Automobile Research Simulators: A Review and New Approaches

R. Wade Allen and Richard H. Klein, Systems Technology, Inc.,
Hawthorne, California
Kenneth Ziedman, Sourthern California Research Institute, Los Angeles

The state of the art of driving simulators is reviewed, and examples of two simulators that have advanced visual display capabilities are presented. Anticipated future developments in simulation technology related to research, driver training, and licensing applications are also discussed.

Simulation is used in man-machine studies for a variety of reasons. Simulating systems is usually less expensive than conducting field studies, more control is allowed over experimental conditions and measurements, and hazardous conditions can be simulated safely. These reasons are clearly behind the current growing use of simulators.

Aircraft simulators avoid very expensive and potentially dangerous flight operations involving multimillion-dollar aircraft and permit design comparisons under controlled task and disturbance conditions. Simulators for training railroad locomotive crews are used for the same reason—i.e., they substitute for a large and complex machine and avoid tying up busy trackage and crew personnel that are needed to conduct real-life operations. Ship operators, too, are starting to use simulators because of the increasing costs of large vessels and crews. In the automotive field, automobile and truck simulators are being used in studies of the driver (e.g., drugs, visual search patterns, and training), the vehicle (e.g., handling qualities, accident avoidance, and design), and the environment (e.g., visibility and roadway characteristics).

This paper attempts to review the capabilities of a number of research-oriented driving simulators used in the United States and Europe. Two facilities are discussed in detail as examples of state-of-the-art approaches to the most difficult simulation capability—generation of the visual field. The paper concludes with some thoughts on the potential future development of driving simulators.

CAPABILITIES OF DRIVING SIMULATORS

A variety of research simulators are summarized in Table 1 by their visual display approach. These approaches have been ranked in order of increasing capability for presenting image complexity, from the relatively simple technique of electronically generating lines on cathode ray tubes (CRTs) to scale-model real-world views.

CRT line drawings are probably the simplest solution for providing an interactive roadway display. They can be generated rapidly by means of electronic circuits (including hybrid computers), and intensity control can be used to obtain the desired image brightness. An unlimited number of electronic computations can be set up to operate in parallel so that high image frame rates can be maintained (within the bandwidths of the circuits) to produce displays that have excellent dynamic characteristics. Projection systems can be used to present large-sized displays (1-3, 5).

Digital-computer-generated imagery can provide complex visual fields for automobile driving (6, 7). But this approach is limited by the serial processing characteristic of digital machines and the fact that computation delay tends to be proportional to image complexity.

Point-light-source techniques provide an alternate approach to simple display generation but tend to be limited in their capability to reproduce photometric conditions (14). This type of display incorporates a traffic scene (i.e., a model) constructed from tinted Plexiglas. Model motion is controlled to represent the speed and heading of the simulated vehicle as it moves past a stationary light source. This results in the shadows of objects being cast on a screen in front of the subject. This approach is limited by the difficulty of constructing and controlling large, complex models. An example is described by Pulling and others (8).

Motion picture simulators (9-11) provide excellent detail but are not truly interactive. Generally, the driver's steering signal provides aiming information to the pan angle of one or two projectors. This gives a realistic impression of heading changes, but realistic changes in lateral placement are not reproducible. Speed is varied by changing projector speed.

Scale models can represent complex geometric conditions (12, 13) but can be tedious and expensive to implement and maintain. The display image is achieved by means of closed-circuit television and a movable camera. The camera can be arranged to either turn and laterally translate over a belt (which moves at scaled vehicle speed) or turn and translate freely over a fixed model. The vehicle dynamics are interactive, and the camera is rotated and translated in response to steering commands. The main drawbacks are limited resolution, lighting, and depth of field; it is also difficult to simulate environmental conditions such as fog and complex lighting situations. Large terrain boards are used where turns and intersections are required. Again, this approach is limited by the difficulty of constructing large, complex models.

