Demand

Peak energy demand (power) may play a role in lighting costs in areas where penalties are placed on users who contribute to peak demand.

IMPLEMENTATION

Figure 2 indicates the effect of lamp performance on the expected cost of maintenance. Points A through E refer to the equivalent reference lines drawn on the right vertical of Figure 1. In a lighting system composed of lamps performing at 50 percent of advertised capability (reference line A in Figure 1) that were replaced at burnout with lamps of equivalent operational (as opposed to advertised) capability, the cost of maintaining the system would be 100 percent greater (point A in Figure 2) than the amount budgeted for the time period. In relating Figure 1 to Figure 2, it can be seen that the performance of the first three groups in Figure 1 could have raised the expected maintenance cost of a lighting system composed exclusively of those lamps and fixtures by 100-900 percent of the expected cost.

In considering the fourth group in Figure 1 (Lamp B, Fixture X) and relating reference line E in Figure 1 to point E in Figure 2, it would appear that this combination would yield substantial savings. However, if a group replacement policy that was based on the manufacturer's lamp mortality data had been in effect, then the indicated savings would not have been realized; the lamps would have been replaced in groups at approximately 92 percent of their advertised life (13 800 h). It must be noted that in 1977 no major lamp manufacturer recommended group replacement of HPS lamps.

It is apparent that the users must find some method to protect themselves from manufacturers of inferior products. The low-bid requirement, in an area such as lamp purchases, can cause a user to incur a substantial maintenance liability through the mandatory purchase of a less than satisfactory product.

The city of Seattle (2) and the state of Idaho (3) have used a life-cycle costing approach to implement a partial solution to this problem. Whether their approach is adequate is yet to be determined.

In order to achieve the savings indicated in Figure 2, group replacement that is based on manufacturer-supplied data must be eliminated in favor of either replacement after individual burnout or a group replacement system that is based on in-house data. The economic feasibility of the latter approach is questionable and needs to be evaluated before serious thought is given to its implementation.

The potential benefits of this study will be largely determined by the effectiveness of the steps taken by users to require performance at the level advertised.

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Abridgment

Pavement Inset Lights for Use During Fog

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Reduced visibility as a result of fog presents a very hazardous condition on the highway because motorists are unable to readily observe pavement markings and signs and the movement of traffic. Afton Mountain, which is traversed by I-64, is often the site of such reduced visibility because of the low cloud cover on the mountaintop during rainy periods.

An acute awareness of the fog problem on Afton Mountain led to a decision by the Virginia Department of Highways and Transportation to install a lighting system that consists of pavement inset lights and low-level illumination lights to aid motorists during periods of fog. The installation was made on a 9.3-km (5.8-mile) section of highway that encompasses the top of Afton Mountain. Since fog often occurs on only a portion of the mountain, the installation was divided into three sections that represent the points observed to most often correspond with the fog patterns. Each section is controlled by two fog detectors, located at or close to the endpoints of the section, that are capable of detecting five levels of fog density. The intensity of the guidance lights within each section is controlled by the density of the fog at each detector.

The fog guidance system consists of unidirectional airport runway lights installed in the pavement edge line along each side of the roadway in both directions, spaced at 61-m (200-ft) intervals on tangent sections and 30.5-m (100-ft) intervals on curved sections. In addition to the white inset lights on the main line, amber lights are installed on one side of the off-ramps. Also, low-level illumination lights are installed on a short section of an on-ramp.

It was felt that the lighting system would help delineate the highway and thus lead to an improvement in traffic operations. However, it was not known how the system of lights would affect vehicle speeds, headways, and placement. Also, there was some concern that the system might promote a false sense of security and lead to higher speed and greater differentials in speed, which would increase the possibility of accidents. It was, therefore, the purpose of this research to investigate the traffic flow characteristics during fog within the system of pavement inset lights installed on Afton Mountain.

The scope of the study included the collection and analysis of traffic flow data before and after the lights were installed. The parameters evaluated were vehicle speeds, headways, queues, and lateral placement. A before-and-after accident analysis was also made. Because of the variability of fog densities for the period of study and the limitations on the time, personnel, and funding allocated for the study, it was not possible to collect traffic flow data for all fog conditions.

