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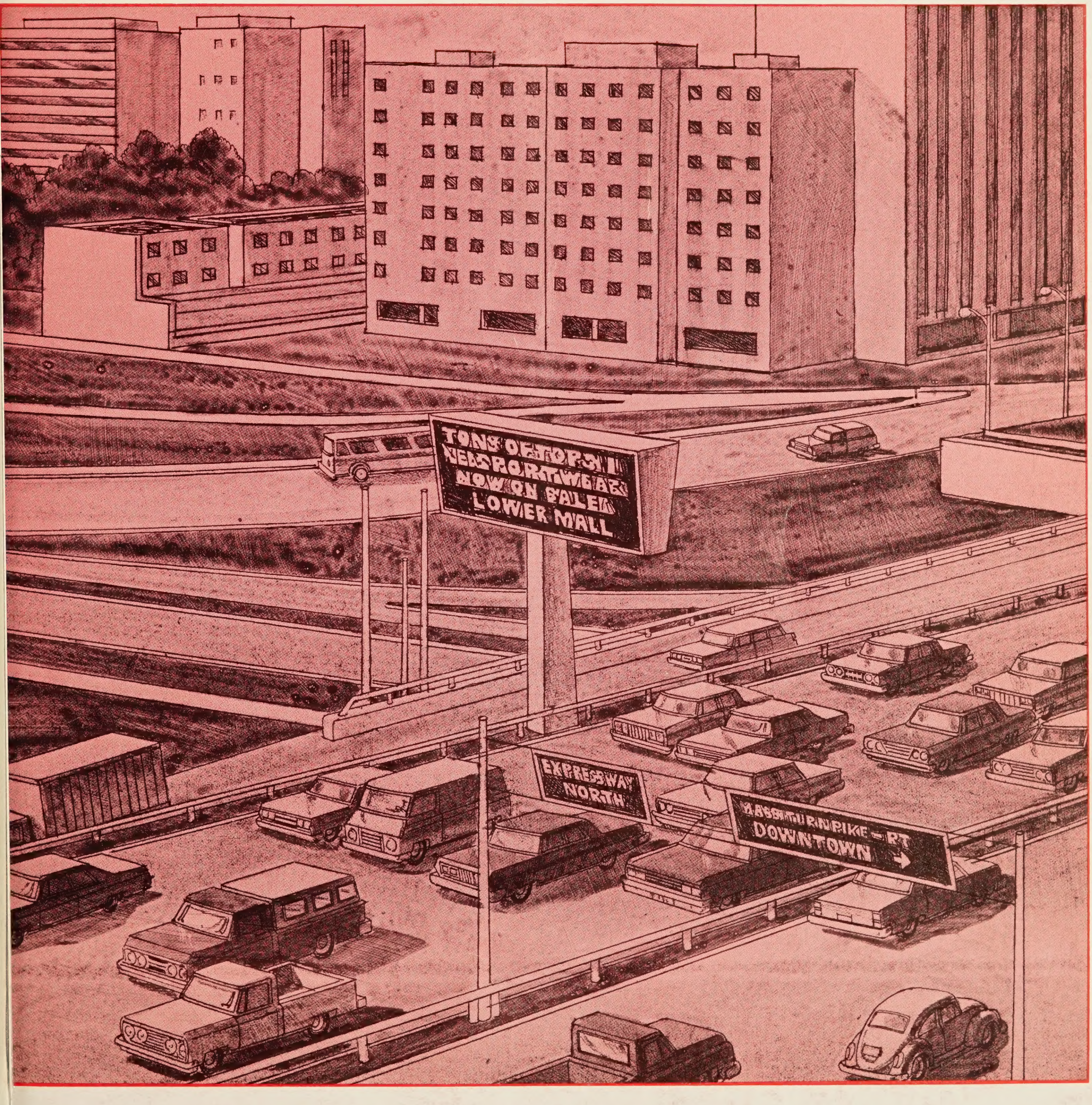

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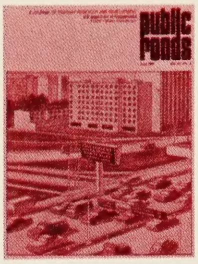

COVER:
Electronic advertising along highways is a safety concern.

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Electronic Advertising Along Highways—Concern for Traffic Safety (1)[1]

by
Jerry Wachtel

Introduction

Businesses, products, and services have been advertised along our Nation's highways since the earliest days of motoring. From the early "Mail Pouch Tobacco" signs painted on the sides of barns and the famous "Burma Shave" signposts along rural primary roads, advertisers have developed increasingly sophisticated techniques to capture the driver's attention long enough to convey a message. At a traveling speed of 56 km/h (35 mph), the spacing of the Burma Shave signs (six panels, each 100 paces apart) required 18 seconds of driver attention, far more than a newspaper or magazine advertiser could expect from readers. (*2*)

As the task of driving has become more complex because of increasing traffic volumes, speeds, number of multilane roads, and complexity in the visual environment, advertising communication techniques have become more sophisticated. Large billboards and high-mounted signs illuminated at night were developed to attract attention at great distances on high-speed freeways. Multi-colored signs, often illuminated with neon tubing, appeared along roadsides to capture attention by presenting a more compelling message than that of a competitor. Sections of highways burdened with commercial advertising became known as "billboard alleys" and "neon jungles."

[1] Italic numbers in parentheses identify references on page 5.

Electronic Signage

In recent years, dramatic developments in electronics, computers, and communications have been applied to signage. Firms worldwide have designed and manufactured signs on which messages and images can be changed by automatic and remote control. This kind of signage, used for both commercial and official functions, varies greatly in the specific display and control technology used. (*3*)

Perhaps the most advanced development in this rapidly growing field of electronic signage is the lamp matrix system consisting of thousands of closely spaced, individually controlled incandescent bulbs with up to 16 discrete sepia-toned shades or full color. The visual result is a pictorial image that may be of very high resolution. A particular kind of lamp matrix system has been described as follows:

> The Theme Tower can best be described as a double-sided electronic bulletin board. Instead of utilizing paint or printing to reproduce advertising copy, the Theme Tower reproduces it electronically. The advertiser's copy is televised and pictorially stored on computer. On command, the computer displays the pictorial electronically on two large matrix panels. The medium also has the capability to reproduce advertising copy using the computer keyboard system. (*4*)

The lamp matrix is one form of a commercial electronic variable message sign (CEVMS). CEVMS's are a distinct subset of the much larger and older category of variable message signs. The latter group, still used for both official and commercial functions, generally shows a limited number or series of changeable messages, most often in a fixed and predetermined sequence. Some variable message signs, however, permit the controller a degree of override capability to prevent a particular message from appearing or to display a message out of sequence.

The CEVMS differs from older variable message signs in two important ways. First, CEVMS's allow real-time control. An operator or an automatic input device can command nearly any message at any time. It is this capability that allows a time and temperature display to be updated as conditions change and allows the operator of an electronic traffic control sign to update its message with reports of an accident or traffic delay.

The second way in which CEVMS's differ from older variable message displays is in their repertoire. Because electronic signs are often computer controlled, they may have almost unlimited display possibilities built into the computer's program (fig. 1). This capability may permit a changing series of messages to be displayed, without duplication, for weeks or months. In addition, by pressing a few keys in a control station, an operator can display any message or message sequence desired. The operator also can control the size, typeface, image contrast and shading (sometimes

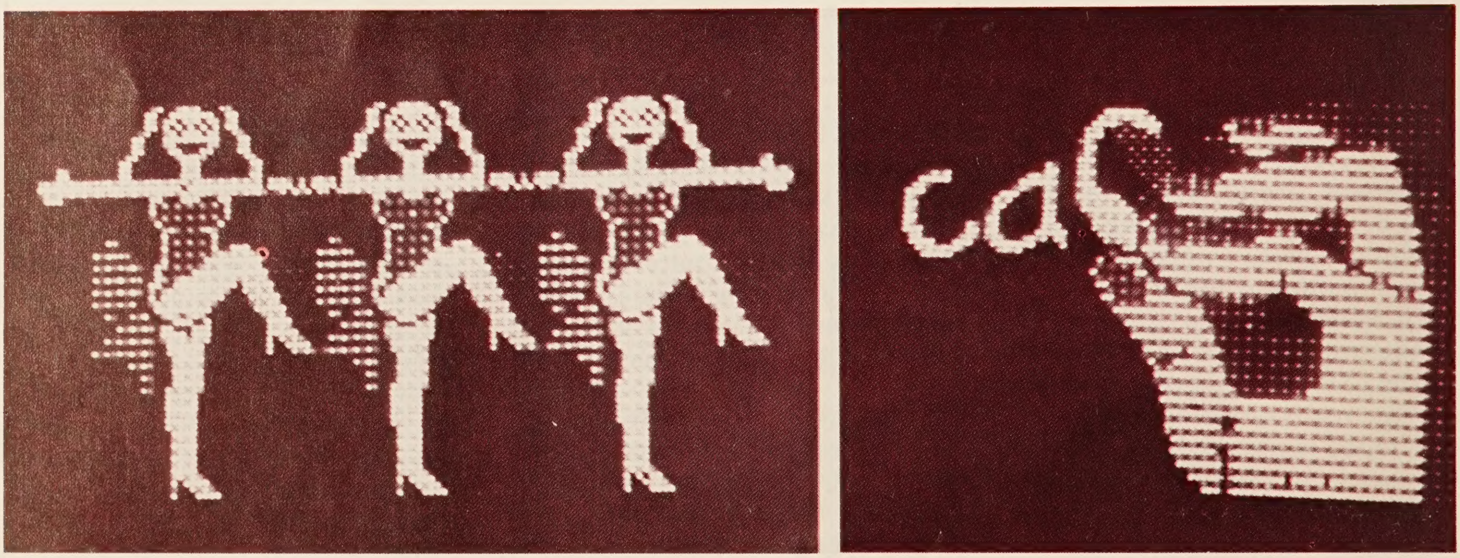

Figure 1.—An off-premise CEVMS that entertains as well as advertises.

color), and speed of movement or animation of messages displayed. This flexibility is seen most commonly on lamp matrix stadium scoreboards (fig. 2).

The Federal Highway Administration (FHWA) Office of Research recently completed a comprehensive review of research literature and operational experience dealing with safety impacts of commercial advertising visible to drivers. This study followed a 1978 amendment to the Highway Beautification Act. The amendment revised the authorization for on-premise advertising signs in controlled areas to allow ". . . signs, displays, and devices *including those which may be changed at reasonable intervals by electronic process or remote control* . . ." (italic indicates new language added). (*5*)

Because earlier laws still in force continued to prohibit any sign that contained, included, or was illuminated by any flashing, intermittent, or moving light or lights and any sign that moved or had animated or moving parts (*6*), it was necessary to determine whether CEVMS's fell within the scope of these prohibitions.

The electric sign industry sought to exempt CEVMS's from these prohibitions, as evidenced by the following statement:

> An electronic information display does not flash or animate static information. The only movement is the changing of information against a solid, colorless background. (*7*)

However, observation of CEVMS's, as well as an understanding of their operating capability, indicates that such signs may be designed and operated to convey the impression of flashing, intermittent, or moving light(s) as well as animation. Therefore, the safety impact of such signs visible to motorists needed to be researched and possible restrictions upon their location or operation needed to be considered.

Figure 2.—A remotely controlled lamp matrix scoreboard.

Safety Impact of Roadside Advertising

Unfortunately, because of the recency of CEVMS technology and application, little research has dealt directly with the effects of this technology. Thus, FHWA researchers examined accident and other highway safety research back to 1950, when the safety impact of roadside advertising upon driver behavior was first questioned. Two of the earliest studies identified created a controversy that has continued. Both studies—one in Minnesota and the other in Michigan—evaluated accident records from data collected in similar areas on similar roads. Statistical analysis procedures differed for each study, and each study has been criticized by other investigators. The studies reached nearly opposite conclusions regarding the safety impact of advertising signs on vehicle accidents. The Minnesota study found that there was such a relationship, and the Michigan study, with one exception, concluded that no such relationship could be demonstrated. The one exception in the Michigan study was that illuminated signs, including but not limited to neon and flashing neon, showed an "appreciable association with accident locations." (*8*)

It was concluded from the FHWA investigation that findings are divided almost equally on both sides of the issue when accident records are used to establish relationships between advertising signs and accidents. A reanalysis in 1973 of some of the earlier studies showed that the better controlled research from experimental, statistical, and methodological standpoints did demonstrate a detrimental impact of advertising signs on traffic safety (*9*), but other accident studies continued to be published which showed no such relationship.

The value of accident data for studying this kind of problem is limited for many reasons: The amount and accuracy of detail in police accident reports differ widely among jurisdictions; the motorist reporting an accident may be unsure, may not remember, or may be unwilling to admit how an accident occurred; the location of the advertising sign may be confounded by the effects of other environmental features that also could have attracted the driver's attention; and the road and traffic conditions may differ greatly from one study site to another, or even on different road segments within the same study site, making direct comparison of findings impossible. In addition to these difficulties, many accident investigations are poorly designed. In the FHWA investigation, only one study was identified that dealt with a real-world accident investigation and met the generally accepted criteria for a true experimental design (in this case, a before-after design with controls). (*10*) This study also was the only examination of a CEVMS that was found. The study determined that there was a significant relationship between the presence and visibility of the CEVMS and traffic accidents. The conclusions of this study contributed to a judicial decision to revoke the operating permit for the sign and later to have the sign removed from the roadside. (*11*)

A chi-square analysis performed on the CEVMS study data showed that although accident rate declined during the study period in both experimental areas (roadway sections where the sign could be seen) and control areas (roadway sections where the sign could not be seen), the decline in the experimental areas was significantly less than that in the control areas.

Yet, many other accident analyses continue to be plagued with problems of experimental and statistical control and interpretation of findings. Therefore, indirect or surrogate measures of driver behavior and traffic movement have been developed and refined and used with increasing success in studies of highway safety. A partial listing of available surrogate measures includes: Driver eye movement behavior; studies of divided attention and subsidiary task performance; traffic conflicts; driver physiological and control performance in an instrumented vehicle; and detailed measurement of vehicle movements within the traffic stream using data collection methods such as video recorders and the FHWA traffic evaluator system.

The few recent studies that address driver/traffic performance in the presence of distractors and roadside advertising agree in their findings that an adverse relationship exists. (*12, 13*)[2]

[2] "Relationship Between Roadside Signs and Traffic Accidents: A Field Investigation," by C. J. Holahan, M. D. Campbell, R. E. Culler, and C. Verselka. Paper presented at the annual meeting of the Transportation Research Board, Washington, D.C., Jan. 18, 1978.

These findings support theoretical research conducted earlier by experimental psychologists. (*14, 15*) It has been argued that human sensory receptors have a limited channel capacity and that the introduction of a novel or distracting stimulus can detract an individual's attention from an ongoing task and degrade his or her performance. (*15*)

Summary

The Federal Law to promote highway safety and the directive to perform research and testing of new developments (*16*) require specific research to be conducted. Whereas the 1978 legislation legitimized commercial signage using the latest electronic technology, earlier laws still in force prohibit signs illuminated by flashing, intermittent, or moving light or signs that move or have animated or moving parts. Although industry representatives claim that CEVMS's do not flash or animate, FHWA research and field observations have demonstrated that many such signs have the potential for animation and for flashing, moving, and intermittent message presentation, and some operating signs already possess these display characteristics. In addition, although a cause and effect relationship between roadside advertising (or any roadside feature) and traffic accidents has not been demonstrated, a correlation has been established, and this relationship has been substantiated in recent studies using surrogate measures of accidents.

The only identified investigation that has directly used an on-the-road traffic accident analysis in the vicinity of a CEVMS has demonstrated a statistically significant correlation between the presence and visibility of the sign and traffic accidents. As surrogate measures of accidents have been improved and have gradually achieved greater acceptance in the traffic engineering community, they have become more valuable for studying the CEVMS safety question.

FHWA will conduct a study to answer key questions posed by the construction and operation of CEVMS's. The first phase, a controlled field experiment using the surrogate measures of driver eye movements and traffic flow, will begin late in 1981. If this first-phase research demonstrates a relationship between the presence of roadside CEVMS's and traffic safety, then a second phase, a laboratory simulation, will evaluate specific design and operating characteristics that appear to contribute to the relationship identified in the first phase. Results of the two phases should provide a valid and clear understanding of any safety impacts of CEVMS's. This understanding, in turn, should provide a basis for any operational definitions and design, placement, and operating requirements that may be needed for such signs visible to motorists traveling on the Nation's highways.

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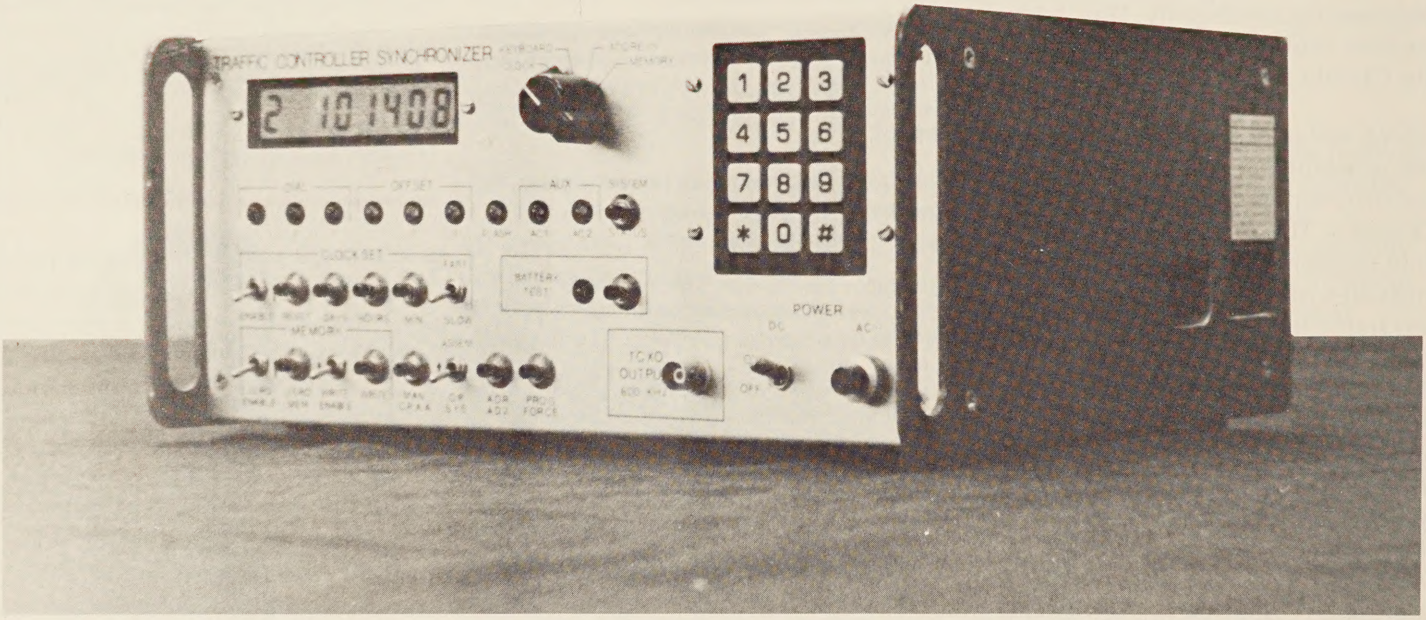
Traffic Controller Synchronizer—Time-Based Traffic Signal Coordination

by
Robert E. Ellington and Richard G. Reynolds



One of the major concerns in the United States today is fuel conservation. Because of unnecessary stops and delays, fuel is wasted at signalized intersections that are not properly timed and coordinated. Of the approximately 240,000 signalized intersections in the United States, only about 35 percent are coordinated using physical interconnection. The prime reason for so few interconnected systems is the high cost to install the interconnecting equipment. Fuel could be conserved if these closely spaced, isolated intersections were coordinated.

In 1977, the Federal Highway Administration (FHWA) initiated the design and development of a low-cost technique for wireless interconnection of traffic signals at urban intersections to improve traffic flow and reduce fuel consumption. The result of this research and development effort is the Traffic Controller Synchronizer (TCS), a solid-state, time-based unit that coordinates existing traffic signal controllers without expensive interconnecting cable, radio, or optical links. This article discusses the development of the TCS, its capabilities, and a recent field application of TCS units at seven suburban intersections in Virginia.

