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BUS DRIVER TRAINING SIMULATOR ASSESSMENT

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FINAL REPORT

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16. Abstract

Simulation has become an increasingly important tool in driving research, highway research, and vehicle design. This report documents the results of an investigation into the feasibility of developing a driving simulator as a means of teaching safe driving and other operating techniques in the training of bus operators. During this investigation, an Advisory Committee, consisting of representatives from small, medium, and large transit properties and from the American Transit Union, provided data on training programs, training costs, and training needs. The AFL-CIO Appalachian Council Research Department furnished the results of their survey on transit training needs and shared their experiences in developing and implementing a standards bus operator training program. Also, the Massachusetts Bay Transportation Authority made their training data available and arranged a tour of their training facilities. Features required of a driving simulator to meet training needs were identified, and the cost of implementing and operating such a simulator were assessed. This report describes the various types of simulators, the benefits of simulation, and the potential benefits of a driving simulator for transit training. This report also presents an evaluation of existing applicable driving simulators, the tradeoffs of developing costs and operational costs versus the effectiveness of the desired features, and current training programs. This study concludes that due to the high costs of simulators with the required features, it appears that no cost benefit would accrue with the use of such a simulator. Therefore, no training time savings and safety benefits could be documented to justify the use of a driving simulator for bus operator training.

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PREFACE

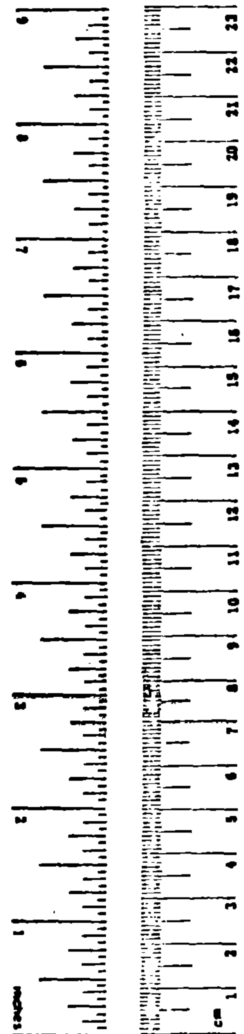
The authors would like to acknowledge the contribution of the Advisory Committee, consisting of representatives of small, medium, and large transit properties, in providing information on current bus driver training programs and training needs. The AFL-CIO Appalachian Council Research Department was most helpful in furnishing the results of their survey on transit training needs and in sharing their experiences in developing and implementing a standard bus operator training program. A special thanks should be given to the Massachusetts Bay Transportation Authority (MBTA) for making their training data available and for arranging a tour of their training facilities.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

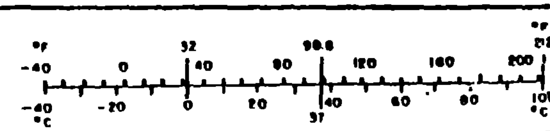
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

1.1 GENERAL

Simulation has become an increasingly important tool in driving research, highway research, and vehicle design. This report presents the results of a study of the feasibility of developing a simulator for bus driver training.

The Bus Driver Training Simulator Evaluation was a study of the use of an automated training device as a means of teaching safe driving and other operating techniques in the training of bus drivers. This effort was performed for the Urban Mass Transportation Administration's (UMTA) Office of Transportation Management.

During this investigation the expertise of two groups was used. First, an Advisory Committee, consisting of representatives from small, medium, and large transit properties* and from the American Transit Union, provided data on training programs, training costs, and training needs. The six members of the Advisory Committee and their affiliations are identified in Table 1. Second, the AFL-CIO Appalachian Council Research Department made available the results of their Transit Training Needs Survey, as well as information on their Bus Operator Training Program, a standardized training program being developed for this group of blue collar transit employees. Both of these programs have been funded by UMTA.

The remainder of this section will describe, for background information, the various types of simulators, the benefits of simulation, and the potential benefits of a driving simulator for transit training. Section 2 presents the objectives of this

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*In this report transit property size is defined as follows:

Small - less than 50 buses in fleet
Medium - 51 to 100 buses in fleet
Large - over 100 buses in fleet.

TABLE 1. ADVISORY COMMITTEE

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investigation. In Section 3, the results of a survey of transit driver training programs are presented. Transit training needs and the capabilities required of a driver training simulator to meet these needs are discussed. An evaluation of existing applicable driving simulators is given in Section 4. Section 5 presents the tradeoffs of development costs and operational costs versus the effectiveness of the desired features and current training programs. The conclusions and findings are given in Section 6.

1.2 BACKGROUND

A simulator is a laboratory device which allows the imitation of a real event. Under test conditions, the simulator can reproduce situations likely to occur in actual performance.

Driving simulators generally consist of a driver's station, a visual system, an instructor's console, and a fixed or moving base. A simulator with a motion base is one in which the simulator operator can be displaced in space in one or more dimensions. A fixed-base simulator provides, at most, vibratory stimulation simulating road and engine flexibility. The driver's station contains a mock-up of a vehicle seat, controls, instrument panels, and windshield display. The instructor's console allows control and monitoring of the operator's performance. The typical elements of a simulator are shown in Figure 1.

