Benchmarking and classification of CBT tools for driver training

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TRAIN-ALL

Integrated System for driver Training and Assessment using Interactive education tools and New training curricula for ALL modes of road transport

Contract no. 031517

Benchmarking and classification of CBT tools for driver training

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V2	19 Oct 2007	Revised version incorporating peer review comments

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Abbreviations List

Abbreviation	Definition
ABS	Anti-lock Braking System
ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance Systems
ASR	Anti Schlupf Regierung – Acceleration Skid Control
BAS	Brake Assist System
CAVE	Cave Automated Virtual Environment
CBT	Computer Based Training
EBD	Electronic Brake-force Distribution
ESP	Electronic Stability Programme
EU	European Union
FCW	Frontal Collision Warning
FOV	Field of View
HMD	Head Mounted Display
HMI	Human Machine Interface
HUD	Head Up Display
IR	Infra-Red
IVICS	In-Vehicle Information and Communication Systems
KMW	Krauss-Maffeï Wegman
LDW	Lane Departure Warning
MMT	Multi Media Tool
RDE	Rheinmetall Defence Electronics
TRL	Transport Research Laboratory
VE	Virtual Environment
VR	Visual Representation
WP	Work Package

Executive Summary

A significant proportion of European road accidents involve particular driver cohorts, foremost novice drivers who are over-represented in accidents in comparison to other age groups of drivers, but also motorcyclists, truck drivers or emergency drivers. Despite some cohort-specific differences in training needs there are training goals that apply to all driver groups. This specifically pertains to the training of higher order strategic factors associated with vehicle driving rather than vehicle control skills that have traditionally been at the heart of training endeavours. These learning targets thereby include journey-based decisions, hazard perception as well as the ability to self-assess and effectively control the way that personal traits affect driving behaviour and risk acceptance (Ivancic & Hesketh, 2000).

The core activity of the task A1.1 (part of Work Package 1) described in this report was the systematic review of a wide range of existing tools and technologies for computer-based training (CBT) of drivers in all TRAIN-ALL application fields. The review covered all CBT tools, with emphasis on driving simulations of all functional levels. The purpose is to provide an indication of the state of the market and take the first steps towards clarifying the types of CBT available and showing how they might be considered during future accreditation and certification of driver training schemes. The focus here is on technology provision, and it must be remembered that evaluation of technology can only be complete in relation to defined operational requirements based on training needs analysis. This report feeds forward into other work packages that consider the curriculum, certification, and cost effectiveness in more detail.

A questionnaire survey was conducted to gather information of multimedia tools (MMT), neurological test batteries and driving simulators used in project member countries and overseas. In total 25 completed questionnaires on multimedia tools, one questionnaire on a neurological test battery and 20 questionnaires on simulators were returned in time for inclusion.

With the rapid development of information and other technologies and decreasing associated costs a large variety of training tools has become available for practically all driver groups, from basic training of novice drivers to in-service training of experienced drivers. Training tools range from simple video sequences to top of the range driving simulators. The interactivity of the multimedia tools makes it possible for the drivers to continuously update and elaborate current knowledge on their own. Additionally, the new technologies may offer the possibility of objectively assessing driving performance and thus support the driving instructor in his role. Further advances may change the traditional instructor-trainee set up by offering opportunities for self-evaluation and remote/distance learning platforms, for example, through e-learning.

The set-up of simulator training often seems to be a mere translation of on-road driving lessons into the virtual worlds. The lack of coverage of the highest levels of the GADGET matrix (strategic and motivational driving goals) may not only be explained by technical inabilities of a simulator, but rather by the absence of an in-vehicle training format that would successfully address these variables. In the future more thought must be given to the development of appropriate course-ware and training formats and settings (e.g. including peers in the training process). This could include the development of driving tasks on the strategic level (e.g. plan a trip in the simulator to a specified location) or could address personal attitudes and motivations by allowing or triggering trainees to disclose them in the training process.

Finally, more and robust evaluation studies of simulator-based driving are urgently needed. To successfully promote simulator-based driving training, evaluation studies on transfer of training are vital in demonstrating the benefits of simulators to a wide, and often sceptical, range of stakeholders.

Classification and benchmarking

Multimedia Tools

Previous clustering of MMT has been based on the interaction level between the user, the tool and the task required by the user:

- No interaction;
- Answering of questions;
- Prediction and progress of scenario, determination of risks.

An alternative clustering of support tools for the theoretical training is possible, based on different characteristics. An important characteristic is the user type and the environment for which each tool is intended. For example:

- Multimedia training tools for use by the trainees either in their home (distance learning) or in the training school;
- Multimedia training tools for use solely in the training school;
- Multimedia training tools for use solely in the home (distance learning).