Introduction

Traffic signals are coordinated by an event (the sync-pulse) occurring at the same time throughout the signal system or by a time-related sequence of events occurring in the system. Methods available for coordinating local intersection controllers include hardwire interconnection, radio transmission, optical coupling, and free-running, electromechanical synchronous motors. Generally hardwire interconnect, whether buried dedicated control cable as in the standard seven-wire and ten-wire systems or leased telephone lines, is costly to install. Buried cable systems cost more than $131 per lin m ($40 per lin ft) in some areas, and leased-line costs have increased 10 times in recent years and will continue to rise.

Some cities, notably Washington, D.C., have connected intersections with a radio link. The link generally is expensive, requires a sophisticated receiver at each controller cabinet, and is susceptible to atmospheric disturbances and noise, signal reflection errors and blind spots in and around large buildings, and loss of the total system by failure of the central transmitter. Much like a radio link, optical coupling of controllers is prone to environmental disruption and high equipment costs and requires line-of-sight signal paths. Coordination using synchronized free-running synchronous motors or relying on the controller's own dial motors has proved partially satisfactory, particularly for short term, loosely coordinated systems. However, because power failures, mechanical gear and bearing drag, and loose tolerances cause such systems to drift apart, the systems require frequent recoordination.

The concept of time-based coordination was developed in the mid-1970's. In a time-based coordination system, accurate real-time clocks are distributed through the traffic control network (in every controller cabinet in a system with no existing cabled interconnections) providing the local controllers with necessary control signals to maintain the desired traffic progression.

Early Cableless Equipment

Time-based coordination, or "cableless" interconnection, of traffic signals was first tried in Europe and Australia. A Cableless Linking Unit was in operation in England as early as 1974. The unit, requiring its own cabinet and consuming about 50 W of power from the commercial line, performed the basic functions of a time-oriented coordination unit. A flexible progressive coordination unit (Flexilink), which also came in a telephone line coupled version, almost replaced the local controller in capability, down to the intra-cycle timing in its software-oriented structure. Closely alined with Flexilink was the Mains Synchronized Coordination Offset Timer (MASCOT) unit. MASCOT, designed to operate primarily with its manufacturer's equipment, was a hardware-based unit with limited time-of-day program capacity. A Cableless Linking Unit, most similar in capability to FHWA's TCS, was developed in Australia.

Each of these early synchronizers was limited by high power consumption, low battery standby time, small program capacity, large size, and poor timekeeping. In the United States, a Sync-Pulse Generator was developed and provided accurate sync-pulse generation with a limited battery backup, but it relied on an external synchronous-motor time clock for its time-of-day capabilities.

TCS Development

The TCS developed by FHWA coordinates existing signal controllers on the basis of time and timing accuracy between units, without cable connection, radio, or optical linking. Modern integrated circuit components and discrete parts have been combined to provide a unit capable of meeting present needs and sophisticated enough to serve as a benchmark for future system designs. The unit is not a microprocessor-based system, and there is no software in the TCS design or function. Reliability, timing accuracy, and environmental stability have been emphasized in the design.

Like the standard seven-wire interconnect, the TCS provides coordination signals directly to the individual controller. The TCS can control a three-dial, three-offset controller with flasher option and provide several special function outputs that may be used at a given installation. The TCS also can coordinate traffic-actuated controllers by issuing the yield command at the appropriate times in the background cycle, although some auxiliary hardware (relays) may be necessary to complete the interface and maintain the actuated capability.

A TCS unit is 127 mm (5 in) high, 305 mm (12 in) wide, 266.7 mm (10.5 in) deep and weighs about 4.5 kg (10.0 lb). A unit usually operates from a 115 VAC commercial powerline and generates necessary internal power levels from that line. Timing functions usually are based on a 60 Hz frequency of the powerline. A TCS unit uses less than 100 mW of power, plus power required by the intersection controller. If commercial power is interrupted, the internal functions of the TCS are maintained by self-contained batteries, which are maintained by trickle charging from the commercial power, and timing operations are continued by an internal crystal oscillator. A TCS will maintain time and program functions for about 100 hours during power loss.

The seven-wire output from the TCS connects the unit to the controller. The following outputs are available: One line each for the Dial 2 and Dial 3 transfer relays; one line for flash transfer; one line each for Resets (or Yields) 1, 2, and 3; and one line for AC common. In addition, two special functions are programable for on/off times independent of the controller interconnect signals.

The TCS must be programed for the functions desired at each intersection, including mode (dial, offset, or yield), cycle times, and special functions, on a time-of-day, day-of-week basis. A standard 12-position keyboard, an eight-digit, seven-segment liquid crystal display (LCD), and control panel switches and buttons are used to program functions. Up to 128 time-of-day functions can be stored in the TCS memory for a 7-day week. The TCS operation also must be initialized (for example, real-time clock and starting program memory location) at installation.

Figure 1.—Field test site for TCS units.

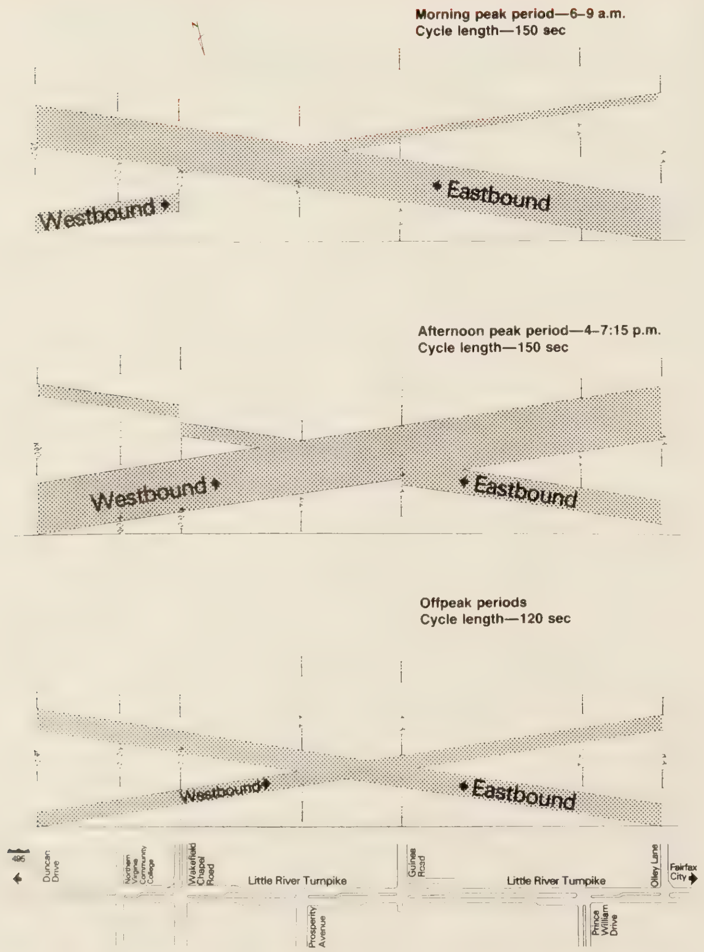


Figure 2.—Time-space diagrams for morning peak, afternoon peak, and offpeak periods on Route 236.

The TCS requires minimum routine maintenance. The batteries should be changed every 2 years, and the crystal oscillator should be readjusted to its center frequency (600 KHz) every year. Depending on operating temperature and age, the internal clock may lose or gain up to 1 second for every 100 hours of operation on the internal crystal oscillator. A large amount of operating time without commercial power may require more frequent resetting of the real-time clocks in TCS units.

FHWA fabricated 25 TCS units. These prototype units field tested time-based coordination and initiated industry development of such equipment.

TCS Field Test

After designing and constructing the TCS, FHWA awarded a contract for testing and evaluating the unit. A test site was selected by FHWA with the cooperation of the Virginia Department of Highways and Transportation (VDH&T). A segment of Route 236 in Fairfax County, Va., was chosen (fig. 1). Route 236, a four-lane divided arterial roadway with unlimited access and an average daily traffic volume of 34,000, had signalized intersections that were not interconnected. The test site began on the easterly end at the first signalized intersection west of Interstate 495 (the Washington, D.C., beltway) and ended approximately 3.2 km (2.0 miles) farther west. Seven signalized intersections were included in the test site, with each intersection being controlled by an Automatic Signal 1826–N controller operating in the full-vehicle actuated mode.

Because this was an uncoordinated system, time-space diagrams had to be developed for the morning peak, afternoon peak, and offpeak periods (fig. 2). During the morning peak period, the bandwidth for the inbound (eastbound) direction was maximized, and during the afternoon peak period, the bandwidth for the outbound (westbound) direction was maximized. The bandwidths were balanced for both directions during the offpeak periods.

An adapter containing three relays was designed and constructed to interface the TCS units with the Route 236 controllers. Because of the limited flexibility of the controllers, the interface was necessary to provide for fully actuated operation when the TCS relinquished control. Twelve connections were added or changed in each controller cabinet to install the TCS with its adapter.

The Route 236 units were installed in two phases. The first phase, cabinet preparation (wiring), was completed during an offpeak period with the cabinet power turned off. As the installation proceeded, each intersection was checked using a TCS containing a test program to insure proper operation. First phase installation averaged 30 minutes per intersection.

The second phase of the installation included programing a TCS for each intersection. Each operation mode for each intersection requires a two-line keyboard entry of function code, time-of-week, dial and offset identification, and timing information (fig. 3). Twenty-nine steps were used to program the weekly operational sequence on Route 236 (table 1). The second phase was completed with actual installation and turn-on of the TCS units in the controller cabinets.

Installation, programing, and turn-on of the TCS units at the seven intersections were completed in less than 8 hours, creating a system of coordinated traffic signals. Preliminary planning (time-space diagrams and cabinet wiring plans) took no more time than would be required for other coordination methods.

Before installing the TCS units, the first phase of a before-after time delay study was performed to demonstrate that travel time required to traverse the system could be reduced by coordinating the previously isolated signalized intersections. Other measures of effectiveness (MOE's), such as the number of stops per vehicle and the total number of stops, have been evaluated in previous studies to determine the benefits of interconnecting isolated intersections. Therefore, it was decided that additional MOE's need not be evaluated for this study.

The floating car method was used to determine the overall time required to travel from the stop bar at the first intersection to the stop bar at the last intersection of the test site. Twenty runs were made both eastbound and westbound during each of the morning peak, afternoon peak, and offpeak periods. The average travel time for each direction by time-of-day is shown in table 2.

Table 1.—TCS operation on Route 236

Day-of-week	Time-of-day	Mode of operation
Sunday	Midnight–7 a.m.	Full actuation
	7 a.m.–midnight	120 sec cycle/semiactuated
Monday through Friday	Midnight–6 a.m.	Full actuation
	6 a.m.–9 a.m.	150 sec cycle/semiactuated
	9 a.m.–4 p.m.	120 sec cycle/semiactuated
	4 p.m.–7:15 p.m.	150 sec cycle/semiactuated
	7:15 p.m.–midnight	120 sec cycle/semiactuated
Saturday	Midnight–7 a.m.	Full actuation
	7 a.m.–midnight	120 sec cycle/semiactuated

Table 2.—Average travel time before TCS installation on Route 236 (November 1979)

Period of day/direction	Time	
	minutes	*seconds*
Morning peak eastbound	6	21
Morning peak westbound	4	37
Afternoon peak eastbound	4	33
Afternoon peak westbound	4	46
Offpeak eastbound	4	12
Offpeak westbound	4	15

The test site was observed for 3 weeks before performing the after phase of the study. The times on the TCS clocks were found to be drifting. Because signal coordination depends on the clocks maintaining accurate time, progression through the system was ineffective. After the clocks were tested by FHWA, it was found that an electrical grounding problem in the cabinet was causing the clocks to drift. After the cabinet wiring was modified, the clocks stopped drifting.

Figure 3.—TCS program input.

Dial	-blank-	Day	-blank-	Hours 10's	Hours units	Minutes 10's	Minutes units
(0-9 except 5)		(0-7)		(00-23)		(00-59)	

Dial	Cycle time 100's	Cycle time 10's	Cycle time units	Offset number	Offset time 100's	Offset time 10's	Offset time units
(0-9 except 5)	(000-199)			(0-3)	(000-199)		

The after phase of the study was run in the same manner as the before phase. Results of the after phase are shown in table 3. The time delay study indicates travel time was reduced an average of 25 percent, resulting in an increase of 11 km/h (7 mph) in the average speed to traverse the test site—from 40 km/h (25 mph) to 51 km/h (32 mph) (table 4).

The performance of the TCS units has been monitored continuously since April 1980, and no major problems have been observed. Data collection on the Route 236 test site ended in January 1981. VDH&T is maintaining the system, and FHWA will continue to assist with technical needs. VDH&T is planning to coordinate 10 additional intersections (approximately 6.4 km [4.0 miles]) on Route 236 inside the Washington, D.C., beltway east to Interstate 395. VDH&T plans to use time-based coordination equipment, perhaps FHWA's residual prototype units.

Field Test Results

Results of the seven-intersection test site for the FHWA TCS units show an annual reduction of 465 371 L (122,938 gal) of gasoline, 181 415 kg (399,951 lb) of carbon monoxide, and from 3.5 percent to 31 percent reduction in hydrocarbons (depending on direction of travel and time-of-day). A cost/benefit analysis of the TCS interconnect shows an annual cost of $540 per intersection, compared with $1,030 per intersection for a wired interconnect with overhead cable and $1,850 per intersection for a wired interconnect with underground conduit.

The user must remember that time-based coordination is not traffic responsive. The TCS performs only those time-of-day functions that it has been programed to perform. A hardwire interconnect can be traffic responsive, can have the capability of two-way communication, and has potential for operator intervention into the system without visiting each intersection as is required with the TCS.

Summary

Since FHWA began its development of the TCS, several manufacturers have produced similar units that are now commercially available. Results from a recent survey sent to all FHWA Regional Offices indicate that time-based coordination has been relatively well accepted by the traffic engineering community. Over 90 jurisdictions have installed, or are planning to install, over 400 units.

Table 3.—Average travel time after TCS installation on Route 236 (March 1980)

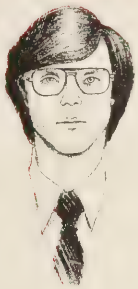
Period of day/direction	Time	
	minutes	*seconds*
Morning peak eastbound	3	38
Morning peak westbound	4	10
Afternoon peak eastbound	3	56
Afternoon peak westbound	3	17
Offpeak eastbound	3	57
Offpeak westbound	3	26

Table 4.—Improvements on Route 236 after TCS installation

Period of day[1]	Direction	Speed change		Pollution change: Carbon monoxide	Pollution change: Hydrocarbons	Fuel consumption change	Travel time change
		miles per hour	*percent*	*pounds per weekday*	*pounds per weekday*	*gallons per weekday*	*percent*
Morning peak	Eastbound	+13.88	74.74	−515.12	−42.93	−149.00	−42.78
	Westbound	+ 2.76	10.81	− 33.05	− 5.52	− 9.41	− 9.75
Afternoon peak	Eastbound	+ 4.06	15.66	−102.51	−14.64	− 25.86	− 13.55
	Westbound	+11.17	45.15	−327.36	−21.82	−147.25	−31.12
Offpeak	Eastbound	+ 1.78	6.34	−136.75	−22.79	− 40.61	− 5.95
	Westbound	+ 6.60	23.79	−424.83	−24.24	−100.71	−19.22

[1] Results shown are for weekdays between 6 a.m. and midnight.
1 mph = 1.61 km/h
1 lb = 0.45 kg
1 gal = 3.78 L

If time-based coordination were implemented across the Nation, we could reduce gasoline consumption by approximately 9.5 million L (2.5 million gal) per day by reducing inefficient vehicle operation at uncoordinated traffic signals. Associated benefits, as with any coordination method, include improved traffic speed and volume and reduced pollution, driver frustration and tension, and accident potential. Installation costs for time-based coordinated systems are approximately 14 times less than those for other methods of coordination. In addition, time-based coordinated systems have projected lower operation and maintenance costs. A time-based coordination system can pay for itself in a few months in reduced fuel consumption alone.



Robert E. Ellington is a highway engineer in the Implementation Division, Office of Development, Federal Highway Administration. Before joining FHWA in 1977, he worked for the District of Columbia Department of Transportation. Mr. Ellington, who has been working in the area of time-based coordination, helped develop the traffic controller synchronizer. He is currently implementation manager for the urban traffic control systems area, which includes development of real-time traffic control software, traffic signal optimization software, and related hardware.

Richard G. Reynolds is an electronics engineer in the Engineering Services Division, Office of Development, Federal Highway Administration. He has been with FHWA since 1975, providing electronic design, consultation, and contract management support to FHWA's Offices of Research and Development. Mr. Reynolds designed the traffic controller synchronizer, as well as other advanced electronic instrumentation, control equipment, and data acquisition systems. He currently is designing a traffic controller cycle timer and managing a contract to improve the visibility of the railroad-highway crossing signal.

Robert E. Ellington and Richard G. Reynolds Receive Awards

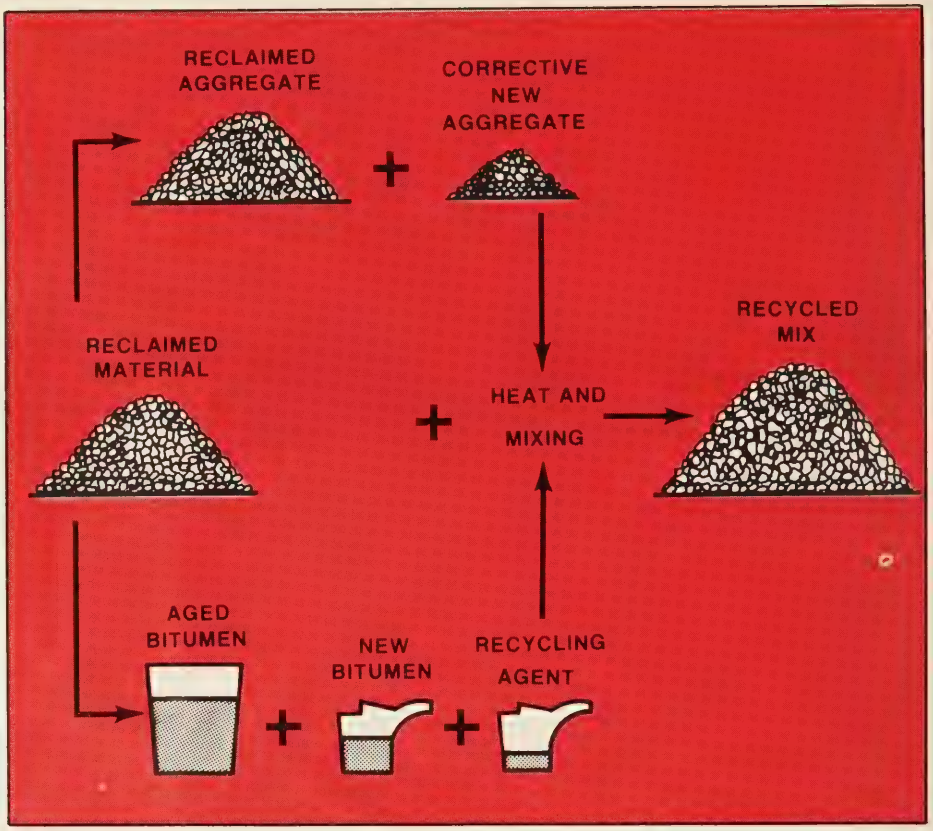
Mr. Robert E. Ellington and Mr. Richard G. Reynolds were the recipients of the 1980 award in the annual outstanding technical achievement competition held among the employees of the Federal Highway Administration Offices of Research and Development. This award covers the documentation of any technical accomplishment, which may be a publication, technical paper, report, or package; an innovative engineering concept; an instrumentation system; test procedure; new specification; mathematical model; or unique computer program. Each eligible candidate is judged on excellence, creativity, and contribution to the highway community, general public, and FHWA.

Mr. Ellington, a highway engineer in the Engineering, Location, and Design Group, Implementation Division, Office of Development, and Mr. Reynolds, an electronics engineer in the Electronics Instrumentation Group, Engineering Services Division, Office of Development, received awards for their development of the traffic controller synchronizer (TCS), a solid-state, time-based control unit that coordinates existing traffic signal controllers without expensive interconnecting cable, radio, or optical links.

Mr. Ellington (left) and Mr. Reynolds (right) are shown receiving a plaque for their accomplishments from Dr. Gerald D. Love, Associate Administrator for Research and Development.

