Techniques of validation for driver's training using a driving simulator.

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Introduction

The presentation based on a non exhaustive literature review has two main purposes: firstly to describe some recent studies focusing on techniques of validation for training using a driving simulator; the second aim is to point out items missing in techniques of validation that require attention, or need research. We have selected eight recent case-studies or experiments planned or achieved, from internet publications and from proceedings of the Driving Simulation Conference. The goal of these experiments was to assess one or several aspects of the validity of training courses using simulation technology. It seems that an important component of validity is the effectiveness of a driver training, but other characteristics can be taking into account, such as usefulness, efficiency (cost, time), or luckless effects.

State of the art

For each of the eight case-studies selected we have highlighted the techniques used to assess the validity of a particular driver training curriculum integrating learning skills on a driving simulator (excepting the last one "MUARC").

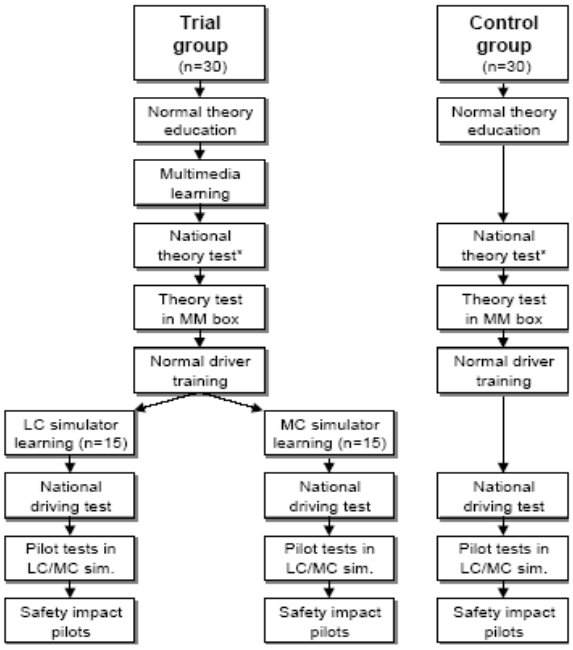
I.1. TNO and ANWB Driving school - the Netherlands

TNO Human Factors has many years of experience performing simulator validation studies, they have worked on curriculum development, design of scenario-based training, they advise on specification, validation and development of driving simulators for training. They have used a survey method to assess training effectiveness with the ANWB organization which has a branch for driver training. The VVCR driving simulator is fully integrated in the existing ARO training curriculum. During the evaluation period the simulator had several training modules specially: vehicle training ground; within a built-up area (2 x 20 min, approx. 70 situations each.); outside a built-up area (2 x 20 min, approx. 40 situations each); highway (2 x 20 min, approx. 15 situations each).
The VVCR driving simulator was tested and evaluated at three ARO driving schools. In total 141 students participated in the study. In the simulator, the students were trained in the traffic participation lessons. These lessons replaced the normal driving lessons on the road.

A student is trained in the simulator, and in the following driving lesson (on the road) the instructor is asked to fill in a questionnaire with specific questions on the performance of the student. The questions were targeted at specific subtasks, such as negotiating intersections and merging highways. Instructors were asked to compare the performance of a particular student with an ‘average’ student at this stage of the normal training curriculum. Students were also asked to fill in a questionnaire on the interest of simulator for training, and two others questionnaires related to simulator sickness.

I.2. TRAINER Project - Preliminary experimental study

The objectives of the EU funded TRAINER project are to develop a new pan-European driver training methodology which will focus more on the enhancement of risk awareness of novice drivers, including the use of new telematic aids. On a total of approximately 100 scenarios, 31 structured in accordance with the four levels of the GADGET matrix (personal preconditions and ambitions, strategical, tactical and operational), were selected and developed to be used in the simulators.