However, the above categorization is subjective and, in general, it is preferable that a driver instructor is present during the training, so that the trainee converse directly with the trainer in case of difficulty or for any question that might arise. Also, the trainer can check and correct the trainee if they have misunderstood something. This can be realised with the trainer being present either in the same room or by some other media (e.g. through the internet or teleconference).

An alternative approach has been explored here. The GADGET matrix provides a strong basis for the clustering of tools according to levels covered by a given multimedia tool. The four levels of the GADGET matrix are:

Goal for life and skills for living (Goals) (Highest Level);

Driving goals and context (Strategy) (High);

Mastery of traffic situations (Master) (Low);

Vehicle manoeuvring (Basic) (Lowest Level).

Each tool has been classified according to the level of training provided. Each tool could cover one or more level of training. The tools have been clustered into three levels:

- Top Level (cluster 1);
- Middle level (cluster 2);
- Lower Level (cluster 3).

In order for a tool to be classified as ‘top level’ it was required to satisfy one of the following criteria:

- Cover all four levels of driver training;
- Cover the two highest levels of the GADGET matrix (Goals and Strategy);
- Cover one of the highest levels of training and both the lower levels of training (Goal or strategy and Mastery and Vehicle manoeuvring).

In order for a tool to be classified as ‘middle level’ it was required to cover at least one of the higher levels of training (Goals and Strategy) as well as one of the lower levels of training (Mastery, Vehicle Manoeuvring). Finally, in order for a tool to be classified as ‘bottom level’ it was required to provide at least one of the lower levels of training (Mastery, Vehicle manoeuvring).

Driving Simulators

A benchmarking system for the driving simulators identified in the questionnaire survey was developed in the style of the flight simulator banding, including five levels, with level A being the lowest and level E being the highest level of complexity of the driving simulator.

The banding did not include all variables deemed relevant for a comprehensive description of driving simulators but focussed on main variables including:

- Replication of vehicle features
- Visual system
- Motion rendition
- Interactivity/number of simulated road users (low (L), medium (M), high (H));
- Sophistication of the simulated road environment, including road layouts and environmental conditions (low (L), medium (M), high (H));
- Breadth of learning opportunities provided, e.g. complexity of training scenarios.

For the purpose of benchmarking, each simulator was considered on all of these variables, and an overall expert assessment made on the balance of the grades (details in appendix). Examples are provided for each of the bands, and the merits and limits of the approach are discussed along with consideration of alternative approaches.

There is no single dimension or attribute that allows a straightforward and non-controversial classification of driving simulators. There are many subsystems within even the most basic simulation training device. Simple, level A devices will employ a visual display, some form of manual input device, and a task presented within a traffic-related environment. As we move up the scale of complexity, motion, sound, and vibration are introduced, and the realism of the dynamic driving task increases. The fact that different systems may have strengths in one area but weaknesses in others compared to systems of roughly similar price and training aim means that a classification which takes a technology focus struggles to provide distinct classes. The table below relates technical capability of a system to some of the learning targets that it can address successfully.

Table 1: Overview of posited parameter values for five simulator bands.

Qualification Level	*General technical requirements*	*Learning targets*
A	The lowest level of driving simulator technical complexity The driving simulator enables the user to navigate the ego-vehicle through a populated road environment displayed on a single channel screen. Rear and side mirror views may not be provided. The movements (vertical and lateral) of the ego-vehicle are controlled by the use of a mock steering wheel and pedals or by joy-stick. Kinaesthetic feedback for driving controls is not provided. The driving simulation does not include realistic gearshifts, a vehicle cabin or a motion system. Changes of the underlying vehicle model are not possible or very limited. The interactivity of simulated road users is low. Low number of simulated road environments and environmental conditions	Suitable for: Awareness raising, visual familiarisation with road environments, or simple entertainment (may have value in promoting life goals and strategic issues)
B	As for Level A plus: Provision of car controls, including pedals, gearshift, steering wheel Provision of an artificial vehicle cab The road environment is displayed on a single visual channel Side or rear mirror views may not be provided No motion system provided Limited number and interactivity of simulated other road users Limited number and realism of simulated road environments and environmental conditions	As for Level A plus: Familiarisation with vehicle controls and procedures possible. Compliance with some rules of the road.
C	As for Level B plus: Realistic feel of car controls (e.g. pedal or steering wheel resistance) A motion system may be provided Wider FOV through multi-channel projection often provided Greater number and realism of simulated road user behaviour Training of more complex driving scenarios possible	As for Level B plus: Training of simple manoeuvring tasks in small number of road environments possible; and some tactical decision making in simple traffic

