TEMPORARY CONSTRUCTION LIGHTING
LOW VOLTAGE LED LIGHTING SYSTEM
UW BOTHELL PHASE 3
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**TABLE OF CONTENTS**

**A. EXECUTIVE SUMMARY ...............................................................8**

1.0 Summary .............................................................................................. 8

**B. INTRODUCTION.............................................................................9**

2.0 Introduction ............................................................................................ 9
3.0 Contract provisions.................................................................................. 11
4.0 Traditional temporary lighting................................................................. 12
5.0 Problems associated with traditional temporary lighting .................... 14

**C. CPO’S APPROACH .....................................................................20**

6.0 Adoption of LED lighting system............................................................ 20
7.0 Benefits................................................................................................. 23
8.0 Limitations ........................................................................................... 27

**D. CASE STUDY .............................................................................30**

9.0 Introduction ............................................................................................ 30
10.0 Methodology ......................................................................................... 31
11.0 Data collection ...................................................................................... 34
12.0 Constraints ........................................................................................... 38
13.0 Findings ............................................................................................... 38

**E. CONCLUSION AND RECOMMENDATIONS ...............................52**

14.0 Conclusion ........................................................................................... 52
15.0 Recommendations.................................................................................. 53
16.0 Future research ..................................................................................... 53

**E. BIBLIOGRAPHY ........................................................................55**

17.0 References............................................................................................ 55
F. ACKNOWLEDGEMENTS ........................................................................................................... 57

G. APPENDICES ....................................................................................................................... 58

Appendix A – LED LAYOUT PLANS ....................................................................................... 59
Appendix B – SURVEY QUESTIONNAIRE .............................................................................. 60
Appendix C – WORKERS’ RESPONSES (RAW DATA) ............................................................... 61
Appendix D – UWB P3 PROJECT SCHEDULE ........................................................................ 62
Appendix E – WORKERS’ RESPONSES (COMPiled TABLE FORMAT) ............................... 63
Appendix F – WORKERS’ RESPONSES (CONVERTED DATA FORMAT) ............................ 64
Appendix G – VISUALIZATION CHART OF WORKERS’ RESPONSES ................................. 65
Appendix H – DETAILED COST CALCULATIONS .................................................................. 66
List of tables

Table 1: OSHA minimum illumination standards (Occupation Safety and Health Act) ....................... 9
Table 2: WAC Lighting Table (Washington Administrative Code) ........................................................ 10
Table 3: IES Illuminance Categories and Values .................................................................................. 10
Table 4: Increase in task performance and reduction in number of rejects as a result of improvements in lighting level (Handbuch fur Beleuchtung, 1999) ....................................................... 17
Table 5: Relative increase in productivity by increasing the lighting level from 300 to 500 lux in metal industry (Philips Industrial Lighting, 2002) ................................................................................. 18
Table 6: Initial material cost estimate (Clear Vu LED Temporary Lighting Cost / Benefit Calculator, 2012) .................................................................................................................................................. 28
Table 7: Preliminary estimate of number of LED modules needed, Clear-Vu Lighting, 2012 .......... 32
Table 8: Cost estimate of metal halides (HID) temporary lighting system in the traditional setup, Nelson Electric, 2014 ........................................................................................................................................... 36
Table 9: Cost estimate of LED lighting system, Nelson Electric, 2014 ................................................ 36
Table 10: Cost estimate of metal halides (HID) temporary lighting system, 5 foot candle requirement, Nelson Electric, 2014 .................................................................................................................. 37
Table 11: Estimate of labor hours required for HID lighting system, VECA, 2014 ......................... 37
Table 12: Average rating of LED lighting vs traditional lighting attributes ...................................... 41
Table 13: Average rating of negative effects of LED lighting vs traditional lighting ..................... 41
Table 14: Summary of material cost comparison between LED system and metal halide system .. 46
Table 15: Summary of installation cost comparison between LED system and metal halide system ................................................................................................................................................. 47
Table 16: Summary of maintenance cost comparison between LED system and metal halide system .................................................................................................................................................. 48
Table 17: Summary of removal cost comparison between LED system and metal halide system... 48
Table 18: Summary of energy cost comparison between LED system and metal halide system ..... 49
Table 19: Summary of total cost comparison between LED system and metal halide system ....... 50
Table 20: Summary of comparison between traditional setup and 5 foot candle requirement setup

------------------------------------------------------------------------------------------------- 51

List of figures

Figure 1 & 2: Wobble lights with cords on the ground on site, Probuilt Professional Lighting, www.probuiltlighting.com................................................................................................................ 12

Figure 3: Suspended incandescent lamps (Smith 2007)........................................................................ 12

Figure 4: Suspended compact florescent lamps, Clear-Vu Lighting, www.clearvulighting.com............ 13

Figure 5: Suspended metal halides (Smith 2007).................................................................................. 13

Figure 6: 400W metal halides shadow effect (Smith).......................................................................... 14

Figure 7: 100W incandescent bulbs shadow effect (Smith)................................................................. 15

Figure 8: 24W fluorescent bulbs shadow effect (Smith) ..................................................................... 15

Figure 9: Number of accidents for different industrial tasks as a function of the lighting level (Volker, Ruschen-schmidt and Gail, 1995) ................................................................. 17

Figure 10: A typical temporary LED construction lighting system (Clear-Vu)......................................... 21

Figure 11: FM10 LED module (Clear-Vu) .............................................................................................. 22

Figure 12: FM2 LED module (Clear-Vu) ............................................................................................ 22

Figure 13: LED Power Supply (Clear-Vu)........................................................................................... 23

Figure 14: Average horizontal illuminance (LRC, June 2013)............................................................ 24

Figure 15: Workers’ response to the four types of temporary lighting (LRC, June 2013) .............. 24

Figure 16: LED construction lights average horizontal illuminance (LRC, November 2013)........... 25

Figure 17: Rating of temp LED lights compared to other temp lights (LRC, November 2013)........... 25

Figure 18: Estimated monthly energy consumed by temporary lighting (LRC, June 2013)........... 26

Figure 19: Estimated payback period (LRC, June 2013).................................................................. 28

Figure 20: Temporary lighting power cables installed within concrete slab .................................... 30

Figure 21: Temporary lighting whips and light fixtures dropped and exposed below ceiling deck. 31
Figures 22 & 23: LED fixtures layout........................................................................................................ 33
Figures 24 & 25: Installation of cables and inserts ................................................................................ 34
Figures 26: Data classification based on trades ...................................................................................... 43
Figures 27 to 34: Visualization of responses to Question 11 classified by trades ................................. 43
A. EXECUTIVE SUMMARY

1.0 Summary

1.1 This case study report first briefly introduces the problems associated with traditional temporary lighting on a construction site and presents a potential solution in the use of temporary LED construction lighting.

1.2 This potential solution was deployed on an existing project site as a case study, with its implementation as documented within this report.

1.3 The case study concluded that the benefits of using temporary LED construction lighting outweighed its limitations and recommends that the Capital Projects Office consider implementing this across its projects but not without making proposed changes to its contract technical specifications and further considerations to the contract arrangements.

1.4 The case study also surfaced other factors that were not previously known and the report identified these as areas of potential future research that can be undertaken by the Department of Construction Management.
B. INTRODUCTION

2.0 Introduction

2.1 Adequate lighting is a necessity on the construction site not just for completion of the works, but also for the quality of the works, safety and productivity of the workers. The minimum amount of lighting required in the Washington state is governed by OSHA and WISHA, with WISHA allowing Washington rules and regulations to be more stringent than OSHA’s if needed.

2.2 OSHA Standard 29 Part 1926.56(a) states, “Construction areas, runways, corridors, offices, shops, and storage areas shall be lighted to not less than the minimum illumination listed in Table D-3 while any work is in progress” (OSHA, 2004). (See Table 1 for OSHA Table D-3)

<table>
<thead>
<tr>
<th>Foot-candles</th>
<th>Area of Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>General construction area lighting</td>
</tr>
<tr>
<td>3</td>
<td>General construction areas, concrete placement, excavation and waste areas, access ways, active storage areas, loading platforms, refueling, and field maintenance areas</td>
</tr>
<tr>
<td>5</td>
<td>Indoors: warehouses, corridors, hallways, and exitways</td>
</tr>
<tr>
<td>5</td>
<td>Tunnels, shafts, and general underground work areas: (Exception: minimum of 10-foot candles is required at tunnel and shaft heading during drilling, mucking, and scaling. Bureau of Mines approved cap lights shall be acceptable for use in the tunnel heading)</td>
</tr>
<tr>
<td>10</td>
<td>General construction plant and shops (e.g., batch plants, screening plants, mechanical and electrical equipment rooms, carpenter shops, rigging lofts and active store rooms, mess halls, and indoor toilets and workrooms.)</td>
</tr>
<tr>
<td>30</td>
<td>First aid stations, infirmaries, and offices</td>
</tr>
</tbody>
</table>

2.3 The Washington Administrative Code (“WAC”) Safety and Health Core Rules, WAC 296-800-21005 stipulates that
a) Adequate lighting must be provided and maintained for all work activities at the workplace (See Table 2)
Table 2: WAC Lighting Table (Washington Administrative Code)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Minimum acceptable average lighting level in an area: (foot-candles)</th>
<th>Any one single measurement used to determine the average lighting level* cannot be less than: (foot-candles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor task</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Outdoor task</td>
<td>5</td>
<td>2.5</td>
</tr>
<tr>
<td>Nontask activities for both indoor and outdoor</td>
<td>3</td>
<td>1.5</td>
</tr>
</tbody>
</table>

*Lighting levels must be measured at thirty inches above the floor/working surface at the task.

b) There must be adequate lighting for employees to see nearby objects that might be potential hazards, to operate emergency controls, or other equipment.

2.4 It is noted that the WAC only establishes the minimal acceptable levels of lighting. Nonetheless, the WAC references the Practice for Industrial Lighting by ANSI/IES for guidelines pertaining to optimal levels of lighting and illumination, with ANSI/IES RP-7-01 recommending the following illumination levels. (See Table 3) –

Table 3: IES Illuminance Categories and Values

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>CATEGORY</th>
<th>LUX</th>
<th>FOOTCANDLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public spaces with dark surroundings</td>
<td>A</td>
<td>20-30-50</td>
<td>2-3-5</td>
</tr>
<tr>
<td>Simple orientation for short temporary visits</td>
<td>B</td>
<td>50-75-100</td>
<td>5-7.5-10</td>
</tr>
<tr>
<td>Working spaces where visual tasks are only occasionally performed</td>
<td>C</td>
<td>100-150-200</td>
<td>10-15-20</td>
</tr>
<tr>
<td>Performance of visual tasks of high contrast or large size</td>
<td>D</td>
<td>200-300-500</td>
<td>20-30-50</td>
</tr>
<tr>
<td>Performance of visual tasks of medium contrast or small size</td>
<td>E</td>
<td>500-750-1000</td>
<td>50-75-100</td>
</tr>
<tr>
<td>Performance of visual tasks of low contrast or very small size</td>
<td>F</td>
<td>1000-1500-2000</td>
<td>100-150-200</td>
</tr>
<tr>
<td>Performance of visual tasks of low contrast or very small size over a prolonged period</td>
<td>G</td>
<td>2000-3000-5000</td>
<td>200-300-500</td>
</tr>
<tr>
<td>Performance of very prolonged and exacting visual tasks</td>
<td>H</td>
<td>5000-7500-10000</td>
<td>500-750-1000</td>
</tr>
<tr>
<td>Performance of very special visual tasks of extremely low contrast</td>
<td>I</td>
<td>10000-15000-20000</td>
<td>1000-1500-2000</td>
</tr>
</tbody>
</table>

A-C for illuminances over a large area (i.e. lobby space)
D-F for localized tasks
G-I for extremely difficult visual tasks
2.5 Neither the ANSI or ASHREA specifically defines the lighting requirements for construction areas. Nonetheless, the nature of working in construction areas is minimally similar to "Working spaces where visual tasks are only occasionally performed". Hence, it would appear that both the ANSI and ASHREA recommend at least a 10 foot candle lighting requirement for a construction site.

2.6 It is notable that whilst different authorities have different recommendations, construction in the state of Washington is minimally required to abide by the WAC and OSHA regulations.

3.0 Contract provisions

3.1 Whilst construction sites can be lit by natural lighting, temporary lighting is usually required for supplement due to the size and design of the building, working hours, time of the year, weather conditions, and type of work carried out.

3.2 Building project specifications therefore often address temporary lighting in Division 1, General Requirements. A typical specification could be as simple as “provide temporary lighting”, or as detailed as requiring one 100-watt lamp for each 250 feet of area, but not less than one per area (Dade County, 2005).

3.3 The University of Washington Capital Projects Office’s lighting requirements is found in Section 01 50 00 Temporary Facilities and Controls Clause 1.6E and states, “Provide and maintain construction lighting to provide adequate general illumination of the work area for all trades. Shield construction lighting from adjacent residential areas”.

3.4 Often, the general contractor would place the duty of providing and maintaining temporary general lighting (and temporary power) under the electrical contractor’s scope of works and include it as part of the electrical bid package. Whilst task lighting has always been the responsibility of the individual subcontractors, the scope of general lighting has always been always been ambiguous. The level of illumination required is usually not clearly defined in the contract provisions, and this often becomes subject to interpretation both by the general contractor and the electrical contractor.
4.0 Traditional temporary lighting

4.1 Regardless of the temporary lighting specifications, over the years, the industry has generally provided temporary lighting in the buildings by –
   a) The general contractor providing egress lighting for corridors, stairwells, sufficient for the workers to get to their work areas
   b) The individual trades providing their own task lighting, sufficient for them to carry out their works

4.2 Typically, depending on the size and design of the building, the general contractor provides egress lighting in one of the following ways –
   a) Wobble lights with cables and extension cords on the ground (See Figure 1 & 2)

   Figure 1 & 2: Wobble lights with cords on the ground on site, Probuilt Professional Lighting, www.probuiltlighting.com

   b) Incandescent lamps (100W or 150W) suspended from the slab deck at a 10’ x 10’ grid (See Figure 3)

   Figure 3: Suspended incandescent lamps (Smith 2007)
c) 23W compact florescent lamps (See Figure 4)

*Figure 4: Suspended compact florescent lamps, Clear-Vu Lighting, www.clearvulighting.com*

d) 400W Metal halides with line voltage cables in concrete (See Figure 5)

*Figure 5: Suspended metal halides (Smith 2007)*
5.0 Problems associated with traditional temporary lighting

5.1 However, various studies have shown that the traditional methods of providing temporary lighting are inadequate.

I. Non-compliance with OSHA requirements

5.2 A site evaluation study in 2006 involving three construction sites showed that all three sites could not meet OSHA illumination guidelines in over 50% of the area during daylight hours (Smith, August 2006). An expansion of the same study carried out in 2007 to investigate thirty additional construction sites yielded similar results of non-compliance (Smith and Azhar, 2007).

5.3 A study carried out on four commonly used traditional lighting methods (Smith, 2008) also revealed that only 400W metal halides at 11 feet off the ground and spaced 30 feet apart provided sufficient light to comply with OSHA requirements for the test area, whereas 100W incandescent lamps spaced 10 feet on center did not comply with OSHA requirements, and 150 W incandescent lamps and 23W florescent lamps only complied with OSHA requirements in the center of the test area.

II. Glare and shadows

5.4 The same study (Smith, 2008) also raised issues of visual discomfort – though the 400W metal halides provided sufficient light to comply with OSHA requirements, the lights were very bright, thereby causing strong glare problems and deep shadows. (See Figure 6)

Figure 6: 400W metal halides shadow effect (Smith)
The other lighting methods also produced shadows, though the impact of the shadows were less pronounced than the metal halides. (See Figure 7 and 8)

*Figure 7: 100W incandescent bulbs shadow effect (Smith)*

*Figure 8: 24W fluorescent bulbs shadow effect (Smith)*

### III. Maintenance

The traditional method of temporary lighting requires constant moving of the lamps, and the lamps also tend to be dropped, broken, and smashed easily due to workers' handling. In addition, lamps also tend to burn out and require frequent replacement throughout a project. Hence, electrical subcontractors often allocate at least one apprentice (depending on the size of the project) to carry out moving, replacement and maintenance work on
temporary lighting on a full-time basis due to the frequency of these works required on the construction site.

IV. Productivity

5.7 There does not appear to be any specific studies done to measure the productivity levels of the workers on construction sites using the traditional methods of providing temporary lighting. However, based on field observations and experiences, workers’ productivity tend to be negatively impacted due to constant disruption by
a) The frequency at which task lighting is required to be located, moved and re-setup
b) Frequent maintenance and repair that arises from easily damaged light bulbs due to workers’ carelessness, and melted light bulbs due to overloading

5.8 Studies were however carried out to compare productivity levels under different light conditions.

5.9 An experiment was carried out in 2008 to measure the difference in productivity for a construction task under differing light conditions (Smith and Farrow, 2008). Two teams were tasked to lay out two “L” shaped walls, with one team placed in an area with ten foot-candles illumination, and the other team placed in an area with two foot-candles illumination. Experiment results revealed that the amount of time taken to complete the construction task was faster for teams who had higher levels of lighting (at an average of 34.1 minutes) than for teams who had lower levels of lighting (at an average of 39.2 minutes).

5.10 Philips Lighting (Philips Lighting, The Netherlands, August 2002) considered the correlation between lighting and visual performance, and lighting and accident reduction to determine the impact of lighting on productivity for the metal industry.