The method of reproduction of the visual field is the area where differences in driving simulators occur. The most common visual display techniques include the following:

1) Motion picture display simulator - Film taken of a roadway is projected onto a screen for viewing by the driver trainee.

2) Scale model closed circuit TV display simulator - A large scale model of a miniature roadway system is used with a moveable TV camera and TV monitor.

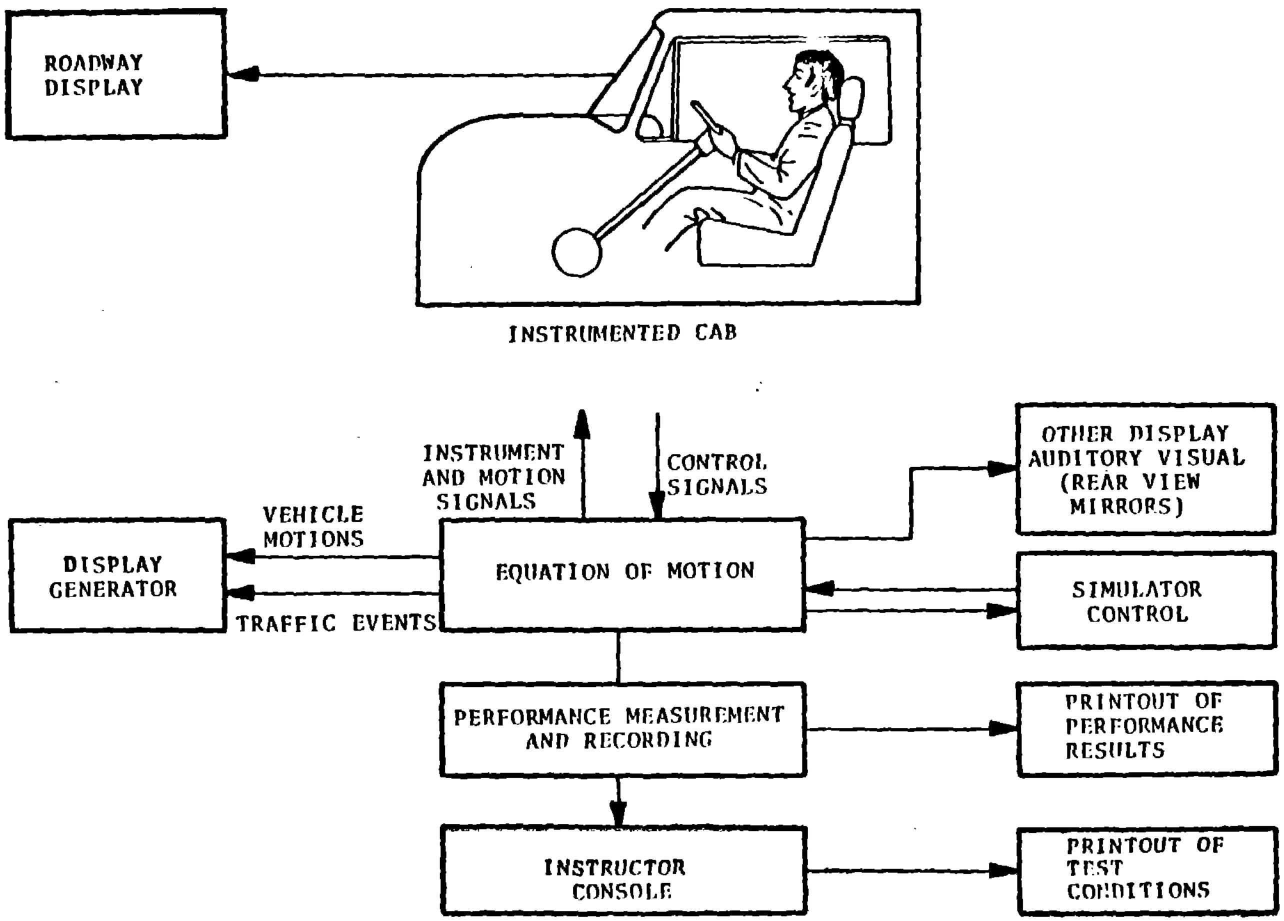

FIGURE 1. DRIVING SIMULATOR COMPONENTS-(CGI TYPE)

3) Computer generated image simulator (CGI) - a numerical description of the environment is stored on a digital computer. The computer generates a synthesized video signal for display on a cathode ray tube (CRT) for viewing by the driver/subject.

4) Point-light source - This shadowgraph type of simulator uses a fixed-point light source and a transparent model. Light is passed through the model and projected onto the viewing screen.

Each of these technologies has advantages and limitations. While the "canned" films provide excellent detail, they are not interactive. The scale model closed-circuit TV simulator limits the response rates and gaming area. Computer generated image simulation provides a truly interactive system, but complex imagery requires corresponding complex computation, and this may slow down the rate of the simulation. A comparison of features and major disadvantages of the four simulation visual approaches is given in Table 2.

