FMCSA Commercial Truck Simulation Validation Study Phase I Pilot Test: Driving Scenario Definition and Development

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Abstract

The Federal Motor Carrier Safety Administration (FMCSA) has commenced a Commercial Motor Vehicle Driving Simulator Validation ("SimVal") study to test the effectiveness of a driver training simulator for purposes of commercial (large truck) driver training and testing. The study has two phases -- Phase I has developed and pilot tested all instructional, testing, and other activities required for the full-scale Phase II SimVal experiment, which will be conducted under a separate contract. The SimVal study will examine the question of whether simulator technology may facilitate and enhance tractor-trailer driver training and longer term driving performance. The study will also assess the benefits of formal entry-level training in and of itself as well as different levels of entry-level training. In addition, the study will showcase the advanced capabilites of a truck simulator to replicate emergency and evasive driving maneuvers. The nature of the study will also allow FMCSA to begin to explore the feasibility of using simulation for commercial driver licensing. This paper reports the methods of the Phase I pilot study with an emphasis on the development of simulation lessons and scenarios. The paper also describes lessons learned for ensuring a valid experimental test of simulation training as well as a high-quality training experience for participating students.

Introduction & Problem Background

The Commercial Motor Vehicle (CMV) Driving Simulator Validation ("SimVal") study is being sponsored by the Federal Motor Carrier Safety Administration (FMCSA) in support of its Research & Technology (R&T) goal of improving the safety performance of CMV drivers. Phase I of the project, completed in September 2005, was performed by the Virginia Tech Transportation Institute (VTTI) through National Highway Traffic Safety Administration (NHTSA) Contract No. DTNH22-00-C-07007, Task Order 20. Phase II of the project, set to begin in fall 2005, will be conducted under a separate contract.

The Commercial Transportation Program of the Delaware Technical & Community College (DTCC) was the site of the Phase I study. The simulator employed in the Phase I study was a full-mission high-fidelity TT-2000 tractor-trailer driving simulator developed by FAAC, Inc. Figure 1 shows the simulator being employed in the Phase I study. Key features of the Phase I TT-2000 configuration include five forward channels of Computer Image Generation (CIG) spanning 225^{o}, inset mirrors including both regular and convex mirror images, selectable transmission including automatic and several manual options, and a selectable overhead view of the driving scene. Simulator features to be added for Phase II include two rear channels of CIG to enable the use of actual rear view mirrors, and a three degree-of-freedom motion seat.

Figure 1. FAAC, Inc. TT-2000 simulator employed in the SimVal study.

The SimVal project is testing the effectiveness of a driver training simulator for purposes of commercial (large combination-unit truck/tractor-trailer) entry-level driver training

and testing, and also demonstrating simulator advanced capabilities to replicate various vehicle configurations, extreme driving conditions, and emergency maneuvers. Moreover, the study includes a more general assessment of the effects of levels of conventional commercial driver training on skill acquisition and on-job performance. This includes skill and performance evaluations of drivers receiving no formal entry-level training and also those receiving training under relatively short, Commercial Drivers License (CDL)-focused training in comparison to accredited, full-curriculum training.

The use of advanced, high-fidelity training simulators is already established as an integral part of many different types of transportation and other complex system operator training. The potential advantages of the use of advanced training simulators include the following:

- Safety – especially for the practice of otherwise dangerous maneuvers.
- Scenario versatility – creation of particular operational situations that may otherwise be unavailable (e.g., weather or roadway environments).
- Standardization – scenarios developed for specific instructional objectives, and organized to ensure that all students are exposed to each learning activity.
- Repeatability – lessons or tests can be replayed to permit extra practice and skill mastery.
- Improved perspectives – provision of overhead or other visual perspectives (especially useful for training CMV turning and backing maneuvers).
- Sophisticated performance measurement – recording and analyzing student performance in more precise and quantitative ways.
- Efficiency – more training events can occur in a given time period.