5.11 The paper noted that an improvement of lighting quality brought about an improvement in visual performance, thereby yielding an improvement in task performance. (See Table 4)
5.12 The paper also noted that there is a clear reduction in the number of accidents with improvements in lighting quality. (See Figure 9)

Figure 9: Number of accidents for different industrial tasks as a function of the lighting level (Völker, Ruschen-schmidt and Gall, 1995)

5.13 The paper concludes that increasing the lighting level from 300 to 500 lux produces an average productivity gain of approximately 8%, or between 3% to 11%, when taking uncertainty into consideration. (See Table 5)
Table 5: Relative increase in productivity by increasing the lighting level from 300 to 500 lux in metal industry (Philips Industrial Lighting, 2002)

<table>
<thead>
<tr>
<th>Metal Industry</th>
<th>Increased lighting level from 300 to 2000 lux (measured)</th>
<th>Increased lighting level from 300 to 500 lux (estimated)</th>
<th>Relative increase in productivity (300 to 500 lux)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in task performance (%)</td>
<td>+ 16</td>
<td>+ 6 ± 3</td>
<td>+ 1.06 ± 0.03</td>
</tr>
<tr>
<td>Reduction in number of rejects (%)</td>
<td>- 29</td>
<td>- 8 ± 3</td>
<td>+ 1.005 ± 0.005</td>
</tr>
<tr>
<td>Accident reduction (%)</td>
<td>- 52</td>
<td>- 14 ± 5</td>
<td>+ 1.01 ± 0.01</td>
</tr>
<tr>
<td>Total relative increase in productivity</td>
<td></td>
<td></td>
<td>+1.075 ± 0.04</td>
</tr>
</tbody>
</table>

1 in the metal industry, rejects will lead to some 2 to 5% loss of productivity
2 accidents will lead in about 2 to 10% of the cases to actual absence of work and thus to loss of productivity. (In above table, 5% has been used in the calculations).

V. **Safety**

5.14 There are no actual statistics as to the number of accidents or OSHA citations caused by poor illumination. However, as shown above, the number of accidents increases as illumination decreases. Based on field observations and experiences, workers are more exposed to high voltage wires as these are used for temporary power and lighting. Workers are also more exposed to broken lamps (See paragraph 5.6 above explaining the broken lamps). In addition, wires and extensions cords on the ground become tripping hazards themselves. Given that the traditional methods of temporary lighting hardly met the OSHA minimum requirements, it is likely that accidents such as tripping over cords occurred due to poor illumination.

VI. **Health**

5.15 One area of concern is the mercury contained inside compact fluorescent bulbs. Mercury is highly toxic, and especially harmful to the brains of both fetuses and children. When these bulbs break on a construction site, mercury escapes as vapor that can be inhaled. To minimize exposure to mercury vapor, the broken bulb fragments must be cleaned up and disposed of properly.

5.16 Another cause for concern is the chipping or cracking in the phosphor surface coating of compact fluorescent bulbs which allows UV rays to escape. A study funded by the U.S. National Science Foundation revealed that “skin cells exposed to compact fluorescent light emissions showed the same damage as those expose to UV light” when placed in
close range of less than one foot to a compact fluorescent bulb. Temporary lighting on a construction site, especially task lighting, whilst not always in such close range, would still often be in close proximity to the workers due to the nature of their jobs.
C. CPO’S APPROACH

6.0 Adoption of LED lighting system

6.1 Due to the problems associated with the traditional method of providing temporary lighting, especially in relation to safety and health, CPO has deployed the use of low voltage temporary LED lighting system to replace traditional temporary lighting on the UW Bothell Phase 3 – Bothell Science and Academic Building project (“UWB P3”) as a case study.

6.2 UWB P3 is an academic building that consists of classrooms, instructional laboratory facilities, collaborative learning spaces, faculty offices, support spaces and a 200-person lecture hall. Construction for the 74,000 square foot building consisting of four levels and one basement level commenced in the spring of 2012 and substantial completion was achieved in March 2014. The construction contract value is 42 million USD and the total project value is 68 million USD.

6.3 The GC/CM is Lease Crutcher Lewis, and the EC/CM is Nelson Electric. The GC/CM (General Contractor / Construction Manager) project delivery method is the engagement of a general contractor on board early on in the design process to provide constructability input such as scheduling, pricing, phasing etc. during design stage to assist the owner in designing a more constructible project. The same general contractor goes on to provide general contracting and construction management services during the construction stage. The EC/CM (Electrical Contractor / Construction Manager) project delivery method is similar to the GC/CM method except that the electrical sub-contractor is engaged on board early to provide his input regarding electrical services design, constructability and installation.

6.4 The GC/CM and EC/CM arrangements were beneficial to the use of UWB P3 as a case study as traditional contractual arrangements would not have incentivized or compensated Lease Crutcher Lewis and Nelson Electric for the use of temporary LED lighting. Under the GC/CM and EC/CM arrangements, Lease Crutcher Lewis and Nelson Electric could be appropriately compensated for having to undertake a new system under CPO’s directive and thus enabled the case study to be carried out smoothly.
6.5 The system adopted on UWB P3 is the FLEX SLS lighting system by Clear-Vu Lighting. A typical setup comprises of 450-watt power systems, LED modules with 10’ whips, a T-connector and low voltage (24V) cables (See Figure 10 below).

*Figure 10: A typical temporary LED construction lighting system (Clear-Vu)*

6.6 There are currently two LED modules produced by Clear-Vu Lighting,

a) FM10, a module of approximately 12’x4’x3’ in size, producing 2400 “focused” lumens, achieves 5 foot-candle per OSHA standard when spaced 20’ on center (See Figure 11)
b) FM2, consisting of one bulb, producing 900 “focused” lumens, achieves 5 foot-candle per OSHA standard when spaced 10’ on center (See Figure 12)

Figure 12: FM2 LED module (Clear-Vu)

6.7 The power system is able to accommodate either 45 FM2 modules, or 15 FM10 LED modules and is available with a dimmer and programmable clock for after-hours emergency egress lighting. (See Figure 13)
7.0 Benefits

7.1 Though the use of LED as a source of temporary construction lighting is relatively new to the construction industry, studies have shown that there are benefits over the traditional lighting system.

I. Better illumination

7.2 The Lighting Research Center (“LRC”) evaluated four types of construction lights at the new campus of New York City’s Police Academy from 2012 to 2013 (LRC, June 2013). The study revealed that LED luminaires provided much better average horizontal illuminance. (See Figure 14)
7.3 74% of the workers surveyed for the same study also considered these lights to be better than the other temporary lights. (See Figure 15)

7.4 In a similar study evaluating the performance of LED construction lights at the same site (New York City Police Academy), the measured illuminance in open areas was about twice the minimum requirements. (See Figure 16)
7.5 40% of the respondents participating in the same study rated the LED construction lights as “better” than other construction lights. Although it is noted that about 50% of the respondents rated LED construction lights to be the same as other construction lights. (See Figure 17)

Figure 17: Rating of temp LED lights compared to other temp lights (LRC, November 2013)

II. Energy savings

7.6 The studies also revealed that LED technology offered energy savings, although it is noted that CFL lamps only consumed slightly more energy than LED lamps (LRC, June 2013). (See Figure 18)
In addition to the proven benefits above, there are other purported benefits to the use of temporary LED construction lighting as elaborated in the following paragraphs below.

**III. Sustainability**

7.8 The FLEX SLS lighting system earned a LEED Innovation in Design (ID) credit due to the significant anticipated decrease in electricity consumption and electrical waste at the Harvard Art Museum project. The project is scheduled for completion in 2014, and anticipates a 75% reduction in energy consumption over two years with a cost savings of $350,000 on its electrical bill.

**IV. Safety**

7.9 The LED modules run on low voltage (24V) as opposed to the 120V line voltage used by traditional temporary lighting systems. In addition, the LED modules are never too hot to touch (in contrast to metal halides, halogen lamps, incandescent bulbs etc.). These characteristics should reduce the possibility of injuries and fires in the event of contact. The LED modules are not easily damaged, hence the likelihood of encountering broken lamps are reduced. As cables are not left loose on the ground, the likelihood of tripping hazards are also reduced.

7.10 As mentioned in section 4 above, better illumination reduces the number of accidents. Since LED lighting provides better illumination than the traditional methods of lighting, the number of accidents on site should decrease.

**V. Productivity**

7.11 As mentioned in section 4 above, better illumination increases productivity levels. Since LED lighting provides better illumination than the traditional methods of lighting, the productivity level on site should increase.
VI. Less maintenance

7.12 The cause of maintenance of temporary lighting on a construction site largely results from:
   a) Burning out of incandescent and fluorescent lamps due to limited lamp life
   b) Damages to incandescent and fluorescent lamps due to mishandling

7.13 With a 50,000-hour lamp life, use of LED lights should eliminate the frequent replacement and disposal of the incandescent and fluorescent lamps traditionally utilized on construction sites. The LED lights are also much more robust, and when subjected to a 15’ drop test, survived unscathed, and should therefore also eliminate the maintenance required due to broken lamps or associated lighting system damages.

VII. Cost savings

7.14 The direct cost savings that the temporary LED lighting system could bring about are:
   a) Maintenance labor cost savings due to reduced time spent on maintenance
   b) Electrical bill savings due to reduced energy consumption

7.15 The indirect cost savings that the temporary LED lighting system could bring about are:
   a) Higher workers’ productivity – Less hazards and less movement, maintenance and repair of light bulbs would invariably increase workers’ productivity and efficiency thereby reducing the amount of time taken to complete the works and reducing labor costs
   b) Lower workers’ compensation claims – A safer site will result in less accidents and less compensation claims

8.0 Limitations

8.1 Though there are several benefits to the use of temporary LED lighting systems over the use of traditional temporary lighting systems, there are a number of limitations as well.

I. High initial materials cost

8.2 Preliminary cost calculations estimated that the material cost of a temporary LED lighting system would be approximately $29,000 more than a traditional temporary lighting system. (See Table 6)
Table 6: Initial material cost estimate (Clear Vu LED Temporary Lighting Cost / Benefit Calculator, 2012)

<table>
<thead>
<tr>
<th>Description</th>
<th>LED Lighting System</th>
<th>Traditional Lighting System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FLEX FM2</td>
<td>FLEX FM10</td>
</tr>
<tr>
<td>Size of project (sf)</td>
<td>74,000</td>
<td>74,000</td>
</tr>
<tr>
<td>Initial number of bulbs</td>
<td>370</td>
<td>37</td>
</tr>
<tr>
<td>Cost per bulb ($)</td>
<td>54.54</td>
<td>165.65</td>
</tr>
<tr>
<td>Cost for romex/stringer per fixture ($)</td>
<td>9.13</td>
<td>9.13</td>
</tr>
<tr>
<td>Cost for power supply per fixture ($)</td>
<td>8.90</td>
<td>28.62</td>
</tr>
<tr>
<td>Initial materials cost per fixture ($)</td>
<td>72.57</td>
<td>203.39</td>
</tr>
<tr>
<td>Total initial materials cost ($)</td>
<td>26,851</td>
<td>7,525</td>
</tr>
<tr>
<td>Total per system ($)</td>
<td>34,377</td>
<td></td>
</tr>
</tbody>
</table>

II. Longer payback period

8.3 Without taking into consideration the maintenance labor benefits, the LRC estimated that the cost of the LED luminaries would only be paid back in several years, much longer than the compact fluorescent lamps. (See Figure 19)

Figure 19: Estimated payback period (LRC, June 2013)
Estimated Payback Period (in months)
(54 hrs/wk; does not include maintenance labor benefits)

![Payback Period Graph](image)

8.4 However, it must be noted that the study was initiated almost two years ago, and since then, technology advancement has reduced the initial costs of the LED luminaries.
III. More difficult installation

8.5 Installation of LED luminaires at the New York City Police Academy reportedly took 50% longer than the installation of other types of lighting (LRC, June 2013).

8.6 A similar study evaluating the performance temporary LED construction lighting for the same project also reported that, according to the electrical contractor, additional time and work was required to install the LED lighting because the LED luminaires required two mounting points (LRC, November 2013).

8.7 However, it must be noted that the study was initiated almost two years ago, and since then, technology advancement has reduced the installation efforts required.

IV. Glares and shadows

8.8 Due to its brightness, it appears that LED lights also produce glares and shadows. However, in the same study by the LRC, about 80% of the workers indicated that glare was not a major concern (LRC, November 2013).
D. CASE STUDY

9.0 Introduction

9.1 The temporary construction lighting system to be provided on UWB P3 was intended to comply with OSHA’s minimum illumination guidelines of 5 foot candles throughout the entire project site. This not only consisted of providing lighting to all corridors and stairwells, as per the traditional setup, but also includes providing at least one light fixture per room, or two or more light fixtures for larger rooms, where necessary.

9.2 Clear-Vu Lighting was approached to provide the temporary LED construction lighting system for this case study because they had previously been involved in similar installations on the East Coast, and also because there did not appear to be any other supplier available when the case study was commissioned.

9.3 As this system made use of low voltage instead of high voltage, the temporary lighting power cables and drivers could be designed to be embedded within the concrete slab, with only the whips and LED light fixtures dropped and exposed below the ceiling deck. (See Figures 20 and 21 below) This would not have been possible with the traditional high voltage setup due to safety reasons.

*Figure 20: Temporary lighting power cables installed within concrete slab*

*(Photo courtesy of Nelson Electric)*
10.0 Methodology

10.1 Installation of the temporary LED construction lighting system was undertaken in a three-stage process –
   a) Pre-construction estimate – estimating the number of light fixtures required
   b) Planning – determination of the location of the lights and controllers
   c) Installation – Physical installation of the electrical cables/wirings, lights, and controllers

I. Pre-construction estimate

10.2 Based on the traditional setup of only lighting the corridors and stairwells, Nelson Electric initially estimated that a total of 135 LED fixtures would be required for the project site.

10.3 Subsequently, using the LED Temporary Lighting Cost / Benefit calculator provided by Clear-Vu Lighting, CPO estimated that approximately 255 LED fixtures would be required in order to provide 5 foot candle general lighting for the entire project site. (See Table 7)
Table 7: Preliminary estimate of number of LED modules needed, Clear-Vu Lighting, 2012

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of project</td>
<td>Sq ft</td>
<td>74,000</td>
</tr>
<tr>
<td>Ceiling height</td>
<td>ft</td>
<td>15</td>
</tr>
<tr>
<td>Desired illumination per floor</td>
<td>fc</td>
<td>5</td>
</tr>
<tr>
<td>LED module spacing</td>
<td>ft</td>
<td>17</td>
</tr>
<tr>
<td>LED module coverage</td>
<td>17ft x 17 ft</td>
<td>Sq ft</td>
</tr>
<tr>
<td>LED modules needed</td>
<td>74,000 / 289</td>
<td>nos</td>
</tr>
</tbody>
</table>

10.4 Nelson Electric eventually adjusted this number to 285 LED fixtures (a mix of 223 FM10 and 62 FM2 modules) based on the project site conditions and layout.

II. Planning

10.5 First, the coordinated MEP layout was visually inspected floor by floor to locate ceiling areas that had no other MEP services running across it to determine possible locations of the LED fixtures. Locations of the walls that reached all the way to the bottom of the concrete deck were also taken into consideration, as they would block any light source once the walls were erected.

10.6 Next, due to the capacity of the drivers, the number of LED fixtures connected to each driver was limited to a maximum of 15 FM10 LED fixtures (one FM10 fixture is approximately equivalent to three FM2 fixtures hence if FM2 fixtures were used, more would be connected to each driver). This impacted the routing of the cables, the number of drivers required to be installed per floor, and the number of circuits required to be run per floor (i.e. due to the number of fixtures required per floor, each floor would require at least two circuits).

10.7 Nelson Electric tried to refrain from installing any LED fixtures in areas where there were only bare concrete ceiling and no false ceiling, as the holes that are left behind after removing the LED fixtures would then be exposed. However, this could not be completely avoided. Hence, Nelson Electric had to ensure that the ceiling would still be aesthetically pleasing upon removal of the LED fixtures. This was achieved by using white-colored inserts that blended in with the final color of the ceiling.

10.8 Upon confirmation of the locations of the fixtures and drivers, approximate measurements of their distances from gridlines were taken to aid the physical installation.

10.9 Figures 22 and 23 show an example of the planned LED fixtures and cabling layout. (Refer to Appendix A for LED layout plans of all floors)
III. Installation

10.10 Based on the approximate dimensions from the gridlines, inserts were placed within the concrete deck for both the fixtures and the whip, and the forms had to be drilled through in order to do so. Cables were then run across the reinforcement bars with approximately 10-foot whips dropped through the decking. (See Figures 24 and 25)
10.11 Coordination with ironworkers was also necessary as the cables were installed concurrently with the reinforcement bars.

10.12 During concrete pours, Nelson Electric would also station an electrician on a “pour watch” to ensure that the cables do not get damaged, and are not tugged and pulled back into the slab during the pour.

10.13 After the concrete has cured, upon stripping of the formwork, the LED fixtures were installed on the floor slab and energized immediately to provide temporary lighting for that floor.

10.14 Where false ceilings are to be put up, the ceiling frames and grids could still be installed except for the grid where the LED fixture is located. That particular grid is left empty and the LED fixture whip is lowered to below the false ceiling level to provide lighting for the site.

11.0 Data collection

11.1 To ascertain the benefits and limitations listed in Sections 6.0 and 7.0, data was collected via the following means –
   a) Interview with Clear-Vu representative
   b) Site interviews with project staff
   c) Survey questionnaires distributed to workers on site
   d) Cost information requested from Nelson Electric
I. Interview with Clear-Vu representative

11.2 A phone interview was conducted with Danny Lax, the Clear-Vu representative, on January 16, 2014. During the interview, Danny Lax provided background information on the traditional lighting systems used on site and its potential hazards. Danny Lax also discussed the design of the temporary LED lighting system specifically for use in construction, the pilot projects that have adopted this system, its advantages, and future developments.