1.3 BENEFITS OF SIMULATION

There are over twenty research driver simulators now in use.[1] The control and safety aspects of a simulator make it a useful and often less expensive tool for driving research and training. A controlled environment is valuable in driver training because precise measurements are possible. Original conditions can be easily reproduced. In addition, the instructor has the ability to create and repeat any desired traffic pattern. Repetition is important in learning maneuvers, such as right turns. Other controls, such as roadway characteristics, driving conditions, and vehicle performance are also possible with a simulator.

TABLE 2. COMPARISON OF SIMULATION VISUAL APPROACHES

SIMULATOR TYPE	SUMMARY OF FEATURES	DISADVANTAGES
Motion picture (MP)	Good Realism 360° Presentation Possible Experimental Control (Repeatability) Scenario Flexibility Medium Price Range ($200,000 to $1,000,000)	Not Interactive
Computer Generated Image (CGI)	360° Presentation Possible Scenario Flexibility (Not Sequential Interactions) Highly Interactive Easily Updated	High Initial and Operating Costs Stylized Display - Lacks Realism
Camera/Model	Good Realism (Potential for Improvement) Max 140° Field of View Interactive	High Initial and Operating Costs
Shadowgraph	Low Initial and Operating Costs ($100,000 to $300,000) 360° Field of View	Realism Limited Scenario Flexibility Expensive

The driving task involves the recognition of hazards, decision making, and performance. With a simulator, the driving student can be exposed safely to the various road and traffic conditions needed to develop important perceptual skills and judgment.

Stress situations can be safely introduced and potentially dangerous situations, e.g., interaction with oncoming traffic, can be experienced without danger to the trainee, instructor, or others.

The potential benefits of a driver training simulator adapted to a transit environment include:

- reduction in the on-road time required for training,
- reduction in non-revenue vehicle use,
- reduction in fuel consumption,
- minimization of accident risk,
- reduction of vehicle damage through driver inexperience,
- a shared mobile unit as an alternative to the "buddy system" for small properties, and
- access to facilities currently beyond a single small property's budget.

2. OBJECTIVE

Transit property managers have expressed interest in the use of a simulator for training bus drivers. This investigation was undertaken for UMTA to make a recommendation concerning the feasibility of developing a driving simulator for use in a transit training environment. The final determination was to be made through the accomplishment of several tasks.

First, existing transit industry training programs were examined. Selected properties, representing small, medium, and large transit properties, were evaluated with respect to goals, time in training, cost effectiveness, techniques employed, and equipment used. Transit training needs were identified with the assistance of the advisory committee.

Next, a survey was made of existing surface simulators. Both currently marketed products and special one of a kind laboratory simulators were considered.

Then, the identified troublesome aspects of bus driver training programs were examined with regard to the possibility of a simulator to meet those needs. Features required of a bus driver training simulator were identified. The cost of implementing the performance features and the cost of operating and maintaining such a simulator were assessed.

The simulator configuration, as defined above, was compared to existing training in regard to cost and effectiveness.

3. TRANSIT TRAINING SURVEY

3.1 GENERAL

Four public transit properties, representing the various size properties, and one private transit property were surveyed with respect to existing transit industry bus driver training programs. The cost, length of training, effectiveness, equipment employed, techniques employed, and goals were examined.

The properties surveyed were the Massachusetts Bay Transportation Authority, Metro Area Transit of Omaha, the Chicago Transit Authority, Pentran of Hampton, VA, and Greyhound Lines Inc. In addition, the results of the AFL-CIO Transit Training Needs Survey Report were used for general background in transit training programs and needs.

Subjects common to transit training programs surveyed were:

1) Orientation,
2) Vehicle Familiarization and Orientation,
3) Operating Techniques and Maneuvers,
4) Defensive Driving Techniques,
5) Accident and Emergency Procedures,
6) Passenger Relations, and
7) Routes and Fare Structures.

The greatest variation occurs in small transit properties using the "buddy system."

3.2 TRANSIT TRAINING NEEDS

The AFL-CIO Training Needs Survey of 62 properties in the Appalachian Region identified the needs of bus operator training programs by the size of the fleet. All properties had requirements for operator training programs in accident prevention, passenger relations, pride and motivation, and driving habits.

Medium and large properties were found to have a need for route familiarization and for periodic retraining. All properties felt a lack of materials, time, and money.

Similar needs were identified by the Advisory Committee and other transit properties not included in the AFL-CIO survey. The teaching of defensive driving techniques and maneuvers needs improvement in order to reduce the accident rate per million miles for transit properties. Retraining is often neglected in bus operator training plans. A requirement exists for an objective method of selecting and testing trainees. Routes, schedules, and fare structures were also identified as items to be taught. For part-time workers, a training program stressing route familiarization is needed, so that routes may be assigned to these operators on an as needed basis.

3.3 CRITERIA FOR A DRIVING SIMULATOR FOR OPERATOR TRAINING

For some of the bus operator training identified as requiring improvement, a driving simulator could be employed. Accident prevention through defensive driving techniques and maneuvers, route familiarization, retraining in these subjects, and selection and scoring of trainees are some areas which would benefit from the use of a simulator. A simulator would not be useful, however, to teach motivation, fare structures, and schedules.

