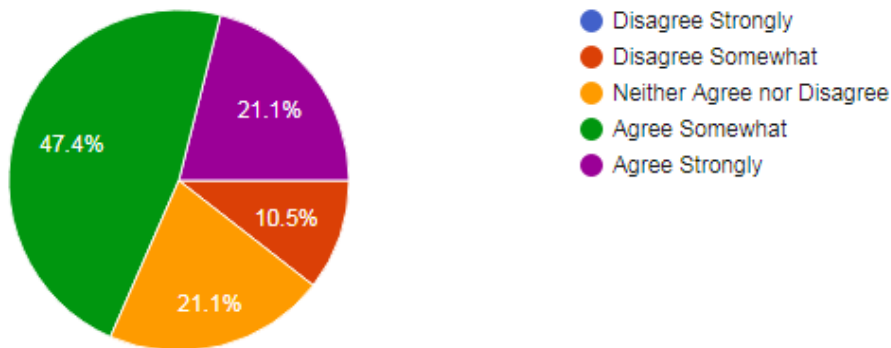


Figure 84. Response to Survey Question 7—LED C

Colors of vegetation look natural.

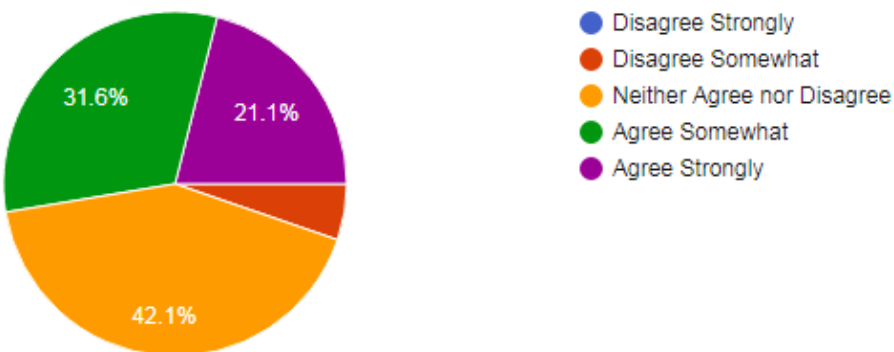


Figure 85. Response to Survey Question 8—LED C

The lighting is too warm in color for a street.

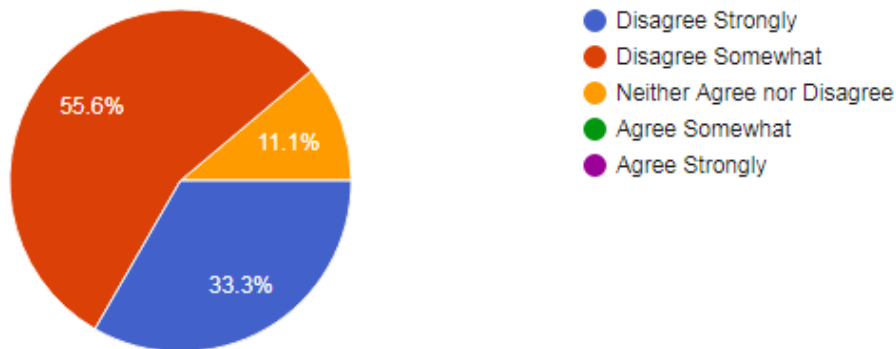


Figure 86. Response to Survey Question 9—LED C

The lighting is too cool in color for a street.

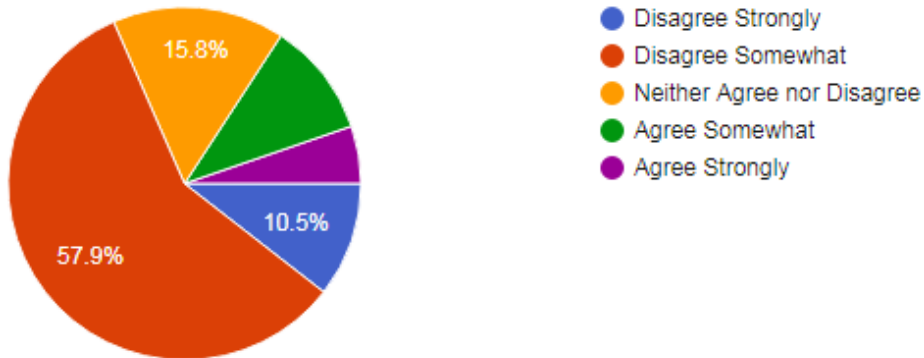


Figure 87. Response to Survey Question 10—LED C

The lighting looks better than other streets.