SimVal Phase I, completed in September 2005, developed and demonstrated all principal instructional and testing units and protocols required for the full-scale Phase II experiment. Phase II, the actual empirical study, will be performed under a separate contract and will conduct several distinct training-related experiments or substudies, as discussed below.

Overview of the Four SimVal Substudies

SimVal consists of four different substudies, three relating to entry-level CMV driver training and one relating primarily to the use of simulators for advanced training and testing. These substudies are based on a study design developed by Emery et al. (1999) but with several significant additions and modifications. For example, the SimVal Study now includes participants that receive “no formal training” to begin to understand the value of training in and of itself, as well as students that complete training from CDL-focused training schools, which employ compressed training schedules. This will allow us to compare longer vs. shorter training programs. The study is described in more detail in two publications currently in preparation (Robin et al., 2005; Knipling et al., 2005).

Substudy A: Entry-Level Training

The primary SimVal substudy is an experimental comparison of the training effectiveness of behind-the-wheel (BTW) training in a conventional tractor-trailer to simulator-based training for driving skill acquisition (as opposed to knowledge) in entry-level commercial driver training. An experimental group will receive approximately 2/3 of its skill training on the simulator and 1/3 BTW. The control group will receive all conventional BTW training. Measures of training include counterbalanced simulator and BTW training tests, CDL test performance (both actual and simulated), and 3- and 12-month longitudinal follow-ups of on-job safety performance. For this instruction, simulation training lessons were developed to correspond to lessons in a comprehensive and accredited entry-level training curriculum. The simulator-based curriculum and scenario development process are described in greater detail below. In addition, a simulator scenario corresponding to the CDL skills test was developed. All developed simulation training and testing scenarios included both instructor and automated scoring of performance and were pilot tested on at least two subjects. During the Phase II study, a training truck will be instrumented to provide automated BTW performance measurements corresponding to the automated measurements available on the simulator.

An important feature of Substudy A is the fact that the DTCC entry-level training curriculum being employed is a full 8-week training program that has been certified by the Professional Truck Drivers Institute (PTDI). To be PTDI-certified, a training program must be fully licensed, meet or exceed minimum training time requirements, meet or exceed minimum requirements for skills taught, and use qualified staff who train students interactively (e.g., in direct BTW training). To be fully effective, a simulator training curriculum should be just as instructionally sound and anchored in job tasks and learning objectives as a BTW training curriculum employing a real tractor-trailer.

Another feature of the SimVal study is that it is employing an enhanced CDL skills test (Brock et al., 2005) as one of its key training criteria. Delaware is a pilot States for a new, enhanced CDL test designed to better reflect required CMV driving skills and provide more reliable and robust quantitative performance measures. A more reliable criterion test will make it easier to detect and document true training effectiveness differences.

Substudy B: Formal vs. Informal Driver Training

Substudy B is a comparison of the knowledge and driving skills of CDL test-takers who have received formal school training to those who have received no formal training (e.g., trained informally by a friend, relative, or on the job). The Substudy B comparison involves gathering interview data from CDL test-takers regarding their commercial vehicle training and driving histories, and relating variations in formal vs. informal training to several of the same dependent measures as used in Substudy A, including CDL skill test score, simulator CDL-equivalent skill test, an additional BTW road/range test, and on-job performance assessed at 3 and 12 months after employment. The Delaware Division of Motor Vehicles is supporting the study by helping to recruit participants for Substudies B and C.

Substudy C: Full-Curriculum vs. CDL-Focused Entry-Level Training

Substudy C is a comparison of the benefits of comprehensive, certified entry-level training to those of CDL-focused training, which normally involves compressed training schedules (e.g., 1-3 weeks). The dependent measures for this study are the same as those in Substudy B. Thus, several key dependent measures are the same for Substudies A, B, and C. This includes actual CDL test skill performance, simulator CDL-equivalent skill test performance, an additional BTW road/range test, and longitudinal job safety performance measures at 3 and 12 months.

