Street Lighting in Salem

University of Oregon
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### Pitt Streetlight Report

Comparison of light-emitting diode (LED) streetlights to high-pressure sodium (HPS), metal halide, and induction lamps

<table>
<thead>
<tr>
<th>Light Technology:</th>
<th>LED</th>
<th>HPS</th>
<th>Metal halide</th>
<th>Induction</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of U.S. streetlamps:</td>
<td>Less than 1</td>
<td>39</td>
<td>27</td>
<td>6</td>
</tr>
<tr>
<td>(total: 131 million)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost per bulb (USD):</td>
<td>9 to 322</td>
<td>12</td>
<td>27</td>
<td>280</td>
</tr>
<tr>
<td>Wattage:</td>
<td>105</td>
<td>150</td>
<td>162.9</td>
<td>109</td>
</tr>
<tr>
<td>Bulbs per 100,000 hrs.:</td>
<td>1.7</td>
<td>4.17</td>
<td>8.28</td>
<td>1</td>
</tr>
<tr>
<td>(vs. one induction)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂ per 100,000 hrs.:</td>
<td>300</td>
<td>450</td>
<td>500</td>
<td>320</td>
</tr>
<tr>
<td>(million kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO₂ per 100,000 hrs.:</td>
<td>1.1</td>
<td>1.6</td>
<td>1.7</td>
<td>1.15</td>
</tr>
<tr>
<td>(million kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFCs per 100,000 hrs.:</td>
<td>4.5</td>
<td>6.4</td>
<td>6.8</td>
<td>4.7</td>
</tr>
<tr>
<td>(kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ecotoxicity:</td>
<td>175</td>
<td>240</td>
<td>260</td>
<td>180</td>
</tr>
<tr>
<td>(million kg of 2,4-D/100,000 hrs.)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiration Impact:</td>
<td>90</td>
<td>100</td>
<td>110</td>
<td>95</td>
</tr>
<tr>
<td>(thousand kg of PM2.5/100,000 hrs.)**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color temperature, brightness:</td>
<td>5,000</td>
<td>2,000</td>
<td>3,000-4,000</td>
<td>5,000</td>
</tr>
<tr>
<td>(degrees Kelvin)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Ecotoxicity was expressed in kilograms of 2,4-Dichlorophenoxyacetic (2,4-D), a common herbicide.
** Respiratory impact was expressed in kilograms of particulates designated as “fine,” or less than 2.5 microns in diameter (PM2.5).

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Image: University of Pittsburgh
### Efficiency

<table>
<thead>
<tr>
<th></th>
<th>Philips 36879-5</th>
<th>General Electric 44047</th>
<th>EverLast Type III Cobra</th>
<th>Global Green EW-3870FX</th>
<th>IQLED Luminaire</th>
<th>Neptun Kometa</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td>HPS</td>
<td>HPS</td>
<td>Induction</td>
<td>Induction</td>
<td>LED</td>
<td>LED</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>~$15</td>
<td>$28.50</td>
<td>~$500</td>
<td>~$262</td>
<td>$1,600</td>
<td>—</td>
</tr>
<tr>
<td><strong>Lifespan (hours)</strong></td>
<td>24,000</td>
<td>24,000</td>
<td>100,000</td>
<td>60,000</td>
<td>50,000</td>
<td>100,000</td>
</tr>
<tr>
<td><strong>Wattage</strong></td>
<td>250</td>
<td>250</td>
<td>70</td>
<td>85</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td><strong>Lumens</strong></td>
<td>28,500</td>
<td>28,000</td>
<td>5,900</td>
<td>5950</td>
<td>10,600</td>
<td>11,200</td>
</tr>
<tr>
<td><strong>Lumens per watt</strong></td>
<td>114</td>
<td>112</td>
<td>84</td>
<td>74</td>
<td>118</td>
<td>112</td>
</tr>
<tr>
<td><strong>CRI</strong></td>
<td>21</td>
<td>21</td>
<td>82-85</td>
<td>80</td>
<td>—</td>
<td>75</td>
</tr>
<tr>
<td><strong>CCT (Kelvin)</strong></td>
<td>2100</td>
<td>2100</td>
<td>5000</td>
<td>6,500</td>
<td>5500</td>
<td>5000</td>
</tr>
</tbody>
</table>

![Efficiency Graph](image)
BENCHMARKING: COST V. LUMENS PER WATT
LEDs & Their Application to Street Lighting:

Single die LED arrays are more reliable than preexisting bulbs, as well as multi-die LEDs. They can save up to 50% on energy costs while being conveniently compact. However, they do require more extensive heat management— if the heat is not measured properly, the LED life span will decrease and will eventually die out completely.