Current Research in the United States to Evaluate Materials Used in Recycling Asphalt Pavements[1]

by
Gene K. Fong



Introduction

The U.S. Department of Transportation, Federal Highway Administration (FHWA), is firmly committed to and fully endorses the concept of recycling highway pavement materials. The initial emphasis in recycling was directed primarily toward the development of improved construction processes and equipment to meet air quality standards and still maintain reasonable production rates. In addition, FHWA recognized the need to further develop the technology necessary to use recycled asphalt pavements as durable, cost-effective, and energy- and material-efficient paving materials. A comprehensive research program was formed to address several major problems of recycling including the variability in the aggregate gradation and asphalt content of the salvaged materials; the adequacy of the mixing operation to produce an intimate mixture between the old and the new asphalt binders (and recycling agents, if added); the physical and chemical compatibility between the recycling agent and old and new binders; and the performance, cost, and energy conservation aspects of recycling.

The major research studies sponsored by FHWA to resolve these problems are discussed in this article, as are other research studies conducted by various highway agencies, universities, and engineering firms.

FHWA Data Bank for Recycled Bituminous Concrete Pavements

During the past few years, many experimental and demonstration recycling projects have been constructed using a variety of salvaged materials, removal and processing techniques, and laydown procedures. Because of the numerous combinations of possible variables, few quantitative

[1] Material contained in this article has been printed in the proceedings of the Seminar on Recycling of Pavement Materials held in Rome, Italy, March 1981.

conclusions can be drawn as to the effects of any one of the variables. It thus becomes essential that all available data be collected and analyzed to predict a recycled asphalt pavement's performance. Material requirements, specifications, and design standards then can be established to insure that the desired service life is obtained. Without a sound base for predicting the pavement's performance, design alternatives cannot be compared. FHWA is developing a comprehensive, cross reference data bank system for recycled bituminous concrete pavements.

Once the data bank system is online and operational, it will be capable of continuously updating stored data, revising data categories in the system, and adding new construction projects to the system. The data to be collected can be separated into the five following groups:

- Project descriptive data (location, size, responsible agency).
- Salvaged material data (kind of material, structural section, cost).
- Design and construction data (design method, laydown operation, equipment).
- Recycled mixture properties data (resilient modulus, fatigue behavior, creep behavior).
- Postconstruction data (performance measurements, visual evaluations, maintenance).

The primary source of data will come from responses by highway agencies to a comprehensive questionnaire; the responses will determine the success and ultimate usefulness of the data bank system. Depending upon the extent of the data provided, the data bank system can be used at least as an inventory system to determine such things as the number of recycling projects in a given State, the number of States that use hot, cold, and surface recycling techniques, the average in-place cost per kilogram (ton) for hot, cold, and surface recycling in a given year, the percentage of recycling projects more than 4 years old, and the most frequently listed reason for rehabilitation using recycling.

However, to make the greatest use of the data bank system an attempt is being made to collect enough data so that performance-related questions can be answered. For example:

1. How many pavements contain a certain recycling agent and what has been their performance?

2. Does the performance of a given recycling agent correlate strongly with any other parameters such as thickness, placement temperature, or asphalt properties?

3. Do certain asphalt cements and recycling agents appear to be incompatible?

4. Does construction equipment, aggregate quality, quality of aged asphalt, or kind of recycling agent affect performance?

5. Is there an optimum amount of salvaged material that should be used to achieve satisfactory performance at a minimum cost?

Currently, the computer software system is being developed, and questionnaires are being completed by various highway agencies. It is anticipated that data from over 250 recycling projects constructed before 1980 will be used to demonstrate the use of the data bank system for inventory and cross referencing.

The Effect of the Recycling Agent

Routine laboratory tests, such as extractions and recoveries, on the salvaged bituminous pavement materials demonstrate that aggregate gradation and asphalt content vary, as do the properties of the recovered bituminous binder. Generally, new aggregates are added to the salvaged material to satisfy gradation requirements, and a recycling agent (or high penetration asphalt cement) is added to restore the properties of the recovered binder to those of current asphalt cements. Typically, the added recycling agent produces a consistency level (viscosity) in the recovered binder that is appropriate for construction and for the intended use of the mixture. During the construction phase in hot-mix recycling, for example, it is sometimes assumed that sufficient mixing occurs in the pugmill and that a uniformly mixed, homogeneous pavement mixture is produced. This is shown schematically in figure 1.

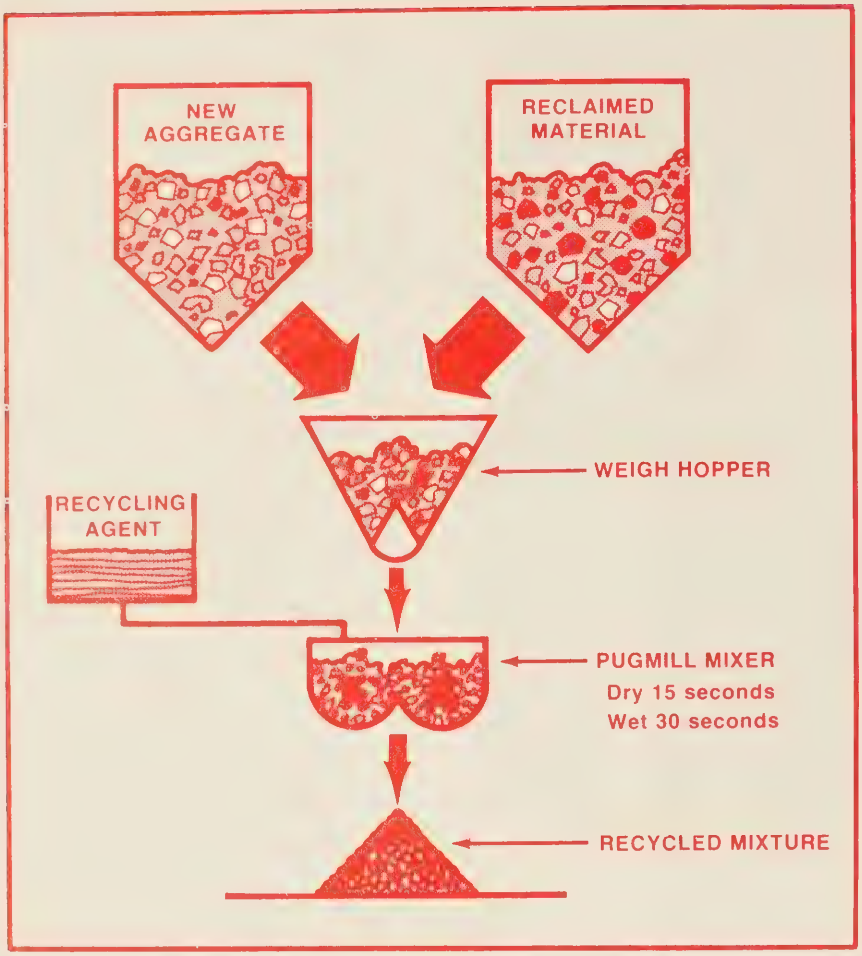


Figure 1.—Hot-mix recycling asphalt pavement.

It is difficult to imagine how a small amount of recycling agent (approximately 2 percent), when combined with the salvaged materials and mixed for a few seconds, can have intimate contact with all surfaces of the old binder.

Efficiency of mixing recycled asphalt pavements

To investigate this problem further, FHWA is developing a test technique to establish quantitatively the ability of the mixing operation in the field to produce an intimate mixture of the reclaimed bituminous materials, recycling agent, new aggregates, and asphalt cement. To insure that the test would have practical value to construction personnel, it was necessary to develop a moderate-cost field technique capable of reproducing quick test results under field conditions. Specifically, the cost of the instrument was not to exceed $10,000; the time to perform measurements and provide results was not to exceed 12 hours; the equipment was to be air transportable weighing 2 to 23 kg (5 to 50 lb); the training for State highway and transportation department technicians would require only 3 to 4 days; and the test would be performed on a standard 102 mm (4 in) diameter field core or laboratory-compacted specimen.

Several "classical" and "nonclassical" highway engineering materials tests were identified and considered as potential mixing efficiency test techniques. Of the classical tests, penetration, viscosity, smoke point, flash point, fire point, volatility, and extraction/recovery were considered as binder tests. However, because extraction/recovery procedures were believed to mask the true dispersion of the recycling agent in the salvaged binder, any test technique requiring an initial extraction/recovery was considered unacceptable. Thus, most of the classical engineering tests identified were not evaluated.

The resilient modulus test, a possible technique applicable to the aggregate-binder mixture, does not require an initial extraction/recovery test and was evaluated using laboratory-prepared specimens. Basically, resilient modulus, M_R, values were found to be less in the laboratory-prepared specimens than in control specimens at nearly all times of testing (elapsed time in days), indicating that the addition of a recycling agent retards hardening. Increasing amounts of the recycling agent decreased the M_R value, as expected. Unfortunately, because of large variations and inconsistent behavior of the data and because the test is performed over a period of up to 40 days, the resilient modulus test was considered unacceptable as an *immediate* indicator of mixing efficiency. Although further laboratory evaluations are necessary, the data suggest that M_R may have potential as a quality control test to *estimate* the amount of recycling agent in a given mixture.

In the area of nonclassical highway engineering material tests, potential techniques considered included light, electron, or scanning microscope; phosphorescence; fluorescence; polarized lights; and ultraviolet/infrared detection and dye chemistry. Among this list, dye chemistry was considered to be the most promising technique.

To evaluate and refine this technique, the effect of dye print materials, dye concentrations (percent weight of recycling agent), applied pressure, and reaction time were investigated.

After evaluating several print materials, including paper and various blends of fabrics, the kind of print material was found to affect significantly the evaluation of the dispersion. At this time, a poplin fabric (35 percent cotton and 65 percent polyester) appears to produce the best results. Among the several dyes evaluated, beta napthol appears to give the best dye prints, with optimum dye concentrations at about 10 percent of the recycling agent (by weight). Optimum applied pressures are about 14 kPa (2 psi) and reaction times are about 2 hours.

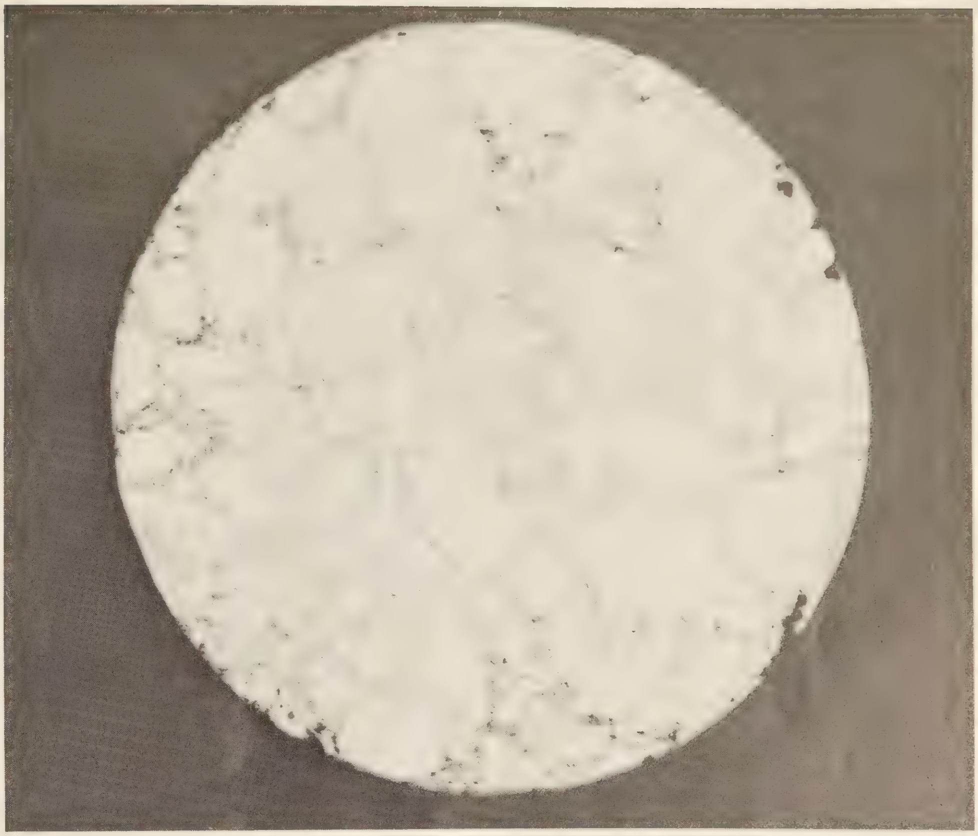


Figure 2.—Dye print showing excellent dispersion of recycling agent.

To use this dye chemistry technique, the dye is added to and thoroughly mixed with the recycling agent (or high penetration asphalt cement). Then, this blend is mixed with the other components of the recycled mixture (salvaged aggregates, asphalt cement, aggregates) using normal recycling construction procedures and techniques. To evaluate the mixing efficiency of the construction operation, samples of the final mixture may be taken from the compacted pavement as a core, or loose material may be sampled either at the plant or before laydown and then made into laboratory compacted specimens. The field core or laboratory specimen is sliced to expose a clean face from which two prints are made.

The dye print, a print of the dye and recycling agent to show the dispersion of the recycling agent, is made by placing the cut face of the specimen on the poplin fabric previously saturated with diazotized aniline. The reaction between the dye and the diazotized aniline produces a red-orange outline wherever the dye (and therefore the recycling agent) is located. The other print, a binder print, is made to show where the binder (old and new asphalt cement, recycling agent, and dye) is located. Instead of the red-orange outline of a dye print, the binder print has a gray, charcoal-colored outline around the aggregate particles. This is done by simply stamping, much like a rubber stamp, the same cut face against another piece of poplin fabric that has been treated with cyclohexane. These two prints then can be visually inspected to determine how well the recycling agent has been mixed into the recycled mixture. Figures 2 and 3 are examples of two dye prints. The uniformity of the shaded area indicates how well the dye, and

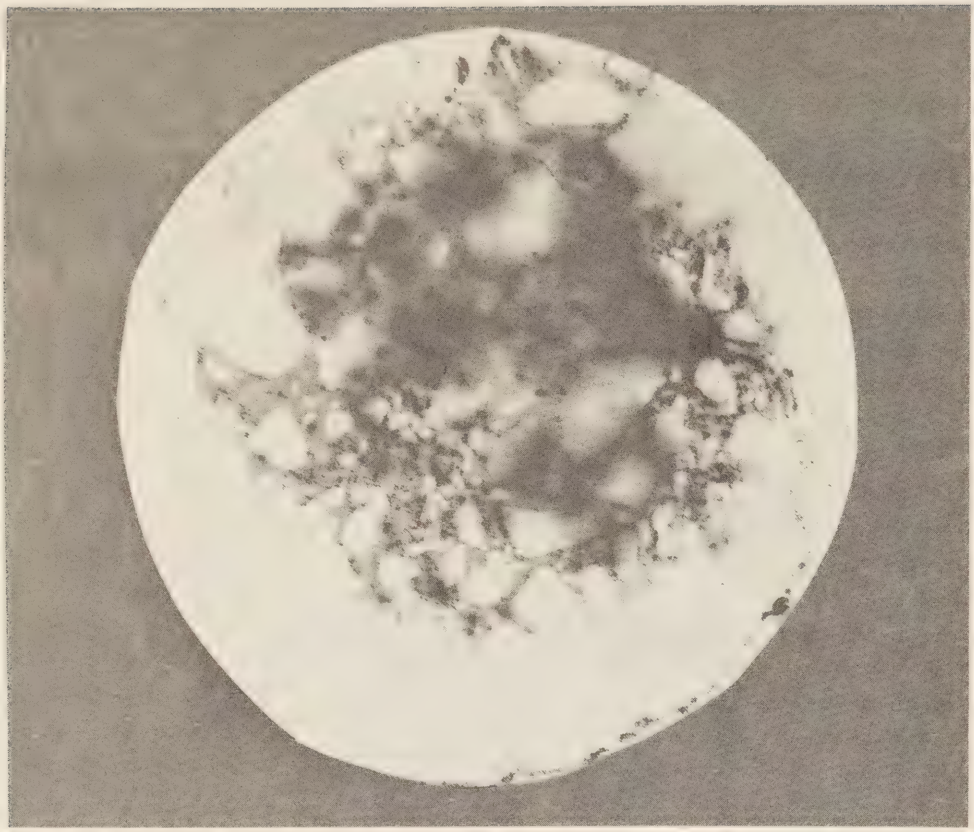


Figure 3.—Dye print showing poor dispersion of recycling agent.

hence the recycling agent, is dispersed in the mixture. Thus, figure 2 shows excellent dispersion and figure 3 shows relatively poor dispersion. In samples where the dispersion is apparently poor, a comparison with the binder print is necessary to estimate the extent of the dispersion. The binder print has uniformly shaded areas like figure 2, but the shaded areas are gray in actual binder prints. In samples with excellent dispersion, comparison with a binder print is not as essential.

To quantify the evaluation, a densitometer has been used to scan both prints to establish the relative location of the binder and aggregate in the final mixture. The optical density of the prints has been analyzed using computer programs to compute summary statistics and provide digital plots of the dye print scans.

Other chemical dyes are being evaluated to find one that produces longer lasting prints. In addition, the test is now being field evaluated on actual construction projects.

Rejuvenating agents for recycled bituminous binders

Another study of recycling agents has evaluated the physical and *chemical* composition of various salvaged bituminous binders in attempts to determine the necessary properties and composition of suitable rejuvenators for pavement recycling. To accomplish this, field samples were obtained from pavements to be recycled, the physical and chemical properties of the recovered binder were determined, the recovered binder was treated with various recycling agents to produce a reconstituted binder having predetermined characteristics and properties, and finally, laboratory mixtures were prepared using mixing techniques to simulate both hot and cold field techniques. The Rostler method for chemical separation was used in the study to establish the chemical composition of asphalts and recycling agents primarily because of the availability of more historical data using this classification system.

Researchers have analyzed the relationships of the chemical compatibility between recycling agents, salvaged binders, and new binders, as well as their relationship to the physical properties of the recycled mixture. Results suggest that recycling agents can restore aged asphalt to desired consistency levels and can be used to produce recycled mixtures with acceptable properties. It was shown that mixture properties can be adjusted by controlling the amount of recycling agent added and are further dependent on the method and temperature of sample preparation. Blending of the recycling agent with the aged asphalt is time- and temperature-dependent. It was concluded that a substantial portion of the softening agent because of the recycling agent is accomplished after the mixture has been mixed, hauled, placed, and compacted.

Materials Characterization of Recycled Bituminous Paving Mixtures

For years, recycling has been promoted on its potential for material, energy, and cost savings.

Recycling commonly is shown to be a cost-competitive alternative to other rehabilitation techniques. The generally used mixture design techniques and construction practices are based on the premise that if recycled mixtures can meet existing design criteria for conventional asphalt pavements, then their structural design coefficients and durability properties also should be the same. However, the advantages and savings of recycling can be lost quickly if the recycled pavements do not reach the level of performance expected. Therefore, a research study was developed as a result of FHWA's concern about the durability and long term performance of recycled asphalt pavement mixtures. The intent of this research is to design and build recycled asphalt pavements, evaluate the material properties before and immediately after recycling and 1 year after construction. The predicted performance of the recycled mixture based on pavement performance models like VESYS will be compared with postconstruction data as a measure of the actual pavement performance.

Flexible Pavement Mixture Design Using a Reclaimed Asphalt Concrete

In this new research study a statistically sound sampling plan will be developed to define the properties of the materials to be used in a recycled pavement mixture and to establish the extent these properties vary. Conceivably, large variation in material properties could affect significantly the mixture design and ultimately the pavement's performance. Adjustments may be required in the construction techniques or in the amount of material that is recycled, which in turn, could have direct impact on production rates and costs. The researchers also will determine the key properties in a salvaged binder that are required for effective restoration when various recycling agents or high penetration asphalt cements are used and will establish testing techniques and procedures that have practical application in a central materials testing laboratory. A stripping test is to be developed that will be nondestructive and will simulate traffic and environmental conditions. Using these three basic elements—a sampling plan, key properties for effective rejuvenation, and a stripping test—the final task will be to establish mix design criteria.

Energy, Economic, Environmental, and Material Conservation of Asphalt Pavement Recycling

In this study, currently used energy equivalency factors to assess the energy requirements of various recycling and conventional asphalt pavement construction operations published in various reports will be field verified, and where necessary, new ones will be developed. In addition, the environmental and material conservation aspects of recycling will be determined to establish the impact recycling really has on the use of new aggregates. The environmental and material conservation aspects will be compared with the alternative normally used to dispose of deteriorated pavement materials such as landfill, shoulder material, base course, and parking lots. Finally, a cost evaluation will be made of various recycling techniques versus conventional rehabilitation methods. Staffing, material, and equipment costs will be identified for each unit of operation as the basic units in the evaluation. It is anticipated that a step-by-step outline to assess the energy, economic, environmental, and material conservation aspects of recycling will be developed for the practicing engineer.

