reporting area lighting conditions, should any unusual visibility condition develop, alarms will alert the dispatcher in the Communication Center and acceptable lighting levels can be achieved for the particular area. An example would be a heavy rainstorm in early evening that involved only one freeway. The transmitter-receiver unit for that roadway would signal low light conditions, and the dispatcher would energize that freeway lighting. Reports from field traffic personnel, executives, and others also result in turn-ons during normal daytime hours (see Figure 9).

The problem that is most noticed and causes the greatest public reaction, that of scattered turn-ons and turn-offs of highway lighting, is now replaced with instantaneous system operation. Since the system is designed to energize or de-energize whole groups of lights at one time, there are never any individual lighting units continually burning and going unnoticed for days or weeks at a time.

Finally, maintenance service time is reduced due to the ability to simply make a mobile radio call to the dispatcher for the turning on or off of any control cabinet. This saves considerable time, since these control cabinets are located off the freeway on frontage roads or cross streets. Specifically, it is necessary to energize high-mast lighting installations in order to service the luminaires. The time saved for the maintenance worker varies from as little as 10 min to 1 h round trip. As many as three other workers may be waiting during this period. Since this operation must be repeated after the repair is finished, an average of 1 h/worker is lost two to three times per week. It is estimated that an annual savings of $6000/year would be realized due to this feature.

The installation of a radio control system for highway lighting has resulted in the solution to the many aforementioned problems. The possibilities, however, for future applications of this technique are very impressive. The development of small-sized transmitters and other electronic equipment opens the way for many practical applications. One of the features of the present system, monitoring of the circuit condition, could be expanded to monitor individually each of the 20 000 luminaires. It is envisioned that a daily printout of lamp outages would be available, which would eliminate the necessity of patrolling for outages. This would result in a more efficient lamp replacement program and reduce energy and the person power required in patrolling. Installation of highway lighting systems requires substantial capital investment, which can only bring a return if the systems are properly operated and maintained. System monitoring can detect problems early and reduce the size of repairs as well as conserve energy (3).

OTHER USES

Information of various types that can be sent to the transmitter-receiver unit can then be forwarded to the central control of the Communication Center for analysis. This might include traffic information as well as electrical parameters. Traffic information, such as detector loop output or detector information of any kind, could be sent over special frequencies. Economic comparisons of the various systems need to be made to ensure future low-cost, reliable information retrieval.

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Abridgment

Programmable Roadway Lighting System as an Integral Traffic Management Component

A. KETVIRTIS

Analysis of vehicle traffic on public roads and streets in urban and rural areas indicates that traffic density and volume vary regularly within a 24-h cycle and that there is a close relation between traffic volume and accident rate. The gap between vehicle miles of travel (demand) and available road capacity (supply) is projected to increase steadily in the future. Traffic planners are faced with the need to improve the present use of the road system without investing major sums of money. Among the objectives of such improvements is maximizing the impact of roadway lighting on traffic flow. It is recommended that roadway lighting systems include a switching flexibility that will enable traffic system operators to relate lighting levels to traffic characteristics. The operation of such variable-level lighting systems is briefly described.

An orderly and effective traffic flow depends on a number of factors, each of which in its own way influences the totality of environmental characteristics in which the motorist is performing the driving task. In planning traffic management, therefore, it is important that these factors are clearly identified, weighed, and integrated into a unified scheme. It is obvious that, if one or more of the major contributors are ignored, success in such a system operation will be limited or, in some cases, inadequate.

The analysis of vehicle traffic on public roads and streets indicates that in urban and rural areas traffic density and volume vary regularly within a 24-h cycle. This variation establishes specific traffic-flow patterns, accentuating the morning and evening peaks as well as a slack period that normally falls between midnight and the early morning hours (Figures 1 and 2).

Based on accident distribution data within a 24-h cycle, it appears that the degree of difficulty in

Figure 1. Fatal accidents by time of day in Ontario: 1979.

