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RESEARCH PROBLEM STATEMENTS: SIMULATION AND MEASUREMENT OF DRIVING

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OPERATION AND MAINTENANCE OF TRANSPORTATION FACILITIES

Patricia F. Waller, Chairman
Group 3 Council
University of North Carolina, Chapel Hill, North Carolina

Committee on Simulation and Measurement of Driving
(as of July 1, 1981)

Dennis A. Attwood, Chairman
Department of Transport, Canada

James K. Williams, Transportation Research Board Staff

Moses Aronsom
Dr. David K, Damkot
Paul S. Fancher
Dr. Slade Hulbert
Richard H. Klein
Dr. James W. Knight
Dr. Rodger J. Koppa
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Dr. Brian S. Repa
Dr. Thomas H. Rockwell
Dr. Clifford P. Seitz
Dr. Alison Smiley
Samuel P. Sturgis
Dr. Kenneth Ziedman
Dr. Helmut T. Zwahlen

INTRODUCTION

Committee A3B06, Simulation and Measurement of Driving, is concerned with the development and application of techniques for the measurement of driver performance including simulation, instrumented vehicles, and mathematical models which synthesize portions of the driving task.

An important function of the Transportation Research Board and each of its technical committees is to identify research needs. The Committee on Simulation and Measurement of Driving, operating within Group 3 of the TRB, has identified eleven areas of research need. These areas of need have been organized as research problem statements in this circular.

While the committee did not elect to prioritize the research problem statements, one through eleven, the needs defined in the statements are each considered to be critical and important to advance the state of the art in simulation and more effective measurement of driving and the driving task.

RESEARCH PROBLEM STATEMENTS

PROBLEM NO. 1

1. TITLE: Develop an In-Car Monitoring Device to Quantitatively Assess Driving Proficiency.

2. PROBLEM: In North America, driving performance tests that are given for licensing or to examine the efficacy of a driver education program, always involve an on-road test that is scored by a trained examiner. While examiner-rated, on-road driving tests appear to be able to identify acceptable driving performance in terms of general driving ability, they are not sensitive to the time-course of vehicle handling skills. On the other hand, the output of the driver-vehicle system can be obtained by currently available transducers and recording systems. Moreover, microprocessors can be used to process transducer data to provide an immediate record of performance.

3. OBJECTIVE: Considering that the current examiner-rated, on-road test methods

   (1) are labor intensive,

   (2) vary in their ability to detect unacceptable driving performance both between and within examiners, and

   (3) are much less able to examine vehicle handling skills than electronic transducers,

   it is recommended that a Research and Development program be initiated to develop an on-line, real-time, performance evaluation system for use in driver licensing and driver education programs.

4. KEY WORDS: Driver Education, Driver Licensing, Driving Performance, Instrumented Vehicles.

5. RELATED WORK: Modern transducer and computer technology, coupled with the application of multivariate discriminant techniques, has been used by Attwood (1979) to examine the use of an on-line monitoring system for driving performance. The results of this pilot work suggest that it could be possible to develop an in-vehicle monitoring system that can detect unacceptable driving performance.

   Attwood, D.A., The effects of driving experience on objective measures of driving performance. Proceedings, 23rd Annual Meeting, Human Factors Society, Boston, October 1979.

6. COST: $250,000.

7. USER COMMUNITY: Provincial and State licensing bodies, driver education agencies.

8. IMPLEMENTATION: The device could be installed on the vehicles operated by the agency using it. The number of vehicles that can be equipped with the device as well as the manner in which it is used (e.g. open-road or range) would depend on its complexity.

9. EFFECTIVENESS: Even if the device effectively screens out 25% of the drivers who would definitely not pass a licensing test, savings in man-days would be substantial.

PROBLEM NO. 2

1. TITLE: Cost-Effective Methods for Training Truck Drivers.

2. PROBLEM: Current methods for training truck drivers use only classrooms, correspondence courses and on-the-road driving on school trucks. The use of actual trucks and gasoline has a large impact on the cost of training. Use of part task and full task truck simulators would reduce the cost considerably to employers and students as well as making training safer and would include more emergency situations. This solution is similar to that of training airline pilots through use of simulators though on a lower monetary scale.

3. OBJECTIVE: To make a cost comparison between the current methods of training truck drivers and proposed courses using different levels of simulation.