Overall, there will be a 40% reduction in the number of street lights in well lit areas, as well as a 50% reduction in energy costs. In total, there will be a 60% decrease in annual lighting costs throughout Salem.
Multi-die LED arrays are generally much less reliable because each element has to be soldered into the circuit board (often by hand in china), vastly increasing the number of potential failure points. Single die LEDs are chemically etched the same way microprocessors are, making them much more reliable.
Mesh Networking in Street Lights:

Mesh Network allows for low-power, short-range wireless network

Central Control
Wireless mesh networks, an emerging technology, may bring the dream of a seamlessly connected world into reality. Wireless mesh networks can easily, effectively and wirelessly connect entire cities using inexpensive, existing technology. Traditional networks rely on a small number of wired access points or wireless hotspots to connect users. In a wireless mesh network, the network connection is spread out among dozens or even hundreds of wireless mesh nodes that “talk” to each other to share the network connection across a large area.

Mesh nodes are small radio transmitters that function in the same way as a wireless router. Nodes use the common WiFi standards known as 802.11a, b and g to communicate wirelessly with users, and, more importantly, with each other. Nodes are programmed with software that tells them how to interact within the larger network. Information travels across the network from point A to point B by hopping wirelessly from one mesh node to the next. The nodes automatically choose the quickest and safest path in a process known as dynamic routing. The biggest advantage of wireless mesh networks -- as opposed to wired or fixed wireless networks -- is that they are truly wireless. Most traditional “wireless” access points still need to be wired to the Internet to broadcast their signal. For large wireless networks, Ethernet cables need to be buried in ceilings and walls and throughout public areas. In a wireless mesh network, only one node needs to be physically wired to a network connection like a DSL Internet modem. That one wired node then shares its Internet connection wirelessly with all other nodes in its vicinity. Those nodes then share the connection wirelessly with the nodes closest to them. The more nodes, the further the connection spreads, creating a wireless “cloud of connectivity” that can serve a small office or a city of millions.

The Internet is the world’s largest mesh network. Information travels across the Internet by being bounced automatically from one router to the next until it reaches its destination. The Internet is often depicted as a “cloud” or “web” of connectivity because of the billions of potential paths across which data can travel.

Wireless mesh network advantages include:

Using fewer wires means it costs less to set up a network, particularly for large areas of coverage. The more nodes you install, the bigger and faster your wireless network becomes.
They rely on the same WiFi standards (802.11a, b and g) already in place for most wireless networks.
They are convenient where Ethernet wall connections are lacking -- for instance, in outdoor concert venues, warehouses or transportation settings.
They are useful for Non-Line-of-Sight (NLoS) network configurations where wireless signals are intermittently blocked. For example, in an amusement park a Ferris wheel occasionally blocks the signal from a wireless access point. If there are dozens or hundreds of other nodes around, the mesh network will adjust to find a clear signal.
Mesh networks are “self configuring;” the network automatically incorporates a new node into the existing structure without needing any adjustments by a network administrator.
Mesh networks are “self healing;” since the network automatically finds the fastest and most reliable paths to send data, even if nodes are blocked or lose their signal.
Wireless mesh configurations allow local networks to run faster, because local packets don’t have to travel back to a central server.
Wireless mesh nodes are easy to install and uninstall, making the network extremely adaptable and expandable as more or less coverage is needed.
PERSONAL INTERVIEWS:

1. How long have you lived in Salem for?

I was born in Salem. I grew up there so, for 20 years.

2. What public areas do you use the most? (Parks, city centers, etc.)

Minto Island Brown I use the most hands down. Also, downtown, since I work at the Y downtown. And schools in my neighborhood.

3. Do you think those places would benefit with better street lighting around the facilities?

Minto Brown island is a park and I like that it is very natural. Therefore I don’t think it needs more lighting. I think downtown is also pretty well lit. However areas such as long stretches of roadways could use more lighting. Especially roads that have curves. Most parks I use, however, seemed to be lit ok.

4. Would you be more attracted to other public areas if the lighting were better?

Possibly.

5. Are there any specific areas that you feel need improvement in lighting?

Not that I can think of.

6. What outdoor activities do you participate in Salem?

Walking the dog at parks, softball tournaments at Wallace marine park... Walking around downtown and field trips with the YMCA such as the park by the capitol building. Playing sand volleyball at the Chemeketa courts.

7. Would the quality of those activities benefit from improved lighting? Or lighting with options?

The sand courts at Chemeketa could definitely use better lighting and make it available for playing at night.

8. Are there opportunities for nighttime outdoor activities in Salem if the lighting were improved (outdoor concerts, dances, games, etc.)? If so, what areas would you like to see the lighting improved in?

I’m from south Salem, so I would like more outdoor activities at this area.

9. How concerned are you about making the lighting improvements eco-friendly?

I would much rather them be eco friendly. However, I really dislike those lights that are an orange-yellowish color and resemble yellow street lights.

10. Are there specific areas of automobile traffic/travel that you know of would benefit from improved lighting? (Areas where a lot of traffic accidents occur) I can’t really think of one right now, sorry!
1. How long have you lived in Salem for?
I've lived in Eugene for 18 years.... Salem, ZERO

2. What public areas do you use the most? (Parks, city centers, etc.)
I go to Alton baker a lot, or campus

3. Do you think those places would benefit with better street lighting around the facilities?
YES. Alton baker is pretty dark and aside from 13th street or university street, the pathways on campus are pretty dark

4. Would you be more attracted to other public areas if the lighting were better?
Yes, I would feel more comfortable to go on night jogs and things of that sort. Or to just hang out downtown

5. Are there any specific areas that you feel need improvement in lighting?
I think the design of the lights could be more attractive, as well as their brightness.