Certain requirements must be placed on a driving simulator if it is used as described above. For example, defensive driving techniques, such as collision avoidance, would require the ability to simulate other vehicles in the visual scene. A field of view of approximately 180° is necessary in order to perceive such hazards as cross traffic, pedestrians, and passing vehicles.

The objective selection and testing of trainees would require a scoring and recording capability as part of a computer subsystem. Programmed instruction, the process of adjusting the course with simulations based on the performance of the trainee, could also be part of the computer subsystem. All necessary descriptions of vehicle performance and interaction with the environment are stored in the vehicle simulation computer and image generator. With this information, driver performance can be analyzed and a decision made on-line as to what exercises need to be repeated.

Kinesthetic and auditory cues, sufficient to produce realism and to avoid such problems as motion sickness in the users of the simulator, are necessary. The amount of realism necessary is, of course, open to question. It is claimed by some researchers[2] that cost estimates for driving simulators are too high because more realism is specified than is needed. Because of this, driving simulators have not been used when they would have been of value. However, motion cues are important for the training of defensive driving maneuvers such as accident avoidance. The inclusion of a motion base is relatively expensive. Auditory cues enhance the simulation without adding much to the total cost and hence should be included in a training simulator.

Table 3 summarizes the simulator requirements for areas of need identified for bus driver training.

TABLE 3. SIMULATOR REQUIREMENTS FOR DEFINED AREAS OF NEED FOR TRANSIT BUS DRIVER TRAINING

AREAS OF NEED	REQUIRED SIMULATOR CAPABILITIES
1) Defensive Driving	Simulation of Other Vehicles (Variable Visual Stimuli) Field of View ~180° Horizontal, 30° Vertical Visual Feedback or Similar Interactive Capability (Speed, Displacement Feedback) Scenario Variation (Speed Range, Driving Situation, Targets), Motion Cues
2) Route Training	Amount of Realism for Identifying Landmarks, etc. Scenario Flexibility
3) Selection and Evaluation of Trainees	Computer Subsystem with Storage Capability for Recording Descriptors of Vehicle Performance and Environment Interaction (Steering, Braking, Acceleration, Speed Information, Direction of Gaze, etc.)

4. SURVEY OF EXISTING SURFACE SIMULATORS

Currently, there are no transit properties that employ simulators in their training programs for bus operators. For this reason, simulators, used for truck or automobile driver training, were evaluated for applicability to bus transit training. Driver simulation systems, capable of 100 percent reproduction of the driving task, are not available. The systems reviewed vary in the degree of simulation that can be achieved.

4.1 MANUFACTURERS OF DRIVER SIMULATION SYSTEMS

4.1.1 Atkins-Merrill, Inc.

A comprehensive search, undertaken to identify and obtain detailed information from corporations involved in manufacturing hardware simulation or lower technology multi-media teaching machines utilized in driver training, produced only two companies actively engaged in the manufacture of hardware systems designed for, or adaptable to, bus driver training.

The simulation systems of Atkins-Merrill, Inc. of Tulsa, Oklahoma are primarily designed for in-flight pilot training. More recently, however, they have been involved in developing driver simulators that are of interest to this review. Currently they are developing a shuttle car simulator for the U.S. Bureau of Mines, which will simulate a mine shuttle car with adequate fidelity for training. This will provide forward and rear visual display via a rear screen projection system, practice in the control of the shuttle car, adherence to prescribed procedures, hazard/contingency recognition and reaction, and feedback to student and instructor. There is also a means for educational specialists to produce and update training films. This project is in its early development stages with projected cost approximately $250,000 per unit.

Atkins-Merrill was also the developer of the Ryder Truck System, a 14-speed truck-tractor transmission shifting simulator currently in use. This simulator consists of a mock driver compartment of a tractor-truck with motion/slide display and sound. The manufacturer is considering expanding this hardware application into a more sophisticated unit with the addition of motion base and a film strip visual system for an additional $106,000 per unit. The cost of the shifting unit alone is $80,000.

The latest driver simulation system, produced by this manufacturer as a pilot project for the U.S. Army, uses a high intensity light to project visual images.[3,4] The unit is mounted in a three to four foot diameter disc attached to the top of the vehicle unit. In the Army installation, the unit is mounted over a five-ton Army truck cab. This visual system provides a 360 degree display for the driver in the simulator. However, the length of the program scenario is limited to the size of the model disc. The Army truck simulator application does have the capacity to provide the student with vehicle motion and sound in relation to the driving activity. The configuration for this simulator is shown in Figure 2.

This simulator system has two limitations. The driver is limited to interfacing with fixed environment situations, since the system cannot be programmed for interaction with other moving vehicles. Also, the technology involved in the system and its size require that it be a fixed installation.

The final cost data for this pilot project is not available. However, the manufacturer estimates that the cost would be in the area of $300,000 per unit. The simulator system is the most technically advanced driver simulator that has been developed to date for a driver training application.

