A TOP-OF-THE-RANGE DRIVING SIMULATOR

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Abstract

The paper refers to some problems of a top-of-the-range driving simulator that have been implemented in 27 EU members by Directive 2003/59/EC. The truck simulator from France, Finland, Germany and USA have been stressed. The Mark III Motion-Based Driver Training Simulator combines a fully operational truck cab with the latest digital simulation technology to create life-like training scenarios that improve driving behavior and skill. Renault has built the simulator which can offer several truck configurations (tractor, rigid, articulated) with different engine and equipment types. Additionally the TRUST 3000 simulator for Truck Driving Training and BUS 3000 simulator for Bus Driving Training were stressed. A top-of-the-range simulator may play the main role in many training areas, it is clear that the particular requirements of the driving industry must be considered in order to develop optimal cost-effective systems. Preliminary analysis shows that simulation can have a beneficial contribution in the areas of fuel efficient driving, emergency situations, poor weather driving skills, and learning the handling characteristics of different types of load. Authors have determined requirements on a top-of-the-range driving simulators.

Keywords: *telematics, telecommunications, informatics, transport telematics, range driving simulator*

1. Introduction

Directive 2003/59/EC of the European Parliament and of the Council (Initial qualification and periodic training for drivers of road vehicles for the carriage of goods or passengers) recommends the use a top-of-the-range simulator in 27 EU members on the initial qualification and periodic training for coaches and buses - mandatory Sept 08, for trucks - mandatory Sept 09 [1]. According to Directive the training for the full initial qualification must be at least 280 hours (approximately 8 weeks). At least 20 of the 280 hours must be devoted to driving a vehicle. Each driver may drive for a maximum of 8 hours of the 20 hours of individual driving on so as to assess training in rational driving based on safety regulations, in particular with regard to vehicle handling in different road conditions and the way they change with different atmospheric conditions and the time of day or night. When driving individually, an instructor, employed by an approved training centre, must accompany the trainee driver. Each driver may drive for a maximum of four hours of the 10 hours of individual driving on a top-of-the-range simulator The same conditions as above apply for the accelerated initial qualification. The training for the accelerated initial qualification must be at least 140 hours (approximately 4 weeks), of which at least 10 hours must be practical driving. Member States may allow a maximum of 4 out of the 10 hours can be undertaken on a top-of-the-range simulator. Compulsory periodic training must be organized by an approved training centre. Their duration must be of 35 hours every 5 years, given in periods of at least 7 hours. Such periodic training may be provided, in part, on top-of-the-range simulator. The maximum administrative validity may be of 5 years for trucks and buses drivers of age and of 1 year for drivers over 65 years of age. According to the Directive, basic vocational training is divided into three areas:

- advanced training in rational driving based on safety rules,

- compliance with regulations,
- health, safety, service and logistics.

In addition there are other areas of direct relevance to possible simulator training. These relate to:
- road traffic regulations
- ergonomic principles
- behaviour in an emergency situation.

The provisions contained in the Directive must be translated into national law in the EU member states by September 2006. Effective that date, the further training measures to reduce the frequency of accidents and energy consumption for trucks will become mandatory.
The Directive does not define precisely the term a top-of-the-range simulator, but many member states interpret it to mean a cab type fully moving simulator.

2. Driving simulator characterization

2.1. General characterization

Simulation provides a representation of reality; and is used when the real thing is dangerous, expensive or not feasible for training. Simulation is often used for part of training, as a practice phase, to allow the learners to try new skills until they have mastered it or at least have reached a point where it is safe to try for real. There are several levels of driving simulators, as follows:
- Level 1, desk-top driving simulator, that can be used for driver assessment, as a driving practice tool, a training aid for classroom instruction, and for remediation or driving behavioral modification. It provided drivers with a method of practicing and improving their driving skills in a safe, "virtual" environment,
- Level 2, non-motion partial-cab driving simulator. The system was designed for the novice driver who needs more time behind the wheel in a realistic driving situation within a safe environment. It provided an intensive AAR (After-Action-Review) report using 3 LCD monitors,
- Level 3, limited-motion partial cab driving simulator, allows for teaching and assessing shifting skills for non-synchronous transmissions, Although the system is not motion-based, it does have forced feedback steering and a rumble seat that vibrates according to surface conditions and sound wave inputs,
- Level 4, full motion full size driving simulator. An adaptive and flexible driver training tool, provides realistic vehicle dynamics including interaction between road surface, tires, and automobile suspension. Diverse scenarios educate and test trainees under many different road, weather, dangerous driving situations, and various traffic conditions,
- Level 5, authentic driving cab mounted on a motion base that provides six degrees of freedom (DOF) to give the driver a complete training experience, offers and experience that is as close to reality as possible.