Qualification Level	*General technical requirements*	*Learning targets*
D	The second highest level of driving simulator complexity As for Level C plus: Provision of realistic vehicle cab Multi channel visual system with provision of rear and side mirror views 6 Degree of freedom motion system provided Larger number and realism of simulated road environments and environmental conditions Behaviour of other road users can be influenced High degree of interactivity with simulated road users provided Change of underlying vehicle model possible Addition of ADAS possible	As for Level C plus: Training of complex manoeuvring tasks including interaction with other road users, hazard perception, and eco-driving
E	The highest level of driving simulator complexity As for Level D plus: 6 Degrees of freedom plus extended x and y motion system (rails) provided Training with highly complex training scenarios with high level of interactivity between road users	As for Level D plus: Wider range of complex manoeuvring tasks recreated adequately due to availability of more comprehensive motion rendering

The assignment of simulators to the bands A to E in this report is not intended to be definitive, nor should it be viewed as having importance beyond that of providing a worked example of how such a system might operate if full information was available for each system under consideration.

Within the TRAIN-ALL project the intention is to further refine the classification in the light of experience and consensus gained through work in other work packages. In particular it should be noted that the importance of the classification and benchmarking exercise, is to move towards a point where a clear view of what level of simulation is required to deliver particular training lessons adequately can be expressed.

There are alternative ways of considering the suitability of different simulators for different teaching goals (for example, relating levels of the GADGET matrix to specific technology criteria). There could be yet other classifications that emerge during the progress of the TRAIN-ALL project, but for current purposes the A-E serves a useful purpose as a descriptive tool. However, though it is clear that a higher band simulator is a more complex technical system than one from a lower band, this should not be confused with issues of fidelity or even quality. There can be poor quality and excellent quality that could fit in any particular benchmarking structure. This report should be seen only as the starting point for the consideration of how best to present training goals (curricula) to the student.

The banding system for simulators will have greater impact once information becomes available in the public domain about the efficacy of training transfer from the various simulated or CBT environments, to real world behaviour and performance. Such data is lacking at present.

The training experience is a function of the characteristics of the trainee, the trainer, and the training delivery system, and the dynamics of the interaction between them. As such, although the scope of the trainer function is likely to change in the future as synthetic training becomes more widely adopted, the importance of the trainer as facilitator, mentor and confidant of the trainee will continue, and be particularly important for those trainees who might not be at ease with the technologies involved.

Although the information available for this review was partial, it shows that benchmarking and classifying in a coherent manner is possible. There appears to be a thriving community in Europe of users and suppliers of multimedia systems and driving simulators, and it is hoped that future developments will lead to continued improvements in training and therefore to the raising of standards for safe and fuel efficient driving.

1 Introduction

1.1 Background of the TRAIN-ALL project

Throughout Europe 40,000 people die and 1,700,000 are injured in road accidents every year. 150,000 victims become permanently disabled. A significant part of these accidents involve particular driver cohorts; foremost novice drivers who are over-represented in accidents in comparison to other age groups of drivers, as well as motorcyclists, truck drivers or emergency drivers.

Research evidence suggests that a considerable percentage of these accidents can be attributed to insufficient or even inappropriate training and may thus be remedied through provision of bespoke training programmes. Particular driver cohorts may thereby differ considerably with regards to accident patterns and training requirements. For example:

- Novice drivers' accident patterns (e.g. single vehicle accidents at night due to loss of control) are frequently related to personal attitudes, risk seeking and –taking characteristics or lack of situational awareness (Maycock, 2002). Several EU-projects on novice driver training (i.e. GADGET and TRAINER) have made the point that traditionally novice driver training has focused on vehicle control skills and traffic rules, without reaching far enough in its efforts to train adequate risk awareness and self-evaluation skills that may be able to reduce accident frequencies.
- The prevalence of traffic-scanning errors in motorcyclists is typically high (Sagberg 2002). Furthermore riders typically have no experience of using safety equipment (i.e. ABS and ASR) and little experience of driving different types of motorcycles.
- Despite a prolonged training period associated with their vocational licence heavy goods vehicle drivers keep being highly involved in specific accident types, e.g. drowsiness-related (Western Australia Road Transport Industry, 1998).
- Emergency vehicles (e.g. police, ambulance, fire and rescues services) are estimated to have an eight times higher risk of being involved in an accident when driving with lights and sirens compared to driving without (Schmiedel & Unterkofler, 1986). On average every police car is involved in an accident once a year. The training of emergency vehicle drivers is, however, often limited to closed courses and crucial training goals such as the interaction with other road users cannot be realised without putting road users at risk.

Despite some cohort-specific differences in training needs there are training goals that will apply to all driver groups mentioned. This specifically pertains to the training of higher order strategic factors associated with vehicle driving rather than vehicle control skills that have traditionally been at the heart of training endeavours. These learning targets thereby include journey-based decisions, hazard perception as well as the ability to self-assess and effectively control the way that personal traits affect driving behaviour and risk acceptance (Ivancic & Hesketh, 2000). In the driving task taxonomy developed in the EU-project GADGET (Hattakka et al. 1999) these learning goals are typically located on the third and fourth level of the taxonomy (see Table 2).