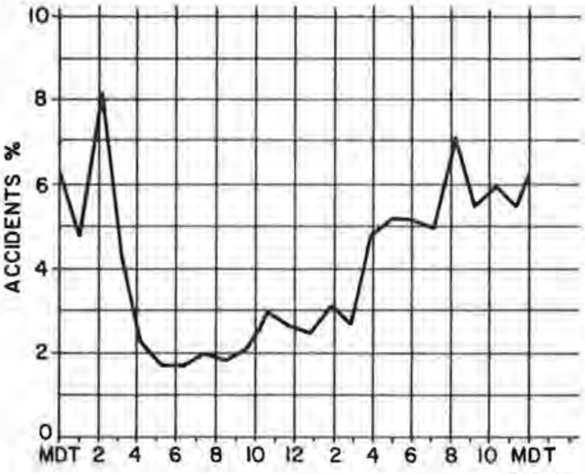
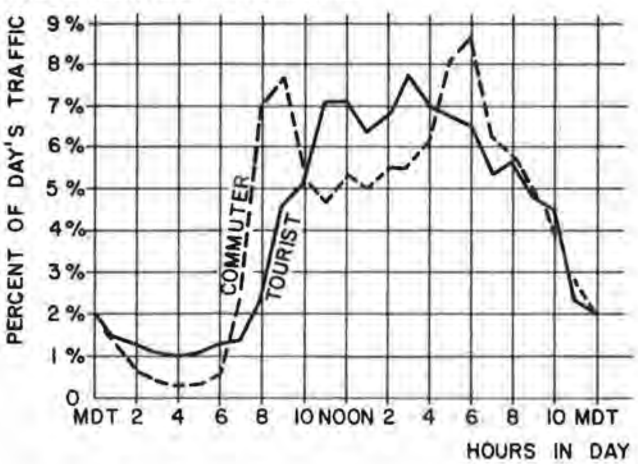


Figure 2. Hourly variations of traffic volume.



performing the driving task coincides with the peaks in traffic volume. An exception is early morning (1:00-2:00 a.m.): The high accident rate for this period perhaps can be attributed to alcohol, drugs, and fatigue.

Perhaps the close relation between volume and accident rate can be explained by the severe restriction of space for a motorist to operate a vehicle on an overcrowded road. In other words, on a crowded road the distance between vehicles is reduced and the motorist is obliged to operate his or her vehicle with considerably greater care and precision than in slack periods.

In order to maximize the impact of lighting on traffic flow, the roadway illumination should be provided with a switching flexibility to enable the traffic system operator to relate lighting levels to traffic characteristics. In other words, the variation in lighting system operation should be programmed according to changing traffic conditions by interfacing it with a traffic surveillance system and subsequently integrating it into overall traffic management.

PROJECTED GROWTH IN VEHICLE TRANSPORTATION

According to recent studies, in spite of the increasing cost of gasoline, vehicle miles of travel (VMT) in the 1980s will continue to grow at an annual rate of 3.5-4 percent. Depending on industrial and demographic activity, the annual increase in the number of registered vehicles will grow by approximately 4-5 percent.

In the State of New York, projected VMT by 1990 will increase by 37 percent (1). Vehicle registration in Ontario is increasing at the rate of 4 percent (2). Because of oil and gas developments, the Canadian provinces of Alberta, Saskatchewan, British Columbia, and possibly Newfoundland are experiencing major industrial growth, attracting migration from other provinces and overseas. The increase in vehicle traffic in these areas is also expected to reach a higher-than-average rate.

The higher cost of gasoline may suggest that, at least temporarily, VMT will decrease. However, improved engine efficiency and smaller vehicle size will encourage motorists to return to their old habits. The present 1979 model car (average) operates at 14.4-mile/gal efficiency, and by 1985 the efficiency is expected to reach 23.5 miles/gal (1). In view of the projected steady VMT growth, the consequences are clearly predictable.

Many of the present roads on this continent are already used to their capacity, and funds for construction of new facilities are diminishing. The gap between VMT (demand) and available road capacity (supply) will be widening at an increased rate. Traffic planners are faced with a new challenge: to improve the use of the present road system without investing major sums of money. The principal objective in achieving such improvements is to develop policies for implementation of more effective traffic management strategies (3).

Improvements in the use of present facilities, however, can be further increased by incorporating into the management of traffic operations other important factors that affect traffic flow. These factors are visual environment, forward visibility, conspicuity, illumination, noise control, pavement design, and vehicle and driver performance.

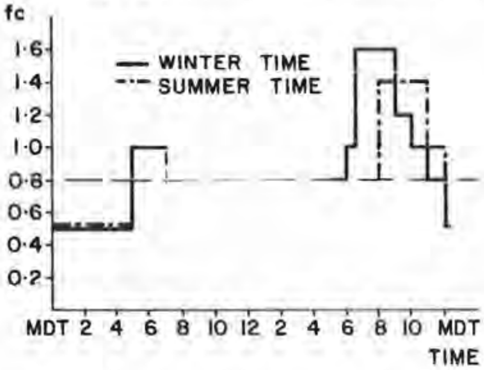
ILLUMINATION AND TRAFFIC SYSTEM OPERATION

As already stipulated, in order to maximize the impact of lighting on traffic flow, roadway illumination control equipment should include a switching flexibility that enables traffic system operators to relate lighting levels to traffic characteristics. For example, when traffic speed and volume increase and headway is reduced, visual contact with immediate objects should be much more precise; thus, the quality of illumination should be compatible with the specific driver's needs. On the other hand, in the early-morning hours traffic flow is often substantially reduced, so the driver's task becomes considerably easier; therefore, the degree of precision of required visual information is not critical.

