CIVIL ENGINEERING STUDIES
Illinois Center for Transportation Series No. 09-043
UILU-ENG-2009-2014
ISSN: 0197-9191

EVALUATION OF LED VEHICULAR AND PEDESTRIAN MODULES

Prepared By
Ali Hajbabaie
Rahim F. Benekohal
Juan C. Medina
Madhav Chitturi
University of Illinois at Urbana-Champaign

Research Report ICT-09-043

A report of the findings of
ICT-R43
Traffic Operations Lab – Signal Systems Testing
Illinois Center for Transportation

April 2009

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-ICT-09-043		

4. Title and Subtitle	5. Report Date
Evaluation of LED Vehicular and Pedestrian Modules	April 2009
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report N o.
Ali Hajbabaie, Rahim F. Benekohal, Juan C. Medina, Madhav Chitturi	ICT-09-043 UILU-ENG-2009-2014
9. Performing Organization Name and Address	10. Work Unit (TRAIS)
Illinois Center for Transportation Department of Civil and Environmental Engineering University of Illinois at Urbana-Champaign 205 N. Mathews Ave Urbana, IL 61801	11. Contract or Grant No. ICT-R43
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address Illinois Department of Transportation Bureau of Materials and Physical Research 126 East Ash Street Springfield, IL 62704	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This study was conducted to verify the compliance of vehicular and pedestrian LED traffic signal modules with the Institute of Transportation Engineers specifications; and to assess drivers' preferences of the LED modules. Four vehicular modules (ACS, Dialight, Leotek, and Lumination) and three pedestrian LED modules (Dialight, Leotek, and Lumination) were used. The compliance verification primarily involved reviewing the independent-lab testing reports, visual inspection of the modules, and analyzing the manufacturers' responses to the questionnaires prepared by the research team. The solid LED modules provided by ASC had several issues with compliance with the ITE specification; however, the modules from other companies either complied or complied with reservation with all the ITE Specifications. No general conclusion were made for the arrow modules since at the time of completion of this study, ITE had not adopted a final specification for them. For pedestrian modules, all companies submitted independent lab test reports for some of the modules, but not for all. The reports showed that all these modules either complied with, or complied with reservation with most of the ITE specifications. To assess drivers' preferences, 120 drivers participated in the evaluation of the modules. For solid modules in daytime, the participants' ratings for the ASC were significantly higher than the other three companies. In nighttime, the ASC red module was rated much brighter than the Leotek module. However, for solid yellow and green modules, the brightness was rated the same for all companies. For red arrow modules in daytime when looking straight ahead, Dialight was rated similar to ASC, but significantly higher than Lumination and Leotek. However, for yellow and green arrows, Dialight was rated higher than all other three companies were. For all three colors of the arrow modules in daytime when looking at an angle, Dialight and ASC were rated significantly higher than Leotek and Lumination. For the pedestrian modules in daytime, the separate 12" Dialight module was rated significantly higher than the Leotek and Lumination modules. For 12" combination modules, Leotek and Dialight were rated higher than Lumination. For the 16"*18" combination modules, Lumination was rated significantly higher than Dialight. In rating the traffic modules, all of the respondents chose brightness, 93% chose color, and 88% selected uniformity as an important factor. The most important factor was brightness for 74%, color for 26%, and uniformity for 27% of the participants. In rating of the pedestrian modules, all of the respondents chose brightness, 94% chose color, 90% selected uniformity, and 70% selected size as an important factor. The most important factor was brightness for 75%, color for 25%, uniformity for 25%, and size for 23% of the participants.

17. Key Words	18. Distribution Statement
	No restrictions.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	154	

ACKNOWLEDGMENT and DISCLAIMER

This publication is based on the results of ICT-R43, **Traffic Operations Lab – Signal Systems Testing.** ICT-R43 was conducted in cooperation with the Illinois Center for Transportation; the Illinois Department of Transportation; and the U.S. Department of Transportation, Federal Highway Administration.

Members of the Technical Review Panel are the following:

Yogesh Gautam, IDOT (Chair)
James Schoenherr, IDOT
Aaron Weatherholt, IDOT

EXECUTIVE SUMMARY

This study was conducted in the Traffic Operations Lab (TOL) of the University of Illinois at Urbana-Champaign to: a) verify the compliance of vehicular and pedestrian LED traffic signal modules with the Institute of Transportation Engineers (ITE) specifications; and b) assess the drivers' preferences of the LED modules. The vehicular LED modules (solid and arrow green, yellow, and red) were provided by four manufacturers (ASC, Dialight, Leotek, and Lumination), and the pedestrian LED modules (three variations of symbolic "hand" and "walk" signs) were provided by three of the manufacturers (Dialight, Leotek, and Lumination). The compliance verification primarily involved reviewing the independent-lab testing reports furnished by the companies, visual inspection of the modules, and analyzing the manufacturers' responses to the questionnaires prepared by the research team. To assess the drivers' preferences, 120 drivers participated in the evaluation of the modules in TOL.

The solid LED modules provided by Leotek, Lumination, and Dialight either complied or complied with reservation with all the ITE Specifications, but there were several issues with ASC modules. For all three solid LED modules from ASC, photometric test results were based on only one sample, instead of six samples. For yellow and green modules, only electric noise emission was tested, and none of the other specifications was tested. For red modules, only four other requirements were tested.

For the arrow modules at the time of completion of this study, ITE had not adopted a final specification and each manufacturer furnished independent lab reports verifying the compliance of their modules with a different version of the ITE specification. Consequently, no general conclusions are made about the compliance of the arrow modules.

For pedestrian modules, all companies submitted independent lab testing reports for some of the modules but not for all. The reports showed that all these modules either complied with, or complied with reservation with most of the ITE specifications.

Some discrepancies were noticed in the independent lab reports where modules that did not satisfy all of the ITE requirements were certified as complying with the requirements. Therefore, it is recommended that the independent lab test reports be carefully reviewed before the modules are accepted as compliant with the ITE Specifications.

For solid modules (red, yellow, green) in the daytime, the participants' ratings for the ASC were significantly higher than the other three companies. For the solid modules in the nighttime, the ASC red module was rated as bright as the Lumination and Dialight, but much brighter than the Leotek module. However, for solid yellow and green modules, the brightness was rated the same for all companies.

For red arrow modules in daytime when looking straight ahead, Dialight was rated similar to ASC, but significantly higher than Lumination and Leotek. However, for yellow and green arrows, Dialight was rated higher than all other three companies were. For all three colors of the arrow modules in daytime when looking at an angle, Dialight and ASC were rated significantly higher than Leotek and Lumination.

For the pedestrian modules in daytime, the separate 12" Dialight module was rated significantly higher than the Leotek and Lumination modules. For 12" combination modules, Leotek and Dialight were rated higher than Lumination. For the 16"*18" combination modules, Lumination was rated significantly higher than Dialight.

In rating the traffic modules, all of the respondents indicated that the brightness was an important factor, 93% of them chose color, and 88% of them selected uniformity as an important factor. The most important factor was brightness for 74% of the participants, color for 26% of them, and uniformity for 27% of them.

In rating of pedestrian modules, all of the respondents said that the brightness was an important factor, 94% chose color, 90% selected uniformity, and 70% selected size as an

important factor. The most important factor was brightness for 75% of the participants, color for 25%, uniformity for 25%, and size for 23% of the participants.

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CHAPTER 1 INTRODUCTION AND OBJECTIVES

In recent years, the Light Emitting Diodes (LEDs) traffic signal modules have been replacing the incandescent lamp modules in the United States. Approximately 260,000 signalized intersections exist in the United States and each intersection has a minimum of 24 and on average 40 signal indicators (Benekohal and Chitturi 2002). The incandescent lamps use 69, 135, or 150 watts of energy. The incandescent lamps are inexpensive; however, they consume a lot of power and require annual preventative lamp replacement. On the other hand, LED signal modules are more expensive (about $50-$100) to purchase but they consume a fraction of the power (around 10 watts) consumed by incandescent lamps. Furthermore, the LED modules are expected to last longer (5 years or more). Considering these facts, the Illinois Department of Transportation (IDOT) encourages replacing the incandescent modules with LED modules under the energy grant. IDOT requires that the modules comply with the Institute of Transportation Engineers (ITE) specifications for LED modules.

This study was conducted at the Traffic Operations Lab (TOL) at the University of Illinois and had two objectives. The first objective was to examine/verify the compliance with the ITE specification of the LED modules furnished by the interested vendors/manufacturers. The second objective was to conduct a survey to obtain drivers' opinions about the LED modules provided by these vendors/manufacturers. The survey had two components: (1) rating of LED (vehicular and pedestrian) modules and (2) identifying the important factors considered by the participants in rating them. Both vehicular and pedestrian modules were rated in daytime conditions. In addition, the brightness of solid modules was rated in nighttime conditions.

Four of the vendors/manufacturers furnished solid and arrow LED modules (ASC, Dialight, Leotek, and Lumination). In addition, three manufacturers (all except ASC), provided LED pedestrian modules.

This report contains six sections and nine appendices. Section 1 introduces the study, describes the objectives, and reviews the previous studies conducted in this area. The ITE specification/compliance is discussed in Section 2. Section 3 provides some information about the survey design. Section 4 describes how the survey was conducted, and results are presented in Section 5. Section 6 includes conclusions and recommendations. Appendices A-G provide detailed information about the compliance with ITE specifications. Appendix H provides a copy of the survey.

The main objectives of this research are:

- To examine/verify the level of compliance of the traffic and pedestrian LED modules provided by four companies with the ITE Specification.
- To determine the drivers' opinions about the traffic and pedestrian modules in daytime.
- To determine the drivers' opinions about the brightness of solid traffic LED modules at nighttime.
- To determine the important factors drivers used in rating the LED modules.

CHAPTER 2 COMPLIANCE WITH ITE SPECIFICATION

One of the objectives of this study was to verify the compliance of the LED traffic signal modules furnished by the vendors with the current ITE Specifications.

The following ITE Specifications were used in this study:

- Solid Modules
- Arrows Modules
- Pedestrian Modules

Based on discussions with IDOT representatives, the various requirements of (clauses) the ITE Specifications were classified into three categories:

- Certifications
- Questions Asked by Manufacturers
- Manual/Visual Verification
- Lab Verification

The categories in which each of the clauses was placed are shown in Appendix A.

2.1 CERTIFICATIONS

Along with the LED modules, each of the vendors had to submit independent lab test reports verifying the compliance of their modules with the ITE Specifications. The majority of the specifications fall into this category. For all those specifications, the independent lab test reports furnished by the vendors were reviewed to check if the modules satisfy the requirements or not. Some specifications included in this category are luminous and colorimetric requirements, turn-on time, turn-off time etc.

2.2 QUESTIONS ASKED FROM MANUFACTURERS

The manufacturers were contacted and requested to provide additional information if it was not clear from the independent lab testing reports whether their modules satisfied certain clauses. The clauses in Section 6 of the ITE Specifications deal with the quality assurance (QA) program, design qualification testing, and production quality control (QC) testing employed by the manufacturers. For example, QA process and test results documentation shall be kept on file for a minimum period of seven years. Since this information is not public knowledge, it was decided that appropriate questions would be sent to the manufacturers to ascertain if they satisfied these requirements. The manufacturers' responses have been incorporated into the report.

2.3 MANUAL/VISUAL VERIFICATION

A visual inspection was sufficient for checking whether the LED modules met certain clauses of the specification. For example, each module will identify the manufacturer, model number, operating characteristics, and serial number, and each module shall have a prominent vertical indexing indicator. A visual check was performed on the models, and the results were incorporated.

2.4. LAB VERIFICATION

Specification 5.6.1 was actually tested in the lab. This specification ensures that the modules draw sufficient current to ensure compatibility and proper triggering and operation of load switches and conflict monitors.

The findings of the evaluation for each individual specification are presented in Appendices A, B, C, and D for Leotek, Dialight, Lumination, and ASC, respectively.

2.5 FINDINGS FOR SOLID MODULES

Based on this evaluation, Leotek, Lumination, and Dialight either comply or comply with reservation with all the specifications. However, several issues exist with ASC LED modules. For all the three solid LED modules from ASC, photometric test results were based on only one sample, instead of six samples required by the ITE Specification. For Yellow and Green modules, only electric noise emission was tested and none of the other specifications was tested. For Red modules, only four other requirements were tested. The researcher contacted ASC twice about these issues, but did not get any response from the company. The details are provided in Appendices A through D.

It should be noted that for some of the specifications, manufacturers' claims of compliance have been accepted without requiring them to provide test reports or proofs of compliance. In addition to the manufacturers' claims about QA & QC processes, the specifications for which the claims have been accepted are:

1. Luminance testing: no testing at temperatures other than room temperature and voltages other than 120 VAC. In addition, no long term testing has been performed.
2. Arizona desert requirements
3. UL94 flame retardant requirements
4. Compliance with ASTM standards
5. Flickering due to voltage fluctuations

2.6 FINDINGS FOR ARROW MODULES

At the time this study was completed, ITE had not adopted a final specification for Arrow modules. Each manufacturer furnished independent lab reports verifying the compliance of their modules with a different version of the ITE specification. The versions used by different manufacturers are as follows:

- ASC: Mar 2004
- Dialight: Nov 2005
- Leotek: April 2006
- Lumination: Feb 2005

Consequently, this study puts forward no conclusions about the compliance of the arrow modules with ITE Specifications.

2.7 FINDINGS FOR PEDESTRIAN MODULES

Dialight submitted independent lab testing reports for only two (out of the four) pedestrian modules. The manufacturer claimed that the 12” Man (430-5770-001X) and Hand (433-7771-001X) modules are identical to 16” combo module (430-6450-001X). Accepting this claim of the manufacturer, all of the four LED Pedestrian modules furnished by Dialight either comply or comply with reservation with most of the ITE Specifications.

Lumination also submitted independent lab testing reports for only three (out of the four) pedestrian modules. No report was submitted for 12” Hand and Man overlay (PS6-CFL1-26A). Walking Man module (PS6-WFM3-26A) furnished by Lumination does not comply with the maximum luminous intensity requirement while it complies with or complies with reservation all the other requirements. The other two Pedestrian (PS6-PFH1-26A and PS7-CFC1-26A) modules comply with or comply with reservation most of the requirements.

The independent lab testing reports furnished by Leotek are based on two samples for 12” modules (TP12B-EH, TP12B-WM and TP12H-HM) and one sample for the 16” combo module (TSL-PED-16-DIL). Subject to this condition, all the 12” modules comply with or comply with reservation all the requirements. The 16” combo module (TSL-PED-16-DIL) does not comply with the maximum luminous intensity requirement, while it complies with or complies with reservation most of the other requirements.

None of the manufacturers provided documentation that clearly demonstrates that the external lens complies with the requirements of section 3.3.3 of the ITE Pedestrian Specification. Details of the compliance are presented in Appendices D, E, and F for Leotek, Dialight, and Lumination, respectively. It should be noted that ASC did not furnish any pedestrian modules for evaluation.

2.8 OTHER FINDINGS AND RECOMMENDATIONS

Some discrepancies have been noted in the independent lab reports certifying the compliance of LED modules with ITE specifications. This was true for all the different independent labs. Modules that do not satisfy the requirements were certified as complying with requirements. For two manufacturers, the LED modules exceeded the maximum luminous intensity requirements of ITE. However, the lab report certified that the modules satisfied that particular requirement. Also, for one manufacturer, although fewer than six LED modules were provided for testing, the lab reports certify that the LED modules satisfy the ITE requirements. It should be noted that ITE requires six modules to be provided for design qualification testing. Therefore, it is strongly recommended that the independent lab test reports be verified with scrutiny before the modules are accepted to be in compliance with the ITE specifications. The model numbers of the LED modules sent to the independent labs are presented in table 2-1.

Table 2-1. Model Numbers of the Models Sent to Independent Labs

	Color	Serial No.
DIALIGHT		
Solid	Red	433-1210-003XL
	Yellow	433-3230-001XL
	Green	433-2220-001XL
Arrow	Red	432-1314-001X
	Yellow	431-3334-001X
	Green	432-2324-001X
Pedestrian	Man	430-7771-001X
	Hand	430-5770-001X
	Combination 12	430-6772-001X
	Combination 16	430-6450-001X
LUMINATION		
Solid	Red	DR6-RTFB-17A
	Yellow	DR6-YTFB-17A
	Green	DR6-GCFB-17A
Arrow	Red	DR6-RTAAN-17A
	Yellow	DR6-YTAAN-17A
	Green	DR6-GCAAN-17A
Pedestrian	Man	PS6-PFH1-26A
	Hand	PS6-WFM3-26A
	Combination 12	PS6-CFC1-26A
	Combination 16	PS6-CFL1-26A
LEOTEK		
Solid	Red	TSL-12R-LX-IL3-A1
	Yellow	TSL-12G-LX-IL3-A
	Green	TSL-12Y-LX-IL3-A1-C
Arrow	Red	TSL-12RA-LD-A1
	Yellow	TSL-12YA-LD-A1
	Green	TSL-12YA-LD-A1
Pedestrian	Man	TP-12B-EH
	Hand	TP-12B-WM
	Combination 12	TP-12B-HM
	Combination 16	TSL-PED-16-D1L
ASC		
Solid	Red	ASC-0300-RB1
	Yellow	ASC-0300-YB1
	Green	ASC-0300-GB1
Arrow	Red	ASC-0300-RA1
	Yellow	ASC-0300-YA1
	Green	ASC-0300-GA1
Pedestrian	Man	N/A
	Hand	N/A
	Combination 12	N/A
	Combination 16	N/A

CHAPTER 3 LED SURVEY DESIGN

One of the objectives of this research was to obtain the drivers' opinions about different LED modules. A survey questionnaire was designed, and data collection was conducted at the Traffic Operations Laboratory at the University of Illinois at Urbana-Champaign. A copy of the survey is presented in Appendix H. Four frames were used for hanging the traffic signal heads that housed circular (solid) and arrow modules. Two of the four frames housed circular modules, and the other two housed arrow modules. Each frame had LED modules from two vendors. On a given signal head, all the lenses were from the same manufacturer. A typical frame is shown in Figure 3-1.

Figure 3-1. Frame A.

It should be noted that each of the three vendors (ASC did not furnish Pedestrian modules) furnished the following four types of Pedestrian modules:

1. 12 inch Walking Man
2. 12 inch Hand
3. 12 inch Overlay of Hand and Walking Man
4. 16 inch Overlay of Hand and Walking Man

The 12 inch Walking Man and 12 inch Hand modules were mounted (one on top of other) in the same pedestrian signal housing unit. The overlays (12 inch and 16 inch) were mounted in a separate housing unit. The Pedestrian modules from all the three manufacturers were mounted next to each other on a separate frame. However, the Pedestrian modules of the same type were placed next to each other. In other words, the 12 inch overlays (from the three manufacturers) were next to each other and similarly the 16 inch overlays and the 12 inch Man and Hand modules. Figure 3-2 shows the setup of the Pedestrian modules.

Figure 3-2. Pedestrian modules.

Observers were asked to stand at six (four for circular and arrow, two for pedestrian modules) different viewing stations for rating the modules. The distance between the viewing station and frame was about 70 feet. This represents approximately the distance between a stopped vehicle and the signal head at an intersection with two through lanes per direction and a left turn pocket. The viewing stations and the frames to be looked at were clearly marked to avoid any confusion. Observers moved from one station to the next after completing the rating at each station.

The survey responses are broadly classified into two groups:

1. Demographic information and drivers' preferences
2. Rating of the LED modules

3.1 DEMOGRAPHIC INFORMATION AND DRIVERS' PREFERENCES

Drivers were asked to identify their age group, indicate if they needed glasses or had any difficulty in distinguishing shades of colors. In addition, drivers were asked to state, separately, the factors that they considered in rating the vehicular and pedestrian modules. To assist the drivers, some possible factors were listed in the questionnaire. These included color, brightness, and uniformity for vehicular modules. For Pedestrian modules, an additional factor of size was included. Spaces were provided so the drivers could write other factors they may have used in rating of the modules. In addition, the participants were requested to rate how important each of these factors were for them on a scale of 1 to 10. A rating of 1 meant LEAST important and a rating of 10 meant MOST important. A sample survey is included in Appendix H.

3.2 RATING OF LED MODULES

3.2.1 Circular Modules

From the viewing stations, the drivers were requested to view and rate the circular modules that were straight ahead of them (71 ft away). Some drivers have previously complained that the circular LED modules are too bright during the nighttime. Consequently, circular modules were evaluated under two conditions: daytime and nighttime. Nighttime condition was “simulated” in the lab by turning off the lighting and blinding all the windows. For the daytime condition, drivers were requested to rate each of the lenses on a scale of 1 to 10, with 1 indicating WORST and 10 indicating BEST. Under nighttime conditions, the drivers were asked to rate each of the lenses on a scale of 1 to 10 where 1 indicated TOO DIM, 5 indicated ABOUT RIGHT, and 10 indicated TOO BRIGHT.

3.2.2 Arrow Modules

Arrow modules were evaluated from two viewing positions: “straight ahead” and “at an angle.” It was noted that the visibility of some of the arrow modules was significantly different when they were viewed at an angle. The viewing stations were marked such that the transverse distance between the arrow (when viewed at an angle) and the drivers would be similar to the distance between a traffic signal placed in the far left side of an intersection (distance 71 ft, lateral distance 25 ft) and driver at a signalized intersection. Drivers were requested to rate each of the lenses (Red, Yellow, and Green) on a scale of 1 to 10, with 1 indicating WORST and 10 indicating BEST. It should be noted that the arrows were not evaluated at “nighttime” because no concerns about arrows being too bright have been expressed.

3.2.3 Pedestrian Modules

It is unlikely that a jurisdiction would use different vendors’ pedestrian modules in the same signal head. Therefore, the drivers were requested to give one rating for the Walking Man and Hand signal modules, whether it was an overlay module or not. The drivers were requested to rate each of the lenses on a scale of 1 to 10, with 1 indicating WORST and 10 indicating BEST.

In Figure 3-3 a photograph of the modules when they were on individually is assembled (Please note that the competing colors were not on at the same time). The models and serial numbers for the modules are given in Table 3-1.

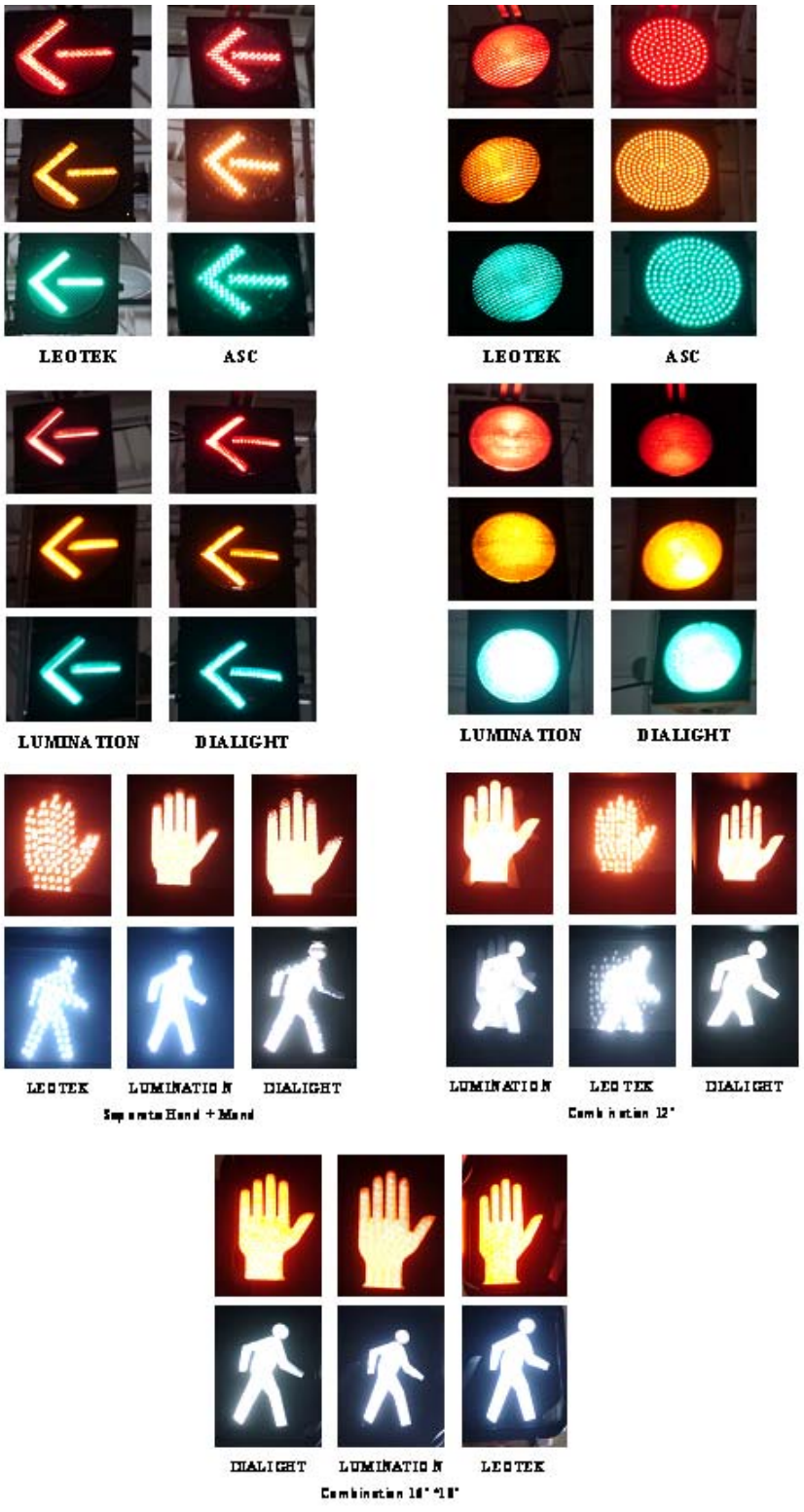


Figure 3-3: Picture of different LED Modules

Table 3-1. Model and Serial Number of the Modules Used in the Survey

	Color	Serial No.	Model No.
DIALIGHT			
Solid	Red	433-1210-003XL	070298780
	Yellow	133-3230-001XL	070254516
	Green	433-2220-001XL	063558182
Arrow	Red	432-1314-001X	062808795
	Yellow	431-3334-001X	062800963
	Green	432-2324-001X	070221642
Pedestrian	Man	430-7771-001X	062993087
	Hand	430-5770-001X	063710585
	Combination 12	430-6772-001X	070256515
	Combination 16	430-6450-011X	070166710
LUMINATION			
Solid	Red	DR6-RTFB-17A	335750036
	Yellow	DR6-YTFB-17A	344350132
	Green	DR6-6CFB-17A	335770287
Arrow	Red	DR6-RTAAN-17A	312290294
	Yellow	DR6-YTAAN-17A	318010121
	Green	DR6-6CAAN-17A	313280080
Pedestrian	Man	PS6-WFM-26A	012200011
	Hand	PS6-PGH1-26A	012100010
	Combination 12	PS6-CFL1-26A	0001
	Combination 16	PS7-CFC1-26A	P00010642
LEOTEK			
Solid	Red	TSL-12R-LX-IL3-A1	6418075
	Yellow	TSL-12Y-LX-IL3-A1	6418418
	Green	TSL-12G-LX-IL3-A1	6418292
Arrow	Red	TSL-12RA-LD-A1	4B00455
	Yellow	TSL-12YA-LD-A1	5A03393
	Green	TSL-12GA-LD-A1	5C19085
Pedestrian	Man	TP12B-WM	6225454
	Hand	TP12B-EH	6225718
	Combination 12	TP12H-HM	7331107
	Combination 16	TSL-PED-16-DIL	7307944
ASC			
Solid	Red	ASC-0300-RB1	R3BA10055
	Yellow	ASC-0300-YB1	Y3BA10036
	Green	ASC-0300-GB1	G3BA10161
Arrow	Red	ASC-0300-RA1	R3AA10085
	Yellow	ASC-0300-YA1	Y3AA10055
	Green	ASC-0300-GA1	G3AA10148
Pedestrian	Man	N/A	N/A
	Hand	N/A	N/A
	Combination 12	N/A	N/A
	Combination 16	N/A	N/A

CHAPTER 4 CONDUCTING THE SURVEY

Surveys were conducted at the Traffic Operations Laboratory (TOL) of the University of Illinois located in Rantoul, Illinois. Four different groups of participants, 120 in total, completed the survey. The survey took about 45 minutes. The first group included 17 IDOT personnel who were at TOL participating in the statewide meeting on June 12, 2007. The second group was composed of 13 graduate students in the transportation program of the University of Illinois who took the survey on August 30, 2007. The third and fourth groups included 90 IDOT personnel from District 5 who also attended a safety training class on October 26 and 29, 2007.

The survey was conducted in the bay area inside TOL in two different steps. First, participants took the initial part of the survey, in which the modules were evaluated under daylight illumination conditions. Then, the second part of the survey was conducted under nighttime illumination, for which all lights inside the bay area were turned off and all windows were completely covered to simulate the ambient lighting experienced at an isolated intersection with no street lighting.

