U.S. Department of Transportation
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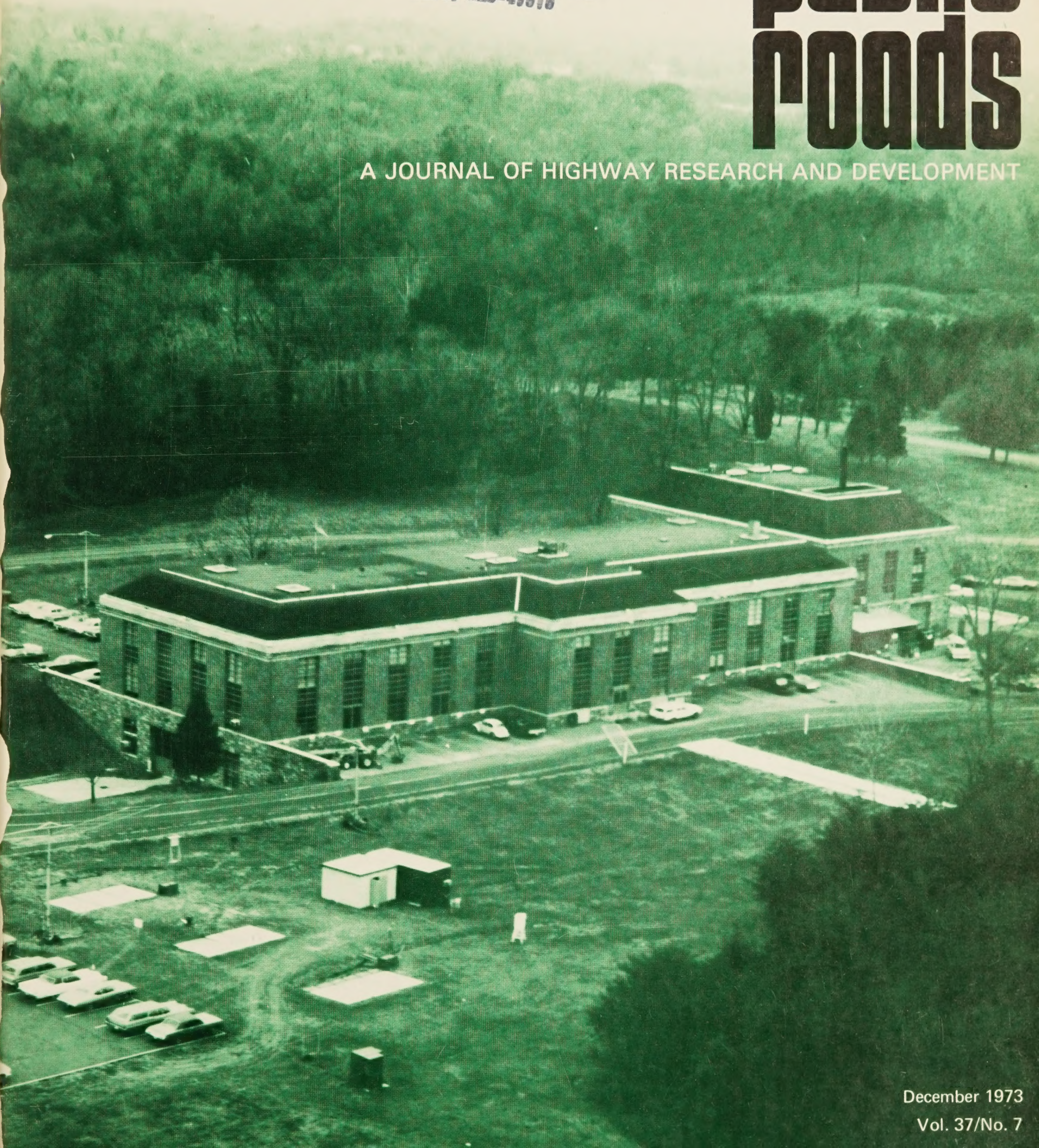
A JOURNAL OF HIGHWAY RESEARCH AND DEVELOPMENT



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G.W. Cleven, Associate Administrator for Research and Development, is responsible for the Fairbank Highway Research Station (See front cover.)

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Moving Merge— A New Concept in Ramp Control,

by Justin True and Dan Rosen

This article describes the evolution of a freeway entrance ramp control system. The system, called a moving merge control system, is designed to help the ramp driver in merging with freeway traffic. At the present time, a moving merge control system is being installed on a single entrance ramp in Tampa, Fla.

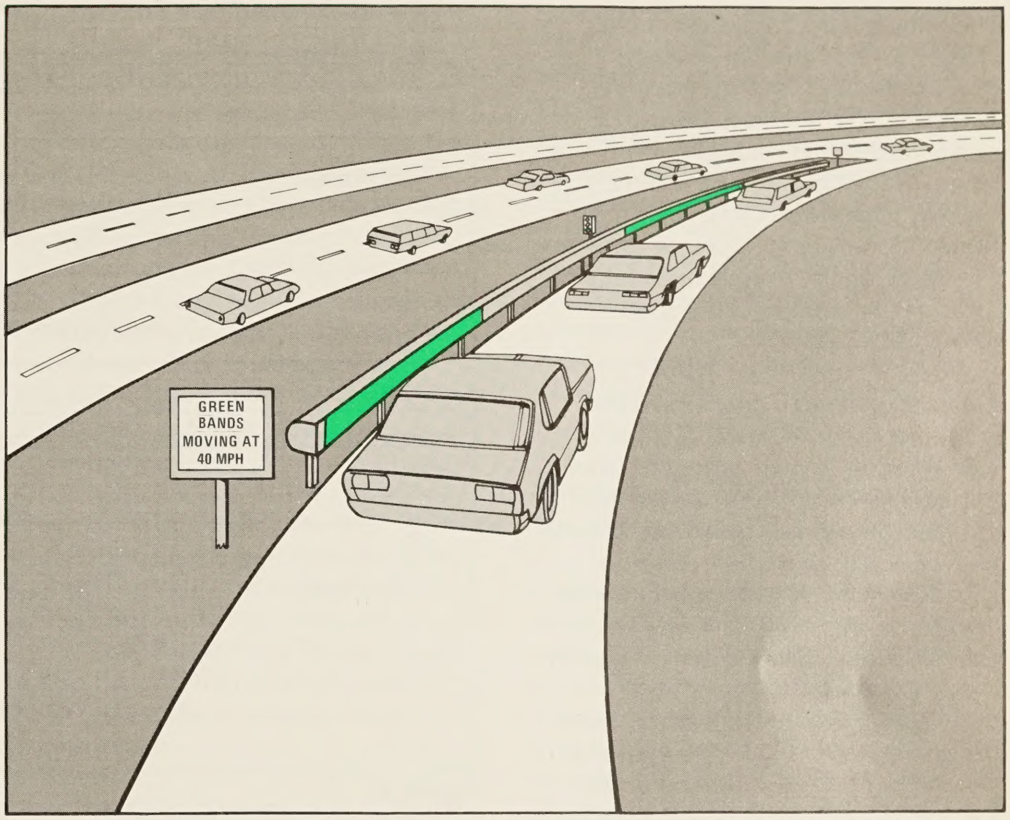


Figure 1.

What are Moving Merge Control Systems?

Moving merge control systems are simply devices installed on freeway entrance ramps. These systems are used to help ramp drivers enter a freeway for those situations where they would otherwise have difficulty in determining adequate size freeway gaps. Moving merge control systems operate on what engineers call the *gap acceptance* principle of ramp control. These control systems are designed to operate in both a *moving mode* and a *stopped mode*.

Figure 1 is an artist's concept of a merge control system operating in the moving mode according to the gap acceptance principle. Vehicle detectors located in the right lane of the freeway are used to detect sufficient size traffic gaps in the right hand freeway lane which will permit safe merging by ramp drivers. In this system, acceptable gaps in the right lane of the freeway are shown as moving bands of green lights in the rampside display. By driving beside one of these green bands, a ramp vehicle will be placed in the proper ramp merging position for entering a safe available gap in the right hand lane of freeway traffic.

Figure 2 illustrates how ramp vehicles in the stopped mode are matched with freeway gaps according to the gap acceptance principle. In this mode of operation, ramp vehicles are required to stop at a traffic signal located on the ramp shoulder. The vehicle detectors in the right lane of the freeway are used to search for gaps which will permit safe merging by ramp drivers. When an acceptable gap is found, the ramp traffic signal is turned green at the proper time so that the leading ramp vehicle can arrive in the freeway merge area to utilize the available gap.

Moving merge control systems are operated in the moving mode during light and moderate freeway volumes and in the stopped mode during peak periods of traffic flow.

Figure 1.—Artist's concept of green band moving merge control system.

The principal advantage of moving merge systems over previously developed ramp control systems is that the former involves the use of rampside displays throughout the length of the ramp for presenting freeway gap information to drivers. Conventional ramp control systems use traffic signals at only one ramp location to communicate gap information to drivers.

Conventional ramp control systems are sometimes operated on control principles other than gap acceptance. For example, some control systems attempt to balance the volume of freeway traffic with the freeway capacity so that it will not become so congested that traffic ceases to flow smoothly. Others have used what is called *occupancy* as a control principle to prevent the freeway from becoming overloaded. Occupancy is simply the percent of time a certain section of the freeway is occupied by vehicles.

Of all the various control systems used to date, the moving merge system is the only one that tries to directly help the driver in the merging maneuver.

Why Have Merging Control Systems?

The problem

There is ample evidence that driving on a freeway is safer than driving on other types of roadways. However, the accident record at freeway interchanges is not impressive. The interchange has been called the "Achilles' heel" of the freeway system.

Entrance ramps and the merging area account for 20 percent of all interchange accidents (*1*).[1] Seventy percent of the accidents occurring on an acceleration lane are of the rear-end or sideswipe type. Many of these accidents are caused by a stopped vehicle waiting for a gap in freeway traffic. The above statistics may not suggest a major crisis, but anyone who has driven on a poorly designed entrance ramp knows that the merging operation can be a difficult task.

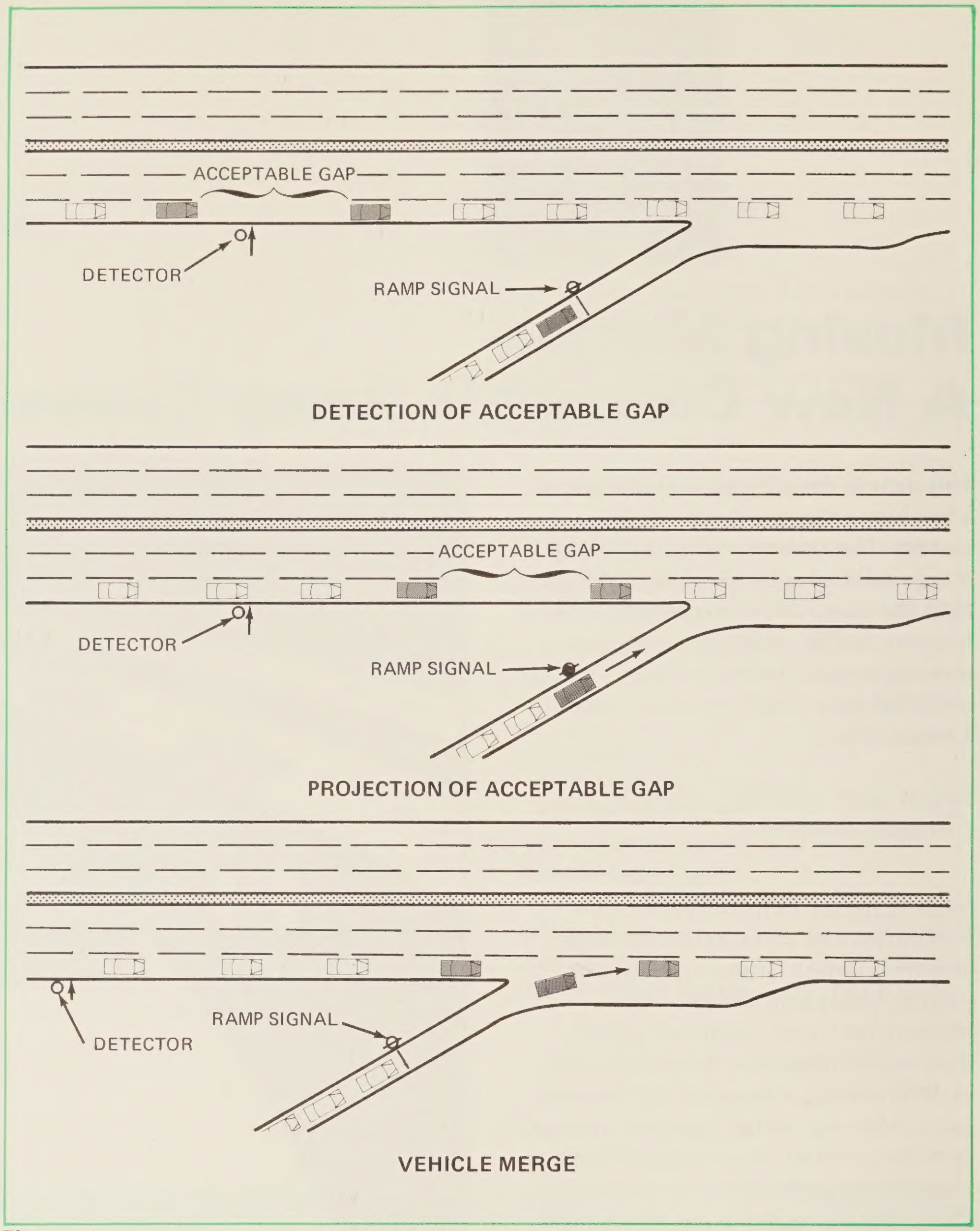


Figure 2.

Figure 2.—Illustration of stopped gap acceptance mode of ramp control.

The following reasons have been set forth as contributing factors to the high accident rate and driver difficulties experienced in performing the merging maneuver (*2*):

- Poor visibility caused by obstructions to vision, headlight glare, or adverse weather keeps the driver on the freeway entrance ramp from seeing gaps in freeway traffic.
- The driver on the ramp must monitor many vehicles on the freeway, each following its own course.

[1]Italic numbers in parentheses identify the references on page 245.

- The ramp driver has difficulty in estimating accurately the speed of vehicles on the freeway; he must depend entirely on his own observation.

- The ramp driver must also monitor other vehicles in his queue which may be stopped in the merge area waiting for gaps in the stream of freeway traffic.

- A short acceleration lane increases the number of accidents. An acceleration lane of less than 200-foot length has 60 percent more accidents than one of over 700 feet (assuming 4 to 5.9 percent merging traffic).

In addition to the accident problem, there is also the problem of congestion on urban freeways during peak traffic periods. Traffic studies have shown that at speeds in the range of 35-40 miles per hour, freeways can carry more traffic than at either higher or lower speeds. Therefore, if the number of vehicles on a freeway can be regulated so that a 35-40 mile per hour speed range is maintained, freeways could be operated more efficiently during peak traffic periods. One way to regulate the amount of traffic using a freeway is by entrance ramp control.

Possible remedies

What can be done to alleviate or reduce the problems of high interchange entrance ramp accident rates, driver difficulties in merging with freeway traffic, and freeway traffic congestion? One obvious solution is to reconstruct problem entrance ramps and/or acceleration lanes. This could involve improving sight distances; i.e., removing bridge walls and railings that restrict the view of the freeway from the ramp. Other reconstruction might include increasing the length of the acceleration lane and flattening the convergence angle (angle between the freeway and entrance ramp). Studies have shown that drivers can merge into traffic easier if acceleration lanes are 700 feet or longer and if the convergence angle is flat (3). Although reconstruction can reduce the accident problem, it will not solve the congestion problem. Reconstruction can also be very costly, especially in urban areas and if the ramp and acceleration lane are on a bridge. There is also the problem of what to do with traffic while the reconstruction is taking place.

Another alternative solution is simply to close the problem entrance ramp. The ramp could be closed permanently or only during certain periods of the day. While this approach may work for some situations, there are many disadvantages. Ramp closures may be confusing to the traveling public, especially strangers, if the closure is permanent. By closing one ramp, the problem may be simply moved to another ramp. The closing may also make freeway access more difficult for a certain group of users if alternate routes to other ramps are not available.

A third possible alternative for improving traffic operations at a problem entrance ramp is by installing a moving merge control system. Such a system is presently being installed on a problem entrance ramp in Tampa, Fla. System operation will be studied and evaluated over the next 18 months. Additional details on this effort are provided later in this article.

Research and development of both metering and moving merge control systems has been in progress over the last several years. The evolution of these two types of systems is discussed in the next two sections.

History of Merging Control Research and Development

Freeway entrance ramp control is a continually evolving process. Some early ramp control experiments were conducted on the John C. Lodge Freeway in Detroit. In these studies, changeable message signs were used to close selected entrance ramps during peak periods. These experiments were only partially successful as a large percentage of drivers disregarded the signs and used the entrance ramps anyway.

Early experiments with ramp metering were also performed in Chicago on the Eisenhower Expressway. A policeman, stationed on the entrance ramp, manually metered the ramp traffic onto the freeway. In later Chicago experiments, a modified traffic signal (only the red and green lenses were used) was installed on the entrance ramp shoulder and traffic was automatically metered onto the freeway on a one-at-a-time basis. Due to the success of the early experiments, there are presently in the Chicago area 75 miles of freeway under surveillance and metering systems on 49 entrance ramps (*4*).

Early entrance ramp control experiments were also performed on the Gulf Freeway in Houston. In these experiments, standard traffic signals (red, amber, green) were installed on the shoulder at eight separate entrance ramps. Human observers were used to change the traffic signal from red to green to permit ramp traffic to enter the freeway (*5*). Based on the success of these experiments, vehicle detectors were installed on the freeway and on the entrance ramp. The detectors were connected to a computer and the computer was used to change the traffic signal lights. Through the use of the detectors and computer, different traffic characteristics could be measured. Experiments were conducted with different types of ramp control strategies.

Benefits that drivers received from these entrance ramp control systems included a reduction in the number of accidents and travel time, and a smoother flow of traffic on the freeway. However, with these early ramp control systems, drivers still did not receive any help in performing merging maneuvers.

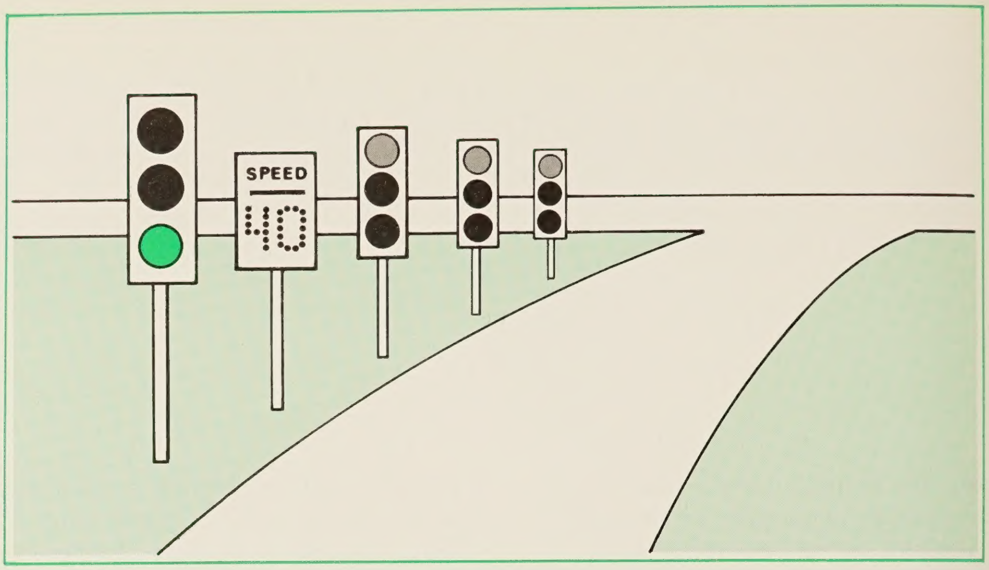


Figure 3.

Working with the Texas Highway Department and the Federal Highway Administration, the Texas Transportation Institute developed the *gap acceptance* type of ramp control where vehicles are stopped on the ramp as shown in figure 2. This gap acceptance control was the forerunner of the moving merge control system that is currently being evaluated in Tampa. The *gap acceptance* type of entrance ramp control has been installed on eight ramps on the Gulf Freeway in Houston and on 39 ramps on the North Central Expressway in Dallas.

A study of accidents during the morning peak period was conducted on the Gulf Freeway. This study compared accidents for a 1-year period *before* ramp controls were installed with a 1-year period *after* the controls had been installed. It was found that accidents had been reduced by 50 percent as a result of the ramp control system (*6*). Other studies have shown that the ramp control system has saved some 51,300 vehicle hours of travel time per year (*7*). A preliminary study of the benefits to drivers on the North Central Expressway in Dallas has also been made (*8*). As a result of the ramp control system, freeway speeds have increased about 15 percent (during the peak period when the controls are in operation) and accidents have been reduced by 47 percent.

The benefits received from these control systems were impressive, but these systems only operated in the peak period. A system that could aid the driver in merging maneuvers during off-peak periods, as well as during the peak periods, should provide increased benefits. As noted earlier, such systems are being developed and are called *moving merge control systems*.

To test the theory of a *moving merge control system,* a pilot test was conducted by the Texas Transportation Institute as part of a contract with the Federal Highway Administration (*9*). The actual testing was performed on an airport runway which simulated a 3-lane freeway, an entrance ramp, and an acceleration lane. The system used a rampside display which consisted of four standard traffic signals located along the left side of the ramp (figure 3). A sign showing the speed of freeway traffic was placed between the first two traffic signals.

Figure 3.—Ramp driver's view of display in pilot tests.

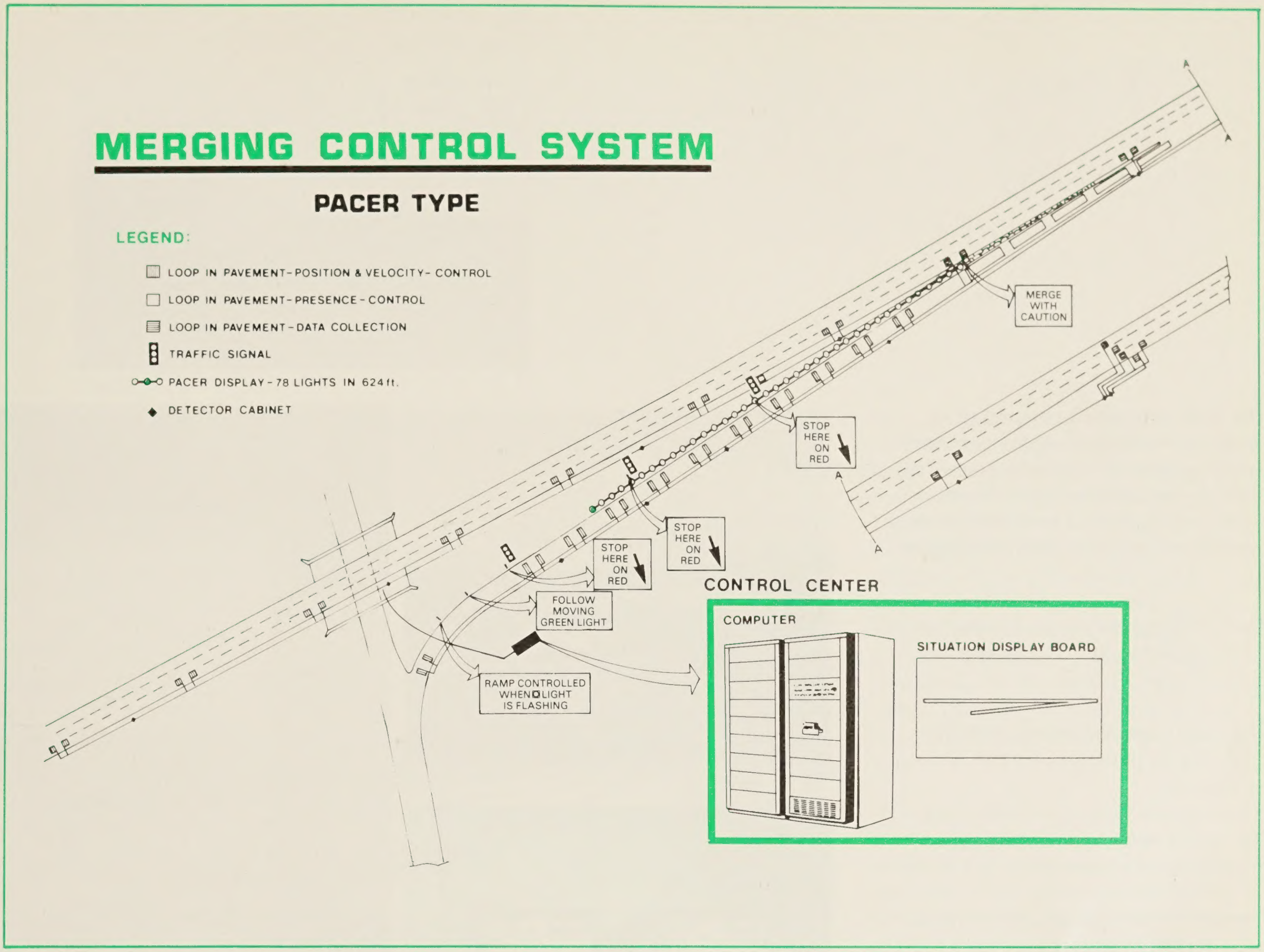


Figure 4.