Research by the National Cooperative Highway Research Program (NCHRP)

Under the NCHRP, States voluntarily pool a small percentage of Federal-aid planning and research funds to finance research activities structured to respond quickly to the needs of State highway and transportation departments. Because FHWA is responsible for the funds used in the NCHRP, it reviews contractor selection and research content. In addition, if the proposed research is expected to contribute to the research objectives of the U.S. Federal Government, the study is incorporated into FHWA's own research program.

A recently completed report provides guidelines on recycling pavement materials for the reconstruction and rehabilitation of existing pavements. (*1*)[2] Although the guidelines have been developed

[2] Italic number in parentheses identifies reference on page 18.

for recycling both asphalt and portland cement concrete pavements, they are more complete for asphalt concrete recycling because the state of the art is more advanced in this area. The guidelines for planning, designing, and constructing recycled pavements are believed suitable for immediate implementation. They are based on extensive field experience and contain procedures for selecting from among recycling alternatives, construction and energy information, material requirements, and model specifications.

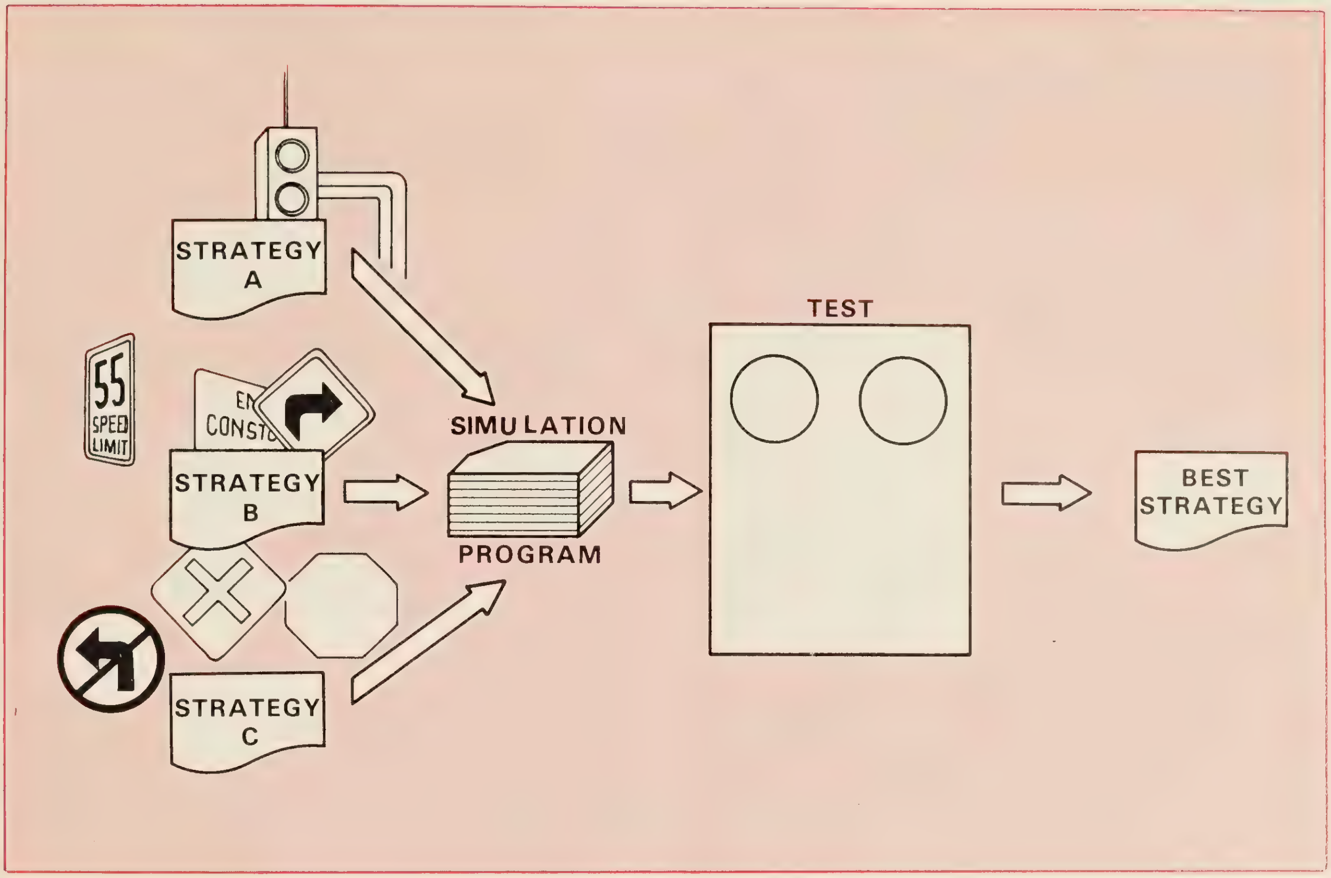
Other Research by Highway Agencies and Universities

Several highway agencies and universities are engaged in research similar to FHWA studies in recycling pavement materials. The Connecticut Department of Transportation is investigating both asphalt and portland cement concrete recycling to develop mix design criteria, energy and cost data, and structural designs. Performance data are being generated from laboratory testing by the University of Illinois to determine whether recycling mixtures will perform satisfactorily for a sufficient time period so that the initial construction costs saved will not be offset by excessive maintenance costs. Purdue University in Lafayette, Ind., is investigating the properties of in-place, cold-mixed recycled pavements. In addition, it is exploring the potential usefulness of foamed asphalt as a stabilizing material and investigating its durability aspects (wetting/drying and freeze/thaw phenomena). The Louisiana Department of Transportation and Development is attempting to determine if there are consistent relationships between the physical properties (viscosity, penetration, ductility) of aged asphalts (using thin film oven test) and the quantity of recycling agents used to restore them to their original properties. Ohio State and the University of Texas are each designing and characterizing recycled pavement mixtures in their respective States. Characterization testing includes tensile strength, modulus of elasticity, fatigue, permanent deformation, creep, and an evaluation of the effects of seasonal variation.

REFERENCE

(1) J. A. Epps, D. N. Little, and R. J. Holmgreen, "Guidelines for Recycling Pavement Materials," National Cooperative Highway Research Program Report No. 224, *Transportation Research Board,* Washington, D.C., September 1980.

Gene K. Fong is a highway research engineer in the Paving and Structural Materials Group, Materials Division, Office of Research, FHWA. Mr. Fong is the project manager for FCP Project 6C, "Use of Waste as Material for Highways." Prior to his present position, he served as an area engineer in FHWA's Michigan Division Office, as a highway engineer in the Office of Highway Planning, and as a highway engineer in FHWA's Region 5 Office of Construction and Materials.



A New System for Traffic Simulation

by
Guido Radelat and George Tiller

In 1973 the Utah Department of Transportation (formerly the Utah State Department of Highways), prompted by numerous citizen complaints, attempted to eliminate a serious traffic congestion problem at the interchange of Interstate 15 and 4500 South Street in Salt Lake County where morning and evening peak hour queues often extended into the Interstate. (*1*)[1] Two solutions were proposed: Installing a new signal phasing plan along 4500 South Street at a cost of $50,000 for new control hardware or simply adjusting the signal controllers to cut cycle length in half at little cost.

Testing the solutions in the field was risky. If congestion were aggravated instead of improved, the failure could produce unpleasant public reaction. The Utah Department of Transportation decided to try a new traffic simulation technique developed by the Federal Highway Administration (FHWA). In a cooperative effort between the Utah Department of Transportation and the University of Utah, both solutions were simulated on a computer. The results indicated that halving the cycle length would decrease congestion significantly.

The change in cycle length was made in the field, and delays to the traffic exiting from the Interstate were reduced effectively, as predicted by the simulation. The computer model used was NETSIM, then known as UTCS–1, and this was one of the first practical applications of traffic simulation by a State highway department. This article discusses early developments in traffic simulation techniques, their relationship with developments in the computer field, and a new traffic simulation system called TRAF.

[1] Italic numbers in parentheses identify references on page 26.

Development of Traffic Simulation Techniques

Since the beginning of traffic engineering, one of the most demanding problems has been predicting, in quantitative terms, the effects of various traffic control strategies on real traffic. This problem has not been easy to solve because traffic is a complex phenomenon difficult to characterize numerically. Mathematical models that adequately described highly idealized and simplified conditions were developed. However, these early models could not portray real-world traffic accurately.

Attention soon turned to discrete event simulation, a promising technique that uses logic and analytical and empirical relationships to analyze the behavior of complex traffic systems. The main shortcoming of this simulation technique was the overwhelming number of computations required to represent the many interrelated events that take place in traffic. Therefore, traffic could not be simulated in a practical manner until the digital computer with its unprecedented computational speed was developed. Shortly after the introduction of early computers in the mid-1950's, traffic simulation models, in the form of elaborate computer programs, began to be created to represent single intersections, short sections of freeways, urban arterials, and even urban networks. Developments in the traffic simulation field and their relationships with developments in the computer field are shown in table 1.

Soon, however, the computations required by the simulation techniques began to challenge the capability of the available computers. One approach for portraying traffic was to simulate each individual vehicle by a set of variables (for example, vehicle type, position, speed, acceleration) that described the vehicle state at a certain time. This set of variables was recalculated at fixed or variable time intervals, considering the effect of traffic controls and vehicle interactions. Models that used this approach were called *microscopic*. Other models represented traffic in overall parameters, such as traffic volume, average speed, and density, or handled the vehicles in groups. These models were called *macroscopic*.

Regardless of the approach used, a model that did not accurately replicate reality was of no practical use. Because of limited modeling experience and inadequate computer capability, most of the early simulations lacked realism. Because microscopic models used fewer simplifying assumptions than their macroscopic counterparts, microscopic models generally were more realistic. On the other hand, microscopic programs required larger computer resources impossible to obtain in those days unless the simulated scenarios were small.

More Detailed Simulation With Advanced Computers

Third generation computers of the late 1960's offered increased storage and faster computation. These computers could simulate urban networks at a microscopic level of detail, but it was not easy to determine the degree of realism or validity of a traffic simulation model. Model predictions had to be validated using equivalent field data. However, collecting pertinent and reliable field data was difficult, and when discrepancies were found between the data and model predictions, it was not known whether the flaw was in the model or data. Despite these validation problems, demand for traffic simulation models grew rapidly in response to the increasing cost of field experimentation and evaluation.

In 1968 FHWA initiated the Urban Traffic Control System (UTCS) project to develop and test advanced traffic signal control strategies. Considerable time and money could be saved if the new strategies were computer

Table 1.—Developments in traffic simulation and their relationships with developments in the computer field

Development in the computer field	Problem	Development in traffic simulation
Availability of first and second generation computers	Inability to pretest traffic control strategies	Simulation of a single intersection
Third generation computers	Lack of realism in simulations	Macroscopic urban network simulation Microscopic simulation UTCS–1 (NETSIM) INTRAS
Advances in computer hardware: • Increased speed and capacity • Decreased unit costs	Inability to pretest traffic management strategies Diversity of approaches and models Poor quality programing Inadequate documentation	TRAFLO
Advances in computer software: • Structured programing • Structured design	Need for more maintenance and support	TRAF

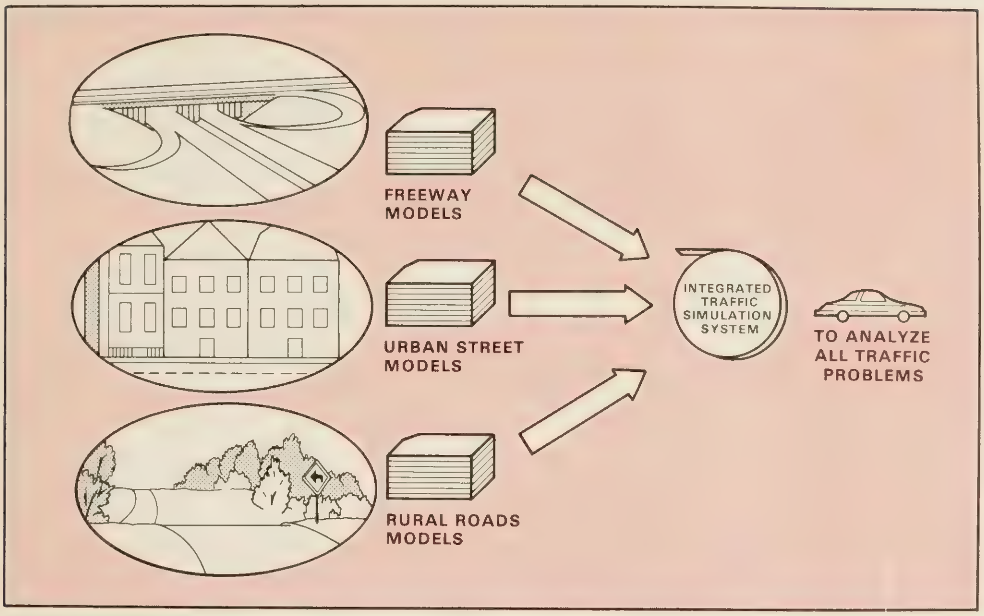


Figure 1.—A feasible integrated traffic simulation system that combines the logic of different kinds of models and is able to analyze all traffic problems.

tested before field evaluation. The UTCS–1 model was developed to perform such computer tests.

UTCS–1, now called NETSIM, is a microscopic model that simulates traffic on urban networks. (*2*) To validate the new model properly, its predictions were compared with a reliable data base collected mainly from time-lapse aerial photographs of a 20-intersection network in Washington, D.C. To cover the entire network with one frame, 70 mm film was used.

Traffic Management Concept

During the mid-1970's, the traditional concept of traffic control was giving way to the broader philosophy of traffic management. In traffic management the goal was not to move vehicles but to optimize the use of urban resources for improving the movement of people and goods without impairing other community values.

The more ambitious traffic management strategies involved larger areas than those affected by traffic control techniques. Because computer resources available in 1976 limited the use of microscopic models to relatively small networks, attention returned to macroscopic traffic simulation techniques. FHWA then developed a macroscopic urban network traffic simulation model (NETFLO) and adapted an existing macroscopic freeway simulation model (FREFLO). These were combined and named TRAFLO.[2]

[2] "Macroscopic Simulation for Urban Traffic Management, Volume 1, Executive Summary, Development of TRAFLO," Report No. FHWA/RD–80/113, *Federal Highway Administration,* Washington, D.C. Not yet published.

While NETSIM and TRAFLO slowly were evolving into practical tools, other simulation models were being developed throughout the United States using different approaches, computer languages, terminology, and documentation. Most early simulation programs were obscure and poorly organized and documented because their developers were concerned primarily with reliable modeling of traffic flow. Little attention was paid to programing style and documentation. However, as soon as the simulation models attained enough reliability to attract users, the need for quality programing and documentation became apparent.

Genesis of a Traffic Simulation System

Although diversity in the early stages of traffic simulation fostered creativity, it later created inefficiency and confusion. Finally, in 1974 the concept of a well-documented, integrated traffic simulation system was beginning to take shape.

In 1975, FHWA's Office of Research investigated the feasibility of creating an integrated traffic simulation system and establishing guidelines for its development. The system was to be able to represent traffic flow on any existing highway facility. It was concluded that such a system was feasible (fig. 1), but the investigation also revealed advances that were taking place in the computer field.

Data Processing Advances and New Areas of Emphasis

For many years advances in microelectronics reduced dramatically the hardware-associated costs of data processing. In contrast, the cost of human time, and thus the cost of producing software to run on the newer and faster computers, increased steadily. The result was that the human time necessary to develop, debug, document, and maintain a program, in addition to the time to learn how to use it, install it on an available computer, code the input data, and analyze the results, was many times more costly than the total computer resources necessary to run the program during its lifetime. Thus, emphasis in software development shifted from computational efficiency to human efficiency.

The human efficiency problem sparked the development and promotion of a highly disciplined coding technique called structured programing. At first controversial, structured programing now is widely accepted because it has improved programer productivity by simplifying the coding process. The philosophy of structured programing was applied first to the system design process, then to systems analysis, and later to many other areas such as system implementation and testing.

The FHWA study also revealed that the problems with simulation programs were widely shared by those who developed or used other kinds of computer software and that the structured techniques directly addressed many of the simulation programing problems. The difficulty of understanding and making changes to a simulation program could be alleviated by using smaller, simpler, and more independent program subroutines. Better structuring of coding logic could make the program easier to follow. Documentation could be improved by limiting the use of flow charts to appropriate situations and by introducing the more functional "HIPO" (hierarchy plus input-process-output) charts. These and other goals, such as reliability and machine independence, together with suggested techniques for achieving the goals, were incorporated then into the objectives and technical guidelines for the integrated traffic simulation system.

Probably the most important revelation of the FHWA study was that computer software maintenance and technical support to users consume more resources than any other activity in the life cycle of a computer program. Maintenance costs are estimated at 40 to 90 percent of the total cost of a system. Experiences with most large computer programs that are never fully "debugged" support these conclusions.

The planned integrated traffic simulation system was envisioned to facilitate maintenance and support operations in two ways: With only one simulation system to maintain and support, these operations could be centralized, and these operations could be automated largely by developing a separate computer program (called an operating system) that would aid in making changes and managing model capabilities.

An FHWA contract study in 1976 developed functional specifications for a new traffic simulation system named TRAF. The TRAF operating system was developed in the first phase of this study. (*3*) The TRAF system is coming to life during the second phase that was initiated in 1979 and is expected to be completed by 1982.

	Microscopic	Macroscopic
URBAN NETWORKS	NETSIM	NETFLO
FREEWAYS	FRESIM	FREFLO
TWO-LANE ROADS	ROADSIM	—

Figure 2.—Component models being integrated into TRAF.

Characteristics and Features of the TRAF Simulation System

TRAF is not an integrated model, but rather an integrated simulation system. Traffic on urban networks, freeways, and two-lane rural roads can be simulated at different levels of detail. Program subroutines containing the best available simulation logic are stored in a master file. Once the needs of a particular application are specified, the appropriate subroutines are selected from the master file and the TRAF operating system generates a simulation program tailored to these needs. Thus, the user is not overwhelmed with unnecessary features.

The following procedure has been established to integrate the best available traffic simulation logic into TRAF:

1. The candidate models to be integrated are reviewed, their basic functions identified, and the functional modules (or subroutines) defined and described.

2. The modules that performed the same or equivalent functions are combined into a single module that performs the common function.

3. The modules resulting from the two previous steps are arranged in logical structure according to the anticipated functions of TRAF.

The traffic simulation logic that is being integrated into TRAF is contained in the component models shown in figure 2. The names of the component models denote their place of application and level of detail. The prefixes NET, FRE, and ROAD indicate urban networks, freeways, and two-lane rural roads, respectively. The suffix SIM means microscopic, and FLO macroscopic. It is believed that this logic represents the best traffic simulation techniques available and will satisfy most traffic simulation needs.

A diagram of the TRAF operating system is shown in figure 3. The operating system is a computer program consisting of the following major components:

- A master file where the subroutines of the component models are stored.
- A file maintenance program that automatically modifies the content of the master file.
- A program generator that reads the features specified by the user, selects the subroutines that provide these features, and produces an application program that satisfies user specifications.
- A report generator that produces various informative computer printouts.