As mentioned earlier, solid and arrow LED modules (including red, yellow, and green modules) from four manufacturers, and pedestrian signals from three manufacturers were evaluated in the survey. The solid and arrow modules were mounted on steel frames hanging from the ceiling of the bay area (at approx. 16 ft from the ground). Two three-head sections, each one containing the red, yellow, and green solid modules from the same manufacturer, were connected to a traffic signal controller. Thus, two frames were needed to mount the solid modules from the four manufacturers (Frames B and C in Figure 4-1).

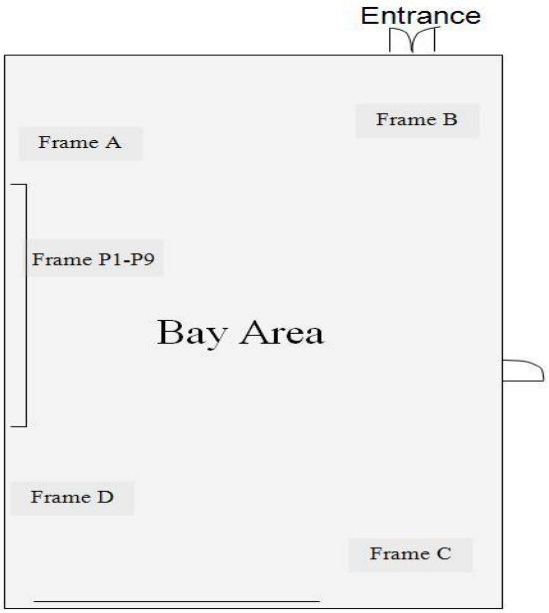


Figure 4-1. Location of frames containing solid, arrow, and pedestrian LED modules.

Similarly, two additional frames were needed to mount the arrow modules (frames A and D in Figure 4-1), for four frames. To avoid any confusion, the frames were located around the bay area in such a way that when participants took the survey they would only see one frame at a given time from a distance of about 71 ft. This distance was similar to the actual distance that could exist between a driver and the signal head at an intersection with two through lanes per direction and a left turn pocket.

On the other hand, the nine pedestrian LED modules were mounted along a frame located on the east side of the bay area (Frame P1-P9 in Figure 4-1). The pedestrian modules were located next to each other along the frame, where signal housings P1 through P3 contained 12” separated hand + man modules (Figure 4–2-A), signal housings P4 through P6 contained 12” combined hand + man modules (Figure 4–2-B), and signal housings P7 through P9 contained 16”x18” hand + man modules (Figure 4–2-C).

A – 12” Hand+Man Separated

B – 12” Hand+Man Combined

C – 16”x18” Hand+Man

Figure 4-2. Pedestrian signals.

Participants were guided through the bay area in such a way that they evaluated the LED modules from well-marked “stations.” Thus, for example, the modules mounted on “Frame A” would be evaluated when the participants were standing on the “Frame A Station.” The actual location of the stations is shown in Figure 4-3. It should be noted that some of the modules were evaluated when participants looked at them “straight” and “at an angle.” The “at an angle” evaluation was only used for the arrow modules, simulating the conditions drivers would find when the arrow signal head is located across the intersection on the left side. The distance between the pedestrian modules and the pedestrian viewing station was 51-55 ft. The top of the pedestrian housing unit was 9.5 feet above the ground level.

Before taking the survey, participants were given directions about the purpose of the survey and how it was intended to be conducted. Then, they were instructed to split in groups of approximately 10 people so that each group would start at a different station, and then move clockwise until all stations had been visited.

Members of the research team were available to answer any questions regarding the survey and helped in directing the groups through the stations. After the groups went around all the stations, they were given around 5-10 minutes to fill out the demographic information and to indicate the criteria used to evaluate the modules.

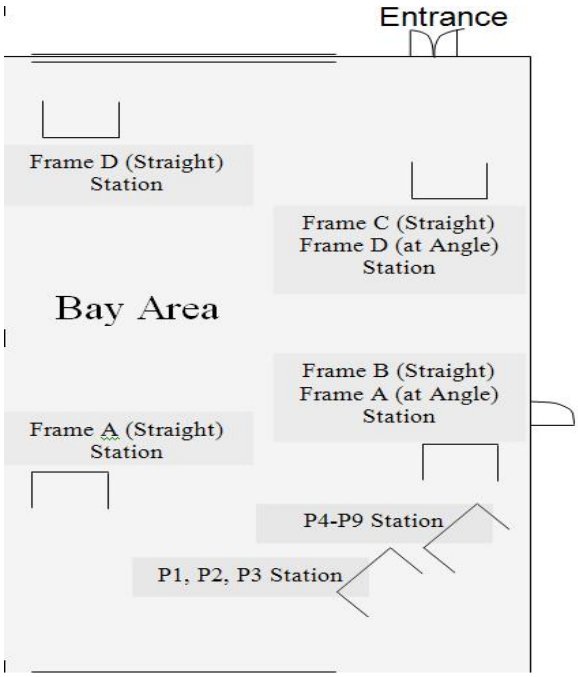


Figure 4-3. Location of “Stations” to evaluate LED modules on each frame.

Finally, participants waited for the lights to be turned off, so that the nighttime section of the survey could begin. When the night section was completed, participants returned the surveys to a member of the research team and the process was completed.

CHAPTER 5 FINDINGS OF THE SURVEY

The surveys were conducted on June 12, 2007; August 30, 2007; October 26, 2007; and October 29, 2007. A total of 120 respondents participated in the surveys. Eleven surveys out of 120 were removed because either they did not carefully rate the modules or had missed some pages of the questionnaire. Table 5-1 shows the demographic information of the remaining 109 participants.

Table 5-1. Demographic Information of the Participants

Difficulty with Colors	Frequency	Percentage
Yes	4	3.7
No	104	95.4
No Answer	1	0.9
Total	109	100.0
Age Group	**Frequency**	**Percentage**
20-29	15	13.8
30-39	19	17.4
40-49	32	29.4
50-59	28	25.7
60 or Greater	14	12.8
No Answer	1	0.9
Total	109	100.0
Wear Glass	**Frequency**	**Percentage**
Yes	31	28.4
No	43	29.5
No Answer	35	32.1
Total	109	100.0

As Table 5-1 shows, 95.4% of the participants did not have any problem with different colors. The participants represented a wide range of driving ages and a good balance between those with and without glasses.

The rest of this section is divided into two parts. In the first part, the driver's ratings of the LED modules are discussed. In the second part, the driver's preferences are discussed.

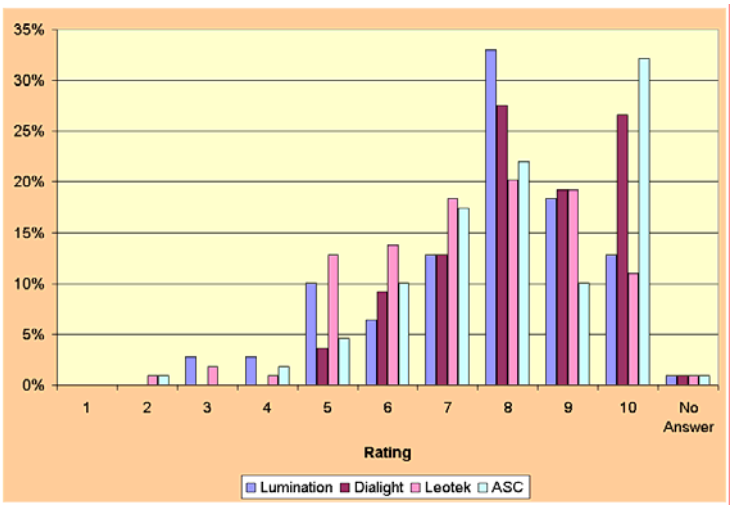
5.1 DRIVERS' RATINGS OF MODULES

First, the daytime results are presented for Solid, Arrow and Pedestrian modules. Following this, the nighttime results for Solid modules are presented.

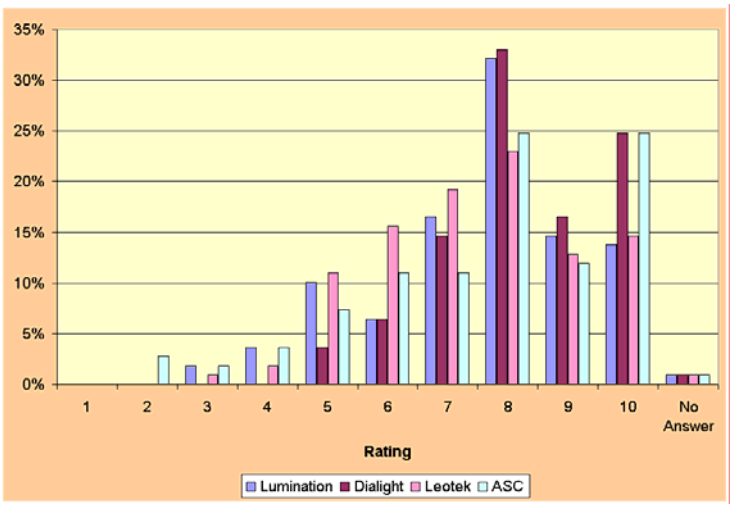
5.1.1 Daytime Results

Solid Modules in Daytime

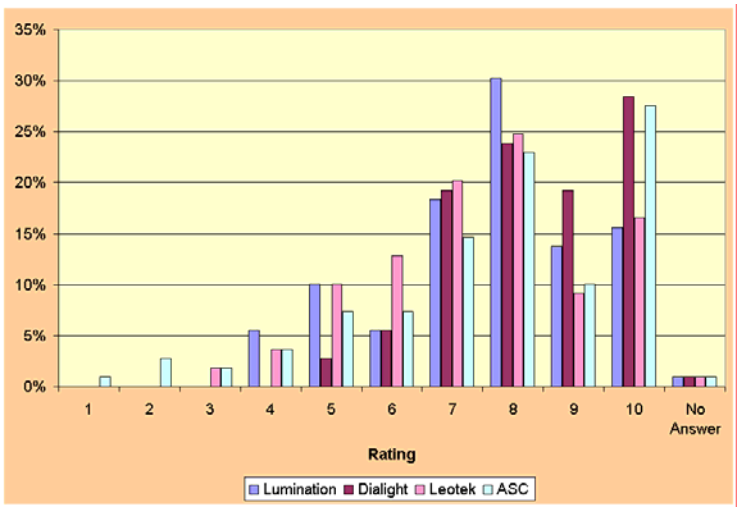
The participants were asked to rate the modules using the following sentence: "On a scale of 1 to 10, where 1 indicates WORST and 10 indicates BEST, please rate each of the LED signal lenses." Figure 5-1 shows the distribution of ratings for each color of the solid modules in the daytime. The ratings for different colors and companies cover a wide range, but a higher concentration is around 8 for all of them.



Red Solid Modules



Yellow Solid Modules



Green Solid Modules

Figure 5-1. Histogram of ratings for different solid modules in the daytime.

Figure 5-2 shows minimum, average, and maximum ratings for each module. For all colors, the average of ratings for the ASC module was slightly higher than the other modules.

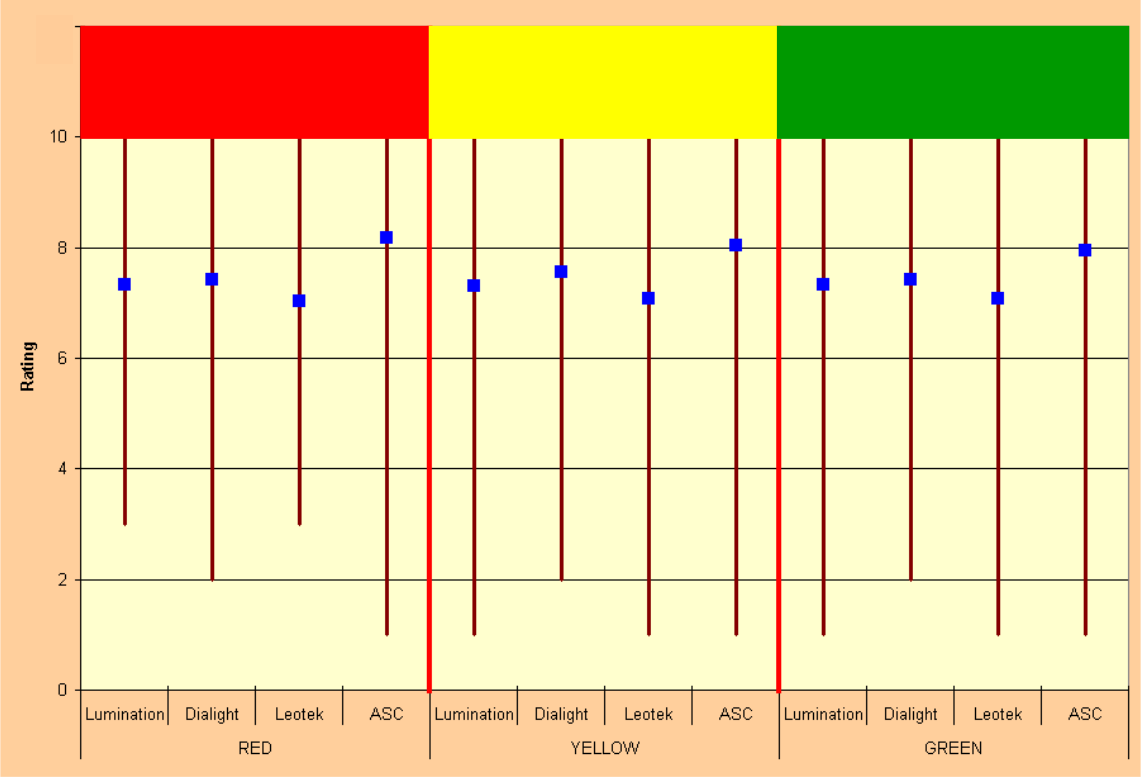


Figure 5-2. Ratings for the solid modules in the daytime.

The least significant difference (LSD) test was performed to determine if the numerical differences between the average ratings of modules were statistically significant. The results are presented in Table 5-2. All modules were rated better than average as the mean rating varied from 7.0 to 8.2. Under the Grouping column of the table, each company is marked with a letter. For the companies marked with the same letter, the average ratings of respondents are not significantly different with 90% confidence. If companies are marked with different letters, the average ratings are significantly different.

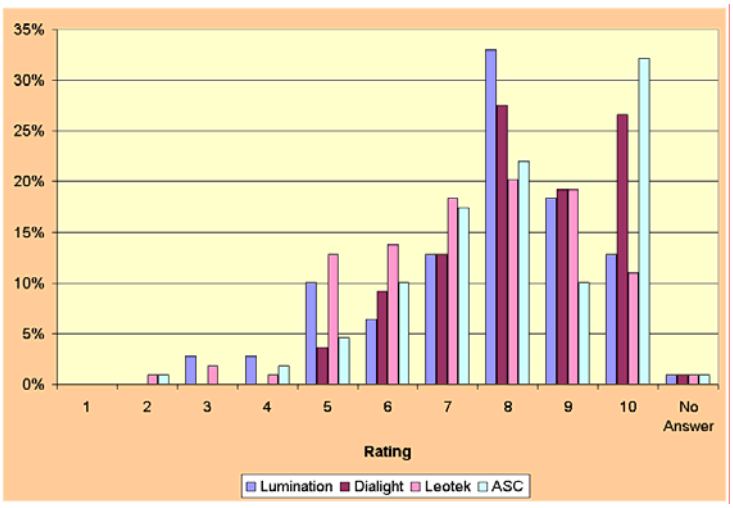
Table 5-2. The LSD results for the Solid Modules in the Day Time

Grouping		Mean	Sample Size	Company
Red				
A		**8.2**	**108**	**ASC**
B		**7.4**	**109**	**Dialight**
B		**7.3**	**109**	**Lumination**
B		**7.0**	**108**	**Leotek**
Yellow				
	A	**8.0**	**108**	**ASC**
	B	**7.5**	**109**	**Dialight**
C	**B**	**7.3**	**109**	**Lumination**
C		**7.1**	**108**	**Leotek**
Green				
A		**8.0**	**108**	**ASC**
B		**7.4**	**109**	**Dialight**
B		**7.3**	**109**	**Lumination**
B		**7.1**	**108**	**Leotek**

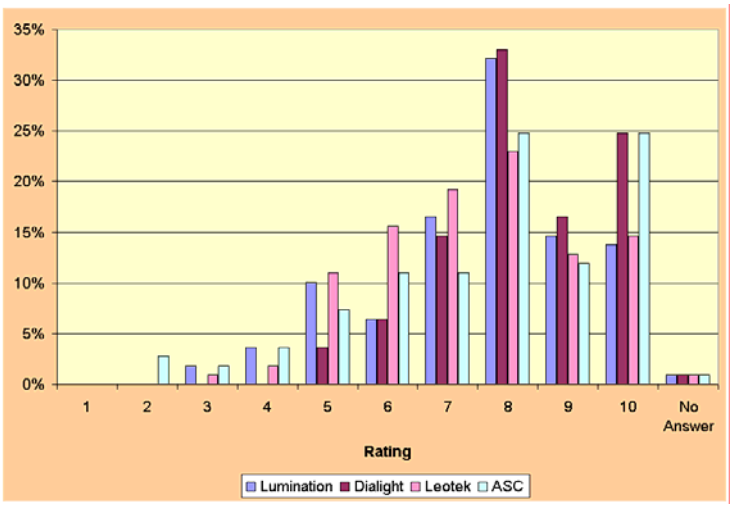
The results of the LSD test indicated that the respondent's ratings for the ASC modules were significantly higher than the ratings for the other three companies (Dialight, Lumination, and Leotek) for all three colors of the solid modules in the daytime. For the yellow color, the Dialight was rated significantly higher than the Leotek.

5.1.2 Arrow Modules in Daytime (Looking Straight)

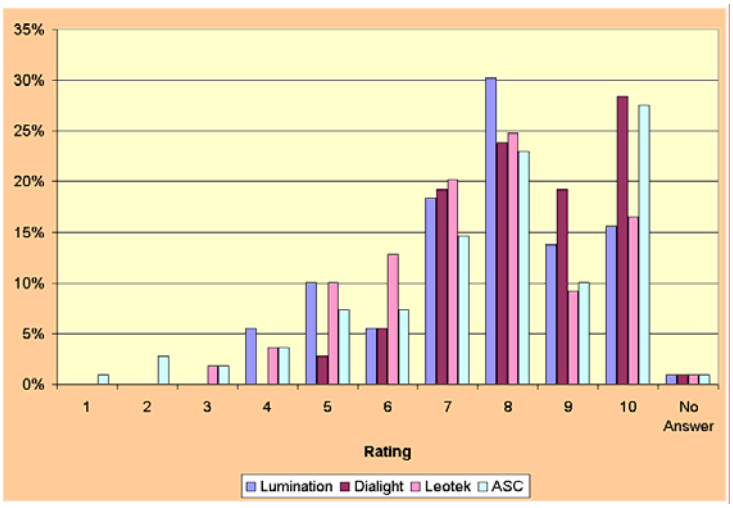
Each respondent was asked to rate each color of the arrow modules while looking straight at them. The question was: "On a scale of 1 to 10, where 1 indicates WORST and 10 indicates BEST, please rate each of the LED signal lenses." Figure 5-3 shows the histogram of the ratings for each color of the arrow modules in the daytime when the respondents look straight at them. Similar to solid modules, the ratings for different colors and companies show a wide range, but a higher concentration is around 8 for all of them.



Red Arrow Modules



Yellow Arrow Modules



Green Arrow Modules

Figure 5-3. Histogram of rating for different arrow modules for looking straight in the daytime.

As Figure 5-4 presents, for all colors on average, Dialight was rated slightly higher than the other companies. In addition, for red color modules, the averages rating for ASC was slightly higher than the ratings for Lumination and Leotek modules.

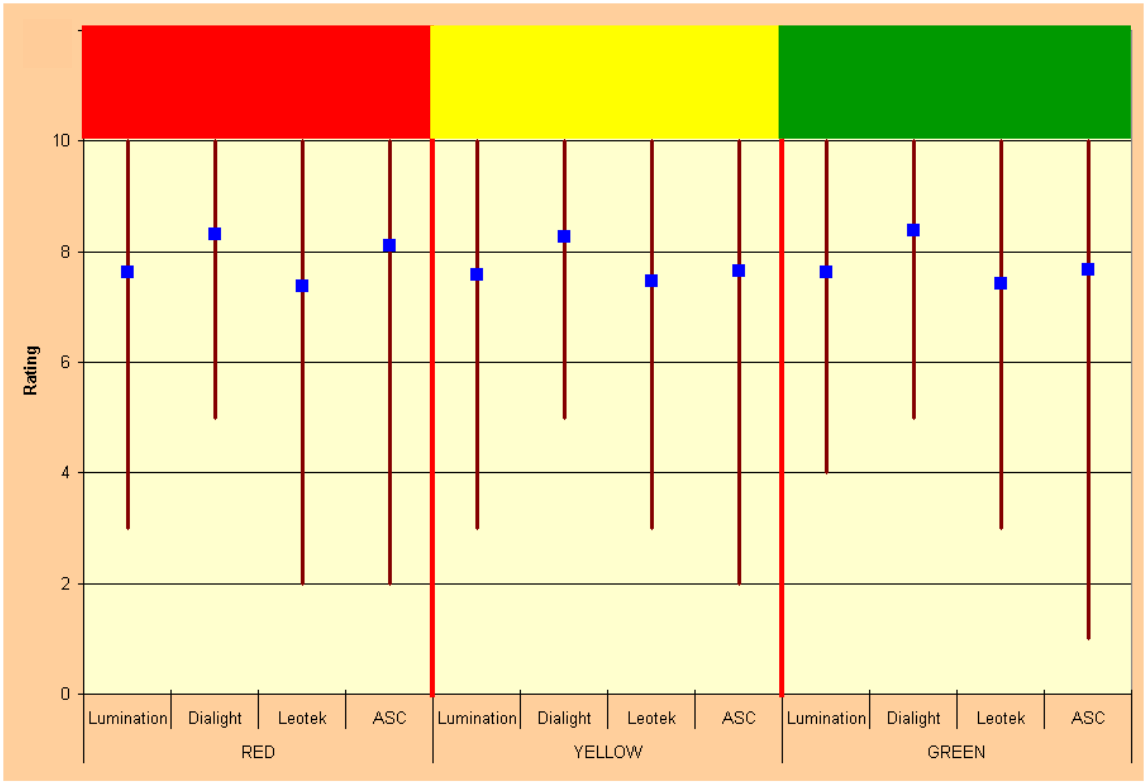


Figure 5-4. Ratings for the arrow modules for looking straight in the daytime.

To determine whether the numerical differences were statistically significant, the LSD test was performed. As presented in Table 5-3, all modules were rated better than average as the mean rating varied from 7.4 to 8.4.

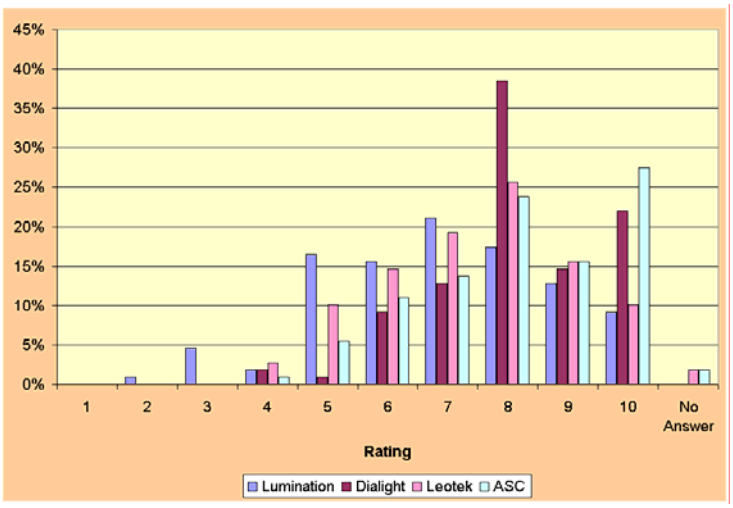
Table 5-3. The LSD Results for the Arrow Modules for Looking Straight in the Day Time

Grouping	Mean	Sample Size	Company
Red			
A	**8.3**	**108**	**Dialight**
A	**8.1**	**108**	**ASC**
B	**7.6**	**108**	**Lumination**
B	**7.4**	**108**	**Leotek**
Yellow			
A	**8.3**	**108**	**Dialight**
B	**7.7**	**108**	**ASC**
B	**7.6**	**108**	**Lumination**
B	**7.5**	**108**	**Leotek**
Green			
A	**8.4**	**108**	**Dialight**
B	**7.7**	**108**	**ASC**
B	**7.6**	**108**	**Lumination**
B	**7.4**	**108**	**Leotek**

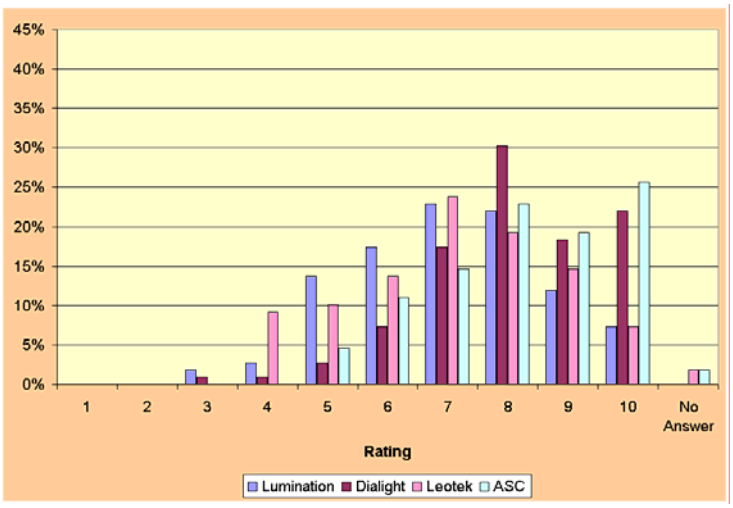
The results of the LSD test showed that for the red color lenses, the Dialight and ASC were rated similarly to each other and significantly higher than the Lumination and Leotek. For both yellow and green colors lenses, the Dialight was rated higher than the other three companies.

5.1.3 Arrow Modules in Daytime (Looking at an Angle)

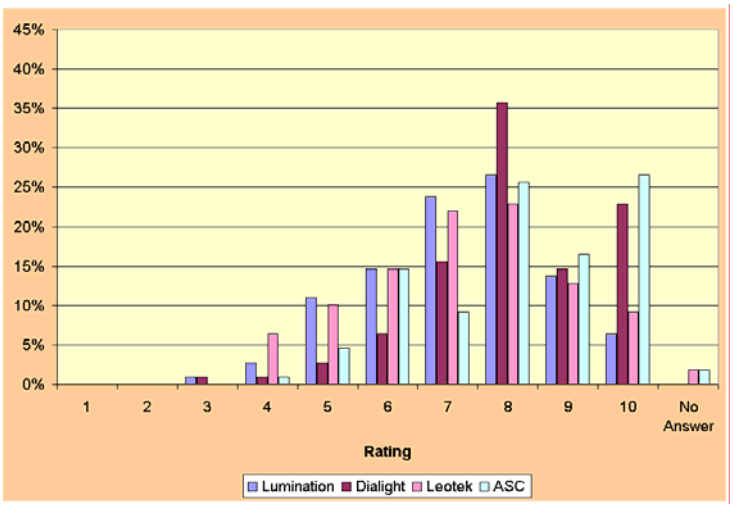
To simulate the conditions drivers would find when the arrow signal head is located across the intersection on the left side, each respondent was asked to rate each color of the arrow modules while viewing them at an angle. The participant were asked: “On a scale of 1 to 10, where 1 indicates WORST and 10 indicates BEST, please rate each of the LED signal lenses.” Figure 5-5 shows the histogram of the ratings for each color of the arrow modules in the daytime when the respondents look at them at an angle. The ratings for different colors and companies cover a wide range, but a higher concentration is around 8 for all of them.



Red Arrow Modules



Yellow Arrow Modules



Green Arrow Modules

Figure 5-5. Histogram of rating for different arrow mod. for looking at an angle in the daytime.

As Figure 5-6 shows, for all colors on average, both Dialight and ASC modules were rated slightly higher than the Lumination and Leotek modules. A LSD test was conducted to determine if these numerical differences were statistically different. The results are presented in Table 5-4.