Different controlled experiments were conducted on the test track. Real vehicles were used in the experiments. Vehicles representing freeway traffic were driven at predetermined speeds and spacings. Ramp signals were controlled in such a manner that if the test driver followed the green signal indications, he would arrive in the merge area opposite a gap in the freeway traffic. This concept is similar to following a sequence of green signals along an urban street. The spacing between the traffic signals on the ramp can be thought of as different blocks along the urban street. The results of this pilot testing were encouraging. It was shown that drivers (at least under controlled conditions) could follow the green lights and be placed in a good merging position.

Figure 4.—Plan view of pacer system.

Development of Two Moving Merge Control Systems

Under a contract with the Federal Highway Administration and in cooperation with the Massachusetts Department of Public Works, the Raytheon Company developed two prototype moving merge control systems. These two systems were installed and tested on the Route 38 entrance ramp to Route 128, southbound, in Woburn, Mass. One of these systems was called the *pacer* system and the other was called the *green band* system.

Description and operation of the pacer system

The pacer moving merge control system tested in Woburn consisted of three major elements:

(1) A detection element (vehicle loop detectors embedded in the pavement).

(2) A computation element (a computer located in the control center).

(3) A driver communication element (signs, traffic signals, and driver display located on the ramp).

The loop detectors consisted of several turns of insulated wire buried in the pavement (figure 5). The wires were connected to a piece of electronic hardware that could tell when a vehicle crossed over the wires (figure 6).

The computation element consisted of a Raytheon Model 703 digital computer (figure 7).

The computer performed all of the calculations necessary for the system to operate.

Figure 5.—Vehicle detectors embedded in pavement.

Figure 6.—Detector electronic hardware in field cabinets.

Figure 7.—Model 703 computer.

Figure 8.—Signs, traffic signals, and driver display used in pacer system.

Figure 9.—MERGE WITH CAUTION sign that can be illuminated under certain conditions.

Figure 10.—Pacer system in operation.

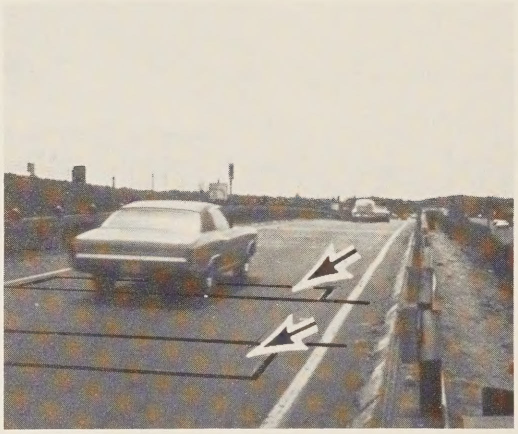


Figure 5.

Figure 6.

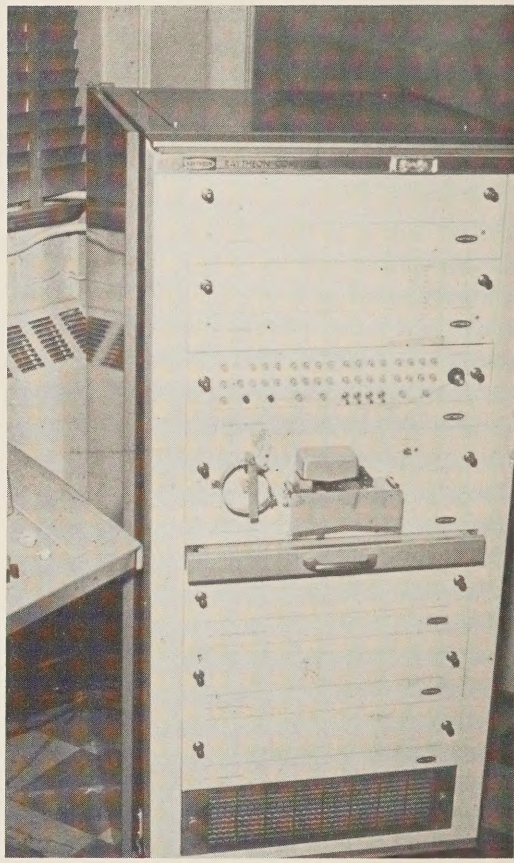


Figure 7.

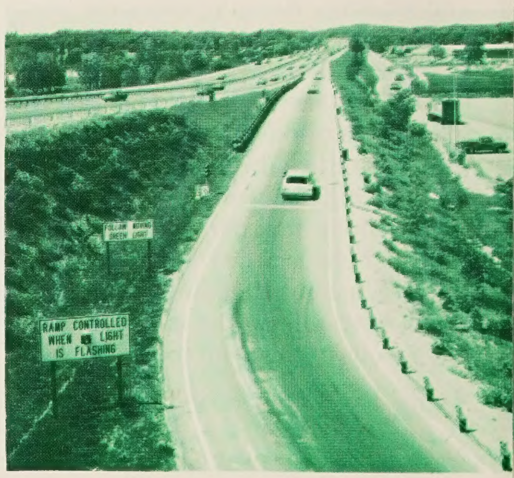


Figure 8.

Figure 9.

Figure 10.

The driver communication element consisted of the traffic signs, traffic signals, and pacer light display, all located along the left shoulder of the ramp. Five fixed message signs and one changeable message sign were used to provide the driver with instructions and information on how to use the system. Figure 8 shows the pacer system as it was installed in Massachusetts. Figure 9 shows the variable message sign. In operation, this sign displayed the message *MERGE WITH CAUTION* if there was no acceptable gap or no message when there was an acceptable gap. Freeway gap information was provided to the driver through a series of pacer lights which consisted of ordinary 8-inch green traffic signal lights mounted 8 feet apart along the left shoulder of the ramp (figure 10). There were 78 such pacer lights. They were illuminated in sequence by the computer to give the illusion of a single light moving at a speed to which the driver could match his vehicle's speed. Thus, the moving display paced the driver by indicating to him how fast his vehicle should be moved to fit into an available freeway gap.

As stated earlier, the pacer system had two modes of operation—moving mode and stopped mode. The system operated in the moving mode during off-peak periods and in *stopped mode* during peak periods of traffic flow.

General system operation was as follows. Detectors in the right lane of the freeway were used to detect the presence of vehicles. This information was sent to the computer via communication cables. The computer calculated the size and speed of gaps in the right freeway lane. At the same time, detectors on the ramp provided information to the computer on the presence and speed of ramp vehicles. The computer then matched ramp vehicles with acceptable gaps; i.e., gaps large enough to permit a smooth merge into the freeway.

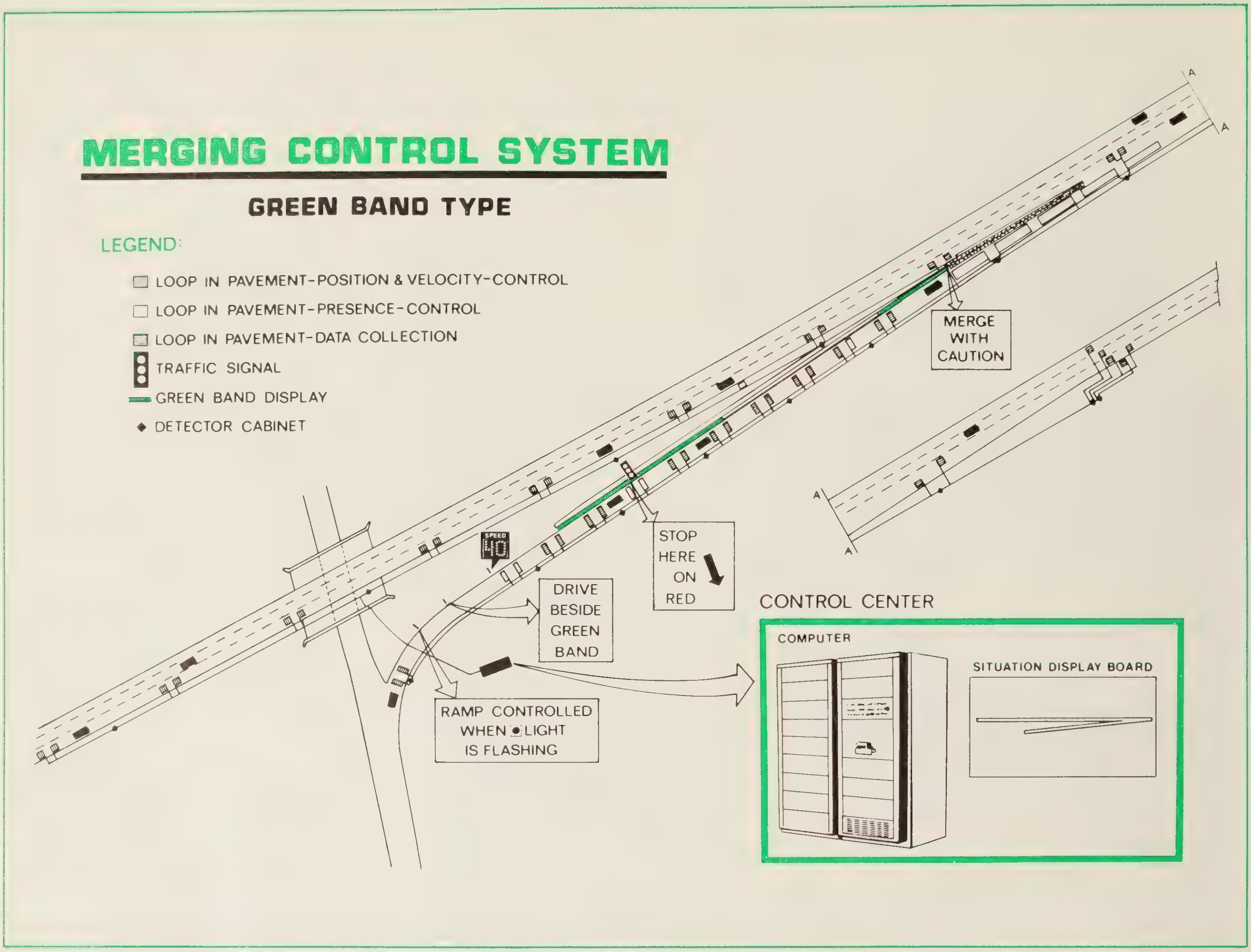


Figure 11.

The computer generated a moving pacer light for each ramp vehicle that had an acceptable gap. The computer could also cause the pacer lights to speed up or slow down depending on what was happening to the gaps on the freeway. The speed and position of all ramp vehicles were reviewed by the computer to assure that there was sufficient space between ramp vehicles to prevent them from tailgating.

If an acceptable gap could not be found for the ramp vehicle, because of heavy traffic, or if an assigned gap was lost because of freeway lane changing, the system commanded the vehicle to stop, provided the ramp vehicle and all trailing vehicles could be stopped safely. Safety checks were based on vehicle spacing, speed, and distance to a traffic signal stop line.

Once traffic was stopped, the computer continuously examined the freeway for gaps. If an acceptable gap was found, the traffic signal nearest the merging area went to green and a pacer light guided the vehicle the remaining distance to the merging area. If no acceptable gap could be found within a preset time, the stopped vehicle was released without a pacer light and the *MERGE WITH CAUTION* sign was activated as the vehicle crossed the last pair of ramp detectors. The pacer system operated in the stopped mode whenever ramp vehicles were stopped.

The pacer system also detected vehicles that stopped in the merge area instead of merging. Whenever the presence detectors in the merging area were occupied longer than 10 seconds, the pacer lights were turned off and the traffic signals were placed in amber, followed by a preset time of steady red and then flashing amber.

If a ramp vehicle was beyond the last ramp traffic signal while under pacer control, and its freeway gap no longer met acceptable gap requirements, then the pacer light was turned off and the *MERGE WITH CAUTION* sign (figure 9) was illuminated.

Figure 11.—Plan view of green band system.

Figure 12.

Figure 13.

Description and operation of the green band system

The green band merging control system used in Woburn, Mass., was composed of three major elements: a detection element, a computation element, and a driver communication element. Figure 11 shows a plan view

Figure 12.—Green band system in operation in Woburn, Mass.

Figure 13.—Woburn green band system showing driver display.

of the green band system. As in the pacer system, the detection element consisted of vehicle detectors embedded in the right lane of the freeway and on the entrance ramp. For the green band system, fewer ramp detectors were used than in the pacer system, because the green band control principle does not require the monitoring of the location and speed of ramp vehicles.

The driver communication element consisted of the following equipment:

(1) One conventional (green-yellow-red) traffic signal.

(2) An advisory speed sign.

(3) A 624-foot display unit covered with green acrylic panels, illuminated from the inside by 4-inch, 75-watt incandescent flood lights mounted 2 feet on centers.

(4) An illuminated *MERGE WITH CAUTION* sign.

As in the rampside pacer display, a sign at the beginning of the ramp (figure 12) provided the driver with information on the operation of the system.

The same Raytheon Model 703 computer was used in the green band system as employed in the pacer system.

One major difference existed in the operation of the green band and pacer systems. In the moving mode of operation, green bands were displayed independent of ramp vehicles. In the pacer system, it was necessary to know the speed and location of individual ramp vehicles before a pacer light would be displayed.

As with the pacer system, the green band system operated in both a moving mode and a stopped mode. Detectors in the right lane of the freeway detected the presence of vehicles. This information was sent to the computer which determined the location and speed of gaps in the freeway right lane. The computer then illuminated bands of green lights which, including appropriate safety factors, represented the acceptable gaps in the right lane of the freeway (figure 13). In the Massachusetts installation the green bands traveled at one of three different speeds—the speed being dependent on freeway traffic conditions. The advisory speed sign located at the beginning of the ramp displayed the speed at which the green bands were traveling which was either 35, 40, or 45 mph.

In the stopped mode operation of the green band system, vehicles would be stopped on the ramp based upon traffic conditions (speed and volume) in the right lane of the freeway. When a vehicle was stopped at the traffic signal, the check-in detector would signal the computer. The computer would search for a gap. If a gap was found, the traffic signal would turn green and a 32-foot-long moving green band would be displayed for the ramp driver to follow to the merge area. If the computer could not find a gap within a few seconds, the traffic signal would turn green but no green band would be displayed. As traffic volumes on the freeway increased and travel speeds reduced, the computer stopped looking for gaps. When this happened, the traffic signal stopped all ramp vehicles and released them one at a time. In this mode of operation the traffic signal operated much the same as a traffic signal on an urban street, except that only one vehicle was released at a time.

Figure 14.

Figure 15.

The green band system also had the following safety features. Detectors were located in the acceleration lane of the freeway. When the computer detected that a vehicle had stopped on the acceleration lane, all moving green bands were turned off. A queue detector was also located near the beginning of the ramp and close to its intersection with the arterial street. This detector was used as part of the stopped mode of operation. If a queue of ramp vehicles extended back over this detector, the computer would cause the ramp traffic signal to release ramp vehicles at a faster rate. Thus, the queue detector prevented ramp vehicles from blocking the arterial street.

Pacer and green band control center

The day-to-day operation of the merging control systems tested in Massachusetts was monitored by an engineer from a control center located in a trailer parked adjacent to the entrance ramp (figure 14). The control center housed the computer, situation display board, and other electronic hardware necessary to operate the system. The situation display board (figure 15) showed the right lane of the freeway and the entrance ramp. A series of miniature lights spaced 1/4 inch apart on the ramp-freeway diagram showed the position of vehicles in the right lane on the freeway and on the entrance ramp. Current status of all driver communication elements was also shown.

Figure 14.—Control center trailer for pacer and green band systems.

Figure 15.—Situation display board in control center.

Results of the Massachusetts test

In order to determine driver reaction to the pacer and green band systems, questionnaires were handed out to ramp vehicle drivers.

Figure 16 shows that for comparison of the green band and pacer systems, the drivers queried had similar characteristics with respect to sex, age, and miles driven. For both systems, approximately the same percentage of the drivers were found to use the systems, (1) daily, and (2) during the 7-9 a.m. peak period.

Drivers were asked their opinions about how helpful they found the systems to be in merging into freeway traffic. Of those using the pacer system, about 80 percent found it helpful, while 5 percent thought that it was difficult to follow the pacer lights. With the green band system, 85 percent considered it helpful and 8 percent considered it difficult to drive beside the green band. Because these responses involved several questions, the percentages do not add up to 100.

Since many drivers used the test ramp repeatedly over a time period, including both systems tests, it was possible to determine their preference of the two systems. Of the 210 drivers who used both systems and returned questionnaires, there was, as illustrated in figure 17, a general preference for the green band system.

Based on responses from the questionnaires and the operation of the pacer and green band systems in the Massachusetts tests, the following five significant statements can be made about moving merge control systems.

(1) Moving merge control systems are technically feasible.
(2) Approximately 80 percent of drivers feel such systems are beneficial.
(3) Merging positions for ramp vehicles are improved.
(4) Drivers prefer the somewhat simpler green band system which is also the more economical system.
(5) The green band system deserves further field test evaluation.

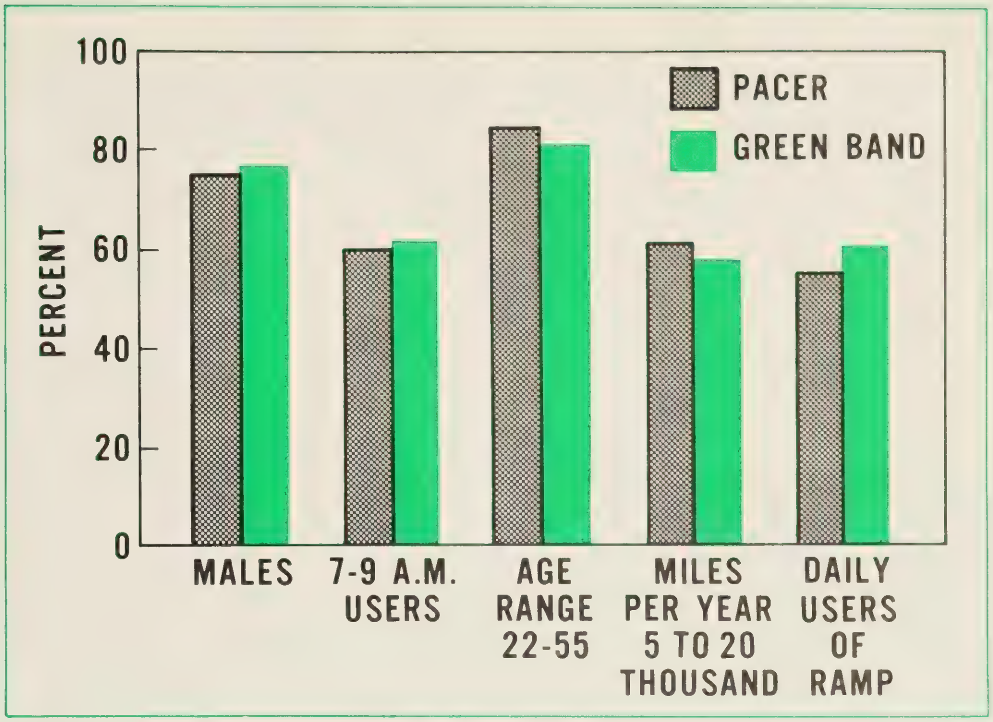


Figure 16.

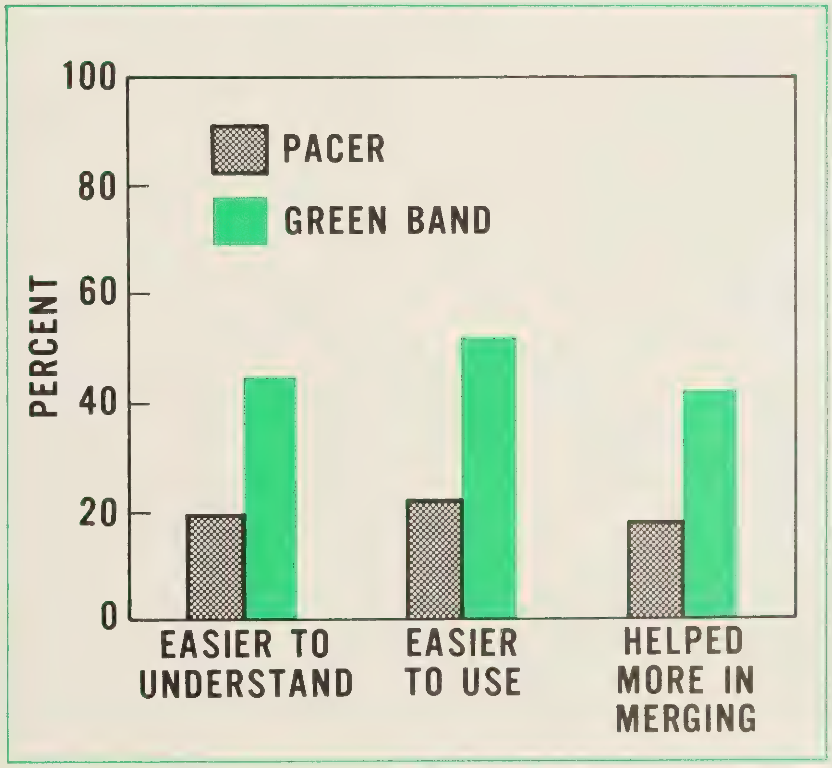


Figure 17.

Figure 16.—Comparative characteristics of questionnaire respondents.

Figure 17.—Comparisons between pacer and green band systems by drivers who had used both.

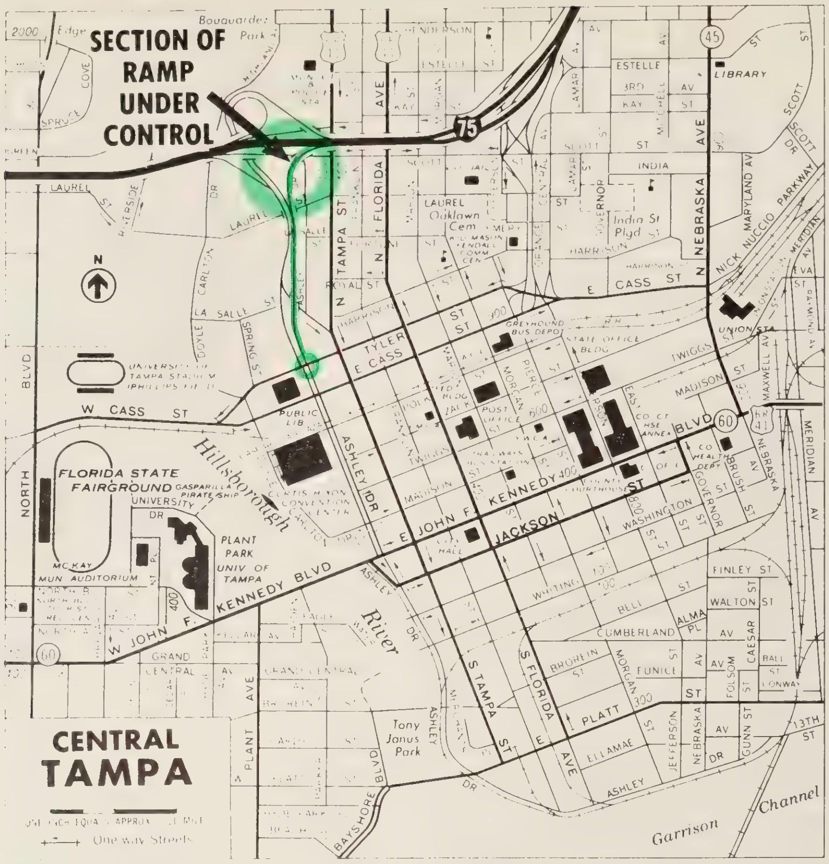


Figure 18.

Recommendations for Experimental Installation

Based on the major findings of the Massachusetts tests, the next logical step in the development of a moving merge control system was to install the preferred green band system on a ramp which was experiencing serious merging problems.

Since the Massachusetts green band system had a number of temporary features (wooden enclosure for the driver display and a control center housed in a trailer) and the geometrics of the ramp and the merging conditions had not presented a severe test of the system, an experimental installation having more permanent features and a longer exposure to traffic at a site with difficult merging conditions was sought. At such a site, an evaluation could be performed to answer the basic question: *Should a green band system be considered a viable alternative for improving the merging operations at a problem entrance ramp?* To answer this question, one or more candidate problem ramps had to be located and the system installed and evaluated. To assist in the search for a problem ramp, the following list of site requirements was developed.

- Entrance ramp should be other than cloverleaf type with restricted sight distance.
- Short acceleration land (under 400 feet).
- High accident experience (over 10 accidents yearly).
- Relatively high off-peak merging volumes, but also two well defined peak periods daily. During peak periods, ramp volume should be approximately 400 to 600 vehicles per hour with a merging problem on the freeway.
- Minimum ramp length of 500 feet.
- Suitable area available on left side of ramp for installation of driver display.
- No upstream on-ramp closer than 1,800 feet, or downstream off-ramp closer than 3,000 feet.
- Reconstruction of site to eliminate unsafe condition would be too costly or impractical for other reasons.

To assist in finding a candidate site, the Federal Highway Administration field offices contacted the State highway and transportation departments for recommendations of ramps which met the selection criteria. Several States responded with candidate sites. After a thorough review of all candidate sites submitted, the Ashley Street entrance ramp to I-75 in Tampa, Fla., was selected for the experimental installation and evaluation of the green band merging control system.

The Tampa Green Band Project

The Ashley Street ramp

Figure 18 shows the location of the Ashley Street entrance ramp with respect to the central Tampa business district. The ramp is shown in green. During the evening peak period, the Ashley Street ramp serves heavy volumes of traffic leaving downtown via I-75. Because of difficult merging conditions, ramp drivers experience considerable delay and ramp traffic nearly backs up to the signal on Ashley, shown as a green circle.

Figure 18.—Map of Central Tampa.

Figure 19.

