NAVIGANT
A Guidehouse Company

150 N Riverside Plaza
Suite 2100
Chicago, IL 60606
www.navigant.com

To:	Erin Daughton, William Burns (ComEd)
CC:	Jennifer Morris (Illinois Commerce Commission)
From:	Karen Maoz, Wayne Leonard, Carly Olig (Navigant)
Date:	January 27, 2020
Re:	Effective Useful Life (EUL) Research for LED Street Lighting Measures

INTRODUCTION

The objective of this research is to refine the 12-year effective useful life (EUL) associated with LED street lighting measures as currently covered in the Illinois Technical Reference Manual (IL TRM).[1] The scope of this additional research does not extend beyond the EUL, and only applies to street, roadway, and exterior area lights.

This research first addressed the technical EUL limits and then identified future research objectives once the roadway fixtures have achieved sufficient service life so as to offer additional context and insight. This research plan was divided in to three tasks:

1. Identify key questions and compile program data (primary research)
2. Drill deeper in to initial questions and review external sources (secondary research)
3. Identify long-term measure review objectives related to measure persistence

This memo focuses primarily on Tasks 1 and 2, then makes recommendations for an updated EUL value. As a result of our research, Navigant recommends that the streetlighting EUL should increase from 12 to 20 years. This memo also provides recommendations on how to proceed with any future research that were previously suggested as part of Tasks 2 and 3.

TASK 1: IDENTIFY KEY QUESTIONS AND COMPILE PROGRAM DATA

The primary focus for Task 1 research was to identify the key questions, EUL drivers, and topics that need to be addressed to update the street lighting EUL in the IL TRM; and then gather this preliminary data from sources that are readily available through the Street Lighting Program.

To complete this task, Navigant:

- Compiled product specification sheets of past projects
- Reviewed the literature for specific facts on operating conditions for street lighting
- Called manufacturers and asked for information related to product warranties and the serviceability of the street lighting components

The findings from each of these initial research areas are covered in the following, topic specific sub-sections. These topics cover each of the most critical influencers that will determine the average

[1] IL TRM Version 8, Volume 2, pg. 524, footnote 880 "DLC streetlighting measure, PGE workpaper, and current TRM values for exterior lighting all have a measure lives in the 11-12-year range. Assuming 50,000 hours of operation, and an annual operating hour of 4,303 hours results in a lifetime of 11.6 years or 5.7 years for 8760 operation. Typical streetlighting spec sheets suggest a longer measure life than 50,000 hours so we recommend the 12-year EUL for this measure."

equipment EUL: the street light components, controls and user-determined aspects of operation, and the expected operating environment.

Rated Life

Navigant sourced rated life data from product specification sheets ("spec sheets") submitted in support of projects incentivized as part of the CY2018 Street Lighting Program. Navigant compiled the rated life (average expected run time in hours) as reported by product manufacturers for a cross-section of equipment installed through the program. The rated life metrics are then converted from hours to years based on annual operating hours supported by the IL TRM. The resulting technical life is then derated to provide an EUL that reflects a real-world operating environment placing strain and other external impacts on equipment that are not captured in the lab tests used to estimate the manufacturer reported rated life.

Manufacturers are not subject to a standard requirement for reporting rated life, instead they report life expectancy at one or more of many lumen maintenance options. Therefore, to have a common cutoff point, Navigant collected rated life data based on the fixture achieving a minimum lumen maintenance of L70.[2] The L70 benchmark is consistent with the approach used by the Design Lights Consortium,[3] a common industry reference. If multiple lumen maintenance values are provided for a single product, Navigant used the maximum rated life if it is at least 70 percent of initial lumen output. For example, some products report a 100,000-hour service life at L90, and if that is the lowest lumen maintenance value available for the given product, then this is captured as is (i.e., it is *not* extrapolated to estimate additional rated life beyond that cited by the manufacturer).

Table 1 documents rated life data for 22 street light fixtures from eight manufacturers. These 22 fixtures are responsible for over 7.7 MW of demand reduction, at least 38 percent of total program savings.[4] Note that many of the fixtures shown are used in multiple projects; however, the demand savings attributed here only reflects the project that the fixture's spec sheet is sourced from. Table 1 provides the Watts per fixture simply to demonstrate the diversity of equipment sizes covered in this sample. Table 1 is sorted based on the demand reduction attributed to each fixture type.

[2] L70 means at least 70 percent of initial light output is maintained for the rated useful life.
[3] See https://www.designlights.org/solid-state-lighting/qualification-requirements/
[4] One additional fixture was checked, belonging to a very large project. However, this project remains in the pre-approval state, therefore it was removed from the analysis. The rated life for that fixture is 100,000 hours, which matches the trend seen across nearly all of the fixtures reviewed.

