In this article we will identify adaptive roadway lighting architectures, describe data used to drive adaptive roadway lighting applications, and examine the Systems Engineering Process (SEP) as defined by the US Dept. of Transportation. Additional learning objectives include developing project-specific user needs, functional requirements, and a traceable test plan needed by the SEP. Lastly, we’ll examine innovative public/private partnerships, particularly in the area of energy savings.

Questions answered by this white paper include:

- What is the data that will drive adaptive roadway lighting?
- When will these applications actually come to be installed?
- Do we really know all these technologies and systems will work together smoothly and seamlessly?
- Who will pay for it?

**What Data Will Drive Adaptive Lighting?**

The data that drives adaptive roadway lighting originates in both fixed and mobile infrastructure.

Fixed infrastructure includes traffic signals, environmental sensors, and other data from the utilities and the Smart Grid (Figure 1).

Traffic signals, particularly the advanced traffic controller (ATC) soon will be able to provide traffic signal information to the lighting system, including for pedestrian lighting applications (Figure 2). The ATC is a Linux-based traffic signal control computer that can run multiple applications including intersection control, ramp metering, dynamic message signs, roadway lighting, and connected vehicle systems. Each of these internal applications runs independently; however, data is able to be shared between applications so if a pedestrian presses the crosswalk button, the crosswalk signal can be actuated and the crosswalk lighting can be enhanced. Similarly, if road friction as reported by connected vehicles has decreased due to rain or snow, the dynamic speed limit signs can display a lower safer speed limit.

Environmental sensors include ambient light level sensors, weather stations, and many other devices. Utility inputs to the lighting system, “Smart Grid” data can include current electricity rates.

Mobile infrastructure includes vehicles, pedestrians, and bicyclists (Figure 3). The greatest impact to the lighting systems controls will be integration of “connected vehicle” and “connected pedestrian/bicycle” technology. The National Highway Transportation Safety Board, in conjunction with the US Department of Transportation, is developing standards and deployment application scenarios that can reduce traffic accidents by up to 80 percent. These technologies broadcast 100 different message types such as speed, direction, and location both to adjacent vehicles within 1,000 feet as well as to mobile phones and fixed infrastructure, such as the lighting system and the...
traffic signal equipment. The message types used by the lighting system can include road friction, ambient light level, headlight status, windshield wiper status, and more. US DOT mandates are expected in this area.

Other Smart Grid inputs to the lighting systems can originate from data sources other than the utility itself (see Figure 5). These can include signals from the network operations center, the electrical distribution network itself or service providers. This data flow is bidirectional where the lighting and the entire transportation network can provide a forward-looking time and price-based forecast of how much power will be needed — and at what price.

The US DOT NTCIP framework as shown in Figure 6 describes three major areas of communications domains, protocols, and standards. These are connected vehicle (V2I), center-to-field communications (NTCIP12XX), and center-to-center communications for adjacent traffic management centers (TMC).

This significant upgrade required for true adaptive roadway lighting systems and the larger traffic management network is composed of many technologies, protocols, and standards. Unambiguous well-formed standards are required so that communications between varied sub-systems occurs reliably and in almost real-time. National and international standards are used rather than standards from smaller trade and user groups.

In order to confirm that all systems work with each other, the US DOT requires the use of the Systems Engineering Process (SEP). The SEP process includes the development of user needs and the development of measurable functional requirements that are dependent upon those user needs. This allows creation of an un-
ambiguous test plan so the user needs can be confirmed as satisfied by the delivered project.

When evaluating standards, it is important to remember the term “standards” is very broad. The standards used in this evolving effort are the product of nationally and internationally recognized Standards Development Organizations such as IEEE, ITE, AASHTO, NEMA and NTCIP — The National Transportation Communications ITS Protocol. The US DOT standard NTCIP 1213 governs “Electrical and Lighting Management Systems.” It is commonly known as “ELMS.” Figure 7 describes the range of standards, their stakeholders, and the geographical breadth of their applications.

The SEP Vee model is represented in Figure 8. Use of the Vee SEP model starts at the upper left side of the Vee. First a “Concept of Operations” is developed, then the system design can proceed. During this process, first-user needs are solicited from the various groups of stakeholders. They are then refined into requirements. The system design is complete once the project developer reaches the bottom of the Vee. By proceeding up the right side of the Vee, the project developer enters the integration phase of the project, where verification and validation of sub-systems, and eventually the full system, occurs. Lastly, a test plan is developed and performed so the project recipient can confirm that all user needs are satisfied.

This technology upgrade occurs at a cost — as do all things. Adaptive roadway lighting systems do benefit from a significant savings of energy over previous generations of lighting technology. Light Emitting Diode (LED) technology can save up to 70% of current energy usage as compared to high pressure sodium lighting. The addition of controls can save even more.

This energy saving can be rededicated in the agency budget to outright purchase of new lighting systems. In a number of proactive agencies, this savings has been used to fund innovative public/private partnership models that allow lighting projects to be installed years ahead of other methods. The chief scenario in this case is that of a municipal or agency lease, very similar to how agencies currently lease fire and EMS trucks and equipment. Typically a lease can run four to eight years.
at a total monthly cost (energy + lease payment) lower than the cost of current energy use by the current legacy system. At the end of the term the title for the lighting equipment then reverts to the agency. With new lighting systems having warranties of ten years and functional lives of much longer, this makes for a compelling business case.

In summary, many technological enhancements are coming to our streets and highways. These include integration of the fixed roadway infrastructure (lighting, signals) with mobile infrastructure (vehicles and people). This convergence will drive many applications that save lives, energy, and other resources. Assisting in this effort are creative new finance models including agency leasing programs.