4. KEY WORDS: Truck driving simulator, part task trainers.

5. RELATED WORK: The Naval Training Equipment Center completed an in-house study in 1978 for the U.S. Marine Corps which showed that use of full task driving training simulators would not be effective for the Marine Corps wheeled vehicle Driver Training program. They found that use of part task and group trainers as well as actual vehicles would result in a cost savings for each student graduate over present training methods. An Army test at Fort Hood in 1975 also showed qualitative improvements through use of simulators.

6. URGENCY/PRIORITY: High Priority. The results would lower fuel use in consonance with the National Energy Conservation Plan.

7. COST: $80,000.

8. USER COMMUNITY: Universities with Driver Training schools, as well as those with Institutes of Transportation and Traffic Engineering, American Trucking Associations, FHWA, State Departments of Education and Transportation, U.S. Department of Education.

9. IMPLEMENTATION: Findings of this research would be used by Truck Driving Schools and Trucking Companies' Training Supervisors to revamp the truck driver training and upgrading/refresher courses and by Training Devices Manufacturers to select and market new training devices appropriate to the new training methods.

10. EFFECTIVENESS: The results of this research when implemented into a new training program should reduce the cost of training a new driver by 66% and reduce the need of actual trucks to a minimum.

PROBLEM NO. 3

1. TITLE: Driver Quality Measurement.

2. PROBLEM: Individuals and agencies concerned with the licensing and/or selection of drivers are continually faced with the problem of assessing the quality of driving behavior. Unfortunately, the techniques currently available for this purpose are far from reliable and are of questionable validity. Even accident involvement (as reflected in state motor-vehicle records) is not a reliable measure of driving quality since the great majority of accidents has been shown to involve previously accident-free drivers who may or may not display equal levels of driving quality.

3. OBJECTIVE:

   (1) Develop a means of objectively defining driving quality which can be evaluated through measurement of observable driving behavior.

   (2) Determine the reliability and validity of the selected measurement technique and the extent to which measured driving behaviors are stable, repeatable, or "characteristic" phenomena.

   (3) Estimate the suitability of the procedure for evaluating the effects of training, experience, impairments, etc.

4. KEY WORDS: Accident Liability, Accident Proneness, Driving Performance, Driver Characteristics, Driver Testing.

5. RELATED WORK: Greenshields, B.D., and Platt, F.N., Development of a method of predicting high-accident and high-violation drivers. Journal of Applied Psychology, 1967, 51, 205-210.

   de Savornin Lahman, L., Leggett, E.C., Stewart, J.R., and Campbell, B.J., Identification of unsafe driving actions and related countermeasures. (Report No. DOT-HS-5-01259) Chapel Hill: University of North Carolina, Highway Safety Research Centre, December 1976.

   Attwood, D.A., The effect of driving experience on objective measures of driving performance. Proceedings of the 23rd Annual Meeting, Human Factors Society, 1979, 277-281.

6. COST: $250,000 - $500,000.

7. USER COMMUNITY: National Highway Traffic Safety Administration.

8. IMPLEMENTATION: Findings of this research could be directly used by driver licensing agencies, courts, businesses who hire professional drivers, research organizations concerned with driver quality evaluation, driver trainers, etc.

PROBLEM NO. 4

1. TITLE: Definition of Limits and Characteristics of Primary Control Imputs.

2. PROBLEM: The state of the art in adaptive equipment to enable disabled people to drive is advancing, but progress is on an empirical basis because too little is known about how to interface the driver with the primary controls (throttle, brake, steering) especially with servo devices which have their own characteristics of lag, resonant frequencies, delay, and gain. The attempt is to duplicate the undisabled drivers control inputs and leave the vehicle controls fundamentally unchanged, but many such conversions compromise handling, avoidance maneuverability, and thus safety.

3. OBJECTIVE:

   (1) Through use of simulations and/or instrumented vehicles determine parameters of variations in gain, lag, and delay in intervening control systems.

   (2) Establish guidelines for adaptive control design related to system characteristics and type.

   (3) Continue progress toward an integrated single input for primary control practical for automotive application.

4. KEY WORDS: Vehicle Controls, Adaptive Equipment, Servos, Interfaces, Disabled Drivers

5. RELATED WORK: Rehabilitation Engineering Centers (primarily at Michigan), Veterans Administration Prosthetics Center, NASA, Southwest Research Institute, Texas A&M University.

6. URGENCY/PRIORITY: 50,000 - 100,000 driving disadvantaged people could gain independent transportation this way. Potential of better serving 1 to 2 million people, especially advanced arthritis patients.