Figure 20.

Some idea of the difficulty drivers face in the merge area is shown in figures 19-21. Figure 19 shows the merge area from ground level looking downstream.

Figure 20 shows the end of the acceleration lane. Since the ramp is on an elevated (structural) section of the freeway, there is no shoulder (or breakdown lane) beyond the end of the tapered acceleration lane. Hence, drivers must either complete their merge by this point or come to a complete stop. In this latter case, the driver is then presented with an even more difficult maneuver of finding an acceptable gap from a standing start. These conditions are shown in figure 21 taken from the roof of a building adjacent to the merge area. Ramp vehicles in the foreground are stopped while vehicles on the freeway (in the background) are moving along at speeds of 45-50 mph. Many merging opportunities are missed at the Ashley Street ramp even though there are gaps in the right lane of the freeway which would be considered acceptable under a normal merging situation.

Figure 21.

Figure 19.—Merge area from ground level looking downstream.

Figure 20.—Downstream merge area showing acceleration lane.

Figure 21.—Vehicles stopped on acceleration lane.

The geometric features—such as ample length of acceleration lane, sight distance, and flat angles of convergence—normally required for good merging operations would be costly to achieve by redesign and reconstruction of the Ashley ramp because of the elevated ramp-freeway section. These factors help to illustrate why this ramp was selected for installation of a system to aid drivers with their merging problem. Figure 22 shows an aerial view of the Ashley Street ramp. Superimposed in the photograph are the elements of the green band merging control system which are now being installed and evaluated.

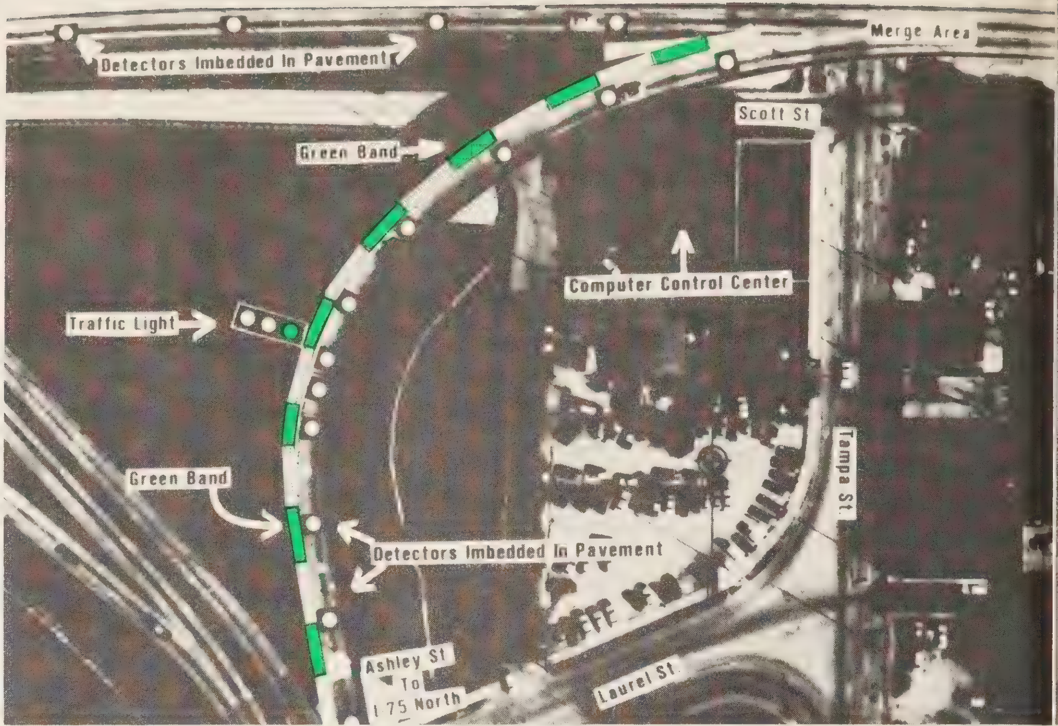


Figure 22.

Launching the Tampa project

By the time the green band merging control system is fully evaluated at the Tampa site, many persons, representing a number of organizations, will have devoted a great deal of time and effort to the project. The green band system is quite sophisticated and requires the talents of many disciplines to achieve operational status. Few organizations possess all the required personnel and resources to accomplish such an undertaking. Thus, the Tampa project has required the cooperation of many organizations, including Federal, State, and local governments as well as university and industry groups. The organizations and the roles each play with respect to the Tampa Project are shown in table 1.

Figure 22.—Ashley Street entrance ramp and layout of green band.

Table 1.—Tampa project organization

Organization	Role	Offices and Location
Federal Highway Administration	Project administration Federal-aid financing Consultation	Headquarters Offices—Washington, D.C. Regional Office—Atlanta, Ga. Division Office—Tallahassee, Fla.
Florida Department of Transportation	Project management and coordination System design and installation of field hardware System integration and checkout State financing	Headquarters Offices—Tallahassee, Fla. District—Bartow, Fla. Project—Tampa, Fla.
University of Florida	Traffic studies Computer program adaption Reporting Preliminary design Consultation System evaluation	Department of Civil and Coastal Engineering—Gainesville, Fla.
City of Tampa	Control center building Consultation Operations and maintenance	Traffic and Planning—Tampa, Fla.
Raytheon Company	Tampa control center hardware Computer programs Consultation	Equipment Division—Sudbury, Mass.

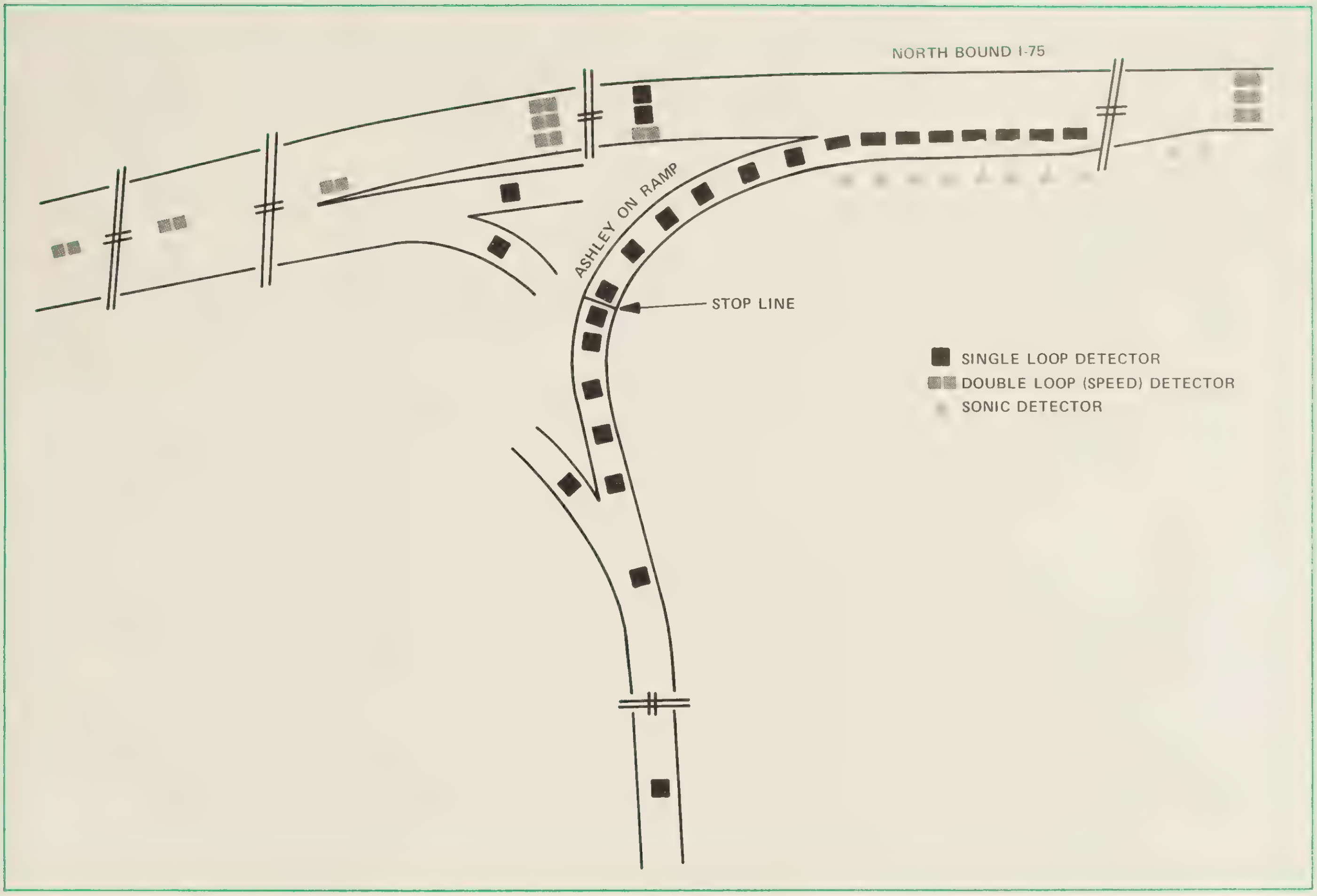


Figure 23.

With such an array of organizations and people involved, it was clear that some type of written agreement, delineating each party's responsibility and role, would be needed to accomplish the project. Accordingly, the government units—Federal, State, and local—signed a *Statement of Intent* to officially launch the project. This document outlined the roles of each party and, most importantly, provided for a technical advisory committee to meet regularly to guide the project. This committee is chaired by Mr. Emmett L. Owens, Traffic Operations Engineer for the Florida Department of Transportation.

Tampa system description

Figure 23 shows the actual layout of the detectors to be used for the Tampa green band system (*10*). From these detectors, traffic flow information will

Figure 23.—Tampa system detector layout.

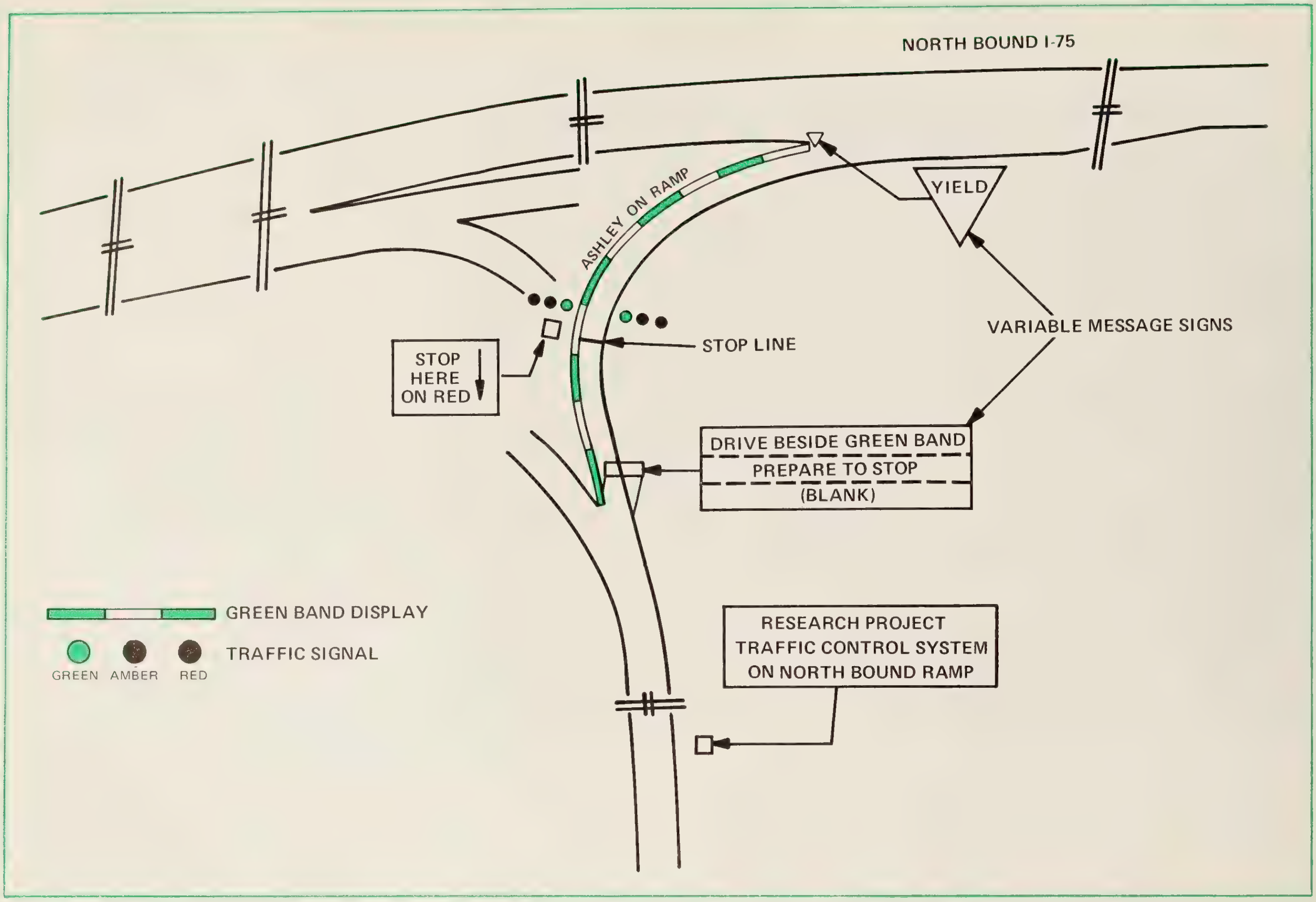


Figure 24.

be sent to the computer in the control center. Based upon traffic flow information (speeds, available gaps, etc.) the computer will send out information to the driver display system shown in figure 24 which consists of the green band display, the traffic signal, and the variable message signs. With the Tampa green band system, ramp drivers will be able to use either the moving mode or the stopped mode for assistance in merging into a freeway gap. In the moving mode, they will drive beside a green band that will lead them into an acceptable gap. In the stopped mode, they will be given an accelerating green band to lead them into an acceptable gap. If in the stopped mode no acceptable gap is available, ramp vehicles will be released one at a time and drivers will be able to select their own gap in which to merge.

The system described here for the Tampa ramp represents a number of changes and refinements from the earlier Woburn, Mass., installation. Because of differences in the sites and other factors, it is expected that the Tampa system will prove to be a significant advance over the earlier installation. In fact, the Tampa project has been undertaken with the aim that if the green band system is found to be a cost-effective way of improving poor ramp freeway merging operations, the project design and documentation will serve as an *implementation package* for installation at other sites.

Tampa evaluation plan

The evaluation plan for the Tampa green band system has been designed to answer the basic question posed earlier: *Is it a viable alternative for improving merging operations at a problem entrance ramp?* To answer this question, studies will be conducted with the specific objective of determining:

- The degree of improvement in freeway operations,
- The degree of improvement in ramp operations and merging capacity,
- The degree of driver usage and acceptance,
- The safety and reliability of operation, and
- The cost-effectiveness of the system as compared to other alternatives such as reconstruction of the ramp.

Figure 24.—Tampa driver display system.

Data required for the evaluation will be collected by a variety of means including the detectors and computer used to run the system, closed circuit television, existing traffic data, an instrumented vehicle, and a public questionnaire.

The evaluation will be done in the classic *before* and *after* style. In the *before* study, the computer and detectors will be used to collect data on existing conditions. Following a sufficient period of data collection, the driver display will then be installed and an *after* study will be performed. A comparison of *before* and *after* data can then be made to satisfy most of the study objectives.

Progress report on the Tampa project

By the end of 1973, all elements of the Tampa green band system are expected to be operational with the exception of the driver display. Data collection for the "before" study will be underway using the detectors and computer and other types of data collection techniques. By early 1974, the "before" study will be completed and installation of the driver display will begin. After a brief *learning* period for drivers to adapt to the system, the "after" study will commence. By the end of 1974, the results of the evaluation should be available.

Prospects for the Future of Merging Control Systems

This discussion of merging control systems, from metered and closed ramp control system experiments in Detroit, Chicago, and Houston to the sophisticated Tampa green band system, would not be complete without mentioning the prospects for future implementation of this type of driver aiding system. Two lines of development seem apparent. In the first, more obvious case, these systems may indeed prove to be a viable alternative solution for ramps with chronic merging problems. In this application, one can easily visualize the refinement and *packaging* of the Tampa system into a stand-along ramp controller, very similar in appearance and application to the present day units which control traffic signals at ordinary intersections.

A second line of development would employ merging control systems not at isolated trouble spots, but as continuous systems at each ramp along a heavily traveled urban or intercity freeway. In this application, the systems would become part of large scale, integrated motorist information systems for guiding drivers and controlling traffic in a corridor (*11*). The contribution of the merging control systems to the overall control of traffic in the corridor would be to provide smooth, safe merging operations so that the mainline traffic flow remains stable and incident free.

Work associated with these two development efforts is a major project within the implementation program of the Federal Highway Administration. Based upon experience gained to date and from that which will be gained in the Tampa project, it will be known where the green band moving merge control system can be effectively used. Thus, from their humble beginning as simple devices for aiding drivers in ramp to freeway merging maneuvers, merging control systems will have evolved to the point where they will be making a major contribution to the optimum use of all freeways in heavily traveled corridors.

REFERENCES

(*1*) Julie Anna Cirillo, "Interstate System Accident Research Study II, Interim Report," *Public Roads*, vol. 35, No. 3, August 1968.

(*2*) "Merging Control Systems," U.S. Department of Transportation, *Federal Highway Administration, Offices of Research and Development*, May 1971.

(*3*) Joseph A. Wattleworth, Johann H. Buhr, Donald R. Drew, and Frank A. Gerig, Jr., "Gap Acceptance and Traffic Interaction in the Freeway Merging Process," *Texas Transportation Institute*, Report 430-3, vol. 3 1967.

(*4*) J. M. McDermott, S. J. Kolenko, and R. J. Wojcik, "Chicago Area Expressway Surveillance and Control: An Interim Report," Illinois Department of Transportation, Bureau of Materials and Physical Research—Report No. 25, June 1973.

(*5*) Donald R. Drew, William R. McCasland, Charles Pinnell, and Joseph A. Wattleworth, "The Development of an Automatic Freeway Merging Control System," *Texas Transportation Institute*, Research Report No. 24-19, November 1966.

(*6*) M. L. Radke, "Freeway Ramp Control Reduces Frequency of Rear-End Accidents," *Texas Transportation Institute*, Research Report 24-21, 1966.

(*7*) Paul F. Everall, "Urban Freeway Surveillance and Control: The State-of-the-Art," U.S. Department of Transportation, *Federal Highway Administration*, November 1972.

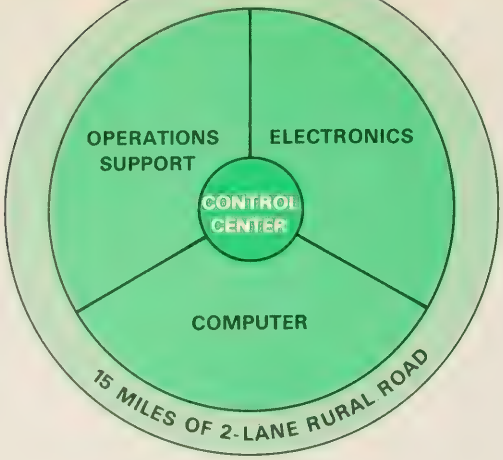
(*8*) Dallas Corridor Study Staff, "Evaluation of Ramp Control Operation on North Central Expressway," *Texas Transportation Institute*, 1972.

(*9*) "Gap Acceptance and Traffic Interaction in the Freeway Merging Process—Phase II Final Report," *Texas Transportation Institute*, Texas A&M University, 1969.

(*10*) "Implementation and Evaluation of a Moving Merge Control System in Tampa," Third Interim Report to State of Florida Department of Transportation, *University of Florida Transportation Research Center*, July 31, 1973.

(*11*) M. F. Maloney, H. A. L. Lindberg, and G. W. Cleven, "A Solution to Intercity Traffic Corridor Problems," *Public Roads*, vol. 37, No. 5, June 1973.

The Maine Facility,



by Stanley R. Byington and Merton J. Rosenbaum

Presented is an overview of the Maine Facility, a 15-mile section of two-lane rural highway instrumented to study driver problems in discrimination, judgment, and vehicle control problems. Computer controlled data collection and roadside communications are provided to test and evaluate static and dynamic remedial aids. Organization and management includes participation by FHWA, DOT/Transportation Systems Center, the Maine State Department of Transportation, and other groups. Initial and future experiments include speed zone, narrow bridge, railroad grade crossing, limited sight intersection, and overtaking on grade problems. Support from the States is being requested through a cooperative research program.

Rural two-lane roads are important in terms of route mileage, extensive vehicle-miles of travel, and a high accident record. Existing problems on such roadways are evident to all who drive them. Conditions such as restricted sight distance, oncoming traffic, and overtaking of slow moving or stopped vehicles all tend to decrease average vehicle speed; hence, increase travel time. Further, such conditions may cause drivers to attempt unsafe passes, follow too closely, or overtake a vehicle ahead at too high a speed; any of which may be accident potential situations. Stated simply, the two-lane rural highway presents a very basic problem—how to improve roadway level of service as reflected by reduced travel times, fewer traffic interruptions, additional freedom to maneuver, increased safety, lower operating costs, and improved driving comfort and convenience—all without incurring the large expenditures required for major reconstruction and upgrading to divided highways.

To better define two-lane rural highway problems and develop and evaluate possible static and dynamic traffic control device solutions, a 15-mile two-lane section of U.S. Route 2 in Maine has been instrumented as a test facility. It is called the Maine Facility.

The purpose of this article is to provide an overview of the Maine Facility, its operation, geometric and traffic characteristics, and utilization with a view to encouraging the States and others to cooperatively and/or individually participate in its use and thereby reduce or eliminate many rural two-lane safety and operation problems.

The Problems

Precise statistical information on two-lane rural roads in the United States is not available. However, if it is assumed that the road classifications listed in table 1 (*1*)[1] are representative of all paved rural two-lane roads in the United States is immediately evident. The table shows, for example, that the percentage of rural road mileage (22 percent) carries a disproportionate share of the traffic (32 percent). This traffic is involved in fatal traffic accidents which account for a disproportionate share of traffic fatalities (48 percent). Of the total mileage shown, at least 163,000 miles carry over 2,000 vehicles per day. The breakdown of roadway mileage by average daily traffic is available only for surfaced mileage on the State and Federal-aid primary system. The 163,000 miles are for undivided roadways with a width less than 27 feet (2).

Some of the typical problems faced by drivers who must drive rural two-lane highways are shown in figure 1. This composite of photographs represents situations currently in existence along the Maine Facility test site.

The upper left photograph depicts the unsafe conditions present at narrow bridges. Narrow bridges are defined in the Manual on Uniform Traffic Control Devices as those having a clear two-way roadway width of 16 to 18 feet, inclusive, or roadway clearance less than the width of the approach roadway.

[1] Italic numbers in parentheses identify the references on page 255.

Figure 1.

Figure 1.—Typical rural two-lane operational problems.
Upper Left: Narrow bridge conflict
Upper Right: Railroad grade crossing conflict
Middle Left: Speed reduction zone
Middle Right: Vehicle queue due to slow moving vehicle
Lower Left: Sight restricted intersection

A survey is presently underway to determine the nature and extent of bridge deficiencies in the United States. It is estimated that this survey will show that about 6,000 bridges in the Federal-aid primary system have widths of 20 feet or less. The report on 1970-1990 National Highway Functional Classification and Needs Study further indicates that more than 24,000 bridges in the total Federal-aid system are either presently deficient or will become deficient before 1990. It is also worth noting that 80 percent of the aforementioned width deficiencies are in rural areas as reported by the staff of the House of Representatives Committee on Public Works, Subcommittee on Investigations and Review, in an unpublished report prepared for the narrow bridge hearings held on June 12-14, 1973.

The upper right-hand photograph demonstrates one type of problem faced by drivers at railroad grade crossings. This crossing on the Maine Facility site is typical of 14,580 other crossings in this country; i.e., crossings with 1,001 to 5,000 highway vehicles and two or less trains per day. Of these crossings, 9,916 have passive protection, like the crossing along the test site which only designates to the driver the location of the crossing. Crossings with either passive or active protection in this highway vehicle-train volume classification have an average number of 0.07 accidents per crossing per year (3).

Table 1.—1971 Rural highway statistics

Road classification	Mileage *Thousands*	Vehicle-miles *Billions*	Fatalities	Injuries *Thousands*
Interstate travelway[1/]	9	24	1,629	33
Other Federal-aid primary	189	205	13,682	316
Federal-aid secondary State	286	96	7,295	167
Federal-aid secondary local	321	51	3,270	109
Total rural	805	376	25,876	625
Total in U.S.	3,733	1,186	53,907	2,660
Rural percentage	22	32	48	23

[1/] Includes highways not yet upgraded to full Interstate design standards but adequate for present traffic; also older sections of existing highways presently serving Interstate corridor traffic.