CURRENT APPROACHES

The basic elements of a general, fixed-base driving simulator are shown in Figure 1. An instrumented cab is tied in with computers and electronic equipment arranged to provide interactive steering and speed control for the driver. Control signals from the cab are processed by vehicle equations of motion to yield instrument drive signals (e.g., speedometer and tachometer) and vehicle motion commands for a display generator. Traffic events such as other vehicles and intersections also provide display-generator commands. The display generator then provides drive signals for a display projection device that presents images of the roadway environment to the driver. The equations of motion can also provide commands for auditory feedback (e.g., speed and tire squeal) and inputs to performance measurement and recording devices.

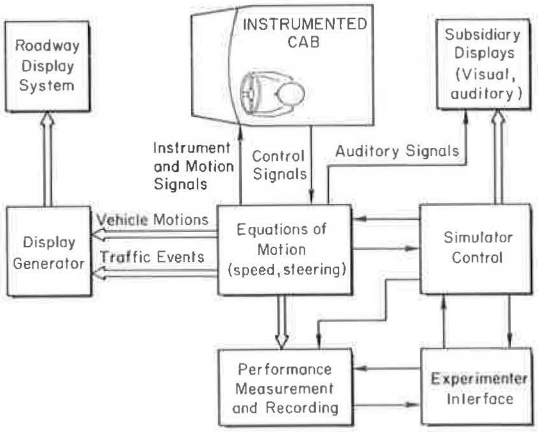
Ideally, the simulation is under some sort of host computer control that provides general monitoring of simulation operation, control of the scenario or traffic-

Table 1. Driving simulators by type of visual display.

Type of Display	Facility	Motion	Vehicle Dynamics	Auditory Cues	Visual Field	Application
Electronically generated imagery	Virginia Polytechnic Institute (1)	4 df	4 df, hybrid	Yes (wind, engine, tires)	TV monitor (39° vertical, 48° horizontal)	Driver-vehicle research
	Systems Technology, Inc. (2)	No	3 df, analog	Yes (engine, tires)	50°	Driver-vehicle research
	FAT, Meckenheim, Germany (3)	Yes	3 df, analog	Yes	40°	Driver-vehicle research
	General Motors (4)	No	4 df, analog	Yes (wind, engine)	54-cm TV with Fresnel lens	Vehicle design
	Volkswagen (5)	Yes	21 df, analog	Yes	Collimated CRT	Vehicle design
Digital computer-generated imagery	Southern California Research Institute (6)	No	2 df, digital	Yes	50°	Driver-vehicle research
	General Electric (proposed only) (7)	-	-	-	-	-
Point light source	Liberty Mutual (General Precision SIM-L-CAR) (8)	No	Lateral position and speed only	No	38°	Headlight glare
Movie film	Institute of Transportation and Traffic Engineers (9)	No	None	Yes	360°	Driver impairments
	Southern California Research Institute (10)	Yaw only	None	Yes	70°	Eye movement studies
	General Motors Technical Center (11)	2 df	Basic	No		Eye movement studies
Scale models (terrain board or endless belt)	University of Southern California, Los Angeles (12)	No	3 df, analog	Yes	40° closed-circuit TV	Driver-vehicle research
	Institute for Perception (TNO) (13)	No	3 df, analog	Yes	50°	Driver-vehicle research

Notes: 1 cm = 0.39 in.
df = degrees of freedom.

Figure 1. Elements of typical driving simulator.



event sequences encountered by the driver, and measurement and recording of performance. Finally, interface controls allow the experimenter-operator to control and monitor the operation of the simulator and the performance of the driver.

Two examples of simulation approaches that use the organization shown in Figure 1 are described below. The first example represents a hybrid approach in which analog and digital computers and electronic circuits are combined to accomplish the various computational requirements. The second example, which is primarily mechanized, uses a digital computer in which simulator control is accomplished primarily by means of high-level language software.

Hybrid Simulation

Several years ago, a simulator was developed by Systems Technology, Inc., to investigate the effects of alcohol on driver decision making (2). Figures 2-5 show aspects of the simulator, which included a fairly sophisticated electronic display generator that displayed such features as dashed lines, road curvature, intersections, and obstacles at various points in a driving scenario. The display was mounted on the dash of the instrumented automobile cab, and subsidiary slide-projected displays of signs and adjacent traffic were provided at either side of the primary roadway display.