A first step of the project was to define the technical requirements for both a low-cost and a mean-cost simulators (software and hardware), and to conduct a simulator validation, based on an experimental trial developed in a series of pilot tests in four different countries.
Four full sets of TRAINER tools will be developed and installed at Belgium/Netherlands, Spain, Sweden, and Greece Research Institute partners. Each set will consist of a multimedia info-box and a low-cost/ mean-cost (both versions) driving simulator. Tests will be conducted on each site with 30+30 learner drivers in a trial group and a control group. The groups will be matched by age, sex and education level. The tests in 4 different countries will account for social and mentality differences between different EU regions. The design of the validation procedure is presented in Figure 1.

Fig 1: Design of the evaluation of the training tool (From TRAINER Project report).

I.3. TRAINER Project - Driver performance criteria

Another second goal of the above EU-funded TRAINER project was to develop a new novice driver training methodology which concentrates on the improvement of higher-order driving skills like anticipatory driving, risk awareness and economical driving.
A study for validating the implemented measurements and indicators for driver performance assessment was conducted. Two driver groups (experts and novices) participated in test rides in the simulated driving environment in order to compare the overall performance of the two groups.

Preliminary test:

A first test was conducted to decide whether the prototypes provide a sufficient subjective impression of "realistic driving", and to know the levels of mental workload imposed and the degree of simulator sickness. 8 expert drivers (driving instructors) and 8 learner drivers (2-4 driving lessons) giving a total subject number of 16 across 2 test sites (UPV (Spain) and CARA (Belgium) participated in this preliminary test (questionnaires and driving through a sequence of scenarios).

Assessment of a trainee's performance during the TRAINER curriculum

The validity of the selected driver behavior indicators will be evaluated in an empirical study comparing the performance of a group of learner drivers with the performance of a group of expert drivers when driving in the TRAINER scenarios.
Precise criteria and acceptance thresholds for each one of the 30 driving simulator scenarios (and 31 multimedia tools) will be defined including two-valued (error / no error) as well as continuous driver performance criteria. Based on these scenario-specific indicators, five grades (A to E) to assess the general performance of a trainee during the curriculum have been formulated for both tools.

I.4. Evaluation of Driving Education Methods in a Driving Simulator:

Universities and high schools of Porto and Minho

After development of a realistic driving simulator dedicated to driver training, a study was conducted to compare the effectiveness of 3 types of driving education methods.
A preliminary experiment involving 20 subjects was used to select the course curriculums that will be used in the final experiment.
For the final experiment 200 novice subjects (without driving license) were assigned 3 groups using one type of driving education method:

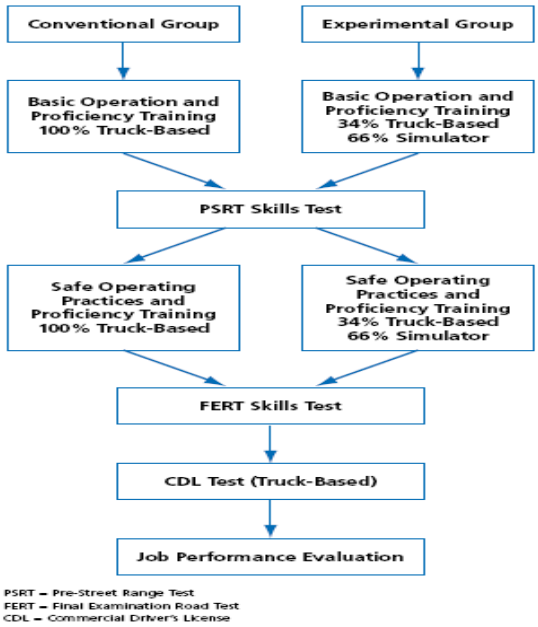
- Traditional driving course (real car) with driving instructors (15 hours),
- Interactive driving simulator (30 hours), lessons will be supervised by a driving instructor and include simulated driving practice under several conditions of traffic intensity, traffic velocity and own vehicle characteristics
- Non interactive driving simulator (40 hours), lessons will be supervised by a driving instructor and include simulated driving practice under several conditions of traffic intensity, traffic velocity and own vehicle characteristics

Initial and final driving performance evaluations will be done using data acquired during tests on a driving simulator. Measures acquired can be divided into three groups: a rating scale of mental effort (RSME); physiological measures, eye movements; and performance measures (reaction time, time-to-line crossing, speed, control of the driving path, ...).