The systematic training of these skills in practical training is difficult as the instructor's control over dynamic traffic situations is low. Furthermore, the training of these skills may put other road users at risk. Hence, realistic, interactive, off-road tools are required that make the drivers aware of their, as well as the road environments' (other road users, infrastructure and vehicles) limitations, the problem of overestimating ability, feedback and risk compensation processes. These training tools would provide the following potential benefits:

- Standardisation and repeatability of training scenarios;
- Targeted creation of learning opportunities;
- Controlled manipulation of the traffic environment (i.e. traffic density, weather conditions, behaviour patterns of ambient traffic etc);

- Allows training of sub tasks;
- Provision of feedback and potentially provision of other road users' perspective (real time or as debrief afterwards);
- Enhanced reliability and objectivity of performance measures;
- Capability to familiarise the driver with assistance - and information systems (IVICS and ADAS) and different vehicle types (including transmission);
- Ability to monitor and adapt training according to each trainee's progress;
- Reduction of risks to other road users and ecological benefits through reduced driving.

Table 2: GADGET training goal matrix (Hattakka et al., 1999).

		Essential curriculum		
		Knowledge and skills	Risk-increasing factors	Self-evaluation
Hierarchical levels of behaviour	Goals for life and skills for living (general)	Knowledge about/ control over how life-goals and personal tendencies affect driving behaviour lifestyle/life situation peer group norms motives self-control, other characteristics personal values	Risky tendencies acceptance of risks self-enhancement through driving high level of sensation seeking complying with social pressure use of alcohol and drugs values, attitudes towards society	Self-evaluation/ awareness of personal skills for impulse control risky tendencies safety-negative motives personal risky habits ...
	Driving goals and context (journey-related)	Knowledge and skills concerning effects of journey goals on driving planning and choosing routes evaluation of requested driving time effects of social pressure inside the car evaluation of necessity of the journey	Risks connected with driver's condition (mood, BAC, etc.) purpose of driving driving environment (rural/urban) social context and company additional motives (competitive, etc.) ...	Self-evaluation/ awareness of personal planning skills typical driving goals typical risky driving motives ...
	Mastery of traffic situations	Knowledge and skills concerning traffic regulations observation/selection of signals anticipation of the development of situations speed adjustment communication driving path driving order distance to others/safety margins	Risks caused by wrong expectations risk-increasing driving style (e. g. aggressive) unsuitable speed adjustment vulnerable road-users not obeying regulations/ unpredictable behaviour information overload difficult conditions (darkness, etc.) insufficient automatism or skills	Self-evaluation/ awareness of strong and weak points of basic traffic skills personal driving style personal safety margins strong and weak points for hazard situations realistic self-evaluation
	Vehicle manoeuvring	Knowledge and skills concerning control of direction and position tyre grip and friction vehicle properties physical phenomena	Risks connected with insufficient automatism or skills unsuitable speed adjustment difficult conditions (low friction, etc.)	Awareness of strong and weak points of basic manoeuvring skills strong and weak points of skills for hazard situations realistic self-evaluation

With the rapid development of information and other technologies and decreasing associated costs a large variety of training tools has become available for practically all driver groups, from basic training of novice drivers to in-service training of experienced drivers. Training tools range from simple video sequences to top of the range driving simulators. The interactivity of the multimedia tools makes it possible for the driver to continuously update and elaborate current knowledge on their own. Additionally, the new technologies may offer the possibility of objectively assessing driving performance and thus to support the driving instructors in their role. Further advancements may change the traditional instructor-trainee set up by offering opportunities for self-evaluation and remote/distance learning platforms.

The value of computer-based training has been the subject matter of several large research national and international projects, including EU projects (i.e. BASIC, VIRTUAL, TRAINER, ADVANCED) which stressed the importance of designing and using appropriate training scenarios.

Despite a substantial body of research, there exists as yet no Europe-wide computer-based training tools market. One of the major obstacles is the high fractionalisation of the market, with most CBT manufacturers operating in few countries and a total lack of standardisation and modularity, that would allow users to expand their systems gradually to different scenarios and user groups or to interconnect different CBT tools. Currently, users are totally dependent upon the viability and market plans of the vendor they choose to purchase from and thus are reluctant to invest more.

1.2 TRAIN-ALL objectives and project partners

The TRAIN-ALL project aims to

1. develop an integrated, modular, computer-based, single-platform system for land-based drivers, including passenger car drivers, truck drivers, emergency drivers and motorcycle riders; and
2. validate it in ten sites throughout Europe.