A truck simulator provides an opportunity to reproduce the characteristics of real vehicles in a virtual environment. It replicates the external factors and conditions with which a vehicle interacts enabling a driver to feel as if they are sitting in the cab of their own vehicle. Scenarios and events are replicated with sufficient reality to ensure that drivers become fully immersed in the experience rather than simply viewing it as an educational program.

The system is controlled via a computer network and realistically replicates a virtual world with all known road topographies and traffic situations. The core of the system is a graphical user interface allowing driver training instructors to quickly and easily create complex driver training exercises with critical traffic situations. This also includes dangerous situations, such as blowing tires, nodding off, improper traffic behavior of pedestrians and cyclists, crosswind or a variety of

different weather and road conditions. Also available for training are variable own vehicles, such as different types of trailers and semi-trailers, touring coaches or public transport buses, load conditions, etc. Additionally, complex loading and docking maneuvers can be trained without any risk of damage on a specially developed virtual maneuvering course. Furthermore, the simulator offers a sophisticated module designed to evaluate driver proficiency as well as a „blue light" module to train drivers of fire fighting and task forces. Driving over snow-covered mountain passes or preparation for left-hand traffic in England at a training site in Berlin are but a few examples of this type of modern training.

The simulator provides a constructive experience for the novice driver and enables more complex exercises to be undertaken by the more mature driver. For novice drivers, truck simulators provide an opportunity to begin their career by applying best practice. For mature drivers, simulation provides the ability to enhance good driving or to detect poor practice and to suggest the necessary steps for remedial action. For companies, it provides an opportunity to educate staff in the driving skills that achieve reduced maintenance costs, improved productivity and, most importantly, to ensure the safety of their actions in all possible situations.

An example of truck simulator architecture (Fig. 1.) consists of a cabin including a motion platform, projection system, sound and image generators, simulation host and control station [3, 4]. A complete software environment called SCANeR II allows to define the scenario and simulation data, to reproduce the driving context, including traffic and road signs, as well as the behaviour of the driven car.