7. COST: $200,000.

8. USER COMMUNITY: All physically disabled, potentially all drivers.

9. IMPLEMENTATION: Through Veterans Administration, National Institutes of Health, and U.S. Department of Transportation funding.

10. EFFECTIVENESS: See Urgency.

PROBLEM NO. 5

1. TITLE: Representation of Driver Characteristics

2. PROBLEM: The ability to analyze the influences of vehicle properties on driver-vehicle system performance is handicapped by the lack of suitable driver representations.

3. OBJECTIVE: The objective of this research is to identify, characterize, and quantify the range of driver control properties needed for analyzing and simulating driver-vehicle system performance.

4. KEY WORDS: Driver Control, Closed-Loop Simulation, Vehicle Handling.

5. RELATED WORK: Numerous researchers have developed computer algorithms for the simulation closed-loop control of highway vehicles. For example, preview time (or distance) and response time-lag are commonly used in driver representations based on control theory.

6. URGENCY/PRIORITY: This work is essential for

evaluating the control difficulties associated with vehicle systems - particularly, in safety related concerns with unusual vehicle configurations or marginally stable vehicles.

7. COST: $50,000 - $500,000.

8. USER COMMUNITY: NHTSA, FHWA, Articulated vehicle users, truck manufacturers.

9. IMPLEMENTATION: Investigate control problems of proposed or existing vehicle combinations or new types of vehicles.

10. EFFECTIVENESS: Reasonable operating speeds and suitable arrangements for towing could be determined. The necessary level of driving control for coping with poor vehicle systems could be estimated.

PROBLEM NO. 6

1. TITLE: Correlation of Eye Movement Patterns and Driver Control Strategy.

2. PROBLEM: As drivers learn to steer a car they control both heading angle and lateral position of the car. These two cues may be controlled using various strategies, some of which result in better and easier tracking than others. As drivers learn steering their eye movement patterns also change. The correlation between control strategy and eye movement patterns has not been established, nor is it clear whether changing the eye movement pattern necessarily changes the control strategy used or vice-versa.

3. OBJECTIVE: Since some tasks are sufficiently complex that a novice tries a number of strategies before selecting an optimum one, it is of interest to establish:

   (1) whether or not eye movement patterns and control strategies are correlated, and

   (2) whether or not directing a novice to use a particular eye pattern, such as one associated with an optimum strategy, results in the novice adopting that strategy.

4. KEYWORDS: Driver Education, Driving Performance, Eye Movement, Manual Control.

5. RELATED WORK: Smiley et al. (1980) used perceptual motor learning theory to develop a strategy model which describes the task of learning steering control in a car. The validity of the model was tested using data from novice drivers in the process of learning. Data from the drivers were modelled using manual control techniques. Changes in strategy with learning were evident. Eye movement data were also recorded using film. However, this technique proved too crude to reach any conclusions about the correlation of eye movement patterns and strategies.

   Smiley, A., Reid, L., and Fraser, T. M., "Changes in Driver Steering Control with Learning." Human Factors, 22(4). August 1980.

6. COST: $300,000.

7. USER COMMUNITY: Driver trainers, other instructors who teach complex tasks.

8. EFFECTIVENESS: If it is possible to help novices select optimum strategies for performing a task, a savings in training time would be realized.

PROBLEM NO. 7

1. TITLE: Evaluation of Driving Simulator Displays.

2. PROBLEM: The most common approach to evaluating real-world visual display systems for driving simulators is to measure the performance characteristics of the transmitting medium and its optical and photometric outputs and to obtain subjective judgments of the output by a group of observers. The evaluation process consists of comparing the performance characteristics and outputs to some criteria based on either broadcast television or simple physiological laboratory tests modified by the opinions of the observers. The net result is that by using present methods no consistent rating of specific visual systems for adequacy of information is possible.

3. OBJECTIVE: A method is needed for defining a performance criterion that will account for the important characteristics of simulated visual environment displayed to the driver of an automobile simulator in quantitative terms.

4. KEY WORDS: Driving Simulation, Driving Simulators.

5. RELATED WORK: None.

6. URGENCY/PRIORITY: To increase use of driving simulators requires adequate design guide for visual simulation.

7. COST: $100,000.

8. IMPLEMENTATION:

   (1) Identify the classification parameters appropriate to visual scenes based on automatic pattern techniques.

   (2) Define the visual cues used by vehicle drivers in accomplishing the driving task.