Table 1. Rated Useful Life – Raw Data

Manufacturer	Watts Per Fixture	Project Specific Demand Savings (kW)*	Rated Useful Life (Hours) **
Leotek	39	3,131	100,000
Leotek	24	1,927	100,000
Philips	161	697	100,000
Leotek	54	234	100,000
GE	98	226	100,000
Leotek	107	204	75,000
American Electric	209	154	100,000
Philips	180	147	100,000
GE	120	122	100,000
GE	149	121	100,000
Philips	137	112	100,000
GE	130	106	100,000
GE	122	99	100,000
Philips	108	88	100,000
Kennal	109	80	100,000
Philips	73	60	100,000
Lyonsview	57	46	100,000
Matech Lighting	57	46	100,000
Lyonsview	38	31	100,000
Lyonsview	36	29	100,000
Cree	90	22	100,000
Philips	40	10	50,000

* Many projects include several fixture models, and many common fixture models are found across a wide selection of projects. The project specific demand savings shown in Table 1 represent only the demand savings attributed to the given fixture within the sampled project. A program level impact per fixture is not readily available as fixture model numbers are not included in the program database.
** Eight of the rated life used are based on L90, six are based on L80, and ten were reported as L70.
Source: Navigant

The equipment ratings shown in Table 1 are subsequently rolled in to a weighted average of 99,300 hours based on the savings associated with that fixture within the limited context of the project that was sampled for this task. For projects that deployed many different fixture models, only a subset of fixtures were compiled here, and only the savings from the sampled fixture are reflected in their associated demand savings. Given the homogeneous rated life found within the sampled equipment, Navigant is confident this result is representative of the population as a whole.

Operating Hours

The IL TRM is the source for operating hours analysis and it assumes operating hours of 4,303 hours per year which is typical for a dusk-to-dawn fixture.

Dividing the above weighted rated life (4,303 hours) by the annual operating hours results in a suggested technical life of 23 years. This is a marked increase over the IL TRM v8.0 estimated EUL of 12 years. However, the 23-year estimate is a theoretical limit for the system under test conditions and ignores natural occurrences that are expected in a real-world application (lightning, voltage spikes, wildlife, design upgrades, or the further evolution of technology). As per Navigant's manufacturer interviews and spec sheet review, four manufacturers now offer a warranty period of ten years, double the previous five-year warranty coverage. Converting this warranty period to hours of use, these extended coverage periods mean that the equipment with a 10-year warranty is now protected for the first 43,000 hours of fixture operation; adding further qualitative support to the finding that an EUL based on 50,000 hours of rated life is likely too short in light of recent product improvements.

Dimming

Navigant reviewed program data and secondary literature to determine if dimming controls would have a sufficient impact on the measure to justify accounting for them in the EUL as reported in the IL TRM. From the technical aspect, no articles were forthcoming on this topic and the product spec sheets did not address any changes to the rated life if the streetlighting included dimming. On the program side, Navigant found that only one participant included dimming controls with their street lights. Although this participant's projects account for 62 percent of the program savings, there is not sufficient adoption of dimming across participants to justify analyzing its potential impacts on the EUL as reported in the IL TRM.[5]

Surge Protectors

Navigant next checked program data to determine if participants installed surge protectors beyond those that may be built into the LED fixture itself. This was the first aspect of what was planned to be a three-part process:

1. Assess the market penetration for external surge protectors
2. Determine need for further research
3. Assess justification for varying the life expectancy of the street lighting fixtures based on the potential impacts of surge protectors installed or not

Of the projects reviewed, only one installation confirmed secondary surge protection was installed. For this project, the invoice indicates that fuses were added at street level for ease of service. As invoices varied widely from project to project, with varying degrees of itemization, this single observation is insufficient to inform a definitive conclusion on saturation rates for surge protectors.

Looking beyond what is supported in the project documentation, the research team expects that some degree of protection is built directly in to the fixture which is not called out in the application because it is an intrinsic part of the hardware. Additionally, no secondary research was found to indicate a defensible net effect of surge protectors on fixture longevity. Given the combined lack of supporting data and installation rates, this line of inquiry into the impact of surge protectors on EUL was curtailed.

Component Level Serviceability

The third system design aspect reviewed was to determine if individual fixture components could be serviced by the system operator. Navigant attempted to contact the eight manufacturers represented in

[5] Even though a high percentage of the CY2018 program savings are under dimming controls, it is the exception to the rule. Therefore, Navigant considered it inappropriate to push that exception through to the broadly applicable IL TRM.

the same sample as the rated life research. Of these, only two of the brands confirmed that individual fixture components (drivers, LED boards, etc.) were field serviceable. Four of the brands said their equipment was only serviceable if sent back under warranty. Technical support was not responsive for the last two companies and their fixtures were assumed unserviceable.

