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CREATION OF A VIRTUAL ROAD FOR TRUCK DRIVER TRAINING AND VALIDATION

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ABSTRACT

The process of digitalizing a local road training route for simulation training at the Carnegie Mellon Driver Training and Safety Institute (CM-DTSI) is presented. A database that is a reproduction of the training route was created and installed in the Thales truck-driving simulator that is used for training at CM-DTSI. The training loop that was digitalized is 13.7 miles (21.9 km) long and contains both rural and city driving and different types of roads, including a controlled access divided highway, a four-lane highway with full access and a center turn lane, a two-lane rural road, city streets, and 12 intersections with stoplights. The Pennsylvania Department of Transportation (PennDOT) provided detailed maps used in the digitalization and plans of all the intersections and the cycles of the traffic lights. Altimetry information was obtained from level curve maps via the Internet site "Terraserver.com" and the software TOPOQUADS (Delorme). Thales proprietary software "Scene Maker" and "Space Magic" for creating and modifying databases were also used. The effort was initiated to provide a basis of comparison between real and virtual truck driving road performance. Issues related to the validation of simulation training with virtual environments are presented and discussed. Specific road driving skills defined by the Professional Truck Driving Institute (PTDI) that can be trained and assessed on the training route are presented. Performance measurement related to the assessment of the skills is discussed. Research plans for validation of the virtual road training are presented.

INTRODUCTION

Carnegie Mellon Driver Training and Safety Institute (CM-DTSI) has implemented a unique curriculum for training tractor-trailer drivers. The training program for novice drivers incorporates core training in the classroom, range and road that follows the widely accepted Professional Truck Driver Institute (PTDI) standards and objectives (www.ptdia.org). CM-DTSI also delivers health and wellness, skid pad and simulator training. Ten hours of simulator training is provided for basic maneuvers, road and traffic situations, and hazardous situations. CM-DTSI uses a high fidelity Trust 800 simulator manufactured by Thales Training and Simulation (TTS) to deliver training (www.tts.thomson-csf.com). This simulator provides a 180-degree horizontal by 45-degree vertical out-the-window visual scene on three rear projector screens via a 3D real time image generator. Rear views are additionally provided for the left and right rear-view mirrors. The cab is mounted on a Moog six degree-of-freedom motion platform, which provides simulation of motions and accelerations. TTS truck driving simulators are in training use throughout Europe, and are considered production devices (1). The TTS simulator has been in continuous use for training at CM-DTSI since August 2000. It utilizes a Renault Premium cab that has been modified to Americanize critical controls and displays, principally the gearbox, which simulates an Eaton-Fuller 10-speed transmission. A view of the TTS truck-driving simulator in operation is given in Figure 1.

Thales has provided proprietary software tools for developing and upgrading exercises and creating databases, which can be used for customizing training at a particular location. These tools include the CREX exercise authoring software, and "SceneMaker" and "Space Magic" software for creating and modifying databases. CM-DTSI has used