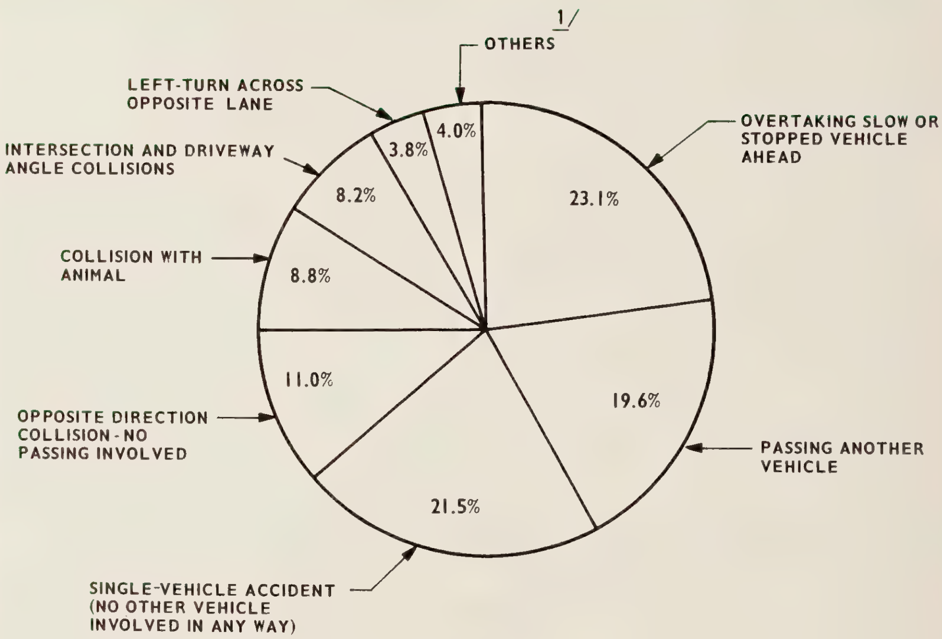


Figure 2.

The remaining photographs in figure 1 represent other traffic situations (referred to later in this article) leading to the type of rural two-lane traffic accidents classified by percentage in figure 2.

Figure 2.—Rural two-lane highway accident. classification (4).

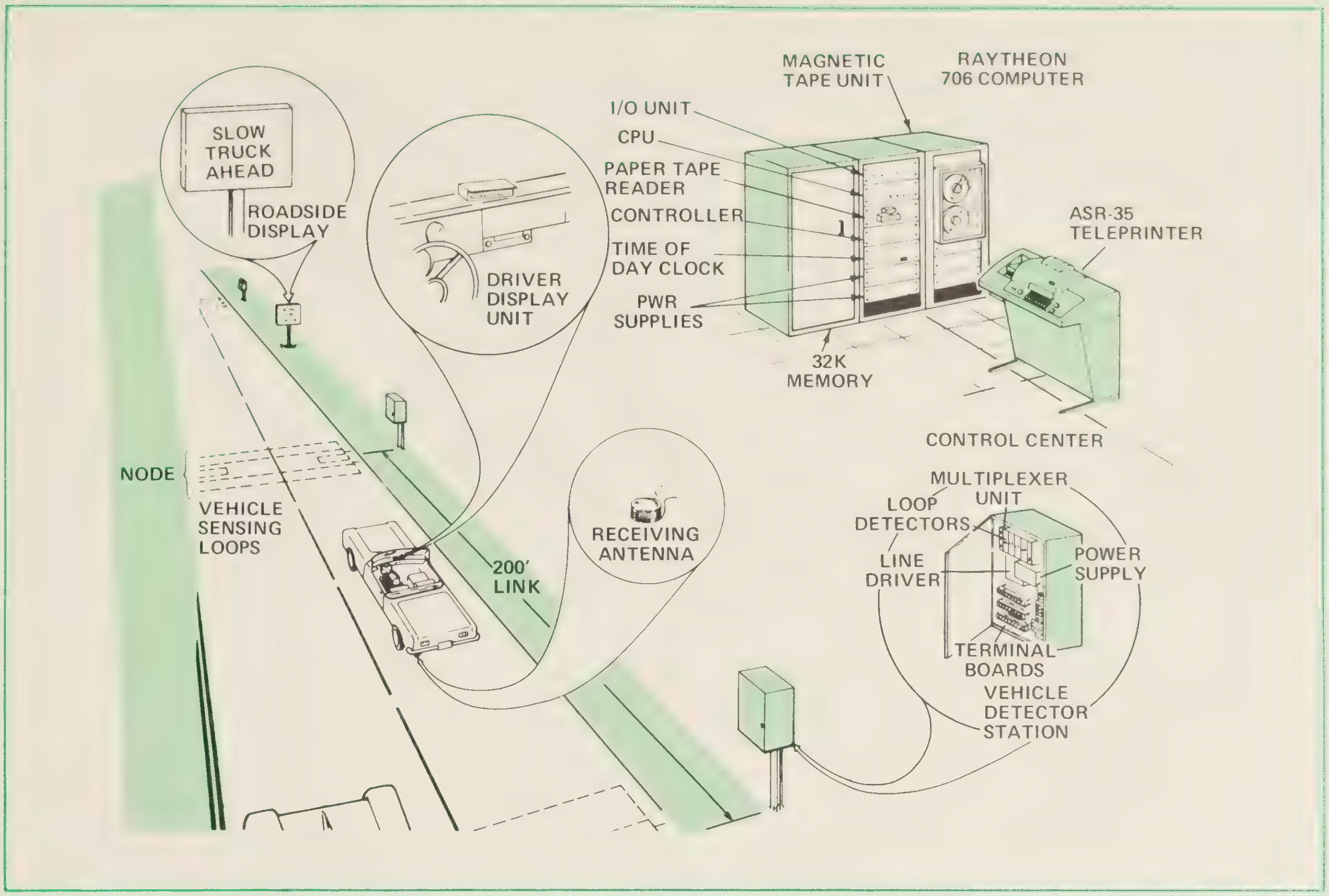


Figure 3.

Considering the extent of these problems, there is a need for a concerted and concentrated effort to develop systems and techniques for aiding drivers in solving discrimination, judgment, information, and vehicle control problems which pertain to overtaking, following, passing, and turning maneuvers, and climatic conditions on two-lane rural highways.

Previous research in this area has been hampered by the lack of instrumentation that is required to follow or track vehicle movements over sufficiently long sections of roadway to detect initial conditions as well as driver reactions to possible remedial aids being tested. Also, some problem solutions appear to require variable messages, either in the form of roadside or in-vehicle displays. To be effective, these must operate in *real time* making necessary the use of computers and roadside communication techniques. For these reasons, the Maine Facility has been designed and installed to monitor traffic data in a very precise manner, communicate with drivers over considerable distances, and evaluate the effectiveness of alternative traffic control remedial aids to be implemented through changes in vehicle codes, driver education programs, the Manual on Uniform Traffic Control Devices, and design policies.

Description of the Maine Facility

The Maine Facility is a computer-controlled data acquisition system that can detect vehicles and track their positions in real time as they travel on an electronically instrumented two-lane highway. These traffic data are stored on magnetic tape for subsequent off-line data reduction and evaluation of traffic behavior.

The system also provides for the transmission of messages to motorists as they travel the instrumented section of highway. The messages can be displayed within the vehicle on a special dash panel display or at roadside on variable message signs.

The prime function of the Maine Facility is to provide a test facility that can accommodate a variety of traffic experiments associated with the motorist, his vehicle, and his environment.

The system which performs the on-line functions is depicted in figure 3. The system can include up to 500 vehicle detector stations (spaced approximately 200 feet apart), associated highway sensing loops, a computer control center, and a network of underground signal and power cables. The control center, which houses the computer and peripherals, can interface with up to 250 detector stations east and 250 stations west of the control center location.

Figure 3.—Maine Facility system.

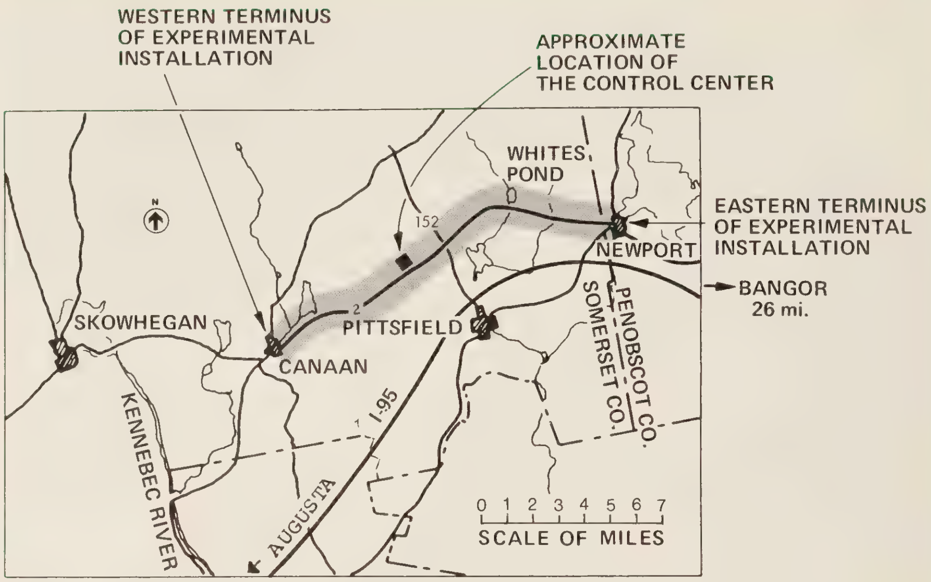


Figure 4.

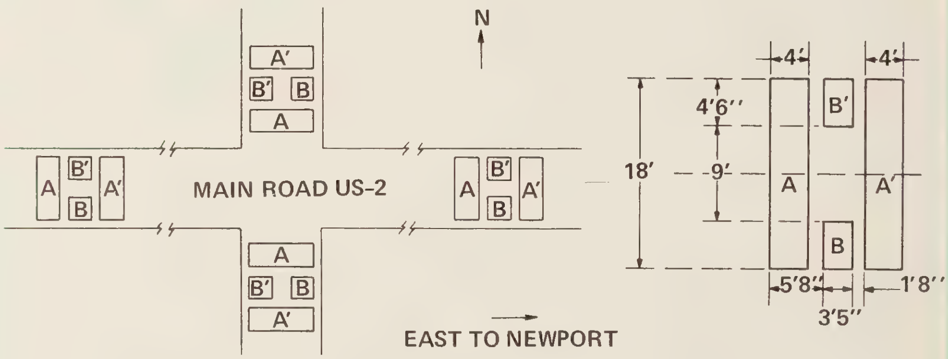


Figure 5.

The Maine Facility is installed on U.S. Route 2 between Newport and Canaan, Maine, as shown in figure 4. The control center is situated 8.5 miles from the eastern terminus of the 15-mile instrumented road.

The sensing loops are installed in sets of four (called a node and shown in figure 5) and are configured to permit the determination of vehicle location and direction. Nodes are spaced uniformly 200 feet apart on the main road. Side roads with a flow of three vehicles/hour or less are not instrumented. Side roads which exceed this flow are instrumented with a node placed approximately 150 feet from the center line of the main road. Other occasional high flow entries and exits of one lane width are also instrumented with a two-sensor node. The Maine Facility has 396 main-road nodes, 10 side-road nodes, and two two-sensor nodes.

The sensing loops at each node are connected to the adjoining vehicle detector station. Only those nodes east of the control center are presently equipped to handle the electronics required to process vehicle detections for transmission to the control center. Twenty-seven portable electronic detector packages are available for use in conjunction with any contiguous or noncontiguous 27 nodes. Ten additional detector packages are now being procured.

Transmission of messages to instrumented vehicles is accomplished via the detector stations and sensing loops. In-vehicle instrumentation consists of a receiver-display assembly and a receiving antenna. Roadside-display messages are also received at the detector stations and channeled to nearby roadside displays. Up to eight unique messages can be transmitted to instrumented vehicles and up to 256 messages to roadside displays.

How the Facility Operates

On-line operation

The following is a discussion of how information flows between the subsystems in the Maine Facility system. Please refer to figure 3 in following the discussion.

Figure 4.—Maine Facility test site.

Figure 5.—Sensor loop configurations.

Loop inductance changes caused by vehicles traveling over loop sensors at a node are transformed to binary states and formatted in that node's vehicle detector station. These states are sampled 16 times each second by the input/output (I/O) subsystem under control of the computer. The computer and I/O subsystem process the state changes to determine vehicle status on the roadway and store this information on a magnetic tape.

Display information is transmitted to instrumented vehicles by means of amplitude modulated carriers transmitted from the control center. An antenna, attached inward of the rear bumper on an instrumented vehicle, receives the transmitted data through the sensor loops. The in-vehicle receiver, mounted below the dash, processes these signals and the message content is displayed on the driver display unit. The display consists of three rear-illuminated color panels which can be lighted in various combinations. Receiver time constants (based upon expected vehicle velocities as calculated from previous system measurements) permit the messages received by a vehicle at one node to be displayed until the next node is reached. If the next node has no message, the in-vehicle display is extinguished.

Messages can also be transmitted to roadside displays by sending instructions manually via the ASR-35 teleprinter or by real-time controlled decisions based on traffic behavior.

Operation of the entire system is under control of a system software operational program which can be supplemented by special operator directives inputted via the teleprinter. These directives provide the flexibility required to modify the communications flow of an operating system (place nodes on-line or off-line) or to request special teleprinter data printouts.

Off-line operation

The ability to collect data accurately and automatically is, of course, essential to any experiment requiring the collection and reduction of large amounts of data.

The on-line operational program processes all interrupts from the I/O unit and prepares a log, on magnetic tape, of the entire traffic data collection run history. These stored data are then used by special off-line data reduction programs. These programs permit the data stored on the magnetic tape, located in the control center of the Maine Facility, to be transformed into several meaningful traffic parameters. Some traffic parameters—both for individual and groups of vehicles—which can be obtained through summation, integration, and differentiation of two or more bits of sensor vehicle presence information (detector states) are listed in table 2.

Table 2.—Traffic measures obtainable from the Maine Facility System

Derived Measures

Individual Vehicle
—Direction of travel
—Spot speed
—Acceleration and deceleration
—Speed variance
—Number of speed changes
—Number of stops
—Stopped time
—Travel time
—Journey speed
—Delay
—Travel pattern (turns from the main road)

Two or more vehicles
—Space-mean speed
—Time-mean speed
—Volume (over any time period: 5 minutes, hour, day, etc.)
—Time headways (between successive vehicles)
—Spacing (between same points on successive vehicles)
—Density
—Passing times
—Number of overtakings
—Number of passes
—Distribution and size of queues
—Gap acceptances (for left turns, crossing maneuvers, and passing maneuvers)
—Number of turning maneuvers
—Cumulative speed distributions
—Total number of stops
—Total delay
—Accumulation (volume/time-mean speed)
—Time spent in queue
—Number of hazardous maneuvers (acceptance of too small gaps; passing aborts)
—Speed violations (at curves, on tangents, entry to town speed zones, etc.)
—Traffic distribution by direction
—Number of intersection conflicts
—Total travel (vehicle-miles)
—Total travel time (vehicle-hours per unit of time)
—Kinetic energy (density × speed squared)
—Optimum service volume (volume at maximum kinetic energy)
—Journey time coefficient of variation (ratio of standard deviation of a group of journey times to the mean journey time)

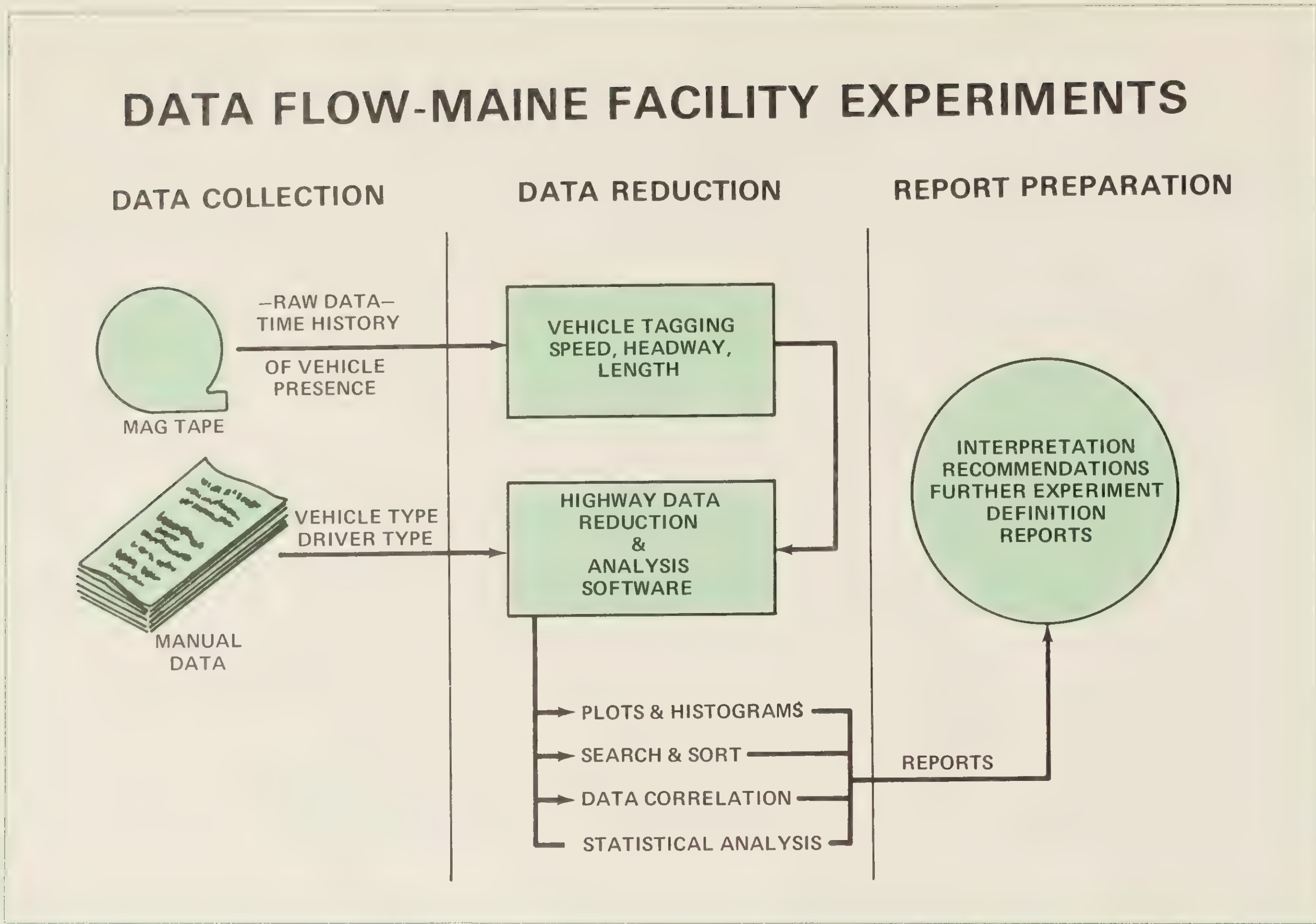


Figure 6.

Figure 6 summarizes the off-line flow of data that is collected from Maine Facility traffic experiments and which result in partial or total solution to rural two-lane highway operational problems.

How the Maine Facility Can Be Used

The Maine Facility is located on a typical paved rural two-lane highway, 10 miles of which are of pre-World War II design. The road segment follows the terrain and consists of a 20-foot-wide bituminous pavement with 2- to 4-foot shoulders. The remaining 5 miles, all of which are east of the control center, are of post-World War II design. This road segment has a 24-foot-wide bituminous pavement and 10-foot stabilized shoulders. Alinement is good.

Figure 6—Data flow for Maine Facility experiments.

East of the control center, there are:

- Reduced speed zone for a small town
- A rural consolidated school
- Both three- and four-legged sight restricted intersections
- A 200-foot-long, narrow bridge
- An at-grade, low train volume, railroad grade crossing
- A major crossroad
- A rest area with picnic facilities
- Steep grades
- Several passing and no-passing zones
- Many residential and farm driveways
- Both paved and unpaved sideroads
- A few roadside businesses.

Traffic varies from a low of around 1,000 vehicles per day in the winter to a high of approximately 4,000 vehicles per day during the summer months. Since the road is the most northerly east-west route across Maine, a significant number of out-of-State and Canadian vehicles use the highway, especially during the summer months. A large percentage of recreational vehicles also use the road during the skiing, summer recreational, and fall foliage time periods. Being a Federal-aid primary and U.S. numbered route, many commercial vehicles also travel the road.

The more important test site geometric and traffic characteristics are summarized in table 3.

The test site also offers a variety of climatic conditions under which experiments may be conducted. The average annual snowfall and rainfall in the vicinity of the Maine Facility are 95 and 42 inches, respectively. The accumulation of snow results from approximately 15 snow storms per year. Ground fog is also prevalent during the morning hours on approximately 15 days throughout the year. General fog is present another 15 days during the year.

In summary, the functional capabilities of the Maine Facility can be divided into the following three categories:

(1) *Data collection* for planning, problem definition, design, model building, and validation activities.

(2) *Monitoring and evaluation* of static type traffic control devices; driver education, maintenance and law enforcement programs; and operation of the facility's hardware elements.

(3) *Operation* as a dynamic feedback traffic control evaluation system.

A corresponding example of each of these three functions are as follows:

(1) Collection of speed data to determine drivers' degree of compliance to speed signs.

(2) Monitoring of passing behavior and evaluation of various passing zone delineation techniques.

(3) Operation and evaluation of a dynamic intersection driver advisory system that informs drivers of the size of gap available.

Table 3,—Site characteristics

System length	15 miles
Speed limits	15, 35, 45, 60 mph
Road type	Two-lane asphalt
Maximum grade	7 percent
Maximum curve	4° 30'
Number of bridges	2
Number of railroad crossings	1
Average daily traffic	1,000 to 4,000 VPD
Percent truck traffic	8 to 12 percent
Estimated capacity (two-way)	700 to 1,600 VPH
Directional traffic distribution	0.60
Pavement width	20 to 24 feet
Shoulder width	2 to 10 feet
Percent passing sight distance	31 percent
Highway intersections	9
Entrances	280

Other typical questions and hypothesis that might be addressed using the Maine Facility are listed below.

■ What is the density function of traffic queue buildups? Where, how, and why do they occur?

■ Where should speed limit signs be installed? That is, at points along the roadway where new and lower speed limits are posted, and at what points in reference to the signing should drivers be expected to comply with the lower limits?

■ What is the frequency of speed violations and where do they most frequently occur? On tangents? Extrances to towns? On horizontal curves? On downgrades?

■ What is the effect of dynamic average speed of traffic variable message signs? Do they reduce the speed variance over the entire roadway? Only in the vicinity of the sign? Would they be effective at narrow structures? At railroad/highway grade crossings? At entrances to towns?

■ What are the effects of various maintenance signing (location in advance of, size, color, etc.) on traffic operation adjacent to and in advance of maintenance operations including sealing, shoulder repair, and roadside mowing?

■ What is the density function of gap acceptance for main road left-turning maneuvers? Passing maneuvers? Crossing maneuvers at crossroads?

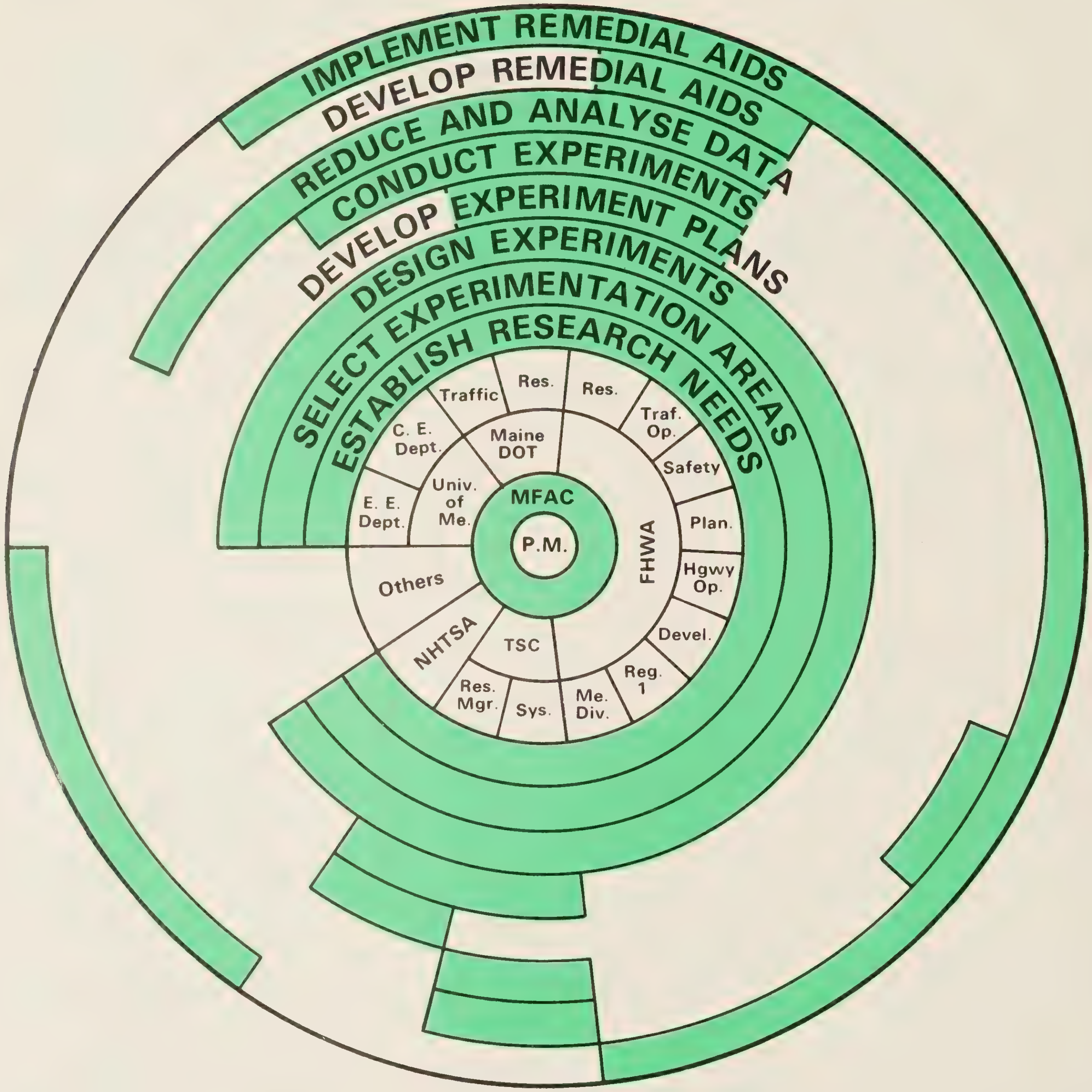
■ What constitutes a hazardous maneuver as defined by the above density functions?

