New Technology: Traffic Engineering Applications

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INTRODUCTION

New technology is being used to a greater and greater degree in the field of traffic engineering. This paper presents three different applications of new technology in the traffic engineering field: photovoltaic systems (solar energy); a new system for sign lighting; and new technologies for variable message signs.

PHOTOVOLTAIC SYSTEMS

Photovoltaic systems, which convert solar energy into electrical energy, are now beginning to be used for a variety of highway engineering applications in the United States. Photovoltaics describes a process in which sunlight is converted into direct current electrical energy. In a typical application, sunlight is collected during daylight hours, converted into direct current electricity, and stored in batteries.

Photovoltaic systems can be practical and economical in areas that have high insolation (solar radiation) and that lack a conventional utility power supply. Because it can cost $10,000 to $20,000 per mile to extend a conventional utility power line, a photovoltaic system can be economical if a power line is more than a short distance away.

There are at least ten applications of photovoltaics in highway engineering in the United States known to the author. They are described below.

Overhead Guide Signs on Freeways. At least four states — California, New Mexico, Arizona, and Florida — have installed these systems. The oldest systems were installed in California in 1984. Arizona State University designed, constructed, and field tested a system in Arizona in 1987. The systems in New Mexico were installed at a cost of $5,500 per sign, which is very competitive with the cost of extending a utility line. Similar photovoltaic systems are being used in the southwestern United States and in other parts of the country to illuminate outdoor advertising signs.

Roadway Illumination. At least three states — California, Hawaii, and Arizona — have used photovoltaics for parking lot or roadway illumination. The first two states used a low pressure sodium light source, while the Arizona system powered a high pressure sodium light source.

Power Supply for Flashing Warning Lights. An Arizona system was installed to power two red flashing warning lights used to draw the motorist's attention to a Stop sign. Unlike the lighting applications, this system requires power 24 hours per day. A system in Utah's Zion National Park is designed to flash warning lights only in the event of emergencies. Thus, the power requirement for this system is much smaller.

Power Supply for Permanent Traffic Counting Stations. This is perhaps the oldest and most widespread use of photovoltaics. South Dakota, in 1982, was powering ten continuous count automatic traffic counters with solar energy. That state's research found that solar power was cost effective and reliable for this purpose. Utah and Idaho are other states that have used solar energy for this purpose.

Power Supply for Railroad-Highway Grade Crossing Warning Devices. In 1979 Alaska installed a solar powered system for flasher signals at a railroad-highway grade crossing. This system is unusual because, at this northern latitude (63 degrees north), there are very long hours of sunlight in the summer and very short hours of sunlight in the winter. Fortunately, there are fewer train operations per day in the winter; the system provides adequate power supply in all seasons.

Power Supply for Dust Storm Warning System. Arizona had a unique dust storm warning system from 1977 through the late 1980's. High winds, blowing dust and dirt through the air in southern Arizona sometimes produce very limited visibility. A series of dust storm warning signs was installed to warn motorists of impending reduced visibility. When the potential for a dust storm was high, the message on these signs was changed from a passive message to a warning message. The solar powered energy supply was used for the sign's radio remote control and for changing the message on the sign.

Power Supply for Irrigation Controllers for Roadway Landscaping. The California State Department of Transportation is using solar energy for automated irrigation controllers. The agency has over 25 square miles of landscaping and much of it requires irrigation.

Large Scale Power Supply for Remote Highway Maintenance Stations. The largest highway application of solar energy in the United States is probably the Caples Lake maintenance station in the rugged Sierra Nevada mountain range. This location is remote and far from utility lines. Until 1985 the station's electrical power was provided by two diesel generators that used 40,000 gallons of diesel fuel a year. About 15,000 gallons of propane was used each year for space heating and heating water.

In 1985 a large photovoltaic system was installed that now provides most of the heat and light at the maintenance station. Although a generator still provides a backup in the event of cloudy weather or high power demand, diesel fuel consumption is now only about 4,000 gallons per year.

Cathodic Protection of Bridge Decks. Reinforcing steel in concrete bridge decks tends to corrode, particularly in locations where salt is used for snow and ice removal. Corrosion can be retarded by use of cathodic protection, a method by which a small electric current is passed through the reinforcing steel. Photovoltaics were used at one location on the George Washington Parkway in Virginia to charge batteries that provided the electric current for the cathodic protection.