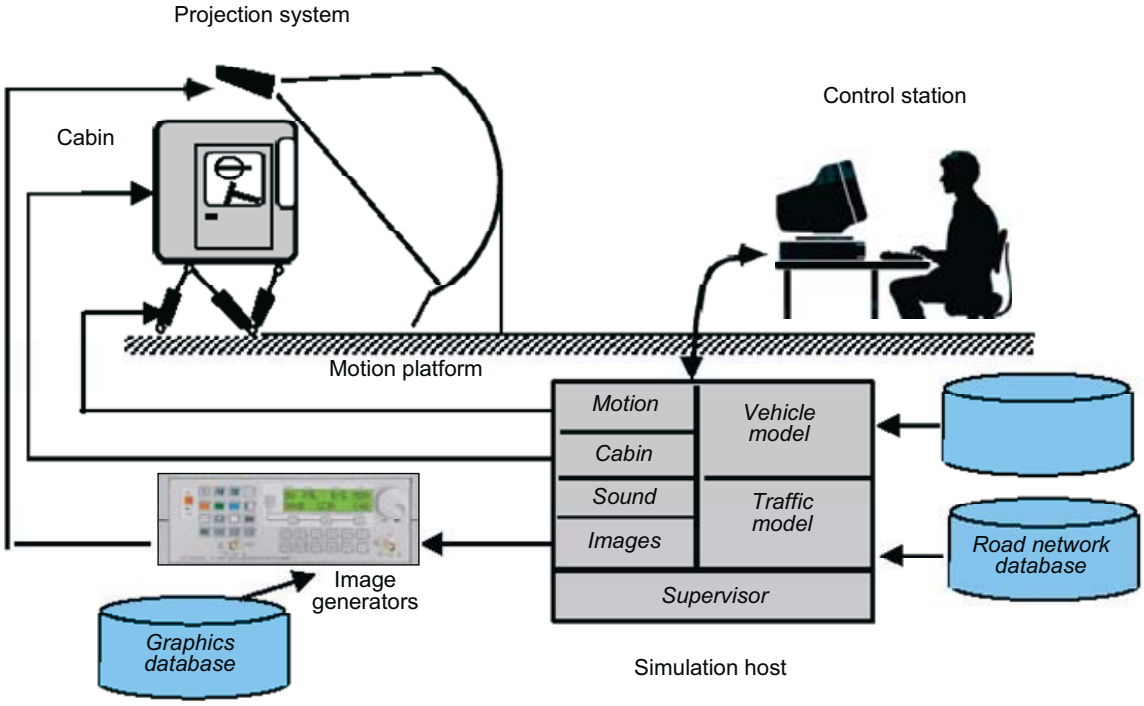

Fig. 1. An example of truck simulator architecture

Motion perception is stimulated both by the visual and motion rendering systems. Tilting the driver cockpit should not induce a modification of visual references, such as the perceived horizon, so as not to produce visual-vestibular conflicts. When the display system is not on-board for instance, a visual compensation should be done with a sufficient synchronization in order for the driver not to perceive discrepancies between visual and vestibular stimuli. It guarantees the stability of perceived horizon during motion with nonzero acceleration.

For motion perception, a crucial information is given by the steering wheel force feedback, perceived by human muscular and particular receptors. This kinesthetic feedback, perhaps the most important when driving a simulator, is difficult to render properly, mainly because of the

transport delay of the whole simulation system.

Building realistic and effective driving simulators requires a huge amount of engineering knowledge and a deep expertise of the perceptual processes underlying driving behavior. Driving is, first of all, a sensory-motor and cognitive activity in which patterns of sensory information are analyzed and exploited to control the state of the vehicle. It is somehow obvious that one of the main concerns of designers and users of driving simulators is to know to what extent the control strategies and the decision-making rules used by the drivers in real-world situations are transposed with fidelity in simulation conditions.

2.2. Top-of-the-range driving simulator requirements

A top-of-the-range simulator so as to assess training in rational driving based on safety regulations, in particular with regard to vehicle handling in different road conditions and the way they change with different atmospheric conditions and the time of day or night. The new methods, using the latest technology, have been put in place to prepare for the forthcoming European directive on the qualification and continuous training of drivers.

The simulator method has been chosen as it offers a number of advantages over traditional training in the vehicle. Its features include traffic situations with gradually increasing difficulty levels, programmable weather conditions, the simulation of extreme situations, etc., all in a safe and cost-effective environment. Simulator should faithfully reproduce the visual, audio and dynamic environment (effects of braking, acceleration, etc.), while allowing interaction with passengers, thanks to the inclusion of ten seats in the cab. It also offers educational advantages, as it allows objective evaluation of the driver's performance.

While it is not intended to replace on-road training, the simulator is a high-quality complementary tool, enhancing the training experience. The validation of driving simulator from a perceptual point of view is an extremely important step in order to qualify driving simulators as a productive tool (i.e. reducing time and costs in prototyping new solutions) and as a realistic and controlled environments to study driver behavior. Visual information is the most important sensory signal apt to determine driving behavior [8, 9]. If the characteristics of the visual information are changed in simulation according to a predetermined amount so as to impact the perception of the driver, one can expect a corresponding change in his driving behavior. Principles of geometry, but also more sophisticated theoretical tools, like the optic flow equations [6], can be used to predict the behavior of the driver [2]. Many perceptual experiments in psychophysical literature have shown that dynamic visual information, such as the optic flow, play an important role in the control of motor variables [10]. The following elements are accounted: the theory of depth perception, ruling out the importance of different visual cues to depth perception [7] and the theoretical framework of the optic flow, which establishes a formal relationship between the amount of induced visual motion pattern and the movement of the observer in a three-dimensional environment [5].

Truck and bus simulator should includes elements and technical details as follows:

1. Original truck or bus driver cabin:
- vehicle controls and operation elements,
- force feedback steering wheel.
2. Multi-channel projection of computer generated scenes:
- 5 channels for drivers out-of window-view covering 180° horizontal x 40° vertical,
- 3 channels for representation of mirror view,
- resolution per channel 3 angle minutes and 60 Hz refresh rate.
3. PC based Image Generator:
- typical road network,
- various weather conditions (four weather seasons, other conditions, like: rain, fog, snow),
- time of the day/night,

- Special effects (vehicle lights, tree shadows, thunders).
4. Autonomous traffic with different categories of road users:
- up to 40 vehicles visible at the same time,
- moving pedestrians, bicyclists, trucks, cars, busses etc.,
- adjustable traffic density and road user behaviour.
5. Electrical motion system with 6 degrees of freedom (6DOF) and 3D virtual object.
- motion system design allows exchange of driver cabin,
- acceleration up to 1 g.
6. sound system for simulation of vehicle and environmental sounds.
7. Accurate model for vehicle dynamic and loading.
8. Instructor Station:
- exercise Creation & Control,
- debriefing Facility,
- administrative functions / report evaluation.