Recently, a Fresnel lens has been mounted in front of the CRT display, as shown in Figure 3, to provide modest magnification (~1.5X) and also to collimate the roadway image to require complete accommodation by the eye. The collimation feature is important in instrument-panel studies in which the eye must change accommodation between panel viewing [~0.75 m (2.5 ft) away] and the road environment [7.5 m (25 ft) to infinity]. A combining glass is also included to optically combine slide-projected signs with the CRT roadway image, both of which are similarly collimated by the Fresnel lens.

Important procedural advancements were also instituted along with the hardware improvements mentioned above. A paper-tape programmer was added to control the occurrence of traffic events as the driver proceeded through a "drive" of fixed length. A monetary reward-penalty system—e.g., accidents and tickets—was used to simulate the risks of real-world driving motivations. Subjects were sent on a drive in which a sequence of many traffic events occurred over a relatively short period of time (e.g., 15 min). During the

Figure 2. Decision-making simulation with direct-view CRT.

Figure 3. CRT with optical combining system viewed through collimating lens.

Figure 4. Projected video road image combined with slide-projected signs.

Figure 5. Video-projected truck-driving display with horizontal and vertical curvature.

drive, comprehensive measures of performance and risk-taking behavior were measured. The reward-penalty structure proved to constrain driver behavior in a fairly realistic manner, and simulator performance and behavior were found to agree quite well with subsequent closed-course tests in an instrumented vehicle (15).

Another display configuration, shown in Figure 4, includes the addition of an Advent Videobeam projector that allows the roadway image to be presented on a screen 1.8 m (6 ft) out in front of the driver. This approach also allows slide-projector images to be optically combined with the roadway image (16). A computer-controlled random-access slide projector is arranged to project onto the roadway display screen (Figure 4). Sign image size is varied by a servo-controlled zoom lens, and image position is controlled by a servo-controlled rotating mirror. A PDP 11/10 computer is programmed to command image size and position so that the signs appear fixed with respect to the roadway as the subject drives past them. The computer also controls the order in which signs are presented and automatically records driver-vehicle response to sign information such as speed limits. A recently completed study of various proposed formats for metric speed-limit signs showed surprising sensitivity among the different designs as measured by speed-distance response, correctness of response, and subjective opinion (17).

A current application of the video-projected roadway display is shown in Figure 5. An Adkins and Merrill instrumented truck cab (including hydraulic gear-shift mechanism) has been modified and tied into an analog computer. The equations of motion provide steering response and a complete simulation of braking behavior (including overheating). The equations and display presentation correctly represent vertical and horizontal road curvature. An eight-bit microcomputer is used to control typical truck-driving scenarios, including grade profiles, interactive traffic on the roadway display, slide-projected adjacent traffic viewed through a side-view mirror, signing projected on the roadway display, and randomly placed police to detect speeding. This simulator configuration should be suitable for a variety of trucking problems, including downgrade braking, handling, driver impairment (from drugs or fatigue), and possibly even driver training and licensing.

In summary, the hybrid approaches discussed above have several advantages. The electronic display generator can present symbols at a high update rate (~100 samples/s) and can accommodate complex features such as curves, obstacles, and dashed lines with simple commands. The generator places no computational load on the other simulation elements and requires only relatively low-frequency commands from the equations of motion or other controlling elements. Mechanization of the equations of motion on an analog computer allows vehicle motions to be computed in real time without computational delay and also provides ease and flexibility in changing vehicle characteristics. Finally, logic, control, performance measurement, and recording functions are best provided by digital computing devices and suitable peripherals. These elements can provide the necessary combination of memory, computational capacity, and programmability for versatile experimental control and measurement of performance in a driving simulator.

Digital Approach

A second approach to driving simulation, one that uses digital computer-generated imagery, has recently been applied by Southern California Research Institute (see Figures 6 and 7). In this application, vehicle dynamics, roadway data bases, scene generation, and performance measures are all implemented by means of software in a general-purpose digital computer. Although this approach is certainly not unique, it was accomplished at a cost that is moderate compared with the cost of previous computer-generated imagery systems used in spacecraft, aircraft, and ship simulations (a hardware investment of about $100 000 for the computer and the related peripherals).