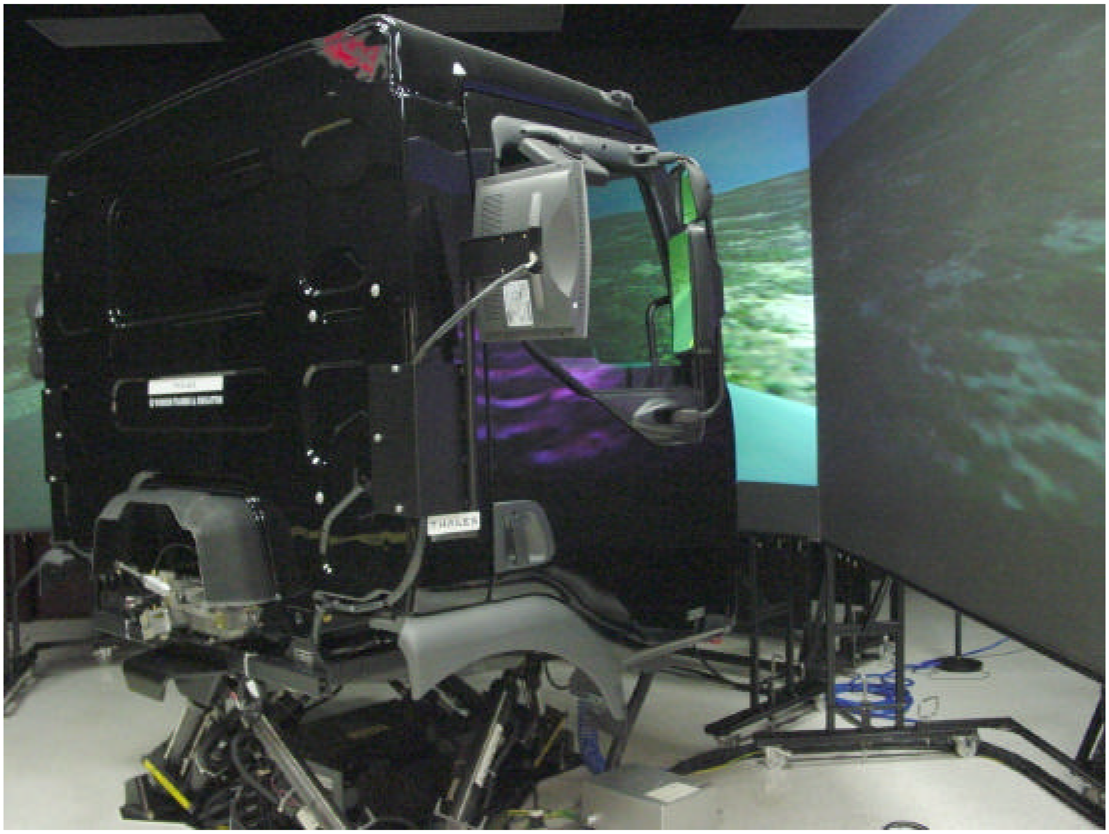

FIGURE 1 View of the TTS truck-driving simulator in operation.

these tools to enhance training in several ways. The physical skid pad at CM-DTSI has been digitalized and installed in the simulator for the purpose of assessing the capability of simulator testing of emergency avoidance driving skills (2). Another database customization project has involved the digitalization of the Commercial Driver Licensing (CDL) test range at the Uniontown, PA CDL testing center. This database has enabled DTSI to introduce students to a virtual version of the test range before they take their licensing exam, thus familiarizing them with the tests and procedures (3). The upgrading and customization of simulation with these databases, along with the effort to digitalize a local road training route described here are part of a program of research designed to eventually determine the amount of real world training that can be profitably supplemented with training in virtual environments, and to determine the driving skills that can be assessed in virtual environments.

Simulator Validation

Simulation training has been widely accepted and incorporated into flight training for many years. Training transfer effectiveness has generally been demonstrated and cost effectiveness is generally favorable because of the great costs associated with flying many types of military and commercial aircraft. Orlansky (4) concludes that the mean percent transfer across a variety of training scenarios was 31%. That is, simulator training reduced training time required on the real equipment by 31%. Additionally, the use of flight simulators for practicing dangerous situations and procedures is a strong selling point. Logically, the information and knowledge regarding flight simulation would have transferred to truck-driving simulation, and use would be widespread in training programs. However, this has not been the case. Validation information, particularly transfer effectiveness, is generally lacking, and cost-effectiveness is a major concern. Cost-effectiveness remains a major issue because full mission truck driving simulators are expensive relative to the cost of a training truck. Some initial costs are offset because such items as fuel and maintenance are eliminated or dramatically reduced with simulation, but not enough at present to offset the initial costs. Simulation must be very effective in this case, or the value of training for dangerous conditions and situations must be demonstrated.

The use of the term "validation" means different things to different users, often dependant on the level of development and the usage of the device. Much of this "validation" research is focused on demonstrating that performance with a particular system or subsystem mimics that of the real world. In this case, measures of performance typically involve driver actions, vehicle response, and subjective ratings. Validation is judged by the extent to which the simulator and the real world evoke similar responses. This type of *convergent* validation is important and useful in the development of simulation devices. Convergent validity may be indicated by demonstrating that performance in the simulator parallels that of real task performance. This may be done in several ways, but the general working hypotheses is that those who perform best in the simulator will perform best on the real task, and vice versa. Thus for example, it would be expected that drivers who had trained on the real task and could perform it well would perform better on the same virtual task than those with no training or experience, and an experiment could be set up to test this hypothesis.