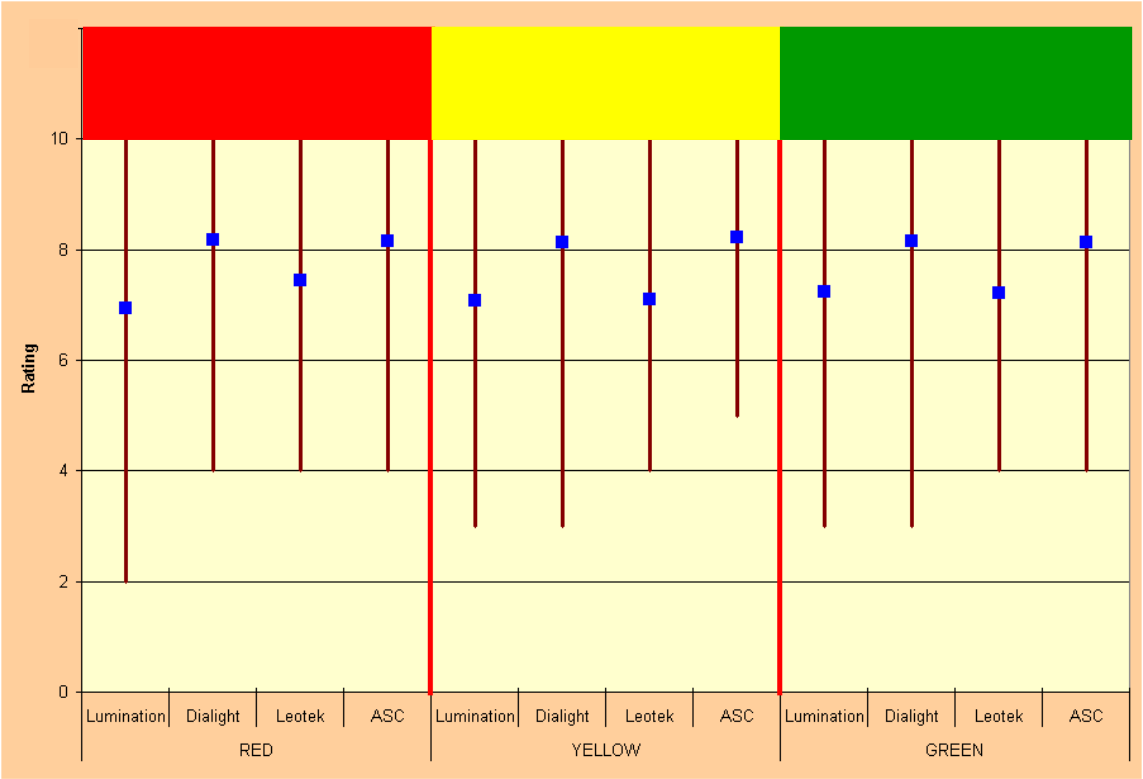


Figure 5-6. Ratings for the arrow modules for looking at an angle in the daytime.

As presented in Table 5-4 all modules were rated better than average as the mean rating varied from 6.9 to 8.2.

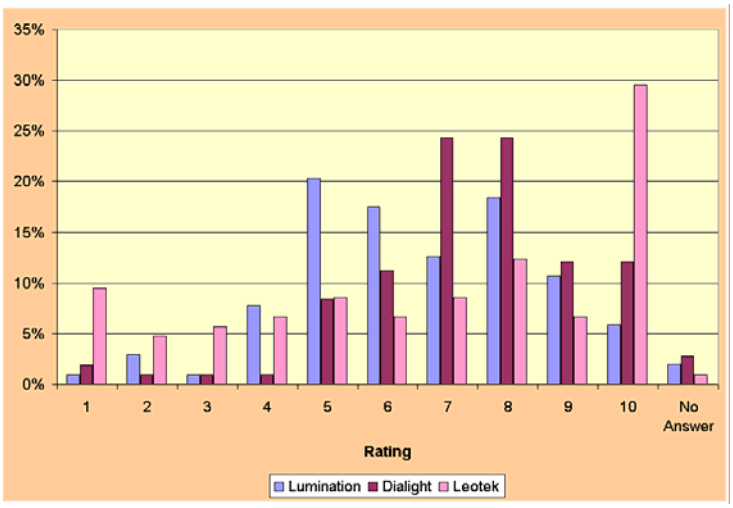
Table 5-4. The LSD Results for the Arrow Modules for Looking at an Angle in the Day Time

Grouping	Mean	Sample Size	Company
Red			
A	**8.2**	**109**	**Dialight**
A	**8.2**	**107**	**ASC**
B	**7.5**	**107**	**Leotek**
C	**6.9**	**109**	**Lumination**
Yellow			
A	**8.2**	**107**	**ASC**
A	**8.1**	**109**	**Dialight**
B	**7.1**	**107**	**Leotek**
B	**7.1**	**109**	**Lumination**
Green			
A	**8.2**	**109**	**Dialight**
A	**8.1**	**107**	**ASC**
B	**7.3**	**109**	**Lumination**
B	**7.2**	**107**	**Leotek**

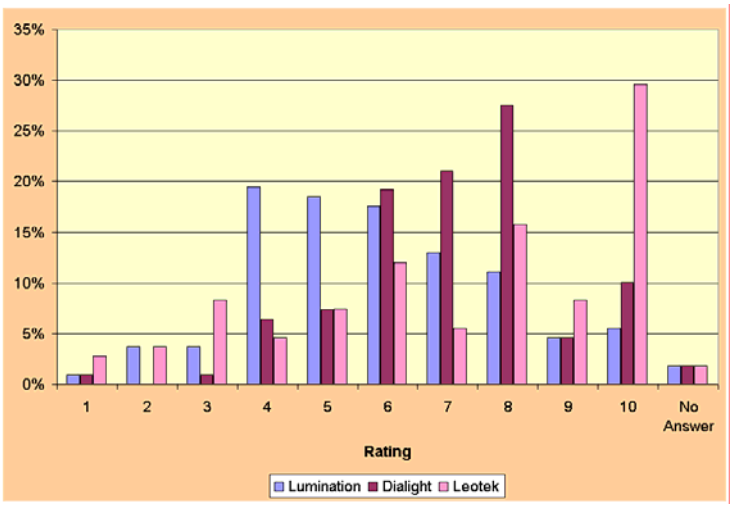
The results of LSD test showed that for all colors, Dialight and ASC modules were rated significantly higher than Leotek and Lumination modules. For the red lenses, Leotek was rated higher than Lumination, but for the other colors, Leotek and Lumination were rated similarly.

5.1.4 Pedestrian Modules in Daytime

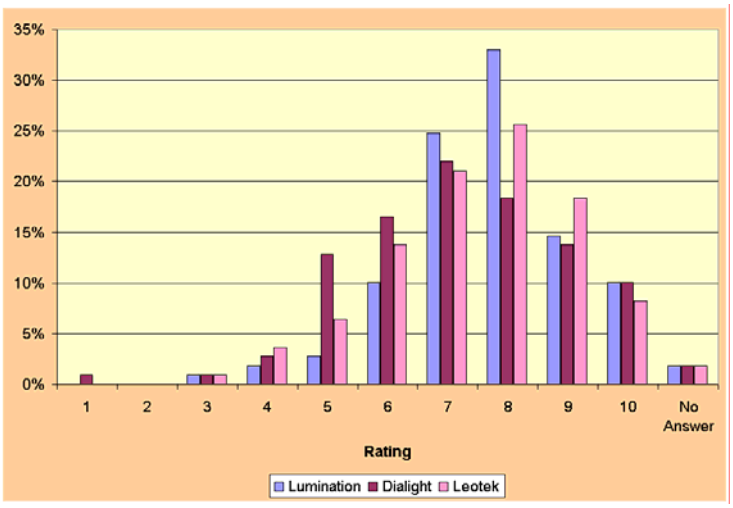
The pedestrian modules for only three companies (Dialight, Leotek, and Lumination) were compared because ASC did not provide any pedestrian module for evaluation. The participants were asked “On a scale of 1 to 10, where 1 indicates WORST and 10 indicates BEST, please rate the combination of LED Man and Hand signal lenses TOGETHER.” It should be noted that for the Man and Hand modules, respondents were asked to provide a single rating because these units are used together in the real world. Figure 5-7 shows the histogram of the ratings for each pedestrian module. The ratings for different modules and companies cover a wide range. For the 16 in. by 18 in. combination module, a higher concentration is around 8.



12” Separate Modules



12” Combination Modules



16x18” Combination Modules

Figure 5-7. Histogram of rating for different pedestrian in the daytime.

As Figure 5-8 shows, for the 12 in. separate modules, the average rating for Dialight was slightly higher than the other modules. For the 12 in. combination modules, Leotek and Dialight were rated similarly and slightly higher than the Lumination. For the 16 in. by 18 in. combination modules, Lumination was rated slightly higher than the rest of modules.

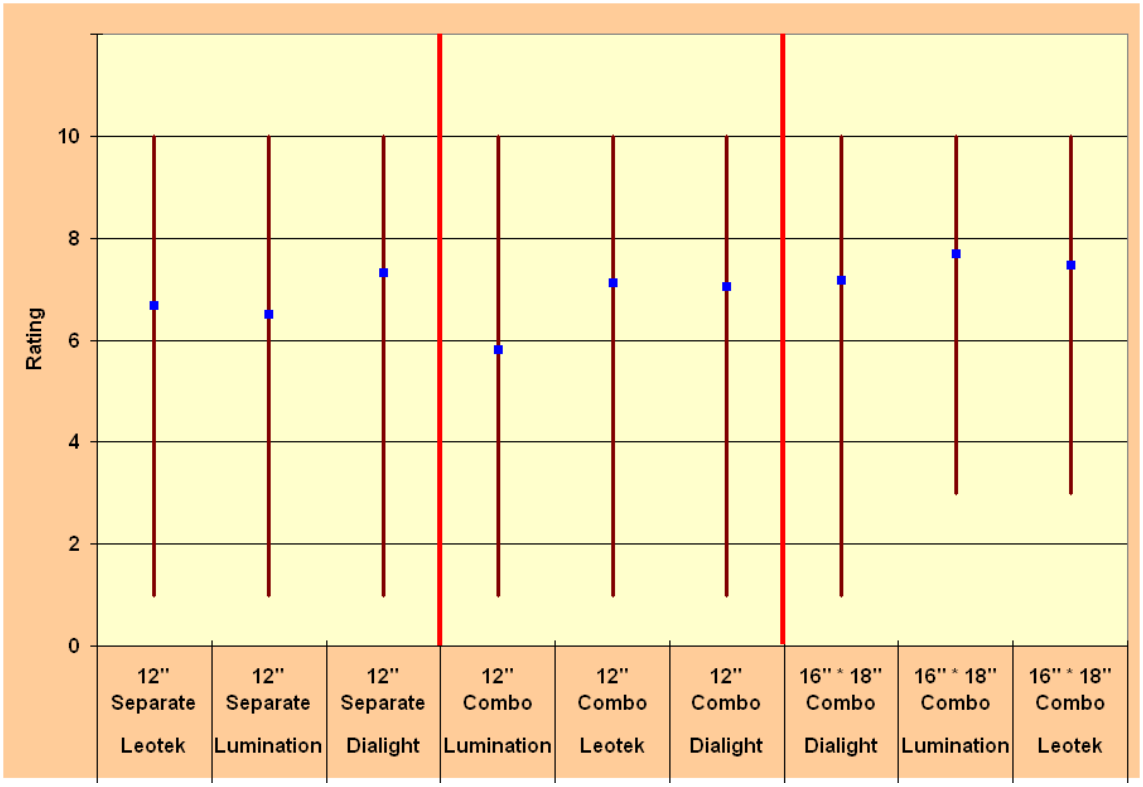


Figure 5-8. Ratings for the pedestrian modules in the daytime.

A LSD test was conducted to determine if these numerical differences were statistically significant. As presented in Table 5-5, all modules were rated better than average as the mean rating varied from 5.8 to 7.7. The ratings for the pedestrian modules had a wider range than the ratings for the vehicular modules.

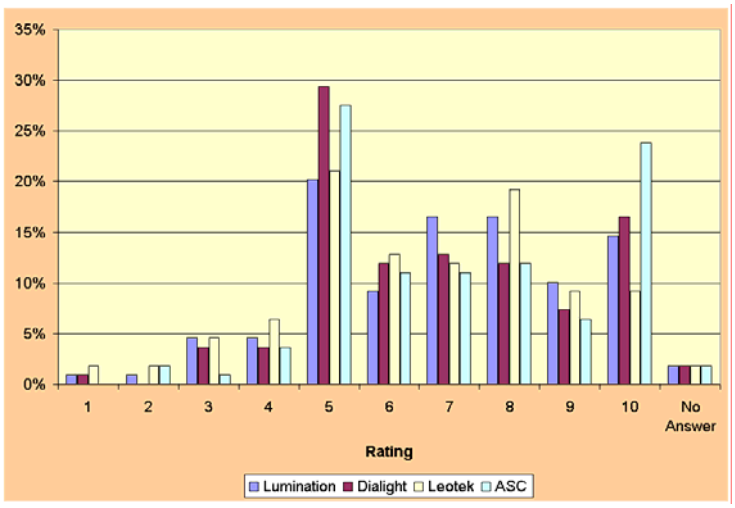
Table 5-5. The LSD Results for the Pedestrian Modules in the Day Time

Grouping		Mean	Sample Size	Company
Man + Hand Separate Modules				
A		**7.3**	**106**	**Dialight**
B		**6.7**	**108**	**Leotek**
B		**6.5**	**107**	**Lumination**
Combination 12”				
A		**7.1**	**107**	**Leotek**
A		**7.1**	**107**	**Dialight**
B		**5.8**	**107**	**Lumination**
Combination 16”*18”				
	A	**7.7**	**107**	**Lumination**
B	**A**	**7.5**	**107**	**Leotek**
B		**7.2**	**107**	**Dialight**

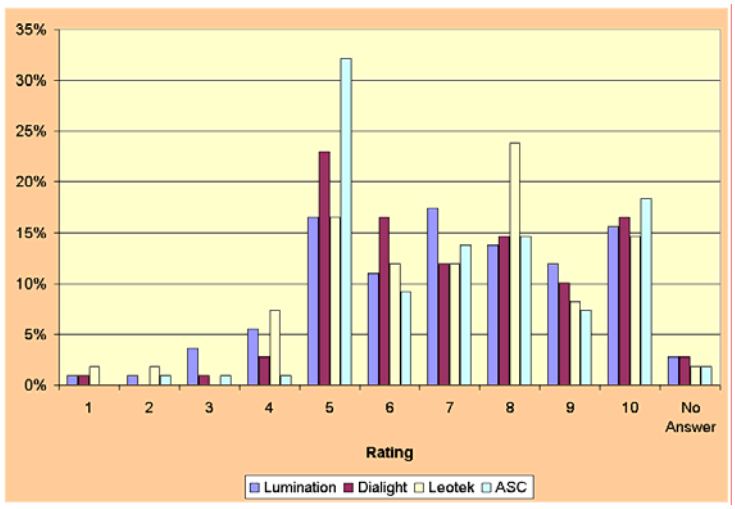
The results of the LSD test showed that the separate 12 in. Dialight pedestrian module was rated significantly higher than Leotek and Lumination modules that were rated similarly. For 12 in. combination modules, Leotek and Dialight were rated similarly and significantly higher than the Lumination. For the 16 in. by 18 in. combination modules, Lumination was rated significantly higher than Dialight.

5.1.6 Solid Modules in Nighttime

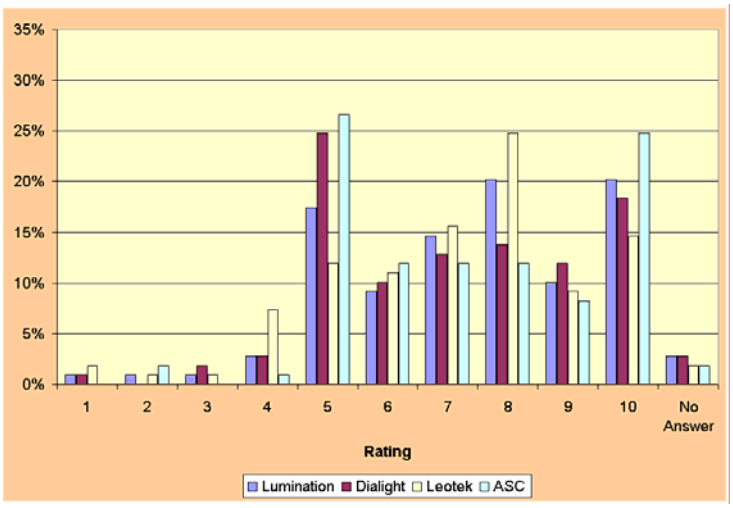
Some of the solid LED modules may be too bright in the dark condition. To identify if different modules were too bright, each respondent was asked to rate the brightness of the solid modules. They were asked: “On a scale of 1 to 10, where 1 indicates TOO DIM, 5 indicates ABOUT RIGHT and 10 indicates TOO BRIGHT, please rate each of the LED signal lenses.” Figure 5-9 shows the histogram of the ratings for each color of the solid modules in the nighttime scenario. The ratings for different colors and companies cover a wide range with most of the ratings being in between “About Right” and “Too Bright”.



Red Solid Mod. in Nighttime



Yellow Sol. Mod. in Nighttime



Green Sol. Mod. in Nighttime

Figure 5-9. Rating for different solid modules in the nighttime.

Figure 5-10 shows minimum, average, and maximum ratings for each module. The average ratings for all companies were around 7, which is higher than “About Right.” This indicates that participants believed that all of the modules were brighter.

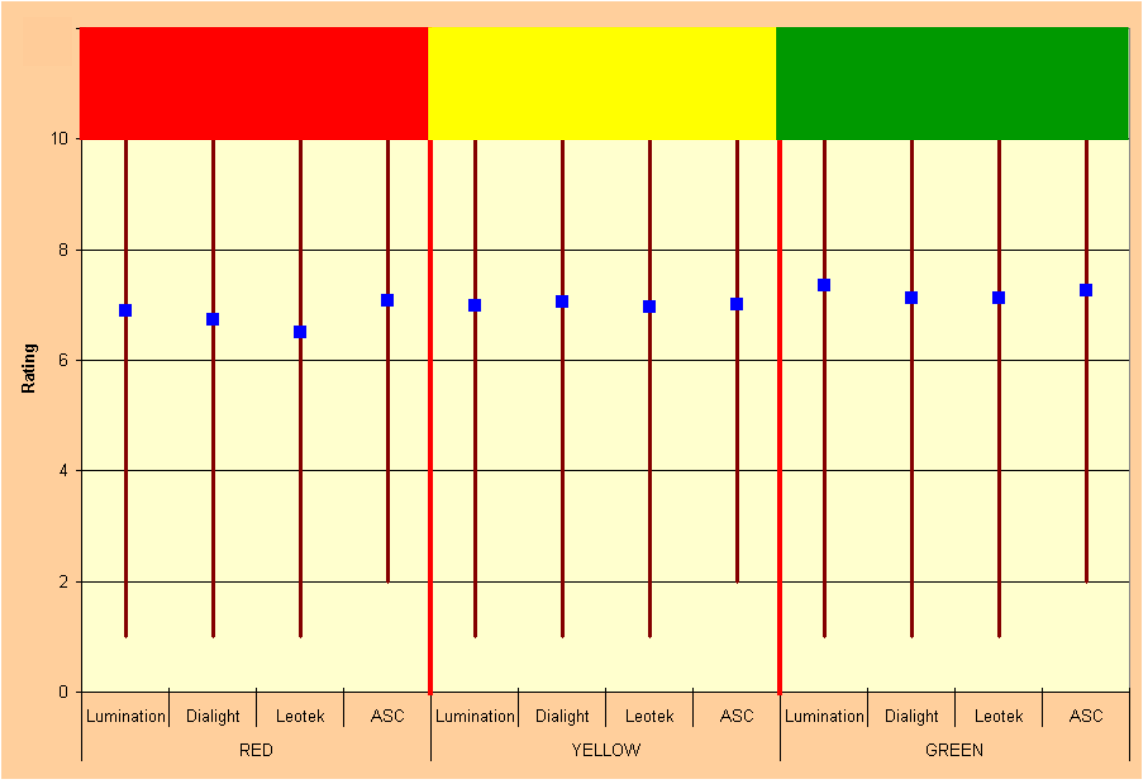


Figure 5-10. Ratings for the solid modules in the nighttime.

The LSD test was performed to determine if any significant difference existed among the brightness of different companies. As presented in Table 5-6, the red module of ASC was as bright as that of Lumination and Dialight, but much brighter than that of Leotek. For yellow and green modules, the brightness was the same for all companies. The mean brightness rating varied from 6.5 to 7.4. All these values were significantly different from 5, which is the rating for “About Right.” The higher than “about Right” rating is expected since these modules were new and are expected to be brighter at the beginning of their life.

Table 5-6. The LSD results for the Solid Modules in the Night Time

Grouping		Mean	Sample Size	Company
Red				
	A	**7.1**	**107**	**ASC**
B	**A**	**6.9**	**107**	**Lumination**
B	**A**	**6.7**	**107**	**Dialight**
B		**6.5**	**107**	**Leotek**
Yellow				
A		**7.1**	**106**	**Dialight**
A		**7.0**	**107**	**ASC**
A		**7.0**	**106**	**Lumination**
A		**7.0**	**107**	**Leotek**
Green				
A		**7.4**	**106**	**Lumination**
A		**7.3**	**107**	**ASC**
A		**7.1**	**106**	**Dialight**
A		**7.1**	**107**	**Leotek**

5.2 IMPORTANT RATING FACTORS

Each participant was asked about the factors he/she used in evaluating the LED traffic signal lenses. Three factors for the vehicular modules and four factors for pedestrian modules were listed in the survey, and participants could mention up to three more factors they used in their evaluation. They were also asked about the importance of each factor on a scale of 1 to 10, where 1 indicates the least and 10 indicates the most important factor.

This part of the study identifies some of the factors that were important to the respondents in rating the modules. The important factors in rating the vehicular modules are studied separately from the factors used for pedestrian modules. The two questions included in the survey to identify these factors were:

1. What factors did you use in evaluating the LED traffic signal lenses? Please rate the importance of these factors on a scale of 1 indicating LEAST important and 10 indicating MOST important. Some factors are listed below.

	FACTORS	IMPORTANCE
o	Brightness	_____
o	Color	_____
o	Uniformity	_____
o	Other (specify): _____	_____
o	Other (specify): _____	_____
o	Other (specify): _____	_____

2. What factors did you use in evaluating the LED Pedestrian signal lenses? Please rate the importance of these factors on a scale of 1 indicating LEAST important and 10 indicating MOST important. Some factors are listed below.

FACTORS	IMPORTANCE
o Brightness	_____
o Color	_____
o Uniformity	_____
o Size	_____
o Other (specify): _____	_____
o Other (specify): _____	_____
o Other (specify): _____	_____

5.2.1 Important Factors in Rating Traffic Modules

For this part, 103 out of 109 participants provided responses. Table 5-7 shows the respondents' opinions about the important factors.

Table 5-7. Participants Opinion about Important Factors in Rating the Traffic Modules

	Frequency	Percent
Brightness	**103**	**100.0**
Color	**96**	**93.2**
Uniformity	**91**	**88.4**
Other Factors	**30**	**29.1**

Table 5-7 shows that 100% of the respondents selected the brightness as an important factor in rating the traffic modules, 93% of them chose color as an important factor, and 88% of them selected uniformity as an important factor. About 29% (30 drivers) of participants identified some other factors as important factors. Thirteen of them wrote clarity and seven of them wrote glare as important factors. Two of them said that the sharpness was an important factor in rating. Some other factors they mentioned as important to their ratings were: thickness, easy to see, too bright, pain in eyes, LED dots, color does not blend, and blurriness.

Table 5-8 shows the number and the percentage of drivers who gave their highest rating to a particular factor. About 74% of the participants believed that the brightness was the most important factor in rating the traffic modules, while 26% believed color, and 27% believed uniformity is the most important factor. Only 7% of them believed clarity and only 2% of them believed glare to be important factors.

Table 5-8. Most Important Factor in Rating the Traffic Modules

Factor	Frequency	Percentage
Brightness	**76**	**73.8**
Color	**27**	**26.2**
Uniformity	**28**	**27.2**
Clarity	**7**	**6.8**
Glare	**2**	**1.9**

The participants were asked to rate the importance of each factor on scale of 1 to 10 (10 being the most important).The Histogram of the importance of each factor is presented in Figure 5-11.

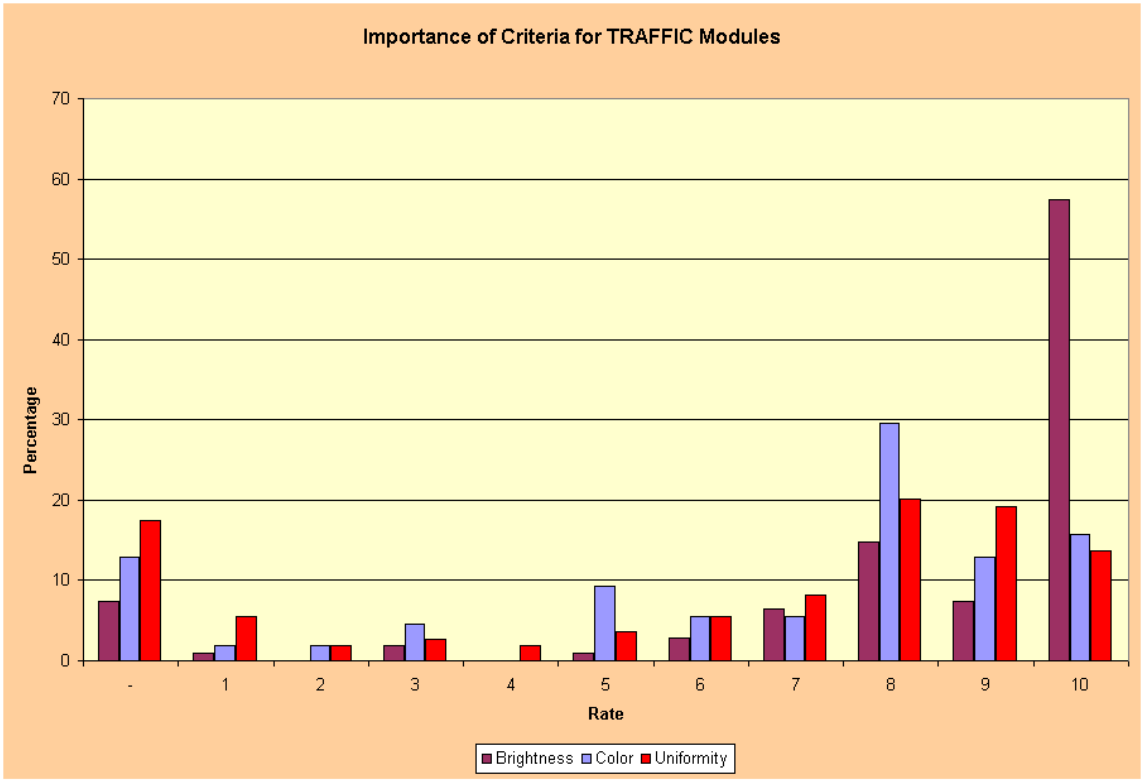


Figure 5-11. Histogram for the importance of each factor.

The average rating for brightness was 9.0, for color was 7.5, and for uniformity was 7.3. For clarity, the average rating was 9.1 and for glare, it was 8.7. A LSD test was conducted to determine if any significant difference exists between the ratings given for each factor. Table 5-9 shows the results of this test. Since only 13 and 7 drivers have rated the clarity and glare factors, these factors were not considered in the test (small sample size).

Table 5- 9: Most Important Factor in Rating the Traffic Modules

Grouping	Mean	Factor
A	**9.0**	**Brightness**
B	**7.5**	**Color**
B	**7.3**	**Uniformity**

The results of LSD test shows that participants rated brightness significantly higher than the color and uniformity factors. This indicates that respondents believed that the brightness was the most important factor among the other factors.

5.2.2 Important Factors in Rating Pedestrian Modules

Each participant was asked about the factors he/she used in evaluating the LED pedestrian signal lenses. Four factors were listed in the survey, and participants could mention up to three additional factors they may have used in their evaluation. They were also asked about the importance of each factor on a scale of 1 to 10 where 1 indicates the least and 10 indicates the most important factor. Selecting each factor means that the respondents believed

that the factor was important to some extent. For this part, 101 out of 109 participants replied. Table 5-10 shows the respondents opinion about the important factors.

Table 5-10. Participants Opinion About Important Factors in Rating the Traffic Modules.

	Frequency	Percent
Brightness	**101**	**100.0**
Color	**95**	**94.1**
Uniformity	**91**	**90.1**
Size	**71**	**70.3**
Other Factors	**20**	**19.8**

Table 5-10 shows that 100% of the respondents selected the brightness as an important factor in rating the traffic modules, 94% of them chose color, 90% of them selected uniformity, and 70% of them selected size as an important factor. About 20% (20 drivers) of participants identified some other factors as important factors. Eight of them wrote clarity and six of them wrote glare as important factors. Two of them said that the sharpness was an important factor in rating. Some other factors they mentioned as important to their ratings were: blurriness, shape, easy to use, too bright, and color does not blend.

Table 5-11 shows the number and the percentage of drivers who gave their highest rating to a particular factor. About 75% of the participants believed that the brightness was the most important factor in rating the pedestrian modules, while 25% believed color, similarly 25% believed uniformity, and 23% believed size is the most important factor. Only 5% of them believed clarity and only 3% of them believed glare to be important factors.

Table 5-11. Most Important Factor in Rating the Traffic Modules

Factor	Frequency	Percentage
Brightness	**76**	**75.3**
Color	**25**	**24.8**
Uniformity	**25**	**24.8**
Size	**23**	**22.8**
Clarity	**5**	**5.0**
Glare	**3**	**3.0**

The participants were asked to rate the importance of each factor on scale of 1 to 10 (10 being the most important).The Histogram of the importance of each factor is presented in Figure 5-12.