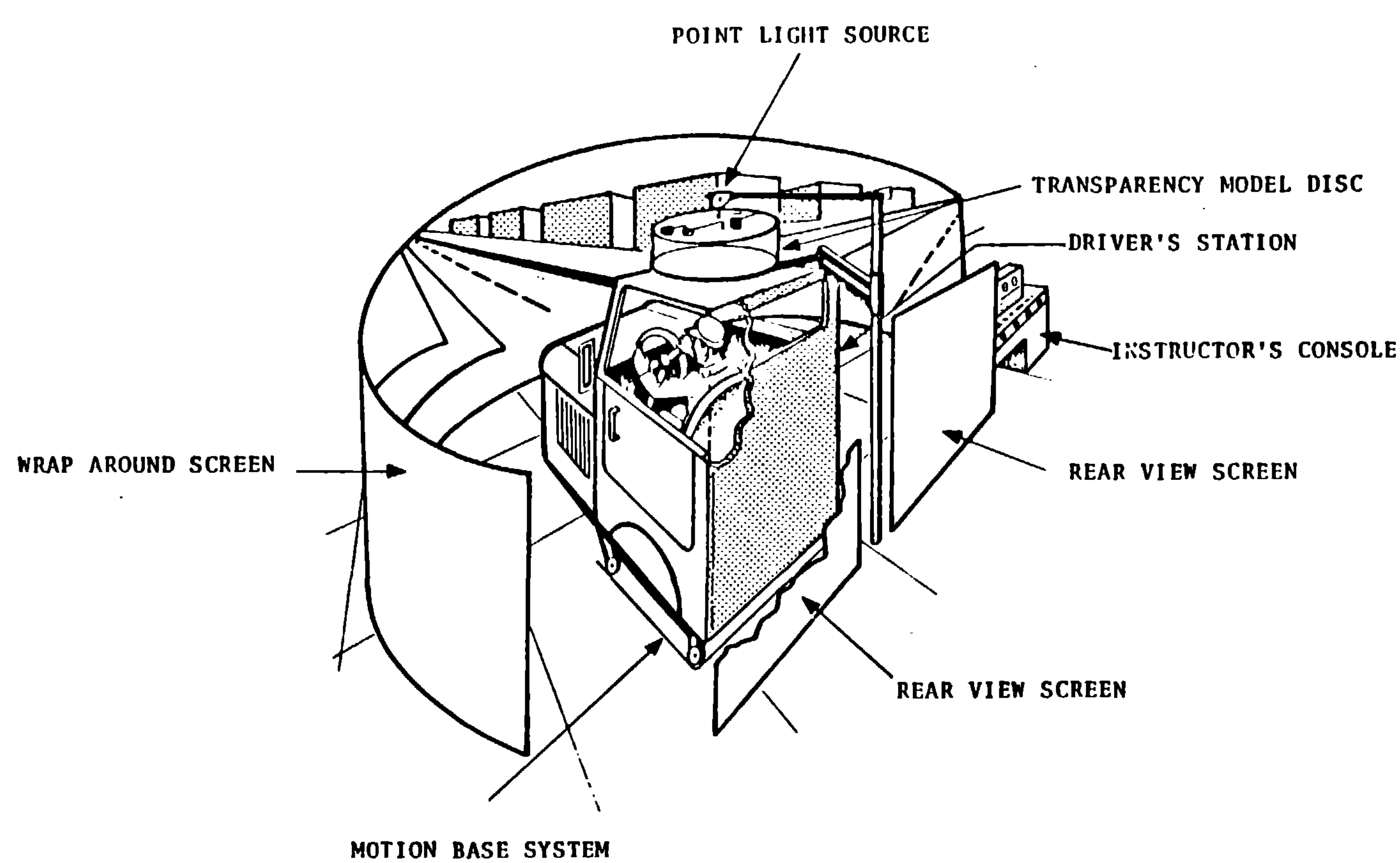

FIGURE 2. ATKINS-MERRILL ARMY TRUCK SIMULATOR

Atkins-Merrill is also involved in the manufacture of a multi-media teaching machine, the "Student Response Monitor," which provides the availability of all modes of multi-media audio/visual presentations, and the recording of student response through individual electronic student response stations. This system also has a central mini-computer unit available which allows automatic grading and analysis of individual student performance.

The Student Response Monitor system is a group paced classroom teaching system that allows the student to interact with a variety of preprogrammed multi-media audio/visual packages and/or direct lecture presentations. A principal benefit is that it does allow for a programmed learning package to be structured, giving the student immediate feedback on the learning process. This system does not attempt to achieve simulation.

The basic "Student Response Monitor" system with 20 student response stations is $8,000. The mini-computer and print-out capability is an additional $10,000.

4.1.2 Doron Precision Systems, Inc.

Doron Precision Systems, Inc. of Binghamton, New York is also involved in the manufacture of hardware utilized in driver training. Doron manufactures the hardware and the software programs produced by the Aetna Insurance Company. They have evolved as the successor to the early driver trainers utilized in high school driver education. These devices were originally pioneered in an effort to reduce the behind-the-wheel training time and cost in high school student driver education programs. There are approximately 3,000 installations in use throughout the United States.

This training system consists of a mock-up with typical vehicle (car) controls. The student responds to a situation on the visual display screen in front of him. This system, while an advanced teaching machine, does not achieve a simulation as defined by this study. The present cost is $56,790 for eight training positions, control console and score printer.