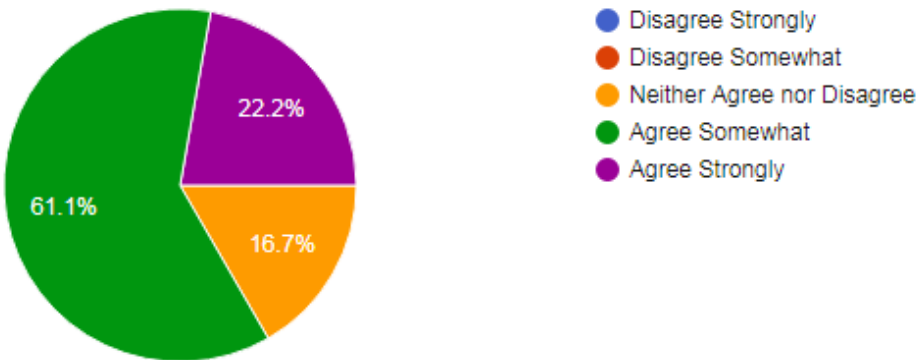


Figure 88. Response to Survey Question 11—LED C

As a driver, I can see the roadway pavement clearly.

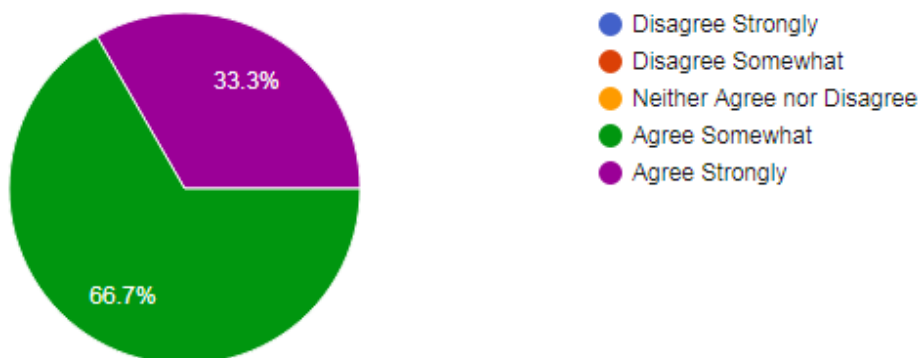


Figure 89. Response to Survey Question 12—LED C

As a driver, I can see other vehicles approaching clearly.

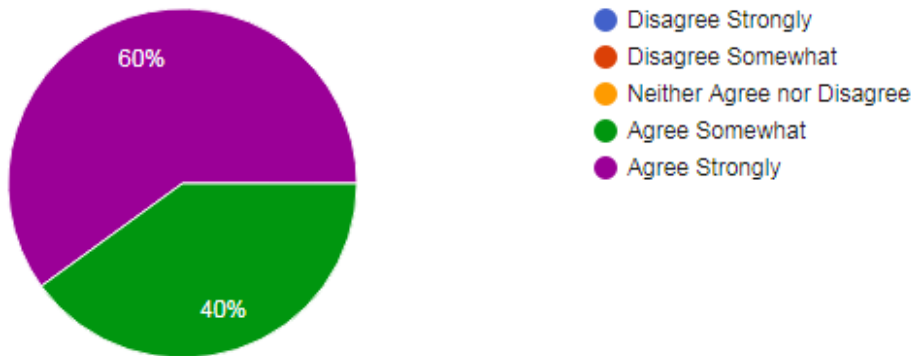


Figure 90. Response to Survey Question 13—LED C

As a driver, I can see pedestrians approaching clearly.

