AUTOMATION IN TRAFFIC OPERATIONS AND HIGHWAY MAINTENANCE

Mathew J. Betz, Arizona State University

The purpose of this paper is to review the application of automation techniques in the fields of traffic operations and highway maintenance. To facilitate review of such a broad subject, I have divided the various automation systems into general categories.

DATA INPUT

The most essential part of an automation system is the input of basic information; one must continually emphasize the fact that the reliability, effectiveness, and validity of every system depends on the quality of the input information.

Automatic data input or sensing devices are now used to process much data. The use of these devices is very common in traffic operations; they include the pneumatic, loop, radar, and traditional types of vehicle presence detectors. Television surveillance can also be included in this category.

There are also important manual methods of data input. These include data obtained from traffic surveys, work reports, productivity analysis, census data, and other manually prepared reports. These methods are still important in traffic operations automation and represent almost the sole input of data to highway maintenance systems.

A new type of manual input system relies on reports or observations of individuals supported by electronic or some other type of equipment. Information is supplied by observers using roadside telephones and helicopter radios. Observations are also made in control rooms by the use of surveillance systems. It is likely that this kind of input, which might be called equipment-aided manual input, needs more study and probably has significant application in maintenance operations and in traffic operations on rural systems where completely automatic data collection becomes too expensive.

INFORMATION PROCESSING

Traditionally, the heart of automated systems has been electronic computers that perform the information-processing function. This processing includes tabulation, summations, analysis of trends, comparison of new or current information with either historical patterns or desirable characteristics, and a multitude of other mathematical calculations. The problems associated with this function include the types of hardware and software necessary, the amount of data to be analyzed, the sophistication of the analysis including the amount of core or disk storage, the use of peripheral equipment, and the urgency of the results (the use of prime time versus nonprime time).

INFORMATION OUTPUT

The first information or automation systems produced various reports that were typically concerned with the direct analysis of data, the scheduling of predictable or recurring items, the important function of keeping relatively current inventories, and cost accounting systems.

In traffic operations, much of this output was related to the analysis of historical data, such as traffic volumes and accidents, and resulted in implementation of some traffic control measures, such as reversible lanes on freeways. For those cities that used three-clock, fixed-time controllers on arterial street systems, the phasing and offsets could be determined from fixed-time analyses and information output.

To date, the major application of automation systems in highway maintenance has entailed the use of systems that provide cost-accounting, inventory-control, and operations-scheduling information. The initial application of most automated systems, has involved regularly scheduled, recurring activities. However, as will be illustrated in the following section, the real impact of automation on highway systems is related to its application in unusual or nonpredictable occurrences.

INFORMATION CONTROL

The most dynamic area of automation in the context of this report, especially in traffic operations, is the information-control system. In these integrated systems, the input, processing, and output are designed to provide information directly to the user of the system. In traffic operations systems, the user would be the motorist; when applied to highway maintenance, the user would probably be the individual highway maintenance office. The system bypasses the technician's interpretation of statistical or numerical results and proceeds directly to the issuance of information or orders to those directly operating within the system. This may be done on a real-time basis. Data collection, processing, and reporting times must be short enough so that an effective response or adjustment in the system can be accomplished.

The answer to what is real time and what is fixed time depends on the type of system under consideration. The two categories of highway systems under discussion here offer a good comparison. What might be considered a real-time response for a maintenance system (1 hour to 1 day) could not be considered a real-time response for a ramp-pacer system on a freeway interchange (seconds or fractions of seconds).

In the area of traffic control, there are a large number of information-control system projects that are currently being designed and implemented. The use of changeable-message signs both on freeways and on rural highways is one development. In addition there are ramp-metering and lane-control projects on freeways and in tunnels.

Even the rural road system is beginning to feel the impact of such systems. The development of a simple passing-aid system for rural roads, which would incorporate sensing, some fairly rudimentary information processing, and changeable-message signs, would indicate to the driver when passing is safe on two-lane, two-directional roadways with inadequate passing-sight distance.

One of the most sophisticated systems tested thus far is the electronic route guidance system of driver navigation and routing. This system involves the use of induction loops, transceivers, computers, on-board receivers, and display equipment that indicates to the driver the appropriate route to be taken from origin to destination. The level of sophistication of this system is such that should the driver make an incorrect turn the equipment would automatically register this and display the proper actions for the newly defined optimal route.

Another area that is being developed is methods of communication for information-control systems. These methods include traditional traffic lights, flashing lights, changeable-message signs, a radio that uses a special highway frequency, an interruptive roadside radio, and various types of pacer systems.

In highway maintenance, there has been very little application of information-control systems. As has been indicated, such systems are extremely useful in dealing with nonscheduled occurrences. Such occurrences are as important in highway maintenance as in traffic operations. Emergency maintenance requirements, washouts, snow removal, and other nonscheduled maintenance would be subject to the influence of information-control automation systems.