6. What outdoor activities do you participate in Salem?
I go to volleyball tournaments sometimes in Salem. And In Eugene I just walk around campus on weekends

7. Would the quality of those activities benefit from improved lighting? Or lighting with options?
Yes. The sidewalks are terrible and it can be hard to see if there are places where you might trip... Add darkness with the general college students drinking activities, and there can be problems.

8. Are there opportunities for nighttime outdoor activities in Salem if the lighting were improved (outdoor concerts, dances, games, etc.)? If so, what areas would you like to see the lighting improved in?
I sometimes play games like Fugitive, and in that case, depending on what team you are on, lighting could be either pro or con. If there was better lighting in public parks, I would feel more comfortable going there in the night time to hang out

9. How concerned are you about making the lighting improvements eco-friendly? eco-friendly would be a plus, but if that increased the cost and could possibly stop lighting improvements from happening because of financial issues, then I would take non-eco friendly lights over eco-friendly lights.

10. Are there specific areas of automobile traffic/travel that you know of would benefit from improved lighting? (Areas where a lot of traffic accidents occur).
The alleyways on campus can be pretty dark sometimes and difficult to see pedestrians, as well as some of the cross-streets close to campus
ONLINE SURVEY:

How We Get Where We’re Going

Daytime Transportation

Nighttime Transportation

Cars

Walking

Bus

Bikes

Walking

Bus

Bikes

Cars
Would You Change Your Habits If Your Routes Were Better Lit?

35% would be more inclined to bike or walk if lighting was better.
Other concerns included:
Unsafe to travel alone
Bad weather conditions
Traveling long distances
Parking

Most difficult things to see at night:
Pedestrians
Bicyclists
Street signs
Lane markings
Animals & other obstacles

Are Lights Used Effectively in your neighborhood?
Yes: 53%
No: 36%
No Streetlights: 11%
Primary Concerns:
Bad visibility in spite of the lighting
Lights weren’t bright enough
Not enough lights
The area felt unsafe in spite of the lighting

Other concerns regarding streetlights:
Consistent lighting, eliminating dark spots
Aesthetics of light poles
Light color temperature
Efficiency and cost of operation

Most Common Reasons for Travel After Dark:
Home from School
Home from Work
Out to restaurant or entertainment
Out to friend or family activity
Shopping
Licht per Anruf: On-Demand Street Lighting

In Germany, the municipalities of Rahden, Lemgo, and Dorentrup have successfully adopted a system where residents can turn streetlights on only as needed simply by dialing their cell phones.

Residents register their phone numbers into the Dial4Light database, and then are able to call Dial4Light and dial in their route number for instant street lighting. Standard streetlights are free to use, but people who wish to use large flood lights at sport fields and the like must pay a small fee.

Pros:

• Saves energy by eliminating unnecessary streetlight use

• Reduces electricity costs

• Reduces light pollution

• Makes residents more responsible for their energy use

• Can operate from mobile or land-line phones

Cons:

• Requires one to remember route numbers to activate the correct streetlights

• Requires use of a phone

• Not well suited for large cities where there is more activity at night

Germany’s Green Idea:
Streetlights on Demand - TIME
Dial4light - Licht per Anruf
Anchorage is bullish on LED street lighting. Mayor Mark Begich commissioned a year-long evaluation of various LED street lights to prove the performance and suitability of this new technology for use on Anchorage roadways.

In July 2008, he announced appropriation of $2.2 million to enable the city to purchase LED fixtures to replace about 140,000 cobra-head-style street lights throughout the city.

“We have studied new lighting technology extensively over the past several months to validate energy and maintenance-cost savings. We have also conducted a lighting conference and public survey that indicated our residents overwhelmingly approve of the new white LED lighting,” said Begich. “With this feedback and estimated cost savings of approximately $1.5 million annually, we are confident about moving ahead with the broad deployment of LED lighting for our roadways.”

The LED street lights in Anchorage are returning a 50-percent energy savings over the fixtures they replaced, which is saving the city approximately $360,000 a year in energy savings alone.

Dan Howe, Deputy City Manager, City of Raleigh, NC

*The City spends substantial amounts of money every year replacing and maintaining lighting. What the LED City initiative means is not necessarily that we will be spending more, but spending more wisely on emerging technology that will save a lot in the long run... The whole point of declaring this public/private initiative is to develop a long-term plan to save money and take advantage of LED technology to spend smartly. The goal is to get the best lighting value for the citizens of Raleigh and serve as a model for other cities seeking to do the same.*

Dan Howe, Deputy City Manager, City of Raleigh, NC
Case Study: Brazil Traffic Lights

Brazilian City’s LUXEON-Based Signals Slash Energy Costs 90%

Cities throughout the U.S. and Europe have been replacing incandescent-based traffic lights with LEDs since the 1990s, drawn by the dramatic cost savings of a light source that consumes roughly 10% of the power required by incandescent lamps. Developing countries have been slower to switch to LED traffic signals in part because of limited capital budgets, but a project in a large suburb of Sao Paolo, Brazil, may light the way.