11.3 The information provided by Danny Lax helped to define the study and craft preliminary questions for the first site interview.

II. Site interview

11.4 Two site interviews were conducted in a round table format with
   a) CPO UWB P3 construction manager, Mark Sweeters, and Nelson Electric’s field foreman, Eric Unseth, on January 24, 2014
   b) CPO UWB P3 construction manager, Mark Sweeters, Lease Crutcher Lewis’ construction manager, Brian Aske, Nelson Electric’s owner, Tim Nelson, and field foreman, Eric Unseth on March 25, 2014

11.5 During the first site interview, Eric Unseth described the traditional temporary lighting system commonly deployed on site, its installation process, and the typical maintenance works and resources required. He also highlighted the disadvantages of the traditional setup, and its safety and environmental concerns. This information helped to define the study and is described in Section 3.0 and 4.0 above.

11.6 Eric Unseth then proceeded to describe the process of planning, coordination and installation of the temporary LED lighting system on the project site. This information laid out the methodology of the case study and is described in Section 9.0 above.

11.7 The site issues encountered and the effects of the temporary LED lighting system were also discussed. This information is described in Section 13.

11.8 During the second site interview, Eric Unseth provided clarifications on the traditional lighting setup, further explanations and comments on the LED setup, and the issues encountered on site; Brian Aske provided a general contractor’s point of view on jobsite temporary lighting requirements, industry interpretations on the requirements, and the implementation and use of a temporary LED construction lighting system. This information is described in Section 11.0.
III. Survey questionnaires

11.9 Survey questionnaires were distributed to the workers on site by Chilly, the safety officer, to obtain their feedback on working in and with the LED lighting. Workers were requested to provide the following input –

a) Personal details including trade and construction experience
b) Activity carried out on site and location of activity
c) Lighting requirements including amount of lighting and frequency
d) Rating of work experience in the traditional lighting setting and the LED lighting setting
e) Comments on working in and with the LED lighting

11.10 The questionnaire is appended in Appendix B and the workers’ responses are appended in Appendix C.

IV. Cost information

11.11 Nelson Electric had initially provided a cost estimate for the use of metal halides lighting in the traditional setup of only lighting the corridors, stairwells (See Table 8).

Table 8: Cost estimate of metal halides (HID) temporary lighting system in the traditional setup, Nelson Electric, 2014

<table>
<thead>
<tr>
<th>Description</th>
<th>Qty</th>
<th>Unit</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install HID lighting 12 per floor</td>
<td>48</td>
<td>Each</td>
<td>$ 1,497</td>
</tr>
<tr>
<td>MC Cable to feed lighting</td>
<td>1</td>
<td>Each</td>
<td>$10,381</td>
</tr>
<tr>
<td>Install HID lighting in stairs</td>
<td>20</td>
<td>Each</td>
<td>$ 624</td>
</tr>
<tr>
<td>MC Cable for stair lighting</td>
<td>1</td>
<td>Each</td>
<td>$ 1,853</td>
</tr>
<tr>
<td>Fixture rental ($6/month each)</td>
<td></td>
<td></td>
<td>$ 6,331</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>$20,686</strong></td>
</tr>
<tr>
<td><strong>Total number of HID</strong></td>
<td>68</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

11.12 Nelson Electric subsequently also provided cost estimates for the following two scenarios –

a) Use of LED lighting based on the actual extent work carried out at UWB P3 to meet 5 foot candle requirements (See Table 9)

Table 9: Cost estimate of LED lighting system, Nelson Electric, 2014

<table>
<thead>
<tr>
<th>LED Construction Lights to Meet 5fc (average)</th>
<th>Qty</th>
<th>Unit</th>
<th>Mat’l</th>
<th>Hrs</th>
<th>Labor</th>
<th>Eq/ Vendor</th>
<th>$/Unit</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear Vu in-slab cable</td>
<td>6120</td>
<td>LF</td>
<td>0.05</td>
<td>0.03</td>
<td>1.92</td>
<td>1.97</td>
<td>12,056</td>
<td></td>
</tr>
<tr>
<td>Clear Vu Power Supply/Controller Install and Connection, install in stack</td>
<td>20</td>
<td>EA</td>
<td>47.89</td>
<td>10.00</td>
<td>639.30</td>
<td>687.19</td>
<td>13,744</td>
<td></td>
</tr>
<tr>
<td>Hang Clear Vu LED Light - Mix of FM10s</td>
<td>285</td>
<td>EA</td>
<td>0.35</td>
<td>22.38</td>
<td></td>
<td>22.38</td>
<td>6,378</td>
<td></td>
</tr>
</tbody>
</table>
b) Use of metal halides lighting based on an estimate of the number of lights that would have been required at UWB P3 in order to meet 5 foot candle requirements; Nelson Electric pointed out that the estimate took into consideration UWB P3’s project design, layout, staircase locations and room configurations (See Table 10)

**Table 10: Cost estimate of metal halides (HID) temporary lighting system, 5 foot candle requirement, Nelson Electric, 2014**

<table>
<thead>
<tr>
<th>Description</th>
<th>Qty</th>
<th>Unit</th>
<th>Material</th>
<th>Hours</th>
<th>Labor</th>
<th>Eq/Vendor</th>
<th>$/Unit</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install HID Lights</td>
<td>191</td>
<td>EA</td>
<td>1.50</td>
<td>0.45</td>
<td>28.77</td>
<td>30.27</td>
<td>5,782</td>
<td></td>
</tr>
<tr>
<td>MC Cable to Feed Lighting (approx 30LF per light)</td>
<td>5730</td>
<td>LF</td>
<td>0.52</td>
<td>0.05</td>
<td>3.20</td>
<td>3.72</td>
<td>21,316</td>
<td></td>
</tr>
<tr>
<td>Install HID Lighting in Stairs</td>
<td>13</td>
<td>EA</td>
<td>1.50</td>
<td>0.75</td>
<td>47.95</td>
<td>49.45</td>
<td>643</td>
<td></td>
</tr>
<tr>
<td>MC Cable for Stair Lighting</td>
<td>520</td>
<td>LF</td>
<td>0.52</td>
<td>0.06</td>
<td>3.84</td>
<td>4.36</td>
<td>2,267</td>
<td></td>
</tr>
<tr>
<td>Ltg Fixture Cost (figured as new fixture purchase instead of rental as comparison)</td>
<td>204</td>
<td>EA</td>
<td>0.00</td>
<td>185.00</td>
<td>185.00</td>
<td>37,740</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance of HID Lighting for duration (broken fixtures, relamping) 4 hrs/wk</td>
<td>1</td>
<td>LS</td>
<td>416.00</td>
<td>26,594.88</td>
<td>390.00</td>
<td>26,984.88</td>
<td>26,985</td>
<td></td>
</tr>
<tr>
<td>Removal of lights and MC</td>
<td>1</td>
<td>LS</td>
<td>160.00</td>
<td>10,228.80</td>
<td>10,228.80</td>
<td>10,229</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>104,962</td>
<td></td>
</tr>
</tbody>
</table>

11.13 With Assistant Professor Ken-yu Lin’s assistance, an estimate was also obtained from another electrical subcontractor, VECA, on the approximate number of hours required for installation and removal of temporary lighting (See Table 11 below) –

**Table 11: Estimate of labor hours required for HID lighting system, VECA, 2014**

<table>
<thead>
<tr>
<th>Description</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation of HID temporary lights</td>
<td>200 hours</td>
</tr>
<tr>
<td>Removal of HID temporary lights</td>
<td>75 hours</td>
</tr>
<tr>
<td>Installation of cabling</td>
<td>150 hours</td>
</tr>
<tr>
<td>Removal of cabling</td>
<td>30-40 hours</td>
</tr>
</tbody>
</table>
12.0 Constraints

12.1 There were only 21 survey responses collected. The small sample size increases the difficulty of reaching holistic conclusions (though not impossible) due to the variability of the responses.

13.0 Findings

13.1 Various results and findings were revealed from the interviews, survey questionnaires and cost information. Both qualitative and quantitative analyses were undertaken in assessing the information and data collected.

I. Interviews

13.2 The interviews uncovered several field and contract document observations that were not apparent prior to the commencement of the study –

I-A. Immediate use of temporary lighting

13.3 Traditionally, temporary lighting was only installed after completion of the shell and core, and in many occasions would only be installed after MEP ductwork was in place. This meant that any trade working on site before then had to depend either on natural lighting or task lighting for their work.

13.4 In contrast, a major benefit of the temporary LED lighting system discovered only during the case study was that, due to the low voltage used, the temporary lighting system could be energized immediately upon the stripping of the formwork. This meant that the building structure was lit up floor by floor, in sequence with the construction works, as the shell and core progressed, providing lighting for the other trades to work in as they moved in to carry out their works. This allowed the temporary lights to be fully lit and in use during the shell and core phase of the project.

13.5 As seen in the UWB P3 schedule (see Appendix D), the roof level structure was completed in August 2013, which was when the project was fully lit up. However, MEP rough-ins was only completed in January 2014, which meant that in a traditional temporary lighting setting, potentially, temporary lighting might only have been fully installed as late as some 5 months later.
I-B. Reflection of light off drywall

13.6 It was observed that the drywalls, when erected, would reflect the LED light, making the surrounding space much brighter. Hence, as the internal partitions got erected, instead of the construction areas looking dimmer than before, the construction areas actually looked brighter.

I-C. Drilling into embedded cables

13.7 One of the problems of embedding the cables within the slab was that they could be accidentally drilled into, through the underside of the slab, when work was being carried out at the ceiling levels. Eric Unseth revealed during the site interviews that on about 12 occasions, workers drilling through the slab for their works accidentally drilled through the cables as well. The short-circuited cables tripped the entire circuit as the driver would not work, and temporary lighting would be cut off for that particular circuit.

13.8 Resolving this issue on site was not complicated if the workers pointed out the exact incident location, as the electricians only needed to break the connection at the affected area, re-run the wires, and reconnect the circuit. However, if the exact incident location were not known, the electricians would then have to troubleshoot to find out where exactly the incident took place before being able to carry out the repair works.

13.9 Nevertheless, Eric Unseth also pointed out that this problem was likely to be unique for this site as the slabs were unusually thin (only 5 inches deep). If the slabs were of a thicker dimension, which is usually the case for most projects, it was highly unlikely that any drilling would hit the temporary lighting cables.

I-D. Upward lighting requirements

13.10 The LED lights were generally hung faced downwards towards the floor. However, upward lighting is usually required for HVAC works. Hence, the HVAC workers either had to use a task lighting stand, or turned the LED light fixtures upwards, and turned it back down when work was completed.

13.11 In response to this requirement, we note that Clear-Vu is intending to provide for upward lighting with its new product.

I-E. Duration of use of temporary lighting

13.12 Due to the ease of removal of the light fixtures and that the embedded cables need not be removed, the temporary lighting could be used until permanent lighting was turned on.
I-F. Temporary lighting contractual requirements

13.13 Brian Aske pointed out that the provision of temporary lighting had always been considered a “means and methods” by the construction industry. This meant that it was up to the general contractor’s discretion as to the manner and form in which temporary lighting was provided for, as long as the contract specifications were met.

13.14 Temporary lighting requirements were usually specified under Division 1, General Requirements, and only required the provision and maintenance of construction lights to provide adequate general illumination of the work area (Refer to paragraph 3.3 for the entire clause). As the specifications never clearly defined what “general illumination of the work area” meant, general contractors usually interpreted this to suggest that as long as:

a) General illumination was provided by the general contractors for the workers to be able to move around on site;

b) Each trade was responsible for providing their own task lighting sufficient to meet the 5 foot candle requirements;

The temporary lighting contract requirements were met.

13.15 Brian Aske also pointed out that the industry mindset has always been to do any piece of work for as minimal a cost as possible. This motto of “do it for less” is even more apparent for temporary works – since they are not permanent, there is an even lesser need to spend money on them.

13.16 As temporary lighting is hardly ever a line item in any general contractor’s bid package, this item is not commonly quantified and is also difficult to quantify as temporary lighting is usually installed together with temporary power and therefore the labor and material costs of temporary lighting are often inseparable from the costs of temporary power.

13.17 In addition, due to the temporary nature and low cost of temporary lighting, pricing of this item would almost always be sacrificed in order to bring the bid price down, especially when bidding for a public works project.

II. Survey questionnaires data analysis

13.18 A total of 21 survey responses were collected from the workers at UWB P3 and were numbered #1 to #21 and tabulated (See Appendix E). Of the 21 responses, two responses were not considered for data analysis because:

a) Response #10 was a response from a forklift operator who worked outside of the building and whose work was not impacted by any type of temporary lighting
b) Response #11 was a response from a painter whose answers were exactly the same as Response #12

13.19 Preliminary analysis of the data revealed that

a) Overall, the workers appeared to have had a more positive experience with LED lighting as compared to the traditional lighting. Based on the ratings of both systems in Question No. 11 of the survey, the average rating of LED lighting’s attributes ranged from 3.5 to 4.0 as compared to an average rating of 2.4 to 3.2 for traditional lighting’s attributes. (See Table 12 below)

<table>
<thead>
<tr>
<th>Description</th>
<th>Average rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LED lighting</td>
</tr>
<tr>
<td>Amount of light provided</td>
<td>3.70</td>
</tr>
<tr>
<td>Consistent and well distributed</td>
<td>3.50</td>
</tr>
<tr>
<td>Productive</td>
<td>3.75</td>
</tr>
<tr>
<td>Visually comfortable</td>
<td>3.84</td>
</tr>
<tr>
<td>Safe operation of work</td>
<td>4.00</td>
</tr>
</tbody>
</table>

b) The average rating of the negative effects of LED lighting were also lower, at a range of 2.1 to 2.4, as compared to an average rating of 3.0 to 3.2 for traditional lighting (See Table 13 below).

<table>
<thead>
<tr>
<th>Description</th>
<th>Average rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LED lighting</td>
</tr>
<tr>
<td>Distracted from work</td>
<td>2.43</td>
</tr>
<tr>
<td>More disruption</td>
<td>2.10</td>
</tr>
<tr>
<td>More coordination efforts</td>
<td>2.10</td>
</tr>
</tbody>
</table>

c) The workers’ experience with LED lighting could be dependent on his trade
d) There did not appear to be any correlation between the workers’ experience with LED lighting and any other factors

13.20 To better ascertain if the workers’ experience with LED lighting had any correlation with any identifiable factors or variables, a data mining software, Weka, was used to analyze the 19 responses. In order to use the software, the data had to be first converted into a compatible format.
13.21 Firstly, all the answers to questions 6 to 10 were converted to TRUE/FALSE; for example, if the survey response indicated that the work location was at the staircase, this data would be converted to TRUE, if the survey response did not indicate this, the data would be converted to FALSE.

13.22 Next, the ratings for work experiences in traditional lighting and LED lighting were compared to determine if the worker considered working with LED lighting a better experience than working with traditional lighting. The ratings statements in Question No. 11 were first converted to comparison statements between LED lighting and traditional lighting as follows –

- LED provides more lighting than TRAD
- LED provides more consistent and well-distributed lighting than TRAD
- I feel more productive with LED lighting than TRAD lighting
- LED lighting is more visually comfortable than TRAD lighting
- LED lighting made my work more operationally safer
- LED distracted me from working properly more than TRAD
- LED disrupted my work more than TRAD
- LED required more coordination efforts than TRAD

13.23 The ratings are then individually compared. A higher rating for LED lighting than traditional lighting would convert the data to TRUE, a smaller rating would be converted as FALSE, and if the ratings for both systems were the same, the data would be converted to NEUTRAL. For instance, if the rating for “Amount of light provided” for LED lighting is 5, and the rating for “Amount of light provided” for traditional lighting is 3, this particular data would be converted to TRUE. (Refer to Appendix F for the converted data)

13.24 The data mining software then uses the converted data to carry out its analysis.

13.25 To ascertain if the preliminary conclusion of a correlation between the trades and the workers’ experience was valid, the data was first classified based on the respective trades as follows (See Figure 26 below) –
13.26 Responses for all the other survey questions were then visualized based on the respective trades (See Figures 27 to 34 below for visualization of responses to Question 11 and Appendix G for the full visualization).
13.27 Based on the visualization, it is noted that the plumbers were in agreement with 5 out of the 8 comparison statements –

- LED provides more lighting than TRAD
- LED lighting is more visually comfortable
- LED did not distract from working properly more than TRAD
- LED did not disrupt their work more than TRAD
- LED did not require more coordination efforts than TRAD

And can therefore be concluded to have generally had a more positive experience working in LED lighting.

13.28 The carpenters also appeared to be fairly consistent in agreeing with 3 out of the 8 comparison statements –

- LED provides more lighting than TRAD
- LED provides more consistent and well distributed lighting than TRAD
- LED lighting is more visually comfortable

However, the carpenters were neutral with regards to the following comparison statements –

- I feel more productive with LED lighting than TRAD lighting
- LED lighting made my work more operationally safer
13.29 The electricians, on the other hand, had mixed reviews as to whether working in LED lighting was a more positive experience than traditional lighting.

13.30 One observation that was not captured quantitatively but was revealed through the workers’ comments was that the workers’ experience with LED lighting could likely be dependent on the verticality of his work. For instance,

   a) Response #20 was submitted by a worker involved in acoustic ceiling works, and in reply to whether the LED lighting was more helpful, he commented that LED lighting “Made it more difficult do to the directional nature of the light shining down impeding your ability to look up towards the light to see past it”

   b) Response #16 was submitted by an electrician, and in reply to the same question, commented that LED lighting “lit up most areas well, but could be blinding at times when working overhead”

13.31 Other observations included –

   a) Response #19 was submitted by an electrician and noted that a lot of time was saved as there were “no cords to trip over”

III. Cost data analysis

13.32 Using the costs obtained from Nelson Electric (see paragraph 11.11 above), a cost analysis was undertaken to compare the costs of providing a temporary metal halides lighting system and a temporary LED lighting system to meet the OSHA 5 foot candle requirements for UWB P3.