Substudy D: Advanced Simulator Training Capabilities

Substudy D is an experimental demonstration of the effectiveness of performance testing and training employing advanced simulator capabilities such as the simulation of emergency evasive maneuvers and hazardous road conditions. The experiment compares the performance of experienced to novice drivers on these types of driving tasks performed in the simulator. It is hypothesized that experienced drivers will perform better on these test scenarios, but that both will consider the sessions to be worthwhile training experiences. More than 30 emergency maneuvers and extreme conditions are included in two test scenarios. Types of events and conditions simulated include tight turns and other potential rollover or jackknife situations, sudden stops (e.g., for pedestrian, other vehicle in roadway ahead), dense fog, slippery roads, steep hills, brake failure, and tire blowout. In addition to the principal scenarios employing a tractor-trailer, a separate plan for simulator evaluations employing tanker vehicles was developed.

Curriculum & Scenario Development

Curriculum and scenario development for the SimVal study has been conducted in a manner intended to ensure that the training is instructionally sound and that there is strong correspondence between the regular BTW curriculum and the simulator curriculum. Exceptions to this correspondence are primarily in those situations where the simulator can provide training opportunities that are not possible for BTW lessons, such as creating emergency situations or varied driving environments.

As previously noted, the DTCC entry-level curriculum is PTDI-certified. This instructional program is extensively documented, including detailed lessons plans and trainee performance evaluation measures for each day of instruction. Road and range BTW skill training lesson plans include a lesson time, description, objectives, materials, procedures, and evaluation methods. The development of a simulator version of the curriculum involved planning simulator training procedures to parallel the BTW procedures, as shown in Table 1.

Table 1. Curriculum Correspondence for a Sample Lesson for the Entry-Level BTW and Simulator Test Subjects

1.5 Shifting 1.4 Basic Control	Total Time: 6hrs Per Person: 1hrs 45mins	Equivalent to CTS104 Day 3 ROAD EXERCISES
	35mins per	1hr 10mins per
DTCC Procedures	**BTW Activities**	**Simulator Activities**
1. Have student legibly print his/her name on logbook cover, properly head log page, sign, and begin to properly record time and status on log grid.	**Primary: Group**	**Noted as SOP: Group**
2. Have each student to enter the vehicle using the three point of contact method.	**Primary: Individual**	**N/A**
3. Have each student show Driver's license, learner's permit, and medical card.	**Primary: Group**	**Noted as SOP: Group**
4. Instruct each student proper use of safety belt.	**Equal: Group**	**Equal: Group**
5. Provide a copy of explanation of errors.	**Equal: Group**	**Equal: Group**
6. Provide verbal coaching to student operating vehicle on training route #1. Expect the students to have a great deal of difficulty focusing on all of the tasks required to operate on the road. Therefore, provide feedback on all errors and correct action	**Secondary: Individual / instructor error list / see design report pages 36-37 & 79 / PTDI curriculum pages 20-21 / PTDI skill book pages 9-10**	**Primary: Individual / create scenario similar to route #1 / use sim error tracking w/ error list/ instructor error list / see design report pages 36-37 & 79 / PTDI curriculum pages 20-21 / PTDI skill book pages 9-10**
7. Make notes on Road Observer's Checklist for basic control.	**Equal: Instructor**	**Equal: Instructor/sim tracking**
8. Have each student drive training route #1 twice.	**Secondary: Indiv./ maintain route equivalency if possible / drive route once for BTW time**	**Primary: Indiv./ maintain route equivalency within time constraints/drive route twice on simulator**
9. At the end of each students turn, give short, positive, critique pointing out improvements during second time on route.	**Equal: Individual**	**Equal: Individual**
10. Conduct post-trip inspection and complete vehicle inspection report. Place VCR today's copy in vehicle and put yesterday's copy along with today's original in tray in classroom	**Primary: Group**	**N/A**
11. Have student complete logbook page. Check for accuracy, have student and instructor sign	**Primary: Group**	**Noted as SOP: Group**
12. Complete portion of Road Trip Sheet pertaining to today's training.	**Equal: Group**	**Equal: Group**