Much of the traditional maintenance organizational structure has been developed to react to and carry out instructions from an information-output system where schedules of recurring operations can be developed. This is a basic, though tacit, assumption in the development of highly structured maintenance divisions and subsections, each of which is responsible for a well-defined set of highways. If information-control systems are to be meaningfully implemented in any area, including highway maintenance, a great degree of flexibility on the part of the operational or line functions of the system will be required. It is the flexibility of the individual automobile driver that has allowed such systems to be implemented relatively quickly in traffic operations. In highway maintenance, it can result in the development of greater flexibility in the mobility of manpower and equipment to meet, on a timely basis, maintenance needs over a broader area. This is especially true in states such as Arizona where there are substantial changes in climatic conditions over very short distances. It may mean the tentatively scheduled or unscheduled movement of both equipment and personnel from one maintenance district to another in order to better meet the requirements of the system.

In addition to the use of information-control systems to meet emergencies, such systems would be of significant benefit in the development of flexible scheduling for maintenance operations. This would require the development of a schedule, possibly on a daily or hourly basis, that could be continually adjusted to meet minor emergencies and regularly expected but unscheduled activities such as the replacement of defective or vandalized bulbs in traffic control signals. The application of information-control systems to highway maintenance is difficult because highway-maintenance activities are separated both in time and in space. Thus, it is not a problem of controlling or reacting to conditions at a specific point; it is a major logistics problem that consists of minimizing costs and time losses due to the transport of man, equipment, and materials. Thus, the system needs to be much more sophisticated than most traffic-operation systems, including the possible incorporation of stochastic modeling and other highly complex activities.

Overall, the characteristics of information-control systems are probably best illustrated by the electronic route guidance system. This system, almost by necessity, must be developed on a real-time basis. Its function is to control the system through the communication of information. The system must also have self-correcting or contingency capabilities to provide further information when the initial advice has not been followed. Many traffic engineers feel that traditional lights and pacer systems are direct-control systems. The electronic route guidance system illustrates the point that none of these systems has direct control because the driver may intentionally or unintentionally make the wrong decision. Motorists are less likely to violate signals if they realize the danger in doing so.

DIRECT-CONTROL SYSTEM

In a direct-control system, the input information, data processing, and actual operation of the system are all fully controlled internally. The automated factory is the traditional example of such a system. Although they are currently at the conception stage, fully controlled systems will probably be used in highway operations and possibly in highway maintenance within the near future. In the area of traffic operations, the fully automated highway represents a direct-control system. Here, the individual motorist effectively becomes a passenger, and complete control of the vehicle is exercised by an automation system. Obviously, one of the major problems of such a system as applied to highway work is compatibility. Most direct-control systems usually require considerable, on-board equipment. This means that entrance into a control system would be restricted to those vehicles that have the equipment; it also means that solutions must be found to the problems of equipment repair and fail-safe controls. Because of these requirements, the cost of such a system for highway operations is probably prohibitive at this time. However, future highway capacity probably can be provided only through the use of fully direct-control systems that allow vehicles to travel at high speeds and low headways.

It is interesting that, at least conceptually, some direct-control systems for highway maintenance are simpler and more easily attainable than those used in current highway operations. The opposite is true for information-control systems. The development of the automatic use of heat and sand and chemical spreading on bridge decks to counteract icing could possibly be accomplished by using relatively simple sensing devices, rudimentary information processing, and automatic distributive mechanisms. When the heating of highway pavements becomes economically feasible for major facilities, it will then be possible to have a direct-control, automated snow-removal (for reasonable amounts of snow), and ice-control system. It is somewhat more difficult, at this time, to foresee applications of the direct-control systems to regularly scheduled, geographically discontinuous maintenance activities such as patching, draining, striping, and taking care of shoulders and roadsides.

One fairly simple method of direct control in traffic operations is the closing of ramps or lanes by the use of gates or other restraining devices. The implementation of fast-acting restraining devices on ramp metering could represent a change from an information-control system to a direct-control system.

SUMMARY

I have attempted to give an overview of highway-maintenance and traffic-operations automation. These systems are rapidly becoming more complex and sophisticated and, therefore, continually more expensive. Therefore, greater care must be exercized in the planning and development of such systems prior to decisions regarding implementation.

Because of the need for planning, the careful and definitive descriptions of what the automated system needs to do becomes increasingly important. It is embarrassing, to say the least, to spend considerable sums of money and time on systems that do not perform a useful function. Many of these mistakes can be avoided if the function of the system is carefully specified from the beginning. Criteria should be developed that will measure the effectiveness of the system.