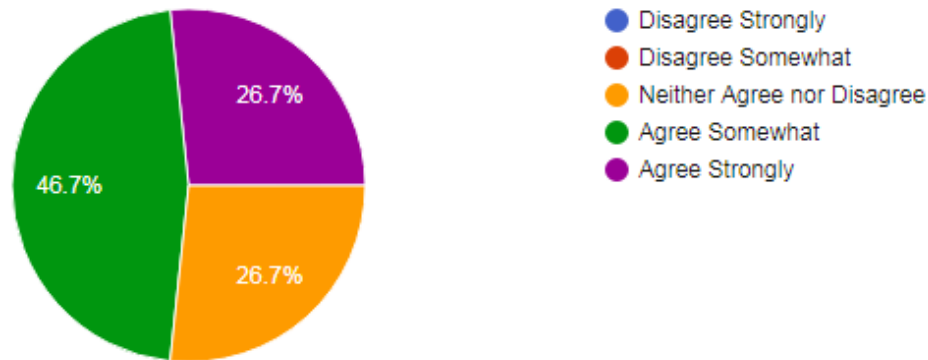


Figure 91. Response to Survey Question 14—LED C

As a driver, I feel safe when driving.

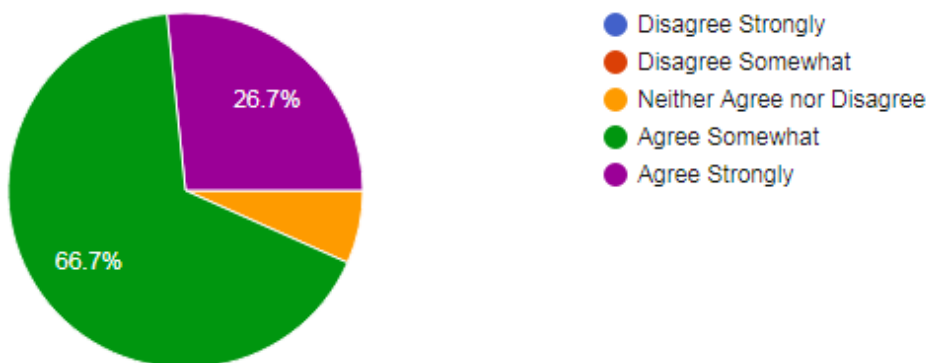


Figure 92. Response to Survey Question 15—LED C

As a pedestrian, I can see other pedestrians approaching clearly.

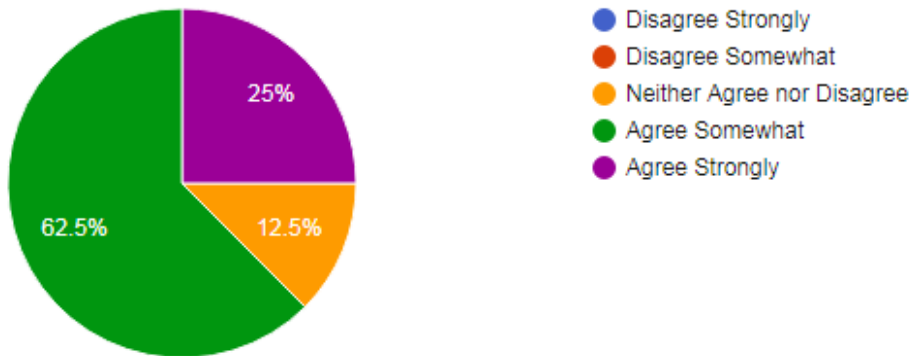


Figure 93. Response to Survey Question 16—LED C

As a pedestrian, I can see faces of other pedestrians clearly.

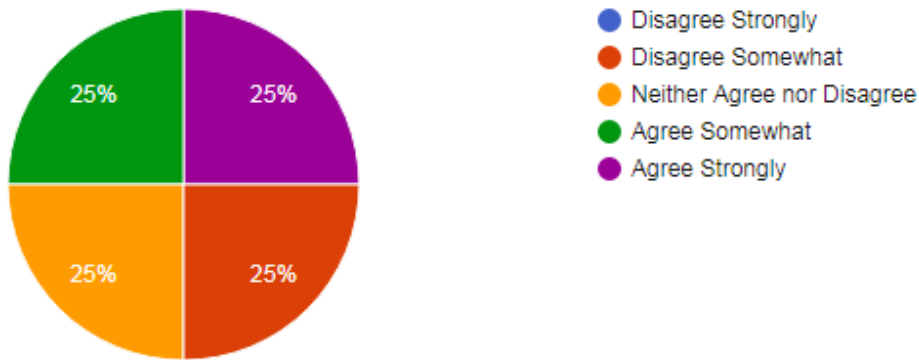


Figure 94. Response to Survey Question 17—LED C

As a pedestrian, I can see vehicles approaching clearly.