Improved Software Quality

The program structure and coding style of most of the TRAF component models was characterized by inadequate design, large complex subroutines that often performed many unrelated functions, and dense, convoluted, and poorly annotated code. Correcting errors and enhancing the component models have been difficult. The redesign and recoding for TRAF has both eliminated these deficiencies and standardized coding

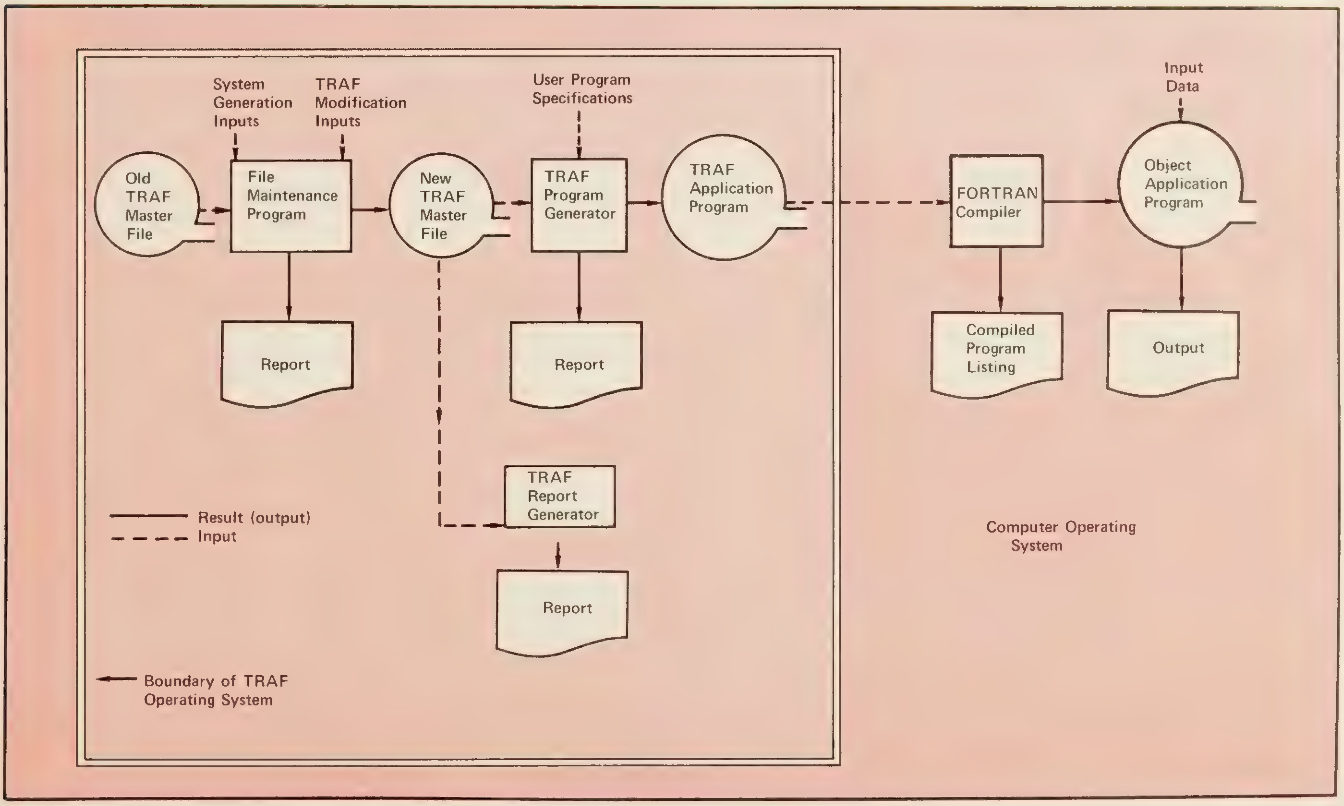


Figure 3.—TRAF operating system components.

Old Style

```
  118 NENT=0
      N=0
C     READ LINK GEOMETRY CARDS
      II=4
      I=9
      GO TO 200
  107 IFORM=8
      IOP=1
      ILENH=28
  119 CALL DRWS(AA)
C     TRA IF NOT A LINK GEOMETRY CARD
      IF(IAA(28).NE.4)GO TO 125
C     ELIMINATE -0 FROM OUTPUT
      J=1
10200 DO 120 I=1,ILENH
  120 IF(IAA(I).EQ.0)IAA(I)=0
      GO TO (10201,10202,10203),J
C     LOOP OVER EACH OF 3 LINK FIELDS
10201 DO 124 K=1,3
      I=IAA2(1,K)
      J=IAA2(2,K)
C     TRA IF FIELD EMPTY
      IF(I.EQ.0)GO TO 124
      IF(J.GT.0.AND.J.LT.800)GO TO 121
  122 WRITE(6,1017)I,J
10121 IERCT=IERCT+1
      GO TO 124
C     VALID NODES, ENTER LINK IN ARRAYS
  121 N=N+1
      IF(N.LE.NMAX)GO TO 10123
      WRITE(6,1019)I,J
      GO TO 10124
C     PRIME SIGI ARRAY
10123 DO 10120 L=1,5
      IF(SIGI(J,L).NE.0)GO TO 10119
      SIGI(J,L)=N
      GO TO 10122
10119 LL=SIGI(J,L)
      IF(ENDNDS(LL,1).NE.I)GO TO 10120
      WRITE(6,1074)I,J,IAA(28)
      N=N-1
      GO TO 10121
10120 CONTINUE
      WRITE(6,1018)I,J
10124 N=N-1
      GO TO 10121
10122 IF(I.GE.800)NENT=NENT+1
10125 ENDNDS(N,1)=I
      ENDNDS(N,2)=J
      LINK(N,2)=IAA2(3,K)
      SUMS(N)=IAA2(4,K)/10
      IAA2(4,K)=IAA2(4,K)-10*SUMS(N)
      IF(SUMS(N).LE.0)SUMS(N)=2
      SUMS(N)=SUMS(N)*100000000
      LINK(N,25)=10000*IAA2(4,K)
      LINK(N,7)=100*IAA2(5,K)
      DO 123 L=6,9
  123 LINK(N,L+6)=IAA2(L,K)*1000
  124 CONTINUE
      GO TO 119
  125 IF(N.GT.0.AND.NENT.GT.0)GO TO 10127
      WRITE(6,1021)N,NENT
      IERCT=IERCT+1
C     BACKSPACE TO REREAD UNDER CORRECT FORMAT
10127 IOP=4
      CALL DRWS(AA)
C     REMAINDER OF CARD INPUT FORMATS MAY BE FOR ANY SUBINTERVAL
C     READ LINK OPERATION CARDS FOR NONFREEWAY LINKS
  130 II=5
      I=8
      GO TO 200
  129 IFORM=9
      IOP=1
      ILENH=40
      CALL DRWS(AA)
C     TRA IF NOT A LINK OPERATION CARD
      IF(IAA(40).NE.5)GO TO 150
C     ELLIMINATE -0
      J=2
      GO TO 10200
C     LOOP OVER EACH OF 3 LINK FIELDS
10202 DO 148 K=1,3
      I=IAA3(1,K)
      J=IAA3(2,K)
      IF(I.EQ.0.AND.J.EQ.0)GO TO 148
```

New Style

```
      SUBROUTINE RDFN11
C
C
C --- CODED    3-22-78 BY B. ANDREWS
C --- REVISED 8-10-79 BY M. MASSUCCI (FOR NETSIM)
C
C --- TITLE - READ, CHECK TYPE 11 CARDS - MODULE 2261.2.2
C
C --- FUNCTION - THIS MODULE CONTROLS THE PROCESSING OF CARD TYPE 11
C
C --- ARGUMENTS - NONE
C
C -------------------------   DESCRIPTION   ---------------------------
C                             -----------
C
C     THIS MODULE DIRECTS THE CARD READING, CHECKING AND STORING OF
C     CARD TYPE 11 DATA
C
C -------------------   THIS ROUTINE CALLED BY   ----------------------
C                       ---------------------
C
C                       LINKFN - MODULE 2261.2
C
C ---------------------   THIS ROUTINE CALLS   ------------------------
C                         -----------------
C
C                       RDNUM  - MODULE 2222.1.1.1
C                       CKFN11 - MODULE 2261.2.2.1
C                       STFN11 - MODULE 2261.2.2.2
C
C ----------------   GLOSSARY OF VARIABLE NAMES   ---------------------
C                    -------------------------
C
C     XBUF    BUFFER ARRAY USED TO STORE CARD CONTENTS
C     YPRINT  PRINT FLAG (.T. IF TABLES OF INPUT DATA NOT PRINTED YET)
C
C ---------------------------------------------------------------------
C
      IMPLICIT INTEGER (A-Q, S-V, X), REAL (R, Z), LOGICAL (W, Y)
C
      COMMON /PRM001/ XBUF(1)
      COMMON /GLR092/ YPRINT
C
      IF (YPRINT) WRITE (6, 1000)
C
C -----  PROCESS CARDS UNTIL A CARD TYPE OTHER THAN A TYPE 11 IS FOUND
C
   10 CONTINUE
      CALL RDNUM
      IF (XBUF(20) .NE. 11)                                     GO TO 20
      CALL CKFN11
      CALL STFN11
                                                                GO TO 10
   20 CONTINUE
C
C -----  OUTPUT EXPLANATION OF CODES
C
      IF (YPRINT) WRITE (6, 1002)
      IF (YPRINT) WRITE (6, 1001)
      RETURN
 1000 FORMAT (1H1, 60X, 12HNETSIM LINKS, ///
     1        86X, 5HSTART, /
     2        19X, 16HPOCKET L A N E S, 4X, 4HTYPE, 36X,
     3        16HOPPOS-  UP     Q, 2X, 4HFREE, 11X, 4HLANE, /
     4        19X, 15HLENGTH FULL PKT, 5X, 16HOF     LANE CHAN,
     5         5X, 41HDESTINATION NODES   ING   LOST   DIS FLOW,
     6         1X, 8HRTOR PED, 2X, 8HALIGN-  , 6HSTREET, /
     7         5X, 37HLINK   SPAN   L    R      L R GRD INT,
     8         2X, 40H1 2 3 4 5 6 7  LEFT THRU RGHT DIAG  NODE,
     9         2X, 25HTIME   HDY SPD  CODE CODE, 1X, 4HMENT,
     1         4X, 4HNAME)
 1001 FORMAT (//// 27X, 19HLANE CHANNELIZATION, 22X, 4HRTOR,
     1              25X, 10HPEDESTRIAN, /
     2              34X, 5HCODES, 28X, 5HCODES, 28X, 5HCODES, //
     3              26X, 15H0  UNRESTRICTED, 18X, 17H0  RTOR PERMITTED,
     4              17X, 17H0  NO PEDESTRIANS, /
     5              26X, 18H1  LEFT TURNS ONLY, 15X,
     6              18H1  RTOR PROHIBITED, 16X, 8H1  LIGHT, /
     7              26X, 13H2  BUSES ONLY, 54X, 11H2  MODERATE, /
     8              26X,  9H3  CLOSED, 58X, 8H3  HEAVY, /
     9              26X, 19H4  RIGHT TURNS ONLY, /
     1              26X, 14H5  CAR - POOLS, /
     2              26X, 22H6  CAR - POOLS + BUSES)
 1002 FORMAT (///45X, 41H* INDICATES DEFAULT VALUES WERE SPECIFIED)
      END
```

Figure 4.—Code style samples.

among the component models to permit useful and efficient automatic code editing. The new code is completely modular (subroutines are short and perform only one function), heavily annotated for readability, formated to make the logic as clear as possible, and carefully planned for minimum branching. Examples of the old and the new codes are shown in figure 4.

Instead of the practically useless detailed flowcharts used to document most of the component models, TRAF uses a modified system of HIPO charts that consists of a set of structure charts showing the *hierarchy* of the program subroutines and their relationships and *input-process-output* charts. The logical processes are described in a highly structured English called pseudocode and are shown separately. Figures 5 and 6 are examples of these charts.

Perhaps most important is the *arrangement* of information in program documentation. In documenting TRAF, a top-down pyramid structure was used, placing the more detailed information in separate volumes for use as references, with the more general descriptions in the front to orient the reader.

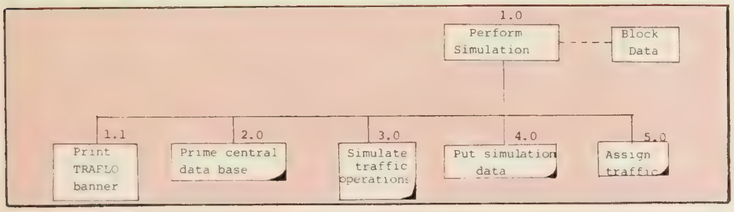


Figure 5.—Example of structure chart, with boxes representing modules of the computer program. Module boxes with their lower right-hand corner shaded have subordinate modules not shown.

Increased Maintenance and User Support

In recent years, FHWA has emphasized computer program maintenance and user assistance. In some cases, a maintenance phase has been added to a software development contract. In others, a separate procurement has been initiated specifically for maintenance and user support services. Also, FHWA's Office of Traffic Operations is establishing a unit to see that traffic-related computer programs are maintained and supported.

Benefits and Future Use of TRAF

The TRAF system will be a single source of traffic simulation programs. Because the potential user is concerned with only one set of documentation and one

INPUT-OUTPUT

Author: E. Lieberman Module: 5.0 Name: TRFASS Date: 3/21/79 Page 1

Title/Description: ASSIGN TRAFFIC/This module is the executive routine which directs processing of the traffic assignment program and subsequent conversion of volume to turn percentages

Input	Output
1. INTMAP array from module 5.2 containing the interface mapping	1. INTMAP to module 5.3
2. IPATH array from module 5.2 containing the path network link volumes	2. IPATH to module 5.3
3. Counters JENTRY, JEXIT, JSSNDS, JNTRNL from module 5.2 containing the number of entry and exit links, source/sink nodes and internal links, respectively, on the geometric network	3. Counters JENTRY, JEXIT, JSSNDS, JNTRNL to module 5.3

PSEUDO-CODE FORM

Author: E. Lieberman Module: 5.0 Name: TRFASS Date: 3/21/79 Page 1

Title/Description: ASSIGN TRAFFIC/This module is the executive routine which directs processing of the traffic assignment program and subsequent conversion of four volume to turn percentages

```
CALL module 5.5 to clean arrays for this overlay
Rewind peripheral units 17 and 19
CALL module 5.2 to retrieve the Interface Mapping Array and the Path Link File
Set JTOTL = JCNTRD + JNTRNL
Set JPTHLK = PTHLNK
CALL module 5.1 to perform traffic assignment (TRAFIC)
Rewind peripheral Unit 21
Set IL = 0
DOUNTIL all records read into IBUF(I), I=1,7
     Increment path link counter, IL = IL + 1
     Store assigned path link volume into PATHVL array (PATHVL(IL) = IBUF(7))
ENDO
CALL module 5.3 to convert volumes on the path network links into turn percentages on the
     geometric network links
CALL module 5.4 to store turn percentages into the subnetwork specific arrays
```

Figure 6.—Input-process-output chart for module 5.0. The input-output portion is separated from the pseudocode, which defines the model logic.

set of input and output formats, the learning process will be simplified. With only one simulation system to maintain and support, these operations can be centralized. The associated operating system will reduce considerably the work involved in performing such functions.

It is anticipated that the immediate application of TRAF will be in traffic research, primarily for testing new traffic control strategies before field experimentation. After controlled application at the research and development level, the new simulation system may be disseminated among the operational traffic engineers for pretesting traffic control strategies and tactics before operational deployment.

Conclusions

Because traffic simulation models are an outgrowth of the digital computer, developments in simulation have paralleled developments in the computer field. But simulation models constitute more than their computer programs because they are manageable representations of real-life systems, and improvements to this representation are always possible.

Therefore, traffic simulation programs are not static, but change continuously during their life cycle for the following reasons:

- Correction of flaws.
- Expansion of applications.
- Innovations in traffic control and traffic management techniques and equipment.
- New developments in the computer field.
- Changes in their underlying models to improve simulation realism.

Traffic simulation models are becoming more realistic and easier to use while their users are becoming more qualified. Traffic simulation model benefits to the traffic community and eventually to the general public become increasingly important. The availability of the TRAF simulation system should promote the use of traffic simulation techniques and extend the benefits derived from them.

The development period of traffic simulation models is ending. Promising simulation models already have been developed to address most traffic problems. Future emphasis will be on enhancing, further validating, extending, refining, and maintaining and supporting existing models and establishing guidelines for model use.

REFERENCES[3]

(1) W. J. Kennedy, Ralph M. Farr, and William D. Labrum, "Implementing Computer Simulation of Traffic Signal Systems," *Traffic Engineering*, vol. 45, No. 7, July 1975, pp. 44–50.

(2) Richard D. Worrall, "Network Flow Simulation for Urban Traffic Control System, Phase II, Volume 5," Report No. FHWA-RD-73-87, *Federal Highway Administration*, Washington, D.C., March 1974. PB No. 230764.

(3) E. Lieberman, "Integrated Traffic Simulation Model—Phase I, Volume 1: Executive Summary," Report No. FHWA/RD-80/086, *Federal Highway Administration*, Washington, D.C., September 1980.

[3]Report with PB number is available from the National Technical Information Service, 5285 Port Royal Rd., Springfield, Va. 22161.

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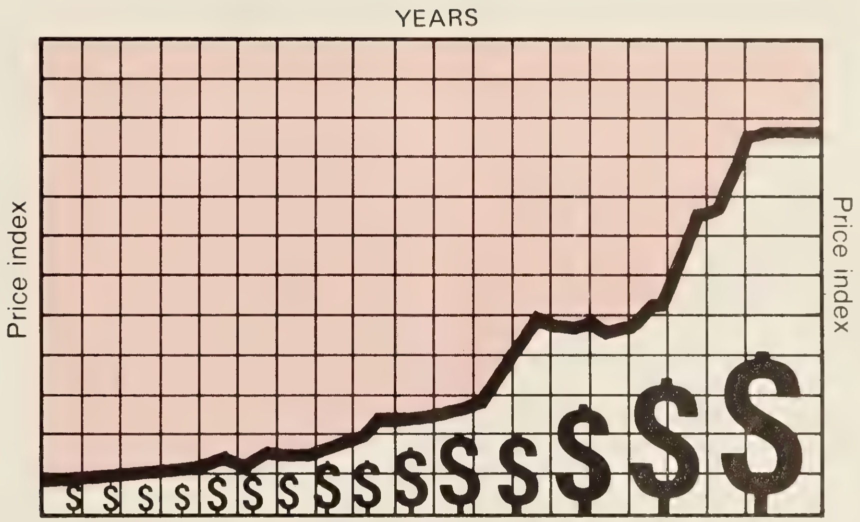
George Tiller is a systems analyst in the Engineering Services Division, Office of Development, Federal Highway Administration. For the past 8 years, he has been involved in traffic simulation research, working with enhancements and support for the NETSIM (then UTCS-1) program. Mr. Tiller also has worked on computer applications in the areas of pavements, bridges, vehicle barriers, traffic control, and soils. He recently has been involved with software engineering and standards, computer program maintenance and support, and office automation.

1977 Becomes the New Base Year for FHWA's Bid Price Index

by
Frank Mirack



The Federal Highway Administration (FHWA) recently changed the base year for the highway construction Bid Price Index to 1977 (1977=100) in accordance with the adoption of 1977 as the latest reference period for all Federal index numbers. The reference period for Federal index numbers is updated approximately every 10 years to insure that the Index is based on a reasonable approximation of the current structure of the industry and to facilitate the visual comprehension of the rates of change in the Index.

This is the fourth base for the Bid Price Index since it was first published in 1933. Discussions of previous bases can be found in *Public Roads* magazines, vol. 14, No. 5, July 1933; vol. 31, No. 10, October 1961; and vol. 36, No. 4, October 1970.

Planning for future highway construction requires an estimate of the amount of highway improvements that can be purchased at current prices by any given appropriation. Because this can be judged best by monitoring the recent price trends in construction items, the Bid Price Index was established to give highway planners a measure of the purchasing power of the Federal-aid construction dollar. The Index shows, on a relative scale, what it would cost at any given time for the quantity of Federal-aid highway construction contracted for during the base period. This is approximated by measuring the changes in bid prices of six indicator items (the same six as in 1967)—common excavation, portland cement concrete (PCC) surfaces, bituminous concrete surfaces, structural reinforcing steel, structural steel, and structural concrete. These six indicator items are the major work items in highway construction, and price changes in each of these items are typical of price changes occurring in similar categories of work. Bid price data for the Index are obtained from the awards of contracts greater than $500,000[1] for Federal-aid highway projects (other than on the secondary system).

[1] Before May 1977, contracts less than $500,000 also were used, however, a 1977 in-house study showed that these small contracts could be eliminated with a negligible effect on the Bid Price Index.