I.5. FMCSA - Federal Motor Carrier Safety Administration-Washington

The FMCSA has conducted a study to empirically validate a low- to mid-cost simulator for purposes of CMV (Commercial motor vehicle) driver training, testing, and licensing. The goal of this study was to determine if the use of simulator supplemented training, as compared to traditional behind-the-wheel (BTW) training, results in the same, better, or worse performance in driver training and on the commercial driver's license (CDL) examination. At the same time a longitudinal study was also projected to ascertain the relationship between type of training method (i.e., simulation vs. truck) and actual job performance by determining if simulator-based training ultimately results in reliable differences in a driver's on-the-road performance.

Part 1 training effectiveness



In a first study focused on training effectiveness, students were divided into two groups, with one group receiving conventional truck-based training (44 hours in an actual vehicle), and the other group receiving simulator supplemented training (66 percent of the BTW training in a simulator (30 hours) and the rest (14 hours) in a vehicle). Simulator assessment took place on 10 of the 16 units of the PTDI curriculum structured in two main parts: Basic Operation and Safe Operating Practices portions.

Fig 2 – Training effectiveness research study design (From FMCSA report)

Part 2 Advanced Capabilities
The goal of this research design was to evaluate the advanced capabilities of the simulator to replicate the more complex driving skills, such as the operation of double and triple combination vehicles, evasive manoeuvers, etc... . Two groups of eight drivers, experienced and novice drivers participated in this study. After drivers receive a brief orientation to the simulator, a general skills pre-test establishes baseline differences between the two groups. Following the pre-test, all drivers will be tested individually on four defined advanced capabilities scenarios. Upon completion of the scenarios, all drivers will participate in a post-test similar to the pre-test. Additionally, the experienced drivers will complete a post-experiment questionnaire to determine the degree of agreement among experienced truck drivers on the simulator's ability to present driving situations in a realistic and useful manner.

Part 3 — Longitudinal Study
This longitudinal study is a continuation of Part 1, and will determine if simulator based training ultimately results in reliable differences in drivers' performance. The student drivers' post-training driving records will be examined at 3 and 12 months following the completion of the CDL examination. Measures of on-the-job driver performance during this part of the study will include the number of crashes, the number of citations, supervisory ratings, and other measures as deemed appropriate.

I.6. RESPECT - Phase 1 - Effectiveness of a 3 days training for truck drivers

RESPECT – "Regulator Simulator based performance training for professional truck drivers" is an EC funded project. This project consists of setting up a 3-day educational programme for truck drivers. The three main aspects of this training are:
- Safety / Reduction of accidents
- Economy / Reduction of fuel consumption, material wear(use deterioration) and travel time
- Environment / Reduction of manoeuvring damages

The 3-day training programme consist of 3 elements
- Theoretical component (classroom / computer based training - CBT)
- Practical component (driving with a real truck)
- Simulator component

Measurement and evaluation scheme

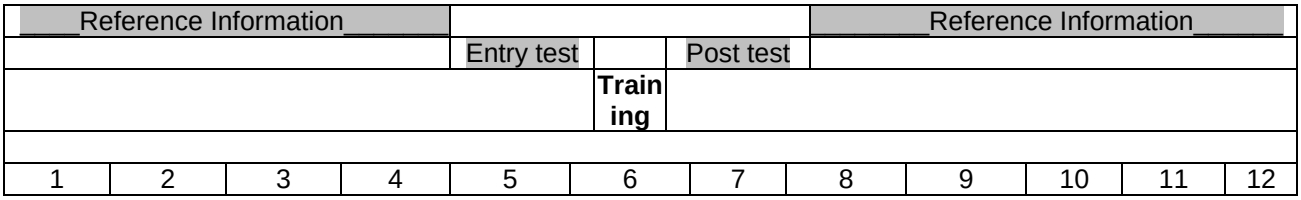


Fig 3 – RESPECT Evaluation scheme (From RESPECT 1 Final technical report)

Around 800 drivers - 200 in each of the 4 countries (The Netherlands, Switzerland, Germany, France). The improvements of the driver due to the training have to be measurable in order to be able to identify the effectiveness of the 3-day training programme. Therefore there has to be a zero state at the start of the training and a measurement when the training is over. The effects of measurement are done in (at least) three ways:
- By means of collecting and analyzing practical data from transport companies (e.g. fuel consumption figures / information on number and costs of accidents).
- By means of a standardized test session on the simulator.
- (optional) Measurement on the training truck to be used for measurement of the effect of the practical component (real truck driving).