Power Supply for Motorist Call Boxes. Selected segments of U.S. freeways have motorist call boxes, a telephone-like device located at the edge of the shoulder at one-half to one mile intervals. Call boxes can be used by motorists with mechanical difficulties to summon assistance. California has several locations where individual call boxes are powered with photovoltaics. If power is derived from solar energy, and if radio is used as the communications medium, there can be substantial savings compared to call boxes connected by underground conduit.

Photovoltaics have been and are being used on an experimental basis for a wide variety of highway engineering applications. In some instances, such as solar powered traffic counting stations, application has moved from an experimental stage to one of routine use in some states.

Use of photovoltaic power supply is practical and economical in selected situations. Generally, the amount of available sunlight must be high and a conventional electric power supply not available to make it economical. A photovoltaic power supply is also more practical where the power requirements are relatively small.

A NEW SYSTEM FOR SIGN LIGHTING

A recent research project at Arizona State University designed a new system for lighting overhead guide signs on freeways that substantially reduces power consumption, requires less maintenance, and is much more economical.

Many states are faced with growing costs for electric power for highway uses. Caltrans (the California Department of Transportation), for example, had its electric power costs for lighting about 15,000 overhead guide signs increased from $1 million in 1977-78 to $2.2 million in 1982-83. The objective of the Arizona research project was to determine if alternative lighting systems could result in reductions in power consumption and maintenance requirements while still providing for the needs of the motorist. The needs of the motorist include adequate legibility distance, uniformity in the lighting displayed on the sign face (a factor in legibility), a lack of visual discomfort (such as glare), and acceptable color rendition.

Arizona had traditionally used fluorescent lighting for its overhead guide signs. The research project considered mercury vapor, metal halide, high pressure sodium and low pressure sodium as alternatives, as well as a variety of lamp sizes and fixtures. Theoretically, there are scores of combinations of light sources, lamp sizes and fixtures that could be used for a lighting system. A lighting expert recommended twenty-five systems for possible consideration. Each was subjected to photometric testing in a laboratory to determine its potential field performance. Ten systems were selected for field testing for a one year period under actual operating conditions in a freeway environment. The ten test systems included each of the light sources listed above and a variety of fixtures.

During the one year field test, a major activity was observer studies. Thirty observers were hired to evaluate each system at night. Because of the known effects of age on visual acuity, nighttime vision, glare recovery, and other factors, the hired observers were composed of 15 individuals ages 18 to 33 and 15 individuals ages 61 to 86. Each observer was a licensed driver and passed a simple visual acuity test to assure that they met the 20/40 vision requirement for driver licensing. Each observer was seated as a passenger in a vehicle and driven past the ten test sites.

Legibility distance (the distance from which a sign could be read) was measured. There was not a great deal of difference in legibility distance among the ten lighting systems. The shortest legibility distance for the older group of observers was 794 feet (average) while the longest legibility distance for the younger group of observers was 952 feet (average).

Uniformity of lighting (differences between very bright spots and very dark spots on a sign) has an impact on sign legibility. Observers were asked to subjectively evaluate lighting uniformity. Some of the fixtures tested in the study did a very good job of taking a point source of light and spreading it out uniformly over a large sign face. Other fixtures did not perform as well. Observers did note some variation in lighting uniformity among the ten signs.

Viewing comfort refers to any visual discomfort that a driver may experience. This may be from glare, from a sign that is too bright in a dark environment, or due to a sudden transition from a bright area (a brightly lit sign) to a dark area. Observers noted some variation in viewing comfort among the ten signs.

Color rendition refers to any distortion in color due to a light source; i.e. the sign appears a different color at night than in daylight. High pressure sodium showed some color distortion (green backgrounds appeared "muddier" and darker). Low pressure sodium resulted in severe color distortion (yellow letters on a dark gray background).

Power consumption was measured once per month during field testing. All of the alternative systems consumed less power than the traditional fluorescent lighting system. The three most efficient systems used only 35 percent, 30 percent, and 28 percent as much energy.

The Illuminating Engineering Society and the American Association of State Highway and Transportation Officials have developed illumination standards for sign lighting which specify how much illumination a sign should receive. During field testing, the luminance of each sign was measured with a telephotometer; each system provided enough illumination to meets the standards.