METHOD

The effect of the system of lights on the traffic flow characteristics was determined by comparing data collected before and after the system was installed. Data were collected for all fog conditions (day and night) occurring during the time allowed for the project. The collection of data was limited to weekdays and to off-peak hours.

For the accident study, data were obtained from the Division of Motor Vehicles.

Site

One location on the two westbound lanes of I-64 over Afton Mountain just east of the Blue Ridge Parkway was chosen for data collection. This location, which had an annual average daily traffic count of approximately 5000 vehicles for the period 1973-1976, is on the level section of the mountaintop and has a slight horizontal curve to the right. There are no interchanges in advance of the site for a distance of 11.3 km (7 miles). Data were collected at only one site.

Collection of Data

Data were collected before (11/27/73—5/1/75) and after (1/26/76—9/30/76) installation of the lighting system by using tape switches placed on the highway. Under clear, dry conditions the tape switches were attached to the road surface with double-faced tape. During adverse weather, they were attached to 0.56-mm (0.022-in) metal ribbons stretched across the highway and fastened to metal anchors in the shoulder and the median.

Data from all the tape switches were recorded simultaneously on a four-channel chart recorder; the switches were identified by assigning different voltages to each. Since the distance between the tape switches on the road and the speed of the chart recorder were known, vehicular speeds and headways were determined by measuring the distances between impulses on the chart.

Vehicle placements were obtained by installing tape switches of different lengths on the right edge of the traffic lane and noting which switch combinations were activated.

The chart recorder was placed in a vehicle parked approximately 304.8 m (1000 ft) past the site to eliminate any influence the parked vehicle may have had on traffic flow. Also, the switches were not conspicuous to motorists.

Weather Conditions

The fog problem considered is one caused by low cloud cover in the mountainous areas. Although the fogs are relatively dense and uniform, variable fog conditions, fog banks, and so on do occur at the edges of the cloud cover and in areas under broken clouds that result from clearing weather. For the evaluation, data were taken only during uniform fog conditions extending at least 152.4-304.8 m (500-1000 ft) in advance of the test site.

Fog Density

It was very important that a relative measure of fog density be obtained, because this influences traffic flow characteristics. The density was determined by noting the number of visible centerline stripes on the pavement during daylight hours and the number of reflectorized shoulder delineators during hours of darkness. These distances were used to identify relative fog densities in the analysis of the data.

Since the tape switches were approximately 304.8 m from the data recorders, the fog densities and the uniformity of the fog were monitored by driving through the site at regular intervals.

RESULTS

The numerous variables associated with the project, problems encountered in data collection during adverse weather conditions, and the time frame in which it was possible to collect the data limited the quantity of data collected. Therefore, the study results reflect only those data for which comparable before-and-after conditions were available.

Speeds

The installation of the pavement inset lights has resulted in a decrease in daytime speeds and an increase in nighttime speeds. For all the sight distances tested in fog during daytime and nighttime, there was a significant increase in the variability of speeds for automobiles in the traffic lane in the after period. Results for the remainder of the comparisons showed no differences for automobiles or tractor-trailers, with the exception of automobiles in the passing lane for a sight-distance interval of 33.5-45.7 m (110-150 ft) ahead of the data collection point. The decrease in daytime speeds is explained by the fact that during daylight hours, within the range of sight distances encountered in fog, the motorist can see at least two or three centerline skips [12.2-m (40-ft) intervals; 4.6-m (15-ft) painted line]; however, the uniqueness of the system, in addition to some glare associated with the lights, caused the motorist to slow down. It is felt that when the data were accumulated the inset lights were a little brighter than they needed to be, which caused the glare and deceleration, and that, once experience allows a realistic coordination between the sight distances in fog and light intensities, speeds will tend to be closer to those found in the before conditions.