I.7. TRUST Thomson Training & Simulation and AFT-IFTIM Companies

TRUST (TRUck Simulator for Training), produced by Thomson Training & Siimulation, addresses the following objectives:
- professional certificate for learner truck drivers,
- advanced training for experienced drivers,
- truck drivers evaluation.

The Company AFT-IFTIM uses the truck driver training system which is composed of a truck training simulator "TRUST" and a stand-alone exercise creation tool "CREX". In this configuration the system provides the following advanced training capabilities:

- it runs a training program, a syllabus of interactive exercises made progressively more complex according to trainee's rate of progress,
- self-training is provided with the simulator : the trainee in his cab can progress at his own pace, autonomously,
- this self-training feature enables an instructor to manage several trainees simultaneously in "multiple training" mode,
- finally, the user can easily create or modify training programs using a user-friendly tool "CREX".

Efficiency

Due to his self training capacities, effectiveness/efficiency can be evaluated by comparing the training duration of a complete training until obtaining the driving license, using TRUST or using an actual vehicle.

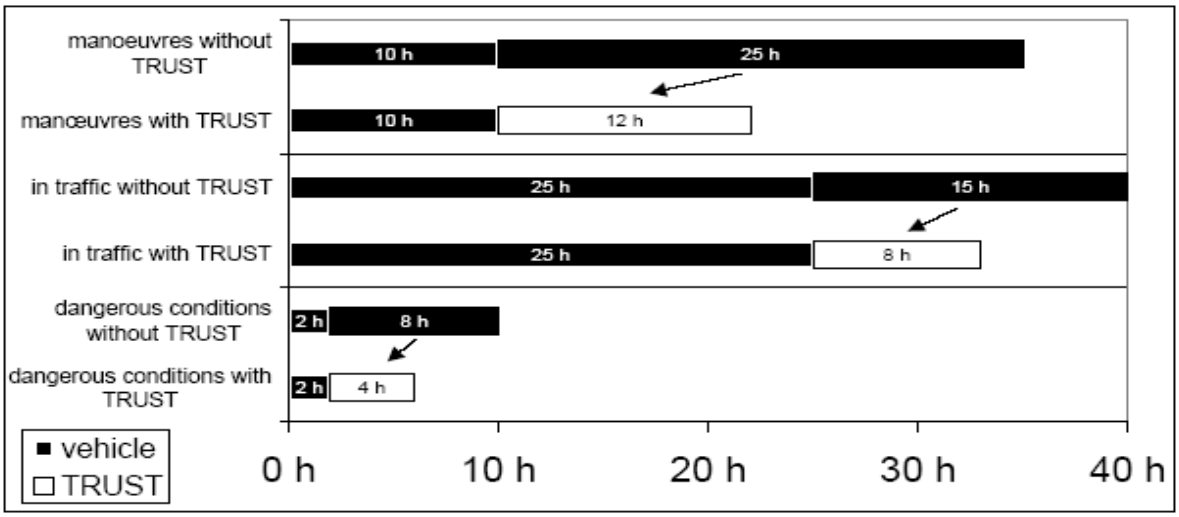


Fig 4 – TRUST Measured training efficiency (From TRUST - DSC2000 Proceedings)

I.8. MUARC - Monash University Accident Research Center

MUARC was commissioned to evaluate the one-day program developed by AAMI Insurance for 18-25 year olds and is comprised of both theoretical and practical components.

