Life Expectancy Evaluation and Replacement Schedule Development for LED Traffic Indicators

Suzanna Long, PhD and Casey Noll
Engineering Management and Systems Engineering Department
Missouri University of Science and Technology, Rolla, Missouri 65409-1060, USA
Introduction

- Research funded by MoDOT
  - TRyy1001

- Motivation:
  - Replacement schedule based on field performance
  - Understanding of useful life of LEDs
  - Economical way to measure and track LED light output
Background

LED (light-emitting diode)

- Use in traffic indicators
- Benefits:
  - 85% Energy Reduction
  - 5-10 Year Life Expectancy
  - Less Maintenance
  - Cheaper Life-cycle Cost
Degradation

- Degradation vs. “burn out”
  - Fundamental difference between LEDs and incandescents

- Growing need for best practices in:
  - Monitoring
  - Maintenance
  - Replacement
Problems with LEDs in Traffic Indicators

Monitoring and Replacement

• 2007 ITE Survey
  – Public agency traffic engineers
  – Vendors and manufacturers

• Confirmed growing issue with current state of monitoring and replacement of LEDs
  • Lack of understanding of ITE specifications
  • 60% have no monitoring & replacement procedure
  • Reactive replacement
Problems with LEDs in Traffic Indicators

Replacement Approach

- No Replacement Approach: 35%
- Complaint Driven: 35%
- Routine, Scheduled Replacement: 24%
- Replace on Vendor Product Life Cycle: 3%
- Based on in-service Test Results: 3%
Methodology

• Field study
  – Hundreds of traffic signals across Missouri

• Original instrument created to collect data (patent filed)
  – Portable
  – Affordable
  – Measure illuminance (lux)
  – Makes study possible
  – Driver’s perspective
Device Methodology

- Device aimed at LED light source
  - Laser-assisted aiming
  - Range finder measures distance for lux→cd conversion
- Light is focused by Fresnel lens directly into digital light meter
- Casing keeps out ambient light
- Device interfaces with computer to store and analyze data
Data Collection and Analysis

- Comprehensive database

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Direction</th>
<th>Indicator Head</th>
<th>Indicator</th>
<th>Manufacturer</th>
<th>Date of Installation</th>
<th>Date Measured</th>
<th>Age</th>
<th>Lux</th>
<th>Distance</th>
</tr>
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<tbody>
<tr>
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</table>

Input into inverse square law to obtain cd

Luminous Intensity \((cd) = \text{Illuminance (lux)} \times \text{Distance}^2 \ (m)\)
# Data Collection and Analysis

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Circular Green</th>
<th>Circular Red</th>
<th>Circular Yellow</th>
<th>Green Arrow</th>
<th>Yellow Arrow</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>1</td>
<td>1</td>
<td>0.3%</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>DIAL</td>
<td>10</td>
<td>67</td>
<td>30</td>
<td>56</td>
<td>28</td>
<td>191</td>
</tr>
<tr>
<td>GE</td>
<td>68</td>
<td>34</td>
<td>5</td>
<td>25</td>
<td>12</td>
<td>144</td>
</tr>
<tr>
<td>LTEK</td>
<td>34</td>
<td></td>
<td>34</td>
<td></td>
<td>1</td>
<td>35</td>
</tr>
<tr>
<td>PHILIPS</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
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<td>1</td>
</tr>
</tbody>
</table>

| Subtotal     | 79             | 102          | 69              | 81          | 41           | 372     |

|                | 21.2%          | 27.4%        | 18.5%           | 21.8%       | 11.0%        | 100%    |
Data Collection and Analysis

Distribution of LEDs by Age

Number of Indicators
Development of Useful Life Models
Degradation

2 Factor Analysis
- Degradation dependent on 2 factors and their interaction
  1. Manufacturer
  2. Indicator Type

10 Subgroups
- Circular Green – Dialight (10)
- Circular Green – GE (68)
- Green Arrow – Dialight (56)
- Green Arrow – GE (25)
- Yellow Arrow – Dialight (28)
- Yellow Arrow – GE (12)
- Circular Red – Dialight (67)
- Circular Red – GE (34)
- Circular Yellow – Dialight (30)
- Circular Yellow – LTEK (34)
## Lab Analysis

<table>
<thead>
<tr>
<th></th>
<th>Average Luminance (cd)</th>
<th>ITE Threshold (-2.5 degrees)</th>
<th>Average Ratio (R:Y:G)</th>
<th>ITE Recommended Ratio (R:Y:G)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12&quot; Red Dialight</td>
<td>376</td>
<td>365</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>12&quot; Yellow Leotek</td>
<td>515</td>
<td>910</td>
<td>1.4</td>
<td>2.5</td>
</tr>
<tr>
<td>12&quot; Green Dialight</td>
<td>551</td>
<td>475</td>
<td>1.5</td>
<td>1.3</td>
</tr>
</tbody>
</table>
# Regression Equations