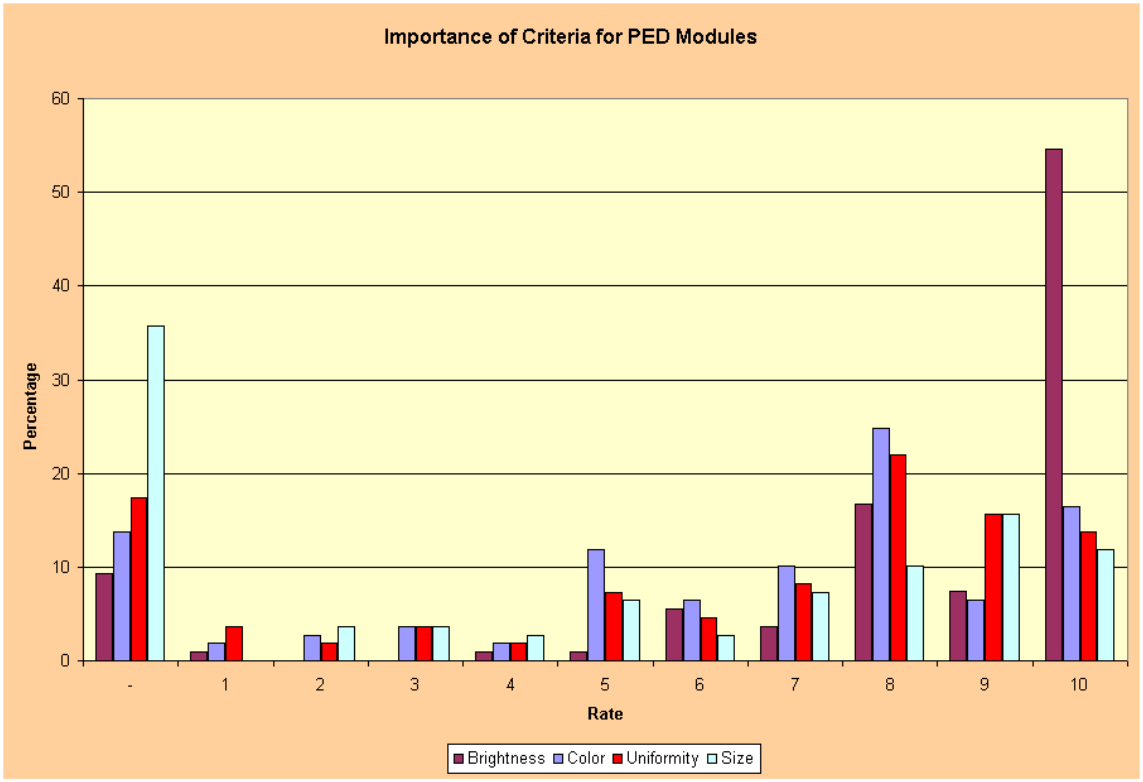


Figure 5-12. Histogram for the importance of each factor.

The average rating for brightness was 9.0, for size was 7.3, for uniformity was 7.3, and for color was 7.1. For clarity, the average rating was 9.6 and for glare, it was 8.0. A LSD test was conducted to determine if any significant difference exists between the ratings given for each factor. Table 5-12 shows the results of this test. Since only 8 and 6 drivers have rated the clarity and glare factors, these factors were not considered in the test (small sample size).

Table 5-12. Most Important Factor in Rating the Traffic Modules

Grouping	Mean	Factor
A	**9.0**	**Brightness**
B	**7.3**	**Size**
B	**7.3**	**Uniformity**
B	**7.1**	**Color**

The results of the LSD test show that participants rated brightness significantly higher than the size, uniformity, and color factors. This indicates that respondents believed that the brightness was the most important factor among the other factors.

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

This study was performed to verify the compliance of the LED traffic (vehicular and pedestrian) signal modules with the ITE specifications and to study the drivers' preferences for the modules. Four manufacturers furnished vehicular LED modules, while only three furnished pedestrian modules.

Verification of compliance with the ITE specifications primarily involved reviewing the independent-lab testing reports furnished by the vendors and manufacturers' responses to the questionnaires prepared by the research team. The only testing of the traffic signal modules was to ensure that they drew sufficient current for proper functioning of the load switches in the controller cabinet. A survey questionnaire was prepared to evaluate the drivers' preferences of the LED modules and administered to 120 participants in the Traffic Operations Lab of the University of Illinois. The conclusions are presented in separate sections for compliance with ITE Specifications and drivers' preferences.

6.1 COMPLIANCE WITH THE ITE SPECIFICATION

The solid LED modules provided by Leotek, Lumination, and Dialight either complied or complied with reservation with all the ITE Specifications, but there are several issues with ASC modules. For all three solid LED modules from ASC, photometric test results were based on only one sample, instead of six samples required by the ITE Specification. For yellow and green modules, only electric noise emission was tested, and none of the other specifications was tested. For red modules, only four other requirements were tested.

For the arrow modules at the time of completion of this study, ITE had not adopted a final specification. As a result, each manufacturer furnished independent lab reports verifying the compliance of their modules with a different version of the ITE specification. Consequently, no general conclusions are made about the compliance of the arrow modules.

Dialight submitted independent lab testing reports for only two pedestrian modules. These two LED modules either comply or comply with reservation with most of the ITE Specifications. Dialight claimed that the 12" Man (430-5770-001X) and Hand (433-7771-001X) modules are identical to 16" combo module (430-6450-001X).

Lumination also submitted independent lab testing reports for only three pedestrian modules. No report was submitted for 12" Hand and Man overlay (PS6-CFL1-26A). The Walking Man module (PS6-WFM3-26A) furnished by Lumination does not comply with the maximum luminous intensity requirement while it complies with or complies with reservation all the other requirements. The other two Pedestrian (PS6-PFH1-26A and PS7-CFC1-26A) modules comply or comply with reservation with most of the requirements.

The independent lab testing reports furnished by Leotek are based on two samples for 12" modules (TP12B-EH, TP12B-WM and TP12H-HM) and one sample for the 16" combo module (TSL-PED-16-DIL). Subject to this condition, all the 12" modules comply or comply with reservation with all the requirements. The 16" combo module (TSL-PED-16-DIL) does not comply with the maximum luminous intensity requirement, while it complies or complies with reservation with most of the other requirements.

Some discrepancies have been noted in the independent lab reports certifying the compliance of LED modules with ITE specifications. Modules that do not satisfy some of the requirements were certified as complying with the requirements. Therefore, it is strongly recommended that the independent lab test reports be carefully reviewed before the modules are accepted as compliant with the ITE Specifications.

6.2 DRIVERS' PREFERENCES

For the circular modules in the daytime, the respondent's ratings for the ASC modules were significantly higher than the ratings for the other three companies (Dialight, Lumination, and Leotek) for all three colors of the solid modules. For the yellow color, the Dialight was rated significantly higher than the Leotek.

For the arrow modules in daytime when looking straight ahead, the Dialight and ASC were rated similarly to each other and significantly higher than the Lumination and Leotek for the red color lenses. For both yellow and green colors lenses, the Dialight was rated higher than all other three companies that were rated similarly.

For the arrow modules in daytime when looking at an angle, Dialight and ASC modules were rated significantly higher than Leotek and Lumination modules for all colors. For the red color lenses, Leotek was rated higher than Lumination, but for the other colors, Leotek and Lumination were rated similarly.

For the pedestrian modules in daytime, the separate 12" Dialight pedestrian module was rated significantly higher than Leotek and Lumination modules that were rated similarly. For 12" combination modules, Leotek and Dialight were rated similarly and significantly higher than the Lumination. For the 16"*18" combination modules, Lumination was rated significantly higher than Dialight.

For the solid modules in the nighttime, the red module of ASC was as bright as that of Lumination and Dialight, but much brighter than that of Leotek. For yellow and green modules, the brightness was the same for all companies.

6.3 IMPORTANT FACTORS IN RATING THE MODULES

All the respondents believed that the brightness was an important factor in rating the traffic modules; 93% of them chose color as an important factor, and 88.4% of them selected uniformity as an important factor. About 29% (30 drivers) of participants identified some other factors as important factors. About 74% of the participants believed that the brightness was the most important factor in rating the traffic modules, while 26% believed color and 27% believed uniformity is the most important factor. Only 7% of them believed clarity and only 2% of them believed glare to be important factors.

All the respondents (100%) believed that the brightness was as an important factor in rating the pedestrian modules; 94% of them chose color, 90% of them selected uniformity, and 70% of them selected size as an important factor. About 20% (20 drivers) of participants identified some other factors as important factors. About 75% of the participants believed that the brightness was the most important factor in rating the pedestrian modules, while 25% believed color, similarly 25% believed uniformity, and 23% believed size is the most important factor. Only 5% of them believed clarity and only 3% of them believed glare to be important factors.

6.4 RECOMMENDATIONS

ITE specifications require that the LED modules meet the luminous intensity requirements for a minimum of 60 months. However, no long-term testing of the LED modules has been performed either by the independent-labs or by the research team. The drivers' preference study shows that about 75% of the respondents believe that brightness is the most important factor. Therefore, it is recommended to conduct long-term testing possibly accelerated testing, on brightness of the LED modules. The study of drivers' preferences shows that only about a quarter of the respondents identified uniformity as the most important factor. This finding is further reinforced by the fact that ASC modules (which are not uniform, while all the

other three manufacturers' modules are) were rated highest for all the three colors of solid LED modules. The economic consequences of this finding can be significant because of the significant price difference between modules that satisfy the uniformity requirement and those that do not. Therefore, a further evaluation of drivers' preferences is recommended to validate these findings using a larger driver population.

REFERENCE

Chitturi, M. V., and R. F. Benekohal, “Drivers’ Evaluation of Performance of LED Traffic Signal Modules”, Traffic Operation Lab, University of Illinois at Urbana Champaign, 2002.

APPENDIX A. Verification of LEOTEK Solid LED Compliance

Verification of Compliance with ITE Specification for LEOTEK Solid LED Modules					
Article	Specification	Means of Testing	Solid Red	Solid Yellow	Solid Green
3.1.1	Stand-alone units shall fit into VTCSH approved traffic signal housings without modification to the housing.	Manual/Visual Verification	Comply	Comply	Comply
3.1.2	Installation of LED modules shall not require special tooling and shall connect directly to the exiting electrical wiring system.	Manual/Visual Verification	Comply	Comply	Comply
3.2.1	LED module shall be capable of replacing existing optical components of the conventional signal head	Manual/Visual Verification	Comply	Comply	Comply
3.2.2	The module front lens shall be compliant to the SAE J576 requirement under ITE 6.4.5.2 test methodology on material exposure and weathering effects.	Certifications	Comply	Comply	Comply
3.2.3	**Optional** Tinted Lens using transparent film or material with similar color and transmissivity characteristics				
3.2.4	The module lens may be a replaceable part, without the need to replace the complete LED signal module.	Manual/Visual Verification	Comply	Comply	Comply
3.3.1	All exposed components shall be suitable for prolonged exposure to the environment without interfering to the function or appearance for a period of at least 60 months (in a	Certifications (Asked Manufacturer)	Comply	Comply	Comply

	south-facing Arizona desert)				
3.3.2	A module shall be rated for use throughout an ambient operating temperature range, measured at the exposed rear of the module, of -40°F to + 165°F as per ITE 6.4.3.2 temperature cycling according to MIL-STD- 883, test method 1010	Certifications	Comply	Comply	Comply
3.3.3	A module shall be protected against dust and moisture intrusion, including rain and blowing rain. (MIL-STD-810F, test method 506.4, procedure 1, Rain and Blowing Rain under ITE 6.4.3.3 test methodology)	Certifications	Comply	Comply	Comply
3.3.4	The module lens shall not crack, craze or yellow due to solar UV irradiation typical for a south-facing Arizona desert installation after a minimum of 60 months in service	Certifications (Asked Manufacturer)	Comply	Comply	Comply
3.4.1	A module shall be self-contained, not requiring on-site assembly.	Manual/Visual Verification	Comply	Comply	Comply
3.4.2	Assembly and manufacturing processes for a module shall be designed that all internal LED and electronic components withstand mechanical shock and vibration due to high wind and other sources. (MIL-STD-883, test method 2007 under ITE 6.4.3.1 test methodology)	Certifications	Comply	Comply	Comply
3.5.1	Materials used for the lens and module construction shall conform to ASTM specifications for the materials, where applicable	Certifications (Asked Manufacturer)	Comply	Comply	Comply

3.5.2	LED module enclosure that contains the power supply shall be made of UL94 flame retardant materials	Certifications (Asked Manufacturer)	Comply	Comply	Comply
3.6.1	Each module shall be identified with manufacturer's name, model, operating characteristics (nominal voltage and stabilized power consumption) and serial number.	Manual/Visual Verification	Comply	Comply	Comply
3.6.2	Modules and removable lenses shall have a prominent and permanent vertical indexing indicator i.e. UP arrow, or the word UP or TOP for correct indexing and orientation in the signal housing.	Manual/Visual Verification	Comply	Comply	Comply
4.1.1	Minimum Luminous intensity must be maintained over the temperature range of -40°F to +165°F over the voltage range of 80 to 135 V AC for a minimum period of 60 months.	Certifications	Comply at 25C and 74C at 120 V. Nothing mentioned about lower temps and other voltages. Mfr claims Complies	Comply at 25C and 74C at 120 V. Nothing mentioned about lower temps and other voltages. Mfr claims Complies	Comply at 25C and 74C at 120 V. Nothing mentioned about lower temps and other voltages. Mfr claims Complies
4.1.1.1 to 4.1.1.5	Calculations of the various intensity: vertical, horizontal, peak minimum, minimum maintained luminous intensity at different angles.	Certifications	Comply	Comply	Comply
4.1.2	Maximum permissible luminous intensity shall not exceed three times the required peak value of the minimum maintained luminous intensity for the selected signal size and color.	Certifications (Asked Manufacturer)	Comply	Comply	Comply

4.1.3	The uniformity of the luminance (cd/m^2) across the entire module lens shall not exceed a max/min ratio of 10 to 1between the maximum and minimum luminance values.	Certifications	Comply	Comply	Comply
4.2.1	Color regions: the measured chromaticity coordinates of modules shall conform to the following: Red: y=0.308, y=0.953-0.947x; y=0.290; Yellow: y=0.151 + 0.556, y=0.972 - 0.976x;y=0.235 + 0.300x; Green: y=0.655 -0.831x, x=0.150; y=0.422-0.278x.	Certifications	Comply	Comply	Comply
4.2.2	Color Uniformity: The dominant wavelength for any individual color measurement of a portion of the emitting surface of a module shall be within + or - 3 nm of the dominant wavelength for the average color measurement of the emitting surface as a whole.	Certifications	Comply	Comply	Comply
5.1	Wire consist of two secured, color coded, 600 V, jacketed wires, a minimum length of 39", 20 AWG, 105°C rated, conforming to NFPA 70.	Manual/Visual Verification	18 AWG and not sure about complying with NFPA 70	18 AWG and not sure about complying with NFPA 70	18 AWG and not sure about complying with NFPA 70
5.2.1	Voltage range of 80 to 135 VAC RMS, operate off a 60 + or – 3 Hz AC line.	Certifications (Asked Manufacturer)	Comply	Comply	Comply
5.2.2	Fluctuations over the voltage range of 80 to 135 VAC shall not affect the luminous intensity by more than + or - 10%.	Certifications	Comply	Comply	Comply

5.2.3	The module shall prevent flicker of the LED output at frequencies less than 100 Hz over the voltage range of 80 to 135 V AC RMS	Certifications (Asked Manufacturer)	Comply	Comply	Comply
5.2.4	Low voltage turn OFF: there shall be no visible illumination from the LED signal module when the applied voltage is less than 35 V AC.	Certifications	Comply	Comply	Comply
5.2.5	Turn ON time: A module shall reach 90 % of full illumination within 75 msec of the application of the nominal operating voltage, Turn OFF time: The signal shall cease emitting visible illumination within 75 msec of the removal of the nominal operating voltage.	Certifications	Comply	Comply	Comply
5.3	Transient Voltage Protection: LED module shall withstand NEMA standard TS-2-2003, section 2.1.8.	Certifications	Comply	Comply	Comply
5.4	Emission of Electronic noise shall meet FCC Title 47, Subpart B, section 15 for class A digital device	Certifications	Comply	Comply	Comply
5.5.1	Power Factor of .90 or greater at nominal voltage and 77°F.	Certifications	Comply	Comply	Comply
5.5.2	THD shall not exceed 20% @ 77°F.	Certifications	Comply	Comply	Comply
5.6.1	Sufficient current draw to ensure compatibility and proper triggering and operation of the load switches and conflict monitors in signal controller units.	Lab Verification	Complied in Lab	Complied in Lab	Complied in Lab
5.6.2	Off state Voltage Decay: Voltage shall decay to less than 10 VAC RMS in less than 100 ms when switched from On to OFF state if maximum load switch leakage current is 10 MA peak.	Certifications	Comply	Comply	Comply

5.7	Failed State Impedance: The module shall be designed to detect catastrophic loss of the LED load. Upon sensing loss of the LED load, the module shall present a resistance of at least 250 Kohms across the input power leads within 300 msec. The LED light source will be said to have failed catastrophically if it fails to show any visible illumination when energized according to Section 5.2.1 after 75 msec.	Certifications	Comply	Comply	Comply
6.1.1	Quality Assurance Program: Modules shall be manufactured in accordance with a vendor quality assurance (QA) program. The QA program shall include two types of quality assurance: (1) design quality assurance and (2) production quality assurance. The production quality assurance shall include statistically controlled routine tests to ensure minimum performance levels of modules built to meet this specification.	Ask Manufacturer to Verify	Comply	Comply	Comply
6.1.2	Record Keeping: QA process and test results documentation shall be kept on file for a minimum period of seven years	Ask Manufacturer to Verify	Comply	Comply	Comply
6.1.3	Module designs not satisfying design qualification testing and the production quality assurance testing performance requirements in Sections 6.3 and 6.4 shall not be labeled, advertised, or sold as conforming to this	Ask Manufacturer to Verify	Comply	Comply	Comply

	specification.				
6.2	Each module shall be identified with the information specified in paragraph 3.6.1.	Manual/Visual Verification	Comply	Comply	Comply
6.3.1	Production Test Requirements: All modules tendered for sale shall undergo the following Production Testing & Inspection prior to shipment. Failure of a module to meet the requirements of Production Testing & Inspection shall be cause for rejection. Test results shall be maintained per the requirement of Section 6.1.2.	Ask Manufacturer to Verify	Comply	Comply	Comply
6.3.1.1	All Production Tests shall be performed at an ambient temperature of 25ºC (77ºF) and at the nominal operating voltage of 120 VAC.	Ask Manufacturer to Verify	Comply	Comply	Comply
6.3.2	Luminous Intensity: All modules shall be tested for luminous intensity. A single point measurement, with a correlation to the intensity requirements of Sections 4.1.1 and 4.1.2 may be used. The purchaser may specify additional measurements. Failure of a module to meet the requirements for minimum maintained luminous intensity (4.1.1) or maximum permissible luminous intensity (4.1.2) shall be cause for rejection of the module.	Ask Manufacturer to Verify	Comply	Comply	Comply

6.3.3	Power Factor: All modules shall be tested for power factor per the requirements of Section 5.5.1. A commercially available power factor meter may be used to perform this measurement. Failure of a module to meet the requirements for power factor (5.5.1) shall be cause for rejection of the module.	Ask Manufacturer to Verify	Comply	Comply	Comply
6.3.4	Current Consumption Measurement: All modules shall be measured for current flow in Amperes. The measured current values shall be compared against the design current values from design qualification measurements in Section 6.4.6.1. A measured current consumption in excess of 120% of the design qualification current value for an ambient temperature of 25ºC (77ºF) shall be cause for rejection of the module.	Ask Manufacturer to Verify	Comply	Comply	Comply
6.3.5	Visual Inspection: All modules shall be visually inspected for any exterior physical damage or assembly anomalies. Careful attention shall be paid to the surface of the lens to ensure there are no scratches (abrasions), cracks, chips, discoloration, or other defects. The presence of any such defects shall be cause for rejection of the module.	Ask Manufacturer to Verify	Comply	Comply	Comply

APPENDIX B. Verification of DIALIGHT Solid LED Compliance

Verification of Compliance with ITE Specification for DIALIGHT Solid LED Modules					
Article	Specification	Means of Testing	Solid Red	Solid Yellow	Solid Green
3.1.1	Stand-alone units shall fit into VTCSH approved traffic signal housings without modification to the housing.	Manual/Visual Verification	Comply	Comply	Comply
3.1.2	Installation of LED modules shall not require special tooling and shall connect directly to the exiting electrical wiring system.	Manual/Visual Verification	Comply	Comply	Comply
3.2.1	LED module shall be capable of replacing existing optical components of the conventional signal head	Manual/Visual Verification	Comply	Comply	Comply
3.2.2	The module front lens shall be compliant to the SAE J576 requirement under ITE 6.4.5.2 test methodology on material exposure and weathering effects.	Certifications	Comply	Comply	Comply
3.2.3	**Optional** Tinted Lens using transparent film or material with similar color and transmissivity characteristics				
3.2.4	The module lens may be a replaceable part, without the need to replace the complete LED signal module.	Manual/Visual Verification	Comply	Comply	Comply
3.3.1	All exposed components shall be suitable for prolonged exposure to the environment without interfering to the function or appearance for a period of at least 60 months (in a south-facing Arizona desert)	Certifications (Asked Manufacturer)	Comply	Comply	Comply

3.3.2	A module shall be rated for use throughout an ambient operating temperature range, measured at the exposed rear of the module, of -40°F to + 165°F as per ITE 6.4.3.2 temperature cycling according to MIL-STD- 883, test method 1010	Certifications	Comply	Comply	Comply
3.3.3	A module shall be protected against dust and moisture intrusion, including rain and blowing rain. (MIL-STD-810F, test method 506.4, procedure 1, Rain and Blowing Rain under ITE 6.4.3.3 test methodology)	Certifications	Comply	Comply	Comply
3.3.4	The module lens shall not crack, craze or yellow due to solar UV irradiation typical for a south-facing Arizona desert installation after a minimum of 60 months in service	Certifications (Asked Manufacturer)	Comply	Comply	Comply
3.4.1	A module shall be self-contained, not requiring on-site assembly.	Manual/Visual Verification	Comply	Comply	Comply
3.4.2	Assembly and manufacturing processes for a module shall be designed that all internal LED and electronic components withstand mechanical shock and vibration due to high wind and other sources. (MIL-STD-883, test method 2007 under ITE 6.4.3.1 test methodology)	Certifications	Comply	Comply	Comply
3.5.1	Materials used for the lens and module construction shall conform to ASTM specifications for the materials, where applicable	Certifications (Asked Manufacturer)	Comply	Comply	Comply
3.5.2	LED module enclosure that contains the power supply shall be made of UL94 flame retardant materials	Certifications (Asked Manufacturer)	Comply	Comply	Comply

3.6.1	Each module shall be identified with manufacturer's name, model, operating characteristics (nominal voltage and stabilized power consumption) and serial number.	Manual/Visual Verification	There is no serial number, but a "Dateco de". No Model # but a Part #	There is no serial number, but a "Datecode" . No Model # but a Part #	There is no serial number, but a "Datecode ". No Model # but a Part #
3.6.2	Modules and removable lenses shall have a prominent and permanent vertical indexing indicator i.e. UP arrow, or the word UP or TOP for correct indexing and orientation in the signal housing.	Manual/Visual Verification	Comply	Comply	Comply
4.1.1	Minimum Luminous intensity must be maintained over the temperature range of -40°F to +165°F over the voltage range of 80 to 135 V AC for a minimum period of 60 months.	Certifications	Comply at 25C and 74C at 120 V. Nothing mention ed about lower temps and other voltages . Mfr claims complie s	Comply at 25C and 74C at 120 V. Nothing mentioned about lower temps and other voltages. Mfr claims complies	Comply at 25C and 74C at 120 V. Nothing mentioned about lower temps and other voltages. Mfr claims complies
4.1.1.1 to 4.1.1.5	Calculations of the various intensity: vertical, horizontal, peak minimum, minimum maintained luminous intensity at different angles.	Certifications	Comply	Comply	Comply
4.1.2	Maximum permissible luminous intensity shall not exceed three times the required peak value of the minimum maintained luminous intensity for the selected signal size and color.	Certifications	Comply	Comply	Comply

4.1.3	The uniformity of the luminance (cd/m^2) across the entire module lens shall not exceed a max/min ratio of 10 to 1between the maximum and minimum luminance values.	Certifications	Comply	Comply	Comply
4.2.1	Color regions: the measured chromaticity coordinates of modules shall conform to the following: Red: y=0.308, y=0.953-0.947x; y=0.290; Yellow: y=0.151 + 0.556, y=0.972 - 0.976x;y=0.235 + 0.300x; Green: y=0.655 - 0.831x, x=0.150; y=0.422-0.278x.	Certifications	Comply	Comply	Comply
4.2.2	Color Uniformity: The dominant wavelength for any individual color measurement of a portion of the emitting surface of a module shall be within + or - 3 nm of the dominant wavelength for the average color measurement of the emitting surface as a whole.	Certifications	Comply	Comply	Comply
5.1	Wire consist of two secured, color coded, 600 V, jacketed wires, a minimum length of 39", 20 AWG, 105°C rated, conforming to NFPA 70.	Manual/Visual Verification	12 AWG and not sure about complyi ng with NFPA 70	12 AWG and not sure about complying with NFPA 70	12 AWG and not sure about complying with NFPA 70
5.2.1	Voltage range of 80 to 135 VAC RMS, operate off a 60 + or – 3 Hz AC line.	Certifications (Asked Manufacturer)	Comply	Comply	Comply
5.2.2	Fluctuations over the voltage range of 80 to 135 VAC shall not affect the luminous intensity by more than + or - 10%.	Certifications (Asked Manufacturer)	Comply	Comply	Comply
5.2.3	The module shall prevent flicker of the LED output at frequencies less then 100 Hz over the voltage range of 80 to 135 V AC RMS	Certifications (Asked Manufacturer)	Comply	Comply	Comply

5.2.4	Low voltage turn OFF: there shall be no visible illumination from the LED signal module when the applied voltage is less than 35 V AC.	Certifications	Comply	Comply	Comply
5.2.5	Turn ON time: A module shall reach 90 % of full illumination within 75 msec of the application of the nominal operating voltage, Turn OFF time: The signal shall cease emitting visible illumination within 75 msec of the removal of the nominal operating voltage.	Certifications	Comply	Comply	Comply
5.3	Transient Voltage Protection: LED module shall withstand NEMA standard TS-2-2003, section 2.1.8.	Certifications	Comply	Comply	Comply
5.4	Emission of Electronic noise shall meet FCC Title 47, Subpart B, section 15 for class A digital device	Certifications	Comply	Comply	Comply
5.5.1	Power Factor of .90 or greater at nominal voltage and 77°F.	Certifications	Comply	Comply	Comply
5.5.2	THD shall not exceed 20% @ 77°F.	Certifications	Comply	Comply	Comply
5.6.1	Sufficient current draw to ensure compatibility and proper triggering and operation of the load switches and conflict monitors in signal controller units.	Lab Verification	Complied in Lab	Complied in Lab	Complied in Lab
5.6.2	Off state Voltage Decay: Voltage shall decay to less than 10 VAC RMS in less than 100 ms when switched from On to OFF state if maximum load switch leakage current is 10 MA peak.	Certifications	Comply	Comply	Comply

5.7	Failed State Impedance: The module shall be designed to detect catastrophic loss of the LED load. Upon sensing loss of the LED load, the module shall present a resistance of at least 250 Kohms across the input power leads within 300 msec. The LED light source will be said to have failed catastrophically if it fails to show any visible illumination when energized according to Section 5.2.1 after 75 msec.	Certifications	Comply	Comply	Comply
6.1.1	Quality Assurance Program: Modules shall be manufactured in accordance with a vendor quality assurance (QA) program. The QA program shall include two types of quality assurance: (1) design quality assurance and (2) production quality assurance. The production quality assurance shall include statistically controlled routine tests to ensure minimum performance levels of modules built to meet this specification.	Ask Manufacturer to Verify	Comply	Comply	Comply
6.1.2	Record Keeping: QA process and test results documentation shall be kept on file for a minimum period of seven years	Ask Manufacturer to Verify	Comply	Comply	Comply
6.1.3	Module designs not satisfying design qualification testing and the production quality assurance testing performance requirements in Sections 6.3 and 6.4 shall not be labeled, advertised, or sold as conforming to this specification.	Ask Manufacturer to Verify	Comply	Comply	Comply

6.2	Each module shall be identified with the information specified in paragraph 3.6.1.	Manual/Visual Verification	Comply	Comply	Comply
6.3.1	Production Test Requirements: All modules tendered for sale shall undergo the following Production Testing & Inspection prior to shipment. Failure of a module to meet the requirements of Production Testing & Inspection shall be cause for rejection. Test results shall be maintained per the requirement of Section 6.1.2.	Ask Manufacturer to Verify	Comply	Comply	Comply
6.3.1.1	All Production Tests shall be performed at an ambient temperature of 25ºC (77ºF) and at the nominal operating voltage of 120 VAC.	Ask Manufacturer to Verify	Comply	Comply	Comply
6.3.2	Luminous Intensity: All modules shall be tested for luminous intensity. A single point measurement, with a correlation to the intensity requirements of Sections 4.1.1 and 4.1.2 may be used. The purchaser may specify additional measurements. Failure of a module to meet the requirements for minimum maintained luminous intensity (4.1.1) or maximum permissible luminous intensity (4.1.2) shall be cause for rejection of the module.	Ask Manufacturer to Verify	Comply	Comply	Comply