Rather than focusing on physical skills, insight training focuses on attitudinal-motivational skills. The aim is to raise drivers' awareness of factors that contribute to crashes and potential risks when driving. Questionnaires were distributed to participants at the time of enrolment in the AAMI / Skilled Drivers program (Time 1). A second questionnaire was completed either just prior to course participation to form a control group, or just following course participation to form a case group (Time 2). This allowed relative short-term outcomes of the course to be evaluated. In order to evaluate more long-term effects, an additional questionnaire was distributed to all participants at approximately eight weeks following their completion of the driver-training program (Time 3).A total of 220 young drivers (54 male, 166 female) responded at Time 1. The final sample, that is, those who completed all three questionnaires, was comprised of 149 of these participants (35 male, 114 female).

I.9. categorization of studies and experiments

N	Study / Reference	drivers	Training description	Goal of the study / experiment – validation / assessment technique
1	**TNO& ANWB** Driving school - The Netherlands **[7] - [1]**	Novice car	Complete curriculum to obtain the driving license.	The effectiveness of a compound training course, including driving simulator training, is assessed by experts (instructors) after a "on the road" test. Questionnaires on simulator sickness and attractiveness of simulator lessons.
2	**TRAINER EC Project** Preliminary experimental study **[10]**	Novice car	31 scenarios, focused on high order driving skills.	Comparison: Low-cost static DS vs mean-cost DS (lateral motion). 60 subjects in 3 groups X 4 countries (Belgium, Greece, Spain and Sweden
3	**TRAINER EC Project** Driver performance criteria **[11]**	Expert/ Novice	30 DS simulator scenarios (+ 31 multimedia tools).	Methodology for validating the implemented measurements and indicators for driver performance assessment. 8 experts+ 8 novices x 2 (Spain and Belgium) for first test. 2 groups – experts and novice drivers – for comparison the overall performance.
4	**Universities and high schools of Porto and Minho [3]**	Novice car	Driving lessons in a real car and / or the driving simulator	Comparison between 3 types of training courses : -Traditional driving course with teachers (15 hours), - Interactive driving simulator (30 hours), - Non interactive driving simulator (40 hours). 20 subjects for preliminary experiment- -200 subjects for final experiment in 3 Groups.
5	**FMCSA** Federal Motor carrier Safety administration Washington **[2]**	Professional truck	Complete curriculum to obtain the driving license.	Assessing the usefulness, effectiveness, and efficiency of simulator in training, testing and licensing of tractor-trailer drivers. Part 1 comparison of training effectiveness, traditional vs simulator based (55 novice truck drivers). Part 2 assessment of the advanced driving capabilities using simulation: 8 experienced ⇔ 8 novice drivers. Part 3 longitudinal study over 3 and 12 month after training.
6	**RESPECT** EC Project Phase1 **[4]**	Professional truck	3-day training course.	Assessing the effectiveness of the 3-day training programme focusing on safety, economy and environment. About 800 drivers - 4 countries (The Netherlands, France, Switzerland, Germany).
7	**TRUST Thomson Training & Simulation ; AFT-IFTIM [9]**	Novice Professional truck	Complete curriculum to obtain the driving license.	Cost/Time efficiency of training by comparison of "traditional» (all in vehicle training) and the TRUST training (in vehicle + driving simulator), by mean of time to get the driving license, under different situations / conditions.
8	**MUARC Monash University Accident Research Center [6]**	Novice young	One day insight training focuses on attitudinal-motivational skills	Evaluation of an insight driver-training program for young drivers. Time 1: questionnaire at time of enrolment (220 drivers).Time 2: questionnaire just prior the course (control group), questionnaire just following (case group).Time 3: questionnaire 8 weeks following the completion of the driver training program.

Table 1: presentation of studies or experiments planned or achieved, to assess the validity of training courses including simulator technology.