Instead of completely replacing each traffic fixture with the standard dome-shaped LED traffic signal ball integrating an LED array, optical lenses and color filter in a single housing, the Brazilian city of Guarulhos retrofitted 5,370 incandescent lamps in 1252 vehicular and 807 pedestrian traffic signals with custom light bulbs illuminated by high-power LUXEON® I LEDs from Philips Lumileds (www.philipslumileds.com).

Spearheaded and funded by electric power distributor Bandeirante Energia S.A (www.bandeirante.com.br/energia) with approval from the Brazilian federal government, the project has slashed signal-related energy usage in Guarulhos by nearly 90%. The savings of 1340 megawatt hours per year is enough to power about 558 Brazilian households. It has also chopped approximately USD$240,000 (R$434,200) per year off the city’s electricity expenditures, freeing funds to add over 300 new traffic lights to improve safety and traffic management.
The initiative cost approximately USD$750,000 (R$1.35 million) and paid for itself in 12 months through a combination of energy savings and maintenance reductions made possible by long LED life. “We’re not only saving money but we’re saving energy as well. It’s good for the city budget, and it’s good for the environment too,” said Paulo de Tarso Carvalhaes, Illumination and Energy Director, City of Guarulhos, São Paulo State.

Combating Energy Waste

The Guarulhos LED retrofit project was inspired by Federal law #9991, passed July 24, 2000. Under that law, Brazil’s energy companies are required to invest 1% of their total revenues on initiatives aimed at reducing energy use. In 2005 Wagner Silvestre, energy efficiency consultant for Bandeirante Energia, began investigating the use of LED traffic lights to help fulfill the requirement.

“I was familiar with LED traffic signal balls that require replacement of the entire traffic signal enclosure, but our local Philips Lumileds representative showed me a new and less expensive LED product developed by a Brazilian company that looked like a regular light bulb and could be changed just as easily. That seemed like a good fit for our needs and resources,” Silvestre said.

Silvestre submitted a proposal to the Agência Nacional de Energia Elétrica (Electric Energy National Agency, or ANEEL)—part of the Mines and Energy Ministry of Brazil, and the government agency that enforces the energy conservation law—to replace all existing green, yellow and red traffic lights, arrows and pedestrian signals in Guarulhos with the new LED bulbs. The plan got the green light in November 2005.

With a population of nearly 1.3 million and one of Brazil’s main airports, Guarulhos is the largest city served by Bandeirante Energia, the second largest city in São Paulo state and the 12th largest incorporated city in Brazil. That made it an ideal showcase for the new LED bulb, which until that point had been used only in a few tiny Brazilian towns as a proof of concept.

New Breed of Bulb

The sample bulb that impressed Silvestre was developed by Meng Engenharia Ltda (www.meng.com.br), a Brazilian company specializing in highway, urban and industrial signaling projects. The lamp was based on a prototype created by engineers at Philips Lumileds in California, who nicknamed it the “bulbeon” because of its resemblance to a conventional light bulb and its use of the company’s LUXEON brand of power LEDs.

Project Wins National Award

The LED retrofit traffic light project in Guarulhos, Brazil, earned a first-place Rational Use and Energy Conservation National Award from the Mines and Energy Ministry of Brazil in 2007. The annual award recognizes initiatives that reduce the use of electric energy and/or oil or natural gas derivatives in favor of renewable sources.

The award was given to Bandeirante Energia S.A., the electric power distributor that initiated the project. Bandeirante Energia provides electric energy to 1.4 million customers in 28 cities in the State of São Paulo. Guarulhos is the largest city served by the utility.
Meng Engenharia adapted the prototype to traffic light applications in a version containing seven LUXEON I LEDs per bulb, a built-in power supply, and the standard E-27 screw-in base used in South America. The distribution of the LEDs across the bulb was designed to replicate the basic radiation pattern of an incandescent bulb filament. The LEDs were positioned to work with the existing reflector inside the traffic light head to avoid the expense of reflector replacement.

Municipalities using this approach can convert their traffic lights by simply unscrewing the old incandescent lamp and screwing the new LED bulb into place. This eliminates the time involved in dismantling the entire traffic head as required with LED traffic signal balls. It also eliminates the need to employ specially trained work teams to perform the upgrade.

**LUXEON-Enabled Energy Savings**

The payoff comes in lowered energy consumption and related savings in electric bills. Thanks to LED technology in general and LUXEON efficiencies in particular, the bulb designed by Meng Engenharia has a 10-watt maximum rating—one-tenth of the 100 watts required to run the conventional traffic lights used in Guarulhos and one-sixth of the 60 watts that drive the city’s pedestrian signals.