Training validity on the other hand is demonstrated by improvement in performance in the simulator (5). Learning must occur before transfer can take place, and thus training validity is an important and necessary element of transfer effectiveness. Ultimately, however, simulators are training devices, and the utility of a trainer is the extent to which training can be cost-effectively accomplished in the simulator. This is established by demonstrating *transfer* validity, the extent to which training in the simulator transfers to the real task. Transfer can be measured in several ways, including time to criterion and the level of performance after a specified amount of time. However, results must be in the form of time saved in the real device for a given amount of simulator training in order to estimate cost-effectiveness of the simulator. That is, an estimate of the substitution ratio must be obtained for a given level of performance; the amount of simulator training that can be substituted for the actual equipment to achieve a criterion level of performance. Then results can be cast in the form of costs/hr, and cost-effectiveness can be established. These methods are described in detail in (6).

The Federal Motor Carrier Safety Administration (FMCSA), formerly the Federal Highway Administration (FHWA) Office of Motor Carrier and Highway Safety (OMCHS), has an active initiative to evaluate the use of simulation for truck-driver training. They have published a research plan designed to validate the use of simulation in the training, testing and licensing of tractor-trailer drivers (7). This plan is quite comprehensive in that virtually all of the driving skill elements defined in the PTDI curriculum will be addressed. The experimental plan involves the specification of a rate of substitution of simulator time for truck time, which is 1.0, and the amount of time to be saved in the truck, 68% on average. That is, one hour of truck time is replaced with an equal amount of simulator time for approximately 68% of the truck training hours, with the remainder of the training done in the truck. The substitution rate is fixed for the experimental plan. However, within experiment testing will allow for some estimation of times to reach criterion, and will allow for some evaluation of simulation training on a skill by skill basis. The execution of this plan will go a long way towards establishing the basic validity of simulation for training tractor-trailer drivers. However, much work will remain in terms of optimizing the use of simulation for training truck drivers. This paper presents a plan for convergent validity testing of a virtual driving route that encompasses a number of driving skills, and is intended to advance knowledge that leads to the eventual optimization of simulation training.

Road Training at CM-DTSI

CM-DTSI uses several training "loops" from the CM-DTSI campus and back to conduct road training for tractor-trailer drivers. This training is part of the required Behind The Wheel (BTW) road time under the PTDI curriculum used at CM-DTSI. CM-DTSI also uses several simulated road environments involving databases that were supplied with the Thales simulator for road training and modified for US use. It occurred to research personnel that the problem of validating the simulator road training could be simplified somewhat if one of the CM-DTSI training loops could be digitalized. It was also hypothesized that the simulator would have better face validity with students if they could drive on roads and streets that were familiar to them. It was further hypothesized that such training in the simulator could help optimize learning in the truck. Accordingly, a training loop was defined which would be digitalized and installed in the simulator as a database.

DATABASE CREATION AND INSTALLATION IN THE SIMULATOR

The training loop selected for incorporation as a database into the simulator involves a route that contains both rural and city driving and different types of roads, including a controlled access divided highway, a four-lane highway with full access and a center turn lane, a two-lane rural road, and city streets. The terrain is rolling and moderately hilly. The route starts at CM-DTSI located on US Hwy 119 at the Connellsville airport approximately eight miles (12.8 km) north of Uniontown, PA. The route runs south on US Hwy 119 from CM-DTSI 1.8 mi (2.9 km) to the Connellsville St exit. It then follows Connellsville Street approximately 3.9 mi (6.2 km) to US business Route 40 in Uniontown. This road is mixed rural and commercial for about 3.5 mi (5.6 km), and then becomes urban. A right turn to the west is required at US business 40 in Uniontown onto what is initially a one way street. After four blocks, a 45-degree left turn is required onto the truck route (Church St) through town.

The route goes through the center of downtown and then a 45-degree right turn is required back onto west business 40. After another six blocks a right is made onto the exit for US 119 north. There is approximately 1.7 mi (2.7 km) of city driving, with four required turns during the city portion of the route. Drivers encounter a total of eight intersections with stoplights in the city. US 119 north is then followed for 6.7 mi (10.7 km) back to CM-DTSI. Going north from Uniontown, US 119 is a controlled access four-lane divided highway for 5.2 mi (8.3 km). It then becomes a full access four-lane highway with a center turn lane for 1.5 mi (2.4 km) until a left turn is required to return to CM-DTSI. This last stretch of US 119 has four intersections with stoplights. A basic plot of the training route is given in Figure 2.