Doron is beginning to develop systems and programs for both truck and school bus driver training and is currently in the process of installing a ten-speed transmission shifting simulator with eight positions for a vocational training school.

In addition, Doron is developing a system for transit bus drivers which will be modeled after the unit used in high school driver education. This unit would be a teaching machine, not a full simulator. The bus driver system being developed will use a 12-inch television screen for display and will have the capability for utilizing a mini-computer for controlling the program and accumulating individual student performance, etc. At the present time, software programs planned for this hardware system include:

- identification of hazards,
- city traffic - light,
- city traffic - heavy,
- emergency problems - decision vs. perception, and
- emergency problems - handling.

Doron anticipates that their 8-unit bus training system, including control console, printer and installation would cost $56,790. However, none of the hardware of this system has yet been manufactured, nor is the software in production.

4.2 ADDITIONAL SIMULATORS

The remaining simulators now in use are one of a kind units specially built for a particular type of driving research. One such simulator, developed by the Southern California Research Institute for human performance studies, uses all digital techniques to compute and generate vehicle dynamics, roadway data base, visual scene and performance measures. The tasks from which a scenario may be composed include curve following, visual search and route sign recognition, vehicle control with simulated heavy wind gusts, obstacle avoidance, following a lead car at constant distance, risk taking (car passing), and peripheral signal detection. The cost of the hardware, which included a general purpose digital computer, a vector generating graphics system and an analog-digital interface was $100K. The software costs were approximately $30K.

While this system allows some interaction with another vehicle (passing tasks and following a lead car), more traffic interaction is required for a transit environment. This would require upgrading the vector generating system and also improving the software. Since the display is stylized, the degree of realism may not be great enough to make it an acceptable alternative.

Another promising development is the video disk. If used as a visual system for a driving simulator, it could combine the advantages of the motion picture visual systems with those of computer generated visual systems. The realism of the "canned" films would be provided. Since the video disk system is easily computer-controlled, the simulation would be truly interactive. Video disk technology, while new, is at an advanced state. Costs are expected to drop in a fashion similar to video cassette equipment. No manufacturer presently offers this type of visual system for a simulator. However, using cost data from other computer controlled video disk applications, it appears that a simulation system could presently be developed for under $200K. These estimates are based on applications developed by the MIT Architectural Machine Group including the moving map funded by the U.S. DOD, Advanced Research Projects Agency (ARPA), Office of Cybernetics Technology and the maintenance training course funded by the U.S. Navy, Office of Naval Research.

5. DISCUSSION

The cost of present simulator systems, in use or being developed, strongly suggests that only the very largest transit properties could afford the investment for the more advanced simulator systems. The current state-of-the-art for total or partial simulation for bus driver training has not yet reached a point where a practical field tested installation can be made.

The evolving technology for possible bus driver training that has the potential to achieve a high level of driving simulation has disadvantages. Driver training simulators require a more sophisticated environmental program and, as a result, are more difficult to produce than flight simulators. For example, a typical driving environment of freeway, local streets, or open highway provides a far greater multitude of possible conflicts and a significantly greater range of pictoral presentations of environment than does a typical flight situation. Essentially, an in-flight simulator, dealing with normal flight and emergencies or take-off and landing procedures, requires a relatively straight forward environmental visual display.

A simple visual representation of a city driving environment with the multitude of interactions with pedestrians, parked vehicles, on-coming traffic, intersecting traffic, etc., presents significantly greater environmental problems to master for simulation. In addition, sound and motion that corollate to the driving environmental situation presented need to be provided.

The most technologically advanced driver training simulator reviewed was the 5-ton Army truck simulator application. As technologically advanced as this simulator is in terms of 360 degree visual system with sound and motion, it does not have the capability to provide the multiplicity of environmental interactions in its display presentation that are needed for comprehensive driver training. The environmental situation presented in

this simulator is confined to portraying streets, intersections and other fixed, immobile elements where there is no interaction with other moving traffic.

The review of available research to determine possible savings in training time and/or improved learning produced mixed findings. In a study[5] to determine the effectiveness of automobile driver instruction programs for the Oregon Motor Vehicle Division, David G. Crosley investigated the influence of five factors, including simulation training. While students with simulator training had slightly fewer accidents overall than students without, the differences were not statistically significant.

In J.A. Cookson's study,[6] "The Effects of Simulation on Violation and Accident Rates of Rural Montana Traffic Education Students," similar findings were reported on accident rates, but there was a significant difference between the violation rate of the two groups, with the simulation group the lower of the two. Studies,[7] conducted in Florida by the National Safety Council, concluded that simulation experience should be offered, not as a substitute for any part of the driver training program, but as an additional phase designed to enrich course offerings. Research[8] to determine the effect of driver education simulation on student performance has suggested that simulators and multiple car ranges be used in addition to the driver training program. A reasonable conclusion suggests that little or no savings in training time would be achieved. If this conclusion is correct, there is little possibility of recovering the capital investment of such a simulator training system.