Only three percent of the sampled savings are associated with the two brands that indicate their products are field serviceable. The remaining 97 percent of the savings come from fixtures that, upon failure, must be returned to the manufacturer for service or wholly replaced. Within the three percent of fixtures that are field serviceable, it is expected that only a small fraction will require service before a complete fixture overhaul becomes more cost effective due to overall fixture age. Navigant assumes that as the fixtures approach the rated life, the probability of component level servicing decreases and the probability of a complete fixture replacement increases.

Because the overall market share of field serviceable fixtures is potentially low, Navigant cannot determine the portion of those fixtures that will benefit from this feature. To conclude, Navigant assumes that component level serviceability has minimal impact on the market weighted average EUL.

Temperature Impacts

Navigant identified studies and data related to the impact of heat on LED life expectancy. This research identified a number of key takeaways. Foremost, the Chicago area minimum daily temperature is almost always below 27ºC (80°F).[6] On average, there are fewer than 10 days a year that have any temperatures exceeding 32°C (90°F).[7] Regardless of the daytime highs, street lights typically operate at night, when temperatures are cooler and radiative heat transfer to the sky is greatest. Therefore, ambient temperatures in excess of the normal operating range are rare.

Product design must target the nominal desired operating temperature of 35°C to 45°C. Operating the LED at a higher operating temperature than it was designed for adversely affects the longevity of the LED lamp. In response to this, the Illuminating Engineering Society developed the LM-80 testing procedure dictating that LED manufacturers test for lumen depreciation at three different temperatures 55°C, 85°C and 105°C. L70 (rated life) can be extrapolated based on operating temperatures.[8] Additionally, field studies conducted by the United Arab Emirates University concluded that the LED street light operating temperatures were fairly stable even during hot days of summer (of over 40°C).[9]

Navigant reviewed product spec sheets to confirm data availability and assess general agreement with the research mentioned above. Two examples are:

- One spec sheet noted an ambient temperature range of 40°C (104°F), with optional upgrade to extend this up to 50°C (122°F)
- The second indicated an operating temperature range of -40° to 125°C (-40° to 257°F). With life expectancy declining significantly only when operating temperatures exceed 150°C (302°F)

These two examples are neither comprehensive nor definitive; however, as a leading indicator, they suggest that normal ambient temperatures are secondary to the fundamental fixture design and that the fixtures are well suited to deal with the expected range of ambient conditions.[10] Therefore, Navigant does not recommend further updates to the IL TRM in order to account for temperature impacts.

[6] The minimum temperature has only exceeded 27°C (80°F) 32 days since records began in 1870. See https://wgntv.com/2019/09/21/what-is-chicagos-warmest-nighttime-temperature/.
[7] See https://www.weather.gov/lot/Chicago_Temperature_Records.
[8] See https://asd-lighting.com/press-news/l70_ratings_and_led_lifetime/.
[9] See https://www.researchgate.net/publication/271420062_Performance_of_LED_street_lights_in_hot_environments.
[10] See https://www.ledtronics.com/technotes/technotes.aspx?id=22.

Other Environmental and External Impacts

Environmental risk factors, societal trends, and technological innovation over the next 20 to 25 years cannot be forecasted within the scope of this review. Additionally, deemed EULs in excess of 15 years are uncommon across the spectrum of typical energy efficiency measures. To remain conservative with savings forecasts of particularly impactful measures such as streetlighting, Navigant defined an adjustment to ensure the predicted savings persist as expected. Navigant recommends taking a conservative approach with adjustments to the EUL assigned to this measure. One option to provide a safety margin on savings is by derating the life expectancy to account for environmental and other external factors not captured by standard test conditions. Navigant is unaware of any definitive guidelines or regulations that would require a derating factor, or otherwise specify a specific percentage that should be applied in this situation. A summary of alternate derating factors and the resulting EUL are provided in Table 2.

Table 2. Impact of Derating Factors on Recommended EUL

Derating Factor	EUL
1%	23
5%	22
10%	21
15%	20
20%	18

Source: Navigant

Navigant's recommendation is to apply a derating factor of 15 percent. This is within reason to account for exogenous impacts without overly curtailing the expected lifetime savings of the measure. Applying a derating factor of 15 percent to the 23-year technical life found in the Operating Hours section above, yields a conservative yet robust EUL of 20 years.

Continuous Product Improvement

The original project scope for this task suggested that the rated life data be collected from product spec sheets. The intention was that this data could be indexed by the installation year to document potential trends tied to product improvements over time.