The developed system will be cost-effective (create viable business), adequate for training, assessment and monitoring of the driver and include all modes of operation (pre-trip, on-trip, emergency handling). Potential effects on road safety and other social benefits of the developed system will be assessed.

Seventeen participating organisations from eight European countries cooperated to develop a Pan-European computer-based platform for drivers' training and assessment. The research is organised in the eight following work packages:

- WP1: Training needs and scenario definition;
- WP2: Towards a single training and assessment platform;
- WP3: Enabling technologies;
- WP4: Tools development;
- WP5: Verification pilot evaluation;
- WP6: Demonstration pilot evaluation;
- WP7: Dissemination and exploitation;
- WP8: Project management.

Each work package comprises a number of tasks to be completed under the leadership of one of the project partners. Task A1.1, the benchmarking and classification of existing tools and technologies, was carried out under the lead of the Transport Research Laboratory (TRL).

1.3 Description of objectives for task A1.1 in WP1

The core activity of task A1.1 was the review of existing tools and technologies for computer-based driver training in all TRAIN-ALL application fields. The review covered all CBT tools, with emphasis on driving simulations of all functional fidelity levels. Special emphasis was put on the functional (i.e. training) complexity of simulations, because the required technical level of a simulation depends on the training objective (e.g. part-task simulators can be sufficient to train novice drivers' basic car control). A critical discussion of the identified training tools' advantages and disadvantages for the TRAIN-ALL application field was central for the specification of promising technological solutions, best practices and technological gaps.

1.4 Data gathering and responses obtained

To obtain comprehensive information on computer-based training tools and technologies currently in use across the EU, a draft data gathering template was informed by the review of previous EU projects such as the TRAINER, TEST and BASIC. The draft questionnaire was circulated for comment, refined and agreed with the project partners. The questionnaire is divided into four sections:

1. contact details of the organisation providing the information on the computer-based training tool(s);
2. a section on multimedia tools in use;
3. a section on neurological test batteries used; and
4. a section on driving simulators in use.

A copy of the questionnaire is attached in Appendix C.

Electronic copies of the questionnaire were sent to all 17 project partners together with an accompanying letter that briefly outlined project aims and advised on the completion of the questionnaire (a copy of the accompanying letter can be found in Appendix C). To capture a maximum number of training tools for systematic review, project partners were asked to distribute questionnaire and accompanying letter to organisations using simulators or multimedia tools for driver training or assessment. Further questionnaire copies were sent out directly to driving school and simulator training providers in Europe and overseas.

Twenty-five completed questionnaires on multimedia tools, one on neurological test batteries (operator: DriveSafety in the United States) and 20 on simulators were returned to TRL. Table 3 and Table 4 provide an overview on operators and product names of the 25 multimedia tools and the 20 simulators that were described in the questionnaires.

Table 3: Details of the 25 multimedia tools described in the questionnaire returns.

Manufacturer	*Country*	*Product Name*	*Year*
The Police Foundation	UK	The Police Driver's Course on Advanced Driving	2005
Driving Standards Agency	UK	What If? The Official Guide to Boosting Rider Awareness	2001
Driving Standards Agency	UK	What If? The Official Guide to Boosting Driver Awareness	2001
Driving Standards Agency	UK	The Official Theory Test for Drivers of Large Vehicles	2003
Driving Standards Agency	UK	The Official Guide to Hazard Perception	2004
University of Wuerzburg	D	Simulation of Emergency Driving	2002
WIVW GmbH[1]	D	Emergency Driving	2005
Degener Lehrmittel GmbH	D	SCAN & TEACH	2000-2003
CERTH/HIT[2] (BOB campaign)	GR	BOB MMT	2001
Backs Electronics Publishing Ltd	GR	Driving Skills	2000
Gutenbic S.A	GR	Feu Vert pour le permis de conduire	2006
CERTH/HIT	GR	INFORMED MMT	2000-2001
CERTH/HIT	GR	Multimedia Training for Students	2005
INTRAS[3]	E	SEVIAL	2000-2004
STR Media AB[4]	S	TK 2000	2003
STR Media AB	S	Vagmarken	2000
Bonnier Multimedia	S	Bonniers Traficskola 3	2001
STR Media AB	S	Korkortstest	2000-2001
Commercial Union Belgium	B	Interactief Defensief Autorijden	2002
De Boeck & Lancier	B	Mijn Rijbewijs zonder omwegen	2001
Vekabest	NL	De nieuwe Rijes	2004
UGA Media	NL	ZEBRA	2001-2003
STR Media AB	NL	En god hjalp med teorin	2002
DriveSafety	US	Vection and HyperDrive	2006
VTK	NL	Klik op de weg/E op weg	2002/03

[1] Wuerzburger Institute fuer verkehrswissenschaften
[2] Center for Research and Technology Hellas/ Hellenic Institute of Transport
[3] Instituto Universitati de Trafico y Seguridad
[4] Sveriges Trafikskolors Riksverbund

Table 4: Details of the 20 simulators described in the questionnaire returns.