One of the most notable aspects of this system is that emphasis was placed on general-purpose computational power rather than on special-purpose components. A PDP 11/60 with full core memory, floating-point processor, cache memory, and a Megatek 7000 series graphic system accomplished this function. The Megatek is a vector-drawing graphics system with a 60-Hz refresh. An Analogic AN5400 provides analog and digital input-output lines for interface with the PDP 11/60. A large-screen [1.8 × 2.4-m (6 × 8-ft) image] rear-projection display was achieved by means of an Advent video projector.

The keys to the software design were modularity and flexibility. A control table describes the roadway situation as the subject progresses through the drive. The table is generated by an auxiliary program that creates a set of input files for the main table-driven scheduler in the real-time environment. The auxiliary program is in essence an interpreter that accepts input from the experimenter (before the real-time experiment is to be run) and then establishes a set of entries in an overall descriptive table for each drive. All events during the drive are specified as a function of distance along the roadway. In this way, a non-computer-oriented individual can design a variety of experiments by using the basic roadway elements described below. The experiment specification can then be stored and run repeatedly on command.

Figure 6. Automobile cab and screen with peripheral light assembly (at right) and stoplight (at top).

The following scene elements, which are shown in Figure 7, are currently generated as part of the dynamic scene:

1. Basic roadway—two lanes with shoulder lines and dashed centerline, straight or curved (arbitrary radius of curvature);
2. Off ramps;
3. Route signs—overhead freeway-type road signs (two letters and arrow);
4. Speed command signs—on shoulder (two letters or numerals);
5. Lateral position and velocity of lead automobile independent of subject automobile; and
6. Obstacles in either lane.

Noncomputer graphic elements, including eight peripheral lights for the subsidiary target-detection task, red-green stationary stoplight, and two 35-mm slide projectors with shutter and slide advance-reverse control capability, can be displayed under computer control.

In current application, driving tasks that use the scenes shown in Figure 7 are presented to the driver in accordance with a preconceived drive—a sequence of tasks in which various parameters can be changed each time a given task occurs. For instance, several risk-taking segments, each of which has a different obstacle spacing, can be defined. Each of these alternate risk-taking segments could be called several times during a drive. As another example, alternate route-sign sequences can be stored and specified for a particular drive. Random disturbances of lateral position and speed can be specified as part of a segment definition. In the present implementation, low-level random disturbances in speed and lateral position are introduced during all segments to increase task loading. More difficult lateral disturbances are used in wind gust and overload segments.

Performance measures are calculated and printed by task immediately after each run. Results are also stored, along with the raw data, for later statistical analysis or possible future reanalysis.

In summary, the digital approach has proved to be advantageous in that some major task changes, suggested after initial evaluation of the task configuration,

Figure 7. Digitally generated roadway scenes: (a) turnoff, (b) route guidance sign, and (c) obstacle in opposing lane.

are being implemented in a relatively short time. The main limitation at this time is the frame-update rate of 7.5/s. This rate is considered acceptable but only minimally so, and various means are being considered for increasing computation rate. Increase in computation speed would also allow more vectors to be displayed and allow for a more complex scene. Avenues for eventual expansion to increase overall performance include hardware perspective computation, higher-resolution video displays, and optimization of aspects of the software.

POTENTIAL AND FUTURE DEVELOPMENT

Simulation Attributes

Future simulator development will be motivated to a great degree by the advantages that simulators have over other approaches. These are summarized below.

Safety

Simulators provide an inherently safe environment for driving research. This is particularly important under conditions that involve exposure to accident situations, which cannot be reproduced ethically under real-world conditions. Research that involves drivers impaired by alcohol, drugs, or fatigue and seriously degraded vehicle and environmental conditions also falls in this category.

Cost

Simulations can often represent the most cost-effective approach in a given application. Complete instrumentation and recording systems for in-vehicle tests can be expensive to set up and maintain. Contriving typical traffic situations, including interactive vehicles and signal controls, on special driving test courses can also be costly. On the other hand, it is often less expensive to set up and operate simulations in a controlled laboratory environment than it is to conduct field tests that are designed to achieve given experimental objectives. In particular, stimuli and events external to the driver's vehicle are substantially cheaper to implement, control, and vary in a simulator than they are on a test track.