■ What is the mean time between failures of inductive loops?

■ How does solo passing and overtaking performance change following driver training in same? What is the lasting effect?

■ Are upcoming passing zones used more frequently when advance notice is given?

■ What signing, markings, and other control devices are needed to obtain better compliance to town speed limits along a two-lane segment of roadway?



P. M.; Project Manager
MFAC: Maine Facility Advisory Committee
TSC: Transportation Systems Center, DOT
NHTSA: National Highway Traffic Safety Administration, DOT

Function Participation

Figure 7.

Current Use and Future Plans for the Facility

Many organizations are now involved in the use and operation of the Maine Facility. These organizations, including the functions they perform with respect to the facility, are shown in figure 7.

The focal point of the Maine Facility is the Federal Highway Administration project manager who is chairman of the Maine Facility Advisory Committee. This committee is composed of representatives from all of the named organizations and subelements surrounding the Maine Facility Advisory Committee band in figure 7. They assist the project manager in such areas as establishing rural two-lane highway research needs, selecting the order in which experiments are to be conducted, and reviewing and commenting on experiment designs. The Maine State Department of Transportation must approve each experiment design prior to the experiment being performed on the highway. Succeeding outer bands (shaded areas) within the figure show the additional functions required to bring experiments from conception through the production of remedial aids and their implementation as related to the organizational elements participating in each function.

Ongoing research

Employing the concepts depicted in figure 7, a set of initial experiments on rural school zone signing was begun early in 1973. The objectives of these experiments are to determine the desirable speed limit(s) for rural school zones, and the sign configurations—including sign locations—which optimize driver understanding, acceptance, and compliance to these speed limits(s). All experiments have been conducted and the collected data are now being reduced and analyzed. We plan to summarize the results of these experiments in a future issue of Public Roads.

A second set of experiments for studying the effects of several speed control devices on traffic entering and passing through small rural towns has now been initiated. The objectives of these experiments, which were begun in October 1973, are to develop safe, practical traffic control devices which will alert drivers to the need for reducing speed when approaching concentrated areas of population, and invoke voluntary compliance with the speed regulatory devices in a manner promoting increased safety in vehicle operation. The experiments are being performed at the location pictured in the left middle photograph in figure 1.

Future research plans

A third set of experiments directed toward examining alternative remedial aids to alert drivers when overtaking slow moving vehicles on steep grades, as shown in the middle right photograph in figure 1, will be designed and initiated during the latter half of fiscal year 1974. During this same period, or earlier, States will be queried as to their interest and the degree they wish to participate in the research uses of the Maine Facility. Problems for research during fiscal year 1975, with State participation, will include those associated with narrow bridges, railroad grade crossings, and intersections with inadequate sight distance like that shown in the lower left photograph in figure 1.

The first two research areas involve problems of national interest and are currently being researched: narrow bridges under NCHRP Project 20-7 and railroad grade crossings under a 25 State cooperative pooled fund effort. Research for these problem areas, employing the Maine Facility, will be keyed to and based upon the needs of the overall national studies.

The fourth effort for fiscal year 1975 will involve the collection and processing of data to provide information for highway designers and traffic engineers on traffic performance, including vehicle equivalency and other factors affecting two-lane highway capacity.

States interested in cooperating in the use of the Maine Facility may be involved in many of the functions shown in figure 7, including membership on the Maine Facility Advisory Committee. To obtain additional information on the facility and its utilization, the reader is referred to the Federal Highway Administration, Traffic Systems Division, HRS-30, Washington, D.C. 20590, and to The Maine Facility System Final Report (5).

REFERENCES

(1) "Fatal and Injury Accident Rates on Federal-aid and Other Highway Systems/1971," *Federal Highway Administration*, Washington, D.C., pp. 16-19, 25, 27-30, 36.

(2) "1971 Highway Statistics," *Federal Highway Administration*, Washington, D.C., pp. 212, 227.

(3) "Railroad-Highway Safety Part II: Recommendations for Resolving the Problem," *Federal Highway Administration and Federal Railroad Administration* Report to Congress, August 1972, pp. II-6, III-14, III-15.

(4) W. J. Kemper, P. E. Huntington, and S. R. Byington, "Overtaking and Passing Accidents," *Public Roads*, vol. 37, No. 3, December 1972, p. 84.

(5) Dennis S. Berg, Walter P. Davis, John J. Freniere, Roger L. Fuller, Allan R. Thayer, Charles W. Torrielli, and John G. Moy, "Maine Facility System," *Raytheon Company*, Sudbury, Mass., June 1973. This final report includes the following five volumes:

- Vol. I—Executive Summary Report
- Vol. II—System Hardware Description, Operation and Test
- Vol. III—System Software Description
- Vol. IV—Special Test Equipment and Performance Tests
- Vol. V—System Acceptance Test

Figure 7.—Maine Facility participating organizations and functions.

HRIS Introduces On-line Retrieval

by Paul E. Irick and Arthur B. Mobley

Users of the Highway Research Information Service (HRIS) now have direct on-line access to summaries of current research projects and to abstracts of recent reports and articles in the field of highway and urban transportation. In this mode of access, the user establishes a telephone connection between his own terminal and the central computer file, queries the file to determine what information is available on specific questions, then decides what to have displayed or printed out—either at his terminal or at the central computer.

On-line access to HRIS is provided through a 7-month retrieval demonstration project conducted by the Highway Research Board (HRB) in cooperation with the Federal Highway Administration (FHWA). Traditional dissemination of HRIS information has been by modes whose access times range from 1 year to 1 week:

- Annual publication of *Highway Research in Progress* and quarterly publication of *HRIS Abstracts*.
- Monthly distribution of abstracts and project summaries for any or all of the 34 HRIS subject areas—a current awareness service.
- Weekly response to specific questions that require retrieval from the entire HRIS file—a file search service.

The demonstration project represents an effort to determine in what ways and to what extent the on-line retrieval mode can be a valuable adjunct to, or substitute for, the traditional access modes. Participants in the project include the HRB, the FHWA, State highway departments, universities, and industries. It is expected that the collective experience of the participants will provide a basis for deciding what role on-line access should play in future HRIS operations.

Specific objectives for the demonstration project are as follows:

- Provide each project participant with on-line access to highway research-in-progress summaries that have been newly acquired or updated by HRIS since 1971 and to HRIS abstracts that have been stored since 1970.
- Provide training and assistance whereby each participant may understand, gain experience, and become proficient in the on-line retrieval process.
- Acquire data and feedback from the on-line retrieval experiences of the participants, and thereby infer the utility of on-line retrieval as an HRIS access mode.

Transportation Research Information System

During the past 2 years, an HRB Committee on Transportation Research Information Systems (TRIS) has recommended that there be established a national network of transportation research information services, that would include HRIS. The work of the TRIS Committee is supported by the Office of the Assistant Secretary for System Development and Technology (TST), Department of Transportation (DOT). One feature of the prospective system is on-line access to a TRIS file that covers the whole range of transportation research information. Thus the HRIS on-line project provides on-line access to all parts of the overall TRIS file that are currently on-line, in particular the component for highway and urban transportation.

Other current and potential components of the TRIS on-line file are represented by the following services:

- TRAIS (Transportation Research Activities Information Service) also sponsored by TST is operated by the Transportation Systems Center located in Cambridge, Mass. This service covers information on all research projects sponsored by DOT.
- RRIS (Railroad Research Information Service) sponsored by the Federal Railroad Administration and operated by the HRB.

<table>
<tr><td></td><td colspan="4">TRANSPORTATION RESEARCH INFORMATION</td></tr>
<tr><td></td><td>AIR</td><td>HIGHWAY</td><td>RAIL</td><td>WATER</td></tr>
<tr><td rowspan="2">Summaries of Ongoing & Recently Completed R&D Projects</td><td colspan="4">DOT R&D Activities - (1) Inactive File (820)
(2) Work in Progress File (2075)
(2900 TRAIS Records for OST, FAA, FHWA, FRA, NHTSA, UMTA, and USCG)</td></tr>
<tr><td></td><td>(3) Highway Research in Progress
(4715 HRIS Records)
HP&R - (705)
NCHRP - (45)
Other US - (1800)
Non-US - (2150)</td><td></td><td></td></tr>
<tr><td rowspan="2">Abstracts of R&D Reports and Abstracts</td><td></td><td>(4) Highway Research Abstracts File
(7362 HRIS Records)
US - (4900)
Non-US - (2500)
1972-3 - (4100)
1970-1 - (3300)</td><td>(5) Railroad Research Abstracts File
(1386 RRIS Records)</td><td></td></tr>
<tr><td colspan="4">(6) DOT Reports Abstracts File
(3000 NTIS Records (estimated) 1970 to date) (planned)</td></tr>
</table>

Notes:

TRAIS Components:	(1) and (2) were updated in July 1973.
HRIS Components:	(3) and (4) were initially loaded in July 1973.
RRIS Component:	(5) was initially loaded in July 1973.

Figure 1.

- MRIS (Maritime Research Information Service) sponsored by the U.S. Maritime Administration and operated by the Maritime Transportation Research Board with HRB assistance.

- HSIS (Highway Safety Information Service) sponsored and operated by the National Highway Traffic Safety Administration.

Through contractual arrangements with Battelle Columbus Laboratories (BCL) at Columbus, Ohio, the TRIS on-line file is stored at the BCL computer center, where the BASIS software system is used for retrieval operations. Now the file contains the HRIS component, an RRIS component, and the TRAIS component, as shown in figure 1. The user may address his questions to all or any combinations of the on-line components of the TRIS file.

The HRIS component consists of approximately 5,000 project summaries and approximately 7,000 abstracts of research reports and articles. The project summaries cover Highway Planning and Research and National Cooperative Highway Research Program projects, nonfederally sponsored research in the U.S., and non-U.S. projects that have been received from the Roads and Transportation Association of Canada (RTAC), the International Road Federation, and the Organization for Economic Cooperation and Development International Road Research Documentation (IRRD) network. The abstract segment of the on-line file covers FHWA reports, Urban Mass Transportation Administration (UMTA) reports, and HRB publications. It also includes abstracts of many other U.S. reports and articles, and abstracts that have been received through RTAC and IRRD.

Figure 1.—Transportation Research Information System on-line retrieval file.

On-line access is provided for only the more current part of the total HRIS file. HRIS has processed and stored an annual average of 10,000 items of research information. At this time the HRIS file contains approximately 11,000 active or recently completed research project summaries and approximately 41,000 abstracts of research documents. Thus the on-line file contains about one-half of all project summaries and about one-sixth of all abstracts that exist in the total HRIS file.

On-line Retrieval Procedures

The on-line retrieval user must first establish a telephone link with the central computer. In the HRIS demonstration project this may be done either by direct dial to BCL or through use of a special network called the TYMNET system. In the second case, the user dials direct to the nearest TYMNET station, and from that point a link is established with the BCL computer at a cost lower than or equal to the cost required for the same direct call. TYMNET permits the user a wider choice among terminals for accessing the BASIS system.

After the user has logged in the BASIS system, perhaps through TYMNET, he specifies that he wishes to search the TRIS file, then indicates which components of the TRIS file are to be searched. Figure 2 shows a user searching the TRIS file from a remote terminal consisting of a cathode ray tube (CRT) screen, keyboard, and printer.

Each record in the HRIS file is either an abstract or a project summary, and is composed of data elements such as accession number, title, author or investigator, dates, and summary. In addition to the individual record, the file contains indexes to the contents of each data element. To start his retrieval, the user types search terms that may be in the index. For each search term, the BASIS system will inform the user how many records contain his search term. He may then form combinations of search terms, using the logical operators AND, OR, or AND NOT, and thereby narrow the retrieval to those records which are presumably of most interest.

Figure 3 shows a terminal printer record of an HRIS on-line search for information on innovations and trade-offs in highway construction. It includes examples of the commands issued by the BCL BASIS system to the remote terminal user, the responses of the user, and the messages transmitted from the central computer to the terminal printer. It also shows the terms used in the search and the search strategy employed by the user. The search indicated there were three items in the file that satisfied the search criteria of the user.

Finally, the user may ask that the retrieved records be displayed at his own terminal or printed out at BCL and received by mail. The user may ask for total record display or for the display of specified data elements for each record. The three items identified in the search shown in figure 3 were displayed as shown in figure 4. The terminal operator selected a format that consisted of two information elements—the title and accession number of each record. Also shown are commands and the BASIS system responses.

One advantage of on-line retrieval is that the user may modify search terms, combination of search terms, or the question itself until the display indicates that no better retrieval strategy can be employed. At the completion of any search the user may initiate a new search from the same file components, specify new components, or log out of the retrieval system.

Figure 3.

```
COMMAND- BASIS,MOBLEY,TRIS


          B A S I S   7 0


COMPONENTS OF THE TRIS COMMON DATA BASE ARE -
 ( LATEST UPDATE = 7-26-73 / TOTAL ITEMS IN BASE = 16360 )
A.   DOT WORK IN PROGRESS - ACTIVE (2075 / 7-26-73)
B.   DOT WORK IN PROGRESS - INACTIVE ( 821 / 7-26-73
C.   HIGHWAY RESEARCH IN PROGRESS ( 4715 / 7-26-73 )
D.   HRIS ABSTRACTS ( 7363 / 7-26-73)
E.   RRIS ABSTRACTS ( 1386 / 7-26-73)


WHICH FILE(S) DO YOU WISH TO SEARCH -
ENTER LETTERS SEPARATED BY COMMAS OR ALL
/      C,D
 12078 ITEMS IN YOUR DEFINED UNIVERSE
ENTER YOUR SEARCH ONE TERM AT A TIME.
 1/    6313,HIGHWAY CONSTRUCTION
   262 ITEMS
 2/    6313,CONSTRUCTION
   144 ITEMS
 3/    (1 OR 2)
   402 ITEMS
ENTER YOUR REQUEST
 4/    INNOVATIONS
    44 ITEMS
 5/    TRADE-OFFS
    19 ITEMS
 6/    (4 OR 5)
    63 ITEMS
ENTER YOUR REQUEST
 7/    (3 AND 6)
     3 ITEMS
```

```
ENTER YOUR REQUEST
 8/    DISPLAY 7
   WHAT FIELDS DO YOU WANT TO SEE\
PRINT OPTIONS FOR THE TRIS DATA BASE ARE...
   SHORT FORMAT  (ENTER NUMBER 1)
   LONG FORMAT  (ENTER NUMBER 2)
   MANAGEMENT FORMAT  (ENTER NUMBER 3)
   SELECT FORMAT  (ENTER FIELD NUMBERS SEPARATED BY COMMAS) OR ALL
       1110,2112
ITEMS FROM THE TRIS DATA BASE ARE...

ITEM    1
ACCESSION NUMBER    :600700
TITLE
EXPERIMENTAL STUDY OF PAVEMENT DESIGN WITH THE USE OF
AUTOMATICALLY STEERED HEAVY VEHICLES

ITEM    2
ACCESSION NUMBER    :607451
TITLE
DESIGN, MANUFACTURE, TRANSPORTATION, AND ERECTION OF
SYSTEMS BRIDGES

ITEM    3
ACCESSION NUMBER    :611394
TITLE
URBAN ANALYSIS
FINISHED WITH PRINTOUT. CONTINUE ENTERING SEARCH TERMS.
 8/    QUIT
END OF TRIS PROCESSING
(DONT FORGET TO "LOGOUT." BEFORE DISCONNECTING.)
GOODBYE............



END    BASIS
COMMAND- LOGOUT
CP TIME     6.702
PP TIME    24.234
SYSTEM SECONDS    18.000
CONNECT TIME    0 HRS.  5 MIN.
 08/28/73  LOGGED OUT AT 15.47.23. <
```

Figure 4.

Figure 2.

Figure 2.—A user searching the TRIS file from a cathode ray tube terminal.

Figure 3.—An HRIS on-line search showing commands, messages, user responses, and search terms and strategy.

Figure 4.—An HRIS on-line display of retrieval document record titles and accession numbers, user logout commands, and system response.

Participants in the HRIS Demonstration Project

The affiliation of the 21 participants in the project is as follows:

California Department of Transportation
Sacramento, Calif.

Indiana State Highway Commission
Indianapolis, Ind.

Michigan Department of Transportation
Ann Arbor, Mich.

New Mexico State Highway Department
Santa Fe, N. Mex.

New York State Department of Transportation
Albany, N.Y.

Ohio Department of Transportation
Columbus, Ohio

Pennsylvania Department of Transportation
Harrisburg, Pa.

Texas State Highway Department
Austin, Tex.

Utah State Department of Highways
Salt Lake City, Utah

Washington State Highway Commission
Olympia, Wash.

Federal Highway Administration (Headquarters)
Washington, D.C.

Federal Highway Administration (Fairbank Highway Research Station)
Washington, D.C.

Federal Highway Administration (Region 3)
Baltimore, Md.

Federal Highway Administration (Region 7)
Kansas City, Mo.

Urban Mass Transportation Administration
Washington, D.C.

Highway Research Board
Washington, D.C.

Canadian Ministry of Transport
Ottawa, Ontario, Canada

Association of American Railroads
Washington, D.C.

Virginia Polytechnic Institute and State University
Blacksburg, Va.

Ford Motor Company
Dearborn, Mich.

Calspan Corporation
Buffalo, N.Y.

The first 15 represent those organizations who provide financial support for HRB activities, including HRIS. The latter five represent organizations who do not provide such financial support, but who have an interest in the work of HRB including the demonstration project. There is a wide geographical distribution among the participating States as well as a large variance between the research programs of those States. It is also noted that in three instances the State university is the participating agent designated by and acting for the State highway department.

Project funds provide for storage of the HRIS file on behalf of all participants and for a limited amount of on-line use by participants in the sponsor group. Each participant is expected to pay the telephone charges for his on-line use. Participants in the nonsponsor group have arranged to pay BCL for all on-line use charges.

Project Phases

The HRIS records were stored for on-line access in July 1973, and on July 27 a conference, held at BCL, brought together the project participants and staff. Plans for the project were discussed, on-line procedures were explained, and participants were given hands-on experience with on-line retrieval.

The HRIS on-line retrieval mode was demonstrated to the 300 plus people who attended the sixth summer meeting of HRB at Olympia, Wash. All of the attendees were able to view live retrievals being made by various registrants before, between, and following the sessions of the meeting. The Washington Department of Highways made the demonstration possible by setting up their on-line terminal at the site of the HRB meeting and providing personnel to operate the terminal and to explain the procedures used to retrieve highway research information on-line. Following the HRB summer meeting, the terminal cathode ray tube (CRT) screen, printer, and keyboard were moved to the Washington Department of Highways building where additional HRIS on-line retrieval demonstrations were given to groups of reference librarians from the universities and industry in the Pacific Northwest and to the public librarians from cities throughout the State.

Members of HRB and BCL staff visited each participant during August, September, and October. In these visits, terminal operations were checked out and additional retrieval experience was acquired.

Throughout the data acquisition phase of the project, each participant will carry out on-line retrieval at his own terminal. On a monthly basis, HRB will receive from each participant the results of four searches that have been made during the month. These data make it possible to infer the range of subject interests and the degree of success with which on-line retrieval has provided useful information. At two points during this phase of the project, all participants will make retrievals for a set of specified questions. Thus the project data will show user variations in approach and success in retrieving information on standard questions.

In October, on-line retrieval of HRIS records was demonstrated as a special feature of a transportation information colloquium at the seventh world meeting of the International Road Federation, held in Munich, Germany.

The last phase of the project is for reporting project results. A preliminary report on project results will be given at the 53rd Annual Meeting of the Highway Research Board in January 1974. There will also be a panel discussion which includes a number of project participants.

In March 1974, a final report will be prepared for FHWA that will cover the preliminary report, data that were acquired after the preliminary report was prepared, and input from the panel discussion at the HRB Annual Meeting.

Behavior of a Curved Steel Box Beam Bridge,

by Robert A. Greig and William L. Armstrong

In this article the authors describe the field testing—dead load and live load—of a curved steel box girder bridge in Springfield, Mass. The single-span bridge consists of two closed steel box girders connected by diaphragms and a composite concrete deck. Dead load strain and deflection information was obtained for the four concrete pours required to complete the deck. The FHWA test vehicle, loaded to a total weight of 73,700 pounds (21.250 kg), was used for static live loading and dynamic loading. The discussion includes web behavior, frequencies and damping, impact factors, bridge accelerations, maximum stresses and deflections of boxes and tie-down rods, and the distribution of the total moments to each box.

From the test results, the authors believe that fatigue considerations should definitely be included in the design of tie-down rods, particularly if the rods are threaded or notched in any way. Also, they believe that fatigue criteria should be considered in the web areas where *oil canning* can develop.

In recent years an evolution in highway interchange alinement has necessitated the use of elevated roadways curved in the horizontal plane. With this has come an increased use of curved girders for reasons of structural efficiency, esthetics, and construction practices.

Due to a number of analysis and design uncertainties, considerable research—both theoretical and experimental—has been conducted on curved girder structures. One such study, "Horizontally Curved Highway Bridges," sponsored by 25 State highway departments in cooperation with the Federal Highway Administration (FHWA), was conducted by a Consortium of University Research Teams (CURT)—comprised of Carnegie-Mellon University, the University of Pennsylvania, the University of Rhode Island, and Syracuse University.

This article describes the field testing, conducted in this study, of a curved steel box girder bridge in Springfield, Mass. The most significant findings concerning both dead load and live load response and subsequent comparisons of test results with theoretical predictions are presented. Detailed reports on the field study have been prepared by the FHWA (*1*)[1] and the University of Rhode Island (*2*).

Description of Bridge

The single span bridge, shown in figure 1, consists of two closed steel box girders connected by diaphragms and a composite concrete deck. The end diaphragms, being very stiff I-sections, are designed to torsionally fix the box girders, whereas the intermediate diaphragms are the more common K-brace type. Each box section is approximately 7 feet (2.135 m) wide by 5 feet (1.525 m) deep and the centerline length and radius of the structure are 130 feet (39.65 m) and 162 feet (49.45 m), respectively. One support is radial; the other is on a severe skew of ap-

[1]Italic numbers in parentheses identify the references on page 266.

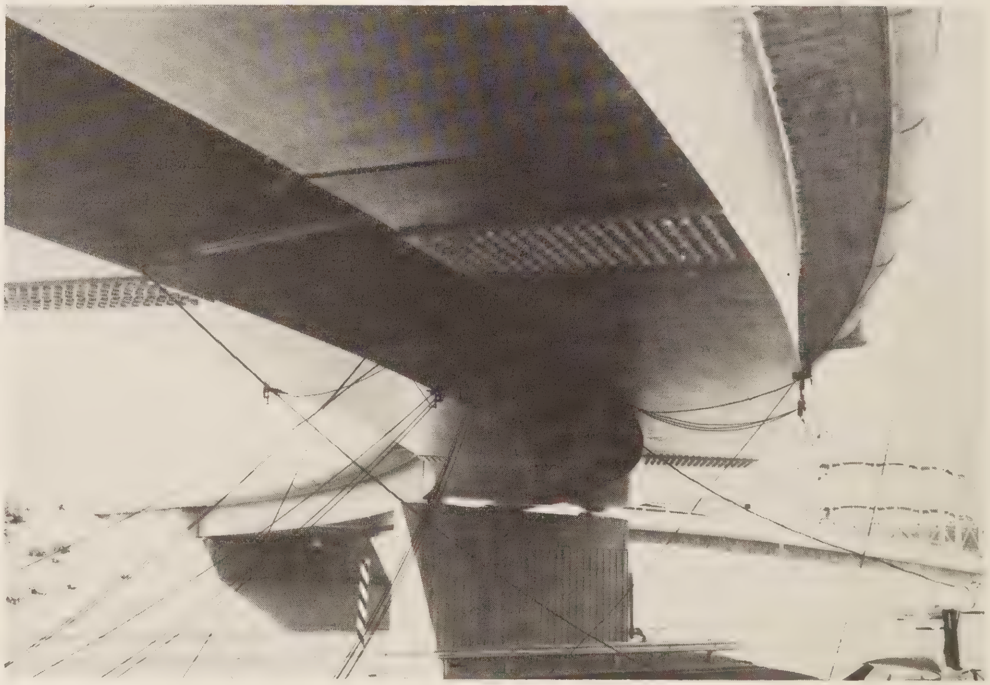


Figure 1.

Figure 1.—Underside of bridge—Springfield, Mass.

proximately 26 degrees. Tie-down rods are required at the supports of the inside box (box with the shorter radius) due to the geometry and weight distribution of the structure.

Dead Load and Static Live Load Testing

Dead load strain and deflection information was obtained for the four concrete pours required to complete the deck. For each of the concrete pours, the following experimental values were obtained:

- Strain readings from 48 box girder gages, located at sections near midspan and near the skewed support, and from six tie-down rod gages.
- Deflection readings under webs of boxes at all interior diaphragm lines by use of surveying equipment.
- Dial indicator readings from distortion rig inside the outside box.
- Deflection readings from dial indicators located under each web along support lines.