Operator	*Country*	*Manufacturer*	*Country*	*Product name*	*Year*
-	GR	GSC Grupo de Simulacion de Conduccion	E	AutoSim	2001
CERTH/HIT	GR	FOERST	D	Smart Simulator	2002
BBP[5]	D	Rheinmetall Defence Electronics	D	Emergency Driving Simulator	2001
WIVW[6]	D	WIVW GmbH	D	Training and Research driving Simulator	2000
Green Dino	NL	Green Dino	NL	Dutch Driving Simulator	2007
Centre Ricerche FIAT	I	CRF Virtual Reality	I	CRF Advanced Driving Simulator	2002
VTI[7]	S	FOERST	D	Fahrsimulator F10PF	2002
Trafikcenter Scantec AB	S	Oryx Simulation	S	Wheel loader, digger machine, crane	2005
Thales	FR	Thales	FR	TRUST 3000	2006
DriveSafety	US	DriveSafety	US	DS-600	2006
Krauss-Maffei Wegman (KMW)	D	KMW	D	Mobile Simulator Safety Training	2006
Arriva	UK	STISIM 400	US	System Technology Incorporated	2003
MPRI (L3COM)	US	MPRI (L3COM)	US	TranSim VS Driver training Simulator	2006
Doron Precision System	US	Doron Precision System	US	460 Truck	
Singapore Ministry of Defence	SG	Lockheed Martin	US	Truck Driver Trainer	2001
British School of Motoring	UK	Faros	FR	EF-X	
Singapore Safety Driving Centre Ltd	Singapore	Honda	J	Honda Driving Simulator	2001

[5] Bayerische Bereitschaftspolizei
[6] Wuerzburger Institut fuer Verkehrswissenschaften
[7] Swedish National Road and Transport Research Institute

Operator	*Country*	*Manufacturer*	*Country*	*Product name*	*Year*
DriveSafety Inc.	US	DriveSafety	US	DS-600	2006
Drive Square LLC	US	Drive Square LLC	US	Portable in-vehicle Driving Simulator	2003-2006
TRL	UK	Thales	FR	TRUST 5000	2005

The information provided covered multimedia tools and simulators in seven of the eight participating countries: the Netherlands (5), Belgium (2), Germany (6), Sweden (6), Italy (1), Spain (1), Greece (7), France (1), the United Kingdom (8) and additionally covered the United States (7), Singapore (1).

2 Survey responses

2.1 Neurological test batteries

Only one questionnaire on neurological test batteries used in the context of simulator-based driver training was obtained. The DriveSafety tool was described as being targeted at all types of user (novice, experiences, driving instructors, the elderly and the disabled). The tool included a wide range of physiological tests, including executive control, active virtual field, alertness, distractibility, divided attention, flexibility, and visual scanning. The only tests the battery did not comprise were go/no go, Schuhfried, and the Wiener test system.

The described test battery takes the form of a custom package designed to be used within the DS-600 simulator; consequently it has special hardware, software and input devices that were not described in detail by DriveSafety. Additionally, the output modality and feedback options are dictated by the custom package supplied.

2.2 Multimedia tools

Seventeen of the 25 multimedia tools described included a specification of the product price. On average, those tools came at a cost of €50.00 (median value), with a minimum of €14.00 and a maximum of €40,000.

As illustrated in Figure 1 the majority of training tools was aimed at learning to drive a car.

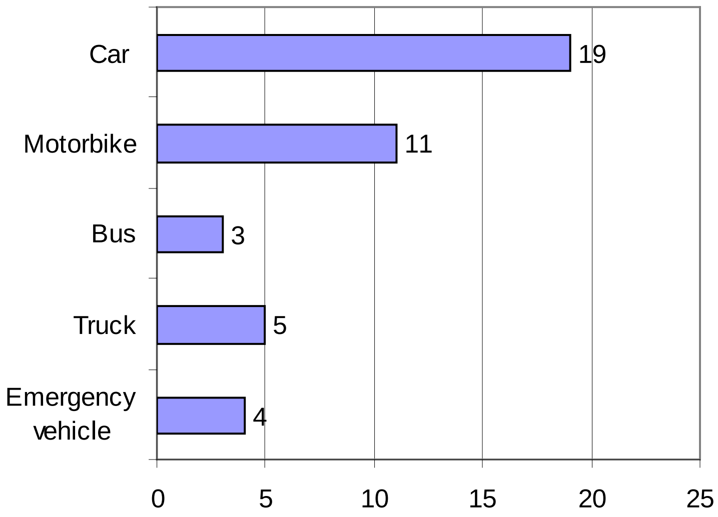


Figure 2.1: Vehicle type multimedia training is aimed at.