Table 1.—Comparison of 1967 and 1977 bases

Item	1967 Base Quantity	1967 Base Unit price	1967 Base Cost	1977 Base Quantity	1977 Base Unit price	1977 Base Cost	Percentage change Quantity	Percentage change Unit price	Percentage change Cost
	thousands		*thousands*	*thousands*		*thousands*			
Common excavation (yd³)	1,656,655	$ 0.541	$ 896,250	282,964	$ 1.164	$ 329,370	−82.9	+115.2	−63.3
Surfacing									
Portland cement concrete (yd²)	79,942	4.428	353,983	17,997	9.953	179,126	−77.5	+124.8	−49.4
Bituminous concrete (ton)	51,230	6.466	331,254	24,709	15.471	382,280	−51.8	+139.3	+15.4
Total			685,237			561,406			−18.1
Structures									
Reinforcing steel (lb)	981,587	0.131	128,392	415,428	0.272	112,997	−57.7	+108.0	−12.0
Structural steel (lb)	885,235	0.247	218,387	448,019	0.520	232,970	−49.4	+110.8	+ 6.7
Structural concrete (yd³)	5,572	70.300	391,682	2,321	143.508	333,047	−58.3	+104.1	−15.0
Total			738,461			679,014			− 8.1
Total highway			2,319,948			1,569,790			−32.3

1 yd³=0.7646 m³
1 yd²=0.8361 m²
1 ton=907 kg
1 lb=0.4536 kg

Table 2.—Comparison of indicator items

Item	1925–1929 quantities at 1925–1929 prices	1957–1959 quantities at 1957–1959 prices	1967 quantities at 1967 prices	1967 quantities at 1977 prices	1977 quantities at 1977 prices
	percent	*percent*	*percent*	*percent*	*percent*
Common excavation	36	34	39	38	21
Surfacing					
Portland cement concrete	48	15	15	16	12
Bituminous concrete	—	16	14	16	24
Total	48	31	29	32	36
Structures					
Reinforcing steel	5	6	6	5	7
Structural steel	2	11	9	9	15
Structural concrete	9	18	17	16	21
Total	16	35	32	30	43
Total highway	100	100	100	100	100

Individual indices are computed for each of the indicator items. Additionally, the two "surfacing" indicator items are combined into an overall surfacing index and the three "structures" indicator items are combined into an overall structures index. The Bid Price Index is a composite of all six indicator items based on their relative weights.

The quarterly publication *Price Trends for Federal-Aid Highway Construction*[2] also includes indices for the urban and rural components of the Bid Price Index and a three-quarter moving index showing the weighted Bid Price Index for the three most recent quarters (using the middle quarter as the reference quarter). These indices have as their base the same quantities and prices used as the base for the composite Bid Price Index.

[2] Copies are available free of charge from the Office of Engineering, Federal-Aid Division, Federal Highway Administration, Washington, D.C. 20590.

Rebasing of the Index involves both updating to the new base year the unit prices to which future prices will be compared and modifying the relative weights of the indicator items to reflect a more recent "market basket" of goods. Weighting of the various indicator items is necessary so that unparallel price movements in the indicator items are reflected in corresponding changes in the Index. A large increase in the price of structural concrete, for example, should have more of an effect on the composite Index than a similar increase in the price of structural reinforcing steel because structural concrete has a larger share of the construction dollar. Table 1 compares the 1967 base with the 1977 base. For the new base, the unit prices are average prices for 1977, and the quantities are an average of quantities of the indicator items for 1976, 1977, and 1978.

Reasons for the noticeable decrease in quantities and the shift in the relative percentages (table 2) include: A doubling of prices during the 1967–1977 period without a matching increase in construction spending; actual shifts toward relatively greater uses of structural steel and bituminous concrete compared with the other indicator items; a decrease in the share of the total construction cost represented by the major excavation, surfacing, and structural items; and a change in methodology in computing the base quantities.

Previous bases were developed by assigning weights to the "indicator" items consistent with the dollar amount spent on the categories of work each item represented. For instance, the weight assigned to the common excavation indicator item also represented the cost for drainage pipe, other categories of excavation, and clay/gravel bases converted to an equivalent quantity of common excavation. Since May 1977, however, bid price data are

Figure 1.—Price trends for Federal-aid highway construction (1977=100).

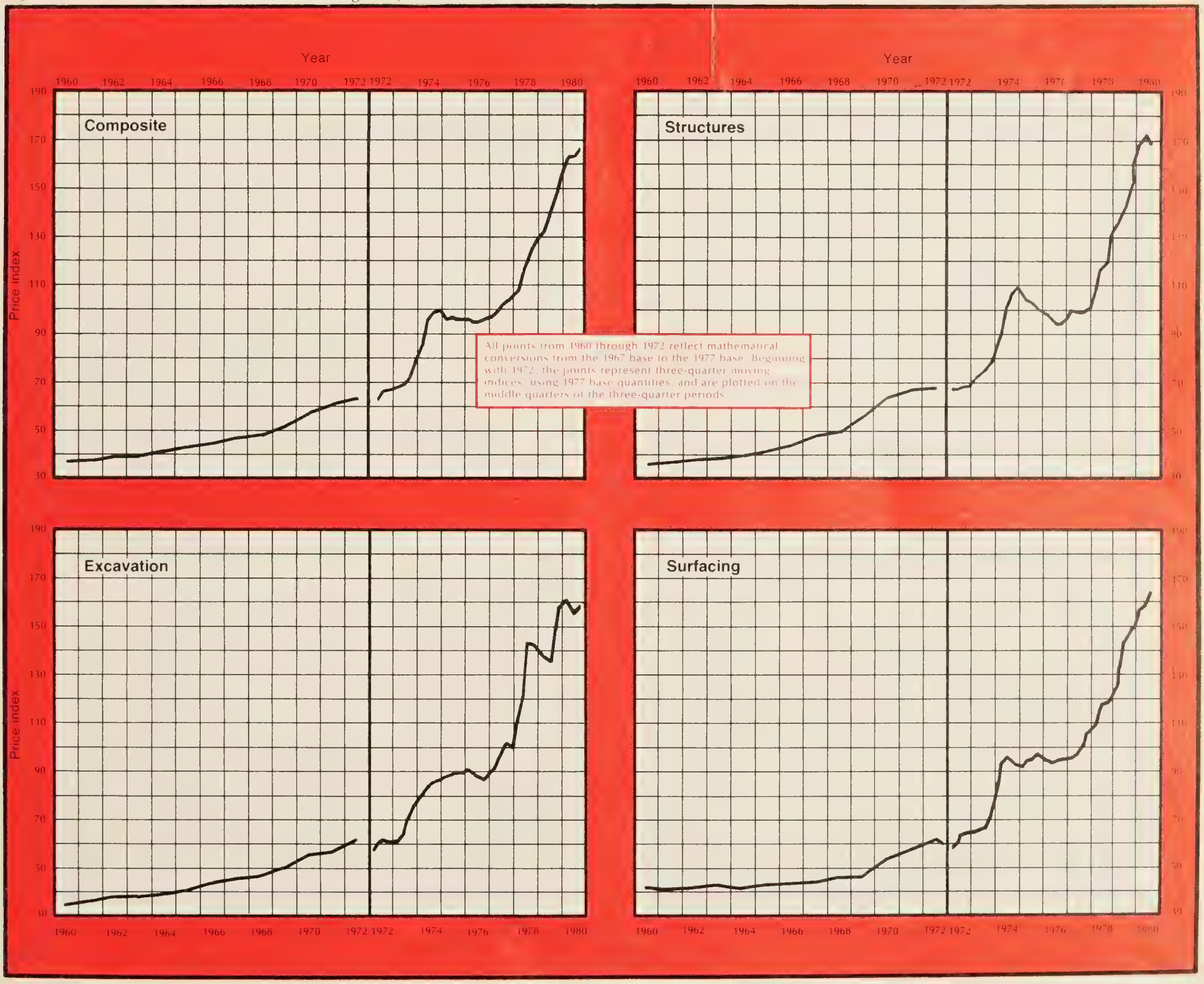


Table 3.--Price trends for Federal-aid highway construction--1977 base

Year	Common excavation		Surfacing					Structures							Composite index
			Portland cement concrete		Bituminous concrete		Surfacing index	Reinforcing steel		Structural steel		Structural concrete		Structures index	
	Average contract price	Index	Average contract price	Index	Average contract price	Index		Average contract price	Index	Average contract price	Index	Average contract price	Index		
	cubic yard		square yard		ton			pound		pound		cubic yard			
1962	0.45	38.4	4.17	43.2	6.32	40.9	42.0	.113	41.4	0.167	32.1	53.88	37.5	36.6	39.0
1963	0.45	38.4	4.24	43.9	6.48	41.9	42.9	.114	41.9	0.182	35.0	57.31	39.9	38.8	39.9
1964	0.46	39.4	4.16	43.1	6.26	40.5	41.7	.112	41.2	0.193	37.1	57.71	40.2	39.4	40.2
1965	0.47	40.6	4.34	44.9	6.50	42.0	43.4	.124	45.4	0.200	38.5	59.63	41.6	41.3	41.7
1966	0.52	44.8	4.50	46.6	6.44	41.6	44.1	.127	46.8	0.224	43.0	63.22	44.1	44.2	44.4
1967	0.54	46.5	4.43	45.8	6.47	41.8	43.8	.131	48.1	0.247	47.4	70.30	49.0	48.4	46.2
1968	0.56	47.7	4.79	49.5	6.77	43.8	46.6	.131	48.3	0.249	47.8	71.81	50.0	49.1	47.8
1969	0.59	50.4	4.87	50.5	7.01	45.3	47.9	.143	52.7	0.316	60.8	81.34	56.7	57.2	51.7
1970	0.66	56.6	5.42	56.1	8.04	51.9	54.0	.163	60.1	0.338	65.0	92.73	64.6	63.9	58.0
1971	0.67	57.6	6.06	62.7	8.54	55.2	58.9	.177	65.1	0.348	67.0	97.02	67.6	67.0	60.8
1972	0.72	62.0	6.25	64.7	9.23	59.7	62.1	.181	66.5	0.342	65.7	100.17	69.8	68.0	63.9
1972	0.72	62.0	6.42	64.5	9.23	59.7	61.2	.181	66.5	0.342	65.7	100.17	69.8	67.9	64.2
1973	0.80	68.4	7.00	70.3	10.02	64.8	66.5	.207	75.9	0.372	71.6	111.81	77.9	75.4	70.8
1974	1.00	85.6	8.88	89.2	14.74	95.3	93.3	.339	124.7	0.551	106.0	136.80	95.3	103.9	96.3
1975	1.03	88.6	8.88	89.2	15.13	97.8	95.1	.297	109.0	0.554	106.5	138.76	96.7	102.1	96.7
1976	1.03	88.7	8.92	89.6	14.83	95.9	93.6	.258	94.7	0.484	93.0	139.59	97.3	95.4	93.4
1977	1.16	100.0	9.95	100.0	15.47	100.0	100.0	.272	100.0	0.520	100.0	143.51	100.0	100.0	100.0
1978															
First quarter	1.13	97.1	10.06	101.1	16.10	104.1	103.1	.283	103.9	0.563	108.3	151.43	105.5	106.2	103.2
Second quarter	1.43	122.6	12.42	124.7	17.54	113.3	117.0	.310	114.0	0.573	110.2	171.78	119.7	115.5	117.5
Third quarter	1.84	157.9	12.30	123.6	17.11	110.6	114.7	.346	127.2	0.638	122.7	193.97	135.2	129.5	130.2
Fourth quarter	1.89	162.8	13.72	137.8	18.09	116.9	123.6	.334	122.7	0.681	130.9	176.17	122.8	125.6	132.7
Annual	1.54	131.9	11.90	119.6	17.16	110.9	113.7	.316	116.1	0.603	116.0	172.41	120.1	118.0	119.4
1979															
First quarter	1.46	125.4	12.12	121.8	18.38	118.8	119.7	.381	140.0	0.737	141.7	195.52	136.2	138.7	129.1
Second quarter	1.54	132.3	13.45	135.2	20.72	133.9	134.3	.411	151.0	0.749	144.0	202.82	141.3	143.8	138.0
Third quarter	1.81	155.7	15.42	155.0	22.08	142.7	146.6	.429	157.8	0.755	145.2	215.41	150.1	149.7	149.8
Fourth quarter	1.86	159.7	17.73	178.2	23.67	153.0	161.0	.489	179.8	0.804	154.7	240.14	167.3	165.1	162.5
Annual	1.62	138.8	14.02	140.9	21.21	137.1	138.3	.421	154.7	0.759	146.0	211.33	147.3	148.1	142.6
1980															
First quarter	1.84	158.0	12.64	126.9	23.89	154.4	145.6	.472	173.7	0.894	171.8	234.32	163.3	168.0	157.9
Second quarter	1.89	162.7	16.63	167.1	25.81	166.9	166.9	.515	189.4	1.063	204.5	206.12	143.6	172.1	168.3
Third quarter	1.71	147.3	16.23	163.1	26.28	169.8	167.7	.475	174.5	0.792	152.2	250.66	174.7	166.9	163.1
Fourth quarter	1.89	162.4	14.77	148.4	25.36	163.9	159.0	.467	171.8	0.834	160.3	234.63	163.5	163.8	161.8
Annual	1.83	157.2	14.92	149.9	25.29	163.5	159.1	.483	177.5	0.941	180.9	226.68	158.0	169.1	163.0

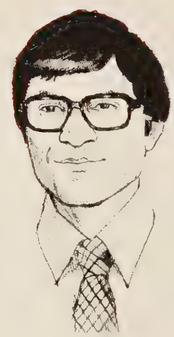
1 yd^3=0.7646 m^3
1 yd^2=0.8361 m^2
1 ton=907 kg
1 lb=0.4536 kg

received only for the six indicator items and not for 15 other items (such as drainage pipe) previously reported. Correspondingly, weights for the 1977 base represent the six indicator items alone. Had the 15 other miscellaneous items been included, it is estimated the weights for the major components would have been excavation, 32 percent; surfaces, 38 percent; and structures, 30 percent.

The base year calculations were modified so that the price shown for PCC surfacing is now based on a standard 229 mm (9 in) thickness rather than on the actual average thickness for the base year as had been the practice. Because the 1967 base thickness was less than 229 mm (9 in), the 124.8 percent increase shown in the price of PCC pavement between 1967 and 1977 would have been only 118.1 percent had the effects of the increase in the base thickness been eliminated.

Closing Notes: The Bid Price Index differs from many other indices in that it is an "output" measure of the costs that contractors will charge Federal and State governments to do work rather than an "input" measure of current material costs to the contractor. It is based on bid prices inplace and measures not only material costs to the contractor but also labor costs, equipment costs, overhead, and profit. And although the bid prices are quoted at the beginning of the contract, they represent anticipated average costs over the life of the contract. Additionally, the Index measures not only inflation but also changes in design/construction standards over time that affect the quality and characteristics of the finished product. Finally, at the national level the Index is affected by the shift in geographical distribution of Federal-aid projects and the change in project types. The Index considers all of these influences as it indicates the purchasing power of the highway construction dollar.

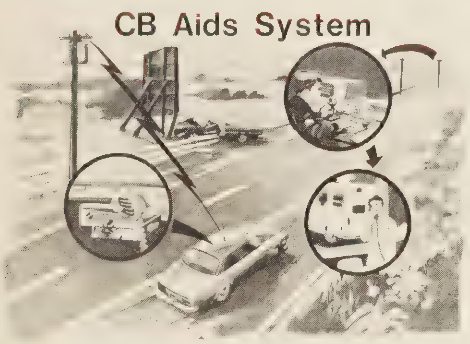
Price trends are shown in table 3 and represented graphically in figure 1.



Frank Mirack is a highway engineer in the Federal-Aid Division, Office of Engineering, Federal Highway Administration. After serving in various FHWA field offices for the last 5 years, Mr. Mirack is now responsible for the cost analysis section of the Interstate Management Branch.

Recent Research Reports You Should Know About

The following are brief descriptions of selected reports recently published by the Office of Research, Federal Highway Administration, which includes the Structures and Applied Mechanics Division, Materials Division, Traffic Systems Division, and Environmental Division. The reports are available from the address noted at the end of each description.



Motorist Aid Citizens Radio Service as a Wide Area Communication System, Report No. FHWA/RD–80/151

by FHWA Traffic Systems Division

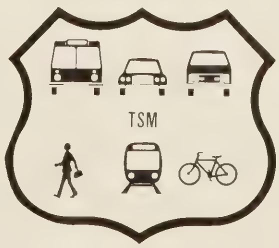
This report discusses the results of the development of the motorist aid system Citizen's Band Automatic Interconnect Digital System (CB-AIDS). The system allows a CB radio user to have channel 9 emergency calls automatically connected to a monitoring agency through a switched telephone network. The system uses a digital adapter in conjunction with a CB radio to establish an automatic telephone patch from unattended remote repeaters to the monitoring agency. The system was tested and evaluated in DeKalb County, Ga.

The report is available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22161 (Stock No. PB 81 177628).

Measures of Effectiveness for Multimodal Urban Traffic Management, Volume 2—Development and Evaluation of TSM Strategies, Report No. FHWA–RD–79–113

by FHWA Traffic Systems Division

This report is the second of three reports documenting a three-phase study that developed measures of effectiveness for traffic systems management (TSM) strategies. This volume is a stand-alone guide for practicing engineers and planners who develop and evaluate urban TSM plans. It provides a framework for TSM strategy development, recommends measures of effectiveness for TSM strategy evaluation, and identifies and demonstrates manual and computer techniques for TSM analysis. Volumes 1 and 3, not yet published, will be a more detailed research report of methodologies and results and an executive summary.



Limited copies of the report are available from the Traffic Systems Division, HRS–31, Federal Highway Administration, Washington, D.C. 20590.

Rail-Highway Crossing Hazard Prediction Research Results, Report No. FRA–RRS–80–002, Rail-Highway Crossing Warning Device Life Cycle Cost Analysis, Report No. FRA–RRS–80–003, and The Effectiveness of Flashing Lights and Flashing Lights With Gates in Reducing Accident Frequency at Public Rail-Highway Crossings, Report No. FRA–RRS–80–005

by FHWA Traffic Systems Division and Federal Railroad Administration (FRA) Office of Safety

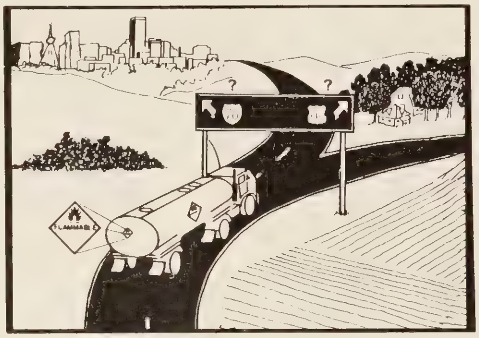
A resource allocation model to help identify crossings for improvement has been developed and is intended for use by States and railroad crossing program managers to help select crossings for further investigation. The model needs three inputs: a crossing site-specific accident prediction, the costs of the warning devices, and the effectiveness of the warning devices.

The accident prediction techniques outlined in Report No. FRA–RRS–80–002 are based on the nationwide crossing inventory data and the FRA crossing accident data. These techniques have successfully identified dangerous crossings and have been used by many States and railroads. The techniques will be refined to incorporate accident history information, which will help to account for factors, such as sight restrictions, not in the crossing inventory data base.

Life cycle costs for rail-highway crossing equipment were provided by various railroads, States, and railway associations. These costs included pre-engineering, labor, material, equipment rental, and maintenance. Variations in costs resulting from number of tracks, crossing location, and kind of train detection system are analyzed and documented in Report No. FRA–RRS–80–003.

New effectiveness values for rail-highway crossing active devices were developed using nationwide accident and inventory data for the years 1975–1978. The effectiveness is defined as the percentage of accident reduction at crossings that results from the installation of active warning devices. Confidence intervals for the effectiveness values were calculated and are documented in Report No. FRA–RRS–80–005.

Limited copies of the reports are available from the Traffic Systems Division, HRS–32, Federal Highway Administration, Washington, D.C. 20590.



Development of Criteria to Designate Routes for Transporting Hazardous Materials, Report No. FHWA/RD–80/105

by FHWA Traffic Systems Division

Recently, public awareness of hazardous materials transportation has increased. Hazardous materials include explosives, radioactive materials, liquefied petroleum gas, liquefied natural gas, poisons, etiologic agents, and liquid and solid flammables. Growing concern about the human and environmental consequences of unintentional releases of these materials has led to greater government and private interest in this problem.

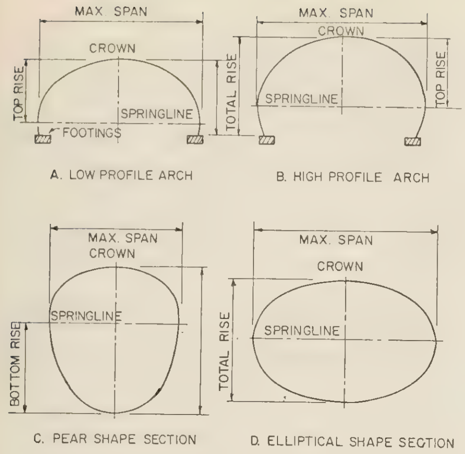
A procedure for designating routes for transporting hazardous materials was developed and pilot tested in three cities. The procedure is based primarily on accident risk. The proximity of fire services and location of sensitive population centers, such as schools and hospitals, are the final determinants in designing a transportation route for hazardous materials.