The FHWA test vehicle (figure 2), loaded to a total weight of 73,700 pounds (21,250 kg), was used for static live load testing. Three truck lanes were established on the roadway—one close to the outside curb (lane 1), one in the middle of the roadway (lane 2), and one close to the inside curb (lane 3). The truck was positioned at midspan in each of the three lanes in both directions for six static conditions. Crawl runs were also made in each lane in both directions from which maximum static response was determined. The same strain gages were used in both the dead load and live load tests. Vertical deflections were measured near midspan at the bottom of each web on each box.

Static Behavior

A planar grid analysis developed at the University of Rhode Island (3) was used in theoretically predicting stresses and deflections for each of the static loadings. In all tests, the predicted values compared favorably with test results. However, for dead load tests the predicted deflections were generally lower than the corresponding measured values. Also, the predicted stress distribution over the cross section assumed the same shape as the measured values but with a shift in the location of the neutral

Figure 2.—Test vehicle crossing bridge southbound in lane one.

Figure 2.

axis. The theoretical neutral axis was generally lower than the measured neutral axis, indicating the possibility that partial composite action was developed between the separate concrete pours. This action was not adequately accounted for in the theoretical analysis that was used. Substantial structural activity under concrete loading was observed: maximum experimental deflection (total four pours)—5.5 inches (13.95 cm); maximum experimental stress (total four pours)—11.5 ksi (79,400 kN/m^2).

For the live load tests the predicted results also compared favorably with measured values although agreement was not as good as those for the dead load tests. For static live load tests the maximum stress of 1.61 ksi (8,015 kN/m^2) occurred in the bottom flange of the outside box.

Figure 3 is a reproduction of an oscillograph trace of a strain gage on one of the tie-down rods at the abutment for a portion of a crawl run, northbound in lane 3. Jumps in the trace show when the wheels of the test vehicle came onto the bridge—A-B (front axle), C-D (drive axle), E-F (rear axle)—and indicate compressive strains (less tension) in the tie-down rod. Notice that the trace rises as the vehicle continues across the bridge. As the truck reaches midspan, the trace crosses the base line "A" producing a tensile strain. Total variation in stress for this run is 4.7 ksi (32,460 kN/m^2). This type of action may be caused by an improperly seated bearing or may be peculiar to the type of tie-down rod design used.

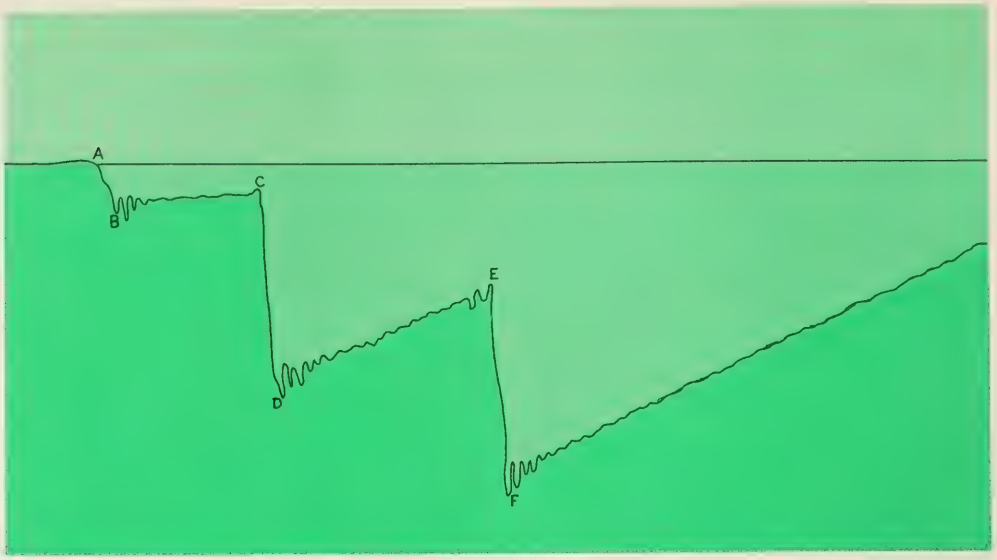


Figure 3.

Dynamic Loading

For the dynamic live load testing, the test vehicle traversed designated lanes marked along the surface of the bridge deck as in the crawl or static loads. Dynamic or impact runs were made in each lane at nominal speeds of 7 mph, 15 mph, and 20 mph (3.13 m/s, 6.72 m/s, and 8.94 m/s). Two air hoses placed 50 feet (15.24 m) from each end of the span monitored vehicle speed and activated the oscillograms. Two additional hoses positioned over the supports of the bridge indicated the longitudinal position of the vehicle on each run.

Dynamic Behavior

Strain and deflection

Strain and deflection measurements were taken at the same locations as in the static or crawl tests. The maximum recorded dynamic deflection of 0.464 inch (1.18 cm) occurred under the outside beam at approximately midspan with the vehicle in lane 1 going southbound at 20 mph (8.94 m/s). Deflections increased with an increase in vehicle speed and also as the vehicle moved from lane 3 to lane 1. For both northbound and southbound runs the maximum deflections occurred when the front axle of the vehicle was approximately 65 percent of the way across the span.

Deflection impact factors were calculated by dividing the difference between the maximum impact deflection at a certain speed and the maximum crawl deflection for that lane by the maximum crawl deflection for the same lane. The deflection impact factors were highest on the outside box and generally tended to increase with an increase in speed. The largest impact factors for each deflection point occurred northbound at 20 mph (8.94 m/s) in lanes 2 and 3. The maximum impact factors varied from 27.0 percent for the inside box to 49.5 percent for the outside box.

In all tests the largest stresses occurred in the outside box. The largest impact stress recorded was 1,970 psi (13,600 kN/m^2) at the bottom flange of the outside box with the vehicle northbound in lane 1 at 20 mph (8.94 m/s). The largest stress always occurred as the front axle of the vehicle

Figure 3.—Oscillograph trace of live load test.

passed 60-65 percent of the way across the bridge. In most tests the stresses increased with an increase in speed and also as the vehicle moved from lane 3 to lane 1. The longitudinal stresses at the gaged section near the skew support in each box were generally too low to establish any conclusions.

The impact factor for stress was computed in the same manner as that for deflection. Values recorded for the outside box were considerably higher than those recorded for the inside box. In both boxes the impact factor generally increased with an increase in speed. The highest recorded impact factors— 19.5 percent for the inside box and 39.2 percent for the outside box—both occurred at 20 mph (8.94 m/s) in lane 3.

Moment

A computer program was used to calculate the maximum experimental moments at the gaged section near midspan using stress areas to find internal forces. These forces nearly balanced when *n* (the ratio of the elastic modulus of steel to that of concrete) equalled 8 for the walk and parapet and 7 for the deck.

For all dynamic runs, the outside box always carried the larger percentage (an average of 64 percent for all runs) of the total moment. The percentage carried by this box decreased almost linearly from 67.9 to 59.9 when the load moved from lane 1 to lane 3 with little difference between northbound and southbound runs. With an increase in speed the maximum moments in both boxes increased with the outside box carrying a slightly larger proportion of the moment.

Impact factors for the maximum moments at the midspan sections were calculated in the same manner as those for deflections. No apparent relation between lane load and impact factor could be detected. The maximum impact factor for moment was 28.9 percent in lane 2 at 20 mph (8.94 m/s) in the outside box.
The AASHO formula (*4*) for straight bridges allows a maximum of 20 percent using the span midlength of the inside box of 124.39 feet (38.0 m).

Tie-down rods

The largest dynamic live load stresses and stress ranges occurred in the tie-down rods at the abutment. As the test vehicle crossed over (or in the vicinity of) the rods, compressive stresses were measured (possibly less tension, depending on initial conditions). But when the vehicle approached mid-span, a reversal (more tension) of the live load stress occurred. In all tie-down rods, the largest stresses recorded were of a compressive nature. As the vehicle moved from lane 1 to lane 3 the tensile stresses became less, the compressive stresses greater, and the total stress range also increased. The maximum dynamic stress range was 5,670 psi (39,100 kN/m^2) in a tie-down rod located at the abutment with the vehicle northbound in lane 3 at 20 mph (8.94 m/s). The largest compressive stress was 5,080 psi (35,100 kN/m^2) with the vehicle northbound in lane 3 at 15 mph (6.72 m/s). For the same tie-down rod the maximum tensile stress was 3,170 psi (21,900 kN/m^2) with the truck in lane 1. Although these maximum stresses did not occur on the same run, a vehicle could possibly enter the span in lane 3 and then move out to lane 1 as it reaches midspan; thereby producing a maximum stress range of approximately 8,000 psi (55,200 kN/m^2).

Web behavior

Strain gages were placed directly opposite each other at three points over the depth of the outside web of the outside box at midspan to determine the midweb bending stress, or *oil canning*, of the web. This stress is defined as half the difference between the inside and outside web gages. Stresses in the compressive gages near the top of the web were small and usually nearly equal to each other. The major difference occurred at the gages located 22 inches (55.8 cm) from the bottom flange, or about one-fourth the depth of the web.

The inside gage generally carried almost twice the stress as that of the outside gage. The larger stress on the inside of the web indicated a bending of the web toward the inside in this region. The ratio of dynamic bending stress to flexural stress varied from 0.287 to 0.420. The bending was always in the same direction as the vehicle crossed the bridge, i.e., no stress reversals.

Frequencies and damping

The dynamic response of a bridge depends upon the dynamic characteristics of the bridge, the vehicle passing over it, and the interaction between them. The impact factor is a function of the frequency match between vehicle and bridge, the state of excitation of the vehicle when entering the bridge, the surface roughness, speed of the vehicle, and the magnitude of the live load.

Test records show that the Springfield bridge vibrates only at the natural frequency of vibrations of 1.93 Hz. The frequency of the cyclic force of the vehicle varies from approximately 2.7 to 3.8 Hz. However, the cyclic variations of vehicle force could not be related to the peak stresses measured at midspan of the bridge.

Two related measures of damping, the logarithmic decrement and Lenzen's criterion, are useful in evaluating a decaying vibration. An estimate of the logarithmic decrement taken from oscillograph records of several runs is 0.11. Lenzen's criterion, described by Wright and Walker (5), is the number of cycles required to reduce the amplitude of vibration to one-tenth of its initial value. With a logarithmic decrement of 0.11, approximately 9.6 cycles reduces the amplitude to one-tenth its initial amplitude. Thus, the residual vibrations are of a transient nature.

Accelerations

The amplitude of acceleration for evaluation of human response may be approximated (5) as:

$$a = D(2\pi f)^2$$

where a is acceleration, D is the maximum dynamic deflection, and f is the natural frequency of the bridge. Using southbound maximum measured deflections ranging from 0.20 to 0.46 inch (5.07 to 11.69 mm) for the four web deflections, the range of peak accelerations is 30 to 68 in/sec^2 (76.3 to 172.9 cm/sec^2); or approximately 0.08 to 0.18 of gravity. According to criteria proposed by Wright and Walker (5) for human response to acceleration, this range of accelerations is perceptible to most pedestrians or passengers sitting in vehicles and unpleasant to some.

Conclusions

Variation in experimental stress across bottom flanges under dead load indicates the presence of some lateral flange bending (approximately 10 percent). There was virtually no stress change across the flanges under static live loading.

The diaphragm stresses, concrete stresses, and box distortions which were measured were of insignificant magnitudes.

The maximum impact factors for deflection and stress occurred with the load in lane 3, whereas that for moment occurred with the load in lane 2. The results indicated that impact factors on this bridge were of significant magnitude to warrant special consideration. The maximum impact factor for moment of 28.9 percent was below the maximum AASHO allowable of 30 percent for straight bridges, but nearly 50 percent higher than that allowed if the AASHO formula for impact is used. Acceleration magnitudes were such that pedestrians or drivers sitting in cars on the bridge would experience vibrations which would be noticeable and perhaps undesireable.

The magnitude of stress ranges in the tie-down rods indicated that fatigue considerations should be included in the design of rods of this type, particularly if the rods are threaded or notched in any way. Fatigue criteria should also be considered in the web areas where *oil canning* can develop.

REFERENCES

(*1*) W. L. Armstrong and J. A. Langdon, "Dynamic Testing of a Curved Box Beam Bridge," *Federal Highway Administration* Report No. FHWA-RD-73-1, February 1973.

(*2*) R. A. Greig, "Field Testing of a Curved Steel Box Girder Bridge in Springfield, Massachusetts," Technical Report No. 1(L), Horizontally Curved Highway Bridges, Research Project HPR-2 (111), *University of Rhode Island,* Kingston, R.I., March 1973.

(*3*) F. H. Lavelle, R. A. Greig, and H. R. Wemmer, "CUGAR1 (CUrved Girder Analysis, Revision 1)—A Program to Analyze Curved Girder Bridges," Engineering Bulletin No. 14, Division of Engineering Research and Development, *University of Rhode Island,* Kingston, R.I., September 1971.

(*4*) "Standard Specifications for Highway Bridges," 10th ed., *American Association of State Highway Officials,* 1969.

(*5*) R. N. Wright and W. H. Walker, "Criteria for the Deflection of Steel Bridges," *American Iron and Steel Institute* Bulletin No. 19, November 1971.

Our Authors

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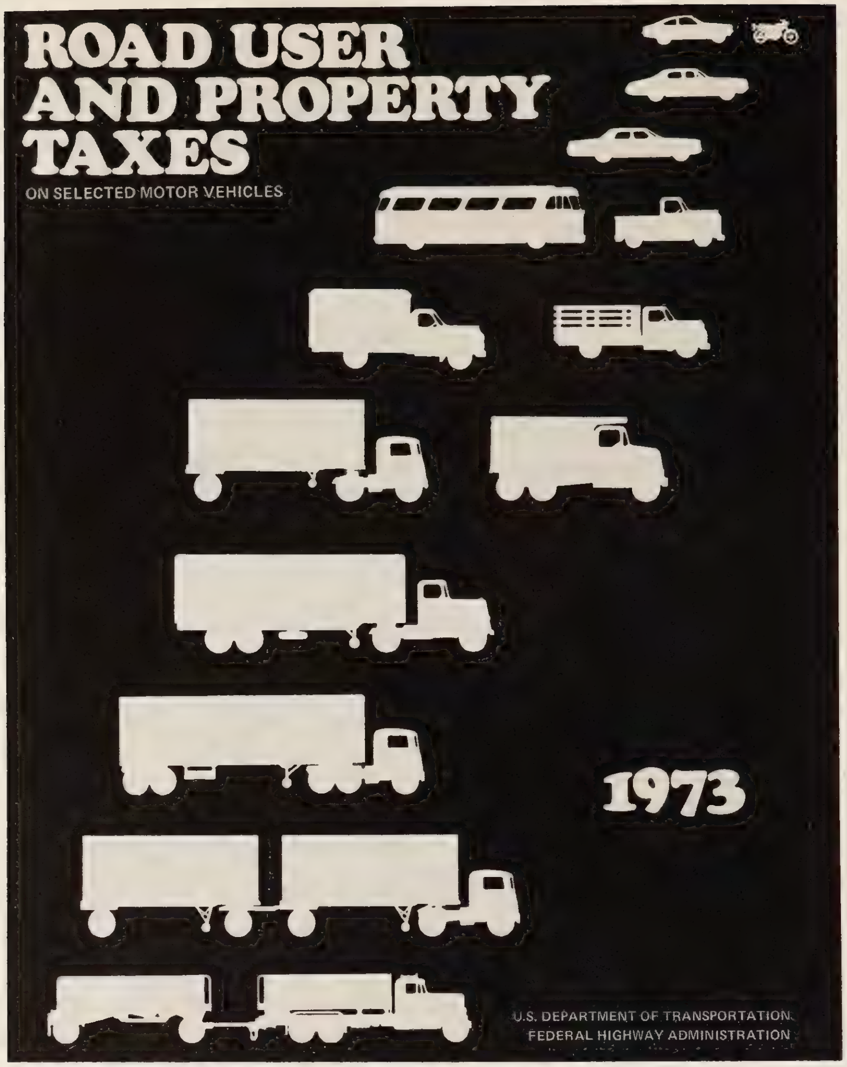


New Publications

Road User and Personal Property Taxes on Selected Motor Vehicles provides basic information for 1973 for each State on road-user and property taxes levied on a selected group of vehicles, which range from a motorcycle to a 76,000-pound truck-trailer combination. The report should be a useful research and planning tool for highway administrators, legislators, and others concerned with highways and with vehicle use and taxation.

The taxation information is presented in tables that show highway-user and total taxes paid to each State, on bar charts in which States are ranked by highway-user and total taxes paid, and on maps that show ranges of highway-user and total taxes paid to each State. This study is the eighth in a series of similar reports, the first of which was published in 1950. Data on a motorcycle and a bus are included for the first time this year.

Copies of the report may be purchased for 90 cents from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

A Guide to Parking Systems Analysis describes the latest procedures available to perform parking analysis. Seven analysis and data processing modules are used to prepare parking data, examine parking behavior, and calibrate a linear programming model of parking choice. Parking data may be derived either from a standard parking survey or from home interview origin-destination data. The procedures allow the user to make increased use of origin-destination data and provide expanded tabulation and analysis capability.

A parking allocation model is used to plan and evaluate parking facilities. The parking allocation model explicitly considers the effects of parking capacity in addition to other measures of parking choice. A case study is described and a set of appendixes describing the function of component programs is included.

This document is for sale ($2.60 a copy) by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Urban Origin-Destination Surveys represents the latest revision of the procedural guide for conducting a comprehensive origin-destination survey. The major new areas covered include quality control and accuracy checks associated with the various surveys.

This document has been prepared to serve as a guide for collecting urban trip and household socio-economic data. It provides the management guidelines necessary to plan, implement, control, and carry the data collection effort to a successful completion. It also provides detailed sample instructions that may be used as the basis for developing specific guidelines for employees doing sample selection, interviewing, coding, and processing. A brief description of various special purpose studies is also included.

The guide is not designed to satisfy every need that may exist with regard to data collection. It is intended that this publication assist the user in determining the data needs for a particular urban area, evaluating the alternative techniques for obtaining the data, and determining the procedures that will be most appropriate to achieve the study's goals.

Copies of **Urban Origin-Destination Surveys** may be purchased for $3.20 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Implementation/ User Packages "how-to-do-it"

The principal tool for implementing research and development is the implementation/user package which provides "how-to-do-it" information to the potential user. The package converts research findings into practical tools. The packaging requirement is accomplished between the identification and promotion stages of implementation.

The following items are brief descriptions of selected packages which are actively being developed, or have been recently completed, by State and Federal highway units in cooperation with the Implementation Division, Offices of Research and Development, Federal Highway Administration [FHWA]. All completed packages will be placed in the National Technical Information Service [NTIS], 5285 Port Royal Road, Springfield, Va. 22151.

Packages Completed

Rubber-Asphalt Binder for Seal Coat Construction

by FHWA Implementation Division

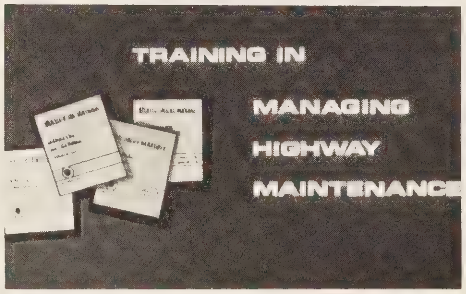
The package presents background information, construction details, and suggested specifications for rubber-asphalt seal coat construction which has been successfully applied in Arizona to inhibit the formation and propagation of cracks that generally render seal coats ineffective. The powdered rubber used in the binder is reclaimed from discarded automobile

tires which have become a major waste disposal problem. The package is in a form that can serve as a user manual for construction engineers. Distribution has been made to States and FHWA field offices. (NTIS PB 219012).

Managing Highway Maintenance Training Guide and Catalog

by FHWA Implementation Division

Research has shown that the efficiency and effectiveness of highway maintenance operations can be significantly improved by applying modern management principles. In recognition of the need to train field engineers, superintendents and foremen who manage highway main-

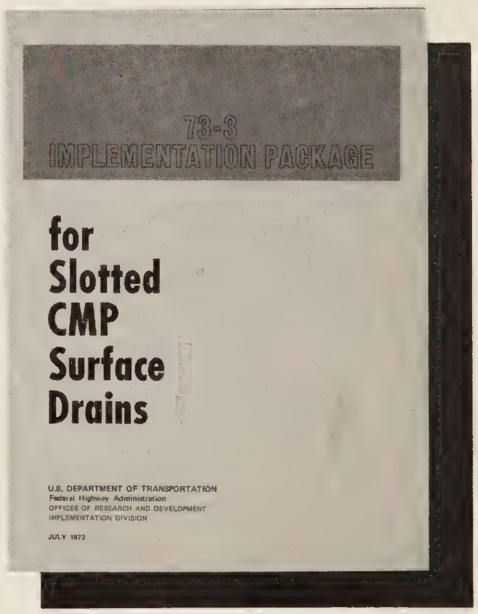


tenance, a comprehensive management training curriculum has been developed and is now completed. Requests for the Training Guide and Catalog and sets of the curriculum should be sent to the National Highway Institute, Federal Highway Administration, Washington, D.C. 20590.

Slotted Corrugated Metal Pipe for Surface Water Drainage

by FHWA Implementation Division

The package illustrates design details and construction installation techniques for slotted corrugated metal pipedrains which have been developed and refined over a period of years by the California Division of Highways. The concept has proven effective in the areas of safety, economy, hydraulic efficiency, maintenance, and esthetics. Distribution has been made to the States and FHWA field offices.

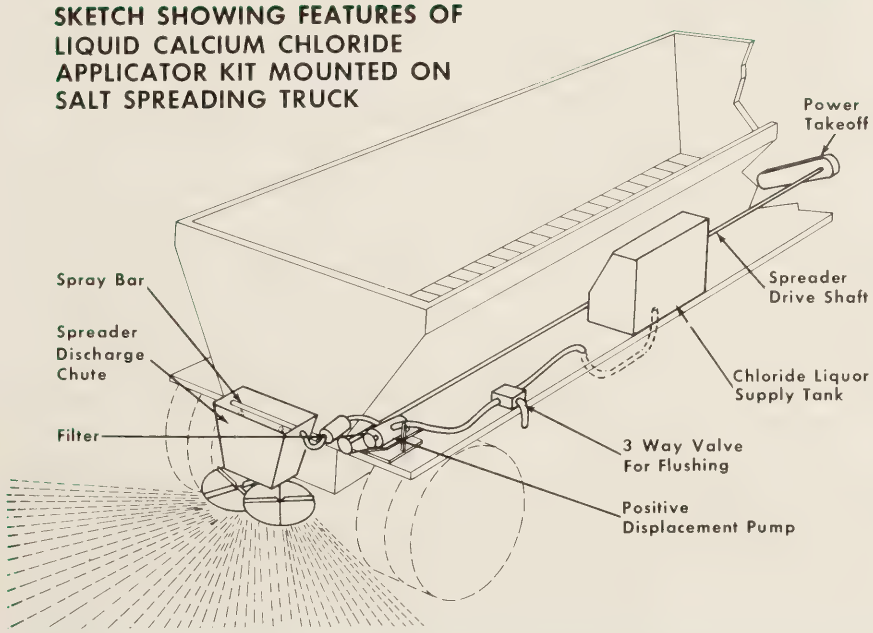


Use of Liquid Calcium Chloride to Improve Deicing and Snow Removal Operations

by FHWA Implementation Division

The package outlines the method developed by the Iowa State Highway Commission for prewetting rock salt with a solution of calcium chloride to speed up and increase the effectiveness of pavement deicing operations. Using a liquid chloride applicator kit installed on existing salt spreading trucks has reduced cost of salting, produced effective melting action at temperatures below 20° F, reduced roadside pollution potential due to salt, and reduced overtime labor costs. The package includes current State practice, a description of the applicator kit, specifications and operating guidelines. Distribution has been made to the States, counties, and FHWA field offices.

SKETCH SHOWING FEATURES OF LIQUID CALCIUM CHLORIDE APPLICATOR KIT MOUNTED ON SALT SPREADING TRUCK



Computerized Bridge Rating System

by Wyoming Highway Department

This package explains the use of the developed computer software system which analyzes and rates highway bridges. The rating system has been developed specifically to assist State highway organizations in accomplishing the structural rating requirements of the national bridge inspection standards. The package can serve two separate needs—as an operational manual for automatic data processing specialists and as a user manual for bridge engineers and technicians. Distribution of the package has been made to the States and FHWA field offices.

Packages in Preparation

Project Management System Utilizing the Critical Path Method

by FHWA Implementation Division

An extremely useful computer program for scheduling emergency relief projects that must be put into service in a minimum time is being finalized for implementation. The system was successfully used in Pennsylvania in scheduling construction to replace a bridge destroyed by hurricane Agnes. The refined user manual for the system will combine methods of networking, critical path computations, and project management techniques.

Open Graded Bituminous Mixtures for Pavements

by FHWA Region 10, Portland, Oreg.

For several years the U.S. Forest Service has successfully used open graded emulsified asphalt mixtures for pavement construction. These open graded mixes have been low in cost and have demonstrated good stability and internal drainage qualities. The package being developed will cite background and experience, construction features, cost data, and guide specifications. The Forest Service cold mix procedure outlined in the report is relatively pollution free.

Prestressed Concrete Panels for Highway Bridge Decking

by Texas Highway Department

The Texas Transportation Institute and the University of Texas have recently completed a joint research study to develop a composite segmental bridge deck comprised of 3 1/4-inch-thick prestressed concrete panels which are used as permanent forms for a subsequent topping of 3 1/2 inches of cast-in-place concrete. The State has recently constructed two bridge decks utilizing this new concept. The current implementation plan includes the preparation of a user-oriented manual for bridge designers in other States. FHWA Region 6 personnel located in Fort Worth, Tex., will assist the Texas Highway Department in preparing this manual.