13.33 The following categories of costs are individually reviewed and compared –

   a) Materials – Costs of the light fixtures, cables, power supplies, controllers etc
   b) Installation – Labor costs of installing the fixtures, cables, including planning
   c) Maintenance – Labor costs of maintenance, moving and repairs required during construction
   d) Removal – Labor costs of removing the fixtures, cables etc from the site
   e) Energy – Power costs incurred for using the fixtures

13.34 In addition, estimates and information from Veca, Clear-Vu, and the NECA Manual of Labor Units are used as a basis of comparison and also to establish a range of possible costs that could be incurred.
Materials

13.35 Nelson Electric’s cost estimates show that the material costs of the LED lights versus the metal halides is $53,952 and $40,990 respectively. (See Table 14 below for a summary and Appendix H for detailed calculations)

Table 14: Summary of material cost comparison between LED system and metal halide system

<table>
<thead>
<tr>
<th>Items</th>
<th>LED</th>
<th>Metal Halides</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Description</td>
<td>Cost ($)</td>
</tr>
<tr>
<td>Material</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cables</td>
<td>6,120 feet</td>
<td>306.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power supply / controller</td>
<td>20 units</td>
<td>957.80</td>
</tr>
<tr>
<td>Light fixtures</td>
<td>223 FM10, 62 FM20</td>
<td>52,689.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-total</td>
<td></td>
<td>53,952.80</td>
</tr>
</tbody>
</table>

13.36 It is noted that the cost of the metal halides itself could range from $125 per fixture to $185 per fixture depending on the brand and quality of fixture purchased. Hence, material costs of 204 metal halides (including cables and accessories) could range from $28,750 to $40,990. In addition, majority of construction sites tend to use a combination of metal halides and incandescent or compact fluorescent bulbs. The extent of the different types of lights used on any given construction project is largely dependent on the type of project, its design, layout and compartmentalization configuration. Hence, Nelson Electric’s estimate of 204 numbers of metal halides at $185 each is likely to be the maximum cost that could be incurred when using a traditional lighting system to meet the 5 foot candle requirements.

13.37 As such, regardless of the range of material costs of metal halides, or the extent of halides, incandescent and compact fluorescent bulbs used, material costs of the LED lighting is higher than the material costs of traditional lighting.

Installation

13.38 Nelson Electric’s cost estimates show that the installation costs of the LED lights versus the metal halides is $30,914 and $26,757 respectively. (See Table 15 below for a summary and Appendix H for detailed calculations)
Table 15: Summary of installation cost comparison between LED system and metal halide system

<table>
<thead>
<tr>
<th>Items</th>
<th>LED</th>
<th>Metal Halides</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Description</td>
<td>Cost ($)</td>
</tr>
<tr>
<td>Installation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cables</td>
<td>6,120 feet</td>
<td>11,750.40</td>
</tr>
<tr>
<td></td>
<td>520 feet (stairs)</td>
<td>1,996.80</td>
</tr>
<tr>
<td>Power supply /</td>
<td>20 nos</td>
<td>12,786.00</td>
</tr>
<tr>
<td>controller</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light fixtures</td>
<td>285 nos</td>
<td>6,378.30</td>
</tr>
<tr>
<td></td>
<td>13 nos (stairs)</td>
<td>642.85</td>
</tr>
<tr>
<td>Sub-total</td>
<td>30,914.70</td>
<td>26,757.22</td>
</tr>
</tbody>
</table>

13.39 VECA estimated that approximately 150 hours and 200 hours would be required to install metal halides and cables respectively. Using Nelson Electric's labor unit rate of $63.93, this gives an estimated installation cost of $22,375.

13.40 The NECA Manual of Labor Units estimates that it would take 2.25 hours to 3.52 hours to install a 150W metal halide (including power cables), depending on the level of difficulty as presented on site. Using Nelson Electric’s labor unit rate of $63.93, this gives an estimated installation cost range of $29,343 to $45,906.

13.41 Nelson Electric observed that installation and planning works for the temporary LED lighting system likely required more effort as –

   a) Embedding the cables in the slab required slightly more planning and coordination with the concreting works as compared to suspending the cables from the ceiling
   b) The capacity of the LED drivers and the use of low voltage meant that at least two circuits had to be run on each floor whereas traditionally, one circuit was sufficient due to the high voltage used

This likely contributed to the higher cost estimate provided by Nelson Electric.

13.42 However, based on the range of installation costs of metal halides, it is noteworthy that costs of installation costs could be comparable.

Maintenance

13.43 Nelson Electric's cost estimates show that the costs of maintaining LED lights versus the costs of maintaining metal halides is $3,324 and $26,984 respectively. (See Table 16 below for a summary and Appendix H for detailed calculations)
Table 16: Summary of maintenance cost comparison between LED system and metal halide system

<table>
<thead>
<tr>
<th>Items</th>
<th>LED</th>
<th>Metal Halides</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Description</td>
<td>Cost ($)</td>
</tr>
<tr>
<td>Maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance &amp; repairs</td>
<td>0.5 hours per week</td>
<td>3,324.36</td>
</tr>
<tr>
<td>Lamp replacement</td>
<td></td>
<td>390.00</td>
</tr>
<tr>
<td>Sub-total</td>
<td>3,324.36</td>
<td>26,984.88</td>
</tr>
</tbody>
</table>

13.44 Nelson Electric had mentioned during the site interviews that on a decent sized project, at least one full-time apprentice is required to maintain, move, repair and replace traditional temporary lighting. Using Nelson Electric's labor unit rate of $63.93, at 40 hours per week, over 24 months, this cost is estimated to be $265,948.

13.45 It is therefore apparent that the costs of maintaining the LED lighting is substantially lower than the costs of maintaining the metal halides. This is likely attributed to the fact that there was hardly any moving, damage and breakages when using LED lighting whereas metal halides may be required to be moved about and/or replaced on site.

Removal

13.46 Nelson Electric's cost estimates show that the costs of removing LED lights upon project completion versus the costs of removing metal halides is $3,835 and $10,228 respectively. (See Table 17 below for a summary and Appendix H for detailed calculations)

Table 17: Summary of removal cost comparison between LED system and metal halide system

<table>
<thead>
<tr>
<th>Items</th>
<th>LED</th>
<th>Metal Halides</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Description</td>
<td>Cost ($)</td>
</tr>
<tr>
<td>Removal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remove fixtures; remove/abandon cables</td>
<td>60 hours</td>
<td>3,835.80</td>
</tr>
<tr>
<td>Sub-total</td>
<td>3,835.80</td>
<td>10,228.80</td>
</tr>
</tbody>
</table>

13.47 VECA estimated that approximately 40 hours and 75 hours would be required to remove metal halides and cables respectively. Using Nelson Electric's labor unit rate of $63.93, this gives an estimated installation cost of $7,360, thus giving a cost range of metal halides removal from $7,360 to $10,228.

13.48 Regardless of the range, it is apparent that the costs of removal of the LED lighting system is still lower than that of the costs of removal of the traditional lighting system.
**Energy**

13.49 Power costs of the two systems were estimated based on the wattage of each type of lighting, the number of hours it was lit during the project duration of 24 months, and a unit cost of $0.0915 per kWH. Nelson Electric explained that the LED lights operated at 100% capacity from 6am to 6pm but were dimmed to about 50% from 6pm to 6am. As metal halides could not be dimmed, the estimate has assumed that they would only be operating at 100% from 6am to 6pm but turned off from 6pm to 6am.

13.50 Based on the above, it is estimated that the power costs of LED lights versus metal halides is $3,442 and $24,527 respectively. (See Table 18 below for a summary and Appendix H for detailed calculations)

*Table 18: Summary of energy cost comparison between LED system and metal halide system*

<table>
<thead>
<tr>
<th>Items</th>
<th>LED</th>
<th>Metal Halides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Cost ($)</td>
<td>Description</td>
</tr>
<tr>
<td>Light fixtures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7W FM10,</td>
<td>1,876.81</td>
<td>150W</td>
</tr>
<tr>
<td>21W FM2</td>
<td>1,565.41</td>
<td></td>
</tr>
<tr>
<td>Sub-total</td>
<td>3,442.21</td>
<td></td>
</tr>
</tbody>
</table>

13.51 Again, majority of construction sites tend to use a combination of metal halides and incandescent or compact fluorescent bulbs. The extent of the different types of lights used on any given construction project is largely dependent on the type of project, its design, layout and compartmentalization configuration. Compact fluorescent bulbs used could be as low as 24W whereas incandescent bulbs used could be 100W or 150W and hence energy consumption in such instances may be lower. Regardless, the wattage of incandescent and compact fluorescent bulbs are still higher than the LED light wattage.

13.52 On the other hand, electrical subcontractors typically do not turn off the metal halides even after construction working hours are over, as in practice, some level of egress lighting is still needed after 6pm. Therefore the actual energy consumption of a temporary metal halides system is even higher.

**Summary**

13.53 Based on Nelson Electric’s estimates, the total estimated costs of the LED lighting system versus the metal halides system is $95,469 and $129,488 respectively. (See Table 19 below)
Table 19: Summary of total cost comparison between LED system and metal halide system

<table>
<thead>
<tr>
<th>Items</th>
<th>LED ($)</th>
<th>Metal Halides ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>53,952.80</td>
<td>40,990.00</td>
</tr>
<tr>
<td>Installation</td>
<td>30,914.70</td>
<td>26,757.22</td>
</tr>
<tr>
<td>Maintenance</td>
<td>3,324.36</td>
<td>26,984.88</td>
</tr>
<tr>
<td>Removal</td>
<td>3,835.80</td>
<td>10,228.00</td>
</tr>
<tr>
<td>Energy</td>
<td>3,442.21</td>
<td>24,527.12</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>95,469.87</strong></td>
<td><strong>129,488.02</strong></td>
</tr>
</tbody>
</table>

13.54 The cost comparison reveals that the initial material and installation costs of using the LED lighting system to provide the 5 foot candle requirements is higher. However, with an anticipated life span of 10 years, the LED lights can be reused on several subsequent projects. Hence, the initial material costs can actually be spread out across several projects and will be offset by its frequent reuse and long life span.

13.55 The cost comparison also reveals that maintenance, removal and energy costs of sustaining the 5 foot candle requirements using the metal halides is much higher and would therefore appear to offset the initial higher costs of using the LED lights. However, it is pertinent to note that the cost savings from maintenance and removal of the LED lights are costs saved by the electrical contractor, and may not necessarily be passed on to the owner.

13.56 In a traditional lump sum electrical bid package, the electrical contractors are not usually requested to price separately for temporary lighting. In fact, these costs are usually partially, if not fully absorbed by the electrical contractors. As such, it is doubtful that bid prices would be adjusted, and hence the owner is unlikely to gain from any costs that the electrical contractor saved due to reduction in temporary lighting maintenance and removal work.

13.57 However, in UWB P3, where Nelson Electric is an EC/CM contractor, and where its costs are fully reimbursable, these savings would be directly passed onto the owner due to the contractual arrangements of this project.

IV. Other observations

13.58 Using the estimated number of fixtures and corresponding cost information provided by Nelson Electric for both the traditional setup of only lighting corridors and stairwells and a lighting setup to meet 5 foot candle requirements, it is therefore possible to confirm if the traditional temporary lighting setup falls short of the 5 foot candle requirements.
The information provided by Nelson Electric (See Table 20 below) reveals that the traditional setup of only providing temporary lighting for corridors and stairwells only costs a fraction of the 5 foot candle setup and is therefore clearly inadequate and does not meet the 5 foot candle requirements at all.

Table 20: Summary of comparison between traditional setup and 5 foot candle requirement setup

<table>
<thead>
<tr>
<th>Description</th>
<th>Traditional setup (only corridors and stairwells)</th>
<th>5 foot candle requirement setup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of metal halides</td>
<td>68</td>
<td>204</td>
</tr>
<tr>
<td>Estimated cost (HID)</td>
<td>$20,686</td>
<td>$104,692</td>
</tr>
<tr>
<td>Number of LED</td>
<td>135</td>
<td>285</td>
</tr>
</tbody>
</table>
E. CONCLUSION AND RECOMMENDATIONS

14.0 Conclusion

14.1 It is apparent that current temporary lighting provisions on construction sites do not meet the 5 foot candle requirement. This is shown in the studies described in Section 5.0, and confirmed by the comparison of the traditional temporary lighting setup and a 5 foot candle requirement temporary lighting setup carried out in Section 13.0 – IV.

14.2 It is noteworthy that some of the inherent problems associated with traditional lighting were not directly caused by using traditional lighting systems, but are instead a result of how the traditional lighting systems were deployed on site. For instance,
   a) The OSHA 5 foot candle requirements could be complied with by the traditional lighting system if more lights were used.
   b) There would be less or minimal tripping hazards if cables and extension cords were not running on the ground, but were properly suspended from the ceiling instead.

14.3 Nonetheless, it is noted that use of the temporary LED lighting system does provide better illumination and minimizes the other identified problems of productivity, maintenance (less maintenance required), safety (less hazards) and health (less risk of mercury and UV exposure).

14.4 In addition, the case study revealed that use of the temporary LED lighting system allowed immediate use of temporary lighting on site as it could be energized upon the stripping of the formwork. The building structure could therefore be lit up in sequence with the construction of the shell and core, providing lighting for other trades to work in, and allowing the building to be fully lit up at least one to two months earlier than it would have been in a traditional temporary lighting setting.

14.5 However, it was also revealed that the temporary LED lighting system required additional pre-construction planning; more time and labor was required for installation, including additional works such as coordination with iron workers. These resulted in higher installation costs.

14.6 Whilst the cost comparison showed that the temporary LED lighting system had lower overall costs, it is pertinent to note that the individual cost savings may belong to different
parties. Hence, as explained, whilst maintenance and removal costs saved would benefit the electrical contractor, these cost savings may not necessarily be passed on to the owner depending on the contractual arrangements.

15.0 Recommendations

15.1 It is recommended that temporary lighting contractual requirements be amended to specifically require 5 foot candle requirements and that these be enforced on the project sites to ensure statutory compliance.

15.2 Given the benefits of LED lighting, it is recommended that this can be implemented on future projects. To ensure its adoption, the use of LED lighting may need to be specifically worded into the contract technical specifications. In addition, in order to benefit from the potential cost savings, contract arrangements may need to be evaluated.

16.0 Future research

I. Contract arrangements

16.1 The cost comparison showed that the electrical contractor would definitely gain from changing the traditional temporary lighting system to the temporary LED lighting system. However, the case study also revealed that the contractual arrangements between the owner and the electrical contractor would likely determine whether the owner actually stands to gain from this change. Hence, future research could consider undertaking a study of the contract arrangements and its implications.

II. Factors influencing workers’ experience

16.2 The case study revealed two potential factors that could influence the workers’ experience with LED lighting system –

a) Verticality of the work space
b) Specific trade and type of work carried out by the worker

16.3 Future research could take these into consideration when designing case studies and experiments.
III. Installation and coordination work

16.4 The case study revealed that a lot of time and effort was spent in the initial planning, coordination and installation works. Future research could consider researching if there was any way to expedite this initial process.
E. BIBLIOGRAPHY

17.0 References

ANSI/IES RP-7-01, Recommended Practice for Lighting Industrial Facilities


Lighting Research Center (2013), Alternative Technologies for Construction Lighting, Field Test Delta Snapshots Issue 6

Lighting Research Center (2013), LEDs for Construction Lighting, Field Test Delta Snapshots Issue 7

Occupational Safety & Health Administration, Standard 29 Part 1926.56(a) Safety and Health Regulations for Construction, Occupational Health and Environmental Controls, Illumination


Washington Administrative Code Safety and Health Core Rules, WAC 296-800-21005, Provide and Maintain Adequate Lighting
F. ACKNOWLEDGEMENTS

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Bruce W Smith, CPC
McWhorter School of Building Science
118 Gorrie Center
Auburn University, AL 36849
Cell: 334-524-1971
Email: smithb2@auburn.edu

Tim Nelson
Nelson Electric
9620 Stone Ave N, Seattle, WA 98103
Cell: 206-719-2365
Email: TNelson@nelsonelec.com
G. APPENDICES
Appendix A – LED LAYOUT PLANS
Appendix B – SURVEY QUESTIONNAIRE
Purpose:
The University of Washington is conducting research on the use of LED based low voltage lighting system for temporary construction lighting at the UW Bothell campus. As workers on this site, we would like to obtain your feedback on working in and with the LED lighting.

There are no known risks and adverse effects to you by providing your opinions in this survey. We will also protect your confidentiality and privacy in any publications and presentations.

Contact for information about the study:
If you have any questions or require further information with respect to this study, please feel free to contact us:

UW CPO Senior Construction Manager: Jeff Angeley (206.391.1836 | angeley@uw.edu)
UW CM Advising Faculty Member: Ken-Yu Lin (206-616-1915 | kenyulin@uw.edu)
Project intern: Yi Jie Huang (206-351-2447 | yijie@uw.edu).

Definition:

| TRAD: Traditional lighting is egress lighting only (corridors and stairwells) by compact florescent and metal halide fixtures and task lighting by trade contractors |
| LED: LED lighting is general lighting everywhere where workers are working to 5ft with low-volt fixtures and task lighting by trade contractors |

Important! Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name: __________________________________________

2. Mobile number/Email: ______________________________

3. Trade: __________________________________________

4. Years of field experience: __________________________

SITE WORK

5. What activity did you carry out on site? __________________________________________

6. Where was the activity carried out? Please check all that applies.
   □ In the staircase
   □ Along the corridor
   □ In a room
   □ Others (Please specify) ____________________________

7. What are the lighting requirements for the activity in a traditional lighting setting?
   Please check all that applies.
   □ None
   □ General lighting
   □ Headlamp
   □ Task lamps (Please specify no.) ______________________
   □ Others (Please specify) ____________________________

8. Was task lighting required on this site for the activity? Yes / No
9. If task lighting was used, where was task lighting required? Please check all that applies.