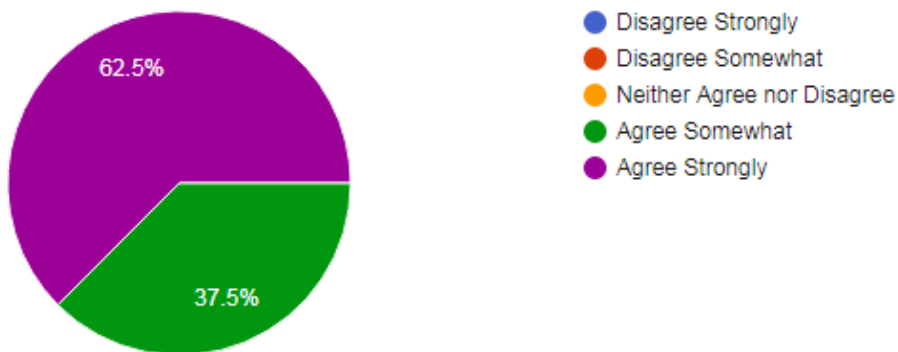
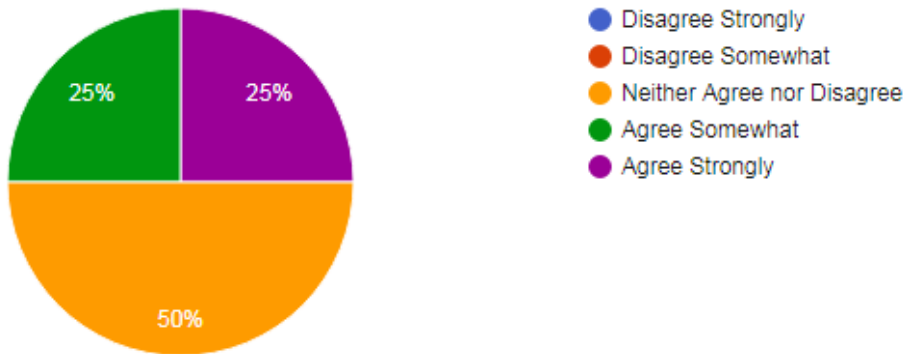


Figure 95. Response to Survey Question 18—LED C

As a pedestrian, I feel secure while walking along this street.



To identify whether the differences in responses to each of the LED lighting types differed from the responses to the HPS roadway lighting, the responses were converted to numerical values, as follows:

- Agree strongly: +2
- Agree somewhat: +1
- Neither agree nor disagree: 0
- Disagree somewhat: -1
- Disagree strongly: -2

Table 1 lists the average numerical response (and standard error of the mean) for each of the 18 statements on the survey questionnaire. Responses for the LED type A (4000 K) in both sections where that type was installed were combined. Student's t-tests were used to compare the average responses for the HPS lighting to the average responses for each LED condition; shaded cells in Table 1 indicate statistically significant ($p < 0.05$) differences.

Table 1. Average Responses to Survey Statements for Each Lighting Condition

Average (and standard error of the mean) responses are shown; shaded cells for the LED conditions indicate statistically significant ($p < 0.05$) differences from the HPS condition.