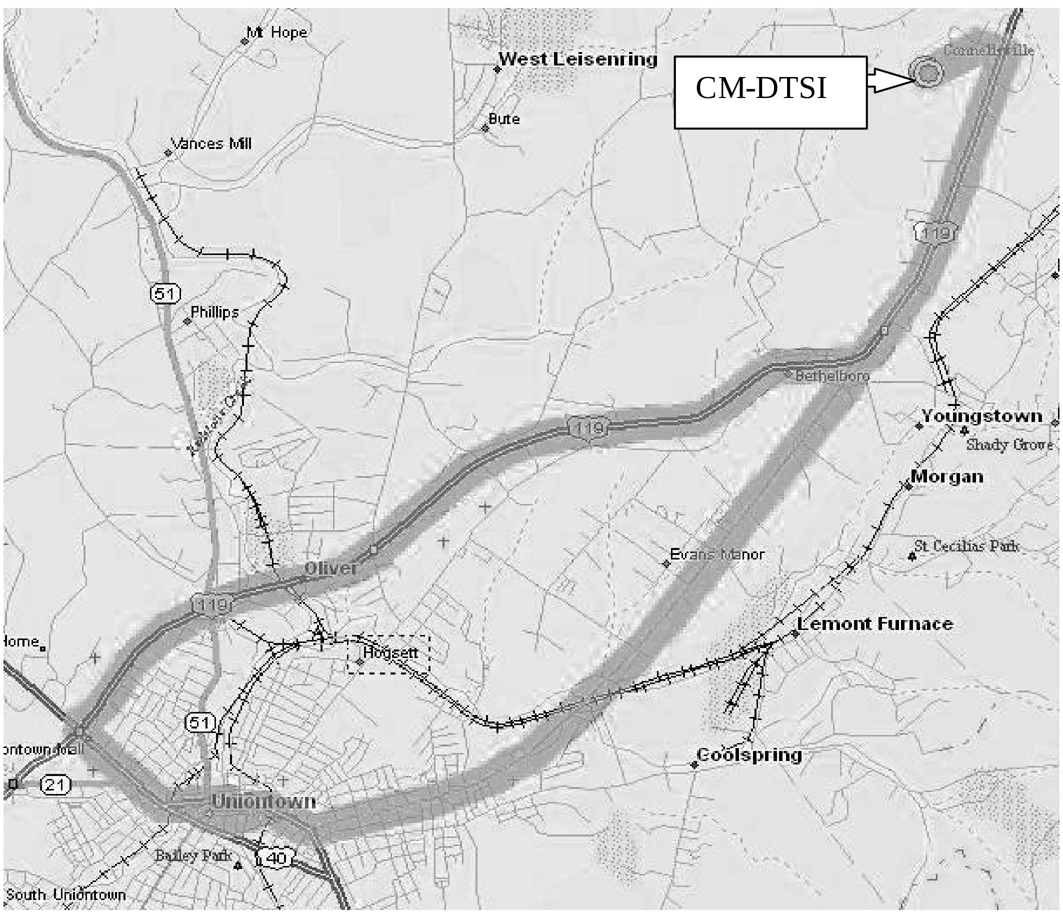

FIGURE 2 Plot of training loop digitalized at CM-DTSI.

Digitalizing the Training Loop

The objective of this effort was to create a database for use in the simulator that would recreate as closely as possible the training loop defined above. The effort started by working with the Pennsylvania Department of Transportation (PennDOT) to obtain the most accurate maps of the area (one meter). These were needed to define the widths, slope, curve of lanes, and the exact positions of road signs. PennDOT provided plans of all the intersections and the cycles of the traffic lights. Altimetry information was obtained from level curve maps via the Internet site "Terraserver.com" and the software TOPOQUADS (Delorme). Altimetry information is considered accurate to 6.0 meters. The work performed in digitalizing the road insures that the virtual road is an accurate and faithful reproduction of the actual road in the defined training loop.