2.3. Reanault truck simulator

The need to enhance the driving realism and the emergence of new simulation needs Renault to develop a new dynamic simulator. Its application field covers the development of vehicle dynamic control systems (stability control, adaptive cruise control), lighting simulation, dynamic comfort, ergonomics and accidentology.

The driving station is a Premium cab which commands have been instrumented. Driver actions on the commands are transmitted to a computer executing the vehicle dynamics model (Tridym). It is a parametrable model which can render several truck configurations (tractor, rigid, articulated) with different engine and equipment types.

The dynamic data computed by the model are transmitted to the dynamic platform for kinaesthetic rendering, to the image generator for visual rendering and to the sound generation system. Two other computers are dedicated, one for simulation scenario management and the other for sound rendering.

Cockpit is instrumented, lightened Premium cab. Command force feedback includes active and passive devices. Active devices on the steering wheel and gearbox lever (including synchronal efforts). Passive devices on accelerator, clutch, brake and parking brake pedals. Mobile platform is an electromechanical Moog platform with 6 degrees of freedom (DOS).

Image generator - Silicon Graphics Onyx Infinite Reality for the frontal view 2 PC/Windows NT with Quantum 3D Voodoo 2 graphics boards for the rear views. Field of view - horizontal: 200° - Vertical: 50° Left, right and wide-angle rear-view mirrors. Software - SCANeR II simulation software.

2.4. Finnish truck and bus simulator

The SimTruck truck and bus simulators have been accepted as a top-of-the-range simulator referenced in the EU directive 2003/59/EC by Finnish authorities, The Ministry of Transport and Communication Finish Vehicle Administration AKF.

The SimTruck driving simulator can be used to train 20 of the required 80 hours for the CE-licence in Finland.

SimTruck driving simulator is based on a Scania R-series Topline cab modified so that driving is possible with both manual and automatic gears. In simulation the simulator represents and behaves like all typical truck models from a delivery van to a 25-meter heavy truck. Several different loads and cargo types can be simulated.

The simulator control devices include all necessary devices to run a truck: Steering, adjustable steering wheel including the steering axle, manual and automatic gearbox, control switches for automatic gears, throttle pedal, clutch pedal (mechanical), brake pedal (pneumatic). Brakes

electronically controlled, ABS included (can be switched off). Retarder controls, parking brake controls, horn, headlight controls (lights implemented virtually), blinkers, instrument panel and indicator lights, door functions (front door), kneeling of chassis, adjustable mirrors. The mirrors react to the normal mirror adjustment controls, which are available to the driver. Fan controls for driver area, cabin fan controls, cabin light controls: roof lights, reading lights, lights, night lights, driver area light controls, ignition lock, cruise control controls, windscreen wiper/washer controls, radio/CD-player, stop sign reset switch, emergency stop for fuel, main power switch, drive level switch, kneeling switch, emergency lights switch, mirror adjustment switch, front fog lights switch, rear fog lights switch.

Instrument panel includes: Speedometer/Tachograph, tachometer, fuel gauge, oil pressure gauge, engine temperature gauge, brake pressure 1 gauge, brake pressure 2 gauge. The feeling of movement in the simulator is created with a moving landscape and a movement platform. The movement platform consists of pneumatic system and a support frame for the movement platform. For visualizing the landscape we use four projectors. Angle of view: over 180 degrees.

A city including: A bus station with platforms, several crossings with traffic lights, crossings with and without separate lanes for different directions, streets with multiple lanes, narrow streets, traffic circles, different kind of stops, overpasses and underpasses, tunnels, speed bumps.

A highway including: Ramps both in and out of the highway, acceleration lanes (short and long), parts with 2 and 3 lanes, a stop ramp. Rural landscape including: wide roads, narrow roads, partially asphalt, partially gravel, speed bumps. Garage environment, parking maneuvers, all maneuvers requested by the driving license, parking, bus stop, need stop.