The bulb’s actual energy usage in Guarulhos has been measured at even lower than 10 watts since the installation was completed in late 2006. The upshot: the power consumed for the city’s vehicular and pedestrian traffic lights on a yearly basis has plummeted from 1520 megawatt hours before the LED retrofit project to just 180 today.

One of the reasons is that LEDs produce far more light and far less heat per watt than incandescent bulbs because of the inherent characteristics of solid-state technology. Another is that no watt-age is wasted on generating unneeded colors and then having to filter them out to produce red, yellow or green signals, since LEDs can produce those colors directly. The LUXEON LEDs used in the Guarulhos bulbs maximize these advantages with industry-leading energy efficiency achieved through advanced engineering.

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**Benefits at a Glance**

- Reduced traffic light energy consumption 90%
- Slashed USD$240,000 off annual electric bill
- Easy field replacement with regular work crews
- Bulbs last 5-10 times longer than incandescents
- Reduced maintenance costs
- Helped utility comply with energy-saving law
- Paid for itself in 12 months
- Freed funds to install additional traffic lights
**Model for Other Municipalities**

Equally important is the longevity of the bulb. In contrast to incandescent traffic lights that must be replaced every one or two years, LUXEON-based luminaires can run non-stop for 10 years. This offsets the higher costs of the LED fixtures, reduces bulb replacement costs over the long term and lowers manpower expenses for manually changing light bulbs, adding to the savings in energy bills.

With its relatively low capital cost, maintenance advantages and ability to provide a fast LED retrofit without replacing the entire traffic light enclosure, the strategy used in Guarulhos offers promise for developing countries dealing with limited resources and less stringent traffic signal standards than those in North America and Europe.

“This same bulb model can be used anywhere in Brazil, elsewhere in South America or in other developing countries to retrofit incandescent traffic lights. It’s relatively inexpensive, it’s reliable, and it doesn’t require expert technicians to make the switch from incandescent to LED fixtures,” said Alberto Montoro, CEO, Meng Engenharia. “With this strategy, even cities and countries with limited resources can migrate to LED signaling.”

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**“This same bulb model can be used anywhere in Brazil, elsewhere in South America or in other developing countries to retrofit incandescent traffic lights. It’s relatively inexpensive, it’s reliable, and it doesn’t require expert technicians to make the switch from incandescent to LED fixtures.”**

- Alberto Montoro
  CEO, Meng Engenharia

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http://www.ledcity.org/Anchorage.htm
ABSTRACT
Growing concern for the environment has spurred interest in environmentally conscious design and manufacturing. The concept of Design for the Life Cycle encompasses all aspects of a product's life cycle from initial conceptual design, through normal product use, to the eventual disposal of the product. A product's architecture, determined during the configuration design stage, plays a large role in determining the product's life cycle characteristics. In this paper, modularity of product architectures with respect to life cycle concerns, not just product functionality and structure, is defined and applied in the analysis of architecture characteristics. A principal hypothesis underlying this work is that high degree of life cycle modularity can be beneficial across all viewpoints of interest because all interested people will view the product similarly and consistently. An architecture decomposition algorithm from the literature is adopted for partitioning architectures into modules from each life cycle viewpoint. Two measures of modularity are proposed: one that measures module correspondence between several viewpoints, and another that measures coupling between modules. The algorithm and measures are applied to the analysis and redesign of an automotive center console. Results of applying the algorithm and measures accurately reflected our intuitive understanding of the original center console design and predicted the results of our redesign. Furthermore, these measures incorporate only configuration information of the product; hence, can be used before detailed design stages.

MOTIVATING EXAMPLE: An Automotive Center Console
An automotive center console often contains many features such as an armrest, a storage area, a cupholder, and vent controls (if back seats need air, as in a sedan) in order to perform many functions. Measured conventionally, a center console exhibits a fairly high modularity. Let us assume that a design team wants to improve an existing design of a center console (CC) with respect to life cycle issues including material recycling, component reuse, and service for a new vehicle release. Typically, a CC contains many different subassemblies, components and materials that complicate such a design task. The center console used as the example in this paper is from a 1993 Chrysler LHS and is shown in Figure 1. In Figure 1, modules which contain compatible materials (i.e., materials that can be recycled as a mixture and thus do not have to be separated before recycling) are highlighted. To be more specific, assume that the design team wants to reconfigure the CC by using modularity as a product architecture strategy. Essentially, the CC is a module by itself (of the car interior). However, there are many subassemblies and components contained within the console that can be intelligently reconfigured into modules by way of material choice, post-life intent, and spatial location. Not every subsystem or detail in the CC will be included in this design problem, but nineteen different console components will be used in the example.