Thirteen of the described tools were specific to the training of one vehicle type, whereas 10 could be used for driver training of two vehicle types (most frequently car and motorbike). One training tool could be used for the training covering four, another one covering five vehicle types. The majority of multimedia training tools therefore seem to be tailored to specific vehicles.

Nine training tools could be used by only one trainee at the time; five answered that the tool could either be used by one trainee at a time or for demonstration purposes with several pupils. Simultaneous use by several trainees was possible with six of the 25 multimedia tools.

Novice drivers were the most important training target group for the multimedia tools described (see also

Figure 2). However, the target group of experienced drivers was also high with 17 of the tools being used for their training. Comparable to the findings on target vehicle groups, the largest proportion of multimedia tools was tailored to the training of one specific trainee group (10 tools), seven could be used for the training of two, five for the training of three groups. Only three of the tools were claimed to be appropriate for the training of all five trainee groups.

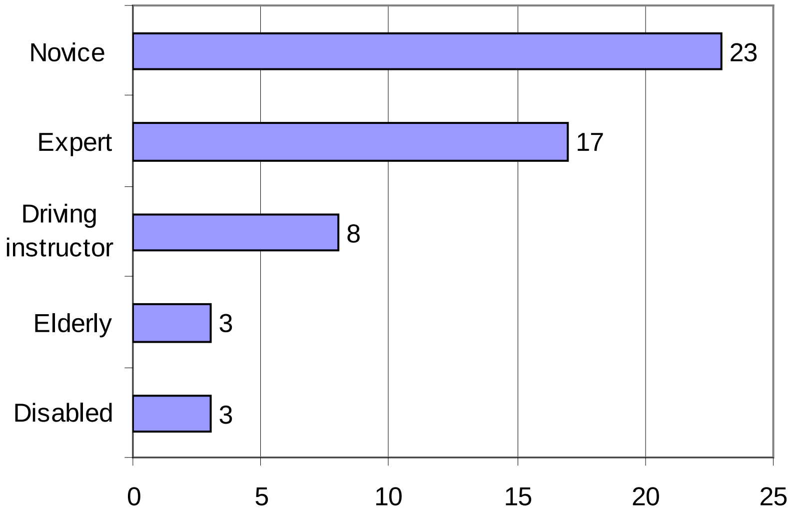


Figure 2.2: Trainee target group for 23 multimedia tools described.

The majority of multimedia tools address learning goals on the manoeuvring level of the driving task (20 tools), followed by learning targets on the control level (n= 14) and the strategic level (n= 13). Ten of the described tools include material on driving goals and underlying motivation and seven can also be used for trainee assessment purposes (see also Figure 3). The 25 multimedia tools most frequently address two training levels (n= 8), seven tools address three levels. Three tools address all four GADGET levels and also allow the assessment of the trainee's performance.

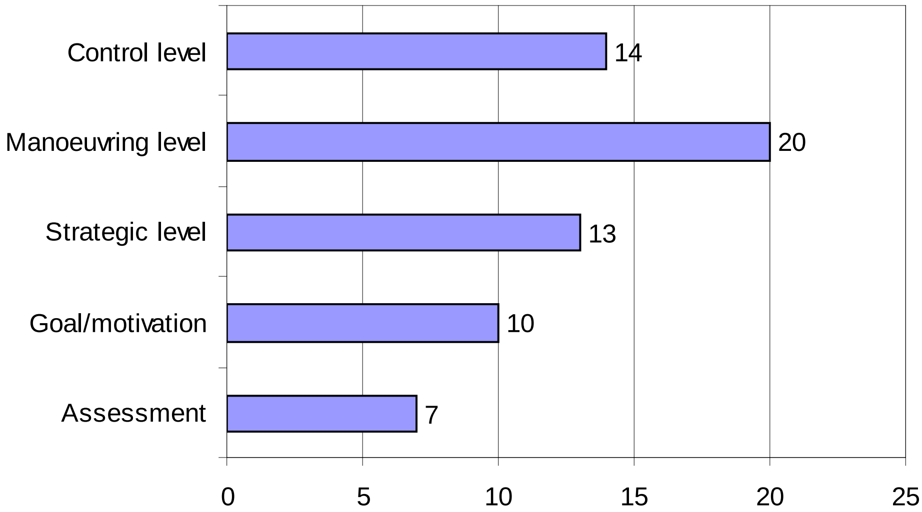


Figure 2.3: Training target level[8] and assessment functions of multimedia tools used.