Statement	HPS	LED A (3000 K)	LED A (4000 K)	LED B	LED C
Overall:					
1. Like the lighting	-1.48 (0.18)	1.05 (0.21)	0.94 (0.13)	0.74 (0.23)	0.90 (0.19)
2. Lighting is comfortable	-1.33 (0.18)	0.95 (0.21)	0.91 (0.15)	0.47 (0.29)	0.89 (0.17)
3. Street looks bright	-1.37 (0.21)	0.68 (0.22)	1.25 (0.13)	0.89 (0.27)	1.32 (0.19)
4. Street looks gloomy	1.26 (0.20)	-1.11 (0.25)	-1.33 (0.11)	-1.06 (0.31)	-1.16 (0.23)
5. Lights are too bright	-1.48 (0.18)	-0.89 (0.21)	-0.36 (0.14)	-0.61 (0.23)	-0.21 (0.21)
6. Sign colors appear clear	-0.33 (0.18)	0.79 (0.16)	0.76 (0.19)	0.83 (0.23)	0.79 (0.21)
7. Vegetation appears natural	-0.48 (0.21)	0.83 (0.19)	0.76 (0.14)	0.78 (0.19)	0.68 (0.20)
8. Lighting too warm in color	0.12 (0.23)	-1.21 (0.22)	-1.24 (0.16)	-1.44 (0.18)	-1.22 (0.15)
9. Lighting too cool in color	-0.37 (0.18)	-1.21 (0.18)	-0.67 (0.18)	-0.65 (0.26)	-0.58 (0.23)
10. Lighting better than other streets	-1.26 (0.14)	0.89 (0.27)	0.97 (0.16)	0.67 (0.28)	1.06 (0.15)
As a driver:					
1. See pavement clearly	-0.59 (0.22)	1.19 (0.21)	1.38 (0.11)	0.93 (0.28)	1.33 (0.13)
2. See other vehicles clearly	-0.19 (0.22)	1.44 (0.18)	1.50 (0.13)	1.33 (0.19)	1.60 (0.13)
3. See pedestrians clearly	-1.48 (0.17)	0.88 (0.22)	1.23 (0.13)	0.60 (0.32)	1.00 (0.20)
4. Feel safe as driver	-0.96 (0.20)	1.00 (0.20)	1.00 (0.14)	0.67 (0.30)	1.20 (0.14)
As a pedestrian:					
1. See other pedestrians	-0.86 (0.25)	0.25 (0.53)	1.23 (0.20)	0.25 (0.45)	1.13 (0.23)
2. See faces clearly	-1.14 (0.21)	0.13 (0.40)	0.69 (0.26)	-0.25 (0.49)	0.50 (0.42)
3. See vehicles clearly	-0.38 (0.22)	1.38 (0.26)	1.46 (0.14)	1.00 (0.50)	1.63 (0.18)
4. Feel secure as pedestrian	-1.19 (0.21)	0.25 (0.45)	0.77 (0.23)	0.13 (0.40)	0.75 (0.31)

Almost all of the responses for the LED conditions were significantly different than those for the HPS lighting condition and represented improvements over HPS. For statement 9, "The color of the lighting is too cool in color for a street," the responses referring to HPS did not differ significantly from LED type A (4000 K), type B or type C. For statement 16, "I can see faces of other pedestrians clearly," LED type B did not differ significantly from HPS.

5 Conclusions

5.1 Discussion

Overall, this study demonstrated that several LED luminaire types can be used to improve visual conditions and save energy compared to HPS lighting systems in retrofit situations where luminaires are mounted on existing utility poles. One finding from this project was that the differences between lighting of the same manufacturer (type A) with different CCTs were relatively small. Central Avenue is a major arterial roadway with many illuminated parking lots, driveways, and side streets. It is possible that if the lighting were more isolated, that people might have been able to notice differences between the different CCTs.

In general, light levels in the roadway itself were increased by a greater amount than on sidewalks or within crosswalks located at intersections. The study also revealed that overall cost savings after converting utility-owned lighting to LED are not likely to be as large as the energy savings that can be achieved. The reason for this is that the initial purchase cost of LED luminaires still tends to be substantially higher than that of HPS luminaires, and the tariff for utility-owned streetlighting includes both energy charges and the cost of the lighting equipment.

One reason that the overall cost savings to the municipalities in the present project was relatively small was that the overall light levels were increased. The layout and selection of HPS luminaires for this part of Central Avenue was performed in the 1980s, when traffic volumes and commercial development along the roadway were lower than they are at present. Concerns about safety, especially for pedestrians (Creighton Manning 2014; O'Brien 2016) led the local municipalities as well as NYSDOT to recommend an increase in the lighting levels along this part of the roadway. If the retrofit had maintained the existing light levels rather than increased them, both the energy savings and the cost savings would have been larger. A potentially important barrier to the conversion of roadway lighting to LED technologies for utility-owned streetlights is that according to State requirements, the municipality must reimburse the utility for the remaining value of the previous streetlighting system. For the 151 streetlights along this part of Central Avenue, the cost was substantial, about \$24,000. Municipalities might choose to convert streetlights to LEDs without purchasing the lighting system outright from the utility, so the utility would be responsible for purchasing, installing, and maintaining the lights. It is important that the reimbursement cost be considered in planning when converting HPS lighting to LED systems.