PRODUCT ARCHITECTURE AND MODULARITY
Configuration design is the process of synthesizing product structures by determining what components and subassemblies are in the product and how they are connected and arranged spatially. Establishing the product structure involves the selection of modules and the design of module interfaces. Modularity is the concept of separating a system into independent parts or modules which can be treated as logical units. The way in which a product is divided into modules has a great affect on the way it is assembled, disassembled, serviced, and retired (among other things). The challenge, then, is to develop methods for configuration design that enable designers to meet requirements on modularity applied to all life cycle viewpoints of interest (assembly, service, recycling, reuse, etc.).
Ulrich and Tung (1991) gave a summary of different types of modularity and their advantages and disadvantages. Benefits of modularity include simplified assembly and disassembly, improved serviceability, easier maintenance, and differential consumption. Potential costs of modularity include redundant physical architecture (due to decreased function sharing), excessive capability due to standardization (designing for the most rigorous application), and the potential for static product architectures and excessive product similarity. The authors also contend that modularity is a relative property that depends on two characteristics of a design: (1) Similarity between the physical and functional architecture of the design, (2) Minimization of incidental interactions between physical components. Accordingly, complete modularity is achieved when there is a one-to-one correspondence between the physical and functional architectures. In fact, in (Ulrich & Eppinger, 1995), the authors state that “Perhaps the most important characteristic of a product’s architecture is its modularity.” The modularity of a product influences its initial cost, ease of service (disassembly and reassembly), and effort required to retire the product. If a product must be disassembled to recycle its materials or reuse any of its components, the way in which these components are arranged into modules is of utmost importance.

For example, car alternators are often recovered for remanufacturing after the car is retired. As a rule of thumb, the quicker and easier it is to remove the alternator from the car, the more economically feasible its remanufacture.

REDESIGN: Center Console
Reducing the number of materials, intelligently clustering compatible materials, and rethinking the post-life intent and service needs could all be beneficial to the modularity assessment and will be pursued here. For example, the complicated retractable cupholder design (which is made up of a mixture of plastic and metal components) could be changed to a single piece of molded ABS plastic that simply attaches to the same spots. Notice that in addition to improving the material recyclability of this component, this sort of configuration change affects the expected serviceability. Whereas the complicated original design is expected to have a frequent need for service due to the many moving parts, the new design should require no service. Changing the Post Life Intent of the cupholder assembly from incineration to recycling also helps this component fit into a module with other components slated for recycling. Other simple changes, such as making the Latch and Front_bracket out of ABS instead of POM and steel, respectively, making both the Foam and Pad out of polyurethane foam (PUR), and making the Bezel entirely out of ABS instead of a mix of materials were also made. Changing the post-life intent for the Pad from incineration to reuse provides a couple of advantages in this modularity evaluation: 1) it rounds out the elimination of the incineration category, helping to tighten the correspondence between viewpoints, and 2) it further groups the Pad with the Foam component, as they have been configured with the same material as well.
The real key here is the Modularity measure that depends upon both the correspondence and independence aspects of modularity. The positive effects of some simple configuration changes were predictable before the redesign was evaluated and verified by its evaluation. While the Modularity measures for the redesign are still not close to unity, they are significantly better than the original console design's measures. This experiment helps to provide support for the usefulness and correctness of the metrics.

CONCLUSIONS
The application of product modularity to design for the life cycle practices has been explored in this paper. Specifically, modularity with respect to life cycle viewpoints, not just product functionality and structure, was defined and applied in the analysis of product architecture characteristics. An algorithm to partition an architecture into modules for a given viewpoint was presented. Two measures of modularity were proposed to measure module correspondence between several viewpoints, and to measure coupling between modules. An automotive center console was analyzed and redesigned based upon the results of applying the measures. Results of this study are summarized as follows:

- the concept of life cycle modularity leads to a uniform method of reasoning with the implications of life cycle requirements on a product’s architecture;
- the proposed measures accurately reflected our intuitive understanding of the original center console design and predicted the results of our redesign;
- these measures incorporate only configuration information of the product; hence, can be used before parametric and detailed design stages;
- the decomposition algorithm works effectively for asymmetric and non-square matrices.

The results of this preliminary study are promising. A more complicated example of an automotive interior is currently underway to better exercise the decomposition algorithm and modularity measures. Other current work includes developing modularity measures for later design stages that consider more detailed information, deriving specific redesign suggestions from the modularity measure results, and integrating the algorithm and measures to our CAD system for architecture analyses directly from assembly models of products. Further collaboration with industrial sponsors will better ground the concepts of life cycle modularity in design practice.

ACKNOWLEDGMENTS
Financial support from NSF, Grant No. DMI-9414715, is gratefully acknowledged. We also acknowledge the Chrysler Corporation for their donations of automotive components.

REFERENCES


PROJECT OBJECTIVE

The City of Salem is currently pursuing options for improving its downtown streetscape with a focus on upgrades to its electrical infrastructure. The driver behind this movement is tied to a street paving program that is expected to be implemented over 3 years, starting during the summer of 2010. The immediate objective of this project is to analyze where additional street lighting will be required to meet the City’s future electrical needs. An analysis and inventory of the existing electrical infrastructure was required to determine where additional services may be desired. The long-term objective for this project is to develop a location plan for future streetscape lighting and electrical service in the downtown core.

PROJECT STUDY AREA

The area of primary concern is the downtown core between Marion Street and Ferry Street to the North and South, and Front Street to High Street, East to West (as shown on the plan sheets in section 3). Data was also collected that stretches North from the project study area up High Street to Hood Street.