6.3.3	Power Factor: All modules shall be tested for power factor per the requirements of Section 5.5.1. A commercially available power factor meter may be used to perform this measurement. Failure of a module to meet the requirements for power factor (5.5.1) shall be cause for rejection of the module.	Ask Manufacturer to Verify	Comply	Comply	Comply
6.3.4	Current Consumption Measurement: All modules shall be measured for current flow in Amperes. The measured current values shall be compared against the design current values from design qualification measurements in Section 6.4.6.1. A measured current consumption in excess of 120% of the design qualification current value for an ambient temperature of 25ºC (77ºF) shall be cause for rejection of the module.	Ask Manufacturer to Verify	Comply	Comply	Comply
6.3.5	Visual Inspection: All modules shall be visually inspected for any exterior physical damage or assembly anomalies. Careful attention shall be paid to the surface of the lens to ensure there are no scratches (abrasions), cracks, chips, discoloration, or other defects. The presence of any such defects shall be cause for rejection of the module.	Ask Manufacturer to Verify	Comply	Comply	Comply

APPENDIX C. Verification of LUMINATION Solid LED Compliance

Verification of Compliance with ITE Specification for LUMINATION SOLID LED MODULES					
Article	Specification	Means of Testing	Solid Red	Solid Yellow	Solid Green
3.1.1	Stand-alone units shall fit into VTCSH approved traffic signal housings without modification to the housing.	Manual/Visual Verification	Comply	Comply	Comply
3.1.2	Installation of LED modules shall not require special tooling and shall connect directly to the exiting electrical wiring system.	Manual/Visual Verification	Comply	Comply	Comply
3.2.1	LED module shall be capable of replacing existing optical components of the conventional signal head	Manual/Visual Verification	Comply	Comply	Comply
3.2.2	The module front lens shall be compliant to the SAE J576 requirement under ITE 6.4.5.2 test methodology on material exposure and weathering effects.	Certifications	Comply	Comply	Comply
3.2.3	**Optional** Tinted Lens using transparent film or material with similar color and transmissivity characteristics				
3.2.4	The module lens may be a replaceable part, without the need to replace the complete LED signal module.	Manual/Visual Verification	Comply	Comply	Comply
3.3.1	All exposed components shall be suitable for prolonged exposure to the environment without interfering to the function or appearance for a period of at least 60 months (in a south-facing Arizona desert)	Certifications	Lumination uses UV Stabilized material and has no historical data of failure against these criteria	Lumination uses UV Stabilized material and has no historical data of failure against these criteria on other signals using same	Lumination uses UV Stabilized material and has no historical data of failure against these criteria on other signals

			on other signals using same material and being in the field for more than 5 years.	material and being in the field for more than 5 years.	using same material and being in the field for more than 5 years.
3.3.2	A module shall be rated for use throughout an ambient operating temperature range, measured at the exposed rear of the module, of -40°F to + 165°F as per ITE 6.4.3.2 temperature cycling according to MIL-STD- 883, test method 1010	Certifications	Comply	Comply	Comply
3.3.3	A module shall be protected against dust and moisture intrusion, including rain and blowing rain. (MIL-STD-810F, test method 506.4, procedure 1, Rain and Blowing Rain under ITE 6.4.3.3 test methodology)	Certifications	Comply	Comply	Comply
3.3.4	The module lens shall not crack, craze or yellow due to solar UV irradiation typical for a south-facing Arizona desert installation after a minimum of 60 months in service	Certifications	Lumination uses UV Stabilized material and has no historical data of failure against these criteria on other signals using same material and being in the field for more	Lumination uses UV Stabilized material and has no historical data of failure against these criteria on other signals using same material and being in the field for more than 5 years.	Lumination uses UV Stabilized material and has no historical data of failure against these criteria on other signals using same material and being in the field for more than 5 years.

			than 5 years.		
3.4.1	A module shall be self-contained, not requiring on-site assembly.	Manual/Visual Verification	Comply	Comply	Comply
3.4.2	Assembly and manufacturing processes for a module shall be designed that all internal LED and electronic components withstand mechanical shock and vibration due to high wind and other sources. (MIL-STD-883, test method 2007 under ITE 6.4.3.1 test methodology)	Certifications	Comply	Comply	Comply
3.5.1	Materials used for the lens and module construction shall conform to ASTM specifications for the materials, where applicable	Certifications	Exposed Plastic to light such as front shell (GE LEXAN 123) and lens complies with the ASTM test methodology.	Exposed Plastic to light such as front shell (GE LEXAN 123) and lens complies with the ASTM test methodology.	Exposed Plastic to light such as front shell (GE LEXAN 123) and lens complies with the ASTM test methodology.
3.5.2	LED module enclosure that contains the power supply shall be made of UL94 flame retardant materials	Certifications	Lumination's GT1 series use Flame retardant plastic material module enclosure (Front Shell and Back Cover)	Lumination's GT1 series use Flame retardant plastic material module enclosure (Front Shell and Back Cover)	Lumination's GT1 series use Flame retardant plastic material module enclosure (Front Shell and Back Cover)

3.6.1	Each module shall be identified with manufacturer's name, model, operating characteristics (nominal voltage and stabilized power consumption) and serial number.	Manual/Visual Verification	Comply	Comply	Comply
3.6.2	Modules and removable lenses shall have a prominent and permanent vertical indexing indicator i.e. UP arrow, or the word UP or TOP for correct indexing and orientation in the signal housing.	Manual/Visual Verification	Comply	Comply	Comply
4.1.1	Minimum Luminous intensity must be maintained over the temperature range of -40°F to +165°F over the voltage range of 80 to 135 V AC for a minimum period of 60 months.	Certifications	Comply at 25C and 74C at 120 V. Nothing mentioned about lower temps and other voltages. Mfr says complies	Comply at 25C and 74C at 120 V. Nothing mentioned about lower temps and other voltages. Mfr says complies	Comply at 25C and 74C at 120 V. Nothing mentioned about lower temps and other voltages. Mfr says complies
4.1.1.1 to 4.1.1.5	Calculations of the various intensity: vertical, horizontal, peak minimum, minimum maintained luminous intensity at different angles.	Certifications	Comply	Comply	Comply
4.1.2	Maximum permissible luminous intensity shall not exceed three times the required peak value of the minimum maintained luminous intensity for the selected signal size and color.	Certifications	Comply	Comply	Comply

4.1.3	The uniformity of the luminance (cd/m^2) across the entire module lens shall not exceed a max/min ratio of 10 to 1between the maximum and minimum luminance values.	Certifications	Comply	Comply	Comply
4.2.1	Color regions: the measured chromaticity coordinates of modules shall conform to the following: Red: y=0.308, y=0.953-0.947x; y=0.290; Yellow: y=0.151 + 0.556, y=0.972 - 0.976x;y=0.235 + 0.300x; Green: y=0.655 - 0.831x, x=0.150; y=0.422-0.278x.	Certifications	Comply	Comply	Comply
4.2.2	Color Uniformity: The dominant wavelength for any individual color measurement of a portion of the emitting surface of a module shall be within + or - 3 nm of the dominant wavelength for the average color measurement of the emitting surface as a whole.	Certifications	Comply	Comply	Comply
5.1	Wire consist of two secured, color coded, 600 V, jacketed wires, a minimum length of 39", 20 AWG, 105°C rated, conforming to NFPA 70.	Manual/Visual Verification	16 AWG and not sure about complyi ng with NFPA 70	16 AWG and not sure about complying with NFPA 70	16 AWG and not sure about complying with NFPA 70
5.2.1	Voltage range of 80 to 135 VAC RMS, operate off a 60 + or – 3 Hz AC line.	Certifications	Comply	Comply	Comply
5.2.2	Fluctuations over the voltage range of 80 to 135 VAC shall not affect the luminous intensity by more than + or - 10%.	Certifications	Comply	Comply	Comply
5.2.3	The module shall prevent flicker of the LED output at frequencies less then 100 Hz over the voltage range of 80 to 135 V AC RMS	Certifications	Comply	Comply	Comply

5.2.4	Low voltage turn OFF: there shall be no visible illumination from the LED signal module when the applied voltage is less than 35 V AC.	Certifications	Comply	Comply	Comply
5.2.5	Turn ON time: A module shall reach 90 % of full illumination within 75 msec of the application of the nominal operating voltage, Turn OFF time: The signal shall cease emitting visible illumination within 75 msec of the removal of the nominal operating voltage.	Certifications	Comply	Comply	Comply
5.3	Transient Voltage Protection: LED module shall withstand NEMA standard TS-2-2003, section 2.1.8.	Certifications	Comply	Comply	Comply
5.4	Emission of Electronic noise shall meet FCC Title 47, Subpart B, section 15 for class A digital device	Certifications	Comply	Comply	Comply
5.5.1	Power Factor of .90 or greater at nominal voltage and 77°F.	Certifications	Comply	Comply	Comply
5.5.2	THD shall not exceed 20% @ 77°F.	Certifications	Comply	Comply	Comply
5.6.1	Sufficient current draw to ensure compatibility and proper triggering and operation of the load switches and conflict monitors in signal controller units.	Lab Verification	Complied in Lab	Complied in Lab	Complied in Lab
5.6.2	Off state Voltage Decay: Voltage shall decay to less than 10 VAC RMS in less than 100 ms when switched from On to OFF state if maximum load switch leakage current is 10 MA peak.	Certifications	Comply	Comply	Comply

5.7	Failed State Impedance: The module shall be designed to detect catastrophic loss of the LED load. Upon sensing loss of the LED load, the module shall present a resistance of at least 250 Kohms across the input power leads within 300 msec. The LED light source will be said to have failed catastrophically if it fails to show any visible illumination when energized according to Section 5.2.1 after 75 msec.	Certifications	Comply	Comply	Comply
6.1.1	Quality Assurance Program: Modules shall be manufactured in accordance with a vendor quality assurance (QA) program. The QA program shall include two types of quality assurance: (1) design quality assurance and (2) production quality assurance. The production quality assurance shall include statistically controlled routine tests to ensure minimum performance levels of modules built to meet this specification.	Ask Manufacturer to Verify	Comply	Comply	Comply
6.1.2	Record Keeping: QA process and test results documentation shall be kept on file for a minimum period of seven years	Ask Manufacturer to Verify	Comply	Comply	Comply
6.1.3	Module designs not satisfying design qualification testing and the production quality assurance testing performance requirements in Sections 6.3 and 6.4 shall not be labeled, advertised, or sold as conforming to this specification.	Ask Manufacturer to Verify	Comply	Comply	Comply

6.2	Each module shall be identified with the information specified in paragraph 3.6.1.	Manual/Visual Verification	Comply	Comply	Comply
6.3.1	Production Test Requirements: All modules tendered for sale shall undergo the following Production Testing & Inspection prior to shipment. Failure of a module to meet the requirements of Production Testing & Inspection shall be cause for rejection. Test results shall be maintained per the requirement of Section 6.1.2.	Ask Manufacturer to Verify	Comply	Comply	Comply
6.3.1.1	All Production Tests shall be performed at an ambient temperature of 25ºC (77ºF) and at the nominal operating voltage of 120 VAC.	Ask Manufacturer to Verify	Comply	Comply	Comply
6.3.2	Luminous Intensity: All modules shall be tested for luminous intensity. A single point measurement, with a correlation to the intensity requirements of Sections 4.1.1 and 4.1.2 may be used. The purchaser may specify additional measurements. Failure of a module to meet the requirements for minimum maintained luminous intensity (4.1.1) or maximum permissible luminous intensity (4.1.2) shall be cause for rejection of the module.	Ask Manufacturer to Verify	Comply	Comply	Comply

6.3.3	Power Factor: All modules shall be tested for power factor per the requirements of Section 5.5.1. A commercially available power factor meter may be used to perform this measurement. Failure of a module to meet the requirements for power factor (5.5.1) shall be cause for rejection of the module.	Ask Manufacturer to Verify	Comply	Comply	Comply
6.3.4	Current Consumption Measurement: All modules shall be measured for current flow in Amperes. The measured current values shall be compared against the design current values from design qualification measurements in Section 6.4.6.1. A measured current consumption in excess of 120% of the design qualification current value for an ambient temperature of 25ºC (77ºF) shall be cause for rejection of the module.	Ask Manufacturer to Verify	Comply	Comply	Comply
6.3.5	Visual Inspection: All modules shall be visually inspected for any exterior physical damage or assembly anomalies. Careful attention shall be paid to the surface of the lens to ensure there are no scratches (abrasions), cracks, chips, discoloration, or other defects. The presence of any such defects shall be cause for rejection of the module.	Ask Manufacturer to Verify	Comply	Comply	Comply

APPENDIX D. Verification of ASC Solid LED Compliance

Verification of Compliance with ITE Specification for ASC SOLID LED MODULES					
Article	Specification	Means of Testing	Solid Red	Solid Yellow	Solid Green
3.1.1	Stand-alone units shall fit into VTCSH approved traffic signal housings without modification to the housing.	Manual/Visual Verification	Comply	Comply	Comply
3.1.2	Installation of LED modules shall not require special tooling and shall connect directly to the exiting electrical wiring system.	Manual/Visual Verification	Comply	Comply	Comply
3.2.1	LED module shall be capable of replacing existing optical components of the conventional signal head	Manual/Visual Verification	Comply	Comply	Comply
3.2.2	The module front lens shall be compliant to the SAE J576 requirement under ITE 6.4.5.2 test methodology on material exposure and weathering effects.	Certifications	Not provided	Not provided	Not provided
3.2.3	**Optional** Tinted Lens using transparent film or material with similar color and transmissivity characteristics				
3.2.4	The module lens may be a replaceable part, without the need to replace the complete LED signal module.	Manual/Visual Verification	Comply	Comply	Comply
3.3.1	All exposed components shall be suitable for prolonged exposure to the environment without interfering to the function or appearance for a period of at least 60 months (in a south-facing Arizona desert)	Certifications	Not provided	Not provided	Not provided

3.3.2	A module shall be rated for use throughout an ambient operating temperature range, measured at the exposed rear of the module, of -40°F to + 165°F as per ITE 6.4.3.2 temperature cycling according to MIL-STD- 883, test method 1010	Certifications	Not provided	Not provided	Not provided
3.3.3	A module shall be protected against dust and moisture intrusion, including rain and blowing rain. (MIL-STD-810F, test method 506.4, procedure 1, Rain and Blowing Rain under ITE 6.4.3.3 test methodology)	Certifications	Comply	Not provided	Not provided
3.3.4	The module lens shall not crack, craze or yellow due to solar UV irradiation typical for a south-facing Arizona desert installation after a minimum of 60 months in service	Certifications	Not provided	Not provided	Not provided
3.4.1	A module shall be self-contained, not requiring on-site assembly.	Manual/Visual Verification	Comply	Comply	Comply
3.4.2	Assembly and manufacturing processes for a module shall be designed that all internal LED and electronic components withstand mechanical shock and vibration due to high wind and other sources. (MIL-STD-883, test method 2007 under ITE 6.4.3.1 test methodology)	Certifications	Not provided	Not provided	Not provided
3.5.1	Materials used for the lens and module construction shall conform to ASTM specifications for the materials, where applicable	Certifications	Not provided	Not provided	Not provided
3.5.2	LED module enclosure that contains the power supply shall be made of UL94 flame retardant materials	Certifications	Not provided	Not provided	Not provided

3.6.1	Each module shall be identified with manufacturer's name, model, operating characteristics (nominal voltage and stabilized power consumption) and serial number.	Manual/Visual Verification	Comply	Comply	Comply
3.6.2	Modules and removable lenses shall have a prominent and permanent vertical indexing indicator i.e. UP arrow, or the word UP or TOP for correct indexing and orientation in the signal housing.	Manual/Visual Verification	Comply	Comply	Comply
4.1.1	Minimum Luminous intensity must be maintained over the temperature range of -40°F to +165°F over the voltage range of 80 to 135 V AC for a minimum period of 60 months.	Certifications	Comply	Comply	Comply
4.1.1.1 to 4.1.1.5	Calculations of the various intensity: vertical, horizontal, peak minimum, minimum maintained luminous intensity at different angles.	Certifications	Comply	Comply	Comply
4.1.2	Maximum permissible luminous intensity shall not exceed three times the required peak value of the minimum maintained luminous intensity for the selected signal size and color.	Certifications	Comply	Comply	Comply
4.1.3	The uniformity of the luminance (cd/m^2) across the entire module lens shall not exceed a max/min ratio of 10 to 1between the maximum and minimum luminance values.	Certifications	Comply	Comply	Comply

4.2.1	Color regions: the measured chromaticity coordinates of modules shall conform to the following: Red: y=0.308, y=0.953-0.947x; y=0.290; Yellow: y=0.151 + 0.556, y=0.972 - 0.976x;y=0.235 + 0.300x; Green: y=0.655 - 0.831x, x=0.150; y=0.422-0.278x.	Certifications	Comply	Comply	Comply
4.2.2	Color Uniformity: The dominant wavelength for any individual color measurement of a portion of the emitting surface of a module shall be within + or - 3 nm of the dominant wavelength for the average color measurement of the emitting surface as a whole.	Certifications	Not provided	Not provided	Not provided
5.1	Wire consist of two secured, color coded, 600 V, jacketed wires, a minimum length of 39", 20 AWG, 105°C rated, conforming to NFPA 70.	Manual/Visual Verification	18 AWG and not sure about complying with NFPA 70	18 AWG and not sure about complying with NFPA 70	18 AWG and not sure about complying with NFPA 70
5.2.1	Voltage range of 80 to 135 VAC RMS, operate off a 60 + or – 3 Hz AC line.	Certifications	Not provided	Not provided	Not provided
5.2.2	Fluctuations over the voltage range of 80 to 135 VAC shall not affect the luminous intensity by more than + or - 10%.	Certifications	Not provided	Not provided	Not provided
5.2.3	The module shall prevent flicker of the LED output at frequencies less then 100 Hz over the voltage range of 80 to 135 V AC RMS	Certifications	Not provided	Not provided	Not provided
5.2.4	Low voltage turn OFF: there shall be no visible illumination from the LED signal module when the applied voltage is less than 35 V AC.	Certifications	Not provided	Not provided	Not provided

5.2.5	Turn ON time: A module shall reach 90 % of full illumination within 75 msec of the application of the nominal operating voltage, Turn OFF time: The signal shall cease emitting visible illumination within 75 msec of the removal of the nominal operating voltage.	Certifications	Not provided	Not provided	Not provided
5.3	Transient Voltage Protection: LED module shall withstand NEMA standard TS-2-2003, section 2.1.8.	Certifications	Comply	Not provided	Not provided
5.4	Emission of Electronic noise shall meet FCC Title 47, Subpart B, section 15 for class A digital device	Certifications	Not provided	Comply	Comply
5.5.1	Power Factor of .90 or greater at nominal voltage and 77°F.	Certifications	Comply	Comply	Comply
5.5.2	THD shall not exceed 20% @ 77°F.	Certifications	Comply	Comply	Comply
5.6.1	Sufficient current draw to ensure compatibility and proper triggering and operation of the load switches and conflict monitors in signal controller units.	Lab Verification	Complied in Lab	Complied in Lab	Complied in Lab
5.6.2	Off state Voltage Decay: Voltage shall decay to less than 10 VAC RMS in less than 100 ms when switched from On to OFF state if maximum load switch leakage current is 10 MA peak.	Certifications	Not provided	Not provided	Not provided
5.7	Failed State Impedance: The module shall be designed to detect catastrophic loss of the LED load. Upon sensing loss of the LED load, the module shall present a resistance of at least 250 Kohms across the input power leads within 300 msec. The LED light source	Certifications	Not provided	Not provided	Not provided

	will be said to have failed catastrophically if it fails to show any visible illumination when energized according to Section 5.2.1 after 75 msec.				
6.1.1	Quality Assurance Program: Modules shall be manufactured in accordance with a vendor quality assurance (QA) program. The QA program shall include two types of quality assurance: (1) design quality assurance and (2) production quality assurance. The production quality assurance shall include statistically controlled routine tests to ensure minimum performance levels of modules built to meet this specification.	Ask Manufacturer to Verify	No Response	No Response	No Response
6.1.2	Record Keeping: QA process and test results documentation shall be kept on file for a minimum period of seven years	Ask Manufacturer to Verify	No Response	No Response	No Response
6.1.3	Module designs not satisfying design qualification testing and the production quality assurance testing performance requirements in Sections 6.3 and 6.4 shall not be labeled, advertised, or sold as conforming to this specification.	Ask Manufacturer to Verify	No Response	No Response	No Response
6.2	Each module shall be identified with the information specified in paragraph 3.6.1.	Manual/Visual Verification	Comply	Comply	Comply
6.3.1	Production Test Requirements: All modules tendered for sale shall undergo the following Production Testing &	Ask Manufacturer to Verify	No Response	No Response	No Response

	Inspection prior to shipment. Failure of a module to meet the requirements of Production Testing & Inspection shall be cause for rejection. Test results shall be maintained per the requirement of Section 6.1.2.				
6.3.1.1	All Production Tests shall be performed at an ambient temperature of 25ºC (77ºF) and at the nominal operating voltage of 120 VAC.	Ask Manufacturer to Verify	No Response	No Response	No Response
6.3.2	Luminous Intensity: All modules shall be tested for luminous intensity. A single point measurement, with a correlation to the intensity requirements of Sections 4.1.1 and 4.1.2 may be used. The purchaser may specify additional measurements. Failure of a module to meet the requirements for minimum maintained luminous intensity (4.1.1) or maximum permissible luminous intensity (4.1.2) shall be cause for rejection of the module.	Ask Manufacturer to Verify	No Response	No Response	No Response
6.3.3	Power Factor: All modules shall be tested for power factor per the requirements of Section 5.5.1. A commercially available power factor meter may be used to perform this measurement. Failure of a module to meet the requirements for power factor (5.5.1) shall be cause for rejection of the module.	Ask Manufacturer to Verify	No Response	No Response	No Response
6.3.4	Current Consumption Measurement: All modules shall be measured for current flow in Amperes.	Ask Manufacturer to Verify	No Response	No Response	No Response

	The measured current values shall be compared against the design current values from design qualification measurements in Section 6.4.6.1. A measured current consumption in excess of 120% of the design qualification current value for an ambient temperature of 25ºC (77ºF) shall be cause for rejection of the module.				
6.3.5	Visual Inspection: All modules shall be visually inspected for any exterior physical damage or assembly anomalies. Careful attention shall be paid to the surface of the lens to ensure there are no scratches (abrasions), cracks, chips, discoloration, or other defects. The presence of any such defects shall be cause for rejection of the module.	Ask Manufacturer to Verify	No Response	No Response	No Response

APPENDIX E. Verification of LEOTEK Pedestrian LED Compliance

Verification for Compliance with ITE Specification for LEOTEK PEDESTRIAN LED Modules						
Article	Specification	Means of Testing	12 inch Walking Man TP12B-WM	12 inch Hand TP12B-EH	16 inch Hand+Walking Man Combination TSL-PED-16-D1L	12 inch Hand+Walking Man Combination TP12H-HM
3.1.1	Usage: Modules shall fit into pedestrian signal housings manufactured in accordance with the ITE PTCSI Standard, March 1985, without modification to the housing.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.1.2	Installation requirements: Installation of a module into an existing pedestrian signal housing shall only require the removal of the existing optical unit components, i.e., lens, lamp module, gaskets, and reflector; shall be weather tight and fit securely in the housing; and shall connect directly to existing electrical wiring. Installation shall not require special tools.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.1.3	New installations: For new installations, the minimum size of the message bearing surface of a module shall be determined by the length of the intended crosswalk, but in no case shall it be less than 229 mm x 229 mm. The sizes of the message bearing surfaces shall be in accordance with the dimensions given in Table 1.					

3.2.1	The module shall be capable of replacing the opticalcomponent of the pedestrian indication.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.2.2	Tinting **(Optional)** - The lens shall be tinted or shall use transparent film or materials with similar characteristics.					
3.2.3	The module lens may be a replaceable part without the need to replace the complete module.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.2.4	Hard Coat **(Optional)** - If requested, on a non-frosted polymeric lens a surface coating or a film shall be used to provide front surface abrasion resistance.					
3.2.5	The configurations of the walking person icon and hand icon are illustrated in Figure 1 and Figure 2 respectively.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.3.1	The module shall be rated for use in the ambient operating temperature range, measured at the exposed rear of the module, of -40°C to +74°C (-40°F to +165°F).	Certifications	Comply	Comply	Comply	Comply
3.3.2	The module shall be protected against dust and moisture intrusion per the requirements of MIL-STD-810F Procedure I, Rain and Blowing Rain.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
3.3.3	The emitting surfaces of the module shall not crack, craze or yellow under exposure to sunlight over the service life of the module.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply

3.4.1	The module shall be a single, self-contained device, not requiring on-site assembly for installation into an existing traffic signal housing. The power supply for the module may be either integral or packaged as a separate module. The power supply may be designed to fit and mount inside the pedestrian signal housing adjacent to the module.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.4.2	The assembly and manufacturing process for the module shall be designed to assure all internal LED and electronic components are adequately supported to withstand mechanical shock and vibration from high winds and other sources.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
3.5.1	Materials used for the lens and module construction shall conform to ASTM specifications for the materials where applicable.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
3.5.2	Enclosures containing either the power supply or electronic components of the module shall be made of UL94VO flame retardant materials. The lens of the module is excluded from this requirement.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
3.6.1	Each module shall be identified on the backside with the manufacturer's name, model number and serial number.	Manual/Visual Verification	Comply	Comply	Comply	Comply

3.6.2	The following operating characteristics shall be identified: nominal operating voltage, power consumption, and Volt-Ampere. The load for the walking person and hand icons are to be stated separately.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.6.3	Modules shall have a prominent and permanent vertical indexing indicator, i.e., UP ARROW or the word UP or TOP, for correct indexing and orientation inside a pedestrian signal housing.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.6.4	Modules conforming to this specification, may have the following statement: “Manufactured in Conformance with the Pedestrian Traffic Control Signal Indications - Part 2: Light Emitting Diode (LED) Pedestrian Signal Modules.” on an attached label.					
4.1.1	For a minimum period of 60 months, the maintained minimum luminance values for the modules under the operating conditions defined in Sections 3.3.1 and 5.2.1, when measured normal to the plane of the icon surface, shall not be less than: Walking person: 2,200 cd/m2; • Hand: 1,400 cd/m2. The luminance of the emitting surface, measured at angles from the normal of the surface, may decrease linearly to a value of 50% of the values listed above at an angle of 15 degrees.The light output requirements in this specification apply to pedestrian signal heads without any visors, hooded or louvered (egg-crate). Addition of such visors may affect the light output of the signal head, and the purchasing agency may wish to consult the issue with the manufacturer.	Certifications	Comply	Comply	Comply	Comply

4.1.2	The uniformity of the walking person and hand icons' luminance shall meet a ratio of not more than 1 to 5 between the minimum and maximum luminance values, as measured in 12mm (0.5 in) diameter spots.	Certifications	Comply	Comply	Comply	Comply
4.1.3	When operating within the temperature range specified in Section 3.3.1, the luminance of the module shall not exceed three times the maintained minimum luminance of the modules, as defined in Section 4.1.1.	Certifications	Comply	Comply	Does not comply for both hand and man	Comply
4.2	The standard colors for the LED Pedestrian Signal Module shall be White for the walking person and Portland Orange for the hand icon. The colors for these icons shall conform to the following color regions, based on the 1931 CIE chromaticity diagram:	Certifications	Comply	Comply	Comply	Comply
4.3	The uniformity of the emitted colors shall be such that any color measurement within a 12mm (0.5 in) spot on the emitting surface shall fall within the following regions around the average measured color of the entire emitting surface:The dominant wavelength for all individual color measurements shall be within ±3 nm of the dominant wavelength for the average of all the individual color measurements.	Certifications	Comply	Comply	Comply	Comply

5.1	All wiring and terminal blocks shall meet the requirements of Section 13.02 of the VTCSH standard. Two secured, color code1 m (39 in) long 600 V, 20 AWG minimum, jacketed wires, conforming to the National Electrical Code, rated for service at +105°C, are to be provided for electrical connection. The following color scheme shall be used: Orange for Hand, Blue for Walking Person and White for the common.	Manual/Visual Verification	Comply	Comply	Comply	Comply
5.2.1	The modules shall operate from a 60±3 Hertz ac line power over a voltage range from 80 VAC RMS to 135VAC RMS.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
5.2.2	Nominal operating voltage for all measurements shall be 120±3 VAC RMS.					
5.2.3	Fluctuations in line voltage over the range of 80VAC RMS to 135VAC RMS shall not affect luminous intensity by more than ±10 percent.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
5.2.4	The LED circuitry shall prevent flicker at less than 100 Hz over the voltage range specified in Section 5.2.1.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
5.2.5	Low Voltage Turn Off: There should be no visible illumination of the module when the applied voltage is less than 35 VAC RMS.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
5.2.6	Turn-On and Turn-Off Time: Each icon of the module shall reach 90% of their full illumination (turn-on) within 75 msec of the application of the nominal operating voltage. The modules shall not be illuminated (turn-off) after 75 msec of the removal of the nominal operating voltage.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply

5.2.7	Default Condition: For abnormal conditions when nominal voltage is applied to the unit across the two-phase wires (rather than being applied to the phase wire and the neutral wire) the pedestrian signal unit shall default to the hand symbol or shall be blank.					
5.3.1	The module's on-board circuitry shall include voltage surge protection to withstand high-repetition noise transients and low-repetition high-energy transients as stated in Section 2.1.6, NEMA Standard TS-2, 1998, or the latest version.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
5.4.1	When requested, the module circuitry shall allow a reduction of the intensity of the light output in response to an input from the traffic signal controller	OPTIONAL				
5.4.2	Dimming, if provided and conforming to Section 5.4.1, shall diminish light output to levels established to match threshold ambient light conditions. The dimming may be in stepped increments or may be continuously variable. The minimum light output when dimmed shall not be less than thirty (30) percent of the maintained minimum luminance values shown in Paragraph 4.1.1.	OPTIONAL				
5.5	The modules and associated on-board circuitry shall conform to Class A requirements of Federal Communications Commission (FCC) Title 47, SubPart B, Section 15 regulations concerning the emission of electronic noise.	Certifications				

5.6.1	The modules shall provide a power factor of 0.90 or greater when operated at nominal operating voltage, and 25ºC (77ºF).	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
5.6.2	Total harmonic distortion induced into an AC power line by the module, operated at nominal operating voltage, at 25ºC (77ºF) shall not exceed 20 percent.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
5.7	The current draw shall be sufficient to ensure compatibility and proper triggering and operation of load current switches and conflict monitors in existing signal controller units.	Certifications				
6.1	Unless otherwise specified all of the tests will be conducted at an ambient temperature of 25°C and at the nominal operating voltage of 120 VAC RMS.					
6.1.1	Quality Assurance Program: The modules shall be manufactured in accordance with a vendor quality assurance (QA) program. The QA program shall include two types of quality assurance: (1) design quality assurance and (2) production quality assurance. The production quality assurance shall include statistically controlled routine tests to ensure minimum performance levels of the modules built to meet this specification.	Ask Manufacturer to verify	Comply	Comply	Comply	Comply
6.1.2	Record Keeping: QA process and test results documentation shall be kept on file for a minimum period of seven years.	Ask Manufacturer to verify	Comply	Comply	Comply	Comply

6.1.3	Conformance: Module designs that do not satisfy the requirements of this specification, as evaluated by the design qualification testing (section 6.4) and the production quality assurance testing (section 6.3) shall not be labeled, advertised, or sold as conforming to this specification.	Ask Manufacturer to verify	Comply	Comply	Comply	Comply
6.2	Each module shall be identified with the manufacturer's name, model and serial number.	Manual/Visual Verification	Comply	Comply	Comply	Comply
6.3	All modules shall undergo the following Production Quality Assurance testing prior to shipment. Failure of any module to meet requirements of these QA tests shall be cause for rejection. QA test results shall be maintained per the requirement of Section 6.1.2.					
6.3.1	Production Luminance Test: All modules shall be tested for maintained minimum luminance. Any measurement with a correlation to the luminance requirements of Section 4.1.1 may be used. Modules that do not meet the maintained minimum luminance requirements as per Section 4.1.1 shall be rejected.	Ask Manufacturer to verify	Comply	Comply	Comply	Comply
6.3.2	Power Factor: All modules shall be tested for power factor to the requirements of Section 5.6.1. A commercially available power factor meter may be used to perform this measurement. Failure of the requirements shall be cause for rejection.	Ask Manufacturer to verify	Comply	Comply	Comply	Comply

6.3.3	Current: All modules shall be measured for the amount of current consumption. The measured current values shall be compared against current values resulting from design qualification measurements in Section 6.4.5.1. Measured current values in excess of 120 percent of the design qualification current values shall be cause for rejection	Ask Manufacturer to verify	Comply	Comply	Comply	Comply
6.3.4	Visual Inspection: All modules shall be visually inspected for any exterior physical damage or assembly anomalies. Careful attention shall be paid to the surface of the lens to ensure there are no scratches (abrasions), cracks, chips, discoloration, or other defects. Presence of any such defects shall be cause for rejection of the module.		Comply	Comply	Comply	Comply
6.4.1	Design Qualification testing shall be performed on new module designs, and when a major design change has been implemented on an existing design. Modules used in design qualification testing shall be representative of the manufacturer's proposed normal production.	Ask Manufacturer to verify	Comply	Comply	Comply	Comply
6.4.1.1	Testing shall be performed once every 5 years or when the module design or LED technology has been changed. Test data shall be retained by the module manufacturer in accordance with Section 6.1.2 or for 60 months following final production of a specific design, whichever is longer.	Ask Manufacturer to verify	Comply	Comply	Comply	Comply

6.4.1.2	Six modules shall be used in Design Qualification Testing. All six modules shall be subjected to conditioning (6.4.2), followed by the Environmental Tests (6.4.3), and followed by the Lens Abrasion Test (6.4.3.4). Following the Environmental Tests, three modules shall undergo Photometric & Colorimetric Tests (6.4.4). The remaining three modules shall undergo the Electrical Tests (6.4.5) and Controller Compatibility Tests (6.4.5.11). Tests shall be conducted in the order described herein, unless otherwise specified.		Does not comply (based on 1 sample)	Does not comply (based on 1 sample)	Does not comply (based on 2 samples)	Does not comply (based on 1 sample)
6.4.1.3	In order for a module design to be considered acceptable for marking with the label described in 3.6.4, all tested modules must comply with the acceptance/rejection criteria for the Environmental Tests (6.4.3), Photometric & Colorimetric Tests (6.4.4), Lens Tests (6.4.5), Electrical Tests (6.4.5), and Controller Assembly Compatibility Tests (6.4.5.11).					
6.4.2	Modules shall be energized for a minimum of 24 hours, at 100% duty cycle, in an ambient temperature of +60°C (+140°F).	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
6.4.3.1	Mechanical Vibration Testing: Three modules shall be tested per MIL-STD-883, Test Method 2007, using three 4-minute cycles along each x, y, and z axis, at a force of 2.5 Gs, with a frequency sweep from 2 Hz to 120 Hz.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply

6.4.3.2	Temperature Cycling. Temperature cycling shall be performed per MIL-STD-883, Test method 1010. The temperature range shall be per Section 3.3.1. A minimum of 20 cycles shall be performed with a 30-minute transfer time between temperature extremes and a 30-minute dwell time at each temperature. Modules under test shall be non-operating.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
6.4.3.3	Moisture Resistance. Moisture resistance testing shall be performed on a sample of three modules per MIL-STD-810F, Procedure I, Rain and Blowing Rain. The test shall be conduced on a stand-alone unit, without a protective housing. The rainfall rate shall be 1.7 mm/min (4 in/hr) and droplet size shall predominantly be between 0.5 mm and 4.5 mm. The module shall be rotated through 120 degrees and the duration of the test shall be 30 minutes. The module shall be energized throughout the test. The water shall be at 25°C. The wind velocity shall be 80 km/hr (50 mph). Any evidence of internal moisture into the module shall be cause for rejection. If the module is equipped with a remote power supply unit, then the test shall be conducted with the remote power supply unit attached to the clamping device holding the LED signal module to the test apparatus.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
6.4.3.4	Hard Coat Test (Optional): When applicable, a sample of three (3) modules shall be tested in accordance to the abrasion resistance test ASTM D1044. A weight of 500 grams shall be applied on a CS10F wheel for 150 cycles.					

6.4.3.5	UV Stabilization: Documentation shall be provided that clearly demonstrates that the external lens complies with the requirements of section 3.3.3.		Not provided	Not provided	Not provided	Not provided
6.4.3.6	Environmental Tests Evaluation: At the conclusion of the Environmental Tests, all the modules will be visually inspected for damage.					
6.4.3.7	Acceptance/Rejection Criteria: The loosening of the lens, or any internal components, or evidence of other physical damage, such as cracking of the module lens or housing or presence of internal moisture after testing a change in haze of the surface under test greater than 15% or if the module extinguishes itself shall be considered a failure for the proposed design.					
6.4.4	Photometric & Calorimetric Tests: Three of the modules that were subjected to the Environmental Tests shall undergo Photometric & Colorimetric Tests. Unless otherwise specified, these tests shall be performed with the modules energized at nominal operating voltage (120 VAC).					
6.4.4.1	Maintained Minimum Luminance: The sample set shall be tested for maintained minimum luminance at both 25°C and 74°C. Prior to making measurements, each module shall be operated at a 100% duty cycle for a minimum of 60 minutes at the test temperature.		Comply	Comply	Comply	Comply

6.4.4.2	For elevated temperature testing at 74°C, the modules to be tested shall be mounted in a temperature-testing chamber so that the external surface of the emitting lens is outside the chamber and all portions behind the lens are within the chamber at a temperature of 74ºC (165ºF). The air temperature in front of the lens of the module shall be maintained at a minimum of 49°C (120°F) during the elevated temperature testing. Measurements shall be made using a luminance meter located on the physical axis of the module lens at a distance such that the selected aperture samples a spot size of 12mm (0.5 inch) at the lens surface. The position of the luminance meter shall be translated from side to side and up and down, so as to sample nine points across the emitting surface of the module.The luminance values for the nine points shall be recorded and the average value calculated.Modules for which the calculated average value of luminance does not meet the requirements of Section 4.1.1 shall be rejected.		Comply	Comply	Comply	Comply
6.4.4.2.1						
6.4.4.2.2						
6.4.4.3	Luminance Uniformity: The sample set shall be tested in accordance with the requirements of Section 4.1.2, using the recorded values of luminance, at a testing temperature of 25°C. The highest and lowest values of luminance shall be recorded and compared. Modules not meeting requirements of Section 4.1.2 shall be rejected.		Comply	Comply	Comply	Comply

6.4.4.3.1	Maximum Luminance: The sample set shall be tested in accordance with the requirements of Section 4.1.3, using the recorded values of luminance, at testing temperatures of 25°C and 74°C. Modules for which the calculated average value of the luminance exceeds the limit established in Section 4.1.3, at either or both temperature levels, shall be rejected		Comply	Comply	Comply	Comply
6.4.4.4	Chromaticity: From the sample set, two modules shall be measured for chromaticity per the requirements of Section 4.2. Prior to making measurements, each module shall be operated at a 100% duty cycle for a minimum of 60 minutes at +25°C (+77°F). Color measurements shall be made using a spectro-radiometer with a maximum bandwidth of 4 nm, or a colorimeter that has a measurement uncertainty of less than 2.5% over the emission bandwidth of the icon under measurement. Measurements shall be made by locating the instrument on the axis normal to the emitting surface of the icon, at a distance such that the meter samples a spot size of 12mm (0.5 inch) at the lens surface. The position of the instrument shall be translated from side to side and up and down, so as to sample nine points across the emitting surface of the module. The chromaticity coordinates of the emitted light at the nine points shall be recorded and the average value calculated. In addition, the dominant wavelengths for the nine sampled points of the hand icon shall be calculated and recorded.		Comply	Comply	Comply	Comply

	Modules for which the calculated average chromaticity coordinates do not meet the requirements of Section 4.2 shall be rejected.					
6.4.4.4.1	Color Uniformity: The sample set shall be tested in accordance with the requirements of Section 4.3, using the recorded values of the chromaticity coordinates (walking person—white icon) or the dominant wavelengths (hand—portland orange icon), from Section 6.4.4.4. Modules not meeting requirements of Section 4.3 shall be rejected.		Comply	Comply	Comply	Comply
6.4.4.5	Photometric & Colorimetric Tests Evaluation: At the conclusion of the Photometric & Colorimetric Tests, the measurement data shall be compared to the requirements of Sections 4.1, 4.2 and 4.3.					
6.4.4.6	Acceptance/Rejection Criteria: The failure of any module to meet all of the requirements for maintained minimum luminance (4.1.1) and maximum permissible luminance (4.1.3) at 25°C and/or 74°C, and the requirements for luminance uniformity (4.1.2), chromaticity (4.2), and color uniformity (4.3) at 25°C, shall be considered a failure of the proposed design.					
6.4.5.1	Current Consumption: The sample set shall be measured for current flow in Amperes. The measured current values shall be used for quality comparison of Production Quality Assurance current measurements on production modules.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply

6.4.5.2	Temperature vs. Power Consumption: The sample set shall be tested to measure the change in power consumption in Watts versus the change in temperature over the specified operating temperature range. This data shall be recorded and made available to all end users.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
6.4.5.3	Power Consumption vs. Long-Term Life: If the rated power consumption of the module at 25°C (77ºF) and 74ºC (165ºF) will change more than 10% over time, the manufacturer shall provide documentation showing the projected power consumption in Watts of the module over a period of 60 months from the date of installation. This documentation must include data for the following temperature points: 0°C (32ºF), 25°C (77ºF), 50ºC (122ºF) and 74ºC (165ºF).	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
6.4.5.4	Power Factor (PF): The sample set shall be measured for power factor per the requirements of Section 5.6.1. A commercially available power factor meter may be used to perform this measurement. The PF shall be calculated separately for each of the icons for the module.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply

6.4.5.5	Total Harmonic Distortion (THD): The sample set shall be measured for total harmonic distortion per the requirements of Section 5.6.2. A commercially available total harmonic distortion meter may be used to perform this measurement. The THD shall be measured for each of the icons for the module.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
6.4.5.6	Low Voltage Turn Off: The sample set shall be measured to ensure compliance with the low voltage turn-off requirement of Section 5.2.5. To test for this condition each icon must first be fully illuminated at the nominal operating voltage. The applied voltage shall then be reduced to the point where there is no visible illumination. This point must be greater than 35 VAC RMS AC.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply

6.4.5.7	Turn-On and Turn-Off Times: The sample set shall be measured to ensure compliance with the turn-on and turn-off requirements of Section 5.2.6. The measurement shall be conducted using a two channel oscilloscope to measure the time delay between when the module is energized at 120 VAC RMS and when the light output reaches 90% of full output. A photo-multiplier tube shall be used to measure the light output of the module. The same apparatus shall be used to measure the time delay between when the module is de-energized and when the light output reaches 0% of full output. The time in msec shall be plotted in the X axis and light output shall be plotted in the Y axis. A module not reaching 90% nominal light output within 75 msec at start-up or still showing light output 75 msec after being de-energized shall be deemed to have failed this test.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply
6.4.5.8	Electronic Noise: From the sample set, a sample of 2 modules shall be tested per the requirements of Section 5.5, with reference to Class A emission limits referenced in Federal Communications Commission (FCC) Title 47, SubPart B, Section 15.					
6.4.5.9	Nondestruct Transient Immunity: The sample set shall be tested for transient immunity using the procedure described in Section 2.1.8, NEMA Standard TS 2-1998. Failure to meet these requirements shall be cause for rejection.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply

6.4.5.10	Electrical Tests Evaluation: At the conclusion of the Electrical Tests, the measurement data shall be compared to the requirements of Sections 5.2 through 5.6.					
6.4.5.10.1	Acceptance/Rejection Criteria: The failure of any module to meet the applicable requirements of Sections 5.2 through 5.6 shall be considered a failure of the proposed design.					
6.4.5.11	Controller Assembly Compatibility. Due to the low load current draw and high off-state impedance of modules, testing shall be performed to ensure the module design is compatible and operates properly with load current switches and conflict monitors in NEMA and Type 170 traffic signal control units. Before performing the following tests, the manufacturer should ascertain which type of signal controller unit(s) the procuring traffic authority customer has in use and tailor these tests to meet the requirements of that type and model of controller unit(s).					
6.4.5.11.1	Load Switch Compatibility. The sample set shall be tested for compatibility and proper operation with load current switches. Each module shall be connected to a variable ac voltage supply. The ac line current into the module shall be monitored for sufficient current draw to ensure proper load switch operation while the voltage is varied from 80 VAC RMS to 135 VAC RMS. Failure of the current draw to ensure proper load current switch operation shall be cause for rejection.					

6.4.5.11.2	Signal Conflict Monitor (MMU) Compatibility: The sample set shall be tested for compatibility and proper operation with signal conflict monitors. Each module shall be operated from a 135 VAC RMS supply. A 19.5 kΩ resistor shall be wired in series in the hot line between the module and the ac power supply. A single-pole-single-throw switch shall be wired in parallel across the 19.5 kΩ resistor. A 220 kΩ shunt resistor shall be wired between the hot line connection and the neutral line connection on the module. Conflict monitor compatibility shall be tested by measuring the voltage decay across the 220 kΩ shunt resistor as follows: The single-pole-single-throw switch shall be closed, shorting out the 19.5 kΩ resistor, allowing the ac power supply to illuminate the module. Next the switch shall be opened, and the voltage across the 220 kΩ shunt resistor shall be measured for a decay to a value equal to or less than 10 VAC RMS within a time period equal to or less than 100 milliseconds. This test shall be repeated a sufficient number of times to ensure that testing occurs at the peak of the ac line voltage cycle. A voltage decay across the 220 kΩ shunt resistor to a value greater than 10 VAC RMS or a decay time to 10 VAC RMS greater then 100 milliseconds shall be cause for rejection.	Certifications (asked Manufacturer)	Comply	Comply	Comply	Comply

6.4.5.11.3	Controller Assembly Compatibility Evaluation: At the conclusion of the Controller Assembly Compatibility Tests, the measurement data shall be compared to the requirements of the specific make and model Controller Assembly with which the module design is intended to operate.					
6.4.5.11.4	Acceptance/Rejection Criteria: Failure of the module to draw sufficient current to ensure compatibility with the load current switches in the appropriate Controller Assembly (5.7) and/or failure of the circuit voltage to decay to a value equal to or less than 10VAC RMS within a time period equal to or less than 100 milliseconds (5.7) shall be considered a failure of the proposed design.					

APPENDIX F. Verification of DIALIGHT Pedestrian LED Compliance

Verification for Compliance with ITE Specification for DIALIGHT PEDESTRIAN LED Modules						
Article	Specification	Means of Testing	Walking Man (430-7771-001X)	Hand (430-5770-001X)	16inch Hand+Walking Man Combination (430-6450-001X)	12 inch Hand+Walking Man Combination
3.1.1	Usage: Modules shall fit into pedestrian signal housings manufactured in accordance with the ITE PTCSI Standard, March 1985, without modification to the housing.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.1.2	Installation requirements: Installation of a module into an existing pedestrian signal housing shall only require the removal of the existing optical unit components, i.e., lens, lamp module, gaskets, and reflector; shall be weather tight and fit securely in the housing; and shall connect directly to existing electrical wiring. Installation shall not require special tools.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.1.3	New installations: For new installations, the minimum size of the message bearing surface of a module shall be determined by the length of the intended crosswalk, but in no case shall it be less than 229 mm x 229 mm. The sizes of the message bearing surfaces shall be in accordance with the dimensions given in Table 1.					

3.2.1	The module shall be capable of replacing the opticalcomponent of the pedestrian indication.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.2.2	Tinting **(Optional)** - The lens shall be tinted or shall use transparent film or materials with similar characteristics.					
3.2.3	The module lens may be a replaceable part without the need to replace the complete module.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.2.4	Hard Coat **(Optional)** - If requested, on a non-frosted polymeric lens a surface coating or a film shall be used to provide front surface abrasion resistance.					
3.2.5	The configurations of the walking person icon and hand icon are illustrated in Figure 1 and Figure 2 respectively.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.3.1	The module shall be rated for use in the ambient operating temperature range, measured at the exposed rear of the module, of -40°C to +74°C (-40°F to +165°F).	Certifications			Comply	Comply
3.3.2	The module shall be protected against dust and moisture intrusion per the requirements of MIL-STD-810F Procedure I, Rain and Blowing Rain.	Certifications (asked Manufacturer)			Comply	Comply
3.3.3	The emitting surfaces of the module shall not crack, craze or yellow under exposure to sunlight over the service life of the module.	Certifications (asked Manufacturer)			Comply	Comply

3.4.1	The module shall be a single, self-contained device, not requiring on-site assembly for installation into an existing traffic signal housing. The power supply for the module may be either integral or packaged as a separate module. The power supply may be designed to fit and mount inside the pedestrian signal housing adjacent to the module.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.4.2	The assembly and manufacturing process for the module shall be designed to assure all internal LED and electronic components are adequately supported to withstand mechanical shock and vibration from high winds and other sources.	Certifications (asked Manufacturer)			Comply	Comply
3.5.1	Materials used for the lens and module construction shall conform to ASTM specifications for the materials where applicable.	Certifications (asked Manufacturer)			Comply	Comply
3.5.2	Enclosures containing either the power supply or electronic components of the module shall be made of UL94VO flame retardant materials. The lens of the module is excluded from this requirement.	Certifications (asked Manufacturer)			Comply	Comply
3.6.1	Each module shall be identified on the backside with the manufacturer's name, model number and serial number.	Manual/Visual Verification	Comply	Comply	Comply	Comply

3.6.2	The following operating characteristics shall be identified: nominal operating voltage, power consumption, and Volt-Ampere. The load for the walking person and hand icons are to be stated separately.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.6.3	Modules shall have a prominent and permanent vertical indexing indicator, i.e., UP ARROW or the word UP or TOP, for correct indexing and orientation inside a pedestrian signal housing.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.6.4	Modules conforming to this specification, may have the following statement: “Manufactured in Conformance with the Pedestrian Traffic Control Signal Indications - Part 2: Light Emitting Diode (LED) Pedestrian Signal Modules.” on an attached label.					
4.1.1	For a minimum period of 60 months, the maintained minimum luminance values for the modules under the operating conditions defined in Sections 3.3.1 and 5.2.1, when measured normal to the plane of the icon surface, shall not be less than: Walking person: 2,200 cd/m2; • Hand: 1,400 cd/m2. The luminance of the emitting surface, measured at angles from the normal of the surface, may decrease linearly to a value of 50% of the values listed above at an angle of 15 degrees.The light output requirements in this specification apply to pedestrian signal heads without any visors, hooded or louvered (egg-crate). Addition of such visors may affect the light output of the signal head, and the purchasing agency	Certifications			Comply	Comply

	may wish to consult the issue with the manufacturer.					
4.1.2	The uniformity of the walking person and hand icons' luminance shall meet a ratio of not more than 1 to 5 between the minimum and maximum luminance values, as measured in 12mm (0.5 in) diameter spots.	Certifications			Comply	Comply
4.1.3	When operating within the temperature range specified in Section 3.3.1, the luminance of the module shall not exceed three times the maintained minimum luminance of the modules, as defined in Section 4.1.1.	Certifications			Comply	Comply
4.2	The standard colors for the LED Pedestrian Signal Module shall be White for the walking person and Portland Orange for the hand icon. The colors for these icons shall conform to the following color regions, based on the 1931 CIE chromaticity diagram:	Certifications			Comply	Comply
4.3	The uniformity of the emitted colors shall be such that any color measurement within a 12mm (0.5 in) spot on the emitting surface shall fall within the following regions around the average measured color of the entire emitting surface:The dominant wavelength for all individual color measurements shall be within ±3 nm of the dominant wavelength for the average of all the individual color measurements.	Certifications			Comply	Comply

5.1	All wiring and terminal blocks shall meet the requirements of Section 13.02 of the VTCSH standard. Two secured, color code1 m (39 in) long 600 V, 20 AWG minimum, jacketed wires, conforming to the National Electrical Code, rated for service at +105°C, are to be provided for electrical connection. The following color scheme shall be used: Orange for Hand, Blue for Walking Person and White for the common.	Manual/Visual Verification			Comply	Comply
5.2.1	The modules shall operate from a 60±3 Hertz ac line power over a voltage range from 80 VAC RMS to 135VAC RMS.	Certifications (asked Manufacturer)			Comply	Comply
5.2.2	Nominal operating voltage for all measurements shall be 120±3 VAC RMS.					
5.2.3	Fluctuations in line voltage over the range of 80VAC RMS to 135VAC RMS shall not affect luminous intensity by more than ±10 percent.	Certifications (asked Manufacturer)			Comply	Comply
5.2.4	The LED circuitry shall prevent flicker at less than 100 Hz over the voltage range specified in Section 5.2.1.	Certifications (asked Manufacturer)			Comply	Comply
5.2.5	Low Voltage Turn Off: There should be no visible illumination of the module when the applied voltage is less than 35 VAC RMS.	Certifications (asked Manufacturer)			Comply	Comply
5.2.6	Turn-On and Turn-Off Time: Each icon of the module shall reach 90% of their full illumination (turn-on) within 75 msec of the application of the nominal operating voltage. The modules shall not be illuminated (turn-off) after 75 msec of the removal of the nominal operating voltage.	Certifications (asked Manufacturer)			Comply	Comply

5.2.7	Default Condition: For abnormal conditions when nominal voltage is applied to the unit across the two-phase wires (rather than being applied to the phase wire and the neutral wire) the pedestrian signal unit shall default to the hand symbol or shall be blank.				Comply	Comply
5.3.1	The module's on-board circuitry shall include voltage surge protection to withstand high-repetition noise transients and low-repetition high-energy transients as stated in Section 2.1.6, NEMA Standard TS-2, 1998, or the latest version.	Certifications (asked Manufacturer)			Comply	Comply
5.4.1	When requested, the module circuitry shall allow a reduction of the intensity of the light output in response to an input from the traffic signal controller	OPTIONAL				
5.4.2	Dimming, if provided and conforming to Section 5.4.1, shall diminish light output to levels established to match threshold ambient light conditions. The dimming may be in stepped increments or may be continuously variable. The minimum light output when dimmed shall not be less than thirty (30) percent of the maintained minimum luminance values shown in Paragraph 4.1.1.	OPTIONAL				
5.5	The modules and associated on-board circuitry shall conform to Class A requirements of Federal Communications Commission (FCC) Title 47, SubPart B, Section 15 regulations concerning the emission of electronic noise.	Certifications			Comply	Comply

5.6.1	The modules shall provide a power factor of 0.90 or greater when operated at nominal operating voltage, and 25ºC (77ºF).	Certifications (asked Manufacturer)			Comply	Comply
5.6.2	Total harmonic distortion induced into an AC power line by the module, operated at nominal operating voltage, at 25ºC (77ºF) shall not exceed 20 percent.	Certifications (asked Manufacturer)			Comply	Comply
5.7	The current draw shall be sufficient to ensure compatibility and proper triggering and operation of load current switches and conflict monitors in existing signal controller units.	Certifications			Tested in Lab	Tested in Lab
6.1	Unless otherwise specified all of the tests will be conducted at an ambient temperature of 25°C and at the nominal operating voltage of 120 VAC RMS.					
6.1.1	Quality Assurance Program: The modules shall be manufactured in accordance with a vendor quality assurance (QA) program. The QA program shall include two types of quality assurance: (1) design quality assurance and (2) production quality assurance. The production quality assurance shall include statistically controlled routine tests to ensure minimum performance levels of the modules built to meet this specification.	Ask Manufacturer to verify	Comply	Comply	Comply	Comply
6.1.2	Record Keeping: QA process and test results documentation shall be kept on file for a minimum period of seven years.	Ask Manufacturer to verify	Comply	Comply	Comply	Comply

6.1.3	Conformance: Module designs that do not satisfy the requirements of this specification, as evaluated by the design qualification testing (section 6.4) and the production quality assurance testing (section 6.3) shall not be labeled, advertised, or sold as conforming to this specification.	Ask Manufacturer to verify	Comply	Comply	Comply	Comply
6.2	Each module shall be identified with the manufacturer's name, model and serial number.	Manual/Visual Verification	Comply	Comply	Comply	Comply
6.3	All modules shall undergo the following Production Quality Assurance testing prior to shipment. Failure of any module to meet requirements of these QA tests shall be cause for rejection. QA test results shall be maintained per the requirement of Section 6.1.2.		Comply	Comply	Comply	Comply
6.3.1	Production Luminance Test: All modules shall be tested for maintained minimum luminance. Any measurement with a correlation to the luminance requirements of Section 4.1.1 may be used. Modules that do not meet the maintained minimum luminance requirements as per Section 4.1.1 shall be rejected.	Ask Manufacturer to verify	Comply	Comply	Comply	Comply
6.3.2	Power Factor: All modules shall be tested for power factor to the requirements of Section 5.6.1. A commercially available power factor meter may be used to perform this measurement. Failure of the requirements shall be cause for rejection.	Ask Manufacturer to verify	Comply	Comply	Comply	Comply

6.3.3	Current: All modules shall be measured for the amount of current consumption. The measured current values shall be compared against current values resulting from design qualification measurements in Section 6.4.5.1. Measured current values in excess of 120 percent of the design qualification current values shall be cause for rejection	Ask Manufacturer to verify	Comply	Comply	Comply	Comply
6.3.4	Visual Inspection: All modules shall be visually inspected for any exterior physical damage or assembly anomalies. Careful attention shall be paid to the surface of the lens to ensure there are no scratches (abrasions), cracks, chips, discoloration, or other defects. Presence of any such defects shall be cause for rejection of the module.		Comply	Comply	Comply	Comply
6.4.1	Design Qualification testing shall be performed on new module designs, and when a major design change has been implemented on an existing design. Modules used in design qualification testing shall be representative of the manufacturer's proposed normal production.	Ask Manufacturer to verify	Comply	Comply	Comply	Comply
6.4.1.1	Testing shall be performed once every 5 years or when the module design or LED technology has been changed. Test data shall be retained by the module manufacturer in accordance with Section 6.1.2 or for 60 months following final production of a specific design, whichever is longer.	Ask Manufacturer to verify	Comply	Comply	Comply	Comply

6.4.1.2	Six modules shall be used in Design Qualification Testing. All six modules shall be subjected to conditioning (6.4.2), followed by the Environmental Tests (6.4.3), and followed by the Lens Abrasion Test (6.4.3.4). Following the Environmental Tests, three modules shall undergo Photometric & Colorimetric Tests (6.4.4). The remaining three modules shall undergo the Electrical Tests (6.4.5) and Controller Compatibility Tests (6.4.5.11). Tests shall be conducted in the order described herein, unless otherwise specified.				Comply	Comply
6.4.1.3	In order for a module design to be considered acceptable for marking with the label described in 3.6.4, all tested modules must comply with the acceptance/rejection criteria for the Environmental Tests (6.4.3), Photometric & Colorimetric Tests (6.4.4), Lens Tests (6.4.5), Electrical Tests (6.4.5), and Controller Assembly Compatibility Tests (6.4.5.11).					
6.4.2	Modules shall be energized for a minimum of 24 hours, at 100% duty cycle, in an ambient temperature of +60°C (+140°F).	Certifications (asked Manufacturer)			Comply	Comply
6.4.3.1	Mechanical Vibration Testing: Three modules shall be tested per MIL-STD-883, Test Method 2007, using three 4-minute cycles along each x, y, and z axis, at a force of 2.5 Gs, with a frequency sweep from 2 Hz to 120 Hz.	Certifications (asked Manufacturer)			Comply	Comply

6.4.3.2	Temperature Cycling. Temperature cycling shall be performed per MIL-STD-883, Test method 1010. The temperature range shall be per Section 3.3.1. A minimum of 20 cycles shall be performed with a 30-minute transfer time between temperature extremes and a 30-minute dwell time at each temperature. Modules under test shall be non-operating.	Certifications (asked Manufacturer)			Comply	Comply
6.4.3.3	Moisture Resistance. Moisture resistance testing shall be performed on a sample of three modules per MIL-STD-810F, Procedure I, Rain and Blowing Rain. The test shall be conduced on a stand-alone unit, without a protective housing. The rainfall rate shall be 1.7 mm/min (4 in/hr) and droplet size shall predominantly be between 0.5 mm and 4.5 mm. The module shall be rotated through 120 degrees and the duration of the test shall be 30 minutes. The module shall be energized throughout the test. The water shall be at 25°C. The wind velocity shall be 80 km/hr (50 mph). Any evidence of internal moisture into the module shall be cause for rejection. If the module is equipped with a remote power supply unit, then the test shall be conducted with the remote power supply unit attached to the clamping device holding the LED signal module to the test apparatus.	Certifications (asked Manufacturer)			Comply	Comply

6.4.3.4	Hard Coat Test (Optional): When applicable, a sample of three (3) modules shall be tested in accordance to the abrasion resistance test ASTM D1044. A weight of 500 grams shall be applied on a CS10F wheel for 150 cycles.					
6.4.3.5	UV Stabilization: Documentation shall be provided that clearly demonstrates that the external lens complies with the requirements of section 3.3.3.		Not provided	Not provided	Not provided	Not provided
6.4.3.6	Environmental Tests Evaluation: At the conclusion of the Environmental Tests, all the modules will be visually inspected for damage.					
6.4.3.7	Acceptance/Rejection Criteria: The loosening of the lens, or any internal components, or evidence of other physical damage, such as cracking of the module lens or housing or presence of internal moisture after testing a change in haze of the surface under test greater than 15% or if the module extinguishes itself shall be considered a failure for the proposed design.					
6.4.4	Photometric & Calorimetric Tests: Three of the modules that were subjected to the Environmental Tests shall undergo Photometric & Colorimetric Tests. Unless otherwise specified, these tests shall be performed with the modules energized at nominal operating voltage (120 VAC).					