All parts have up and down hills and viewing obstacles as the real landscape. The total area of the virtual landscape is about 200 square kilometers and the total length of the streets and roads is approximately 1 000 kilometers. The routes can be selected freely. Localizing of the landscape and inclusion of other cities can be done.

Minimum of 25 vehicles, pedestrians, bicyclists, slow vehicles, a roadwork with traffic signs, Unexpected situations: a pedestrian steps on the lane, an animal runs to the road, a vehicle disobeys red light, a traffic jam, the bus develops a technical fault (flat tire, engine stop while driving).

Different weather and road conditions and times of day: Daylight: clear, rain, snow, fog, wind, Dark: stepless adjustment of darkness, clear, rain, snow, fog, wind. All weather and road conditions can be combined with all traffic conditions.

The simulator makes it possible to practice e.g. different weather and traffic conditions, reversing and approaching a stop, customer service situations, ticket sales, driving with automatic or manual gearbox, driving with different RPMs, use of retarder and other control devices, economical driving so that changes in the environment can be eliminated, only the driver's actions affect fuel consumption, driving in a city, on the countryside, on a highway, in traffic circles.

SimBus driving simulator, as defined, is a device that as closely as possible emulates a bus in traffic. The moving base makes it possible for the simulator to move in different directions, real sounds, real control devices and the cabin of a real bus make the device so realistic that the driver feels like driving a real bus.

SimBus driving simulator can take up to 11 passengers, which allows also to practice customer service situation along with driving. The SimBus driving simulator is based on a complete bus body (Volvo, Van Hool, etc.) modified so that driving is possible with both manual and automatic gears. Chassis length is about 5 meters, width about 2.5 meters and height about 3.1 meters. Weight including the movement platform is about 4 000 kg. In simulation the simulator represents and behaves as a two-axle, 10-meter to 15-meter bus. (also articulated bus, 18 meters).

The space needed for the simulator: approximately 100 square meters. Height: minimum of 5 meters. As a custom option the SimBus driving simulator can be built on different cabin types and models as specified by the customer. Also the traffic environment can be modified according to customer's wishes.

2.5. The FTM truck simulator (Germany)

The FTM driving simulator was constructed at the interface of the field vehicle and simulator development. The adaptive control of the driver is influenced by the simulated accelerations which differ from the knowledge of the driver in reality. Beside the visualization this is the most important factor for the sense of presence of the driver. One part of the accelerations at driving operation can be represented by the pitch of the cabin. It has been shown, that this part is infinitesimal small, when the speed of pitch is below the memory threshold for angular acceleration (0.1-0.2 rad/s2). If the memory threshold will exceed, to picture a big part of acceleration beyond the gradient, the test person will perceive the pitch motion.

To offer the driver real operating, an original vehicle will be worked up. Because the driving simulator will be used with different car and truck cabins, a mechanical interface of the motion platform should be designed.

For the FTM driving simulator it is important to install a software concept that allows unfolded and standardized interfaces enhancements and accommodations. There of is concerned especially the model of driving dynamics, which can be modified and can be exchanged for different vehicles and above all the replica of a truck.

With the visualization pool the driving situations are immediately determined. Besides the quality of textur and the definiton of attributes of the passable surfaces determines which visual, vestibular and tactile informations for lane can be created for the driver. Therfore it must be possible to generate task-spezified user-defined landscapes and streets and to integrate this in the visualization pool. This point is exspecially interesting for tasks of research in cooperation wirh the industriy, for example for the simulation of the handling cours of a company.

Particularly to can test driving assistant systems at the driving simulator, specific traffic and driving situations must be generated. The further development of the necessary intelligent autonomic road user in interaction with a dynamical changeable visualization pool is to visible on a basic point in the driving simulator development. Furthermore software modules are to be integrated in the simulator environments which simulate the functionality of driving assistant systems and utilise the analogical information of the driving environment, traffic and the street course of the visualization pool.

Because of the big qualitative and quantitative deviation of the diagrammed accelerations in the driving simulator compared to a real drive there is a high failure rate of test persons. Simulator and motion sickness make it impossible to carry out long tests in the simulator with the concerned persons. The decrease of this rate by the use of an improved calculating algorithm of the acceleration execution is a further approach of further development of the planned driving simulator. Beneath an improvement of the software the disassembly with a transversal skid system shall contribute an improvement of the acceleration presentation. This topic offers students of the faculty of mechanical engineering the possibility, to handle challenging and interdisciplinary tasks at the field of informatics together with the driving simulator producers.