Limited copies of the report are available from the Traffic Systems Division, HRS–33, Federal Highway Administration, Washington, D.C. 20590.

Structural Evaluation of New Concepts for Long-Span Culverts and Culvert Installations, Report No. FHWA–RD–79–115

by FHWA Structures and Applied Mechanics Division

This report describes analyses of the structural performance of corrugated metal culverts for roadway span lengths of 5 to 15 m (15 to 50 ft) and of smaller reinforced concrete and corrugated metal circular pipe culverts with nominal diameters of 2 m (6 ft). Safer and more economical new structural design concepts for culverts are evaluated for both dead load and live load behavior. Guidelines for the structural analyses of long-span culverts include available experimental results, such as displacements, thrusts, soil pressures, and time effects, which are presented in graphs illustrating key structural trends and behavioral characteristics. A finite element soil-structure model of a typical long-span culvert system is used to assess the effects of changes in fundamental system parameters using the Federal Highway Administration Culvert Analysis and Design (CANDE) computer program. Incremental construction loads, temporary compaction loads, and traffic loads are analyzed for both symmetric and nonsymmetric applications. Nonlinear effects of geometry, culvert materials, soil materials, and soil-structure interface slippage were studied to determine their relative importance.



Because long-span corrugated metal culverts consist of flexible cross section shapes (arches, ellipses, and inverted pears), the proper placement of soil backfill around the culvert is critical during construction. Proper placement of soil backfill minimizes structural distress and distortion of the metal culvert that could lead to loss of stability of the entire long-span system. The analytical study covers modifications to the backfill (incorporation of reinforced earth, selective soil stabilization, and soft inclusions above the crown of the culvert to promote positive soil arching) and modifications to the metal culvert (slotted joint connections and increased bending stiffness). Results suggest that horizontal rows of reinforced earth layers placed along the sides of the culvert between the footing and crown may be the most cost-effective technique to limit structural deformations and enhance structural capacity. Controlled joint slippage may be a cost-effective method for reducing thrust stress in the culvert wall.

In addition, the relative merits of old and new concepts for installing smaller circular pipe culverts under high fills are analytically evaluated in this report. Parameters and concepts that were investigated include bedding configurations, imperfect trench designs and new concepts of selective placement of stabilized soil or soft backpacking, V-notch trenching beneath the pipe, and encapsulated fluid jackets for concrete pipe.

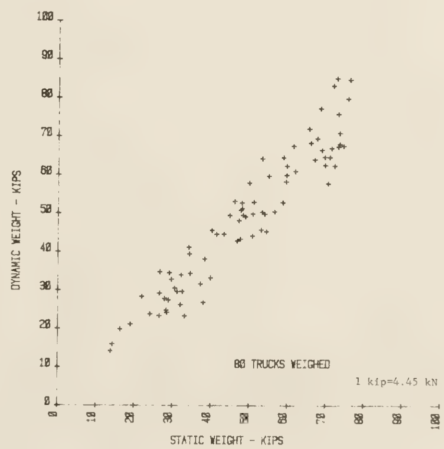
The report is available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22161 (Stock No. PB 80 138027).

Weigh-In-Motion Instrumentation, Report No. FHWA-RD-78-81

by FHWA Structures and Applied Mechanics Division

Accurate information on the number and magnitude of vehicle gross and axle loads being carried by various U.S. highway systems is essential for estimating future design, construction, and maintenance requirements for bridges and pavements. This report describes a highway vehicle weigh-in-motion (WIM) instrumentation system that obtains the gross and axle weights of a vehicle moving at normal traffic speed across a bridge. Weights are derived from measurements of the vehicle-induced live load strains in the load-carrying members of the bridge. Bridges suitable for WIM system installation are available on most highways.

The WIM system consists of strain gage transducers mounted on each of the main load-carrying bridge members at a load-sensitive cross section, a control minicomputer located in an instrument van that is generally parked beneath the bridge, and accessory equipment housed in the van, such as strain gage signal conditioning and amplification circuitry, a digital magnetic tape recorder, and a teletypewriter. Traffic sensors installed on the pavement approach to the instrumented bridge measure vehicle velocity and axle spacing, necessary inputs to the weight calculation computer program.



The WIM sequence begins when an operator with a view of the highway approach to the bridge presses an "axle number" selector switch on a handheld control box to signal the WIM system to respond to the number of axles of an oncoming vehicle. The front wheels of the vehicle crossing the final roadway traffic sensor adjacent to the bridge initiate strain gage data collection. Live load strains are measured continuously by the WIM system until the vehicle has left the instrumented span. The measured live load strains from each bridge member are summed at equal time increments to provide the total bending strain. The computerized weight-prediction algorithm correlates the measured strain with the theoretical bending moment influence line ordinate for the corresponding vehicle position on the span. In field validation tests with various heavy vehicles of known weight crossing an instrumented bridge span, the gross weights and axle weights calculated from live load strains corresponded closely to scale weights. More than one cross section may be gaged and the results averaged for greater accuracy.

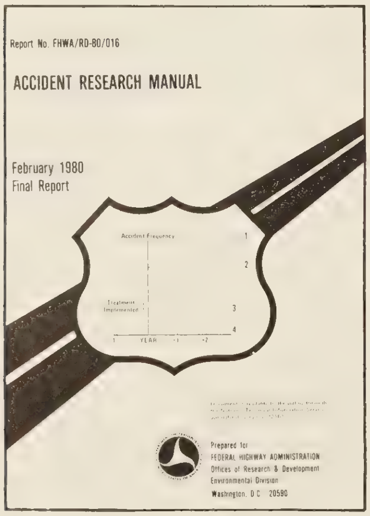
In the prototype WIM system described in this report, the magnetic tape records of field data were processed on a laboratory digital computer to convert the measured live load strains to vehicle weights. It is possible to obtain the vehicle weights in real time in the field with certain system modifications as outlined in this report.

The report is available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22161 (Stock No. PB 80 126972).

Accident Research Manual, Report No. FHWA/RD–80/016

by FHWA Environmental Division

This manual presents several research techniques that can improve the quality and reporting of highway accident research performed within limited budgets. The manual addresses research aimed at evaluating accident countermeasures and identifying and examining underlying relationships between accidents and other highway factors. The manual is designed for use in classroom training, as a reference text, and as a self-study program and is intended primarily for the engineer/analyst who has some background in statistical analysis.



The manual does not emphasize the simple before/after experimental method, which is used inappropriately in many highway-related accident research studies. Rather, it emphasizes eight alternate, more valid, research methods (such as before/after with control groups, before/after with comparison groups, and interrupted time series) that could increase the reliability and usability of the research results. The manual also discusses real-world limitations in the data routinely used in accident analysis and the importance of the researcher in the design and interpretation of research results.

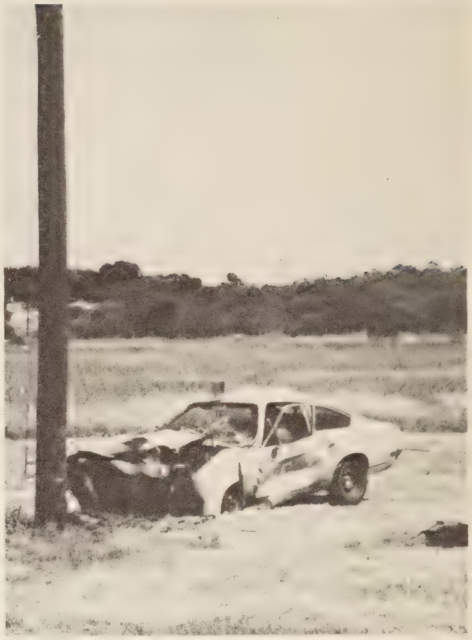
The manual is available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22161 (Stock No. PB 81 155152).

Accident Analysis—Breakaway and Nonbreakaway Poles Including Sign and Light Standards Along Highways, Volume I (Report No. DOT–HS–805–604), Volume II (Report No. DOT–HS–805–605), and Volume III (Report No. DOT–HS–805–606)

by FHWA Environmental Division and National Highway Traffic Safety Administration

These reports provide detailed information on the characteristics of pole accidents and evaluate current accident countermeasures, such as breakaway devices.

Reported pole accidents accounted for 3.3 percent of all accidents reported in the study areas but constituted 20.6 percent of all fatal accidents and 9.9 percent of all injury accidents. Utility poles were the most frequently struck pole type, accounting for 67.1 percent of all pole accidents, followed by sign supports (16 percent), luminaires (14.4 percent), and traffic signal supports (2.4 percent). Smaller and lighter cars are more likely to have higher resultant injury frequency and severity than larger and heavier cars.



The effectiveness of a breakaway modification lies in its ability to limit and reduce the velocity and momentum change regardless of impact speed—thus, the resultant injury frequency and severity. However, breakaway modification for small signs does not appear to be effective in further reducing the already low severity of nonbreakaway small sign supports. The cost effectiveness of a breakaway modification varies with individual sites depending on the expected accident frequency, the impact speed frequency distribution, and the accident cost estimates.

Volume I, **Executive Summary,** gives the conclusions and recommendations of the study. Volume II, **Technical Report,** is the detailed analyses of the study. Volume III presents all **Appendixes.**

Limited copies of each volume are available from the Environmental Division, HRS–43, Federal Highway Administration, Washington, D.C. 20590.

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

The following are brief descriptions of selected items that have been recently completed by State and Federal highway units in cooperation with the Implementation Division, Office of Development, Federal Highway Administration (FHWA). Some items by others are included when they have a special interest to highway agencies.

U.S. Department of Transportation
Federal Highway Administration
Office of Development
Implementation Division (HDV–20)
Washington, D.C. 20590

Items available from the Implementation Division can be obtained by including a self-addressed mailing label with the request.

Motorists Information Services, Report No. FHWA–TS–80–201

by FHWA Implementation Division

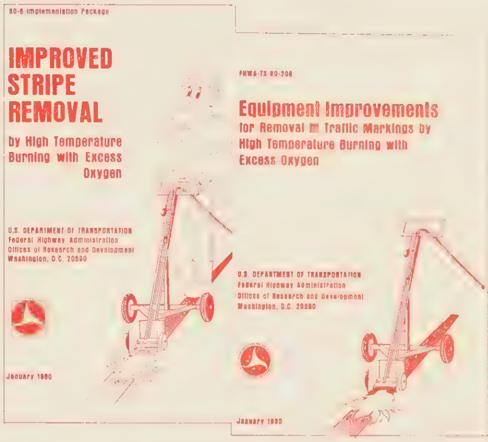
The Interstate highway system, while providing a safe and efficient means of travel, has intensified the need for improved motorists information systems. State highway agencies are now accepting larger roles in providing motorists information facilities and services. These systems are designed to help travelers with direction finding and trip planning for goods, services, recreational facilities, and other travel-related matters. The convenience of highway travel depends on the effective use of modern communications technology in a comprehensive and coordinated system of information services.

This report includes a brief history of providing motorists information and a review of various techniques used by State highway and transportation departments to meet motorists information needs.

The report may be purchased for \$2.50 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Stock No. 050–001–00203–5).

Improved Stripe Removal by High Temperature Burning With Excess Oxygen, Implementation Package 80–6 and Equipment Improvements for Removal of Traffic Markings by High Temperature Burning With Excess Oxygen, Report No. FHWA–TS–80–208

by FHWA Implementation Division



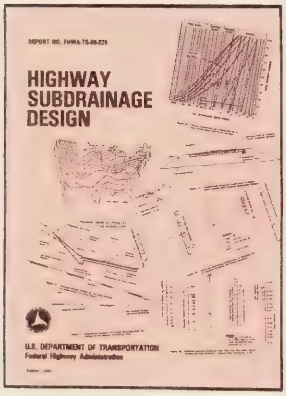
High temperature burning with excess oxygen has been found to be an efficient, practical, and easy-to-use method of traffic stripe removal for portland cement concrete and asphaltic concrete pavements. High temperature burning is less costly than most current removal operations and causes minimal pavement damage. This implementation package is a design, operation, and maintenance manual for implementing this system of traffic stripe removal.

The technology sharing report documents a study to modify and improve currently available burner equipment and to develop and evaluate mechanical methods for removing burned residue from various pavement surfaces. Equipment modifications include an improved tube-head design with reduced fuel consumption, better heat distribution, and greater Btu's at the burning surface, an improved burner carriage design, an improved mounting geometry for the burner heads, and an alternate residue removal method.

The implementation package and report are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22161 (Stock Nos. PB 80 201627 and PB 80 202807).

Highway Subdrainage Design, Report No. FHWA-TS-80-224

by FHWA Implementation Division



Water trapped under highway pavements and in cut slopes can lead to premature pavement failure. The design of subsurface drainage features will remain a state of the art rather than a science because of the nonuniformity of soil and aggregates and variable quantities of water. Analysis techniques now are available, however, and can be used as aids in solving subsurface drainage problems in both pavements and ground water flow.

This guide, divided into five chapters, includes: discussions on the adverse effects of subsurface water, the kinds, sources, and movements of subsurface water, and the kinds of subsurface drainage installations to control this water; the data required for subsurface analysis and design; pavement drainage methods and criteria; the control of ground water; and construction and maintenance of subsurface systems. Each chapter includes charts and figures that will help the designer deal with most pavement drainage and slope stability problems.

The guide may be purchased for $5.50 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Stock No. 050–001–00195–1).

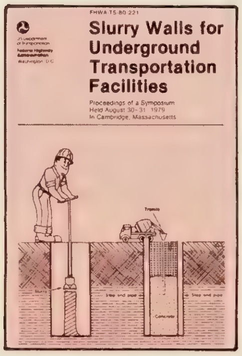
Slurry Walls for Underground Transportation Facilities, Report No. FHWA-TS-80-221

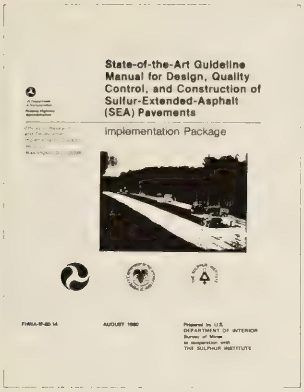
by FHWA Implementation Division

The slurry wall, also known as the slurry trench wall or diaphragm wall, is a proven method of temporary ground support for open excavations where vertical cuts are necessary. The method is particularly efficient and economical where high ground water, heavy building surcharges, or dense surface development and activity are encountered. In addition to providing temporary support, the slurry wall can be incorporated as part of the permanent underground structure. Examples of slurry walls as part of the underground structure in transportation facilities include cut-and-cover tunnels and retaining walls for depressed highway sections.

This report contains 20 papers presented at an August 1979 symposium on slurry wall design and construction sponsored by the Federal Highway Administration. The papers cover design, construction, geotechnical, instrumentation, economic, and legal aspects of slurry walls for ground support and cite examples of slurry wall applications around the world.

The report may be purchased for $8.50 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Stock No. 050–001–00199–5).





State-of-the-Art Guideline Manual for Design, Quality Control, and Construction of Sulfur-Extended-Asphalt (SEA) Pavements, Implementation Package 80–14

by FHWA Implementation Division

SEA binders conserve asphalt by replacing some asphalt in conventional flexible pavement mixes with sulfur. These new binders appear to possess properties comparable to asphalt. This manual provides the highway community with the most definitive state-of-the-art guidelines available for using these binders. Information is included on design, construction, quality control, equipment, mixing plants, specifications, and safety. The manual should be of interest to personnel in pavement construction, design, maintenance, and materials testing.

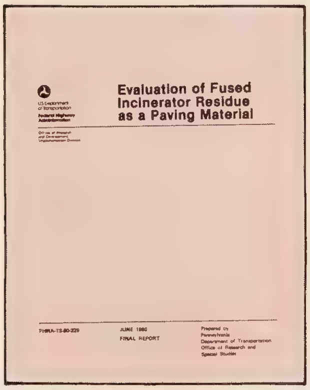
Limited copies of the manual are available from the Implementation Division.

Evaluation of Fused Incinerator Residue as a Paving Material, Report No. FHWA–TS–80–229

by FHWA Implementation Division

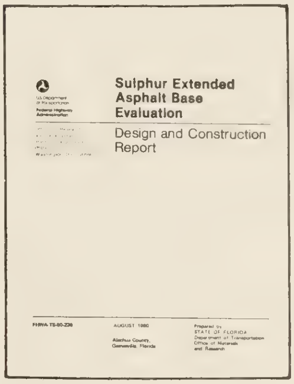
This report describes a successful 3-year evaluation of a pavement wearing course in which fused incinerator residue was used as an aggregate. Construction, special testing, and the evaluation of the wearing course are described. Fused residue is processed by subjecting incinerator residue (burned trash) to temperatures a few hundred degrees higher than those found in a conventional incinerator plant. Although not currently viable economically, the use of fused residue may be economical in the future.

Limited copies of the report are available from the Implementation Division.



Sulphur Extended Asphalt Base Evaluation, Design and Construction Report, Report No. FHWA–TS–80–238 and Executive Summary, Report No. FHWA–TS–80–239

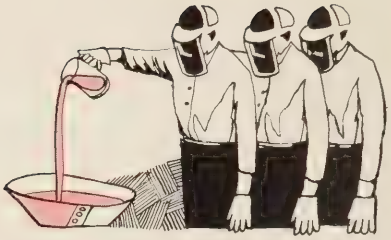
by FHWA Implementation Division



These reports describe the procedures and testing used during the design and construction of sulfur-extended-asphalt (SEA) trial sections in Florida. The SEA binders were formulated by mixing the sulfur and asphalt in pipes before introducing the materials to the batch plant (in-line blending). The binders were used to construct base courses with 76, 127, and 178 mm (3, 5, and 7 in) thicknesses. The sulfur/asphalt weight ratio was 40/60, and comparable aggregate gradations were used in SEA and asphalt sections.

Limited copies of the reports are available from the Implementation Division.

New Research in Progress



The following items identify new research studies that have been reported by FHWA's Offices of Research and Development. Space limitation precludes publishing a complete list. 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)—Performing State Highway or Transportation Department; National Cooperative Highway Research Program (NCHRP)—Program Director, National Cooperative Highway Research Program, Transportation Research Board, 2101 Constitution Avenue, NW., Washington, D.C. 20418.

FCP Category 1—Improved Highway Design and Operation for Safety

FCP Project 1B: Ride Quality of Commercial Motor Vehicles and the Impact on Driver Performance

Title: Instrumentation System for Monitoring Forces and Motions on Articulated Vehicles. (FCP No. 31B5214)
Objective: Design, assemble, and test an instrumentation system to measure forces exerted by pavement, vibrations generated on moving trucks, and vibrations transmitted to the driver.
Performing Organization: Calspan Corporation, Buffalo, N.Y. 14225
Expected Completion Date: September 1982
Estimated Cost: $225,000 (FHWA Administrative Contract)

FCP Project 1M: Rural Highway Operational Safety Improvements

Title: Geometric Treatments for Reducing Passing Accidents at Rural Intersections on Two-Lane Highways. (FCP No. 31M2122)
Objective: Identify factors associated with passing accidents at intersections on two-lane highways. Develop geometric design modifications and evaluate through simulation. Develop a handbook-style documentation and perform a limited demonstration of the new approaches.
Performing Organization: Progressive Consultants, Southfield, Mich. 48075
Expected Completion Date: March 1982
Estimated Cost: $318,000 (FHWA Administrative Contract)

FCP Project 1N: Safety of Bicyclists, Moped Operators, and Pedestrians

Title: Pedestrian Signalization Alternatives. (FCP No. 31N1092)
Objective: Determine safety benefits of pedestrian signalization. Develop alternatives to flashing walk and don't walk signals. Develop warrants for pedestrian signals and actuation devices. Investigate the use of yield signs or signals for pedestrians.
Performing Organization: Goodell Grivas, Inc., Southfield, Mich. 48075
Expected Completion Date: March 1983
Estimated Cost: $267,000 (FHWA Administrative Contract)

FCP Project 1V: Roadside Safety Hardware for Nonfreeway Facilities

Title: Improved Performance of Small Sign Supports. (FCP No. 31V3023)
Objective: Establish design vehicles to define impact speeds, angles, and other test conditions for acceptance testing of small sign and luminaire supports. Evaluate small sign supports and current design standards.
Performing Organization: Mobility Systems and Equipment, Los Angeles, Calif. 90045
Expected Completion Date: March 1984
Estimated Cost: $637,000 (FHWA Administrative Contract)

FCP Project 1W: Measurement and Evaluation of Pavement Surface Characteristics

Title: Calibration Services for Pavement Survey Equipment. (FCP No. 31W4042)
Objective: Investigate need, feasibility, and cost effectiveness of centralized calibration services for various kinds of pavement survey equipment.