   (3) Based on the above, define the real-world scenes in forms more manageable for automatic classification and recognition purposes (this will represent for the particular environment a signature that can then be analyzed for its classification properties).

(4) Relate the data on the parameters mathematically in a matrix to permit prediction of the visual cue recognition from the processed information.

(5) Check the validity of this matrix with new visual scenes and new subjects.

9. EFFECTIVENESS: Will increase use of driving simulators for training and research.

PROBLEM NO. 8

1. TITLE: Relation Between Perception and Driving Capability.

2. PROBLEM: It is generally agreed that much information which is essential to the safe operation of a motor vehicle is acquired visually. This realization has resulted in considerable research attempting to relate various vision measures to driving performance. The results of this work have been somewhat disappointing, with the few significant correlations being low.

It is important to realize that vision as it has been measured in these studies is but the first step in a complex and incompletely understood process called "perception," which includes integration and interpretation of stimuli. We know that people differ in perceptual dimensions much as they do in visual dimensions but, except for the work on Field Dependence, little has been done to relate individual differences in perception to the ability to safely drive a car.

Researchers at HSRI, dealing with populations of brain-injured and normal persons, used a number of perceptual tests and related performance on them to driving ability. Correlations of about 0.7 were obtained between certain of the tests and driving ability measured both objectively and subjectively. The results are encouraging and suggest that further work would be worthwhile.

3. OBJECTIVE: There are three main objectives in the proposed program:

(1) Determine whether there is a significant relationship between perceptual measures and driving ability

(2) If so, develop a screening battery which can be administered by relatively unsophisticated persons

(3) Devise means for retraining, alerting, or otherwise compensating for measured perceptual difficulties.

4. KEY WORDS: Driver Perception, Visual Performance.

5. RELATED WORK: Reference has already been made to the volume of work on Field Dependence. More general work, except for the recent study by Sivak and others at the Highway Safety Research Institute, University of Michigan, is virtually nonexistent.

6. URGENCY/PRIORITY: This is a promising area. It is recommended that high priority be given to a pilot screening of sufficient size to be able to answer the question "is further work worthwhile?" Such a pilot study could probably be carried out for $100,000 - $150,000 in 1980 dollars.

7. COST: The total program would probably cost $500,000 - $750,000 in 1980 dollars.

8. USER COMMUNITY: National Highway Traffic Safety Administration.

9. IMPLEMENTATION: Assuming positive results, perceptual screening may be appropriate, especially as a part of driver education, with consequent tailoring of the curriculum to meet the special needs of students with significant deficiencies. It is possible that such screening could become part of the regular licensing process, with persons falling below designated cut-offs being referred for special training, etc.

10. EFFECTIVENESS: It is known that perceptual failures account for some crashes (e.g., the problem of motorcycle conspicuity). If the problem is serious enough, there could be a significant gain in terms of reduced accidents and associated costs to society.

PROBLEM NO. 9

1. TITLE: Effects of Motion Cues Using Variable Stability Vehicles.

2. PROBLEM: Driving simulators are currently fixed base vehicles, or in some cases limited moving apparatus. The effects of no motion, or limited motion cues, in these simulators have not yet been adequately established with comparisons to true motion. Comparison tests using a 3 degree of freedom simulator at Virginia Polytechnic Institute have shown there are in fact motion effects; however, to properly determine these effects additional research will be required using a variable stability vehicle such as those used by General Motors and in Australia. Currently, only the latter vehicle is operational; thus it will be necessary to rebuild and plan future use of a variable stability vehicle.

3. OBJECTIVE:

(1) Develop new variable stability vehicle or rebuild and improve existing vehicles.

(2) Plan joint fixed base simulator/full scale vehicle tests to determine effects of motion cues for different experimental applications.

(3) Utilize variable stability vehicle in other applications as in "on-the-road" simulator.

4. KEY WORDS: Motion cues, Variable Stability,

Handling.

5. RELATED WORK: Comparison of Human Driver Dynamics in an Automobile on the Road with Those in Simulators Having Complex and Simple Visual Displays. STI paper 173A, presented at the 55th Annual Meeting of the TRB, Washington, D.C., January 1976.
McLane, R. C., and Wierwille, W. W., "The Influence of Motion and Audio Cues on Driver Performance in an Automobile Simulator." Human Factors, 1975, 17(5), pp. 488-501.