Table 4 shows the various systems reviewed for both simulation and multi-media teaching machines. In each instance the training system was categorized to determine if the particular simulator and/or teaching machine system could perform the basic bus driver training functions that were identified. Table 4 indicates that the multi-media systems produced by both manufacturers can be programmed to accommodate the greatest variety of

TABLE 4. COMPARISON OF SIMULATORS WITH TEACHING MACHINES

Manufacturer	Can Teach Skill Training	Can Teach Defensive Driving	Can Teach Non Driving Function	System Mobile	Estimated Cost
ATKINS-MERRILL					
Hardware Simulators (Army Truck)	yes	no	yes	no	$300,000
Shifting	yes	no	no	yes	$ 80,000
Multi-Media Systems (teaching machines)	yes	yes	yes	yes	$ 8,000 20 positions
Software Simulators	yes	no	yes	DNA	Included above
Multi-Media Systems	yes	yes	yes	DNA	
DORON					
Hardware Simulators - (None Available)	DNA	DNA	DNA	DNA	
Multi-Media (Driver Trainer Units)	yes	yes	no	yes	$ 56,790
Software Simulators	DNA	DNA	DNA	DNA	
Multi-Media	yes	yes	no	DNA	Included above

Yes - The hardware system has capability of performing required functions even though current system is not available.
No - The hardware and/or software system cannot perform needed functions.
DNA - Does Not Apply

training programs for the primary driver training areas identified. In addition, these systems can be acquired at a fraction of the cost of simulators. Those transit properties, training a large number of individuals annually, should be able to produce cost effective training from these types of systems.

While there is a great deal in current literature related to the possible safety impact of high school driver education programs, including the use of the driver trainer system, it has not been firmly established that safer drivers have been produced. Whether or not the same types of training devices will produce a safer commercial vehicle driver would have to be addressed in a study which specifically utilizes hardware and software programs designed for heavy duty commercial drivers and which would make an appropriate research model designed to develop useful data.

A limited survey of transit properties was made to approximate the average cost of training an individual inexperienced in bus transit driving. The results of this survey indicate that $2500.00 is the approximate average cost of training a new driver. For most properties, less than 200 new drivers are trained annually. In addition, in the behind-the-wheel portion of driver training for medium or large properties, a range of 45 to 68 gallons of fuel per student is used.

To consider the possible cost benefits of a driver training simulator, a typical training class model was developed based on the results of a training survey assumed to be representative for the transit industry. The following assumptions were made. Student daily wage was set at $30.00. The daily wage for the behind-the-wheel driver instructor was set at $80.00. The classroom instructor was assumed to be a salaried supervisor, and no wage cost was assigned in the model. An average of two hundred drivers a year are to be trained by the typical property, and class size is set at twenty trainees. Based on the transit survey, the training course is 22 days in length and includes 4.3 days of classroom instruction and 17.7 days of behind-the-wheel driver training.

A two student per instructor ratio is assumed, using one student driver and one student observer per instruction situation.

Due to the mixed findings of the literature search on time saving of behind-the-wheel training with the use of a simulator, a specific time saving was not identified. For purposes of this model, an assumption was made that a possible twenty percent behind-the-wheel time reduction would be achieved with the use of a driver simulator.

In assigning simulator time versus behind-the-wheel, it was assumed that for an adequate transfer of learning to occur, two hours of simulator training was required for each hour that behind-the-wheel training was reduced.

Currently, the learning transfer time ratio between the typical driver education system used in high schools and behind-the-wheel time is that four hours classroom trainer time may be substituted for one hour behind-the-wheel. Unlike high school driver education which deals with beginning drivers, bus driver training involves teaching experienced auto drivers how to drive a bus. It was assumed that a higher rate of learning transfer would occur and, therefore, the more conservative ratio of two hours simulator versus one hour behind-the-wheel was used for this model.

Table 5 indicates that class cost without using a simulator was $27,360 and required 22 days. The class, using a simulator as modelled, cost $26,660 and required 25.5 days of training, a savings of $700 in training 20 students using the simulator. This assumes that the cost of any additional instruction time on the simulator will be included in the operational costs of such a system.

For the four types of simulators discussed in Section 1, acquisition and maintenance costs are estimated as follows. The shadowgraph type simulation (like the Army truck simulator) would cost about $300,000 and have an operation and maintenance cost of $60,000/year. A motion picture simulation with the required capabilities would cost $300,000 to $1,000,000 with operational

TABLE 5. COMPARISON OF SALARIES AND COURSE LENGTH (STANDARD VS. SIMULATOR TRAINING COURSE)

Case I: On-Road Time Reduced by 20 Percent (Replacement with Simulator Training Hours at a 2:1 ratio).

	COURSE LENGTH (DAYS)		INSTRUCTOR DAYS/COURSE	
	NORMAL	WITH SIMULATOR	NORMAL	WITH SIMULATOR
Classroom	4.3	4.3	-	-
Behind Wheel	17.7	14.2	177	142
Simulator	0.0	7.0	0	0*
Total Training	22.0	25.5	177	142

	SALARY DATA (DOLLARS)		
	NORMAL	WITH SIMULATOR	SAVINGS WITH SIMULATOR
Salary/Student/Course	660	765	-
Total Student Salaries/ Course	13,200	15,300	-2,100
Annual Student Salaries	132,000	153,000	-21,000
Instructor Salary/Course	14,160	11,360	2,800
Yearly Instructor Salaries	141,600	113,600	28,000
Total Yearly Salaries (Students and Instructors)	273,600	266,600	7,000

*Assumption is that instructor is not required for any of the simulator training time (unlikely). Operational personnel costs are included in maintenance cost.

costs as high as $100,000/year. State-of-the-art CGI and camera/model systems would have even higher initial and operational costs.