5.2 Statement on Implementation

The findings from the present project can be used by transportation agencies in planning for retrofit conversions of HPS streetlighting to LED, by electric utilities in the identification of LED lighting systems that are suitable for lighting major arterial roadways, and by municipalities investigating whether to purchase streetlights from the utility or to convert to LED through utility-owned lighting.

6 References

- Bullough JD. 2012. Guide for Optimizing the Effectiveness and Efficiency of Roadway Lighting, C-10-14. Albany, NY: New York State Department of Transportation.
- Bullough JD, Radetsky LC. 2013. Analysis of New Highway Lighting Technologies, NCHRP 20-7/305. Washington, DC: Transportation Research Board.
- Bullough JD, Skinner NP, Brons JA. 2015. Analysis of Energy Efficient Highway Lighting Retrofits, C-14-12. Albany, NY: New York State Department of Transportation.
- Creighton Manning. 2014. NY Route 5 Comprehensive Pedestrian Safety Study. Albany, NY: New York State Department of Transportation.
- Navigant Consulting. 2012. 2010 U.S. Lighting Market Characterization. Washington, DC: U.S. Department of Energy.
- New York State Office of the Comptroller. 2007. Street Lighting Cost Containment, 2007-MR-4. Albany, NY: New York State Office of the Comptroller.
- O'Brien T. 2016. Route 5 from Albany to Schenectady taking a grim toll. Albany Times Union (February 21).
- Radetsky LC. 2010. Specifier Reports: Streetlights for Collector Roads. Troy, NY: Rensselaer Polytechnic Institute.
- Radetsky LC. 2011. Specifier Reports: Streetlights for Local Roads. Troy, NY: Rensselaer Polytechnic Institute.
- Winner T, Arnold G. 2014. Street Lighting in New York State: Opportunities and Challenges. 14-42. Albany, NY: New York State Energy Research and Development Authority.

Appendix A. Route 5 Crosswalk Lighting Analysis: Existing Lighting Values—Measured

Intersection	Route 5 West		Route 5 East		Cross Street North		Cross Street South		Averages		Comparison Increase/Decrease from Jan. 2014 to April 2019
	Measured January 2014	Measured April 2019	Measured January 2014	Measured April 2019	Measured January 2014	Measured April 2019	Measured January 2014	Measured April 2019	Measured January 2014	Measured April 2019	
Colonie Plaza	1.5	1.34	0.4	0.54	0.2	0.84	0.3	0.66	0.60	0.85	0.25
Rte 155 - New Karner	1.7	0.67	1.6	1.87	0.2	0.28	0.2	0.38	0.93	0.80	-0.13
Vly Road	2.4	1.45	0.6	0.55	0.4	0.44	0.5	0.83	0.98	0.82	-0.18
Shoprite/ Willow Avenue	0.3	0.38	1	1.32	0.2	0.44	0.3	0.25	0.45	0.60	0.15
Red Fox Drive/ Lanci Lane	0.7	no crossing	0.4	0.52	0.2	0.35	0.5	0.53	0.45	0.47	0.02
Jupiter Lane	1	1.12	1.3	1.28	0.5	0.42	0.2	0.29	0.75	0.78	0.03
Lincoln Avenue/ Parkwood Drive	0.4	0.22	1.3	0.97	0.3	0.15	0.4	0.32	0.60	0.42	-0.18
Nicholas Drive/ Woolard Ave	0.2	no crossing	0.6	0.87	0.3	0.57	0.2	0.81	0.33	0.75	0.42
Wolf Road	no crossing	no crossing	1.9	1.2	0.5	1.0	0.7	0.3	1.03	0.83	-0.15
Colonie Center/ Northway Mall West	no crossing	no crossing	1.4	1.67	1.2	1.13	1.90	1.78	1.50	1.53	0.4
Colonie Center/ Northway Mall East	2.3	3.68	no crossing	no crossing	1.5	1.92	1	0.95	1.60	2.18	0.58
Fuller Road	0.8	no crossing	2.6	2.33	0.3	0.98	1	0.70	1.18	1.34	0.14

Notes:

- 1) Measured lighting values were field measured with a photometer (all values are in footcandles—1 footcandle equals approximately 10.76 lux).
- 2) At the Colonie Plaza (Route 5 WEST) location, the adjacent business (Key Bank) appeared to be providing the most light to the area. There are various locations where crosswalks existed in 2014 that do not exist currently.

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