- [ ] In the staircase
- [ ] Along the corridor
- [ ] In a room
- [ ] Others (Please specify)

10. If task lighting was used,
   a) How much task lighting was required? b) How often was task lighting required?

- [ ] 1 task lamp  [ ] Once a week
- [ ] 2 task lamp  [ ] More than once a week
- [ ] More than 2 task lamp  [ ] Everyday

11. Please rate your work experience in the two systems –

   - TRAD – Traditional lighting is egress lighting only (corridors and stairwells) by compact florescent and metal halide fixtures and task lighting by trade contractors
   - LED – LED lighting is general lighting everywhere where workers are working to 5ft with low-volt fixtures and task lighting by trade contractors

   **On a scale of 1 to 5, where**
   
   (1) bad (2) poor (3) fair (4) good (5) excellent

<table>
<thead>
<tr>
<th></th>
<th>TRAD</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Amount of lighting provided to carry out your work</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>B Consistent and well distributed lighting provided</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>C How productive did you feel?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>D Was it visually comfortable?</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>E The safe operation of your work</td>
<td>_____</td>
<td>_____</td>
</tr>
</tbody>
</table>

   **On a scale of 1 to 5, where 1) disagree (2) somewhat disagree (3) neutral (4) somewhat agree (5) agree**

<table>
<thead>
<tr>
<th></th>
<th>TRAD</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>F You were distracted from working properly</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>G There was more disruption to your work</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>H The system required more coordination efforts with other trades/activities</td>
<td>_____</td>
<td>_____</td>
</tr>
</tbody>
</table>
11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

__________________________________________

12. Did working in the LED temporary lighting require any additional work / adjustments on your part? Yes / No

13. If yes, what were these additional work / adjustments?

__________________________________________

14. Can we contact you if we have further questions? Yes / No

Thank you for your time!
Please return the survey to Mark Sweeters (@ the Lease Crutcher Lewis main trailer).
Appendix C – WORKERS’ RESPONSES (RAW DATA)
PLEASE RETURN COMPLETED SURVEYS TO CLLLY OR AT THE LAWS OFFICE.

Purpose:
The University of Washington is conducting research on the use of LED based low voltage lighting system for temporary construction lighting at the UW Bothell campus. As workers on this site, we would like to obtain your feedback on working in and with the LED lighting.

There are no known risks and adverse effects to you by providing your opinions in this survey. We will also protect your confidentiality and privacy in any publications and presentations.

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Definition:

**TRAD**: Traditional lighting is egress lighting only (corridors and stairwells) by compact florescent and metal halide fixtures and task lighting by trade contractors

**LED**: LED lighting is general lighting everywhere where workers are working to 5ft with low-volt fixtures and task lighting by trade contractors

Important! Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name: TIM BECKER
2. Mobile number/Email: 425-239-7229
3. Trade: UNION STEAM FITTER
4. Years of field experience: 7

SITE WORK

5. What activity did you carry out on site?

STEAMFITTER RELATED ACTIVITIES / PIPING - PUMPS

6. Where was the activity carried out? Please check all that applies.
- In the staircase
- Along the corridor
- In a room
- Others (Please specify) ENTRIE BUILDING

7. What are the lighting requirements for the activity in a traditional lighting setting?
   Please check all that applies.
- None
- General lighting
- Headlamp
- Task lamps (Please specify no.)
- Others (Please specify)

8. Was task lighting required on this site for the activity? Yes No
9. If task lighting was used, where was task lighting required? Please check all that applies.

☐ In the staircase
☐ Along the corridor
☑ In a room
☑ Others (Please specify) [PENTHOUSE]

10. If task lighting was used,
   a) How much task lighting was required? b) How often was task lighting required?

☐ 1 task lamp           ☐ Once a week
☐ 2 task lamp           ☐ More than once a week
☑ More than 2 task lamp  ☐ Everyday

11. Please rate your work experience in the two systems –
   • TRAD -- Traditional lighting is egress lighting only (corridors and stairwells) by compact fluorescent and metal halide fixtures and task lighting by trade contractors
   • LED -- LED lighting is general lighting everywhere where workers are working to 5ft with low-volt fixtures and task lighting by trade contractors

   On a scale of 1 to 5, where
   (1) bad (2) poor (3) fair (4) good (5) excellent

   A Amount of lighting provided to carry out your work
   B Consistent and well distributed lighting provided
   C How productive did you feel?
   D Was it visually comfortable?
   E The safe operation of your work

   On a scale of 1 to 5, where 1) disagree (2) somewhat disagree (3) neutral (4) somewhat agree (5) agree

   F You were distracted from working properly
   G There was more disruption to your work
   H The system required more coordination efforts with other trades/activities

<table>
<thead>
<tr>
<th></th>
<th>TRAD</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>E</td>
<td>5</td>
<td>5</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>TRAD</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>3</td>
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<td>1</td>
</tr>
</tbody>
</table>
11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

**VERY HELPFUL!!!**

**I COULD SEE TO DO MY JOB CORRECTLY.**

12. Did working in the LED temporary lighting require any additional work / adjustments on your part?  

   Yes / No

13. If yes, what were these additional work / adjustments?

14. Can we contact you if we have further questions?  

   Yes / No

Thank you for your time!
Please return the survey to Mark Sweeters (@ the Lease Crutcher Lewis main trailer).
Please return completed surveys to Chilly or W at the Lewis Office.

Purpose:
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Project intern: Yi Jie Huang (206-351-2447 | yijie@uw.edu).

Definition:

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<td>LED lighting is <strong>general lighting everywhere</strong> where workers are working to 5ft. with low-volt fixtures <strong>and task lighting</strong> by trade contractors</td>
</tr>
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Important! Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name: Daryl Owens
2. Mobile number/Email: 206-396-2545
3. Trade: Plumber
4. Years of field experience: 32

SITE WORK

5. What activity did you carry out on site? 
   Plumber foreman

6. Where was the activity carried out? Please check all that applies.
   □ In the staircase
   □ Along the corridor
   □ In a room
   □ Others (Please specify)

7. What are the lighting requirements for the activity in a traditional lighting setting?
   Please check all that applies.
   □ None
   □ General lighting
   □ Headlamp
   □ Task lamps (Please specify no.)
   □ Others (Please specify)

8. Was task lighting required on this site for the activity? 
   Yes/No
   Occasionally

2
9. If task lighting was used, where was task lighting required? Please check all that applies.

☐ In the staircase
☒ Along the corridor
☒ In a room
☐ Others (Please specify)

10. If task lighting was used,

a) How much task lighting was required?  
☐ 1 task lamp
☐ 2 task lamp
☐ More than 2 task lamp

b) How often was task lighting required?
☐ Once a week
☐ More than once a week
☒ Everyday

11. Please rate your work experience in the two systems –

- TRAD – Traditional lighting is express lighting only (corridors and stairwells) by compact florescent and metal halide fixtures and task lighting by trade contractors
- LED – LED lighting is general lighting everywhere where workers are working to 5ft with low-volt fixtures and task lighting by trade contractors

**On a scale of 1 to 5, where**  
(1) bad  (2) poor  (3) fair  (4) good  (5) excellent

A Amount of lighting provided to carry out your work
TRAD | LED
---|---
1 | 4

B Consistent and well distributed lighting provided
TRAD | LED
---|---
1 | 4

C How productive did you feel?
TRAD | LED
---|---
1 | 5

D Was it visually comfortable?
TRAD | LED
---|---
1 | 5

E The safe operation of your work

**On a scale of 1 to 5, where 1) disagree (2) somewhat disagree (3) neutral (4) somewhat agree (5) agree**

F You were distracted from working properly
TRAD | LED
---|---
5 | 1

G There was more disruption to your work
TRAD | LED
---|---
5 | 1

H The system required more coordination efforts with other trades/activities
TRAD | LED
---|---
5 | 1
11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

much more helpful. Less task lights... was required ther-by reducing wasted time of pulling cords, finding task lights...

12. Did working in the LED temporary lighting require any additional work / adjustments on your part? Yes / No

13. If yes, what were these additional work / adjustments?

ADA

14. Can we contact you if we have further questions? Yes / No

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PLEASE RETURN COMPLETED SURVEYS TO CHI LI OR W AT THE LEIS OFFICE.

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| LED: LED lighting is general lighting everywhere where workers are working to fit with low-volt fixtures and task lighting by trade contractors |

Important! Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name: Glen Felkins
2. Mobile number/Email: 253-972-3841 veesselpro@comcast.net
3. Trade: Plumbing
4. Years of field experience: 25

SITE WORK

5. What activity did you carry out on site?
   plumbing/trim

6. Where was the activity carried out? Please check all that applies.
   □ In the staircase
   □ Along the corridor
   X □ In a room
   □ Others (Please specify) ______________________________

7. What are the lighting requirements for the activity in a traditional lighting setting? Please check all that applies.
   □ None
   □ General lighting
   X □ Headlamp
   □ Task lamps (Please specify no.)
   □ Others (Please specify) ______________________________

8. Was task lighting required on this site for the activity? ❌ Yes/No
9. If task lighting was used, where was task lighting required? Please check all that applies.

- [ ] In the staircase
- [ ] Along the corridor
- [x] In a room
- [ ] Others (Please specify)

10. If task lighting was used
   a) How much task lighting was required?
      - [x] 1 task lamp
      - [ ] 2 task lamp
      - [ ] More than 2 task lamp
   b) How often was task lighting required?
      - [ ] Once a week
      - [ ] More than once a week
      - [x] Everyday

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   - TRAD — Traditional lighting is egess lighting only (corridors and stairwells) by compact fluorescent and metal halide fixtures and task lighting by trade contractors
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   On a scale of 1 to 5, where
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   On a scale of 1 to 5, where 1) disagree  (2) somewhat disagree  (3) neutral  (4) somewhat agree  (5) agree

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11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

HELPFUL

12. Did working in the LED temporary lighting require any additional work / adjustments on your part? Yes No

13. If yes, what were these additional work / adjustments?

14. Can we contact you if we have further questions? Yes No

Thank you for your time!
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PLEASE RETURN COMPLETED SURVEYS TO CINDY OR WALTER AT THE LAW OFFICE.

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Important! Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name: Warren Brown
2. Mobile number/Email: Wbrown@Hermanson.com
3. Trade: Plumber
4. Years of field experience: 18

SITE WORK

5. What activity did you carry out on site?
   Some ground work, Rough-in, and Trim

6. Where was the activity carried out? Please check all that applies.
   - In the staircase
   - Along the corridor
   - In a room
   - Others (Please specify) [All over the building]

7. What are the lighting requirements for the activity in a traditional lighting setting?
   Please check all that applies.
   - None
   - General lighting
   - Headlamp
   - Task lamps (Please specify no.)
   - Others (Please specify)

8. Was task lighting required on this site for the activity? Yes/No 
   (very little)
9. If task lighting was used, where was task lighting required? Please check all that applies.
- In the staircase
- Along the corridor
- In a room
- Others (Please specify)  
  Under cabinets

10. If task lighting was used,
   a) How much task lighting was required? b) How often was task lighting required?
- 1 task lamp
- 2 task lamp
- More than 2 task lamp
- Once a week
- More than once a week
- Everyday

11. Please rate your work experience in the two systems –
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On a scale of 1 to 5, where
(1) bad (2) poor (3) fair (4) good (5) excellent

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<td>5</td>
</tr>
<tr>
<td>B Consistent and well distributed lighting provided</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>C How productive did you feel?</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>D Was it visually comfortable?</td>
<td>2</td>
<td>5</td>
</tr>
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<td>E The safe operation of your work</td>
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On a scale of 1 to 5, where 1) disagree (2) somewhat disagree (3) neutral (4) somewhat agree (5) agree

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</tr>
<tr>
<td>G There was more disruption to your work</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>H The system required more coordination efforts with other trades/activities</td>
<td>3</td>
<td>2</td>
</tr>
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11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

Helpful, not tripping over temporary lighting cords, or if they hang lights running into them or moving them because they are in the way.

12. Did working in the LED temporary lighting require any additional work / adjustments on your part?

Yes / No

13. If yes, what were these additional work / adjustments?

14. Can we contact you if we have further questions?

Yes / No

Thank you for your time!
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Important! Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name: ____________________________

2. Mobile number/Email: ____________________________

3. Trade: Plumber

4. Years of field experience: 7

SITE WORK

5. What activity did you carry out on site? Plumbing/Piping

6. Where was the activity carried out? Please check all that applies.
   - [ ] In the staircase
   - [ ] Along the corridor
   - [ ] In a room
   - [ ] Others (Please specify) Mech. Room

7. What are the lighting requirements for the activity in a traditional lighting setting? Please check all that applies.
   - [ ] None
   - [ ] General lighting
   - [ ] Headlamp
   - [ ] Task lamps (Please specify no.) Headlamp
   - [ ] Others (Please specify)

8. Was task lighting required on this site for the activity? Yes

---

2
9. If task lighting was used, where was task lighting required? Please check all that applies.

☐ In the staircase
☒ Along the corridor
☐ In a room
☐ Others (Please specify)

10. If task lighting was used,
   a) How much task lighting was required?  b) How often was task lighting required?
   ☒ 1 task lamp
   ☐ 2 task lamp
   ☐ More than 2 task lamp
   ☐ Once a week
   ☐ More than once a week
   ☒ Everyday

11. Please rate your work experience in the two systems –
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   On a scale of 1 to 5, where
   (1) bad  (2) poor  (3) fair  (4) good  (5) excellent
   A  Amount of lighting provided to carry out your work
   ☐ 1
   ☒ 2
   ☐ 3
   ☒ 4
   ☐ 5
   B  Consistent and well distributed lighting provided
   ☒ 1
   ☐ 2
   ☒ 3
   ☒ 4
   ☐ 5
   C  How productive did you feel?
   ☐ 1
   ☒ 2
   ☒ 3
   ☒ 4
   ☐ 5
   D  Was it visually comfortable?
   ☒ 1
   ☒ 2
   ☒ 3
   ☒ 4
   ☒ 5
   E  The safe operation of your work
   ☒ 1
   ☒ 2
   ☒ 3
   ☒ 4
   ☒ 5

   On a scale of 1 to 5, where 1) disagree  (2) somewhat disagree  (3) neutral  (4) somewhat agree  (5) agree
   F  You were distracted from working properly
   ☐ 1
   ☒ 2
   ☒ 3
   ☒ 4
   ☒ 5
   G  There was more disruption to your work
   ☒ 1
   ☒ 2
   ☒ 3
   ☒ 4
   ☒ 5
   H  The system required more coordination efforts with other trades/activities
   ☒ 1
   ☒ 2
   ☒ 3
   ☒ 4
   ☒ 5
11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

Good - Low Heat, Good Clear Light

12. Did working in the LED temporary lighting require any additional work / adjustments on your part? Yes / No

13. If yes, what were these additional work / adjustments?

Aim Light @ Work Sometimes

14. Can we contact you if we have further questions? Yes / No

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Important! Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name: Eli Williamson

2. Mobile number/Email:

3. Trade: Electrician

4. Years of field experience: 6 yrs

SITE WORK

5. What activity did you carry out on site? Electrical work

6. Where was the activity carried out? Please check all that applies.
   - [x] In the staircase
   - [x] Along the corridor
   - [x] In a room
   - [ ] Others (Please specify)

7. What are the lighting requirements for the activity in a traditional lighting setting? Please check all that applies.
   - [x] None
   - [x] General lighting
   - [ ] Headlamp
   - [x] Task lamps (Please specify no.)
   - [ ] Others (Please specify) Indoor Dark Rooms

8. Was task lighting required on this site for the activity? Yes/No Yes
9. If task lighting was used, where was task lighting required? Please check all that applies.
☐ In the staircase
☐ Along the corridor
☒ In a room
☐ Others (Please specify)

10. If task lighting was used,
a) How much task lighting was required? b) How often was task lighting required?
☒ 1 task lamp
☒ 2 task lamp
☐ More than 2 task lamp
☐ Once a week
☐ More than once a week
☐ Everyday

11. Please rate your work experience in the two systems –
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On a scale of 1 to 5, where
(1) bad (2) poor (3) fair (4) good (5) excellent
A Amount of lighting provided to carry out your work
B Consistent and well distributed lighting provided
C How productive did you feel?
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F You were distracted from working properly
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11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

**WAS MORE HELPFUL, WAS NICE HAVING EVERY OVERHEAD.**

12. Did working in the LED temporary lighting require any additional work / adjustments on your part?  
   **SOMETIMES PPL WERE WORKING ON SLAB WOULD HURT WHERE HAMMERS.**

13. If yes, what were these additional work / adjustments?
   **TROUBLESHOOTING WHERE THE PROBLEMS WERE, AND TAKING TIME TO FIX IT.**

14. Can we contact you if we have further questions?  
   **Yes ☐ No ☐**

Thank you for your time!  
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Important! Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name: Marcus Cole
2. Mobile number/Email: mac_24_04@yahoo
3. Trade: Electrician
4. Years of field experience: 4

SITE WORK

5. What activity did you carry out on site? Lighting

6. Where was the activity carried out? Please check all that applies.
   □ In the staircase
   □ Along the corridor
   □ In a room
   ☑ Others (Please specify) Hallways

7. What are the lighting requirements for the activity in a traditional lighting setting? Please check all that applies.
   □ None
   ☑ General lighting
   □ Headlamp
   □ Task lamps (Please specify no.)
   □ Others (Please specify)

8. Was task lighting required on this site for the activity? Yes/No
9. If task lighting was used, where was task lighting required? Please check all that applies.
   - In the staircase
   - Along the corridor
   - In a room
   - Others (Please specify)

   [ ] Hallways

10. If task lighting was used,
   a) How much task lighting was required?  b) How often was task lighting required?
   - 1 task lamp
   - 2 task lamp
   - More than 2 task lamp
   - Once a week
   - More than once a week
   - Everyday

11. Please rate your work experience in the two systems -
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   On a scale of 1 to 5, where (1) bad (2) poor (3) fair (4) good (5) excellent
   A Amount of lighting provided to carry out your work
   B Consistent and well distributed lighting provided
   C How productive did you feel?
   D Was it visually comfortable?
   E The safe operation of your work

   On a scale of 1 to 5, where 1) disagree 2) somewhat disagree 3) neutral 4) somewhat agree 5) agree
   F You were distracted from working properly
   G There was more disruption to your work
   H The system required more coordination efforts with other trades/activities

   TRAD  |  LED
   --------|--------
   2      | 4      
   2      | 4      
   2      | 4      
   2      | 4      

   TRAD  |  LED
   --------|--------
   4      | 2      
   4      | 2      
   4      | 2      

11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

A tad bright when inches from
But output is optimal for work

12. Did working in the LED temporary lighting require any additional work / adjustments on your part?  
Yes / No

13. If yes, what were these additional work / adjustments?

14. Can we contact you if we have further questions?  
Yes / No

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UW CM Advising Faculty Member: Ken-Yu Lin (206-616-1915 | kenyulin@uw.edu)
Project Intern: Yi Jie Huang (206-351-2447 | yijie@uw.edu).