Daytime fog creates restrictive driving conditions; however, it is during nighttime fog that driving becomes difficult, primarily because of the driver's inability to see pavement markings and delineators whose retroreflectivity is significantly reduced under night or wet-weather conditions. Also, the reflection of the vehicle's headlights from the fog seriously restricts the motorist's visibility. The significant increases in speeds during nighttime fog give strong support to the contention that the inset lighting system provides additional delineation for guidance. However, it should be noted that the increase in speed at night for the after condition increases the accident potential, since even the nighttime speeds before installation exceed those required for a safe stopping distance.

Safe Stopping Distance

For all conditions investigated (before and after), the actual sight distances were less than the safe stopping distances, a finding that indicates that drivers tend to go too fast for sight distances in fog. It is noted above that the increase in nighttime speeds since the installation of the lights raises the accident potential as a result of the increased stopping distances required. However, the low traffic volume encountered on this rural section of Interstate highway, especially at night, leads to a decrease in vehicle interaction that lessens the significance associated with the safe stopping distance. Also, the improved delineation is thought to help prevent vehicle stoppages along the roadway.

Headways

A review of the headway data showed little difference in headways between the before and after conditions during the hours of daylight. However, available data showed a decrease in nighttime headways (below 3 s) after the inset lights were installed. This finding, coupled with results that showed less vehicle queuing in the after condition, indicates that motorists were using the inset lights for guidance rather than relying on car following.

Queuing

There was a decrease in daytime vehicle queuing for the sight distance of 33.5-45.7 m (110-150 ft) but little difference within the range of 45.7-61.0 m (150-200 ft). At night, for both sight distances considered, there was a decrease in vehicle queuing. There was little difference in the numbers of vehicles in the queues. The increase in headways and decrease in vehicle queuing at night might indicate a reduction in the potential for accidents under the lighting system. However, it should be noted that, for severely restricted sight distances before the system was installed, vehicles tended to form queues for the purpose of being led through the fog, which may be thought of as being safer than having no one to follow.

Lateral Placement

During daylight, the lateral placement of automobiles was farther from the right edge line after the lights were installed. Also, the placement was farther from the edge line during fog for both the before and after periods than it was during clear weather conditions. Both automobiles and tractor-trailers were positioned farther from the edge line for nighttime fog conditions than for clear conditions.

Accidents

It would be difficult to surmise what, if any, increase in accident potential would result from the differences noted in traffic flow parameters. There has been only one accident during fog conditions since the system of lights was installed. Also, in a recent subjective evaluation of the system, more than 95 percent of the motorists interviewed indicated that they were aided by the system and 90 percent reported that the lights reduced their anxiety while driving in fog (1).

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Driver Performance with Right-Side Convex Mirrors

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The mirror-use behavior of drivers was investigated as they gathered information from rearview mirrors in order to execute freeway lane changes and merges. Nine drivers (three novice, three experienced, and three mature) drove a 1973 Buick LeSabre with and without a right-side fender-mounted convex mirror along a 22.5-km (14-mile) freeway route. The total time to obtain information per maneuver was the same for both cases. In a subsequent study, the mirror-use behavior of five subjects who drove a 1976 Nova without a right-side convex mirror was compared with that of 12 subjects who drove the same vehicle with a right-side door-mounted convex mirror. Again there were no differences in total time to obtain rear-vision information. Experienced drivers (mean age = 24) took less time to obtain information when a right-side convex mirror was available than when it was not; older drivers (mean age = 61) took more time. Also, experienced drivers required about 10 h of driving experience to become efficient users of a right-side convex mirror, while older drivers required considerably more driving experience. Finally, a comparison of right-side door- and fender-mounted convex mirrors indicated that the drivers' total time to obtain information was the same for each mounting location, but drivers who had the fender-mounted mirror made a greater number of direct looks to the rear.

Some drivers may find it difficult to obtain the proper information necessary to execute lane changes and merges to the right. Factors that contribute to this difficulty include the following: (a) plane mirrors located on the right door do not always provide an adequate field of view, (b) sail panels located at the right rear of the vehicle can obstruct vision, (c) high head restraints can restrict the vision of short drivers, and (d) physical afflictions and old age can restrict turning one's head to