Computerized Roadway Design System

by Texas Highway Department

The Roadway Design System (RDS) is an automation tool that assists the highway design engineer by greatly expanding productivity and flexibility in the design process. The preliminary system has been tested in FHWA and State highway offices and work is underway to refine the system and make it more applicable on a widespread basis. The updated package will include system refinements, training materials, and documents for operating and maintaining the computer programs.

Concrete Delamination Detector for Inspecting Bridge Decks

by FHWA Implementation Division

A delamination detector has been developed which acoustically senses and records the location of voids and disbonded concrete—a major bridge deck deterioration problem. Commercial models of the device will be available in the near future. The user package being developed includes operating and calibrating procedures, instructions on interpretation of data, and maintenance requirements for the device. Audio-visual materials will be included.

Slotted Underdrains for Pavement System Drainage

by FHWA Region 8, Denver, Colo.

A package being developed will describe the use of the slotted underdrain system which results in greater efficiency in the performance of drainage layers, filter layers, and drainage pipe. The package will include a comparison of current State designs, design procedures, and promotional visual aids.

Texas Crash Cushion

by Texas Highway Department and FHWA Region 6, Fort Worth, Tex.

The Texas Crash Cushion, consisting of a number of 55-gallon steel drums, has been adapted to provide highway maintenance vehicles with protection from rear-end collisions by errant vehicles. Wheels and a trailer hitch have been added to the Texas Crash Cushion so that it can be attached to a maintenance vehicle such as a dump truck to provide such needed protection to the truck and maintenance personnel. The implementation activity will include the development of a how-to-do-it manual on the process of designing the portable or mobile trailer system to protect slowly moving or stopped maintenance vehicles working on highways. The manual will also include the appropriate procedure for attaching the protective system to the highway maintenance vehicle.

Vegetation and Erosion Control Under Guide Rails and Median Barriers

by Connecticut Department of Transportation

A combination of Bunker "L" oil and a soil sterilant have proven effective in eliminating vegetation and controlling erosion under guide rails for 3 to 4 years. This eliminates expensive and hazardous hand mowing and provides erosion control which cannot be realized by use of soil sterilant alone. The information will include illustrations, mixing and placement methods, costs, and some of the State's experience.

Breakaway Barricades

by Nevada Department of Highways

An economical safety barricade which can be reused has been developed by maintenance engineers in the Nevada Highway Department. Numerous personal injury and property damage accidents involving standard barricades led to this development. Experience has shown that these barricades significantly reduce the severity of these accidents and, while standard barricades are usually demolished, these can readily be reassembled and used again. A film and scale models will be provided for States and FHWA field offices and a descriptive pamphlet will be made for more widespread dissemination.

Surface Coatings

by Nevada Department of Highways

Painting of concrete structures in lieu of hand rubbing has been implemented by several States. A user package will be prepared by Nevada describing their experience and will include construction details, materials or paint used, cost, and recommended specifications. This method is cheaper and more esthetically pleasing than hand rubbing and is relatively maintenance free.

Encapsulated Subgrades

by U.S. Army Corps of Engineers

A user package is being prepared by the Corps of Engineers at the Waterways Experiment Station, Vicksburg, Miss. This manual will include construction methods, costs, applications, and specifications for the membrane encapsulated subgrades. This method provides engineers with a rapid and stable road building technique for use in areas where moisture is a problem in stabilizing the pavement structural section and where aggregates are scarce.

Culvert Outlet Protection Program

by Wyoming State Highway Department

In response to a widely expressed need to form criteria for the design and protection of culverts from scour and flooding, the personnel of the hydraulics section of Wyoming State Highway Department are developing a package which includes the results of research carried out by Colorado State University, the Corps of Engineers, and other investigators. This package will include a computer program which will enable the engineer to quickly determine an optimum design of an energy dissipation device or method to be used at the culvert outlet for any given set of hydrological and hydraulic conditions.

Hi-Dri Cell Crash Cushion

by FHWA Implementation Division

A design manual is being developed covering the design, installation, and maintenance aspects of the Hi-Dri Cell Crash Cushion developed by Energy Absorption Systems, Incorporated. This crash cushion concept has been approved as an alternate design for serviceable hardware on the Federal-aid Highway System.

The Federal Highway Administration's Fairbank Highway Research Station is located in a woodland setting just off the George Washington Parkway in McLean, Va., across the Potomac River from Washington, D.C. It has been the center for Federal highway research and development activity since World War II.

In 1964, the Station was named after the late Herbert S. Fairbank, an authority on highway research, planning, and construction. He joined the Bureau of Public Roads in 1910 and was named head of Research and Planning in 1934 and Deputy Commissioner for Research in 1944. Mr. Fairbank laid the groundwork for the soon to be completed National System of Interstate and Defense Highways.

The Station houses over 200 researchers, engineers, and supporting staff and includes a great variety of complex technical equipment, much of it specially designed, to investigate the many problems identified in the Federally Coordinated Program of Research and Development in Highway Transportation.

New Research in Progress

The following items identify new research studies that have been reported by FHWA's Offices of Research and Development. These studies are sponsored in whole or in part with Federal highway funds. For further details, please contact the following: Staff and Contract Research—Editor; Highway Planning and Research (HP&R Research)—Performing State Highway Department; National Cooperative Highway Research Program (NCHRP)—Program Director, National Cooperative Highway Research Program, Highway Research Board, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

FCP Category 1—Improved Highway Design and Operation for Safety

FCP Project 1A: Traffic Engineering Improvements for Safety.

Title: Efficacy of Red and Yellow Turn Arrows in Traffic Signals (FCP No. 31A1534)
Objective: The work includes investigation of the effectiveness of red and yellow signal arrows to control traffic at intersections. The study will determine when and where such devices should be used and guidelines will be developed for the inclusion or exclusion of red and yellow arrows as uniform standard traffic control devices.
Performing Organization: D.C. Department of Highways and Traffic, Washington, D.C. 20004.
Expected Completion Date: December 1974
Estimated Cost: $75,000 (FHWA Administrative Contract)

FCP Project 1E: Safety of Pedestrians and Abutting Property Occupants.

Title: Causative Factors and Countermeasures for Rural Pedestrian Accidents (FCP No. 31E2092)
Objective: This study will: (1) Develop a data collection system needed for an analysis of an adequate sample of rural pedestrian accidents, (2) collect and analyze data to identify causal factors of rural pedestrian accidents, (3) develop rural pedestrian countermeasures, and (4) evaluate countermeasures through behavioral/operational measures of pedestrian and vehicular traffic.
Performing Organization: Biotechnology, Inc., Falls Church, Va. 22042
Expected Completion Date: June 1976
Estimated Cost: $192,000 (FHWA Administrative Contract)

FCP Project 1G: Safer Traffic Guardrails and Bridge Railings.

Title: Upgrading Safety Performance in Retrofitting Traffic Railing Systems (FCP No. 31G2054)
Objective: Computer simulations will be utilized in conjunction with full scale impact tests involving single vehicles and guardrails, bridgerails, transitions, and ends. The results will be incorporated in improved railing system designs.
Performing Organization: Southwest Research Institute, San Antonio, Tex. 78284
Expected Completion Date: December 1975
Estimated Cost: $196,000 (FHWA Administrative Contract)

Title: Establishment of Interim Standards Required to Contain Heavy Vehicles (FCP No. 31G2062)
Objective: Establishment of interim standards involving heavy vehicle—guardrail, bridgerail—attenuator involvement. Computer simulation results will be verified by full scale test in a separate T&E contract.
Performing Organization: ENSCO, Springfield, Va. 22151
Expected Completion Date: June 1975
Estimated Cost: $126,000 (FHWA Administrative Contract)

FCP Project 1H: Skid Accident Reduction.

Title: Surface Wear and Skid Resistance Properties for Portland Cement Concrete Pavement (FCP No. 41H1252)
Objective: To investigate the wear and skid resistance properties of portland cement concrete pavement surfaces as these properties are affected by aggregates, mixture design, surface texture, curing methods, construction methods, and test speed.
Performing Organization: North Carolina State University, Raleigh, N.C. 27607
Expected Completion Date: September 1975
Estimated Cost: $75,000 (HP&R)

Title: Effectiveness of Alternative Skid Reduction Measures (FCP No. 31H5014)
Objective: Develop relationships between pavement skid number and wet-weather accidents for a variety of highway and traffic conditions; and to define and evaluate, on a cost-effectiveness basis, a range of alternative solutions for maintaining frictional requirements during wet weather.
Performing Organization: Midwest Research Institute, Kansas City, Mo. 64110
Expected Completion Date: June 1976
Estimated Cost: $435,000 (FHWA Administrative Contract)

FCP Project 1I: Traffic Lane Delineation Systems for Adequate Visibility and Durability.

Title: Hemispherical Beads for Pavement Marking Retroreflectors (FCP No. 31I1093)
Objective: Develop and test a hemispherical bead lane delineation system for improved wet-night visibility performance with adequate resistance to steel-bladed snowplowing and medium to high-density traffic wear.
Performing Organization: Penn State University, University Park, Pa. 16802
Expected Completion Date: August 1975
Estimated Cost: $76,000 (FHWA Administrative Contract)

Title: Lane Delineation with Improved Durability. (FCP No. 31I2092)
Objective: Develop or modify striping materials to obtain improved durability; materials shall be useful under all weather conditions; materials shall be evaluated by laboratory and field tests.
Performing Organization: Southwest Research Institute, San Antonio, Tex. 78284
Expected Completion Date: June 1975
Estimated Cost: $138,000 (FHWA Administrative Contract)

FCP Project 1K: Accident Research and Factors for Economic Analysis.

Title: Motor Vehicle Traffic Accidents in Relation to Geometrics and Traffic Features of Highway Intersections. (FCP No. 31K4018)
Objective: Determine the accident causal factors for intersection accidents at various configurations of rural and urban highway intersections at grade; analyze possible relationships, evaluate the probable effects of relevant Federal Motor Vehicle and Highway Safety Program standards and recommend conclusive countermeasures.
Performing Organization: Stanford Research Institute, Menlo Park, Calif. 94025
Expected Completion Date: June 1975
Estimated Cost: $379,000 (FHWA Administrative Contract)

Title: Performance of Safety Devices. (FCP No. 41K4095)
Objective: To determine whether recently installed New York State safety devices, such as impact attenuators and breakaway luminaire and sign support bases, are performing in service as intended and as expected from previous testing programs.
Performing Organization: Department of Transportation, Albany, N.Y. 12226
Expected Completion Date: March 1975
Estimated Cost: $77,000 (HP&R)

FCP Project 1O: Aids to Surveillance and Control

Title: Structural and Geometric Design of Highway Railroad Grade Crossings. (FCP No. 41O1042)
Objective: To develop implementable, structural and geometrical design criteria for highway-railroad grade crossings.
Performing Organization: Texas Transportation Institute, College Station, Tex. 78701
Expected Completion Date: August 1976
Estimated Cost: $120,000 (HP&R)

FCP Category 2—Reduction of Traffic Congestion, and Improved Operational Efficiency

FCP Project 2B: Development and Testing of Advanced Control Strategies in the Urban Traffic Control System.

Title: Vehicle Detection. (FCP No. 32B5262)
Objective: To develop and evaluate a "self-powered" vehicle detector and to fabricate and evaluate 10 production prototype models of the magnetic gradient vehicle detector (MGVD).
Performing Organization: Honeywell, Minneapolis, Minn. 55413
Expected Completion Date: October 1974
Estimated Cost: $234,000 (FHWA Administrative Contract)

Title: Detection Devices to Optimize Computerized Traffic Control. (FCP No. 42B5304)
Objective: To review literature for any recent detection devices; to obtain and evaluate any new detection devices and, if none are found to be acceptable, to design and develop a computer compatible detection device.
Performing Organization: Division of Highways, Sacramento, Calif. 95814
Expected Completion Date: June 1978
Estimated Cost: $87,000 (HP&R)

FCP Project 2C: Requirements for Alternate Routing to Distribute Traffic Between and Around Cities—Single Diversion Point.

Title: Diversion of Inter-city Traffic at a Single Point. (FCP No. 32C1011)
Objective: To develop requirements for a real-time alternate routing system by establishing a "test bed" system for experimentation, in cooperation with the Maryland State Highway Administration.
Performing Organization: Sperry Systems Management Division, Great Neck, N.Y. 11020
Expected Completion Date: December 1975
Estimated Cost: $298,000 (FHWA Administrative Contract)

FCP Project 2G: Coordination of the Traffic Operation of an Urban (Dallas) Freeway with Parallel and Cross Arterial Streets.

Title: Signal Progression on Routes in Suburban-to-Rural Areas. (FCP No. 42G1012)
Objective: To develop criteria for the introduction of signal progression on major arterials in suburban areas. The literature will be reviewed, techniques to determine the effect of signal progression will be developed, field data will be collected and analyzed, and the expected results will be design criteria.
Performing Organization: Ohio State University, Columbus, Ohio 43210
Expected Completion Date: August 1975
Estimated Cost: $57,000 (HP&R)

FCP Category 3—Environmental Considerations in Highway Design, Location, Construction, and Operation

FCP Project 3B: Socio-Economic Factors in Highway Engineering and Location.

Title: Social and Environmental Impacts of Alternative Highway Locations (FCP No. 33B1042)
Objective: Development of an analytical and evaluative procedure for highway official use to define and evaluate highway-related social and environmental changes.
Performing Organization: National Bureau of Standards, Washington, D.C. 20234
Expected Completion Date: May 1975
Estimated Cost: $307,000 (FHWA Administrative Contract)

FCP Category 4—Improved Materials Utilization and Durability

FCP Project 4A: Minimize Early Deterioration of Bituminous Concrete.

Title: Application of Fracture Mechanics for Improved Design of Bituminous Concrete. (FCP No. 34A2202)
Objective: To further develop and quantify in a mechanistic manner the fracture mechanics concepts applicable to the fatigue and fracture processes for the improved design and bituminous concrete mixtures as related to resistance to cracking.
Performing Organization: Ohio State University, Columbus, Ohio 43212
Expected Completion Date: December 1974
Estimated Cost: $93,000 (FHWA Administrative Contract)

FCP Project 4B: Eliminate Premature Deterioration of Portland Cement Concrete.

Title: Neutralization of Chlorides in Concrete (FCP No. 34B1262)
Objective: Methods of neutralizing, immobilizing, flushing out, or otherwise treating chloride ions in order to make them ineffectual in migrating to the reinforcing steel in the concrete and taking part in the electro-chemical reactions that cause corrosion shall be investigated in laboratory and field testing.
Performing Organization: Battelle Memorial Institute, Columbus, Ohio 43201
Expected Completion Date: June 1975
Estimated Cost: $222,000 (FHWA Administrative Contract)

Title: Electro-Osmotic Techniques for Removal of Chlorides from Concrete and Emplacement of Concrete Sealants. (FCP No. 44B1352)
Objective: Develop a method of removing or complexing chloride ions in concrete by electro-osmosis techniques. Possibility of moving other materials such as monomers or polymers into the concrete to prevent future ingress of water and chlorides will also be investigated.
Performing Organization: State Highway Commission, Topeka, Kans. 66612
Expected Completion Date: December 1975
Estimated Cost: $48,000 (HP&R)

Title: Influence of Environment and Materials on D-Cracking. (FCP No. 44B3072)
Objective: Measure moisture movements in subbases and slabs, determine effectiveness of altering aggregate sources, grading, and quantity; monitor pavement performance, and assist in setting up laboratory acceptance tests.
Performing Organization: Portland Cement Association, Skokie, Ill. 60076
Expected Completion Date: June 1977
Estimated Cost: $341,000 (HP&R)

FCP Project 4C: Use of Waste as Material for Highways.

Title: Technology for Use of Sulphate Waste in Road Construction (FCP No. 34C2022)
Objective: This study will develop the technology required for using sulphate waste as aggregate and binder in road construction.
Performing Organization: Gillette Research Institute, Rockville, Md. 20850
Expected Completion Date: June 1975
Estimated Cost: $168,000 (FHWA Administrative Contract)

FCP Project 4D: Remedial Treatment of Soil Materials for Earth Structures and Foundations.

Title: Role of Magnesium in the Stabilization of Soils with Lime (FCP No. 34D3102)
Objective: To determine the role of magnesium and the relative effectiveness of calcitic and dolomitic lime for stabilizing U.S. soils and to identify physical, chemical, and mineralogical soil or lime characteristics which govern lime reactivity.
Performing Organization: Portland Cement Association, Skokie, Ill. 60076
Expected Completion Date: December 1974
Estimated Cost: $143,000 (FHWA Administrative Contract)

Title: Design and Construction Guidelines for Shale Embankments (FCP No. 44D5022)
Objective: To develop methodology for moisture-density relationships, long term strength characteristics, degradability and other sampling and testing techniques for design and construction of shale embankments.
Performing Organization: Purdue University, Lafayette, Ind. 47907
Expected Completion Date: October 1976
Estimated Cost: $52,000 (HP&R)

FCP Project 4F: Develop More Significant and Rapid Test Procedures for Quality Assurance.

Title: Correlation of the Texas Highway Department Cone Penetrometer Test N-Value with Shear Strength of the Soil Tested. (FCP No. 44F1194)
Objective: The Texas Highway Department cone penetrometer N-values are to be related to relative density, effective overburden pressure, grain size distribution, and degree of saturation. Nuclear devices are to be used to determine in situ density at depths where N-values are obtained. Data are to be used for preliminary pile design.
Performing Organization: Texas Transportation Institute, College Station, Tex. 77843
Expected Completion Date: August 1974
Estimated Cost: $120,000 (HP&R)

FCP Category 5—Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

FCP Project 5C: New Methodology for Flexible Pavement Design.

Title: Modification of the VESYS II Computer Programs and Design Framework. (FCP No. 35C3142)
Objective: Modify the computer programs and design framework to improve their prediction capabilities and to interrelate in a modular manner the subsystems and models which will comprise the final design system.
Performing Organization: University of Utah, Salt Lake City, Utah 84114
Expected Completion Date: December 1974
Estimated Cost: $100,000 (FHWA Administrative Contract)

FCP Project 5D: Structural Rehabilitation of Pavement Systems.

Title: Equipment for the Measurement of Pavement Performance in Texas. (FCP No. 45D1093)
Objective: To improve the efficiency in data reduction in roughness measurements and improve the data collection procedure in pavement distress measurements.
Performing Organization: Highway Department, Austin, Tex. 78701
Expected Completion Date: August 1976
Estimated Cost: $116,000 (HP&R)

Title: Flexible Pavement Performance Evaluation Using Deflection Criteria. (FCP No. 45D2162)
Objective: Develop methods utilizing deflection measurements of flexible pavements in Nebraska to measure structural adequacy for a sufficiency rating system, to determine composite strengths of a flexible pavement, and to develop procedures for using deflections or composite strengths to predict pavement rehabilitation needs.
Performing Organization: Department of Roads, Lincoln, Nebr. 68509
Expected Completion Date: June 1976
Estimated Cost: $330,000 (HP&R)

Title: Study of Pavement Overlay Design. (FCP No. 45D2182)
Objective: To develop a workable, rational overlay design procedure encompassing the best state-of-the-art information concerning overlay design, specifically noting the effects of load, climate, pavement conditions, and pavement history.
Performing Organization: Ohio State University, Columbus, Ohio 43210
Expected Completion Date: June 1976
Estimated Cost: $163,000 (HP&R)

Title: Evaluation of a Dynamic Load Inducing Device. (FCP No. 45D2234)
Objective: To develop standard evaluation criteria using a dynamic load-inducing device with which the structural adequacy of an asphaltic concrete pavement may be established rapidly. To establish design criteria to determine the thickness of an overlay sufficient to reconstitute the structural adequacy of areas of potential failure.
Performing Organization: State Highway Administration, Baltimore, Md. 21201
Expected Completion Date: June 1976
Estimated Cost: $94,000 (HP&R)

FCP Project 5F: Bridge Safety Inspection.

Title: Field Tests of an Orthotropic Bridge. (FCP No. 45F3012)
Objective: Field measurements of the static live load behavior of a prototype orthotropic steel plate bridge will be compared with design assumptions in order to verify and refine the design procedure.
Performing Organization: Department of Transportation, Albany, N.Y. 12226
Expected Completion Date: March 1975
Estimated Cost: $51,000 (HP&R)

Title: Temperature Induced Stresses in Highway Bridges by Finite Element Analysis and Field Tests. (FCP No. 45F3022)
Objective: To establish quantitative magnitudes of temperature induced strains and deflections by field tests of one or two bridge types and to correlate these results with a finite element analysis using measured field temperatures as input.
Performing Organization: University of Texas, Austin, Tex. 78701
Expected Completion Date: August 1975
Estimated Cost: $59,000 (HP&R)

FCP Project 5H: Protection of the Highway System from Hazards Attributed to Flooding.

Title: Inlet Capacity Testing. (FCP No. 45H2382)
Objective: To develop hydraulic design charts for grate and slotted drain-type inlets presently being used for bicycle safety.

Performing Organization: Los Angeles Hydraulic Research Laboratory, Los Angeles, Calif. 90012
Expected Completion Date: June 1975
Estimated Cost: $50,000 (HP&R)

Title: Field and Laboratory Evaluation of Energy Dissipators. (FCP No. 45H3832)
Objective: (1) Develop simple pre-cast modular energy dissipators, (2) field evaluate concrete pipe utilizing roughness rings as an energy dissipating device, and (3) reevaluate current Ohio Department of Transportation design criteria with regard to designing energy dissipators.
Performing Organization: University of Akron, Akron, Ohio 44325
Expected Completion Date: August 1977
Estimated Cost: $170,000 (HP&R)

FCP Project 5I: Improved Structural Design and Construction Techniques for Culverts.

Title: Field Performance of Flexible Culvert Pipes (FCP No. 4512132)
Objective: Obtain and analyze field data on flexible metal culvert performance and on properties of backfill and embankment. Use analysis to evaluate current design and construction practices.
Performing Organization: Ohio State University, Columbus, Ohio 43215
Expected Completion Date: September 1976
Estimated Cost: $159,000 (HP&R)

Title: Instrumentation of Culvert Pipes Under Deep Fill (FCP No. 4512142)
Objective: Observe, measure, and record deflection, strains in culvert, settlement in embankment in flexible and rigid culverts under deep fill.
Performing Organization: Virginia Highway Research Council, Charlottesville, Va. 22803
Expected Completion Date: June 1976
Estimated Cost: $50,000 (HP&R)

Title: Improved Technology for the Structural Design of all Types of Pipe Culvert Installations (FCP No. 3513112)
Objective: Develop a general procedure for the design of all types of pipe culverts and determine optimum installation procedures and other techniques to permit maximum economical utilization of pipe strength.
Performing Organization: Naval Civil Engineering Laboratory, Port Hueneme, Calif. 93043
Expected Completion Date: July 1975
Estimated Cost: $145,000 (FHWA Administrative Contract)

FCP Project 5J: Rigid Pavement Systems Design.

Title: Performance Study of Continuously Reinforced Concrete Pavement on I-95 (FCP No. 45J1314)
Objective: Test sections in each contract will be observed for cracking, roughness, skid, wear, terminal joint movements, crack openings, temperature, cores, traffic, and maintenance.
Performing Organization: State Highway Administration, Baltimore, Md. 21203
Expected Completion Date: June 1978
Estimated Cost: $80,000 (HP&R)

Title: Preformed Elastomeric Joint Sealing Systems—Field Evaluation Phase (FCP No. 55J1424)
Objective: Conduct field study program to evaluate the adequacy of the tentative guide specifications for sealing joints in portland cement concrete pavements developed in NCHRP project 4-9; verify or modify guide specifications on the basis of information developed in the field study program and other information from documented research and experience.
Performing Organization: Department of Highways, Salt Lake City, Utah 84104
Expected Completion Date: December 1977
Estimated Cost: $125,000 (NCHRP)

FCP Category 6—Development and Implementation of Research

FCP Project 6B: Construction and Maintenance Methods and Equipment

Title: Slotted Underdrains (FCP No. 36B1103)
Objective: A user manual and visual aids package will be prepared on the slotted underdrain concept developed by Region 8 of the Federal Highway Administration.
Performing Organization: Region 8 Federal Highway Project Office, Denver, Colo. 80225
Expected Completion Date: July 1974
Estimated Cost: $25,000 (FHWA Administrative Contract)

FCP Project 6C: Traffic Engineering

Title: Traffic Control Systems Handbook (FCP No. 36C1033)
Objective: Development of a handbook covering the basic principles of analysis and design, installation, operation and maintenance of Traffic Control Systems for freeways and urban street networks.
Performing Organization: Pinnell, Anderson, and Wilshire, Dallas, Tex. 75240
Expected Completion Date: December 1974
Estimated Cost: $219,000 (FHWA Administrative Contract)

FCP Project 6Z: Implementation of Research Projects.

Title: Implementation of Research Findings (FCP No. 46Z1583)
Objective: Special efforts to insure that the results of research and development projects are brought into operating practice.
Performing Organization: Department of Transportation, Harrisburg, Pa. 17120
Expected Completion Date: June 1975
Estimated Cost: $75,000 (HP&R)

Title: Implementation of Research (FCP No. 46Z1603)
Objective: Special efforts to insure that the results of research and development projects are brought into operating practice.
Performing Organization: Department of Highways, Oklahoma City, Okla. 73105
Expected Completion Date: July 1975
Estimated Cost: $80,000 (HP&R)

Title: Implementation of Research (FCP No. 46Z1613)
Objective: Special efforts to insure that the results of research and development projects are brought into operating practice.
Performing Organization: Division of Highways, Springfield, Ill. 62706
Expected Completion Date: July 1975
Estimated Cost: $115,000 (HP&R)

FCP Category 9—Research and Development Management and Coordination

FCP Project 9A: Support Activities.