Definition:

TRAD: Traditional lighting is egress lighting only (corridors and stairwells) by compact florescent and metal halide fixtures and task lighting by trade contractors

LED: LED lighting is general lighting everywhere where workers are working to 5ft with low-volt fixtures and task lighting by trade contractors

Important! Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name: E.R. WANG

2. Mobile number/Email: 425.750.1809

3. Trade: ELECTRICAL

4. Years of field experience: 7

SITE WORK

5. What activity did you carry out on site?

MECHANICAL WORK ELECTRICAL WORK

6. Where was the activity carried out? Please check all that applies.
   - In the staircase
   - Along the corridor
   - In a room
   - Others (Please specify)

7. What are the lighting requirements for the activity in a traditional lighting setting? Please check all that applies.
   - None
   - General lighting
   - Headlamp
   - Task lamps (Please specify no.)
   - Others (Please specify)

8. Was task lighting required on this site for the activity? Yes No
9. If task lighting was used, where was task lighting required? Please check all that applies.

☐ In the staircase
☐ Along the corridor
☒ In a room
☐ Others (Please specify)

10. If task lighting was used,

a) How much task lighting was required? b) How often was task lighting required?

☐ 1 task lamp
☐ 2 task lamp
☒ More than 2 task lamp

☐ Once a week
☐ More than once a week
☒ Everyday

11. Please rate your work experience in the two systems –

- TRAD – Traditional lighting is egress lighting only (corridors and stairwells) by compact fluorescent and metal halide fixtures and task lighting by trade contractors
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On a scale of 1 to 5, where
(1) bad  (2) poor  (3) fair  (4) good  (5) excellent

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<td>Amount of lighting provided to carry out your work</td>
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<td>B</td>
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On a scale of 1 to 5, where 1) disagree  (2) somewhat disagree  (3) neutral  (4) somewhat agree  (5) agree

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<td>There was more disruption to your work</td>
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<td>H</td>
<td>The system required more coordination efforts with other trades/activities</td>
<td>7</td>
</tr>
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11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

It was never that lighting was still needed.

For the overall lighting, in my opinion, was better.

12. Did working in the LED temporary lighting require any additional work / adjustments on your part? Yes / No

13. If yes, what were these additional work / adjustments?

14. Can we contact you if we have further questions? Yes / No

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***Important! Please read the definition before filling out the survey.***
PERSONAL DETAILS

1. Name: David Murphy
2. Mobile number/Email: 425-726-2260 / Dave@vanderlipco.com
3. Trade: Framer / hanger
4. Years of field experience: 18

SITE WORK

5. What activity did you carry out on site?
   Field Supt. for framing, sheetrock, taping

6. Where was the activity carried out? Please check all that applies.
   ☒ In the staircase
   ☐ Along the corridor
   ☒ In a room
   ☐ Others (Please specify)

7. What are the lighting requirements for the activity in a traditional lighting setting?
   Please check all that applies.
   ☐ None
   ☒ General lighting
   ☐ Headlamp
   ☒ Task lamps (Please specify no.) 1
   ☐ Others (Please specify)

8. Was task lighting required on this site for the activity? Yes No
9. If task lighting was used, where was task lighting required? Please check all that applies.
   □ In the staircase
   □ Along the corridor
   ☒ In a room
   □ Others (Please specify)

10. If task lighting was used,
   a) How much task lighting was required? b) How often was task lighting required?
   ☒ 1 task lamp
   □ 2 task lamp
   □ More than 2 task lamp
   □ Once a week
   □ More than once a week
   ☒ Everyday

11. Please rate your work experience in the two systems –
   • TRAD – Traditional lighting is egress lighting only (corridors and stairwells) by compact florescent and metal halide fixtures and task lighting by trade contractors
   • LED – LED lighting is general lighting everywhere where workers are working to 5ft with low-volt fixtures and task lighting by trade contractors

   On a scale of 1 to 5, where
   (1) bad (2) poor (3) fair (4) good (5) excellent
   A Amount of lighting provided to carry out your work
   B Consistent and well distributed lighting provided
   C How productive did you feel?
   D Was it visually comfortable?
   E The safe operation of your work

   On a scale of 1 to 5, where 1) disagree  (2) somewhat disagree  (3) neutral  (4) somewhat agree  (5) agree
   F You were distracted from working properly
   G There was more disruption to your work
   H The system required more coordination efforts with other trades/activities

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11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

More helpful. There were less or no light strings coming going through walls.

12. Did working in the LED temporary lighting require any additional work / adjustments on your part? Yes [X] No

13. If yes, what were these additional work / adjustments?

14. Can we contact you if we have further questions? Yes [X] No

Thank you for your time!
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Project Engineer: Yi-jie Huang (206-535-2447 | yi-jie@uw.edu)

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Complete Surveys

To call: (206) 543-8080

Complete Surveys

To call: (206) 543-8080

Important: Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name:  
   JCFC Staff

2. Mobile number/Email:  
   360.348.1034 for staff@jcf.com

3. Trade:  
   Operator

4. Years of field experience:  
   25

SITE WORK

5. What activity did you carry out on site?  
   Fork lift operator

6. Where was the activity carried out? Please check all that applies.
   - In the staircase
   - Along the corridor
   - In a room
   - Others (Please specify)  
     Outside

7. What are the lighting requirements for the activity in a traditional lighting setting?  
   Please check all that applies.
   - None
   - General lighting
   - Headlamp
   - Task lamps (Please specify no.)
   - Others (Please specify)  
     A fork lift is equipped with light

8. Was task lighting required on this site for the activity?  
   Yes / No
9. If task lighting was used, where was task lighting required? Please check all that applies.

☐ In the staircase
☐ Along the corridor
☐ In a room
☐ Others (Please specify)

10. If task lighting was used,
a) How much task lighting was required? b) How often was task lighting required?

☐ 1 task lamp  ☐ Once a week
☐ 2 task lamp  ☐ More than once a week
☐ More than 2 task lamp ☐ Everyday

11. Please rate your work experience in the two systems –

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On a scale of 1 to 5, where

(1) bad  (2) poor  (3) fair  (4) good  (5) excellent

A Amount of lighting provided to carry out your work

B Consistent and well distributed lighting provided

C How productive did you feel?

D Was it visually comfortable?

E The safe operation of your work

On a scale of 1 to 5, where 1) disagree (2) somewhat disagree (3) neutral (4) somewhat agree (5) agree

F You were distracted from working properly

G There was more disruption to your work

H The system required more coordination efforts with other trades/activities

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3
11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

I worked out side building.

12. Did working in the LED temporary lighting require any additional work / adjustments on your part? □ Yes □ No

13. If yes, what were these additional work / adjustments?

had electricians re adjust at loading areas to not shine out of building

14. Can we contact you if we have further questions? □ Yes □ No

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| LED: LED lighting is **eneral lighting everywhere** where workers are working to 5ft with low-volt fixtures and **ask lighting** by trade contractors |

Important! Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name: Jose Martinez
2. Mobile number/Email: 206-271-1205
3. Trade: Commercial Painting
4. Years of field experience: 18 Years

SITE WORK

5. What activity did you carry out on site? Painting, Seal, Clean

6. Where was the activity carried out? Please check all that applies.
   - [X] In the staircase
   - [X] Along the corridor
   - [X] In a room
   - [X] Others (Please specify)

   ALL AREAS

7. What are the lighting requirements for the activity in a traditional lighting setting? Please check all that applies.
   - [ ] None
   - [X] General lighting
   - [X] Headlamp
   - [ ] Task lamps (Please specify no.)
   - [ ] Others (Please specify)

8. Was task lighting required on this site for the activity? Yes/No
9. If task lighting was used, where was task lighting required? Please check all that applies.
- [ ] In the staircase
- [ ] Along the corridor
- [x] In a room
- [ ] Others (Please specify)

10. If task lighting was used.
   a) How much task lighting was required?
   - [ ] 1 task lamp
   - [ ] 2 task lamp
   - [ ] More than 2 task lamp

   b) How often was task lighting required?
   - [ ] Once a week
   - [ ] More than once a week
   - [x] Everyday

11. Please rate your work experience in the two systems:
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   - LED – LED lighting is general lighting everywhere where workers are working to 5 ft with low-volt fixtures and task lighting by trade contractors

   | On a scale of 1 to 5, where (1) bad (2) poor (3) fair (4) good (5) excellent |
   | A Amount of lighting provided to carry out your work | TRAD | LED |
   | B Consistent and well distributed lighting provided | 2  | 2 |
   | C How productive did you feel? | 2  | 2 |
   | D Was it visually comfortable? | 1  | 1 |
   | E The safe operation of your work | 2  | 2 |

   | On a scale of 1 to 5, where 1) disagree (2) somewhat disagree (3) neutral (4) somewhat agree (5) agree |
   | F You were distracted from working properly | TRAD | LED |
   | G There was more disruption to your work | 5  | 5 |
   | H The system required more coordination efforts with other trades/activities | 4  | 4 |
11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

More difficult poor dispersed light

12. Did working in the LED temporary lighting require any additional work / adjustments on your part? Yes / No

13. If yes, what were these additional work / adjustments?

Eye strain mental pain

14. Can we contact you if we have further questions? Yes / No

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PERSONAL DETAILS
1. Name: PATRICK P. FOOTE
2. Mobile number/Email: 206-769-1216
3. Trade: COMMERCIAL PAINTING
4. Years of field experience: 32 yrs

SITE WORK
5. What activity did you carry out on site?
   ALL PHASES OF PAINTING, CLEAN, SEAL

6. Where was the activity carried out? Please check all that applies.
   ☒ In the staircase
   ☒ Along the corridor
   ☒ In a room
   ☒ Others (Please specify)
   ALL AREAS

7. What are the lighting requirements for the activity in a traditional lighting setting? Please check all that applies.
   ☐ None
   ☒ General lighting
   ☒ Headlamp
   ☒ Task lamps (Please specify no.)
   ☐ Others (Please specify)
   HALOGEN LIGHTS

8. Was task lighting required on this site for the activity? ☐ Yes ☐ No
9. If task lighting was used, where was task lighting required? Please check all that applies.
   ☐ In the staircase
   ☑ Along the corridor
   ☐ In a room
   ☐ Others (Please specify)

10. If task lighting was used,
    a) How much task lighting was required?  b) How often was task lighting required?
       ☐ 1 task lamp  ☐ Once a week
       ☐ 2 task lamp  ☐ More than once a week
       ☐ More than 2 task lamp  ☐ Everyday

11. Please rate your work experience in the two systems –
    • TRAD – Traditional lighting is egress lighting only (corridors and stairwells) by compact
      fluorescent and metal halide fixtures and task lighting by trade contractors
    • LED – LED lighting is general lighting everywhere where workers are working to 5ft
      with low-volt fixtures and task lighting by trade contractors

    On a scale of 1 to 5, where
    (1) bad  (2) poor  (3) fair  (4) good  (5) excellent
    A Amount of lighting provided to carry out your work
       ☑ 2
       ☑ 2
    B Consistent and well distributed lighting provided
       ☑ 2
       ☑ 2
    C How productive did you feel?
       ☑ 1
       ☑ 1
    D Was it visually comfortable?
       ☑ 1
       ☑ 2
    E The safe operation of your work
       ☑ 2
       ☑ 2

    On a scale of 1 to 5, where 1) disagree  (2) somewhat disagree  (3) neutral  (4) somewhat agree  (5) agree
    F You were distracted from working properly
       ☑ 5
       ☑ 5
    G There was more disruption to your work
       ☑ 4
       ☑ 4
    H The system required more coordination efforts with other trades/activities
       ☑ 4
       ☑ 4
11. Was the LED temporary lighting more helpful for your work or did it make it more
difficult to work? Why?

MORE DIFFICULT. POOR DEFUSED LITE,

HARSH SHADOWS / BAD LIGHTING / F
SORSE BLOCKED PARTIALLY !

12. Did working in the LED temporary lighting require any
additional work / adjustments on your part?

Yes / No

13. If yes, what were these additional work / adjustments?

EYE STRAIN, MENTAL FATIGUE

14. Can we contact you if we have further questions?

Yes / No

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PERSONAL DETAILS
1. Name: Keith Guthrie

2. Mobile number/Email:

3. Trade: Carpenter

4. Years of field experience: 30

SITE WORK
5. What activity did you carry out on site?
   - Install ceiling, cabinets, countertops, backsplash, wood ceiling, walls

6. Where was the activity carried out? Please check all that applies.
   - ☐ In the staircase
   - ☐ Along the corridor
   - ☑ In a room
   - ☐ Others (Please specify) Vestibules

7. What are the lighting requirements for the activity in a traditional lighting setting? Please check all that applies.
   - ☐ None
   - ☑ General lighting
   - ☐ Headlamp
   - ☐ Task lamps (Please specify no.)
   - ☐ Others (Please specify)

8. Was task lighting required on this site for the activity? ☐ Yes/ ☑ No
9. If task lighting was used, where was task lighting required? Please check all that applies.

☐ In the staircase
☒ Along the corridor
☒ In a room
☒ Others (Please specify)  

10. If task lighting was used,
   a) How much task lighting was required? b) How often was task lighting required?

☐ 1 task lamp
☒ 2 task lamp
☐ More than 2 task lamp

☐ Once a week
☐ More than once a week
☒ Everyday

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A Amount of lighting provided to carry out your work
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On a scale of 1 to 5, where 1) disagree (2) somewhat disagree (3) neutral (4) somewhat agree (5) agree

F You were distracted from working properly
G There was more disruption to your work
H The system required more coordination efforts with other trades/activities

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11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

more difficult because it was insufficient

12. Did working in the LED temporary lighting require any additional work / adjustments on your part?

Yes / No

13. If yes, what were these additional work / adjustments?

run down and more temp lighting as required

14. Can we contact you if we have further questions?

Yes / No

Thank you for your time!
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TO CLILY OR \textbf{W} AT THE LAW'S OFFICE.

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UW CM Advising Faculty Member: Ken-Yu Lin (206-616-1915 | kenyulin@uw.edu)
Project intern: Yi Jie Huang (206-351-2447 | yijie@uw.edu).

Definition:

| TRAD: Traditional lighting is \textit{egress} lighting only (corridors and stairwells) by compact florescent and metal halide fixtures \textit{and} task \textit{lighting} by trade contractors |
| LED: LED lighting is \textit{general lighting everywhere} where workers are working to 5ft with low-volt fixtures \textit{and} task \textit{lighting} by trade contractors |

Important! Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name: Mark Kellogg
2. Mobile number/Email: 253-820-5591
3. Trade: Carpenter
4. Years of field experience: 38 years

SITE WORK

5. What activity did you carry out on site?
   Epoxy Teg, Table Frames, Frame Heads, Wood Paneling

6. Where was the activity carried out? Please check all that applies.
   □ In the staircase
   □ Along the corridor
   □ In a room
   □ Others (Please specify)

7. What are the lighting requirements for the activity in a traditional lighting setting?
   Please check all that applies.
   □ None
   □ General lighting
   □ Headlamp
   □ Task lamps (Please specify no.)
   □ Others (Please specify)

8. Was task lighting required on this site for the activity? Yes / No
   Occasionally

2
9. If task lighting was used, where was task lighting required? Please check all that applies.