Thales has provided proprietary software tools for developing and upgrading databases and exercises, which can be used for customizing training at a particular location. These tools include "SceneMaker" and "Space Magic" software for creating and modifying databases, which were used in the development of the virtual training loop. Every effort was made to reproduce the environment around the roads in an accurate manner. However, some compromise was necessary between creating the most realistic environment and the computing capabilities of the simulator to retain a good quality visual presentation. Emphasis was placed on recreating the city as accurately as possible. The textures of the city buildings were created via photos of the downtown to create not only virtual buildings, but also the atmosphere and feeling of city driving. The environment surrounding the roads in rural areas was reproduced with less detail. Objects such as buildings, trees and cars were placed in the rural areas in sufficient detail to produce a normal impression of rural driving, and visual perception of speed. Figures 3 through 10 provide samples of simulator driving scenes at various points as the virtual route is driven.

FIGURE 3 View on Connellsville St exit, going under US 119.

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FIGURE 4 View from Connellsville St heading south.

FIGURE 5 View going west through intersection of Church and Beeson streets.

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FIGURE 6 View approaching Morgantown St. facing west on Church St.

FIGURE 7 Passing the George Marshal memorial facing west on US business 40.

FIGURE 8 View at inte rsection of Business 40 and Mt Vernon St, showing stoplights.

FIGURE 9 View of exit to US 119 north from business 40 west.

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FIGURE 10 Northbound on US 119 at the Pittsburgh St exit.

Simulator Exercise Creation

The Thales truck-driving simulator is supplied with an exercise authoring tool, which is used for developing custom training exercises. Training exercises can be created by a user who is not a software engineer or programmer using the Exercise Creation Tool (CREX). The exercise authoring tool provides a means for the user to create a wide variety of simulator exercises in an assortment of scenarios and environments, define specific task conditions and set computerized evaluation parameters. Exercises can be created or modified in the Windows NT environment, independent of the primary simulation and the instructor station via a separate workstation. The user has the means to define, develop and/or modify the following:

?? Select an exercise database or data base subset, e.g. maneuver area, rural roads, highway, city, mountain.

?? Define generic parameters such as time of day, weather conditions, and trainee vehicle

?? Create or modify the trainees mission (list of tasks), maneuvers and displacements

?? Create and edit trainee guidance via a vocal message. These messages can be used to guide and instruct the trainee during training exercises

?? Choose evaluation criteria

?? Activate or remove breakdowns

?? Create or modify traffic elements

?? Utilize cartography to show information on the current exercise

?? Specify end of task conditions

?? Create sequences of exercises that can be run at the instructor station or in self-instruction mode.

Evaluation capability

Evaluation criteria can be set that are global (evaluated during the entire exercise) or local (evaluated only during a specified task). Examples of variables that can be evaluated globally are speed, RPM and lane keeping. A number or evaluation categories such as gearbox, engine, position and driving rules are available, and the users set the specific criteria that they want evaluated. These include variables such as steering wheel angle, steering wheel movements, tractor/trailer angle, fuel consumption, stalled engine, not following road signs, not following traffic lights, incorrect use of turn indicators, sudden braking, gear change without declutching, following too close, too close to traffic in adjacent lanes, clutch pedal position and others. The defined criteria can then be automatically scored using the following statistics, which can be adjusted by the user:

?? Minimum Success rate in Percent (e.g. within specified RPM)

?? Maximum error rate (e.g. following too close)

?? Number of errors or faults

?? A final or total score is computed

?? Individual criterion scores may be weighted by the user in determining the final score

Traffic Creation

Traffic elements can be defined and given specific "missions". Elements are selected from the available databases and include vehicles and cones, which the user can put into the exercise. Traffic elements include trucks, cars, motorcycles, trains, pedestrians and bicycles. There are also three traffic animations that can be defined and put into an exercise, which includes traffic lights, railway gates and bridges. A number of missions and instructions can be assigned to a traffic element including: Go to a point, wait for an event, wait for time, "random" behavior, follow trajectory, avoid collision, respect stop signs, respect speed limit, follow a specific speed, follow priority rights, respect traffic lights, and change lane.