An economic analysis was performed for each system. Initial costs for fixtures, lamps, installation (labor and equipment) were amortized to determine an annual owning cost. Annual operating costs included electric power, washing of lamps and fixtures, lamp replacement, and ballast replacement. The total annual owning and operating cost varied considerably among the ten systems. The traditional fluorescent system had a cost of $423 per year for an 8 foot high by 20 foot wide sign. All other systems were less expensive. The cheapest was $115 per year.

Based upon the observer study results and the economic analysis, a system was recommended consisting of a 150 watt high pressure sodium lamp and a fixture manufactured by the Holophane Corporation. The fixture is one which does a very good job of taking a point source of light and spreading it out over a sign face. The new system allows one high pressure sodium fixture to replace two fluorescent fixtures on an average size sign panel, thereby reducing installation and maintenance costs. Comparable illumination levels are maintained even though only one-third as much power is consumed. Of the ten systems tested, this one had the longest legibility distance, the lowest total annual owning and operating cost, and an acceptable level of color distortion, according to the observers.

An economic analysis conducted by the Arizona Department of Transportation showed that if the approximately 600 overhead guide signs in the state were converted to this system, a net savings of $4 million would be realized over a 25 year period. The savings would be in energy and maintenance costs. Using FHWA demonstration monies, lighting systems were converted in 1987 and 1988.

NEW TECHNOLOGIES FOR VARIABLE MESSAGE SIGNS

Intelligent vehicle-highway systems (IVHS) is an area that is now receiving a lot of attention. Freeway management systems (freeway surveillance and control systems) represent the current state-of-the-art in IVHS. Among other functions, freeway management systems identify accidents, incidents, points of congestion or other problems, provide this information to the motorist and, sometimes, recommend motorist actions such as route diversion. One way these systems communicate with the motorist is through variable message signs (VMS).

Variable message signs are able to present a variety of messages by creating letters through a matrix of points on a sign face. A lamp matrix is the oldest technology. A flip-disk technology is newer and has been used extensively. Two very new technologies for roadway applications are light emitting diode (LED) and fiberoptic.

Variable message signs will receive extensive use in the future as more freeway management systems are installed. In the Phoenix area alone, a planned freeway management system is expected to have eighty-eight variable message signs within about ten years.

A recent research project in Arizona compared the flip-disk, LED and fiberoptic technologies. In many respects this study was similar to the sign lighting study described above. Legibility and viewing comfort were again evaluated using two groups of younger and older observers. A third parameter — target value — was also evaluated. Target value refers to the "noticeability" of a sign, or the sign's ability to capture the attention of the driver. Power consumption was measured and an economic analysis performed.

Four flip-disk, two LED, and four fiberoptic signs were installed on the Phoenix area freeway system and evaluated. Each sign had three rows of 18 characters each. Letter heights were 18 inches on each sign.

One difference between the sign lighting study and the variable message sign study was that observer studies were conducted under a variety of lighting conditions. The sign lighting study only considered nighttime performance. The VMS study evaluated variable message signs at night, in the daytime, and in the early morning and late afternoon when bright sunlight may shine directly on the sign face or cause a strong silhouette when the sun is directly behind a sign.

The flip-disk sign did not perform as well as the LED or fiberoptic signs in terms of target value and legibility distance. Generally, the fiberoptic sign performed better or about equal to the LED sign, depending upon the lighting condition and the age group.

In terms of power consumption, the LED signs consume power to dissipate heat generated by the light emitting diodes. The fiberoptic signs do not require heat dissipation. As a result, the LED signs consume substantially more electric power.

The initial cost of the fiberoptic signs, based on bid prices, was $118,003 each. This included the sign, controller cabinet, sign controller, and testing. LED signs cost $141,437 each. An economic analysis was performed (for the LED and fiberoptic signs) that considered the annual owning cost, annual power cost, and the relative maintenance cost (on an annual basis). The fiberoptic signs were found to have an annual cost of $5,000 to $6,000 less than the LED signs.

CONCLUSION

New technology will continue to be developed for traffic engineering applications, both for intelligent vehicles and highways and for other applications. New technology will provide many advantages, including economy and safety. The traffic engineering community needs to identify, develop, and implement new technology to better serve the highway user.

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