Performing Organization: Automated Management Systems, Lanham, Md. 20801
Expected Completion Date: March 1982
Estimated Cost: $158,000 (FHWA Administrative Contract)

FCP Project 1X: Highway Safety Program Effectiveness Evaluation

Title: Testing of Improved Evaluation Techniques Using a Representative Set of Accident Countermeasures. (FCP No. 31X2022)
Objective: Perfect and test dynamic programing, integer programing, and incremental benefit/loss analysis with improved solution algorithm as cost effectiveness analysis techniques using data from five States.
Performing Organization: Texas A&M Research Foundation, College Station, Tex. 77843
Expected Completion Date: September 1982
Estimated Cost: $293,000 (FHWA Administrative Contract)

FCP Project 1Y: Traffic Management in Construction and Maintenance Zones

Title: Improved Pedestrian Controls in Highway Work Zones. (FCP No. 31Y1132)
Objective: Determine pedestrian information needs and develop techniques and devices to facilitate the movement of pedestrians through work zones. Consider all kinds of work zones and work zone operations for all kinds of urban and suburban highway facilities under both day and night conditions.
Performing Organization: AMAF Industries, Inc., Columbia, Md. 21044
Expected Completion Date: January 1982
Estimated Cost: $88,000 (FHWA Administrative Contract)

Title: Geometric Design Requirements for Highway Work Zones. (FCP No. 31Y1142)
Objective: Determine minimum geometric requirements for highway work zones considering volume, kind of traffic, and duration of construction. Base requirements on traffic operations, economic trade offs, and safety effectiveness. Consider geometric elements including restricted lane widths, shoulder dropoffs, and median crossover design.
Performing Organization: Midwest Research Institute, Kansas City, Mo. 64110
Expected Completion Date: September 1982
Estimated Cost: $418,000 (FHWA Administrative Contract)

FCP Category 2—Reduce Congestion and Improve Energy Efficiency

FCP Project 2L: Detection and Communications for Traffic Systems

Title: Visual Incident Detection Evaluation Operation (Video). (FCP No. 42L1042)
Objective: Develop the image transmission phase of the SCAN project and extend its concept to cover permanent station location within a system concept. Test the field applicability of TV surveillance using low frame rate samples of real time images processed at the roadside.
Performing Organization: Maryland Department of Transportation, Baltimore, Md. 21211
Expected Completion Date: January 1982
Estimated Cost: $387,000 (HP&R)

Title: Application, Analysis, and Prototype Development of a Sensor for Control of Arterials and Networks (SCAN). (FCP No. 32L1172)
Objective: Develop a prototype WADS sensor. Develop a prototype design that is environmentally hardened, uses a rugged, low-cost charge coupled device imager, and uses low-cost microprocessors.
Performing Organization: Jet Propulsion Laboratory, Pasadena, Calif. 91105
Expected Completion Date: March 1983
Estimated Cost: $250,000 (FHWA Administrative Contract)

Title: Automatic Audio Signing. (FCP No. 32L2112)
Objective: Review prior research activity in automatic audio signing. Perform a detailed system design analysis, fabricate hardware at the engineering model and prototype levels, and perform a pilot demonstration program for this hardware.
Performing Organization: Atlantic Research Corporation, Springfield, Va. 22161
Expected Completion Date: September 1982
Estimated Cost: $769,000 (FHWA Administrative Contract)

FCP Project 2P: Improved Utilization of Available Freeway Lanes

Title: Calibration and Validation of FREFLO. (FCP No. 32P4064)
Objective: Determine the speed-density parameters and the perception-reaction coefficient needed to run the FREFLO freeway computer simulation model. Validate the model with data from Minneapolis and Los Angeles.
Performing Organization: Verac, Inc., San Diego, Calif. 92117
Expected Completion Date: January 1982
Estimated Cost: $60,000 (FHWA Administrative Contract)

FCP Category 4—Improved Materials Utilization and Durability

FCP Project 4G: Substitute and Improved Materials to Reduce Effects of Energy Problems on Highways

Title: Sulfur Extended Asphalt (SEA) Laboratory Investigation Strength and Durability Characteristics. (FCP No. 44G1504)
Objective: Evaluate the applicability of using SEA in Washington State, develop design criteria that will improve the use of SEA mixtures, and assess the price and availability of sulfur in Washington State.
Performing Organization: University of Washington, Seattle, Wash. 98105
Funding Agency: Washington State Highway Commission
Expected Completion Date: March 1982
Estimated Cost: $66,000 (HP&R)

FCP Project 4K: Cost Effective Rigid Concrete Construction and Rehabilitation in Adverse Environments

Title: Long Term Monitoring of Bridge Deck Protective Systems. (FCP No. 44K2082)
Objective: Monitor various bridge decks that have been installed with waterproof membranes and one each of the latex modified and high density concrete overlays. Measure half-cell potential, resistivity, and visual inspection.
Performing Organization: New Jersey Department of Transportation, Trenton, N.J. 08625
Expected Completion Date: September 1990
Estimated Cost: $80,000 (HP&R)

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

FCP Project 5D: Structural Rehabilitation of Pavement Systems

Title: Evaluation of Construction Methods and Performance of Load Transfer Restoration. (FCP No. 45D2744)
Objective: Determine the economic and technical feasibility of several methods of restoring load transfer, and reduce pavement corner deflections of existing plain jointed concrete pavements.
Performing Organization: Georgia Department of Transportation, Atlanta, Ga. 30334
Expected Completion Date: November 1982
Estimated Cost: $60,000 (HP&R)

Title: Evaluating and Quantifying User Perception of Pavement Serviceability. (FCP No. 45D4174)
Objective: Correlate Pennsylvania's subjective rating of a variety of road types and classifications to the road roughness measurements made by the Pennsylvania Department of Transportation's Mays Meters.
Performing Organization: Ketron, Inc., Harrisburg, Pa. 17108
Funding Agency: Pennsylvania Department of Transportation
Expected Completion Date: April 1982
Estimated Cost: $175,000 (HP&R)

FCP Project 5E: Premium Pavements for "Zero Maintenance"

Title: Highway Cost Allocation for Pavement Maintenance and Rehabilitation. (FCP No. 35E1051)
Objective: Investigate a method of pavement cost allocation based on incremental changes in pavement life cycle costs with increasing axle loads. Consider independent and load-interactive effects of environment on pavement deterioration on rigid and flexible pavements using EAROMAR and VESYS.
Performing Organization: Massachusetts Institute of Technology, Cambridge, Mass. 02139
Expected Completion Date: January 1982
Estimated Cost: $90,000 (FHWA Administrative Contract)

FCP Project 5K: New Bridge Design Concepts

Title: Application of the Captive Column Concept to Highway-Related Structures. (FCP No. 45K3092)
Objective: Evaluate the structural properties of captive columns and their applicability to highway structures.
Performing Organization: University of North Dakota, Grand Forks, N. Dak. 58201
Funding Agency: North Dakota Highway Department
Expected Completion Date: February 1982
Estimated Cost: $130,000 (HP&R)

FCP Project 5L: Safe Life Design for Bridges

Title: Loading Spectrum Experienced by Bridge Structures in the United States. (FCP No. 35L3052)
Objective: Design and outfit three mobile, bridge weigh-in-motion systems to be used at 40 representative bridge sites to collect,

process, and evaluate information for accurate assessment of the effects of current heavy vehicle loadings on the life of the highway system.
Performing Organization: Bridge Weighing Systems, Warrensville Heights, Ohio 44128
Expected Completion Date: January 1982
Estimated Cost: $364,000 (FHWA Administrative Contract)

FCP Category 9—Research and Development Management and Coordination

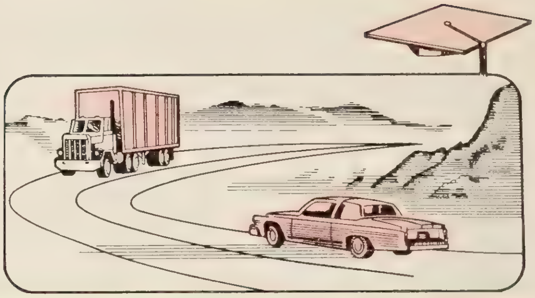
FCP Project 9B: New Concepts Development and Systems Characterization

Title: Statistical Guidelines for Traffic Simulation Experiments. (FCP No. 39B2042)
Objective: Provide statistical guidelines that will promote effective applications of traffic simulation models. Include a handbook of guidelines for the NETSIM model.
Performing Organization: JFT Associates, Los Angeles, Calif. 90045
Expected Completion Date: March 1983
Estimated Cost: $229,000 (FHWA Administrative Contract)

FCP Category 0—Other New Studies

Title: Study of Cement Aggregate Reactions Using Nebraska Aggregates and Cements With Varying Equivalent Alkali Contents. (FCP No. 40M5572)
Objective: Study the Nebraska Department of Roads concrete mixes with aggregates from various locations throughout the State and cements with varying equivalent alkali contents. Test the specimens for freeze-thaw and wetting/drying compression, and then rate the specimens according to their durability.
Performing Organization: University of Nebraska, Lincoln, Nebr. 68588
Funding Agency: Nebraska Department of Roads
Expected Completion Date: June 1983
Estimated Cost: $100,000 (HP&R)

Research Associate Program for University Faculty



What is the FHWA Research Associate Program?

The Research Associate Program of the Federal Highway Administration (FHWA), developed under the Intergovernmental Personnel Act, provides for 1-year research assignments at FHWA's Fairbank Highway Research Station, located near Washington, D.C., or in some instances, at the Department of Transportation Headquarters Building in Washington, D.C.

Who is eligible?

The program is designed primarily for college and university faculty members who are interested in areas of research included in FHWA's Federally Coordinated Program (FCP) of Research and Development in Highway Transportation. The program is broad, and therefore the eligible academic disciplines involved in the program are diverse. Scientists and engineers employed in research capacities by State or local governments also will be considered.

What kinds of research may be undertaken?

A one-page description of each of several possible research assignments will be provided to individuals who request it. Brief summaries of sample assignments are shown below.

Sample assignments:

- Develop new techniques and concepts for design and construction of highway bridges.
- Investigate factors that influence the onset and propagation of corrosion and deterioration of highway structural steel.
- Develop an improved procedure for computing the capacity and level of service of unsignalized intersections.
- Review, evaluate, and synthesize information on design speed in relation to geometrics, safety, traffic operations, and critical vehicle characteristics; develop a procedure whereby design speed can be made consistent with highway use.
- Synthesize and develop best management practices for control of highway storm water runoff pollution.

Areas of research:

Because of the diversity of highway problems, a variety of research areas is involved as shown below.

- **Structures**
Structural safety and economy of highway bridges, piers, tunnels, culverts, and retaining walls; bridge inspection and evaluation; wind and earthquake protection; traffic railings, energy-absorbing barriers, sign and luminaire supports, curbs, and other roadside features related to vehicle occupant protection; pavement/tire traction interface; criteria and procedures for design, construction, and rehabilitation of flexible, rigid, and composite highway pavement systems.

- **Materials**
Engineering properties of soils and aggregates; sampling and testing methods, portland cement concrete constituents, reinforcement and protection; asphaltic concrete constituents, quality and mixing techniques; chemical soil stabilizers, pavement binders and sealers; corrosion protection; signing and delineation materials; use of waste and substitute materials in highway construction.

- **Traffic**
Traffic engineering, control and traffic management for all highway environments, including rural roads, freeways, corridors, urban arterials, and signalized networks; traffic models and computer simulation; human factors aspects of traffic control devices and presentation of information to drivers; electronics and advanced technology applications to highway and driver communications and operations.

• **Environmental and Hydraulics**
Economic and social aspects of highway and geometric design; environmental effects related to air, noise, water, and sedimentation pollution; adverse weather and night visibility conditions; hydraulics and hydrology; accident research.

What research facilities are available?

Extensive laboratory facilities are available at Fairbank Highway Research Station; several additional laboratories are now under construction and are scheduled for completion in 1982. Equipment and instrumentation for related field studies also are available.

Structures

- Structural Testing Lab—full-size and scale model bridge static and fatigue loading tests
- Impact Test Facility—test procedures for obtaining valid vehicle-structure impact data[1]
- Wind Tunnel—section model tests of long-span cable suspended bridges
- Accelerated Pavement Test System—life cycle testing in the laboratory of full-scale pavement sections with rolling wheel loads[1]

Materials

- Pavement Components Lab—components characteristics of pavement component layers[1]
- Pavement Test Equipment—road roughness, friction, and texture, road topography[1]
- Concrete Labs—specimen preparation and testing
- Petrography—rock and concrete specimen examination
- Bituminous Mixtures Lab—properties of bituminous materials and mixtures
- Aggregate Processing and Test Lab—preparation and tests of aggregates and materials incorporating aggregates
- Soils Lab—soil testing
- Nucleonic Lab—nuclear instruments for testing soils, concrete, and other materials
- Soil-Structure Interaction Lab—piles, footings, retaining walls
- Analytic Chemistry and Electron Microscopy Lab
- Wet Chemistry Lab—chemical and coatings analysis
- Organic Binders Lab—extractions and testing of organic binders

Traffic

- Human Factors Lab—slide and motion picture presentation of experimental traffic control devices
- Instrumented Vehicle—physiological, driver-vehicle measurement, eye movement, in-vehicle sign display
- Highway Simulator—testing of traffic control devices by means of computer-driven interactive display of highway driving situations[1]
- Highway Communications Lab—use of radio and telephone for motorist aid and information, traffic sensors[1]
- Traffic Programs Lab—development, support, and training related to traffic computer simulation and control programs[1]

Environmental and Hydraulics

- Highway Esthetics Lab—assessment of user response to highway features using models and pupillometer[1]
- Environmental Quality Testing Lab—noise, air, and water pollution field instrumentation[1]
- Hydraulics Lab—scale modeling and instrumentation[1]

What support facilities are available?

The research associate has at his or her disposal several kinds of support facilities including the following:

- Electronic instrumentation service and support for design, fabrication, testing, and installation of laboratory electronic circuits and systems.
- Computer technology support for systems analysis, programing, and administration of computer programs.
- Mechanical design and fabrication of laboratory special-purpose equipment, scale models, and test equipment.
- The most extensive transportation library in the United States and a technical information staff responsible for technical publications and *Public Roads* magazine.

Is there an opportunity to publish research results?

Technical reports of research under contract and by staff and associates are published by FHWA as R&D reports with initial distribution to FHWA Washington

[1]New laboratory to be completed in 1982.

Headquarters and field offices, State highway and transportation departments, municipalities, and other selected highway-related addresses as warranted by the subject matter and degree of implementation potential. Thereafter, reports generally are disseminated by the National Technical Information Service. Applications of research results are encouraged by means of Implementation Packages. Abstracts of all reports are sent to the Highway Research Information Service. In addition, articles summarizing FHWA research activities by the staff associates and others are published in *Public Roads*. Papers by staff, associates, and contractors regularly are presented at annual meetings of the Transportation Research Board and printed in its publications. Papers also appear in specialized professional journals and in proceedings of conferences where they have been presented. Research by staff and associates may be used for dissertation topics.

Academic disciplines are diverse

The academic disciplines involved in highway research are numerous and varied. Environmental-related research, for example, employs physicists, psychologists, and sanitary engineers. Structural research employs bridge, pavement design, and mechanical engineers. Involved in hydraulic research are hydraulic engineers, hydrologists, and geomorphologists. Materials research employs geologists, chemists, and materials engineers. Traffic research employs traffic engineers, electronic engineers, and psychologists. Safety research involves several of the above disciplines. Many of the research areas employ mathematicians, statisticians, and highway engineers.

What are the conditions of the appointment?

The candidate's present employer initiates the request for an Intergovernmental Personnel Act appointment under the Research Associate Program. Once FHWA and the participating college, university, or government agency have agreed upon an assignment, its terms and conditions are set forth in a written agreement. Assignments normally last 1 year and may begin at any time during the year. Salary generally is established at the level of the employee's regular salary paid by the participating agency plus any future pay increases that become effective during the assignment. Between half and full funding is provided by FHWA, including travel and related expenses, with the balance provided by the participating agency. The assignee is entitled to 13 workdays each of annual and sick leave per year plus Federal holidays.

Living conditions in Washington, D.C., area

Washington, D.C., is a cosmopolitan city where daily headlines make news throughout the world. In this fast-changing scene, it does not take long to feel at home. Fairbank Highway Research Station, the research associate's worksite, is located near McLean, Va., in a campus-like setting 16 km (10 miles) northwest of downtown Washington, D.C., amid semi-rural wooded parkland. Housing of all kinds is available. Schools are excellent. There are many ways to enjoy leisure time, and they need not be expensive. In addition to museums, art galleries, and national monuments, there are parks and numerous outdoor recreation facilities. Community centers and community colleges throughout the metropolitan area sponsor a variety of free or low-cost courses. There are many folk and square dancing groups, theater groups, and choral societies. Concerts, ballet, and theater from many nations are presented nightly. Many fine restaurants and an international cuisine are available throughout the area.

Where may further information be obtained?

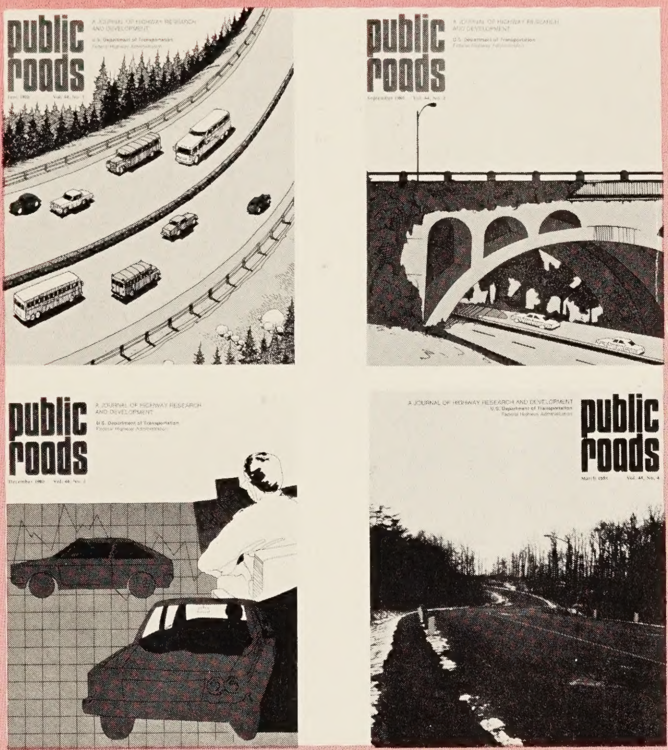
To obtain additional information and application forms send your name, mailing address, telephone number, general areas of interest (Structures, Hydraulics, Materials, Environment, Traffic), specialties and academic disciplines, and name of college, university, or government agency to:

Program Coordinator (HRD–2)
Office of Research and Development
Federal Highway Administration
Washington, D.C. 20590

You will be sent information to assist you and your employer in applying for the Research Associate Program. In addition you will receive descriptions of research assignments in your general interest areas, with the name and telephone number of a scientist or engineer who heads the group with whom you may work.

U.S. Government Printing Office: 1981—341-783/3

TITLE SHEET, VOLUME 44



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A JOURNAL OF HIGHWAY RESEARCH AND DEVELOPMENT

VOLUME

44

June 1980–March 1981

U.S. Department of Transportation
Federal Highway Administration

The title sheet for volume 44, June 1980–March 1981, of *Public Roads, A Journal of Highway Research and Development,* is now available. This sheet contains a chronological list of article titles and an alphabetical list of authors' names. Copies of this title sheet can be obtained by sending a request to the editor of the magazine, U.S. Department of Transportation, Federal Highway Administration, HDV–14, Washington, D.C. 20590.

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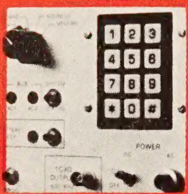
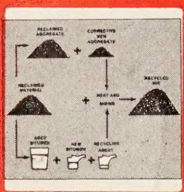
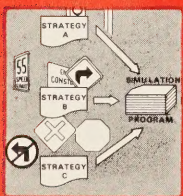


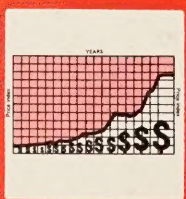
Traffic Controller Synchronizer—Time-Based Signal Coordination



Current Research in the United States to Evaluate Materials Used in Recycling Asphalt Pavements



A New System for Traffic Simulation



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