Driving Skills

Driving skills that will be trained and evaluated as part of this research effort encompass basic control skills including starting, stopping and shifting, managing and adjusting vehicle speed, managing and adjusting vehicle space, and performing visual search. Various skill elements that will be trained and assessed include smooth starts, proper up shifting with double clutching, matching gears to speed, use of proper RPM range, proper downshifting, smooth stops without excessive or hard braking, proper left and right turns including lane positioning and trailer off tracking management, lane centering, systematic visual search including use of mirrors and proper scan lead time, recognize blind spots, proper intersection and crossing scan, proper use of speed to maintain space, proper lane changing, proper following distance, proper merging, and proper use of signals.

RESEARCH DESIGN

The first experiment in the research plan will involve two groups of subjects, differing in experience level. There will be 12 in each group. Each subject will run the route in the simulator and on the road. The order of performing simulator and actual routes will be counterbalanced. All subjects will be given simulator orientation and practice on the basic controls. Several hypotheses will be tested. It is hypothesized that experienced drivers will perform better than inexperienced drivers on the actual road and in the simulator. It is also hypothesized that there will be a relationship within each group between performance on the road and in the simulator. Support for these hypotheses would provide an indication of validity of the simulator.

The second experiment will involve a transfer of training experiment, in which 12 novice students in an experimental group will train in the simulator on the virtual training loop to a criterion level, and then go out on the actual training loop for an evaluation run. The performance of this group will be compared to a control that does not receive the simulator training on the virtual loop before going out on the real training loop for an evaluation run. All other elements of the drivers training, including simulator training on exercises that do not involve road driving will be the same. It is hypothesized that the group trained in the simulator on the virtual loop will perform better than the control group. It is also hypothesized that the simulator training will result in less stress for drivers when they perform on the real training route for the first time, by virtue of familiarization in the simulator. Accordingly, non-invasive measures of stress such as heart rate will be taken in addition to the driving performance information.

Performance Measurement Tools

Performance measurement will be a key element for the success of the research plan as the training route involves a number of driving skills and variables. Performance measurement will involve both subjective ratings by experienced instructors, and performance data collected via an on-board data collection system. Subjective ratings of performance will be accomplished by experienced instructors via standard road driving evaluation forms in use at CM-DTSI. CM-DTSI uses an on-board data collection system designed by Accident Prevention Plus (www.applus.com), which consists of a recorder mounted in the truck, a “smart” card used to collect and transfer data collected in the truck, a memory card used for temporary data storage, a reader used to download data and transfer it to a PC, and Pilote 2001 software used to process the raw data. The recorder collects data at 5 Hz from up to 24 sensors that are hard wired into various vehicle systems. Examples of variables that are collected include speed, RPM, fuel consumption, clutch position, brake position, braking intensity, accelerator position, lateral and longitudinal acceleration (requires the installation of an accelerometer), and gear position. The Pilote 2001 software supports summarization and graphical presentation of the data in a variety of ways. The APP system is installed in the simulator as well as the training trucks at CM-DTSI. Performance measurement in the simulator will be accomplished via the CREX evaluation system as well as the APP system.

DISCUSSION AND SUMMARY

A driver training road route used at CM-DTSI has been digitalized and installed as a database in the truck driving simulator at CM-DTSI. The process and method for developing the database were described. This effort was conducted as part of an effort to explore the use of virtual environments for training truck drivers, and to eventually determine the amount of simulator training that will carry over to the actual environment. The recreation of a training loop already used for training and testing will facilitate the process of validation. In particular, it will facilitate the use of convergent validation methodology, wherein validation is judged by the extent to which the simulator and the real world evoke similar responses. A method for testing convergent validity of the virtual training loop is described. Ultimately however, training in virtual environments is only of value if the training actually carries over to the real environment. It is therefore necessary to provide convincing evidence of transfer validity.

A transfer of training experimental design is presented which will determine empirically the amount of simulation training that transfers or carries over to the real task environment. Flipo (1) has presented results of a two-year effort to integrate simulation training into a truck driver-training program at AFT-IFTIM in France. AFT-IFTIM substituted more than half of truck training time with simulation time. In some cases two or more hours of truck time was substituted with only an hour of simulator time. These efficiencies were apparently possible because time can often be used more efficiently in the simulator than in the truck. AFT-IFTIM found that there was no decrement in driving test scores for those students who received training in the simulator at the defined substitution ratios and replacement percents. The validation research proposed here goes a step beyond the work done at AFT-IFTIM, proceeding to a more detailed investigation of simulator training transfer for road driving skills.

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