6. URGENCY/PRIORITY: While not of the highest urgency, this area represents a critical need.

7. COST: unknown.

8. USER COMMUNITY: Research, accident avoidance vehicle design.

PROBLEM NO. 10

1. TITLE: Evaluate the Effectiveness of Advanced Driver Training Techniques.

2. PROBLEM: A number of "advanced" driver training programs have been devised and operated in the past twenty years. These programs have been designed to give drivers "hands-on-wheel" practice in accident avoidance techniques and more generalized vehicle limit maneuvers such as evasive maneuvering, serpentine steering, high deceleration controlled braking, off-road recovery, and skid control on slippery surfaces.
While such programs are of substantial apparent effectiveness and generate considerable anecdotal praise from proponents and trainees, an objective, large scale evaluation of the effectiveness of such programs has not been carried out, leaving the real value of such programs open to question.

3. OBJECTIVE: This project will assemble a curriculum of the most promising accident avoidance driving behaviors, develop techniques for quantifying driving performance, establish criteria to define driving proficiency, train to criterion a large sample of drivers, measure the retention of training at selected intervals, follow the detailed accident involvement history of the trained group and a control group over a three to five year period, and produce a benefit/cost analysis of the training program.
The project will establish the overall effectiveness of advanced driver training in terms of accident (or accident severity) reduction and will provide intermediate measures of skill improvement and retention.

4. KEY WORDS: Advanced Driver Training, Emergency Reaction Driving, Program Evaluation, Benefit/Cost Analysis.

5. RELATED WORK: Research/training projects of a similar nature have been carried out by the U.S. Coast Guard and by Essex Corp. under NHTSA sponsorship. Both projects had favorable results but were carried out on a limited scale.

6. URGENCY/PRIORITY: Moderately high. If programs of this type are found to produce significant reductions in accident loss, they could be implemented rapidly.

7. COST: $1 - $3 million.

8. USER COMMUNITY: NHTSA.

9. IMPLEMENTATION: Successful programs of this type could be integrated into existing driver education curricula. Programs could also be instituted by commercial driver training organizations, military services (who loose a large number of personnel through motor-vehicle accidents), and commercial fleet operators who are concerned with the control of losses.

10. EFFECTIVENESS: Implementation of more effective training programs would produce a significant reduction in motor vehicle accident losses.

PROBLEM NO. 11

1. TITLE: Complexity of Simulated Visual Image Requirements for Cost Effective and Positive Transfer of Training.

2. PROBLEM: Many methods exist presently to present visual information in simulated vehicular environments. These methods range from photographic presentation of the visual scene to model board displays to sophisticated computer-generated imagery systems. The latter appears to be the method currently preferred and will find greater application for the future. Such systems offer a variety of advantages in terms of flexibility and the capability of being applied to any visual scenes necessary when compared to model board displays or point light source techniques. However, the cost of computer-generated imagery is expensive but competitive with other techniques which do not share the flexibility and adaptability advantage. Of course, the more complex the visual scene generated, the more expensive the cost of visual simulation. Basic visual research has not yet addressed requirements necessary for determining the fundamental visual information required for positive transfer of training from simulator to the real world.

3. OBJECTIVES: Computer-generated imagery (CGI) employed by many simulator facilities across all vehicular simulators (i.e., flight, ship, tank, submarine, automobile, etc.) has many advantages over alternative forms of visual simulation. For training, it is essential to determine the most cost effective form of CGI necessary to promote positive transfer of training. Various levels of visual complexity, line drawings, line drawing plus texture in the form of shading, dots, etc., and full form color should be compared to determine their effectiveness in promoting

positive transfer of training to the real world. If such effects can be achieved by line drawings plus textures, then a considerable savings can be appreciated, broadening the application of simulation by reducing cumbersome costs.

4. KEY WORDS: Visual Fidelity, Transfer of Training.

5. RELATED WORK: None.

6. COST: $400,000 - $800,000.

7. IMPLEMENTATION:

   (1) Define levels of visual complexity with respect to Gibson's Ecological Approach to Perception. (Flow Field Analysis).

   (2) Determine vehicular type to be employed for study.

   (3) Determine performance measures for assessing transfer of training.

   (4) Define scenarios under which training and transfer studies will be conducted.

8. EFFECTIVENESS: Provide breakthrough in cost-effective application of simulators for training of highly dependent visual tasks which currently require expensive visual scenes for lack of empirical data contrary to this current practice of high-cost, high-fidelity visual simulation.