The rated life data collected as part of Task 1 supports that the measure has evolved over the last few years and the EUL has improved. The rapidity and uniformity of this increase (a single, market-wide step from 50,000 hours up to 100,000 hours) suggests that the technical improvements are incremental.

Task 2: Drill Deeper on Initial Questions and Review External Sources

In Task 2 the evaluation team built on Task 1 by including research from secondary sources and flagging data gaps that need to be shelved until the technology matures and the program life cycle is sufficient to offer further insight, or further secondary data is available.

Table 3, below, captures the Task 2 research objectives and suggestions based on the findings from Task 1.

Table 3. Secondary Research Objectives

EUL Topic	Research Ideas	Observations
Early Burnout	• Can we get, data on burnout rates for previously incentivized equipment?* • Coordinate with the Street Lighting Program to determine if burnout data is available, or if it can be captured as the program and equipment matures. • Presume the majority of equipment failure that occurs during the equipment warranty period is replaced.	• No burnout data is available in the program database; nor is it reasonable for the program to track burnout for every incentivized fixture. • A separate, dedicated persistence study would be necessary to capture this data. • Within the past few years, several manufacturers increased warranty periods from five up to ten years. • Given the high initial cost of this equipment, Navigant assumes participants will address any early burnout through the warranty.
Dimming	• Only one participant included dimming capability. Potential interview questions include: o What was their motivation for applying dimmers to their system? o What is the initial output setting (percentage of full capacity) for these installations? o How do they plan to calibrate or adjust the level of dimming over the life of the measure? o Does dimming impact the equipment's technical life? • Identify and review any readily available references that provide evidence of the impact of dimming on LED fixture life.	• Research curtailed because this control option is only used by a single participant. Therefore, any additional findings linked to this topic are unlikely to impact the EUL recommendation for the measure across the broader population.
Surge Protectors	• Identify and review any readily available references that provide evidence of the impact of surge protectors on LED fixture life expectancy.	• Navigant's findings from Task 1 suggest that there is insufficient data available to inform surge protector install rates. Therefore, additional secondary research on this topic is not justified.
Temperature	• Brief literature review to identify any readily available data on the effect of ambient temperature on fixture EUL. • Confirm L70 test protocol. • Reference regional typical meteorological year (TMY) data to determine effect of typical local temperatures on lamp performance†	• Secondary research, test procedure documentation, and product spec sheets consistently indicate that the fixtures are well suited to deal with the expected range of ambient conditions.

EUL Topic	Research Ideas	Observations
Product Improvement	• Rated life data collected from product spec sheets should be indexed by the installation year to document potential trends tied to product improvements. • Plot data to identify any trends or notable impacts of product improvement that are expected to continue in the near future.	• The rated life data collected as part of Task 1 supports that the measure has evolved. • Given the stairstep nature of the recent life expectancy and homogeneous data set, a new EUL is proposed. • Continue to monitor for signs of future technology improvements reaching the market and revisit accordingly.

* This early in the product life cycle, it will be difficult to get data directly from historical program participants. Additionally, most installations are within the warranty period.
† The value of this information will need to be gauged relative to results from the initial literature review. Further review will only be pursued if the impact on the EUL is greater than +/-20%
Source: Navigant

FUTURE RESEARCH

One of the primary concerns raised by the EUL research to date is that of measure persistence. However, measures incentivized by the ComEd Street Lighting Program have not been in place long enough to inform this through direct measurement at this time. Therefore, Navigant recommends revisiting the EUL for street lighting in two to three years for data on more installations, as well as, any burnout information.

The two primary topics suggested for a future update are:

- Burnout monitoring
- End of life maintenance schedule

As covered in the Early Burnout section of Task 2, burnout monitoring is advised on an on-going basis, particularly once the program has accumulated a few additional years of data.

Given the lack of product serviceability noted in the findings from Task 1 and the probability of stepped technological advances noted in the product improvement section of Task 2, Navigant finds it highly probable that any early fixture failures will be replaced on a one-off basis. Once the service life of the fleet is reached, it is likely the bulk of the fixtures will be replaced en masse. Given these initial findings, further review of the end of life maintenance schedule is unnecessary at this time.

RECOMMENDATIONS

Navigant recommends pursuing an IL TRM update changing the EUL for LED based street lights from 12 to 20 years.

Additional near-term research is unlikely to result in a meaningful (multi-year) impact on the recommended EUL. Therefore, the remaining Task 2 items should be retracted from the current scope of work.

Fixture failure rates and dimming control adoption rates are worth revisiting in two to three years (Task 3), once additional program history is available to support insights on market trends and equipment longevity.