Experimental Control

Simulations can make it possible to control experimental conditions over a wider range than field tests and can be easily changed from one condition to the next. This capability can be important in terms of experimental design considerations, such as allowing back-to-back comparisons of disparate experimental conditions. The computer control developments discussed above will act to reduce cost and increase flexibility in providing these capabilities as software programming replaces hardware mechanization of experimental condition alternatives.

Measurement

Criterion variables can easily be made available in a driving simulator. This is particularly true of computer-based simulators in which performance measures can be simply mechanized. Digital computer systems can further provide for on-line data processing, formatting, and storage and the reduction and compact arrangement of data.

Simulator Applications

Past applications tend to bear out the attributes of simulators discussed above and provide encouragement for future developments in driving simulators. Good correlations between simulator and field test data have been obtained in several research studies on vehicle handling (4), alcohol and decision making (15), and adverse visibility (18). There is also some optimism regarding the role of simulators in driver training (14) and licensing (19). Some possible future simulator applications are discussed below.

Research

Advanced simulators will continue to play a key role in driving research. Investigation of situations that involve high accident risk will continue to depend heavily on simulation. Environmental variables, including signing, roadway delineation, and factors that affect visibility, will be increasingly studied by means of simulation (17, 18). Simulation is useful in the general study of driver workload (20). Finally, sophisticated simulations can be used to investigate the potential role of simpler, more limited part-task simulations (21). This last role will be useful in establishing the essential part-task requirements for simulator applications that require simplicity and low cost—e.g., driver education and training.

Driver Education and Training

Film simulators are currently used in driver education and training, but they have limited interactive capability. Simulators with full interactive displays could have a substantial impact in this area if hardware costs could be reduced. Decision-making situations that involve such factors as interactive traffic, route guidance, and signalized intersections could be contrived to exercise students' perceptual and cognitive driving skills and to encourage defensive driving techniques. However, a significant research program, including studies of the transfer of training to real-world conditions, will be required to validate the effectiveness of simulator training for driver education.

Driver Licensing

Interactive simulators can be set up to present a sequence of decision-making and defensive driving situations in a controlled fashion that will measure the traffic safety potential of prospective drivers. This could represent an improvement over current behind-the-wheel tests, which are relatively uncontrolled in terms of traffic events encountered on a given route. Scoring could be automated and based on performance in a variety of traffic events. As with driver training, further research is required for this application; such research should include validation studies of simulator tests as a predictive measure of driving skill and knowledge and subsequent driving safety records.

Simulation Requirements

Simulators typically provide only part-task representation of actual driving, and the needs of each application will dictate specific simulation requirements. Typically, the expense and complexity of simulators will increase with required fidelity, and cost-benefit decisions will be required to establish simulator requirements in given situations. Operational reliability will decrease with increasing complexity, and cost-benefit considerations should include the following operational factors as well as initial construction costs.

Visual Display

The visual display is certainly a key element in all simulators, but its required complexity varies according to the application. Where risk perception and decision making are important, more display elements are required to represent complex interactive situations. Driver training and licensing will probably prove to require relatively sophisticated displays to adequately represent the road environments that are important to traffic safety.

Motion

Motion cues are important in situations that are designed to represent accident-avoidance maneuvering. High-performance maneuvering would require good motion fidelity in order to be adequately represented. Motion systems are expensive, however, and experience in aviation simulation has shown that inappropriate motion cues can have negative effects on the training and performance of the subject. Research on simulator motion-cue requirements is now under way, and the requirements and specifications for motion cues should be carefully considered.

Audition

Auditory cues are probably one of the least expensive means of providing additional information to the driver. Developments in the toy market for video games and computer-controlled toys have spurred development of very inexpensive sound-generation electronics that can be used to create the sounds of tire screeching, horns, sirens, engines, and wind.

Controls

Active-control feel systems should also be considered in future simulation developments. Characteristics of steering and shifting force may be important in simulations of commercial vehicles, such as the truck system described previously. Automobiles with power steering can be adequately represented by means of passive spring return mechanisms, but current trends toward smaller automobiles and fewer power accessories may require consideration of active feel systems.