Title: Rational Determination of Priority Targets for Research and Development (FCP No. 39A1010)
Objective: A practical procedure for setting highway research priorities will be developed. The primary features of the procedure will be guidelines for quantifying the expected benefits of proposed research and a framework for arraying and trading-off expected benefits to aid in decisionmaking.
Performing Organization: Stanford Research Institute, Menlo Park, Calif. 94025
Expected Completion Date: June 1975
Estimated Cost: $369,000 (FHWA Administrative Contract)

Title: A Comparative Analysis of Urban Transportation Requirements (FCP No. 39A1080)
Objective: A comparative analysis of transportation service in over 20 U.S. and foreign urban areas. This will include the economics, organization, and administration of transportation planning, implementation, and operation of various public and private systems.
Performing Organization: International Road Federation, Washington, D.C. 20005
Expected Completion Date: December 1974
Estimated Cost: $96,000 (FHWA Administrative Contract)

Title: Highway Research Board Services. (FCP No. 39A2016)
Objective: Support and stimulate the urgent highway R&D program of the FHWA. Disseminate highway and urban transportation R&D findings. Operate the Highway Research Information Service (HRIS).
Performing Organization: National Academy of Science, Washington, D.C. 20418
Expected Completion Date: August 1974
Estimated Cost: $1,138,000 (FHWA Administrative Contract)

Non-FCP Category 0—Other New Studies

Title: A Model for Effective Public Involvement in Highway Decisionmaking. (Non-FCP No. 40E1122)
Objective: To evaluate the effectiveness of the Utah State Department of Highways' public hearing procedures and public notification techniques. Community surveys will be evaluated as a method of obtaining a more complete understanding of potential attitudes that may exist in an affected community.
Performing Organization: Department of Highways, Salt Lake City, Utah 84104
Expected Completion Date: June 1975
Estimated Cost: $25,000 (HP&R)

Title: Control of Permafrost Degradation Beneath Roadways by use of a Peat Underlay (Non-FCP No. 40F3185)
Objective: A layer of compacted peat will be incorporated beneath a roadway pavement system to prevent thaw of underlying ice-rich permafrost, in a roadway cut section. Information on climatological data, soil properties, surface and subsurface temperatures and roadway elevation changes with time will be obtained to permit theoretical thermal analysis of the results of the study.
Performing Organization: Department of Highways, Juneau, Alaska 99801
Expected Completion Date: June 1975
Estimated Cost: $25,000 (HP&R)

Title: Evaluation of Effectiveness of Membrane Waterproofing for Concrete Bridge Decks (Non-FCP No. 40F3344)
Objective: Evaluate various types of membrane waterproofing materials to determine their effectiveness in protecting concrete bridge decks from deterioration due to the use of deicing agents.
Performing Organization: Department of Highways, Columbus, Ohio 43215
Expected Completion Date: August 1974
Estimated Cost: $25,000 (HP&R)

Title: Automation of Construction Material and Haul Quantity Documentation (Non-FCP No. 40F3374)
Objective: Develop and demonstrate an automated system to weigh, print and record weights of materials delivered to highway construction projects.
Performing Organization: Highway Department, Austin, Tex. 78701
Expected Completion Date: August 1975
Estimated Cost: $25,000 (HP&R)

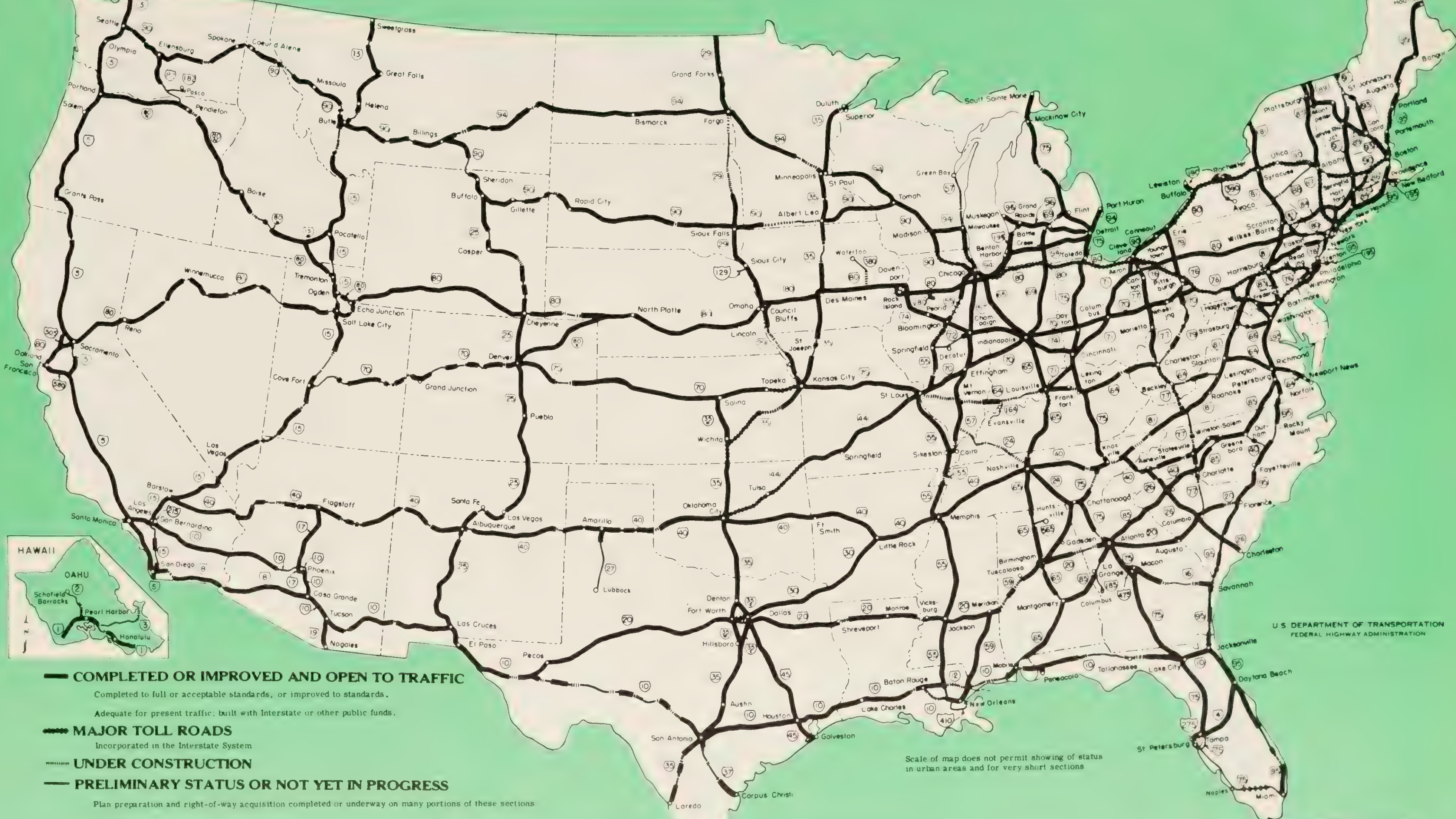
Title: Effectiveness of Neoprene Seals in Latex Paints (Non-FCP No. 40M3263)
Objective: The primary aim of this project is to find a number of highly qualified interior and exterior latex paints. A second aim is to develop, where necessary, suitable methods for the rapid evaluation of such paints.
Performing Organization: Department of Highways, Baton Rouge, La. 70804
Expected Completion Date: January 1978
Estimated Cost: $25,000 (HP&R)

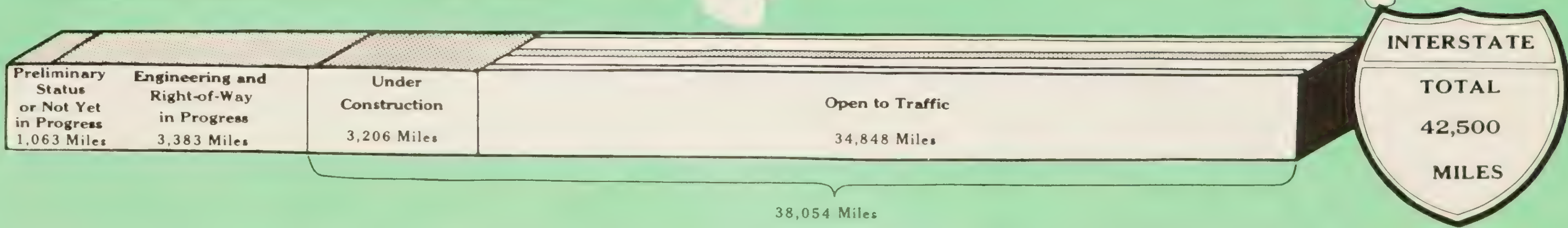
Title: Effectiveness of Neoprene Seals in Preventing Concrete Pavement Contraction Joint Deterioration (Non-FCP No. 40S4584)
Objective: A field investigation will determine the extent of the deicing chemical penetration of the joints sealed with preformed neoprene. If joint deterioration is a problem caused by the salts, the rate of concrete deterioration and chloride penetration will be determined.
Performing Organization: Department of State Highways, Lansing, Mich. 48904
Expected Completion Date: June 1977
Estimated Cost: $26,000 (HP&R)

Title: Driver Training Program Curriculum Development (Non-FCP No. 30Z0097)
Objective: Develop driver training curriculum.
Performing Organization: Rowland and Company, Inc., Haddonfield, N.J. 08033
Expected Completion Date: August 1974
Estimated Cost: $143,000 (FHWA Administrative Contract)

THE NATIONAL SYSTEM OF INTERSTATE AND DEFENSE HIGHWAYS

STATUS OF IMPROVEMENT AS OF JUNE 30, 1973





Highway Research and Development Reports Available from National Technical Information Service

The following highway research and development reports are for sale by the National Technical Information Service, Sills Building, 5285 Port Royal Road, Springfield, Va. 22151.

Other highway research and development reports available from the National Technical Information Service will be announced in future issues.

STRUCTURES

Stock No.

PB 219258 Variables Associated with Automobile Tire Hydroplaning.

PB 219642 Effects of Shoring Composite U-Beam Members.

PB 220114 Effect of Load Variations on the Flexural Fatigue Strength of Plain Concrete.

PB 220116 Guidelines for the Design of Subsurface Drainage Systems for Highway Structural Sections.

PB 220117 Shear Connector Studies on Curved Girders.

PB 220126 Stresses and Deformations in Jail Gulch Embankment.

PB 220177 The Residual Strength of Seattle Clays During Triaxial Testing.

PB 220197 Computer Program for Non-Prismatic Folded Plates with Plate and Beam Elements.

PB 220277 The Short Term Failure Criterion for Seattle Clays.

PB 220278 Cylinder Pile Design of the Basis of New Soil Test Procedures.

PB 220285 Performance Study of Typical Virginia Pavements.

PB 220286 Flow and Fracture Properties of Seattle Clays.

PB 220287 Lateral Loads on Piles.

PB 220289 A Comprehensive Structural Design for Stabilized Pavement Layers.

PB 220290 Wave Equation Analysis of Full-Scale Test Piles Using Measured Field Data.

PB 220304 Field Measurements of Lateral Earth Pressures on a Cantilever Retaining Wall.

PB 220306 Ultrasonic Inspection of Butt Welds in Highway Bridges.

PB 220320 Investigation of Subgrade Moisture Conditions in Connection with the Design of Flexible Pavement Structures.

PB 220321 A Study of Pavement Skid Resistance at High Speeds and at Locations Shown to be Focal Points of Accidents.

PB 220326 Automated Minimum Cost Design of Simple Span Prestressed Concrete Box Girder Bridges.

PB 220336 North Cascades Highway SR-20 Avalanche Atlas.

PB 220341 Tensile Behavior of Subbase Materials Under Repetitive Loading.

PB 220367 Factors Affecting Vehicle Skids: A Basis for Wet Weather Speed Zoning.

PB 220370 Evaluation of the Ion Exchange Landslide Correction Technique.

PB 220373 A Theoretical and Experimental Study of Dynamic Highway Loading.

PB 220379 Performance Analysis of Cylinder-Beam Retaining Walls—Seattle Freeway—Seneca Street to Olive Way.

PB 220388 Texas Crash Cushion Trailer to Protect Highway Maintenance Vehicles.

PB 220540 Creep Limit and Residual Strength Relationship.

PB 220541 The Dynamic Shear Behavior of Seattle Clays.

PB 220542 Summary and Practical Implications of the University of Washington Soil Engineering Research (1965-1970).

PB 220589 Experimental Paved Shoulders on Frost Susceptible Soils.

PB 220611 A Summary of Discrete-Element Methods of Analysis for Pavement Slabs.

PB 220813 Pavement Faulting Study Extent and Severity of Pavement Faulting in Georgia.

PB 220830 Collapsible Soils in Louisiana.

PB 220838 Criteria for the Design of Axially Loaded Drilled Shafts.

PB 220852 Capacity of Pile Anchors.

PB 220853 Truck Tests on Texas Concrete Median Barrier.

PB 220854 A Nonlinear Analysis of Statically Loaded Plane Frames Using a Discrete Element Model.

PB 220858 Prediction of Low-Temperature and Thermal-Fatigue Cracking in Flexible Pavements.

PB 220879 Crash Test of Mile Post Marker.

PB 220889 Lateral Resistance and Deflection of Piles—Final Report, Phase I.

PB 220890 A Rheological Study of Cohesive Soils.

PB 220896 The Effect of Internal Weld Defects on the Fatigue Behavior of Welded Connections.

PB 220897 Finite-Element Analysis of Bridge Decks.

PB 220915 Lateral Load Behavior of Drilled Shafts.
PB 220918 Soil Support and Structural Coefficients for Flexible Pavements in Pennsylvania.
PB 220937 Analysis of Integral Abutment Bridges.
PB 220940 Use of Synthetic Rubber in Asphalt Pavement to Determine Mixture Behavior, Pavement Performance, and Thermorhelogical Properties.
PB 221080 Avalanche Studies (1971-1972).
PB 221112 An Investigation of Design Criteria for Stresses Induced by Semi-Integral End Bents: Phase 1—Feasibility Study.
PB 221120 Measurement and Prediction of the Dynamic Tire Forces of a Passenger Vehicle on a Highway.
PB 221134 Effects of Curing and Falsework Support Periods on Dead Load Deflections of Reinforced Concrete Slab Bridges.
PB 221158 Dynamic Tests of a Prestressed Concrete Median Barrier Type 50.
PB 221167 Evaluation of a Prestressed Panel, Cast-in-Place Concrete Bridge.
PB 221379 Studded Tire Pavement Wear Reduction and Repair. Phase 1.
PB 221399 Lilac Road Overcrossing Study.
PB 221421 Design of Embankments on Soft Soil.
PB 221683 Settlement of Highway Bridge Approaches and Embankment Foundations—Bluegrass Parkway Bridges over Chaplin River.
PB 221719 Structural Design of Asphalt Pavements (Arizona)—Final Report, Phase I.
PB 221753 Synthesis of Recent Trench Backfilling Studies.
PB 221840 Statewide Survey of Blowups in Resurfaced Concrete Pavements.
PB 221848 Experimental Installations of Impact-Attenuating Devices.
PB 221910 Estimation of Concrete Strains and Prestress Losses in Pretensioned Members.
PB 221917 Relaxation Behavior of Prestressing Strands.
PB 221957 Analysis of Thermally Loaded Laminated Circular Plates.
PB 221969 A Pavement Feedback Data System.
PB 222033 Effects of Diaphragms in Continuous Slab and Girder Highway Bridges.
PB 222054 The Inelastic Analysis of Reinforced and Prestressed Concrete Beams.
PB 222453 Stress-Corrosion Susceptibility of Highway Bridge Construction Steels.
PB 222770 Skid-Test Trailer—Description, Evaluation, and Adaptation.
PB 222779 Improved Tensile Strength for Cement-Treated Bases and Subbases.
PB 222987 Performance Study of Continuously Reinforced Concrete Pavements.

MATERIALS

Stock No.
PB 219833 Techniques for Retarding the Penetration of Deicers into Cement Paste and Mortar.
PB 220707 Lightweight Hot-Mix, Cold-Laid Maintenance Mixture.
PB 220778 A Vacuum Saturation Method for Predicting the Freeze-Thaw Durability of Stabilized Materials.
PB 221008 A Vibratory Compaction Test Method for Granular Materials.
PB 221098 Investigation of Paints and Glass Beads Used in Traffic Delineation Markings. Phase 3
PB 221299 Mechanical Method of Preparing Soil for Test.
PB 221324 Internally Sealed Concrete—Phase I.
PB 221423 Seismic Test for Compaction of Embankment, Base Course, and Pavement Layers.
PB 221424 Electrical Resistivity Instruments for Measuring Thickness and Other Characteristics of Pavement Layers.
PB 221665 Correlation of Physical Properties with Chemical Composition of Paving Grade Asphalts.
PB 222345 Evaluation of Strains in Bituminous Surfaces: Stiffness-Fatigue Investigation.
PB 222631 Evaluation of Gap Graded Asphalt Concrete Mixtures (Complete Set).
PB 222632 Part I: Mechanical Properties.
PB 222633 Part II: Statistical Design and Analysis.
PB 222634 Part III: Appendix

TRAFFIC

Stock No.
PB 220866 Urban Traffic Control and Bus Priority System Software Manual (Complete Set).
PB 220867 Vol. I—Functional Description and Flow Charts.

PB 220868 Vol. II—Variable Definitions Algorithm and Offline Software Descriptions.
PB 221737 Calculation of Arterial and Freeway Capacity.
PB 221743 Audible Roadway Delineators.
PB 222295 Traffic Signal Opitmization Program Source Tape.
PB 222399 Freeway Traffic Flow Following a Lane Blockage.

ENVIRONMENT

Stock No.
PB 215034 Toward the Derivation of Simultaneous Equation Models for Estimating Winter Maintenance Costs in Pennsylvania.
PB 220888 An Evaluation of Hurricane Agnes' Floods in Comparison to Bridge Design Information Available for Pennsylvania Contemporaneously.
PB 221160 Summary of Staff and Contract Research on Safety of Wide Buses.
PB 221161 Evergreen Point Bridge Toll Booth Ventilation Study.
PB 222193 Vehicle Noise Study—Final Report.
PB 222488 Hydraulic Performance of Pennsylvania Highway Drainage Inlets Installed in Paved Channels.

PB 222750 Establishment and Maintenance of Roadside Plantings and Turf.
PB 222866 Comparisons of Full-Scale Embankment Tests with Computer Simulations—Vol. I, Test Results and Comparisons.
PB 222894 Large Vehicle-Induced Aerodynamic Disturbances. Critique of Past Studies and Recommendations for Further Research.

IMPLEMENTATION

Stock No.
PB 220764 Maintenance Scheduling and Reporting.
PB 221348 The Dryer-Drum Mixing Process for Producing Asphalt Mixtures in the State of Washington.
PB 221351 Experimental Lime Stabilization Project—Norman County. Final Report.
PB 222008 Highway Perspective Plot Program.
PB 222009 Project Management System (PMS) Through the Use of the Critical Path Method (CPM).
PB 222398 Adaptation of Analytical and Semi-analytical Numerical Photogrammetry Methods into Production Routines in Highway Photogrammetry.
PB 222964 Comprehensive Highway Maintenance Study—Final Report.

PLANNING

Stock No.
PB 220750 Economic and Social Effects of Highways.
PB 220814 Economic Effects of Interstate 80, Grinnell, Iowa.
PB 220887 Social Characteristics of Neighborhoods as Indicators of the Effects of Highway Improvements.

PB 221746 Puget Sound Governmental Conference—Trip Generation Update.
PB 221751 Puget Sound Governmental Conference—Forecasting Travel Patterns.
PB 221757 Puget Sound Governmental Conference—Highway System Development.
PB 222126 Blue Streak Bus Rapid Transit Demonstration Project (Complete Set).
PB 222127 Summary of Final Report.
PB 222128 Appendix.

Publications of the Federal Highway Administration

The following publications are sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Orders should be sent direct to the Superintendent of Documents. Prepayment is required.

Aggregate Gradation for Highways: Simplification, Standardization, and Uniform Application, and a new Graphical Evaluation Chart (1962), 25 cents.

Analysis and Modeling of Relationships between Accidents and the Geometrics and Traffic Characteristics of the Interstate System (1969), $1.

A Book About Space (1970), 75 cents.

Bridge Inspector's Training Manual (1970), $2.50; (1971), $2.50.

Capacity Analysis Techniques for Design of Signalized Intersections (1967), 45 cents.

Corrugated Metal Pipe (1970), 35 cents.

Evaluation of Potential Effects of U.S. Freight Transportation Advances on Highway Requirements (Research Phases 1 and 2), $2.75.

Fatal and Injury Accident Rates on Federal-Aid and Other Highway Systems (1971), 45 cents.

Federal-Aid Highway Map (42x65 inches) (1970), $1.50.

Federal Assistance Available (1971), 10 cents.

Federal Laws, Regulations, and Other Material Relating to Highways (1970), $2.50; (1972), $2.50.

The Freeway in the City (1968), $3.

Freeways to Urban Development (1966), 15 cents.

A Guide to Parking Systems Analysis, $2.60.

Handbook of Highway Safety Design and Operating Practices (1968), 40 cents; (1973), $2.
- Supplement No. 1 (Nov. 1968), 35 cents.
- Supplement No. 2 (Nov. 1969), 40 cents.

The Highway and Its Environment, 3d Annual Awards Competition, (1970), 60 cents.

Highway Joint Development and Multiple Use (1970), $1.50.

Highway Research & Development Studies Using Federal-Aid Research and Planning Funds (1970), $2.50.

Highway Statistics (published annually since 1945): 1968, $1.75; 1970, $1.75. (Other years out of print.)

Highway Transportation (Nov. 1970), 65 cents; (Spring 1971), 60 cents; (Fall 1971), 45 cents; (Spring 1972), 55 cents.

Highway Transportation Research and Development Studies (1972), $4.20.

Hydraulic Engineering Circulars:
- No. 5—Hydraulic Charts for the Selection of Highway Culverts (1965), 55 cents.
- No. 9—Debris Control Structures (1971), 50 cents.
- No. 10—Capacity Charts for the Hydraulic Design of Highway Culverts (1965), $1.
- No. 11—Use of Riprap for Bank Protection (1967), 50 cents.
- No. 12—Drainage of Highway Pavements (1969), $1.

Hydraulic Design Series:
- No. 1—Hydraulics of Bridge Waterways, 2d ed. (1970), $1.25.
- No. 3—Design Charts for Open-Channel Flow (1961), $1.50.
- No. 4—Design of Roadside Drainage Channels (1965), 65 cents.

Hydraulic Flow Resistance Factors for Corrugated Metal Conduits (1970), 55 cents.

Interstate System Accident Research Study-1 (1970), $1.

Interstate System Route and Log Finder List (1971), 25 cents.

Joint Development Opportunities Outside the Highway Right-of-Way (1971), 20 cents.

Labor Compliance Manual for Direct Federal and Federal-Aid Construction, 3d ed. (1970), $3.75.

License Plates (1972), 20 cents.

Manual of Instructions for Construction of Roads and Bridges on Federal Highway Projects (1970), $3.25 (for use with specifications—FP-69).

Manual on Uniform Traffic Control Devices for Streets and Highways (1971), $3.50.

Maximum Safe Speed for Motor Vehicles (1969), $1.

Modal Split—Documentation of Nine Methods for Estimating Transit Usage (1970), $1.25.

Motor Carrier Safety Regulations (1971), 65 cents.

National Highway Needs Report, H. Comm. Print 91st Cong., 70 cents.

The National System of Interstate and Defense Highways (1971), 15 cents.

The New Look in Traffic Signs and Marking (1972), 35 cents.

Park & Recreational Facilities (1971), 45 cents; (1972), 70 cents.

Program Documentation Urban Transportation Planning (March 1972), $6.25.

Quality Assurance in Highway Construction. (Reprinted from PUBLIC ROADS, A Journal of Highway Research, vol. 35, Nos. 6-11, 1969), 50 cents.

R&D Highway and Safety Transportation Systems Studies (1970), $2.50; (1971), $2.75.

Read Before Driving (1971), 15 cents.

Reinforced Concrete Bridge Members—Ultimate Design (1969), 45 cents.

Reinforced Concrete Pipe Culverts—Criteria for Structural Design and Installation (1963), 30 cents.

Road User and Personal Property Taxes on Selected Motor Vehicles (1973), 90 cents.

The Role of Third Structure Taxes in the Highway User Tax Family (1968), $2.25.

Safety Rest Area Development (1970), $1.

Specifications for Aerial Surveys and Mapping by Photogrammetrical Methods for Highways (1968), $2.

Standard Land Use Coding Manual (1965), 50 cents.

Standard Plans for Highway Bridges:
- Vol. I—Concrete Superstructures (1968), $1.25.
- Vol. II—Structural Steel Superstructures (1968), $1.
- Vol. III—Timber Bridges (1969), 75 cents.
- Vol. IV—Typical Continuous Bridges (1969), $1.50.
- Vol. V—Typical Pedestrian Bridges (1962), $1.75.

Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects (1969), $3.50.

Standard Traffic Control Signs Chart (as defined in the Manual on Uniform Traffic Control Devices)
- 22x34—20 cents, $15 per 100
- 11x17—10 cents, $5 per 100

Transportation Planning Data for Urbanized Areas based on 1960 census (1970), $9.25.

Typical Plans for Retaining Walls (1969), 75 cents.

Ultrasonic Testing Inspection for Butt Welds in Highway and Railway Bridges (1968), 55 cents.

Urban Origin-Destination Surveys, $3.20.

Urban Planning General Information (March 1972), $2.75.

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