☐ In the staircase
☐ Along the corridor
☒ In a room
☒ Others (Please specify)  

[Shady areas]

10. If task lighting was used,
   a) How much task lighting was required? b) How often was task lighting required?
   ☒ 1 task lamp
   ☐ 2 task lamp
   ☐ More than 2 task lamp

☒ Once a week or 15%
☐ More than once a week
☐ Everyday

11. Please rate your work experience in the two systems:
   • TRAD – Traditional lighting is egress lighting only (corridors and stairwells) by compact florescent and metal halide fixtures and task lighting by trade contractors
   • LED – LED lighting is general lighting everywhere where workers are working to 5 ft with low-volt fixtures and task lighting by trade contractors

   On a scale of 1 to 5, where
   (1) bad (2) poor (3) fair (4) good (5) excellent

<table>
<thead>
<tr>
<th>A</th>
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<tbody>
<tr>
<td>Amount of lighting provided to carry out your work</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>Consistent and well distributed lighting provided</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>How productive did you feel?</td>
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</tr>
<tr>
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<td>4</td>
</tr>
<tr>
<td>E</td>
<td>The safe operation of your work</td>
<td>4</td>
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   On a scale of 1 to 5, where 1) disagree 2) somewhat disagree 3) neutral 4) somewhat agree 5) agree

<table>
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<tr>
<th>F</th>
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<td>3</td>
</tr>
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<td>5</td>
</tr>
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</table>
11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

More helpful

12. Did working in the LED temporary lighting require any additional work / adjustments on your part? Yes / No

13. If yes, what were these additional work / adjustments? N/A

14. Can we contact you if we have further questions? Yes / No

Thank you for your time!
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PLEASE RETURN COMPLETED SURVEYS
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Important! Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name: Sithumon Witegon

2. Mobile number/Email: 360-651-3633 / Witegon-95@msn.com

3. Trade: Electrical

4. Years of field experience: 16 years

SITE WORK

5. What activity did you carry out on site?

Installing Deluca Light,
Remove Temp Light.

6. Where was the activity carried out? Please check all that applies.
   ☑ In the staircase
   ☑ Along the corridor
   ☑ In a room
   ☐ Others (Please specify)

7. What are the lighting requirements for the activity in a traditional lighting setting? Please check all that applies.
   ☐ None
   ☑ General lighting
   ☑ Headlamp
   ☑ Task lamps (Please specify no.)
   ☐ Others (Please specify)

8. Was task lighting required on this site for the activity? Yes/No
9. If task lighting was used, where was task lighting required? Please check all that applies.
- [ ] In the staircase
- [ ] Along the corridor
- [x] In a room
- [x] Others (Please specify)  

Storage closer

10. If task lighting was used,
   a) How much task lighting was required?  b) How often was task lighting required?
- [x] 1 task lamp
- [ ] 2 task lamp
- [ ] More than 2 task lamp
- [ ] Once a week
- [ ] More than once a week
- [ ] Everyday

11. Please rate your work experience in the two systems –
   - TRAD – Traditional lighting is [crossed out] lighting only (corridors and stairwells) by compact florescent and metal halide fixtures and task lighting by trade contractors
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   **On a scale of 1 to 5, where**
   (1) bad (2) poor (3) fair (4) good (5) excellent

   **TRAD** | **LED**
   --- | ---
   A Amount of lighting provided to carry out your work | 2 | 4
   B Consistent and well distributed lighting provided | 2 | 3
   C How productive did you feel? | 3 | 4
   D Was it visually comfortable? | 4 | 5
   E The safe operation of your work | 4 | 4

   **On a scale of 1 to 5, where 1) disagree (2) somewhat disagree (3) neutral (4) somewhat agree (5) agree**

   **TRAD** | **LED**
   --- | ---
   F You were distracted from working properly | 3 | 3
   G There was more disruption to your work | 2 | 1
   H The system required more coordination efforts with other trades/activities | 1 | 4
11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

The scale that I think was more helpful — the amount of light per fixture

Was better than TRAD and made cooler making work near fixtures more pleasant. Also it was easier to maneuver lifts out of the way who worry of extending lift.

12. Did working in the LED temporary lighting require any additional work / adjustments on your part? Yes [ ] No [x]

13. If yes, what were those additional work / adjustments?

14. Can we contact you if we have further questions? Yes [x] No [ ]

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Important! Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name: Amber Van Vooest
   
2. Mobile number/Email: get.ambered@yahoo.com
3. Trade: Electrician

4. Years of field experience: 8

SITE WORK

5. What activity did you carry out on site? Electrical work

6. Where was the activity carried out? Please check all that applies.
   
   □ In the staircase
   ✅ Along the corridor
   ✅ In a room
   □ Others (Please specify)

7. What are the lighting requirements for the activity in a traditional lighting setting? Please check all that applies.
   
   □ None
   ✅ General lighting
   ✅ Headlamp
   □ Task lamps (Please specify no.)
   □ Others (Please specify)

8. Was task lighting required on this site for the activity? (Yes/No) Yes
   
   at times additional light was required, a headlamp usually worked.
9. If task lighting was used, where was task lighting required? Please check all that applies.

- [ ] In the staircase
- [ ] Along the corridor
- [x] In a room
- [x] Others (Please specify)  in ceilings and some rooms

10. If task lighting was used,
   a) How much task lighting was required? b) How often was task lighting required?

- [ ] 1 task lamp  
- [ ] 2 task lamp  
- [ ] More than 2 task lamp  
- [ ] Once a week  
- [ ] More than once a week  
- [ ] Everyday

11. Please rate your work experience in the two systems –
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<td>3</td>
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11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

It lit up most areas well, but could be blinding at times when working overhead.

12. Did working in the LED temporary lighting require any additional work / adjustments on your part? [ ] Yes [ ] No

13. If yes, what were these additional work / adjustments?

When there was work to be done near a light, I would have to paint it away so it would not blind me.

14. Can we contact you if we have further questions? [ ] Yes [ ] No

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Important! Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name: Theran Wofford
2. Mobile number/Email: twofford71@gmail.com
3. Trade: mechanical Insulator
4. Years of field experience: 10

SITE WORK

5. What activity did you carry out on site?
   Insulating mechanical systems

6. Where was the activity carried out? Please check all that applies.
   □ In the staircase
   □ Along the corridor
   □ In a room
   □ Others (Please specify) Roof mechanical Rooms

7. What are the lighting requirements for the activity in a traditional lighting setting?
   Please check all that applies.
   □ None
   ☒ General lighting
   □ Headlamp
   ☒ Task lamps (Please specify no.) 1
   □ Others (Please specify)

8. Was task lighting required on this site for the activity? Yes/No
9. If task lighting was used, where was task lighting required? Please check all that applies.
   □ In the staircase
   □ Along the corridor
   ☑ In a room
   □ Others (Please specify)

10. If task lighting was used,
   a) How much task lighting was required? b) How often was task lighting required?
   ☑ 1 task lamp  ☑ Once a week
   □ 2 task lamp  □ More than once a week
   □ More than 2 task lamp  □ Everyday

11. Please rate your work experience in the two systems –
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     florescent and metal halide fixtures and task lighting by trade contractors
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     with low-volt fixtures and task lighting by trade contractors

   On a scale of 1 to 5, where
   (1) bad  (2) poor  (3) fair  (4) good  (5) excellent
   A Amount of lighting provided to carry out your work
      TRAD  LED
      4     3
   B Consistent and well distributed lighting provided
      1     4
   C How productive did you feel?
      3     7
   D Was it visually comfortable?
      2     4
   E The safe operation of your work
      3     3

   On a scale of 1 to 5, where 1) disagree  (2) somewhat disagree  (3) neutral
   (4) somewhat agree  (5) agree
   F You were distracted from working properly
      TRAD  LED
      1     1
   G There was more disruption to your work
      1     1
   H The system required more coordination efforts with other trades/activities
      1     1
11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

A little more difficult. LED wasn't as bright. Luminated less area.

12. Did working in the LED temporary lighting require any additional work / adjustments on your part? Yes / No

13. If yes, what were these additional work / adjustments?

14. Can we contact you if we have further questions? Yes / No

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PERSONAL DETAILS

1. Name: Rosemary Ayers
2. Mobile number/Email: 360-528-9291
3. Trade: Laborer
4. Years of field experience: 10

SITE WORK

5. What activity did you carry out on site?
   Clean-up

6. Where was the activity carried out? Please check all that applies.
   • In the staircase
   • Along the corridor
   • In a room
   • Others (Please specify)

7. What are the lighting requirements for the activity in a traditional lighting setting? Please check all that applies.
   • None
   • General lighting
   • Headlamp
   • Task lamps (Please specify no.)
   • Others (Please specify)

8. Was task lighting required on this site for the activity?  Yes/No
9. If task lighting was used, where was task lighting required? Please check all that applies.

☐ In the staircase
☐ Along the corridor
☐ In a room
☐ Others (Please specify)

10. If task lighting was used,
   a) How much task lighting was required? b) How often was task lighting required?

☐ 1 task lamp ☐ Once a week
☐ 2 task lamp ☐ More than once a week
☐ More than 2 task lamp ☐ Everyday

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11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

Very helpful. We were able to complete tasks assigned due to lighting.

12. Did working in the LED temporary lighting require any additional work / adjustments on your part? Yes / No

13. If yes, what were these additional work / adjustments?

14. Can we contact you if we have further questions? Yes / No

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PERSONAL DETAILS

1. Name: Miwa's Azumi
2. Mobile number/Email: 206-353-6633
3. Trade: Electrician
4. Years of field experience: 15 years

SITE WORK

5. What activity did you carry out on site? Low volt

6. Where was the activity carried out? Please check all that applies.
   □ In the staircase
   □ Along the corridor
   □ In a room
   □ Others (Please specify)

7. What are the lighting requirements for the activity in a traditional lighting setting? Please check all that applies.
   □ None
   □ General lighting
   □ Headlamp
   □ Task lamps (Please specify no.)
   □ Others (Please specify)

8. Was task lighting required on this site for the activity? Yes/No

2
9. If task lighting was used, where was task lighting required? Please check all that applies.

☐ In the staircase
☐ Along the corridor
☒ In a room
☐ Others (Please specify)

10. If task lighting was used,

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11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

Very helpful - Saved a lot of time

No cords to trip over.

12. Did working in the LED temporary lighting require any additional work / adjustments on your part? Yes / No

13. If yes, what were these additional work / adjustments?

14. Can we contact you if we have further questions? Yes / No

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Project intern: Yi Jie Huang (206-351-2447 | yijie@uw.edu).

Definition:

TRAD: Traditional lighting is egress lighting only (corridors and stairwells) by compact florescent and metal halide fixtures and task lighting by trade contractors

LED: LED lighting is general lighting everywhere where workers are working to 5ft with low-volt fixtures and task lighting by trade contractors

Important! Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name: Danny Moore
2. Mobile number/Email: 425-444-6267
3. Trade: Acoustical Ceilings
4. Years of field experience: 12

SITE WORK

5. What activity did you carry out on site?
   - Install ceiling grid

6. Where was the activity carried out? Please check all that applies.
   - In the staircase
   - Along the corridor
   - In a room
   - Others (Please specify)

7. What are the lighting requirements for the activity in a traditional lighting setting?
   Please check all that applies.
   - None
   - General lighting
   - Headlamp
   - Task lamps (Please specify no.)
   - Others (Please specify)

8. Was task lighting required on this site for the activity? [Yes] No
9. If task lighting was used, where was task lighting required? Please check all that applies.
- ☑ In the staircase
- ☑ Along the corridor
- ☑ In a room
- ☐ Others (Please specify)

10. If task lighting was used,
   a) How much task lighting was required?
      - ☐ 1 task lamp
      - ☐ 2 task lamp
      - ☐ More than 2 task lamp
   b) How often was task lighting required?
      - ☐ Once a week
      - ☑ More than once a week
      - ☒ Everyday

11. Please rate your work experience in the two systems –
   - TRAD – Traditional lighting is express lighting only (corridors and stairwells) by compact florescent and metal halide fixtures and task lighting by trade contractors
   - LED – LED lighting is general lighting everywhere where workers are working to 5ft with low-volt fixtures and task lighting by trade contractors

   **On a scale of 1 to 5, where**
   (1) bad (2) poor (3) fair (4) good (5) excellent

<table>
<thead>
<tr>
<th>Item</th>
<th>TRAD</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Amount of lighting provided to carry out your work</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>B Consistent and well distributed lighting provided</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>C How productive did you feel?</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>D Was it visually comfortable?</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>E The safe operation of your work</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

   **On a scale of 1 to 5, where 1) disagree (2) somewhat disagree (3) neutral (4) somewhat agree (5) agree**

<table>
<thead>
<tr>
<th>Item</th>
<th>TRAD</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>F You were distracted from working properly</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>G There was more disruption to your work</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>H The system required more coordination efforts with other trades/activities</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

Made it more difficult due to the directional nature of the light shining down impeding your ability to look up towards the light to see past it.

12. Did working in the LED temporary lighting require any additional work / adjustments on your part?  Yes / No

13. If yes, what were these additional work / adjustments?

Finding and moving work task to be able to see from other angles.

14. Can we contact you if we have further questions?  Yes / No

Thank you for your time!
Please return the survey to Mark Sweeters (@ the Lease Crutcher Lewis main trailer).
PLEASE RETURN COMPLETED SURVEYS TO CUMY OR AT THE LAW OFFICE.

Purpose:
The University of Washington is conducting research on the use of LED based low voltage lighting system for temporary construction lighting at the UW Bothell campus. As workers on this site, we would like to obtain your feedback on working in and with the LED lighting.

There are no known risks and adverse effects to you by providing your opinions in this survey. We will also protect your confidentiality and privacy in any publications and presentations.

Contact for information about the study:
If you have any questions or require further information with respect to this study, please feel free to contact us:

UW CPO Senior Construction Manager: Jeff Angeley (206.391.1836 | angeley@uw.edu)
UW CM Advising Faculty Member: Ken-Yu Lin (206-616-1913 | kenyulin@uw.edu)
Project intern: Yi Jie Huang (206-351-2447 | yijie@uw.edu).

Definition:

| TRAD: Traditional lighting is egress lighting only (corridors and stairwells) by compact florescent and metal halide fixtures and task lighting by trade contractors |
| LED: LED lighting is general lighting everywhere where workers are working to 5ft with low-volt fixtures and task lighting by trade contractors |

Important! Please read the definition before filling out the survey.
PERSONAL DETAILS

1. Name: Andrew Hofmeister
2. Mobile number/Email: (425) 322-8663 aşhmei$t@rocesin.carr
3. Trade: Carpenter
4. Years of field experience: 15

SITE WORK

5. What activity did you carry out on site?
   installation of lab case work/ tops/equipment - Doors/hardware
   Millwork - Toilet partitions

6. Where was the activity carried out? Please check all that applies.
   □ In the staircase
   □ Along the corridor
   □ In a room
   □ Others (Please specify) lobbies

7. What are the lighting requirements for the activity in a traditional lighting setting?
   Please check all that applies.
   □ None
   □ General lighting
   □ Headlamp
   □ Task lamps (Please specify no.) 1
   □ Others (Please specify)

8. Was task lighting required on this site for the activity? Yes ☑ No ☐
9. If task lighting was used, where was task lighting required? Please check all that applies.

- [ ] In the staircase
- [ ] Along the corridor
- [ ] In a room
- [ ] Others (Please specify)

10. If task lighting was used,

a) How much task lighting was required? b) How often was task lighting required?

- [ ] 1 task lamp
- [ ] 2 task lamp
- [ ] More than 2 task lamp
- [ ] Once a week
- [ ] More than once a week
- [ ] Everyday

11. Please rate your work experience in the two systems –

- TRAD – Traditional lighting is egress lighting only (corridors and stairwells) by compact florescent and metal halide fixtures and task lighting by trade contractors
- LED – LED lighting is general lighting everywhere where workers are working to 5ft with low-volt fixtures and task lighting by trade contractors

<table>
<thead>
<tr>
<th>On a scale of 1 to 5, where</th>
<th>TRAD</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) bad (2) poor (3) fair (4) good (5) excellent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Amount of lighting provided to carry out your work</td>
<td>3</td>
<td>5</td>
</tr>
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<td>B Consistent and well distributed lighting provided</td>
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</tr>
<tr>
<td>C How productive did you feel?</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>D Was it visually comfortable?</td>
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<td>5</td>
</tr>
<tr>
<td>E The safe operation of your work</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

| On a scale of 1 to 5, where 1) disagree (2) somewhat disagree (3) neutral (4) somewhat agree (5) agree |
|---------------------------|------|-----|
| TRAD | LED |
| F You were distracted from working properly | 3    | 3   |
| G There was more disruption to your work | 3    | 3   |
| H The system required more coordination efforts with other trades/activities | 3    | 3   |
11. Was the LED temporary lighting more helpful for your work or did it make it more difficult to work? Why?

Helpful. Because there was no need to set up task lighting.

