THE VALUE PROPOSITION

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AT THE CROSSROADS OF INTERSECTIONS

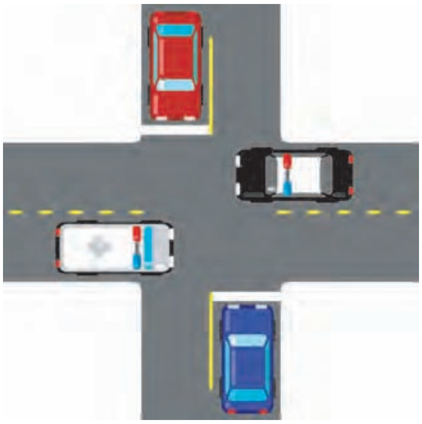
A valid benefit metric can lead us toward new ways to light roadways

As suggested in a recent installment of this column by Peter Boyce (*LD+A,* November 2014), quantifying the value of many types of roadway lighting can be challenging. Driving at night involves a number of different visual tasks with different requirements—some involve on-axis vision and others off-axis, some involve a lot of thinking while others are almost reflex-like. Undoubtedly, lighting should provide benefits for drivers for these tasks, but at the right place and time. A major challenge for the roadway lighting specifier is identifying the right place and time, for the right benefits.

The new edition of ANSI/IES RP-8-14, *Roadway Lighting*,[1] begins to address this challenge by asking the specifier to consider if and when roadway lighting provides benefits beyond, for example, those already provided by systems such as car headlights. Ultimately, weighing the benefits of lighting against the costs to determine its value.[2] In this column, I'd like to consider one specific roadway application—lighting roadway intersections—to see how we can quantify, economically, the benefits and hence the value of lighting.

A WIDE SWATH

Few would doubt that lighting roadway intersections has tangible benefits in terms of safety. Many studies over several decades suggest that lighting intersections can reduce nighttime crashes, by amounts ranging from about 10 percent to more than 60 percent. The 10 percent value is probably more accurate because lighting is rarely the only safety feature found at potentially unsafe intersections. Unfortunately, most studies haven't controlled for factors like signs, turn lanes, improved markings or signals that often accompany roadway lighting, and the benefits of lighting from those studies is probably inflated.



Nor are all intersections the same. In a recent study,[3] the benefits of roadway lighting, as currently practiced for urban and rural intersections with and without traffic signals, were estimated. Statistical models, accounting for other roadway features as described above, revealed that lighting was more beneficial at urban intersections than at rural ones. Why? Rural intersections are dark—why wouldn't lighting help reduce crashes there? It might have to do with the way we illuminate rural intersections, with one or two streetlights at the junction of the intersection, and with no other lights.

Here's a thought experiment. You're stopped at a rural intersection at night, waiting to turn onto the intersecting road. You see the oncoming headlights of a car approaching from a few hundred feet away. Do you have enough time to turn? Without roadway lighting, all you see are oncoming headlights. If the car were under a streetlight, you would see not only headlights but also the car's body (figure) and the surrounding terrain (ground). This figure-ground information would make it easier to judge how fast it was moving and whether you should turn or not. But even if the intersection were lighted, streetlights at the junction wouldn't illuminate a car that was a few hundred feet away, so lighting couldn't help you decide. It wouldn't provide a meaningful benefit.

VALIDATING THE BENEFITS

In his action plan for demonstrating the benefits of lighting, Peter Boyce demands clear epidemiological evidence and a plausible mechanism involving lighting. The aforementioned statistical study[3] provides the epidemiology for roadway intersection lighting, but is the mechanism underlying my thought experiment plausible? Yes: most crashes at intersections are between vehicles, and misjudging the relative speed of other vehicles is a major cause of those crashes.[4] Making these judgments is an on-axis visual task, where visual performance is well described using conventional, photopic light levels.

But light level alone is not the right benefit metric, because it doesn't predict how quickly and accurately a driver can see. In addition, the contrast and size of the object to be seen, as well as the age of the person doing the seeing, determine visual speed and accuracy. The relative visual performance (RVP) model includes these factors, and predicts visual speed and accuracy for many nighttime driving tasks.[5]

Roadway intersection lighting differs from situations where pedestrians or other hazards show up in peripheral vision at nighttime light levels, or where pedestrian judgments about personal security are important. For these situations, metrics involving mesopic vision and scene brightness perception exist. There isn't yet epidemiological evidence supporting those benefit metrics, but there are plausible mechanisms.[2]

Returning to RVP as a benefit metric for roadway intersection lighting, we estimated the increase in visibility for making figure-ground judgments under different light levels, different lighting configurations like junction-only or continuous lighting, and in urban and rural ambient conditions. Visibility improvements were smallest for junction-only rural intersection lighting and largest for urban intersections. Even more, the improvements were proportional to the statistical nighttime crash reductions associated with lighting at different types of intersections.[3] The relationship between the statistical and visibility approaches supports the validity of RVP as a relevant benefit metric for lighting at roadway intersections.

PREDICTIONS WE CAN COUNT ON

The beauty of having a valid benefit metric is not so much in confirming what we already know—that roadway intersection lighting as currently practiced can reduce nighttime crashes—but in helping make predictions about new ways to light intersections. For example, instead of lighting a rural intersection with a single streetlight throughout the night, we could install multiple streetlights along the legs of the major intersecting roads, giving drivers figure-ground information they need. Not only would this improve visibility seven-fold compared to business as usual, it should yield a seven-fold crash reduction at night.

Or, we could allocate lighting energy differently throughout the night through adaptive lighting controls, using more light when traffic volume is high and less when volume is low. Based on hourly patterns of nighttime traffic throughout the night, an adaptive lighting strategy like this could almost double the visibility and crash reduction benefit, with no change in overall energy use.

From a decision-making perspective, we can quantify the monetary costs of lighting in terms of equipment, energy and maintenance. And, since we can estimate the visibility improvement from roadway intersection lighting using the RVP model, we can estimate the expected nighttime crash reduction benefit from that lighting. Further, because authorities have defined the financial losses associated with crashes ranging in severity, we can quantify the economic value of crashes avoided because of roadway intersection lighting.

For roadway intersection lighting to have a net positive value, the ratio of its benefit to its cost should exceed a value of one. For rural intersections, this occurs only when the daily traffic volume on the main intersecting road is about 1,900 vehicles per day or greater.[6] If the traffic volume is lower, the costs of lighting outweigh the economic benefits because not enough people experience those benefits. With higher traffic volumes, the economic benefits outweigh the costs.

THE ROAD AHEAD

This example is specific to roadway intersection lighting, where most crashes are between vehicles and where mainly on-axis vision is important for avoiding crashes. In other applications, like residential streets with many young children, or animal crossings, off-axis vision could be important for safety, and the spectral content of roadway lighting might be much more important. In other locations, safety might not even be the dominant concern, but rather peoples' perception of personal security, such as in an urban downtown district.

Quantifying the value of lighting in these situations will require different metrics, but the basic framework for understanding value is the same as I've outlined above. A valid benefit metric that can be quantified economically, like RVP for safety under roadway intersection lighting, will provide lighting specifiers with a sound basis for making decisions.

However, even when we cannot yet quantify visual benefits economically, there is no need for paralysis. We can use benefit metrics like mesopic vision or perceived brightness, which already have plausible mechanisms involving lighting, to specify lighting that provides the same or greater benefits as those provided with existing practices, perhaps with lower costs, thus enhancing the value.[2] And if a valid benefit metric is unknown, researchers will have a path forward to answer the questions needed to develop it. Either way, the road toward value-driven lighting can be made clearer.

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