MEETING THE OBJECTIVES: “THE PROCESS”

This project involved strategic coordination between Portland General Electric and Salem Electric, the two electric providers for the downtown core. The service boundary between the two companies is shown on the plan drawings located in section 2, and is basically divided by Commercial Street. Both agencies supplied as-built information of their existing systems. This as-built information along with point tie data, has been provided in Appendix A, B, and C. A lighting inventory (sheet EX 1.0) was created using the provided as-built information along with on-site field verification.

A Lighting Study was performed by the City of Salem based on I.E.S. lighting standards (Appendix H). This data was used to create an optimum lighting layout using pedestrian scale lighting and street lighting to achieve the required minimum standards. Using this street light data, a typical block lighting plan was created (shown on sheet EX 2.1).

Based on the typical proposed block lighting layout, a plan was generated to show lighting deficiencies within the project study area (sheet EX 2.0). This plan shows that the majority of the study area does not meet the desired lighting levels. A master plan for the proposed Streetscape Lighting was created (sheet SP 1.0) showing the lighting improvements needed to bring the deficient areas up to the optimum illumination levels.

Included in the City of Salem’s goals for future development was the addition of Electrical Vehicle (E.V.) charging stations. A plan was created to show the potential locations for these fixtures (Sheet SP 2.0). Guidelines for the deployment of the E.V. Charging stations can be found in appendix I.

The proposed electrical demands were then coordinated with PGE and Salem Electric to determine the appropriate method and location for providing power to these elements. In discussions with PGE and Salem Electric it was determined that all future electrical fixtures would need to be served by meters. The E.V. charging stations would be served in separate meters in order to quantify and measure the usage of the electricity. PGE and Salem Electric provided additional plans (Appendix K and L) showing the proposed meter location and the related transformer connections.

An electrical circuitry plan was then created by WHPacific to determine the number of meters and meter locations. (Appendix M). The circuitry plan was also used to identify the required conduit street crossing locations. In addition, the circuitry plan has taken into account the need for additional “Christmas Lighting Outlet” (Appendix G). All of this circuitry information was compiled on sheet SP 3.0. This Proposed Metered Service and Conduit Location Plan was used to create cost estimates related to future installations of these facilities.
### City of Salem Dowtown Streetscape Infrastructure Study

**Preliminary Document**

**City of Salem Downtown Streetscape Infrastructure Study**

**Preliminary Document**

**City of Salem Downtown Streetscape Infrastructure Study**

**Preliminary Document**

**City of Salem Downtown Streetscape Infrastructure Study**

**Preliminary Document**

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**PART II - TOTAL COST TOIMES TWO (TWO TIMES)**

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**PART IV - TOTAL COST TOIMES TWO (TWO TIMES)**

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City of Salem - Downtown Streetscape Infrastructure Study
3.1.2 Isofootcandle chart

An isofootcandle chart is used to describe the light pattern a luminaire produces. These charts show exact plots or lines of equal footcandle levels on the work plane with the fixture at a designated mounting height.

An isofootcandle curve for a typical cobra head HPS luminaire is shown below.

Once the CU is determined, the isofootcandle chart can be used to determine the Minimum Maintained Illumination Value and other discrete points in the system.

Isofootcandle Chart Example:

Before using the isofootcandle chart, the point at which the minimum maintained illumination value is desired must be determined. For purposes of example, assume 120 feet to the right or left of the current position. This is a longitudinal distance along the roadway that will depend on actual pole spacing. The following steps should be followed:

1. Enter the isofootcandle chart at the Luminaire Position point and move left to the correct Ratio of Longitudinal Distance to Mounting Height. In this case the ratio would be 120/40 or 3.0.
2. If required, move up or down to correct for the exact luminaire position in relation to point of interest (no correction for our example).
3. Read the illumination factor directly from the isobar, use interpolation if required. In this case, the value would be 0.0125. This value represents the uncorrected footcandles at the location tested.

This information is used to determine the proper spacing and design standards, which are discussed in detail in Chapter 4.

This data shows the inefficiencies of existing street lights: casting light evenly around its base rather than focusing the light on desired areas. It can be concluded that through the use of lenses and a new fixture shape, street light efficiency could be greatly increased while reducing overall costs.
Two curves are shown in the graphic, one for the street side (normally the desired area to be lit) and one for the house side (the direction away from the primary lit direction). The street curve represents the utilization of the bare lamp, in percent, as the ratio of transverse distance to mounting height increases.

CU Calculation Example:

1. To obtain the pavement area CU, enter the CU curve for the Street Side at the correct transverse distance to mounting height ratio. In this case, the ratio would be 46/40 or 1.15. Follow the chart up until you reach the Street curve and read the Utilized Lumens (in percent). This results in 36 percent.

2. To obtain the shoulder area CU, enter the CU curve for the Street Side at the correct transverse distance to mounting height ratio. In this case, the ratio would be 10/40 or 0.25. Follow the chart up until you reach the Street curve and read the Utilized Lumens (in percent). This results in 10 percent.