12. Did working in the LED temporary lighting require any additional work / adjustments on your part?  Yes / No

13. If yes, what were these additional work / adjustments?

14. Can we contact you if we have further questions?  Yes / No

Thank you for your time!
Please return the survey to Mark Sweeters (@ the Lease Crutcher Lewis main trailer).
Appendix D – UWB P3 PROJECT SCHEDULE
<table>
<thead>
<tr>
<th>Act ID</th>
<th>Activity Description</th>
<th>QSp</th>
<th>Rem</th>
<th>Early Start</th>
<th>Early Finish</th>
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</thead>
<tbody>
<tr>
<td>4717</td>
<td>LEED Flush</td>
<td>10d</td>
<td>10d</td>
<td>21MAR14</td>
<td>3APR14</td>
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<tr>
<td>4720</td>
<td>Interiors Complete</td>
<td>0</td>
<td>0</td>
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<td>19MAR14</td>
</tr>
<tr>
<td>4723</td>
<td>Lighting Commissioning</td>
<td>15d</td>
<td>15d</td>
<td>19FEB14 A</td>
<td>17MAR14</td>
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<tr>
<td>4740</td>
<td>Access Control / Install / Test / Commission</td>
<td>10d</td>
<td>10FEB14</td>
<td>21MAR14</td>
<td></td>
</tr>
<tr>
<td>4800</td>
<td>Fire Alarm / Life Safety Testing &amp; Inspections</td>
<td>15d</td>
<td>15FEB14</td>
<td>18MAR14</td>
<td></td>
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<tr>
<td>4825</td>
<td>Substantial Completion and Close Out</td>
<td>0</td>
<td>0</td>
<td>21MAR14</td>
<td></td>
</tr>
<tr>
<td>4890</td>
<td>Punch List</td>
<td>25d</td>
<td>25d</td>
<td>4APR14</td>
<td>21MAR14</td>
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<tr>
<td>4900</td>
<td>Final Inspections and Cert. of Occupancy</td>
<td>0</td>
<td>0</td>
<td>20MAR14</td>
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<tr>
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<td>Final Completion</td>
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<td>0</td>
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<tr>
<td>4940</td>
<td>UWB Move in / FF&amp;E</td>
<td>40d</td>
<td>40d</td>
<td>27JUN14</td>
<td></td>
</tr>
</tbody>
</table>

Lease Crutcher Lewis Construction
University of Washington Bothell B3
Appendix E – WORKERS’ RESPONSES (COMPiled TABLE FORMAT)
<table>
<thead>
<tr>
<th>QUESTIONNAIRE SURVEY DATA</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Survey No</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Name</strong></td>
<td>Tim Becker</td>
<td>Daryl Owens</td>
<td>Glen Felkins</td>
<td>Warren Brown</td>
<td>Eli Williamson</td>
<td>Marcus Cole</td>
<td></td>
</tr>
<tr>
<td><strong>Mobile no/Email</strong></td>
<td>425-239-7229</td>
<td>206-396-6545</td>
<td>253-973-5911</td>
<td><a href="mailto:wdrow@hermanson.com">wdrow@hermanson.com</a></td>
<td><a href="mailto:mac_24_04@yahoo.com">mac_24_04@yahoo.com</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Trade</strong></td>
<td>Plumber</td>
<td>Plumber</td>
<td>Plumber</td>
<td>Plumber</td>
<td>Electrician</td>
<td>Electrician</td>
<td></td>
</tr>
<tr>
<td><strong>Years of Exp</strong></td>
<td>7</td>
<td>32</td>
<td>25</td>
<td>18</td>
<td>7</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td><strong>Activity</strong></td>
<td>Steamfitter / piping-pump</td>
<td>Plumber foreman</td>
<td>Plumbing / trim</td>
<td>Ground work, rough-in, trim</td>
<td>Plumbing / piping</td>
<td>Electrical work</td>
<td>Lighting</td>
</tr>
</tbody>
</table>

### Location

<table>
<thead>
<tr>
<th></th>
<th>Staircase</th>
<th>Along corridor</th>
<th>Room</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Staircase</strong></td>
<td>✔ ✔</td>
<td>✔ ✔ ✔ ✔</td>
<td>✔ ✔ ✔</td>
<td>Entire building</td>
</tr>
<tr>
<td><strong>Along corridor</strong></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
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<td><strong>Room</strong></td>
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<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

### TRADE lighting requirements

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>General</th>
<th>Headlamp</th>
<th>Task lamps</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>None</strong></td>
<td>✔ ✔ ✔ ✔</td>
<td>✔ ✔ ✔ ✔</td>
<td>✔ ✔ ✔</td>
<td>✔ ✔ ✔</td>
<td>✔ ✔ ✔</td>
</tr>
<tr>
<td><strong>General</strong></td>
<td>✔ ✔ ✔</td>
<td>✔ ✔ ✔</td>
<td>✔ ✔ ✔</td>
<td>✔ ✔ ✔</td>
<td>✔ ✔ ✔</td>
</tr>
<tr>
<td><strong>Headlamp</strong></td>
<td>✔ ✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Task lamps</strong></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td><strong>Others</strong></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

### Task lighting on this site?

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>Occassionally</th>
<th>YES</th>
<th>Very little</th>
<th>YES</th>
<th>YES</th>
<th>YES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Staircase</strong></td>
<td>✔ ✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Along corridor</strong></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
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</tr>
<tr>
<td><strong>Room</strong></td>
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<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Location

<table>
<thead>
<tr>
<th></th>
<th>Penthouse</th>
<th>Above ceiling heights, under cabinets</th>
<th>Under cabinets</th>
<th>Beam pockets, cabinets, above racks</th>
<th>Hallways</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Staircase</strong></td>
<td>✔ ✔</td>
<td>✔ ✔</td>
<td>✔ ✔</td>
<td>✔ ✔</td>
<td>✔ ✔</td>
</tr>
<tr>
<td><strong>Along corridor</strong></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Room</strong></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

### How much was required?

<table>
<thead>
<tr>
<th></th>
<th>1 lamp</th>
<th>2 lamps</th>
<th>More than 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>10a</strong></td>
<td>✔ ✔ ✔</td>
<td>✔ ✔ ✔</td>
<td>✔ ✔ ✔</td>
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</tbody>
</table>

### How often?

<table>
<thead>
<tr>
<th></th>
<th>Once a week</th>
<th>More than once a week</th>
<th>Everyday</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>10b</strong></td>
<td>✔ ✔ ✔</td>
<td>✔ ✔ ✔</td>
<td>✔ ✔ ✔</td>
</tr>
<tr>
<td>Survey No</td>
<td>Name</td>
<td>Mobile no/Email</td>
<td>Trade</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------</td>
<td>----------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>1</td>
<td>Tim Becker</td>
<td>425-239-7229</td>
<td>Plumber</td>
</tr>
<tr>
<td>2</td>
<td>Daryl Owens</td>
<td>206-396-6545</td>
<td>Plumber</td>
</tr>
<tr>
<td>3</td>
<td>Glen Felkins</td>
<td>253-973-5911</td>
<td>Plumber</td>
</tr>
<tr>
<td>4</td>
<td>Warren Brown</td>
<td><a href="mailto:wdrow@hermanson.com">wdrow@hermanson.com</a></td>
<td>Plumber</td>
</tr>
<tr>
<td>5</td>
<td>Eli Williamson</td>
<td><a href="mailto:mac_24_04@yahoo.com">mac_24_04@yahoo.com</a></td>
<td>Plumber</td>
</tr>
<tr>
<td>6</td>
<td>Marcus Cole</td>
<td></td>
<td>Electrician</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td>Electrician</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>11 TRAD</th>
<th>T-Amount of lighting provided</th>
<th>3</th>
<th>1</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T-Consistent and well distributed</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
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<td></td>
<td>T-Productive</td>
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<td>1</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>T-Visually comfortable</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>T-Safe operation of work</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>T-Distacted from work</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>T-More disruption</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>T-More coordination efforts</td>
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<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>4</td>
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<table>
<thead>
<tr>
<th>11 LED</th>
<th>L-Amount of lighting provided</th>
<th>5</th>
<th>4</th>
<th>4</th>
<th>5</th>
<th>4</th>
<th>4</th>
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<tbody>
<tr>
<td></td>
<td>L-Consistent and well distributed</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>L-Productive</td>
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<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
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<td>L-Visually comfortable</td>
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<td>5</td>
<td>4</td>
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<td>4</td>
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<td></td>
<td>L-Safe operation of work</td>
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<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
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<th>11 More helpful?</th>
<th>Very helpful. Could see to do job correctly</th>
<th>More helpful. Less task lighting required. Reduce wasted time of pulling cords, finding task lights</th>
<th>Helpful</th>
<th>Helpful. Not tripping over temp lighting cords, or if they hang lights running into them or moving them because they are in the wrong place</th>
<th>Good. Low heat. Good clear light</th>
<th>More helpful. Nice having everything overhead</th>
<th>A tad bright when inches from it. But output is optimal for work</th>
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<table>
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<th>13 What adjustments?</th>
<th>Aim light at work sometimes</th>
<th>People drill into wire. Troubleshoot problem, takes time to fix</th>
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Page 63-2
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<th>Years of Exp</th>
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<th>How often?</th>
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<td>7</td>
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<td>2</td>
<td>David Murphy</td>
<td>425-736-2260</td>
<td>Framer/hanger</td>
<td>18</td>
<td>Field suit for framing, sheetrock, topping</td>
<td>Along corridor</td>
<td>General</td>
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<td>1 lamp</td>
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<td>3</td>
<td>Patrick P. Foctz</td>
<td>206-769-1216</td>
<td>Painter</td>
<td>32</td>
<td>All phases of painting, caulk, seal</td>
<td>Room</td>
<td>Headlamp</td>
<td>YES</td>
<td>(1)</td>
<td>(or less)</td>
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<td>4</td>
<td>Keith Guthrie</td>
<td>30</td>
<td>Carpenter</td>
<td>30</td>
<td>Install ceiling grid, cabinets, countertops, backsplash, wood ceiling &amp; wallpan</td>
<td>Others</td>
<td>Task lamp(s)</td>
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<td>(Halogen)</td>
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<tr>
<td>5</td>
<td>Mark Kellog</td>
<td>38</td>
<td>Carpenter</td>
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<td>Epoxy top, table frames, fume hoods, wood paneling</td>
<td>Vestibules</td>
<td>Task lamps</td>
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<td>6</td>
<td>Shannon Wheaton</td>
<td>16</td>
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<td>16</td>
<td>Install permanent lighting. Remove temp lighting</td>
<td>Others</td>
<td>Others (at times additional light was required, a headlamp usually worked)</td>
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<tr>
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<td>Amber Van Voorst</td>
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- 1st Location: Staircase
- 2nd Location: Along corridor
- 3rd Location: Room
- 4th Location: All areas
- 5th Location: Vestibules
- 6th Location: Shadowy areas
- 7th Location: Storage closets
- 8th Location: In ceilings and some rooms

- 9th Location: Enough to see
- 10a How much was required?: 1 lamp, 2 lamps, More than 2
- 10b How often?: Once a week, More than once a week, Everyday
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<td>Patrick P. Foctz</td>
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<td>More helpful?</td>
<td>It was neutral task lighting was still needed but the overall lighting in a room was better</td>
<td>More helpful. There were less or no light string cords going through walls</td>
<td>More difficult. Poor diffused light. Harsh shadows. Bad lighting if source blocked partially</td>
<td>More difficult because it was insufficient</td>
<td>More helpful. The scale tips to more helpful - the amount of light per fixture was better than trad and also cooler making work near fixture more pleasant - also it was easier to manuver lighting out of the way without worry of extinguishing light</td>
<td>It lit up most areas well, but could be blinding at times when working overhead</td>
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<td>What adjustments?</td>
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<td>When there was work to be done near a light I would have to point it away so it would not blind me.</td>
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<tr>
<td>1</td>
<td>Theron Wofford</td>
<td><a href="mailto:twofford71@gmail.com">twofford71@gmail.com</a></td>
<td>Mechanical insulator</td>
<td>16</td>
<td>Insulating mechanical systems</td>
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<td>Rosemary Ayers</td>
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<td>Installation of lab case work/tops/equipment - doors/hardware millwork - toilet partitions</td>
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**Note:** The table represents a questionnaire survey data with responses for various questions. The table includes details about names, mobile numbers, trades, years of experience, activities, location, TRAD lighting requirements, and task lighting on the site for different users.
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**11 More helpful?**
- Theron Wofford: A little more difficult, LED wasn't as bright, illuminated less area
- Rosemary Ayers: very helpful. Was able to complete tasks assigned do to lighting
- Mirwais Azami: Very helpful - saved a lot of time no cords to trip over
- Danny Moore: Made it more difficult to do the directional nature of the light shining down impeding your ability to look up towards the light to see past it
- Andrew Hofmeister: Helpful. Because there was no need to set up task lighting

**12 Additional work/adjustments?**
- Theron Wofford: NO
- Rosemary Ayers: NO
- Mirwais Azami: NO
- Danny Moore: YES
- Andrew Hofmeister: NO

**13 What adjustments?**
- Finding and moving work task to be able to see from other angles
Appendix F – WORKERS’ RESPONSES (CONVERTED DATA FORMAT)
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<td>How often?</td>
<td>Once a week</td>
<td>FALSE</td>
<td>FALSE</td>
<td>TRUE</td>
<td>FALSE</td>
<td>TRUE</td>
<td>FALSE</td>
</tr>
<tr>
<td>10b</td>
<td></td>
<td></td>
<td>More than once a week</td>
<td>FALSE</td>
<td>FALSE</td>
<td>FALSE</td>
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<td>FALSE</td>
<td>TRUE</td>
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<tr>
<td>10b</td>
<td></td>
<td></td>
<td>Everyday</td>
<td>TRUE</td>
<td>TRUE</td>
<td>FALSE</td>
<td>FALSE</td>
<td>FALSE</td>
<td>TRUE</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>LED provides more light than TRAD</td>
<td>NEUTRAL</td>
<td>TRUE</td>
<td>TRUE</td>
<td>NEUTRAL</td>
<td>TRUE</td>
<td>TRUE</td>
<td>TRUE</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>LED provides more consistent and well distributed lighting than TRAD</td>
<td>NEUTRAL</td>
<td>TRUE</td>
<td>TRUE</td>
<td>TRUE</td>
<td>TRUE</td>
<td>TRUE</td>
<td>TRUE</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>I feel more productive with LED lighting than TRAD</td>
<td>NEUTRAL</td>
<td>TRUE</td>
<td>TRUE</td>
<td>NEUTRAL</td>
<td>TRUE</td>
<td>TRUE</td>
<td>TRUE</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>LED lighting is more visually comfortable than TRAD</td>
<td>NEUTRAL</td>
<td>TRUE</td>
<td>NEUTRAL</td>
<td>TRUE</td>
<td>TRUE</td>
<td>TRUE</td>
<td>TRUE</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>LED lighting made my work more operationally safer</td>
<td>NEUTRAL</td>
<td>TRUE</td>
<td>TRUE</td>
<td>NEUTRAL</td>
<td>TRUE</td>
<td>TRUE</td>
<td>TRUE</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>LED distracted me from working properly more than TRAD</td>
<td>NEUTRAL</td>
<td>FALSE</td>
<td>NEUTRAL</td>
<td>NEUTRAL</td>
<td>NEUTRAL</td>
<td>NEUTRAL</td>
<td>TRUE</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>LED disrupted my work more than TRAD</td>
<td>NEUTRAL</td>
<td>FALSE</td>
<td>NEUTRAL</td>
<td>NEUTRAL</td>
<td>NEUTRAL</td>
<td>NEUTRAL</td>
<td>NEUTRAL</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>LED required more coordination efforts than TRAD</td>
<td>NEUTRAL</td>
<td>FALSE</td>
<td>TRUE</td>
<td>NEUTRAL</td>
<td>NEUTRAL</td>
<td>NEUTRAL</td>
<td>NEUTRAL</td>
</tr>
</tbody>
</table>
Appendix G – VISUALIZATION CHART OF WORKERS’ RESPONSES
Appendix H – DETAILED COST CALCULATIONS
<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Unit</th>
<th>Rate</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable</td>
<td>6,120.00</td>
<td>LF</td>
<td>$0.05</td>
<td>$306.00</td>
</tr>
<tr>
<td>Power supply/controller connection</td>
<td>20.00</td>
<td>EA</td>
<td>$47.89</td>
<td>$957.80</td>
</tr>
<tr>
<td>Light fixtures</td>
<td>285.00</td>
<td></td>
<td>$52,689.00</td>
<td>$306.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$5,730.00</td>
<td>$2,979.60</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>$40,990.00</td>
<td>$2,597.60</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Installation</th>
<th>Quantity</th>
<th>Unit</th>
<th>Rate</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install cable</td>
<td>6,120.00</td>
<td>LF</td>
<td>$1.92</td>
<td>$11,750.40</td>
</tr>
<tr>
<td>Install power supply/controller</td>
<td>20.00</td>
<td>EA</td>
<td>$639.30</td>
<td>$12,786.00</td>
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<tr>
<td>Install fixtures</td>
<td>285.00</td>
<td>EA</td>
<td>$22.38</td>
<td>$6,378.30</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>$18,336.00</td>
<td>$3,835.80</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$26,984.88</td>
<td>$3,835.80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maintenance</th>
<th>Quantity</th>
<th>Unit</th>
<th>Rate</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance &amp; repairs</td>
<td>52.00</td>
<td>HR</td>
<td>$63.93</td>
<td>$3,324.36</td>
</tr>
<tr>
<td>Fixtures replacement</td>
<td></td>
<td></td>
<td>$26,594.88</td>
<td>$390.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$26,984.88</td>
<td>$390.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Removal</th>
<th>Quantity</th>
<th>Unit</th>
<th>Rate</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removal of fixtures;</td>
<td>60.00</td>
<td>HR</td>
<td>$63.93</td>
<td>$3,835.80</td>
</tr>
<tr>
<td>Removal/Abandon cables</td>
<td></td>
<td></td>
<td>$10,228.80</td>
<td>$3,835.80</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>$10,228.80</td>
<td>$3,835.80</td>
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</tbody>
</table>

| TOTAL                          |          |      |        | $92,027.66 |

<table>
<thead>
<tr>
<th>Power costs</th>
<th>Quantity</th>
<th>Unit</th>
<th>Rate</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>223 FM10 (100% for 12 hours)</td>
<td>13,674.36</td>
<td>kWH</td>
<td>$0.09</td>
<td>$1,251.20</td>
</tr>
<tr>
<td>223 FM10 (50% for 12 hours)</td>
<td>6,837.18</td>
<td>kWH</td>
<td>$0.09</td>
<td>$625.60</td>
</tr>
<tr>
<td>62 FM2 (100% for 12 hours)</td>
<td>11,405.52</td>
<td>kWH</td>
<td>$0.09</td>
<td>$1,043.61</td>
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<tr>
<td>62 FM2 (50% for 12 hours)</td>
<td>5,702.76</td>
<td>kWH</td>
<td>$0.09</td>
<td>$521.80</td>
</tr>
<tr>
<td></td>
<td>37,619.82</td>
<td></td>
<td>$3,442.21</td>
<td>$3,442.21</td>
</tr>
</tbody>
</table>

| TOTAL                          |          |      |        | $95,469.87 |

| TOTAL                          |          |      |        | $129,488.02 |