6.4.4.1	Maintained Minimum Luminance: The sample set shall be tested for maintained minimum luminance at both 25°C and 74°C. Prior to making measurements, each module shall be operated at a 100% duty cycle for a minimum of 60 minutes at the test temperature.				Comply	Comply
6.4.4.2	For elevated temperature testing at 74°C, the modules to be tested shall be mounted in a temperature-testing chamber so that the external surface of the emitting lens is outside the chamber and all portions behind the lens are within the chamber at a temperature of 74ºC (165ºF). The air temperature in front of the lens of the module shall be maintained at a minimum of 49°C (120°F) during the elevated temperature testing. Measurements shall be made using a luminance meter located on the physical axis of the module lens at a distance such that the selected aperture samples a spot size of 12mm (0.5 inch) at the lens surface. The position of the luminance meter shall be translated from side to side and up and down, so as to sample nine points across the emitting surface of the module.The luminance values for the nine points shall be recorded and the average value calculated.Modules for which the calculated average value of luminance does not meet the requirements of Section 4.1.1 shall be rejected.				Comply	Comply
6.4.4.2.1						
6.4.4.2.2						

6.4.4.3	Luminance Uniformity: The sample set shall be tested in accordance with the requirements of Section 4.1.2, using the recorded values of luminance, at a testing temperature of 25°C. The highest and lowest values of luminance shall be recorded and compared. Modules not meeting requirements of Section 4.1.2 shall be rejected.				Comply	Comply
6.4.4.3.1	Maximum Luminance: The sample set shall be tested in accordance with the requirements of Section 4.1.3, using the recorded values of luminance, at testing temperatures of 25°C and 74°C. Modules for which the calculated average value of the luminance exceeds the limit established in Section 4.1.3, at either or both temperature levels, shall be rejected				Comply	Comply
6.4.4.4	Chromaticity: From the sample set, two modules shall be measured for chromaticity per the requirements of Section 4.2. Prior to making measurements, each module shall be operated at a 100% duty cycle for a minimum of 60 minutes at +25°C (+77°F). Color measurements shall be made using a spectro-radiometer with a maximum bandwidth of 4 nm, or a colorimeter that has a measurement uncertainty of less than 2.5% over the emission bandwidth of the icon under measurement. Measurements shall be made by locating the instrument on the axis normal to the emitting surface of the icon, at a distance such that the meter samples a spot size of 12mm (0.5 inch) at the lens surface. The				Comply	Comply

	position of the instrument shall be translated from side to side and up and down, so as to sample nine points across the emitting surface of the module. The chromaticity coordinates of the emitted light at the nine points shall be recorded and the average value calculated. In addition, the dominant wavelengths for the nine sampled points of the hand icon shall be calculated and recorded. Modules for which the calculated average chromaticity coordinates do not meet the requirements of Section 4.2 shall be rejected.					
6.4.4.4.1	Color Uniformity: The sample set shall be tested in accordance with the requirements of Section 4.3, using the recorded values of the chromaticity coordinates (walking person—white icon) or the dominant wavelengths (hand—portland orange icon), from Section 6.4.4.4. Modules not meeting requirements of Section 4.3 shall be rejected.				Comply	Comply
6.4.4.5	Photometric & Colorimetric Tests Evaluation: At the conclusion of the Photometric & Colorimetric Tests, the measurement data shall be compared to the requirements of Sections 4.1, 4.2 and 4.3.					

6.4.4.6	Acceptance/Rejection Criteria: The failure of any module to meet all of the requirements for maintained minimum luminance (4.1.1) and maximum permissible luminance (4.1.3) at 25°C and/or 74°C, and the requirements for luminance uniformity (4.1.2), chromaticity (4.2), and color uniformity (4.3) at 25°C, shall be considered a failure of the proposed design.					
6.4.5.1	Current Consumption: The sample set shall be measured for current flow in Amperes. The measured current values shall be used for quality comparison of Production Quality Assurance current measurements on production modules.	Certifications (asked Manufacturer)			Comply	Comply
6.4.5.2	Temperature vs. Power Consumption: The sample set shall be tested to measure the change in power consumption in Watts versus the change in temperature over the specified operating temperature range. This data shall be recorded and made available to all end users.	Certifications (asked Manufacturer)			Comply	Comply
6.4.5.3	Power Consumption vs. Long-Term Life: If the rated power consumption of the module at 25°C (77ºF) and 74ºC (165ºF) will change more than 10% over time, the manufacturer shall provide documentation showing the projected power consumption in Watts of the module over a period of 60 months from the date of installation. This documentation must include data for the following temperature points: 0°C (32ºF), 25°C (77ºF), 50ºC (122ºF) and 74ºC (165ºF).	Certifications (asked Manufacturer)			Comply	Comply

6.4.5.4	Power Factor (PF): The sample set shall be measured for power factor per the requirements of Section 5.6.1. A commercially available power factor meter may be used to perform this measurement. The PF shall be calculated separately for each of the icons for the module.	Certifications (asked Manufacturer)			Comply	Comply
6.4.5.5	Total Harmonic Distortion (THD): The sample set shall be measured for total harmonic distortion per the requirements of Section 5.6.2. A commercially available total harmonic distortion meter may be used to perform this measurement. The THD shall be measured for each of the icons for the module.	Certifications (asked Manufacturer)			Comply	Comply
6.4.5.6	Low Voltage Turn Off: The sample set shall be measured to ensure compliance with the low voltage turn-off requirement of Section 5.2.5. To test for this condition each icon must first be fully illuminated at the nominal operating voltage. The applied voltage shall then be reduced to the point where there is no visible illumination. This point must be greater than 35 VAC RMS AC.	Certifications (asked Manufacturer)			Comply	Comply

6.4.5.7	Turn-On and Turn-Off Times: The sample set shall be measured to ensure compliance with the turn-on and turn-off requirements of Section 5.2.6. The measurement shall be conducted using a two channel oscilloscope to measure the time delay between when the module is energized at 120 VAC RMS and when the light output reaches 90% of full output. A photo-multiplier tube shall be used to measure the light output of the module. The same apparatus shall be used to measure the time delay between when the module is de-energized and when the light output reaches 0% of full output. The time in msec shall be plotted in the X axis and light output shall be plotted in the Y axis. A module not reaching 90% nominal light output within 75 msec at start-up or still showing light output 75 msec after being de-energized shall be deemed to have failed this test.	Certifications (asked Manufacturer)			Comply	Comply
6.4.5.8	Electronic Noise: From the sample set, a sample of 2 modules shall be tested per the requirements of Section 5.5, with reference to Class A emission limits referenced in Federal Communications Commission (FCC) Title 47, SubPart B, Section 15.				Comply	Comply
6.4.5.9	Nondestruct Transient Immunity: The sample set shall be tested for transient immunity using the procedure described in Section 2.1.8, NEMA Standard TS 2-1998. Failure to meet these requirements shall be cause for rejection.	Certifications (asked Manufacturer)			Comply	Comply

6.4.5.10	Electrical Tests Evaluation: At the conclusion of the Electrical Tests, the measurement data shall be compared to the requirements of Sections 5.2 through 5.6.					
6.4.5.10.1	Acceptance/Rejection Criteria: The failure of any module to meet the applicable requirements of Sections 5.2 through 5.6 shall be considered a failure of the proposed design.					
6.4.5.11	Controller Assembly Compatibility. Due to the low load current draw and high off-state impedance of modules, testing shall be performed to ensure the module design is compatible and operates properly with load current switches and conflict monitors in NEMA and Type 170 traffic signal control units. Before performing the following tests, the manufacturer should ascertain which type of signal controller unit(s) the procuring traffic authority customer has in use and tailor these tests to meet the requirements of that type and model of controller unit(s).					
6.4.5.11.1	Load Switch Compatibility. The sample set shall be tested for compatibility and proper operation with load current switches. Each module shall be connected to a variable ac voltage supply. The ac line current into the module shall be monitored for sufficient current draw to ensure proper load switch operation while the voltage is varied from 80 VAC RMS to 135 VAC RMS. Failure of the current draw to ensure proper load current switch operation shall be cause for rejection.				Comply	Comply

6.4.5.11.2	Signal Conflict Monitor (MMU) Compatibility: The sample set shall be tested for compatibility and proper operation with signal conflict monitors. Each module shall be operated from a 135 VAC RMS supply. A 19.5 kΩ resistor shall be wired in series in the hot line between the module and the ac power supply. A single-pole-single-throw switch shall be wired in parallel across the 19.5 kΩ resistor. A 220 kΩ shunt resistor shall be wired between the hot line connection and the neutral line connection on the module. Conflict monitor compatibility shall be tested by measuring the voltage decay across the 220 kΩ shunt resistor as follows: The single-pole-single-throw switch shall be closed, shorting out the 19.5 kΩ resistor, allowing the ac power supply to illuminate the module. Next the switch shall be opened, and the voltage across the 220 kΩ shunt resistor shall be measured for a decay to a value equal to or less than 10 VAC RMS within a time period equal to or less than 100 milliseconds. This test shall be repeated a sufficient number of times to ensure that testing occurs at the peak of the ac line voltage cycle. A voltage decay across the 220 kΩ shunt resistor to a value greater than 10 VAC RMS or a decay time to 10 VAC RMS greater then 100 milliseconds shall be cause for rejection.	Certifications (asked Manufacturer)			Comply	Comply

6.4.5.11.3	Controller Assembly Compatibility Evaluation: At the conclusion of the Controller Assembly Compatibility Tests, the measurement data shall be compared to the requirements of the specific make and model Controller Assembly with which the module design is intended to operate.					
6.4.5.11.4	Acceptance/Rejection Criteria: Failure of the module to draw sufficient current to ensure compatibility with the load current switches in the appropriate Controller Assembly (5.7) and/or failure of the circuit voltage to decay to a value equal to or less than 10VAC RMS within a time period equal to or less than 100 milliseconds (5.7) shall be considered a failure of the proposed design.					

APPENDIX G. Verification of LUMINATION Pedestrian LED Compliance

Verification for Compliance with ITE Specification for LUMINATION PEDESTRIAN LED Modules						
Article	Specification	Means of Testing	12 inch Walking Man (PS6-WFM3-26A)	12 inch Hand (PS6-PFH1-26A)	16inch Hand+Walking Man Combination (PS7-CFC1-26A)	12 inch Hand+Walking Man Combination (PS6-CFL1-26A)
3.1.1	Usage: Modules shall fit into pedestrian signal housings manufactured in accordance with the ITE PTCSI Standard, March 1985, without modification to the housing.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.1.2	Installation requirements: Installation of a module into an existing pedestrian signal housing shall only require the removal of the existing optical unit components, i.e., lens, lamp module, gaskets, and reflector; shall be weather tight and fit securely in the housing; and shall connect directly to existing electrical wiring. Installation shall not require special tools.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.1.3	New installations: For new installations, the minimum size of the message bearing surface of a module shall be determined by the length of the intended crosswalk, but in no case shall it be less than 229 mm x 229 mm. The sizes of the message bearing surfaces shall be in accordance with the dimensions given in Table 1.					

3.2.1	The module shall be capable of replacing the opticalcomponent of the pedestrian indication.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.2.2	Tinting **(Optional)** - The lens shall be tinted or shall use transparent film or materials with similar characteristics.	OPTIONAL				
3.2.3	The module lens may be a replaceable part without the need to replace the complete module.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.2.4	Hard Coat **(Optional)** - If requested, on a non-frosted polymeric lens a surface coating or a film shall be used to provide front surface abrasion resistance.	OPTIONAL				
3.2.5	The configurations of the walking person icon and hand icon are illustrated in Figure 1 and Figure 2 respectively.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.3.1	The module shall be rated for use in the ambient operating temperature range, measured at the exposed rear of the module, of -40°C to +74°C (-40°F to +165°F).	Certifications	Comply	Comply	Comply	
3.3.2	The module shall be protected against dust and moisture intrusion per the requirements of MIL-STD-810F Procedure I, Rain and Blowing Rain.	Certifications	Comply	Comply	Comply	
3.3.3	The emitting surfaces of the module shall not crack, craze or yellow under exposure to sunlight over the service life of the module.	Certifications (asked manufacturer)	Comply	Comply	Comply	

3.4.1	The module shall be a single, self-contained device, not requiring on-site assembly for installation into an existing traffic signal housing. The power supply for the module may be either integral or packaged as a separate module. The power supply may be designed to fit and mount inside the pedestrian signal housing adjacent to the module.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.4.2	The assembly and manufacturing process for the module shall be designed to assure all internal LED and electronic components are adequately supported to withstand mechanical shock and vibration from high winds and other sources.	Certifications	Comply	Comply	Comply	
3.5.1	Materials used for the lens and module construction shall conform to ASTM specifications for the materials where applicable.	Certifications (asked manufacturer)	Comply	Comply	Comply	
3.5.2	Enclosures containing either the power supply or electronic components of the module shall be made of UL94VO flame retardant materials. The lens of the module is excluded from this requirement.	Certifications (asked manufacturer)	Comply	Comply	Comply	
3.6.1	Each module shall be identified on the backside with the manufacturer's name, model number and serial number.	Manual/Visual Verification	Comply	Comply	Comply	Comply

3.6.2	The following operating characteristics shall be identified: nominal operating voltage, power consumption, and Volt-Ampere. The load for the walking person and hand icons are to be stated separately.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.6.3	Modules shall have a prominent and permanent vertical indexing indicator, i.e., UP ARROW or the word UP or TOP, for correct indexing and orientation inside a pedestrian signal housing.	Manual/Visual Verification	Comply	Comply	Comply	Comply
3.6.4	Modules conforming to this specification, may have the following statement: “Manufactured in Conformance with the Pedestrian Traffic Control Signal Indications - Part 2: Light Emitting Diode (LED) Pedestrian Signal Modules.” on an attached label.					
4.1.1	For a minimum period of 60 months, the maintained minimum luminance values for the modules under the operating conditions defined in Sections 3.3.1 and 5.2.1, when measured normal to the plane of the icon surface, shall not be less than: Walking person: 2,200 cd/m2; • Hand: 1,400 cd/m2. The luminance of the emitting surface, measured at angles from the normal of the surface, may decrease linearly to a value of 50% of the values listed above at an angle of 15 degrees.The light output requirements in this specification apply to pedestrian signal heads without any visors, hooded or louvered (egg-crate). Addition of such visors may affect the light output of the signal head, and the purchasing agency may wish to consult the issue with the manufacturer.	Certifications	Comply	Comply	Comply	

4.1.2	The uniformity of the walking person and hand icons' luminance shall meet a ratio of not more than 1 to 5 between the minimum and maximum luminance values, as measured in 12mm (0.5 in) diameter spots.	Certifications	Comply	Comply	Comply	
4.1.3	When operating within the temperature range specified in Section 3.3.1, the luminance of the module shall not exceed three times the maintained minimum luminance of the modules, as defined in Section 4.1.1.	Certifications	Does not Comply	Comply	Comply	
4.2	The standard colors for the LED Pedestrian Signal Module shall be White for the walking person and Portland Orange for the hand icon. The colors for these icons shall conform to the following color regions, based on the 1931 CIE chromaticity diagram:	Certifications	Comply	Comply	Comply	
4.3	The uniformity of the emitted colors shall be such that any color measurement within a 12mm (0.5 in) spot on the emitting surface shall fall within the following regions around the average measured color of the entire emitting surface:The dominant wavelength for all individual color measurements shall be within ±3 nm of the dominant wavelength for the average of all the individual color measurements.	Certifications	Comply	Comply	Comply	

5.1	All wiring and terminal blocks shall meet the requirements of Section 13.02 of the VTCSH standard. Two secured, color code1 m (39 in) long 600 V, 20 AWG minimum, jacketed wires, conforming to the National Electrical Code, rated for service at +105°C, are to be provided for electrical connection. The following color scheme shall be used: Orange for Hand, Blue for Walking Person and White for the common.	Manual/Visual Verification				
5.2.1	The modules shall operate from a 60±3 Hertz ac line power over a voltage range from 80 VAC RMS to 135VAC RMS.	Certifications	Comply	Comply	Comply	
5.2.2	Nominal operating voltage for all measurements shall be 120±3 VAC RMS.					
5.2.3	Fluctuations in line voltage over the range of 80VAC RMS to 135VAC RMS shall not affect luminous intensity by more than ±10 percent.	Certifications	Ambiguous response: Internal power supply tests show that output drive current will vary by much less than 5% over the voltage range for both hand and	Ambiguous response: Internal power supply tests show that output drive current will vary by much less than 5% over the voltage	Ambiguous response: Internal power supply tests show that output drive current will vary by much less than 5% over the voltage range for both hand and person symbols	

			person symbols	range for both hand and person symbols		
5.2.4	The LED circuitry shall prevent flicker at less than 100 Hz over the voltage range specified in Section 5.2.1.	Certifications	Ambiguous response: Flickering tests are always performed as part of the design and testing process of power supplies at GE Lumination but not required as part of the design qualification process required by ITE.	Ambiguous response: Flickering tests are always performed as part of the design and testing process of power supplies at GE Lumination but not required as part of the design qualification process required	Ambiguous response: Flickering tests are always performed as part of the design and testing process of power supplies at GE Lumination but not required as part of the design qualification process required by ITE.	

				by ITE.		
5.2.5	Low Voltage Turn Off: There should be no visible illumination of the module when the applied voltage is less than 35 VAC RMS.	Certifications	Comply	Comply	Comply	
5.2.6	Turn-On and Turn-Off Time: Each icon of the module shall reach 90% of their full illumination (turn-on) within 75 msec of the application of the nominal operating voltage. The modules shall not be illuminated (turn-off) after 75 msec of the removal of the nominal operating voltage.	Certifications	Comply	Comply	Comply	
5.2.7	Default Condition: For abnormal conditions when nominal voltage is applied to the unit across the two-phase wires (rather than being applied to the phase wire and the neutral wire) the pedestrian signal unit shall default to the hand symbol or shall be blank.					
5.3.1	The module's on-board circuitry shall include voltage surge protection to withstand high-repetition noise transients and low-repetition high-energy transients as stated in Section 2.1.6, NEMA Standard TS-2, 1998, or the latest version.	Certifications	Comply	Comply	Comply	
5.4.1	When requested, the module circuitry shall allow a reduction of the intensity of the light output in response to an input from the traffic signal controller	OPTIONAL				

5.4.2	Dimming, if provided and conforming to Section 5.4.1, shall diminish light output to levels established to match threshold ambient light conditions. The dimming may be in stepped increments or may be continuously variable. The minimum light output when dimmed shall not be less than thirty (30) percent of the maintained minimum luminance values shown in Paragraph 4.1.1.	OPTIONAL				
5.5	The modules and associated on-board circuitry shall conform to Class A requirements of Federal Communications Commission (FCC) Title 47, SubPart B, Section 15 regulations concerning the emission of electronic noise.	Certifications	Comply	Comply	Comply	
5.6.1	The modules shall provide a power factor of 0.90 or greater when operated at nominal operating voltage, and 25ºC (77ºF).	Certifications	Comply	Comply	Comply	
5.6.2	Total harmonic distortion induced into an AC power line by the module, operated at nominal operating voltage, at 25ºC (77ºF) shall not exceed 20 percent.	Certifications	Comply	Comply	Comply	
5.7	The current draw shall be sufficient to ensure compatibility and proper triggering and operation of load current switches and conflict monitors in existing signal controller units.	Certifications	Tested in Lab	Tested in Lab	Tested in Lab	
6.1	Unless otherwise specified all of the tests will be conducted at an ambient temperature of 25°C and at the nominal operating voltage of 120 VAC RMS.					

6.1.1	Quality Assurance Program: The modules shall be manufactured in accordance with a vendor quality assurance (QA) program. The QA program shall include two types of quality assurance: (1) design quality assurance and (2) production quality assurance. The production quality assurance shall include statistically controlled routine tests to ensure minimum performance levels of the modules built to meet this specification.	Ask Manufacturer to verify	Comply	Comply	Comply	
6.1.2	Record Keeping: QA process and test results documentation shall be kept on file for a minimum period of seven years.	Ask Manufacturer to verify	Comply	Comply	Comply	
6.1.3	Conformance: Module designs that do not satisfy the requirements of this specification, as evaluated by the design qualification testing (section 6.4) and the production quality assurance testing (section 6.3) shall not be labeled, advertised, or sold as conforming to this specification.	Ask Manufacturer to verify	Comply	Comply	Comply	
6.2	Each module shall be identified with the manufacturer's name, model and serial number.	Manual/Visual Verification	Comply	Comply	Comply	
6.3	All modules shall undergo the following Production Quality Assurance testing prior to shipment. Failure of any module to meet requirements of these QA tests shall be cause for rejection. QA test results shall be maintained per the requirement of Section 6.1.2.					

6.3.1	Production Luminance Test: All modules shall be tested for maintained minimum luminance. Any measurement with a correlation to the luminance requirements of Section 4.1.1 may be used. Modules that do not meet the maintained minimum luminance requirements as per Section 4.1.1 shall be rejected.	Ask Manufacturer to verify	Comply	Comply	Comply	
6.3.2	Power Factor: All modules shall be tested for power factor to the requirements of Section 5.6.1. A commercially available power factor meter may be used to perform this measurement. Failure of the requirements shall be cause for rejection.	Ask Manufacturer to verify	Comply	Comply	Comply	
6.3.3	Current: All modules shall be measured for the amount of current consumption. The measured current values shall be compared against current values resulting from design qualification measurements in Section 6.4.5.1. Measured current values in excess of 120 percent of the design qualification current values shall be cause for rejection	Ask Manufacturer to verify	Comply	Comply	Comply	
6.3.4	Visual Inspection: All modules shall be visually inspected for any exterior physical damage or assembly anomalies. Careful attention shall be paid to the surface of the lens to ensure there are no scratches (abrasions), cracks, chips, discoloration, or other defects. Presence of any such defects shall be cause for rejection of the module.					

6.4.1	Design Qualification testing shall be performed on new module designs, and when a major design change has been implemented on an existing design. Modules used in design qualification testing shall be representative of the manufacturer's proposed normal production.	Ask Manufacturer to verify	Comply	Comply	Comply	
6.4.1.1	Testing shall be performed once every 5 years or when the module design or LED technology has been changed. Test data shall be retained by the module manufacturer in accordance with Section 6.1.2 or for 60 months following final production of a specific design, whichever is longer.	Ask Manufacturer to verify	Comply	Comply	Comply	
6.4.1.2	Six modules shall be used in Design Qualification Testing. All six modules shall be subjected to conditioning (6.4.2), followed by the Environmental Tests (6.4.3), and followed by the Lens Abrasion Test (6.4.3.4). Following the Environmental Tests, three modules shall undergo Photometric & Colorimetric Tests (6.4.4). The remaining three modules shall undergo the Electrical Tests (6.4.5) and Controller Compatibility Tests (6.4.5.11). Tests shall be conducted in the order described herein, unless otherwise specified.					

6.4.1.3	In order for a module design to be considered acceptable for marking with the label described in 3.6.4, all tested modules must comply with the acceptance/rejection criteria for the Environmental Tests (6.4.3), Photometric & Colorimetric Tests (6.4.4), Lens Tests (6.4.5), Electrical Tests (6.4.5), and Controller Assembly Compatibility Tests (6.4.5.11).					
6.4.2	Modules shall be energized for a minimum of 24 hours, at 100% duty cycle, in an ambient temperature of +60°C (+140°F).	Certifications	Comply	Comply	Comply	
6.4.3.1	Mechanical Vibration Testing: Three modules shall be tested per MIL-STD-883, Test Method 2007, using three 4-minute cycles along each x, y, and z axis, at a force of 2.5 Gs, with a frequency sweep from 2 Hz to 120 Hz.	Certifications	Comply	Comply	Comply	
6.4.3.2	Temperature Cycling. Temperature cycling shall be performed per MIL-STD-883, Test method 1010. The temperature range shall be per Section 3.3.1. A minimum of 20 cycles shall be performed with a 30-minute transfer time between temperature extremes and a 30-minute dwell time at each temperature. Modules under test shall be non-operating.	Certifications	Comply	Comply	Comply	

6.4.3.3	Moisture Resistance. Moisture resistance testing shall be performed on a sample of three modules per MIL-STD-810F, Procedure I, Rain and Blowing Rain. The test shall be conduced on a stand-alone unit, without a protective housing. The rainfall rate shall be 1.7 mm/min (4 in/hr) and droplet size shall predominantly be between 0.5 mm and 4.5 mm. The module shall be rotated through 120 degrees and the duration of the test shall be 30 minutes. The module shall be energized throughout the test. The water shall be at 25°C. The wind velocity shall be 80 km/hr (50 mph). Any evidence of internal moisture into the module shall be cause for rejection. If the module is equipped with a remote power supply unit, then the test shall be conducted with the remote power supply unit attached to the clamping device holding the LED signal module to the test apparatus.	Certifications	Comply	Comply	Comply	
6.4.3.4	Hard Coat Test (Optional): When applicable, a sample of three (3) modules shall be tested in accordance to the abrasion resistance test ASTM D1044. A weight of 500 grams shall be applied on a CS10F wheel for 150 cycles.	OPTIONAL				
6.4.3.5	UV Stabilization: Documentation shall be provided that clearly demonstrates that the external lens complies with the requirements of section 3.3.3.	Certifications	Not provided	Not provided	Not provided	
6.4.3.6	Environmental Tests Evaluation: At the conclusion of the Environmental Tests, all the modules will be visually inspected for damage.					