The driving simulator is always embedded in curriculum including also "on the road" training, excepting N4 and N8 cases,

N	Study - experiment	drivers	Test technique
1	**TNO& ANWB** Driving school - The Netherlands	Novice car	"On the road" test, assessed by experts (instructors).
2	**TRAINER EC Project** Preliminary experimental study	Novice car	National driver's license test + DS (Driving Simulator) specific test.
3	**TRAINER EC Project** Driver performance criteria	Expert/ Novice	Preliminary test: questionnaires and driving on simulator. Assessment of a trainee's performance: comparison of performance between of a group of learning drivers and a group of experts on driving simulator.
4	**Universities and high schools of Porto and Minho**	Novice car	Comparison of 3 types of training, using data acquired during test on a driving simulator: rating scale of mental effort (RSME); physiological measures, eye movements; and performance measures (reaction time, time-to-line crossing, speed, control of the driving path, ...).
5	**FMCSA** Federal Motor carrier Safety administration Washington	Professional truck	Part 1 training effectiveness: comparison of performance between a group of learning drivers trained by conventional method and a group of learning drivers using simulator supplemented training (tests on truck an on DS). Part 2 Advanced Capabilities: comparison of the performance of a group of learner drivers with the performance of a group of expert (test on DS). Part 3 — Longitudinal study.
6	**RESPECT** EC Project Phase 1	Professional truck	Pre ant post training test on driving simulator. Longitudinal Study – data from transport companies
7	**TRUST Thomson Training & Simulation AFT-IFTIM**	Novice Professional truck	Comparison of the duration of a complete training, between learning drivers using TRUST and learning drivers using a real vehicle, to obtain the national driver's license test
8	**MUARC Monash University Accident Research Center**	Novice young	Questionnaire at time of enrolment (220 drivers), questionnaire before and after the training program, and then questionnaire 8 weeks following the completion of the driver training program.

Table 2: Validation techniques used

In this sample of studies, excepting N7 and N8 cases, the assessment of the training curriculum is obtained by comparison between 2 groups of learners; a test group and a reference group. For novice drivers a test group with simulator supplemented training is compared to a reference group with traditional training. The comparison is done by assessment of driving performances by mean of a test "on road" or "in a driving simulator". The methods for assessing "driving performance" are multiple:

- by an investigator, to obtain the national driver's license N2 and N7,
- by an expert (instructor) N1,
- by data acquired on a driving simulator N4,
- by questionnaire,
- by longitudinal study, following of cohorts.

Conclusion - Research needs

Traffic model

The GADGET-matrix (Hatakka et al. 1999).Reference[10], shows that training on driving simulator is more effective in the high level of the hierarchical description of the driving task i.e. strategical and tactical level. Two points may be highlighted:

- To acquire knowledge and skills concerning mastery of traffic situations such as traffic regulations, observation/selection of signals, anticipation of the development of situations, speed adjustment, distance to others/ safety margins, etc.., it is necessary to have a "good" traffic model, able to produce a realistic traffic environment around the learner.
- Learning in a driving simulator can be better than traditional method in its ability to produce easily and without any risk, number of different complex situations.

The traffic model is an essential component of a driving simulator dedicated to learning, it seems important to have tools to assess its quality and to know the validity conditions.

Questions on long terms effects of training

T. M. Senserrick & G. C. Swinburne Reference [6] "Traditional driver-training programs that aim to improve vehicle-handling skills, including maneuvering exercises and skid training, have tended to be relatively ineffective in reducing crashes. In fact, the introduction of skid training into driver-training programs has been found to increase certain crash types for young drivers".
It will be interesting to verify that training on driving simulators, by increasing the mastery of complex or dangerous situations, do not result in luckless effects like reducing risk awareness, more particularity for young drivers,

Need for an elaborate performance measurement

Dr. B. Kappé -TNO-Human Factors "To allow the driver's progress to be monitored, an elaborate performance measurement system is required. Traditionally, performance measurement systems specify driving performance in terms of (standard deviation or standard error of) lateral or longitudinal position, speed, relative speed etc. Performance measurement on the basis of these basic performance measurements is difficult though. For each and every scenario, these parameters have to be set. Furthermore, if scenario's become more complex, it is difficult to determine which parameters have to be monitored, and what their relation is with the desired outcome of the scenario. At TNO-HF we are investigating methods to evaluate driver performance by comparing it with the traffic model. This 'virtual instructor' is in fact one of the computer-generated vehicles, that is used as a normative model to evaluate the driver's performance. This allows driving performance to be evaluated on a higher level, for instance on the level of traffic rules (i.e. do you have priority or not)."

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