Sound libraries and sound generation are included in delivery, but FTM wants to specify and build up the end equipment. The high quality presentation of sounds is to get improved by a clever choice and installation. A system of high capacity subwoofer for deep frequencies in combination with a tuned booster will allow the optimization of the sound presentation for the driving simulator with relative small expenditure.

Actuators and sensors for the cabin are parts of the driving simulator, which normally not are in the core competence of the simulator producer, but rather in the core competence of the operator, because here is the interface of the different application-tasks. Therefore the following components are designed and realized in active work:

- electro motor for the simulation of the steering moment with electronics and control,
- simulation of the prake-pedal and accelerator pedal traits,

- diverse switches, contacts, conductions,
- camera, screen and interphone.

The projection dome has to be designed and produced individually for the FTM driving simulator concept. Because of the increase of traffic and the rise of comfort and drive functions at the vehicle the driver has to work in his car with more information input. To manage the more complex controllers of the driver in the traffic, he will be observed and provided from sophisticated sensors and control technical driving assistant systems. This innovation for the increase of the active driving safety is combined in the term driving assistant system. At the development of the systems it is especially important, to create flexible and reproduced situations, which in reality is difficult to realize. The driving simulator will get an important development tool for the tests of these systems, because he can simulate real situations.

2.6. The Mark III Motion-Based Driver Training Simulator (USA)

The Mark III Motion-Based Driver Training Simulator combines a fully operational truck cab with the latest digital simulation technology to create life-like training scenarios that improve driving behavior and skill. The Mark III uses high resolution projection imaging on three screens to create a 180° field of vision that is expandable to 360°. Two LCD side mirrors simulate the rear view from the truck cab. Users can select from a variety of visual environments, training scenarios and special effects including extreme weather conditions. Audio and vibration systems add accurate driving noise and feel. Users can choose from more than 140 transmissions, 240 engines and 33 axle ratios. Closed-circuit television allows observers to watch the driver from the operator console.

Tab. 1. Specifications of The Mark III

Height	180 inches	4.57 meters
Width	240 inches	6.40 meters
Depth	288 inches	7.32 meters
Weight	4200 pounds	1906Kg
Power Requirements	90-amp	220 VAC
Minimum Room Size	30 feet by 30 feet by 16 feet high	
Cooling BTU per hour	20.000	

Driver training program includes a unique combination of state-of-the-art simulation, Computer-Based Training and classroom instruction. Drivers receive cost-effective, realistic training in a risk-free environment. The Mark III features:

- five-channel immersive driving environment,
- 1024x768 resolution,
- three screen 180° display expandable to 360°,
- two simulated rear-view mirrors,
- adjustable properties such as vehicle and load weight,
- visual databases available: urban, highway, rural, suburban, freeway and off-road,
- multiple interactive driving scenarios,
- special effects: day/night/dusk and adverse weather (e.g., fog, rain, snow),
- artificial intelligence scenario vehicles,
- 1024x768 High-resolution projectors provide six-screen imaging,
- audio and vibration system for accurate driving noises,

- fully operation dash, instrument panel and controls,
- windows based operating systems,
- closed-circuit TV for observation of driver.

2.7. Truck and bus simulators of Thales

Thales is a leading international electronics and systems group, serving defense, aerospace, security and services markets worldwide and global leader in simulation, modeling, and training, for civil and military markets. Specifications include:

- a cabin replicating that of a real truck,
- a realistic motion of a truck on the road,
- a screen on which a virtual environment is projected and which reproduces the most critical situations in all areas of training,
- an instructor station allowing the teacher to monitor up to 5 pupils at the same time,
- an automatic evaluation tool which will allow a detailed analysis of each student to be made during a training session and used for subsequent debriefing,
- a visual data base reproducing a skid pad area,
- a tool to create a library of training courses fully adapted to aptitude evaluation, initial qualification and periodic training.

TRUST 3000 is a tool for training Heavy Goods Vehicles (HGV) drivers. It recreates most of the situations encountered on the road, from the simplest to the most complex. Until 2006, 42 units have been sold to training organizations spread amongst ten European countries (Belgium, Denmark, Finland, France, Germany, Holland, United Kingdom, Norway, Portugal and Spain). The simulator has contributed to the training of around 140,000 transport professional drivers (goods, passenger and armed forces vehicles).