6.4.3.7	Acceptance/Rejection Criteria: The loosening of the lens, or any internal components, or evidence of other physical damage, such as cracking of the module lens or housing or presence of internal moisture after testing a change in haze of the surface under test greater than 15% or if the module extinguishes itself shall be considered a failure for the proposed design.					
6.4.4	Photometric & Calorimetric Tests: Three of the modules that were subjected to the Environmental Tests shall undergo Photometric & Colorimetric Tests. Unless otherwise specified, these tests shall be performed with the modules energized at nominal operating voltage (120 VAC).					
6.4.4.1	Maintained Minimum Luminance: The sample set shall be tested for maintained minimum luminance at both 25°C and 74°C. Prior to making measurements, each module shall be operated at a 100% duty cycle for a minimum of 60 minutes at the test temperature.					

6.4.4.2	For elevated temperature testing at 74°C, the modules to be tested shall be mounted in a temperature-testing chamber so that the external surface of the emitting lens is outside the chamber and all portions behind the lens are within the chamber at a temperature of 74ºC (165ºF). The air temperature in front of the lens of the module shall be maintained at a minimum of 49°C (120°F) during the elevated temperature testing. Measurements shall be made using a luminance meter located on the physical axis of the module lens at a distance such that the selected aperture samples a spot size of 12mm (0.5 inch) at the lens surface. The position of the luminance meter shall be translated from side to side and up and down, so as to sample nine points across the emitting surface of the module.The luminance values for the nine points shall be recorded and the average value calculated.Modules for which the calculated average value of luminance does not meet the requirements of Section 4.1.1 shall be rejected.	Certifications	Comply	Comply	Comply	
6.4.4.2.1						
6.4.4.2.2						
6.4.4.3	Luminance Uniformity: The sample set shall be tested in accordance with the requirements of Section 4.1.2, using the recorded values of luminance, at a testing temperature of 25°C. The highest and lowest values of luminance shall be recorded and compared. Modules not meeting requirements of Section 4.1.2 shall be rejected.	Certifications	Comply	Comply	Comply	

6.4.4.3.1	Maximum Luminance: The sample set shall be tested in accordance with the requirements of Section 4.1.3, using the recorded values of luminance, at testing temperatures of 25°C and 74°C. Modules for which the calculated average value of the luminance exceeds the limit established in Section 4.1.3, at either or both temperature levels, shall be rejected	Certifications	Does not Comply	Comply	Comply	
6.4.4.4	Chromaticity: From the sample set, two modules shall be measured for chromaticity per the requirements of Section 4.2. Prior to making measurements, each module shall be operated at a 100% duty cycle for a minimum of 60 minutes at +25°C (+77°F). Color measurements shall be made using a spectro-radiometer with a maximum bandwidth of 4 nm, or a colorimeter that has a measurement uncertainty of less than 2.5% over the emission bandwidth of the icon under measurement. Measurements shall be made by locating the instrument on the axis normal to the emitting surface of the icon, at a distance such that the meter samples a spot size of 12mm (0.5 inch) at the lens surface. The position of the instrument shall be translated from side to side and up and down, so as to sample nine points across the emitting surface of the module. The chromaticity coordinates of the emitted light at the nine points shall be recorded and the average value calculated. In addition, the dominant wavelengths for the nine sampled points of the hand icon shall be calculated and recorded.	Certifications	Comply	Comply	Comply	

	Modules for which the calculated average chromaticity coordinates do not meet the requirements of Section 4.2 shall be rejected.					
6.4.4.4.1	Color Uniformity: The sample set shall be tested in accordance with the requirements of Section 4.3, using the recorded values of the chromaticity coordinates (walking person—white icon) or the dominant wavelengths (hand—portland orange icon), from Section 6.4.4.4. Modules not meeting requirements of Section 4.3 shall be rejected.	Certifications	Comply	Comply	Comply	
6.4.4.5	Photometric & Colorimetric Tests Evaluation: At the conclusion of the Photometric & Colorimetric Tests, the measurement data shall be compared to the requirements of Sections 4.1, 4.2 and 4.3.					
6.4.4.6	Acceptance/Rejection Criteria: The failure of any module to meet all of the requirements for maintained minimum luminance (4.1.1) and maximum permissible luminance (4.1.3) at 25°C and/or 74°C, and the requirements for luminance uniformity (4.1.2), chromaticity (4.2), and color uniformity (4.3) at 25°C, shall be considered a failure of the proposed design.					
6.4.5.1	Current Consumption: The sample set shall be measured for current flow in Amperes. The measured current values shall be used for quality comparison of Production Quality Assurance current measurements on production modules.	Certifications	Comply	Comply	Comply	

6.4.5.2	Temperature vs. Power Consumption: The sample set shall be tested to measure the change in power consumption in Watts versus the change in temperature over the specified operating temperature range. This data shall be recorded and made available to all end users.	Certifications	Comply	Comply	Comply	
6.4.5.3	Power Consumption vs. Long-Term Life: If the rated power consumption of the module at 25°C (77ºF) and 74ºC (165ºF) will change more than 10% over time, the manufacturer shall provide documentation showing the projected power consumption in Watts of the module over a period of 60 months from the date of installation. This documentation must include data for the following temperature points: 0°C (32ºF), 25°C (77ºF), 50ºC (122ºF) and 74ºC (165ºF).	Certifications	Comply	Comply	Comply	
6.4.5.4	Power Factor (PF): The sample set shall be measured for power factor per the requirements of Section 5.6.1. A commercially available power factor meter may be used to perform this measurement. The PF shall be calculated separately for each of the icons for the module.	Certifications	Comply	Comply	Comply	
6.4.5.5	Total Harmonic Distortion (THD): The sample set shall be measured for total harmonic distortion per the requirements of Section 5.6.2. A commercially available total harmonic distortion meter may be used to perform this measurement. The THD shall be measured for each of the icons for the module.	Certifications	Comply	Comply	Comply	

6.4.5.6	Low Voltage Turn Off: The sample set shall be measured to ensure compliance with the low voltage turn-off requirement of Section 5.2.5. To test for this condition each icon must first be fully illuminated at the nominal operating voltage. The applied voltage shall then be reduced to the point where there is no visible illumination. This point must be greater than 35 VAC RMS AC.	Certifications	Comply	Comply	Comply	
6.4.5.7	Turn-On and Turn-Off Times: The sample set shall be measured to ensure compliance with the turn-on and turn-off requirements of Section 5.2.6. The measurement shall be conducted using a two channel oscilloscope to measure the time delay between when the module is energized at 120 VAC RMS and when the light output reaches 90% of full output. A photo-multiplier tube shall be used to measure the light output of the module. The same apparatus shall be used to measure the time delay between when the module is de-energized and when the light output reaches 0% of full output. The time in msec shall be plotted in the X axis and light output shall be plotted in the Y axis. A module not reaching 90% nominal light output within 75 msec at start-up or still showing light output 75 msec after being de-energized shall be deemed to have failed this test.	Certifications	Comply	Comply	Comply	

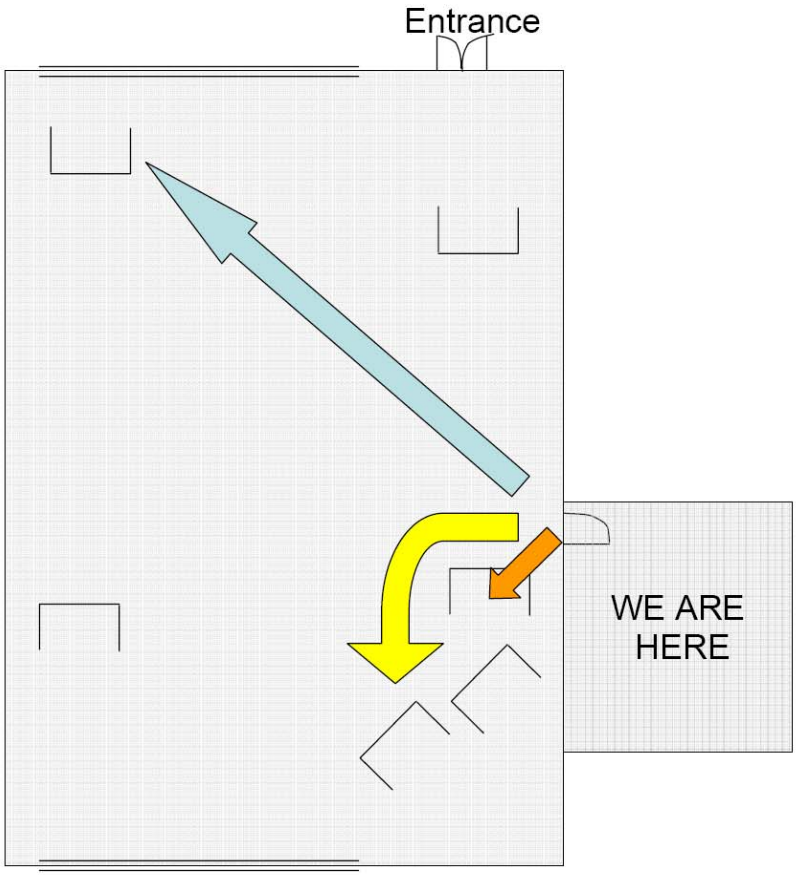
6.4.5.8	Electronic Noise: From the sample set, a sample of 2 modules shall be tested per the requirements of Section 5.5, with reference to Class A emission limits referenced in Federal Communications Commission (FCC) Title 47, SubPart B, Section 15.	Certifications	Comply	Comply	Comply	
6.4.5.9	Nondestruct Transient Immunity: The sample set shall be tested for transient immunity using the procedure described in Section 2.1.8, NEMA Standard TS 2-1998. Failure to meet these requirements shall be cause for rejection.	Certifications	Comply	Comply	Comply	
6.4.5.10	Electrical Tests Evaluation: At the conclusion of the Electrical Tests, the measurement data shall be compared to the requirements of Sections 5.2 through 5.6.					
6.4.5.10.1	Acceptance/Rejection Criteria: The failure of any module to meet the applicable requirements of Sections 5.2 through 5.6 shall be considered a failure of the proposed design.					
6.4.5.11	Controller Assembly Compatibility. Due to the low load current draw and high off-state impedance of modules, testing shall be performed to ensure the module design is compatible and operates properly with load current switches and conflict monitors in NEMA and Type 170 traffic signal control units. Before performing the following tests, the manufacturer should ascertain which type of signal controller unit(s) the procuring traffic authority customer has in use and tailor these tests to meet the requirements of that type and model of controller unit(s).					

6.4.5.11.1	Load Switch Compatibility. The sample set shall be tested for compatibility and proper operation with load current switches. Each module shall be connected to a variable ac voltage supply. The ac line current into the module shall be monitored for sufficient current draw to ensure proper load switch operation while the voltage is varied from 80 VAC RMS to 135 VAC RMS. Failure of the current draw to ensure proper load current switch operation shall be cause for rejection.	Certifications	Tested in Lab	Tested in Lab	Tested in Lab	
6.4.5.11.2	Signal Conflict Monitor (MMU) Compatibility: The sample set shall be tested for compatibility and proper operation with signal conflict monitors. Each module shall be operated from a 135 VAC RMS supply. A 19.5 kΩ resistor shall be wired in series in the hot line between the module and the ac power supply. A single-pole-single-throw switch shall be wired in parallel across the 19.5 kΩ resistor. A 220 kΩ shunt resistor shall be wired between the hot line connection and the neutral line connection on the module. Conflict monitor compatibility shall be tested by measuring the voltage decay across the 220 kΩ shunt resistor as follows: The single-pole-single-throw switch shall be closed, shorting out the 19.5 kΩ resistor, allowing the ac power supply to illuminate the module. Next the switch shall be opened, and the voltage across the 220 kΩ shunt resistor shall be measured for a decay to a value equal to or less than 10 VAC RMS within a time period equal to or less than 100 milliseconds. This	Certifications	Comply	Comply	Comply	

	test shall be repeated a sufficient number of times to ensure that testing occurs at the peak of the ac line voltage cycle. A voltage decay across the 220 kΩ shunt resistor to a value greater than 10 VAC RMS or a decay time to 10 VAC RMS greater then 100 milliseconds shall be cause for rejection.					
6.4.5.11.3	Controller Assembly Compatibility Evaluation: At the conclusion of the Controller Assembly Compatibility Tests, the measurement data shall be compared to the requirements of the specific make and model Controller Assembly with which the module design is intended to operate.					
6.4.5.11.4	Acceptance/Rejection Criteria: Failure of the module to draw sufficient current to ensure compatibility with the load current switches in the appropriate Controller Assembly (5.7) and/or failure of the circuit voltage to decay to a value equal to or less than 10VAC RMS within a time period equal to or less than 100 milliseconds (5.7) shall be considered a failure of the proposed design.					

APPENDIX H. LED Signal Modules Survey

LED SIGNAL MODULES SURVEY



- Are you required to wear glasses or contact lens when driving?
  a. No b. Yes (please wear them when viewing LEDs)

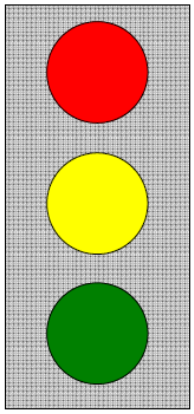
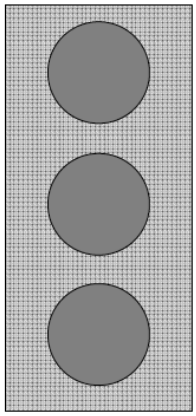
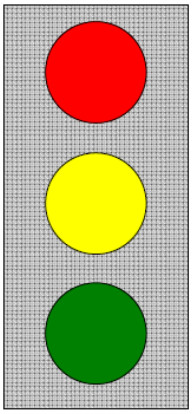
Frame B (Straight) and Frame A (At an Angle) Station

On a scale of 1 to 10, where 1 indicates WORST and 10 indicates BEST, please rate each of the LED signal lenses.

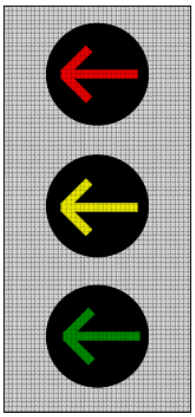
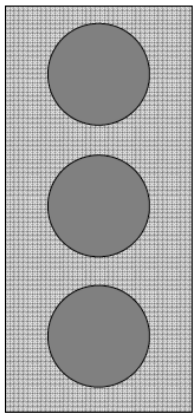
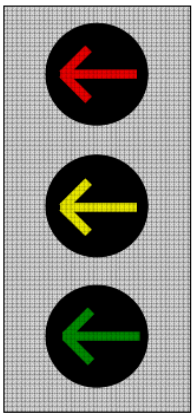
1 **10**

Worst Best

- Please look at **Frame B (Straight)**

RATINGS	LEFT	MIDDLE	RIGHT	RATINGS
RED ---------				RED -------
YELLOW --------				YELLOW -------
GREEN --------				GREEN --------

- Please look at **Frame A (at an Angle)**

RATINGS	LEFT	MIDDLE	RIGHT	RATINGS
RED --------				RED ---------
YELLOW --------				YELLOW ---------
GREEN -------				GREEN --------

AFTER FINISHING, PLEASE FOLLOW THE ARROWS TO THE NEXT STATION

P4 through P9 Station

On a scale of 1 to 10, where 1 indicates WORST and 10 indicates BEST, please **rate** the combination of LED **Man and Hand** signal lenses **TOGETHER**.

1 **10**

Worst Best

- Please look at Ped housings **P4, P5, and P6**

Rating	P4	Rating	P5	Rating	P6
------		-----		------	

- Please look at Ped housings **P7, P8, and P9**

Rating	P7	Rating	P8	Rating	P9
-----		-----		-----	

AFTER FINISHING, PLEASE FOLLOW THE ARROWS TO THE NEXT STATION

P1, P2, P3 Station

On a scale of 1 to 10, where 1 indicates WORST and 10 indicates BEST, please **rate** the LED **Man and Hand** signal lenses **TOGETHER**.

1 **10**

Worst Best

- Please look at Ped housings **P1, P2, and P3**

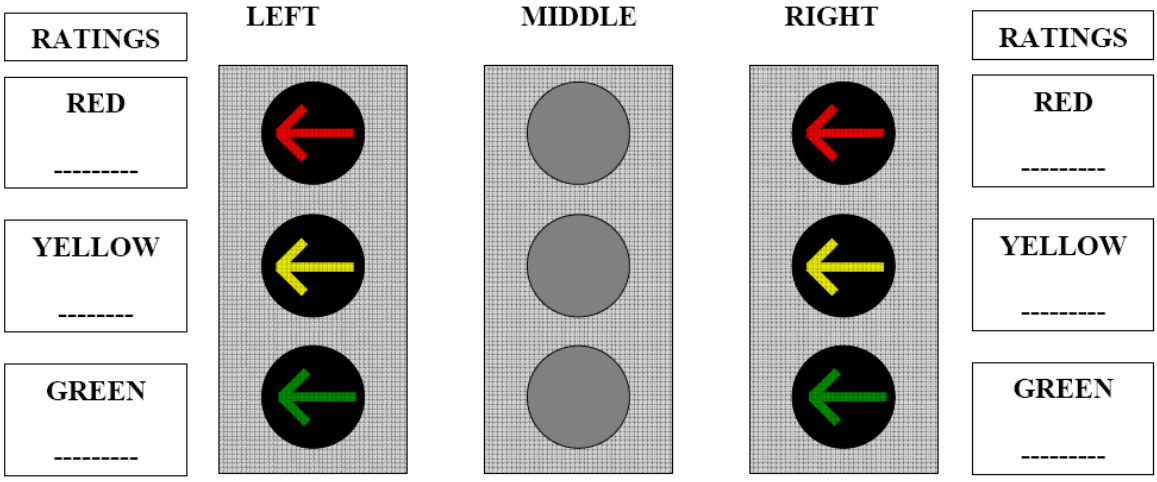
Rating	P1	Rating	P2	Rating	P3
------		------		------	

AFTER FINISHING, PLEASE FOLLOW THE ARROWS TO THE NEXT STATION

Frame A (Straight) Station

On a scale of 1 to 10, where 1 indicates WORST and 10 indicates BEST, please rate each of the LED signal lenses.

- Please look at **Frame A (Straight)**

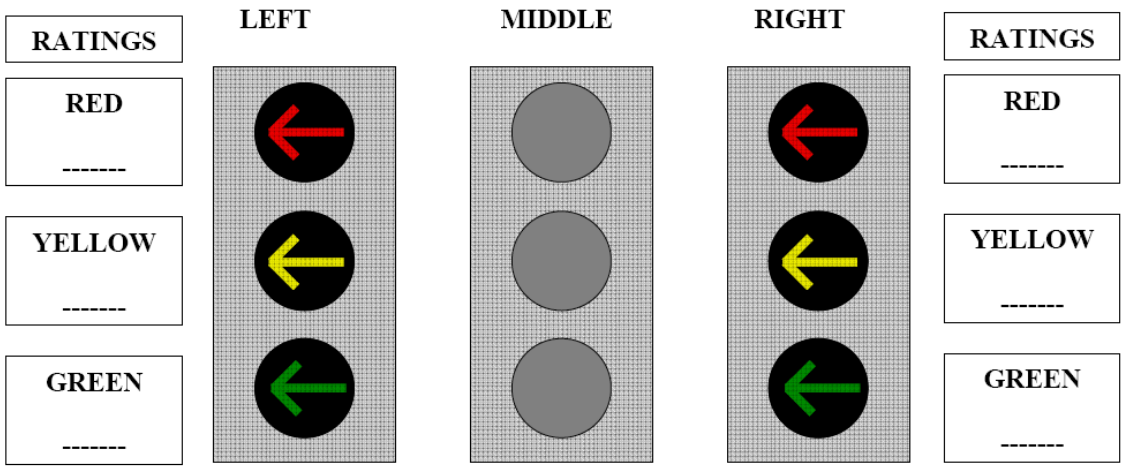


AFTER FINISHING, PLEASE FOLLOW THE ARROWS TO THE NEXT STATION

Frame D (Straight) Station

On a scale of 1 to 10, where 1 indicates WORST and 10 indicates BEST, please rate each of the LED signal lenses.

- Please look at **Frame D (Straight)**



AFTER FINISHING, PLEASE FOLLOW THE ARROWS TO THE NEXT STATION

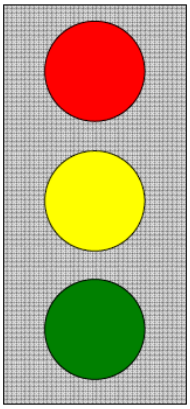
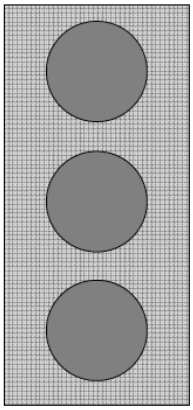
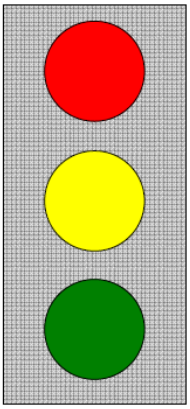
Frame C (Straight) and Frame D (At an Angle Station)

On a scale of 1 to 10, where 1 indicates WORST and 10 indicates BEST, please rate each of the LED signal lenses.

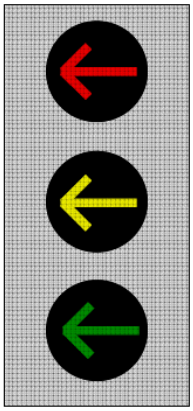
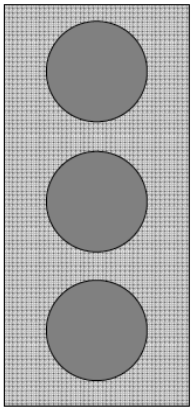
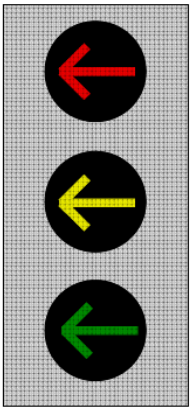
1 **10**

Worst Best

- Please look at **Frame C (Straight)**

RATINGS	LEFT	MIDDLE	RIGHT	RATINGS
RED --------				RED -------
YELLOW --------				YELLOW --------
GREEN ---------				GREEN --------

- Please look at **Frame D (at an Angle)**

RATINGS	LEFT	MIDDLE	RIGHT	RATINGS
RED ---------				RED --------
YELLOW ---------				YELLOW --------
GREEN ---------				GREEN ---------

AFTER FINISHING, PLEASE FOLLOW THE ARROWS TO THE NEXT STATION

- What age group do you belong to:
  a) 20-29 b) 30-39 c) 40-49 d) 50-59 e) 60 or greater

- Do you have difficulty in distinguishing shades of colors

  a) No b) Yes (If yes, what colors? _____)

- What factors did you use in evaluating the LED traffic signal lenses? Please rate the importance of these factors on a scale of 1 indicating LEAST important and 10 indicating MOST important. Some factors are listed below.

FACTORS	IMPORTANCE
○ Brightness	_____
○ Color	_____
○ Uniformity	_____
○ Other (specify): _____	_____
○ Other (specify): _____	_____
○ Other (specify): _____	_____

- What factors did you use in evaluating the LED Pedestrian signal lenses? Please rate the importance of these factors on a scale of 1 indicating LEAST important and 10 indicating MOST important. Some factors are listed below.

FACTORS	IMPORTANCE
○ Brightness	_____
○ Color	_____
○ Uniformity	_____
○ Size	_____
○ Other (specify): _____	_____
○ Other (specify): _____	_____
○ Other (specify): _____	_____

- Do you have any comments or suggestions about any of the LED modules?

_____
_____
_____
_____
_____

THANK YOU FOR YOUR PARTICIPATION

PLEASE GO TO

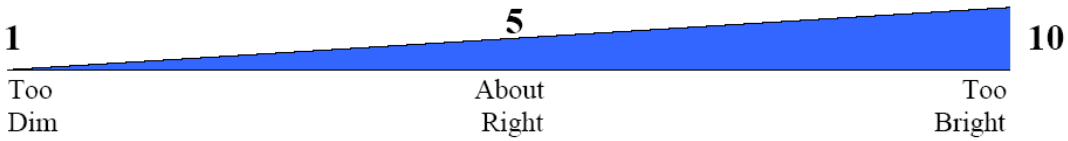
Frame C (Straight) and Frame D (At an Angle) Station

(**NEAR THE LAB ENTRANCE**)

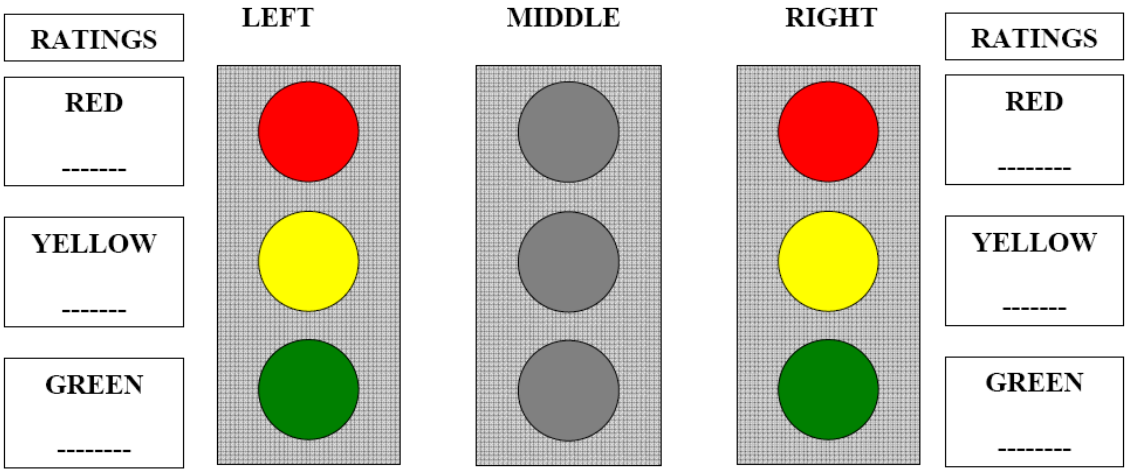
REMAINING PART OF THE SURVEY WILL BE COMPLETED AFTER THE LIGHTS ARE TURNED OFF

Frame C (Straight) and Frame D (At an Angle) Station

On a scale of 1 to 10, where 1 indicates TOO DIM, 5 indicates ABOUT RIGHT and 10 indicates TOO BRIGHT, please rate each of the LED signal lenses.



- Please look at **Frame C (Straight)**



PLEASE GO TO

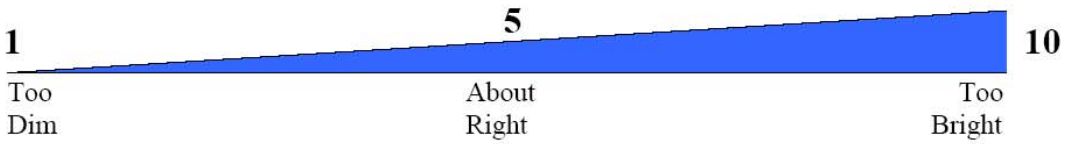
Frame B (Straight) and Frame A (At an Angle) Station

(**NEAR THE CLASSROOM**)

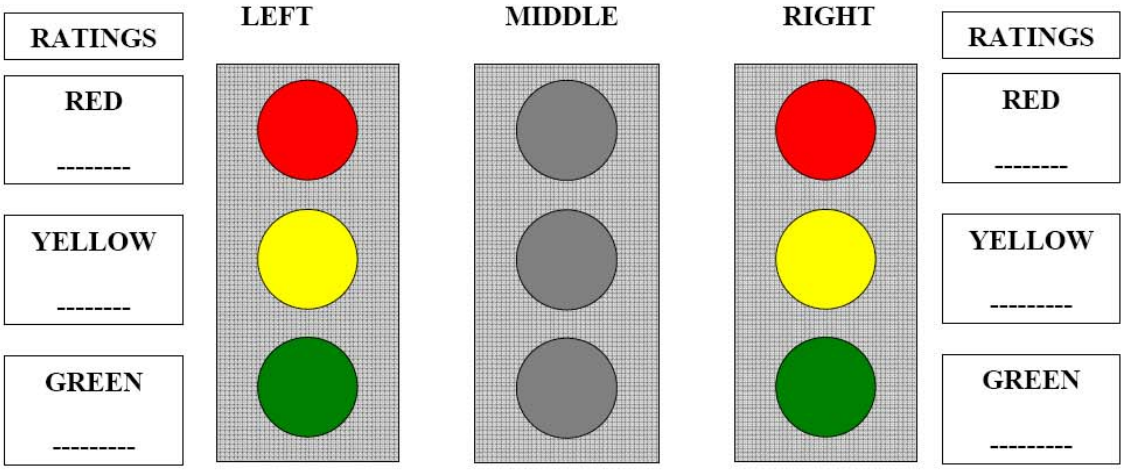
REMAINING PART OF THE SURVEY WILL BE COMPLETED AFTER THE LIGHTS ARE TURNED OFF

Frame B (Straight) and Frame A (At an Angle) Station

On a scale of 1 to 10, where 1 indicates TOO DIM, 5 indicates ABOUT RIGHT and 10 indicates TOO BRIGHT, please rate each of the LED signal lenses.



- Please look at **Frame B (Straight)**

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