3. The CU from the “triangle” that forms from the luminaire to the near pavement edge is subtracted from the “triangle” that forms from the luminaire to the far side pavement edge. This results in a CU of approximately 26 percent.
SITE DOCUMENTATION

Salem, OR
Analysis:

After two visits to Salem, OR (one during the day, and one during the night) it became very apparent that the lighting in the downtown area was redundant, and there was a lot of excess and unnecessary light in a single area.

This inspired us to create a system that would cover a large area with light using fewer fixtures. To do this, the system would need to be adaptable to various scenarios and would therefore accommodate the city in several locations.

Modularity would also benefit the system by adding more opportunities for adaptation as well as ease in maintenance and repair.
**EXISTING LIGHTING ANALYSIS**

Type: Cobra head  
Height: 20'  
Power: 250 W  
Measured Illuminance (footcandles):

Type: Cobra head  
Height: 30'  
Power: 250 W  
Measured Illuminance (footcandles):
ANALYSIS:

Upon research, it was found that there was still sufficient lighting even after the light meter had a reading of zero Footcandles. Using this information, we designed fixtures with the goal in mind of using less lighting more efficiently. Specifically, removing redundancies and improving the performance of necessary fixtures in the city of Salem, OR.

Sylvania Light Meter
- measures illuminance in footcandles with +/-5% accuracy
- range from 0-2000 footcandles
Cardboard Light Layout Model:

Ideal/Proposed Lighting Layout:

As lighting needs change, you can simply change out the lens and get an entirely new footprint from the same 'bulb'.

15 poles along 1 block

5 poles along 1 block

One pole supports multiple lighting elements, depending on the situation.

Changing the orientation of intersection lighting.
Site Layout:

This layout shows how effective the ViperHead system would be in lighting the streets and sidewalks of downtown Salem, OR.
Our proposed plan concentrates the light to the width of a standard 4-lane road, while maintaining the same length coverage.

Primarily using lenses, our goal is to eliminate the brightest points in the middle and push that light to expand the 1 foot candle zone. At the same time, we keep more light on the road by narrowing the focus of the beam.
In major intersections, the lighting would still be effective using minimal poles due to the overlapping areas of light. Two main poles on opposing street corners would shine into the middle of the intersection to cover the greatest surface area possible. Both pedestrians and cars would have substantial lighting to behave as they wish.

Proposed Pedestrian Lighting:
By grouping them together and piggybacking off the streetlight poles where possible, we can reduce the visual clutter while maintaining the same or improving the quality of light.
Modular light units
up to 8 in one pole
with various lengths

Hinge

Leather cable with clamp to
lower fixture for easy
maintenance

LED stop
pedestrian lighting

Will not work with hanging
planters

Unit lock together

Signed: Leif Sylvest
6/6/11
Solar panel is above the tree canopy, the light is below.

Can be done with/without existing light poles.

Eliminates dark spots.

Light source to reduce light pollution.

Larger streetlights for residential neighborhoods:
- Sit below large trees.
- Provide more light to pedestrians so they can be seen.
- Maybe dimmer but more consistent than standard streetlights.
Maintenance

Light & Electronics at ground level

Pivot point allows for maintenance without blocking the street with a vehicle or ladder

Lock box protects system; only accessible by those w/ a key (or code)
The Viper Head: Pedestrian Version
Cardboard form study and development focusing on modularity and multipurpose designs:
Modular fixture design. Upper right: Pedestrian Lighting. Lower left: street lighting.
CAD RENDERINGS

- Pole segment
- Fixture connector poles
- Pole cap
- Pole connecting collar
- Fixtures
- Lenses
Sample Street Layout

Lighting Configuration Options:
In Use:
Street Lighting:

- Width: 13.5" (34.29 cm)
- Height: 7" (17.78 cm)
- Depth: 16.75" (42.53 cm)
Pedestrian Lighting:
Several advancements in lighting systems are currently being made today, though the primary focus is to transfer preexisting systems into ones that support LEDs. Based on research, observation, and form exploration, we have concluded that the next step in lighting advancement is creating an implementing a modular system that works with the LED trend. Benefits from utilizing a system made of different components are listed below:

-- Eco-Friendly:
Parts would only be created as the community needed them. Also, if a pole were to get damaged, the single damaged part could be replaced rather than the entire system, using as little materials and effort as possible. Also, fewer modular poles would do the job of several preexisting poles.

-- Ease in Maintenance & Repair:
If a single part were damaged or needed replacement, the modular system would allow for the maintenance crew to identify and replace just that part, rather than replacing a larger system.

-- Ease in Installation:
The modular system can be easily added onto preexisting systems. Installation in a new spot can also be easily done because having multiple parts allows the system to accommodate any urban or industrial scenario.

-- Adaptable:
Once LED’s are replaced by something more efficient, the modular system can be broken down and adapt to the new technology without having to replace the entire system.

-- Energy Efficient:
The use of LED’s will help reduce energy costs and decrease the amount of maintenance needed of the life span of the light. Overall, energy costs would be reduced by 60%.
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