A $700 savings per class represents only a $7000 savings per year for a transit property training two hundred students annually. Additional savings occur due to decreased fuel use as a result of reducing behind-the-wheel driving instruction. The survey data indicated that fuel use for driver training averaged 65.2 gallons per student trained. With the twenty percent reduction in behind-the-wheel driving, a savings of 13 gallons per student would be realized. For a transit property training 200 new drivers annually, this would only be a $5200/year saving, even at the predicted fuel cost of $2/gallon. No additional savings, as a result of decreased bus use, is considered here as all properties surveyed indicate that regular in-service equipment is used in training. As a result of decreased bus use, a savings in the wear and tear of equipment is possible, but no dollar savings can be estimated.

Using the acquisition and operation costs of $300,000 and $60,000 for the lowest priced type of simulator, it can be seen that with the optimistic fuel and salary savings of $12,000 annually a transit property would not realize any cost benefit from simulation.

Even if a fifty percent reduction in behind-the-wheel driver training is realized, and a one-to-one substitution could be made with simulator training from Table 6, it can be seen that a salary savings of $70,400 would be realized. For the shadowgraph type of simulation it would require almost 15 years before a large transit property would derive any cost benefit.

TABLE 6. COMPARISON OF SALARIES AND COURSE LENGTH (STANDARD VS. SIMULATOR TRAINING COURSE)

Case II: On-Road Time Reduced by 50 Percent (Replacement with Simulator Training Hours at a 1:1 Ratio.)

	COURSE LENGTH (DAYS)		INSTRUCTOR DAYS/COURSE	
	NORMAL	WITH SIMULATOR	NORMAL	WITH SIMULATOR
Classroom	4.3	4.3	-	
Behind Wheel	17.7	8.9	177	89
Simulator	0.0	8.8	0	0
Total Training	22.0	22.0	177	89
	SALARY DATA (DOLLARS)			
	NORMAL	WITH SIMULATOR	SAVINGS WITH SIMULATOR	
Salary/Student/Course	660	660	-	
Total Student Salaries/Course	13,200	13,200	-	
Annual Student Salaries	132,000	132,000	-	
Instructor Salaries/Course	14,160	7,120	7,040	
Yearly Instructor Salaries	141,600	71,200	70,400	
Total Yearly Salaries (Students and Instructors)	273,600	203,200	70,400	

*Assumption is that instructor is not required for any of the simulator training time (unlikely). Operational personnel costs are included in maintenance costs.

6. FINDINGS

6.1 SCOPE OF FINDINGS

The findings stated in this report apply only to the categories of driver training investigated in this study, transit bus operator training. No attempt has been made to apply these findings to other elements of bus driver training or other vehicle operations.

6.2 COST BENETIT

The present state-of-the-art of driver simulators does not provide the capability to produce the range of pictorial presentation necessary for comprehensive bus driver training at an affordable cost. Advances have been made in programming techniques and the addition of movement in the simulator base. However, units with full motion base require special installations to house the simulator, support equipment and full time support personnel. These limitations, when added to the minimum capital investment requirement of $250K to $300K, place these systems beyond the reach of all but the largest transit properties.

Current advances in video disk equipment may offer the required level of complexity for visual display at an affordable cost. At present, though, no simulators utilize this type of equipment. No cost benefit could be identified with the use of simulation in bus driver training. The initial and maintenance costs far outweigh any possible savings in fuel use or salary costs.

6.3 SAFETY BENEFITS

Simulator training safety benefits could not be specifically identified during this review. While a great deal has been written about driver education effectiveness,[9] i.e, its potential

to reduce accident involvement, the results thus far are inconclusive. This includes evaluation of several situations where Doron type training equipment was in use. No comparable research effort could be found where simulator, or other sophisticated hardware systems, were used in bus driver training. Research of this nature needs to be undertaken to provide data on the suggested safety benefits of simulators for driver training.

6.4 FUEL REDUCTION

A fuel savings would be achieved by using a simulator for bus driver training. As the behind-the-wheel driving time is reduced, fuel savings are increased. Using an average of 65 gallons of fuel per student trained, a savings of 13 gallons per student is realized with a 20 percent reduction in behind-the-wheel training time. For a transit property training 200 drivers annually, this would represent a 2,600 gallon fuel savings of the 13,000 gallons normally used for this purpose.

6.5 ALTERNATIVE

Multi-media type teaching machines could provide an effective training alternative to simulators. Multi-media training systems provide most of the training benefits suggested of simulators, i.e., standardized instructional formats and trainee reinforcement of training material for more effective learning. Since these systems cost substantially less than a simulator (usually under $10K), the hardware is within the reach of more transit properties. It is suggested that this approach be further pursued to determine if the training benefits suggested can be established.

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