<table>
<thead>
<tr>
<th>Type</th>
<th>Regression Equation</th>
<th>Solution (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular, Green, Dial</td>
<td>$Y = -32.415X + 531.07$</td>
<td>8.45</td>
</tr>
<tr>
<td>Circular, Green, GE</td>
<td>$Y = -28.139X + 386.6$</td>
<td>4.61</td>
</tr>
<tr>
<td>Arrow, Green, Dial</td>
<td>$Y = -12.681X + 154.61$</td>
<td>8.95</td>
</tr>
<tr>
<td>Arrow, Green, GE</td>
<td>$Y = -9.8846X + 116.46$</td>
<td>7.63</td>
</tr>
<tr>
<td>Circular, Red, Dial</td>
<td>$Y = -10.932X + 190.99$</td>
<td>***</td>
</tr>
<tr>
<td>Circular, Red, GE</td>
<td>$Y = -6.8846X + 507.27$</td>
<td>***</td>
</tr>
<tr>
<td>Circular, Yellow, Dial</td>
<td>$Y = -22.332X + 298.37$</td>
<td>***</td>
</tr>
<tr>
<td>Arrow, Yellow, GE</td>
<td>$Y = -33.366X + 274.37$</td>
<td>5.85</td>
</tr>
<tr>
<td>Arrow, Yellow, Dial</td>
<td>$Y = -5.9974X + 115.56$</td>
<td>6.09</td>
</tr>
</tbody>
</table>
Results

• Replacement Schedule for Dial

<table>
<thead>
<tr>
<th>Type</th>
<th>Age for Replacement (yrs)</th>
<th>ITE Threshold (cd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular, Green</td>
<td>(8 years, 9 years)</td>
<td>257</td>
</tr>
<tr>
<td>Arrow, Green</td>
<td>(8 years, 9 years)</td>
<td>41</td>
</tr>
<tr>
<td>Arrow, Yellow</td>
<td>(5 years, 6 years)</td>
<td>79</td>
</tr>
</tbody>
</table>

• Replacement Schedule for GE

<table>
<thead>
<tr>
<th>Type</th>
<th>Age for replacement (yrs)</th>
<th>ITE Threshold (cd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular, Green</td>
<td>(4 years, 5 years)</td>
<td>257</td>
</tr>
<tr>
<td>Arrow, Green</td>
<td>(7 years, 8 years)</td>
<td>41</td>
</tr>
<tr>
<td>Arrow Yellow</td>
<td>(5 years, 6 years)</td>
<td>79</td>
</tr>
</tbody>
</table>
Energy Saving

• Energy savings from replacing incandescent lights with LED signals are considerable.

- Annual energy savings ($)
  - Red: $70/signal; Green: $64/signal; Yellow: $7/signal (due to lower utilization than red and green signals)
  - Electricity costs have been reduced to 1.2 million per year
Extended Useful Life

- LED signals last for approx. 7-9 years before they drop below ITE standard.
- Incandescent bulbs burn out on average in two years

**Useful Life Comparison**

- LED LB
- LED UB
- Incandescent
- LED average
Reduced Maintenance Costs

• LED signals substantially reduce the chance of emergent replacement/reparation
  – don’t burn out like incandescent bulbs
• The interval of scheduled replacement is reduced from 2 years to approx. 7 years!
  – Labor hours have been reduced to approximately 170K per year.
  – It may be further reduced by implementing the replacement schedules developed in the LED traffic signal project
Conclusions

Differences in LED Manufacturing

Older LED Design with 200 individual LEDs

Newer “Incandescent Look” Design with only 6 LEDs
Conclusions

• LEDs are superior to incandescents
• LED degradation varies based on 2 factors
  – Manufacturer
  – Indicator type
• Group replacement → Reduced maintenance cost
• DOTs facing reduced budgets
• Recommend 7 year group replacement of all LEDs on an intersection by intersection basis
• Comprehensive database to track light intensity readings
Future Work

• Continued longitudinal study of same sample of LEDs over a longer period of time
• Investigate the effects of varied manufacturer design on LED performance and degradation
• LED Road Luminaires
A special thanks to MoDOT for funding this research project. We especially thank Jennifer Harper and Julie Stotlemeyer for their support and assistance. We also thank Tom Ryan, PE, who served as the external reviewer for this project.
Questions?
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