FURTHER RESEARCH

Ultimately, the specification of any simulator application will require knowledge of the elements of the driving environment that are critical to that application. Further research is required to determine the importance to the driver of various visual, motion, kinesthetic, and auditory cues. Some of this research will require the use of sophisticated, high-fidelity simulators and instrumented vehicles. Once the requirements on the simulated driving environment are established, more limited simulators can be considered for applications such as training and licensing. Additional studies on the transfer of training to actual conditions and the validity of the criteria used may also be required before simulators gain wide acceptance as training and licensing instruments.

REFERENCES

1. W. W. Wierwille. A Part-Task Driving Simulator for Teaching and Research. Trans., Computers in Education Division, American Soc. for Engineering Education, Vol. 5, Dec. 1973, pp. 193-203.
2. R. W. Allen, J. R. Hogge, and S. H. Schwartz. An Interactive Driving Simulation for Driver Control and Decision-Making Research. 11th Annual Conference on Manual Control, National Aeronautics and Space Administration, Rept. TM X-62,464, May 1975, pp. 396-407.
3. E. Donges. Experimental Investigation of Human Steering Behavior in a Simulated Road Driving Task. ATZ Automobiltechnische Zeitschrift, Vol. 77, No. 5/6, 1975, pp. 141-146.
4. B. Repa, A. A. Alexandridis, L. J. Howell, and W. W. Wierwille. Study of Vehicle Steering and Response Characteristics in Simulated and Actual Driving. Presented at SAE International Automotive Congress and Exposition, Detroit, Feb. 27-March 3, 1978. Paper 780011.
5. W. Lincke, B. Richter, and R. Schmidt. Simulation and Measurement of Driver Vehicle Handling Performance. Presented at SAE Automobile Engineering Meeting, Detroit, May 14-18, 1973.
6. S. Michelson, R. Niemann, R. Olch, A. Smiley, and K. Ziedman. A Driving Simulator for Human Performance Studies Using All Digital Techniques. Southern California Research Institute, Los Angeles, Nov. 1978.
7. M. G. Gilliland. Application of Computer Generated Imagery to Driver Training, Highway Research, and Design. North Carolina Symposium on Highway Safety, Raleigh, Vol. 8, Spring 1973, pp. 3-33.
8. N. Pulling and others. Headlight Glare Resistance and Driver Aid. Proc., Human Factors Soc., Santa Monica, CA, 1978.
9. R. H. Kemmerer, Jr., and S. F. Hulbert. UCLA Driving Simulation Laboratory: With a 360 Degree Scene Around a Full Size Car. Proc., Soc. of Photo-Optical Instrumentation Engineers, Vol. 59, March 1975, pp. 158-170.
10. K. Zeidman and H. Moskowitz. The Effects of Alcohol on Driver's Visual Information Processing. Southern California Research Institute, Los Angeles, Tech. Rept. (in preparation).
11. P. Kyropoulos. Simulators: Boon or Boondoggle? North Carolina Symposium on Highway Safety, Vol. 8, Spring 1973, pp. 37-48.
12. D. H. Weir and C. K. Wojcik. Simulator Studies of the Driver's Dynamic Response in Steering Control Tasks. HRB, Highway Research Record 364, 1971, pp. 1-15.
13. A Large-Scale Simulation System for the Study of Navigation and Driving Behavior. Institute for Perception, Soesterberg, the Netherlands, Documentation Sheet 39e, May 1978.
14. H. H. Shuttel, S. P. Shumacher, and R. D. Gatewood. Driver Training Simulators, Ranges and Modified Cars: A Review and Critique of the Experimental Literature. American Institute for Research, Rept. AIR-86400-7/71-IR, July 1971.
15. R. W. Allen, S. H. Schwartz, J. R. Hogge, and A. C. Stein. The Effects of Alcohol on the Driver's Decision-Making Behavior. U.S. Department of Transportation, Vols. 1 and 2, Repts. DOT-HS-803 608 and 803 609, Feb. 1978.
16. R. W. Allen, J. R. Hogge, and S. H. Schwartz. A Simulator for Research in Driver, Vehicle and Environment Interaction. Presented at the 56th Annual Meeting, TRB, 1977.
17. S. H. Schwartz, R. W. Allen, and A. C. Stein. A Simulator Study of Driver Reaction to Metric Speed