After parallel curriculum procedures were outlined, a simulator roadway route and scenario was developed to correspond to the route for the road portion of the BTW training. It was not feasible to create an exact virtual Georgetown area roadway network, and indeed replicating an actual roadway system would not be a realistic prospect for most commercial driver training schools employing simulators. Instead, sections of roadway and terrain from simulated environments provided by FAAC were selected to be similar to the actual DTCC training routes. The simulator routes are similar in terrain, roadway type, traffic density, and traffic controls (e.g., intersection signs and signals) as the actual DTCC BTW routes. Figure 2 shows the simulator route for the lesson, and Table 2 compares the BTW and simulator scenarios in terms of roadway segments and required turns and other maneuvers. For range lessons, the simulator environment was programmed to have the same critical spatial parameters (e.g., cone spacing for parking exercises) as the BTW training range.

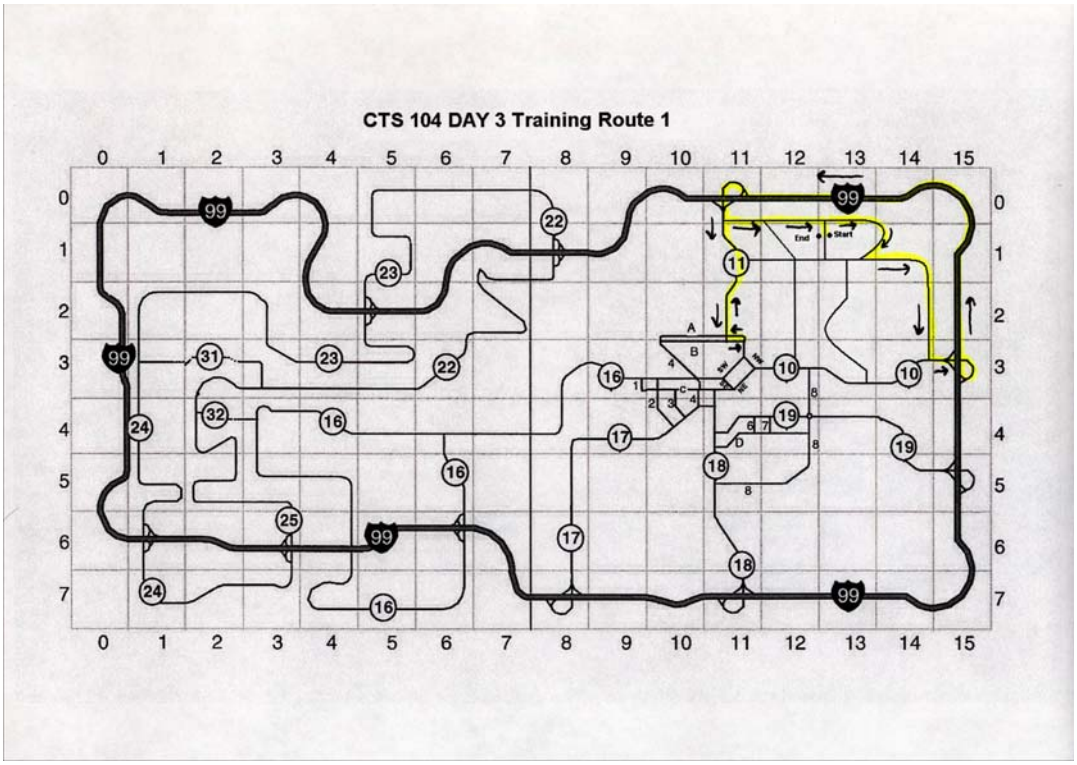

Figure 2. Simulator Lesson Training Route (Upper Right of Map)

The steps involved in conceptualizing, planning, programming, pilot testing, and documenting simulation scenarios for the entry-level lessons included the following:

- Compare scenario database maps and DTCC training route maps to plan a route.
- Use FAAC Scenario Tool Box software on PC and program route to be driven. (Note: This feature allowed scenarios to be programmed off-site from the simulator, greatly reducing cost and time required.)
- Use Scenario Tool Box software on PC to script and program other traffic and events.
- Load scenario onto simulator. Drive route and iterate on environment, traffic, visuals.
- Have driver trainers (or other experts) drive the scenario to critique and iterate on route, traffic, and maneuvers, and in comparison to DTCC routes.
- Document scenario including time and length, route layout, vehicle dynamics, environmental properties, traffic density, and scoring parameters.
- Run pilot subjects (actual CMV driver trainees).
- Record instructor scoring and simulator scoring for each student.
- Make necessary iterations to the route after pilot subjects are run.
- Analyze scoring and develop spreadsheets, databases, and graphs for documentation.

Table 2. Comparison of BTW and Simulator Routes

BTW Group Driving Route	vs.	Simulator Route
Driving Time: ~ 1hr 45 min		**Sim Driving Time: ~ 1hr 10 min** **BTW Driving Time: ~ 35 min**
Route Length: ~ 14 miles		**Route Length: ~ 15 miles**
Driving Route Details: Roads are a mix of 2 lane and 4 lane divided. Speed limit varies up to 55 mph. Rural and small town. Light to moderate traffic.		**Simulator Route Details:** Roads are a mix of 2 lane, 4 lane divided, and 4 lane non-divided. Speed limit varies up to 55 mph. Rural and small town. Light to moderate traffic (more aggressive during 2nd loop).
Events/Maneuvers		**Events/Maneuvers**
Right turn at stop sign, US 9		**Right turn at stop sign, AA St.**
Rail Road crossing		**None**
Left turn at stop sign, CR 431		**Left turn at stop sign, BB St.**
Right turn, yield sign, curved entrance		**Left turn at yield sign, Rt. 10**
Right turn at stop sign, US 9, entering 4 lane highway		**On ramp entrance to 4 lane highway, under bridge and loop around, I-99**
Straight thru traffic light		**None**
Left turn at traffic light, DE 404, 2 left turn lanes, leaving 4 lane highway		**Exit 4 lane highway via right hand exit ramp, Rt. 11**
None		**Straight thru traffic light**
Left turn, no stop sign, CR 521		**Left turn at traffic light, B St.**
Left turn, no stop sign, CR 519		**Left turn at traffic light, 5th St.**
Right turn at stop sign, US 113, entering 4 lane highway		**Right turn at traffic light, Rt. 11**
Straight thru traffic light		**None**
Left turn at traffic light, CR 431		**Right turn, no stop sign, AA St.**
Right turn, no stop sign, US 9		**Straight thru stop sign**
Rail Road crossing		**None**
Left turn, no stop sign, Nanticoke Rd		**Right turn stop sign, EE St.**

For the entry-level training test (Substudy A), it was critical to develop simulator lessons that were parallel and comparable to the existing DTCC BTW lessons. For the simulator advanced capabilities test, however, there was no existing or corresponding BTW curriculum, so the simulator test scenarios were designed and developed based on simulator capabilities and the importance of the task/skill for CMV driving safety. The "back end" scenario test driving, pilot testing, performance recording, and documentation steps were similar to those described for the entry-level scenarios.

Program Status & Timeline

SimVal Phase I has designed, developed, pilot tested, and documented simulator and other training sessions, tests, and other activities, programs, and materials required for the full-scale Phase II SimVal study. SimVal Phase II will be conducted under a separate contract, and is planned to begin this fall. The full-scale, 24-30 month study will consist of the four substudies described, will seek to facilitate the use of advanced simulators for improving CMV training, and will also employ multiple, enhanced criterion measures to

assess the value of various degrees of CMV entry-level training as well as comparing simulator to BTW training methods.

References

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