It should be noted that TRUST 3000 replicates a Premium truck of Renault Vehicle Industry and comprises a software model developed in collaboration with Renault themselves. In the same way, BUS 3000 will conform to the technical requirements of the European committee responsible for following-up on Directive 2003/59/CE transposition, to ensure it is recognized as a „Top-of-the-range Simulator". This committee will meet for the first time in February 2005 and its work was completed by the end of 2005.

Lastly, BUS 3000 will be manufactured to the same quality standards as Thales high-end simulators , which will ensure a high availability ratio. Long term support higher than 10 years will be provided at the customer request.

BUS3000 will have all the characteristics of the Truck Simulator (TRUST3000) manufactured by Thales, of which 36 items have been delivered or are on order, and have been used to train more than 85,000 drivers in 6 EU Member States to date (Belgium, Denmark, Spain, France, UK and the Netherlands).

3. Conclusion

A wide variety of driving simulators is available nowadays. The technical characteristics of the simulators cover a wide range of specifications. The present state of the technology seems to make it possible to implement different driver training applications with a growing level of complexity and fidelity to real driving conditions. The validation of simulators is also an area were there is still a need for further advance. A methodological approach to driver simulator validation for driver training is required as a key step towards extended use of simulators as standard tools in the driver training process in Europe.

Research of driving simulators should focus on needs of different groups of drivers, but it should also consider the role of the trainer and his task in the process of simulator training. The further research should also take more into account the psychological factors that influence the

safe behaviour on roads (since it is clear that skilled driver does not mean safe driver) but also on motion sickness is needed.

Nevertheless, there is a lack of common technical specifications both at national level and at European level that define the minimum conditions that a simulator should have to be suitable for use in the different levels of driver training applications.

At the present no more than 10% of commercial drivers have received training beyond what is required for obtaining their driving licences. The implementation of Directive 2003/59/EC of the European Parliament and of the Council of 15 July 2003 on the initial qualification and periodic training of drivers of certain road vehicles for the carriage of goods or passengers will contribute to change this situation, as drivers will have the obligation to undergo periodic training every five years.

The final objective has to be a continuous training program that is keeping drivers up dated about the main issues of the daily duties of a bus driver, and also covering prevention procedures for cases when the vehicle is stopped. Research carried out by accidents analyzes confirmed that formal training for professional drivers, in particular training in defensive driving, combined with other incentive systems, can reduce the accident rate by around 20%.

References

[1] *Directive 2003/59/EC of the European Parliament and of the Council of 15 July 2003 on the initial qualification and periodic training of drivers of certain road vehicles for the carriage of goods or passengers,* Official Journal of the European Union L 226/4, 10.9.2003.

[2] Gibson, J. J., Crooks, L. E., *A theoretical field-analysis of automobile-driving,* The American Journal of Psychology, Vol. 51, pp. 453-471, 1938.

[3] Kemeny, A., *Renault, Direction de la Recherche - Research Division Technocentre Renault,* TCR AVA 212, 2000.

[4] Kemeny, A., Reymond, G., *Transport delay analysis in driving simulators with head mounted displays*, Proceedings of the DSC'97, France, Sep.1997, pp. 85-98.

[5] Koenderink, J. J., *Optic flow,* Vision Res, Vol. 26, pp. 161-180, 1986.

[6] Lee, D. N., *The optic flow field.* Philosophical Transactions of the Royal Society, London, B, Vol. 290, pp. 169-179, 1980.

[7] Palmer, S. E., *Vision Science.* Photons to Phenomenology, Cambridge, MA, Mit Press, 1999.

[8] Reymond, G., Kemeny, A., *Motion cueing in the Renault driving simulator,* Vehicle System Dynamics, Vol. XX, 2000.

[9] Reymond, G., Kemeny, A., Droulez, J., Berthoz, A., *Role of lateral acceleration in curve driving: driver model and experiments on a real vehicle and a driving simulator.* Human Factors, Vol. 2001.

[10] Warren, W. H., Kay, B. A., Zosh, W. D., Duchon, A. P. and Sahuc S., *Optic flow is used to control human walking*, Nature Neuroscience, Vol. 4, pp. 213-216, 2001.