Signs. Systems Technology, Inc., Hawthorne, CA, Rept. TR-1065-2, April 1978.
18. R. W. Allen and J. F. O'Hanlon. Driver Steering Performance Effects of Roadway Delineation and Visibility Conditions. Presented at the 58th Annual Meeting, TRB, 1979.
19. J. F. O'Brien. Is There a Place for the Simulator in Driver Licensing? Traffic Safety, Vol. 78, No. 8, Aug. 1978.
20. T. G. Hicks and W. W. Wierwille. Comparison of Five Mental Workload Assessment Procedures in a Moving Base Driving Simulator. Human Factors, Vol. 21, 1979.
21. W. W. Wierwille and P. P. Fung. Comparison of Computer Generated and Simulated Motion Picture Displays in a Driving Simulation. Human Factors, Vol. 17, Dec. 1975, pp. 577-590.

Publication of this paper sponsored by Committee on Simulation and Measurement of Driving.

Notice: The Transportation Research Board does not endorse products or manufacturers. Trade and manufacturers' names appear in this paper because they are considered essential to its object.

Development of a Traffic Records System for Local Jurisdictions

Martin E. Lipinski, Memphis State University

A traffic records system for small and medium-sized cities and counties has been developed. The system is designed for maximum utilization of manual record-keeping procedures and for use as a supplement to existing criminal justice records. Three basic components are included in the system: input data, a filing system, and output reports. Recommendations for specific elements to be included within each component are included. The suggested system includes three levels of record keeping. The recommended level for a specific agency depends on the volume of traffic records and the capabilities of each jurisdiction. A discussion of the format used in the preparation of a manual that describes the system is included. Future plans for presenting seminars and providing technical assistance in the use of system methods are described.

Reducing the number of injuries and fatalities on the nation's streets and highways remains a major challenge for transportation safety officials. To achieve the goal of improving highway safety requires a comprehensive approach that includes analysis of a multitude of factors such as driver behavior, vehicle performance, enforcement practices, engineering techniques, judicial responses, and legislative activities. A key element in this comprehensive approach is the establishment of a traffic records system to provide information to decision makers. The data provided in this system will help in determining the extent of the accident problem, formulating programs needed to reduce accidents, and evaluating the effectiveness of these programs.

In recent years, the emphasis in traffic records systems has been placed on the development and refinement of computerized records systems for large urban areas and for statewide application. Continual improvement of these larger systems is certainly needed. But the problems of maintaining adequate records systems are particularly acute in small and medium-sized cities and counties. These jurisdictions, some of which have extensive traffic safety responsibilities, often have limited data collection capabilities and may lack the trained personnel to effectively develop, store, and use the pertinent information.

Agencies that maintain traffic accident and citation records often assign low priority to the maintenance of traffic records because of their limited enforcement staffs and heavy work loads. For example, Tennessee officials have noted that many enforcement agencies are not meeting their legal obligation to forward accident reports to the state department of safety in Nashville.

The Tennessee Governor's Safety Program sponsored the study reported here to meet the needs of local jurisdictions for improved methods of traffic record keeping. The objective of the study was to develop a manual traffic records system for use by local jurisdictions. The establishment of a generalized framework that could be used to formulate individualized records systems for agencies of various sizes was considered to be a primary factor in the development of the system. The methods described do not require the use of computers or sophisticated data-processing techniques. They can be implemented by improving existing manual filing procedures.

ORGANIZATION OF THE STUDY

To develop a records system that would provide the basic data necessary to make traffic safety decisions, the study was conducted in two parts:

1. A survey of existing traffic records systems in use in Tennessee and a review of the literature on development of traffic records systems and
2. The development of a complete records system and the preparation of a manual that describes the components of the system and their use.

SURVEY OF RECORDS SYSTEMS

The survey of traffic records systems consisted of two components: a survey of literature on manual traffic records systems and a review of current record-keeping practices among cities and counties in Tennessee.

The literature survey revealed that the majority of recommended manual traffic records systems contain common elements (1-7). These elements include maintaining accident files by location, using spot maps, and establishing supplementary files of citations and other pertinent data including records of alcohol in-