The volume of traffic on urban expressways and freeways is normally the heaviest between 5:00 and 6:00 p.m. (Figure 2); however, since the speed at that time is slower, it is not essential in that period to increase the illumination level above the normal value. After 6:00 p.m., traffic density begins to diminish and the speed picks up. With higher speed and still relatively heavy traffic volume, the possibility of severe accidents increases; thus, visibility conditions should be improved (see Figures 2 and 3).

From the data published by numerous previous researchers (4), it appears that, by adjusting the visibility (illumination) conditions in relation to traffic volume, improvements in road capacity and motorist safety can be achieved.

Figure 3. Lighting levels related to accidents and traffic volume.



If one analyzes the traffic accident distribution within a 24-h cycle (Figure 1), it is evident that there are two peaks in the curve. The first one coincides with the early-evening rush hours, and the second occurs after midnight. The latter perhaps can be explained by driver fatigue, alcohol, and the rest cycle; therefore, it is doubtful that a higher level of illumination would have a significant influence on accident prevention at that period.

By taking into account the patterns of traffic volume and accident distribution, lighting levels can be varied as shown in Figure 3.

OPERATION OF VARIABLE-LEVEL LIGHTING SYSTEM

As already indicated, it is desirable to design a lighting system that permits changes in the lighting level. Where traffic management systems are used, data collected by sensors monitoring traffic volume, speed, pavement conditions, and air pollution are used to control the access rate to the main traffic routes by adjusting the traffic signal cycle. This information is also used in conveying messages (variable-message signs) to drivers about difficulties ahead.

If the lighting system operation functions as a part of traffic management, some of the sensors and the electronic equipment used for traffic monitoring may be used to initiate appropriate signals for lighting system control. However, at the present time experience in operating variable-level lighting systems is very limited, and thus more research data are needed before the operating policies can be firmed up.

PROGRAMMABLE LIGHTING SYSTEMS

Since the traffic volume on many major routes on this continent fluctuates to a ratio of 10:1, it is desirable to have a lighting system that reflects the driver's changing visibility needs. Because the traffic volume (and accidents) during rush hours represents a large portion of the total traffic count in a 24-h cycle, it is reasonable to think that the illumination level at these periods should be adjusted upward above the reference level (normal operation) (4) and that during the slack periods the level may be reduced to below the normal value.

In order to investigate the feasibility of such a lighting system, the Ontario Ministry of Transportation and Communications authorized a study (5) that resulted in a survey of electronic control equipment and ballast design that covered mainly operation of mercury vapor and high-pressure sodium lamps. From this study, it was learned that the outdoor lighting industry is in a position to provide reliable lighting system equipment for operation related to traffic needs and adaptable for interfacing with traffic surveillance equipment.

In addition to the fact that this system can be programmed to operate in relation to traffic requirements, it also provides the possibility for significant energy saving. Under normal conditions the lighting system design is based on the "maintained-level" principle. In other words, at the end of the economic lamp life, the level of illuminance provided by the system should not be less than the maintained value. For this reason, the designer is obliged to initially overdesign the system by 35-40 percent to compensate for the dirt factor and lamp-light loss factor. A system capable of controlling the lamp output can therefore be operated at the maintained level at the initial stage, which would result in approximately 20 percent average annual saving in energy consumption.

CONCLUSIONS

If one analyzes the traffic volume within a 24-h cycle with respect to accident occurrence, it is evident that the increase in accidents in the 6:00-8:00 p.m. period is related to overcrowding of the roads. The high accident rate in the early morning hours (midnight-2:00 a.m.) can perhaps be attributed to alcohol, drugs, and fatigue.

On a crowded road, the space for operating a vehicle is often drastically reduced, which necessitates more precise visual information to guide the vehicle safely.

By relating the characteristics of the visual environment to the driving difficulty, a more effective use of visual energy (supplied by vehicle headlights and fixed-source information) can be achieved. Since the quality of the visual environment and the conspicuity within the traffic corridor are mainly controlled by fixed-source illumination, the lighting level should be programmed and its controls interfaced with overall traffic system operation.

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