The majority of multimedia trainings described come in a CD-ROM format (n= 13), three are video-based. Five of tools use a combination of CD-ROM and video. Interactive websites are represented by two tools and the remaining tools use a DVD format or a closed network.

As the majority of tools are CD-ROM or DVDs the most frequent system requirement is a PC (23 out of 25 multimedia tools). The PC needs to be fitted with a soundcard for 20 tools and with an Mpeg card/ AVI system for 15 of the MMT. Additional requirements include video (n= 11) and internal memory (n= 5). The software platform for all computer-based MMT is Windows 95 or higher. Browser compatibility was only relevant for two of the MMTs, both German Emergency Driving Training tools, which operate as an interactive website/ closed network.

Seven out of 25 MMTs are developed for the use by the trainee at home. The same number of tools provides greater flexibility and can be used at home, for demonstration purposes through the instructor or by the trainee at the driving school (see Figure 4). One tool was for demonstration purposes only.

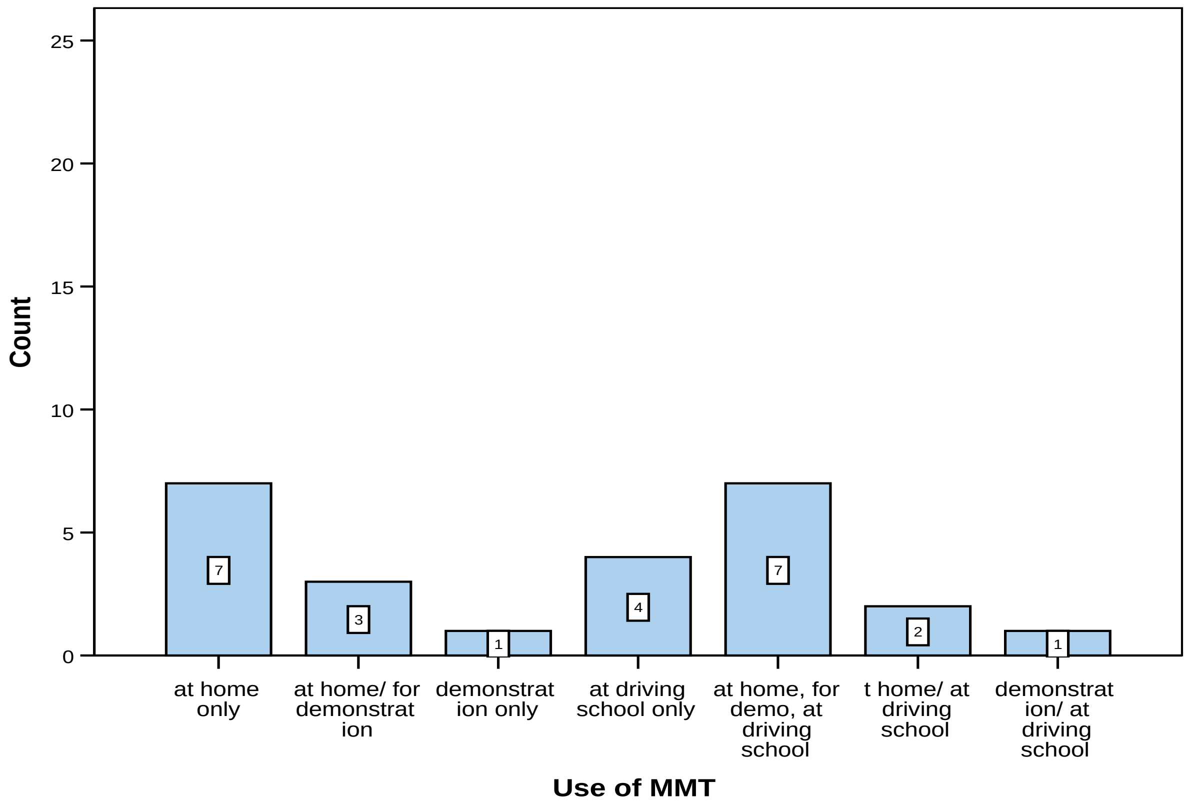


Figure 2.4: Answers to the questions where the MMT can be used.

Twenty two of the described tools were operated by the trainee through pressing the keyboard or clicking the computer mouse. For the remaining three tools, one had to be operated by a specific input button, for the other two the input devices were not specified.

Unsurprisingly all MMTs required the trainee to observe (as illustrated in Figure 5). In 21 out of 25 tools the trainee had to make driving decisions. Predicting traffic scene development and answering questions and naming hazards was required by 19 of the reviewed training tools respectively. Naming hazards was required in 18 tools. Stopping the scene was least frequently required as a response by the trainee (n= 11).

[8] 4 GADGET levels

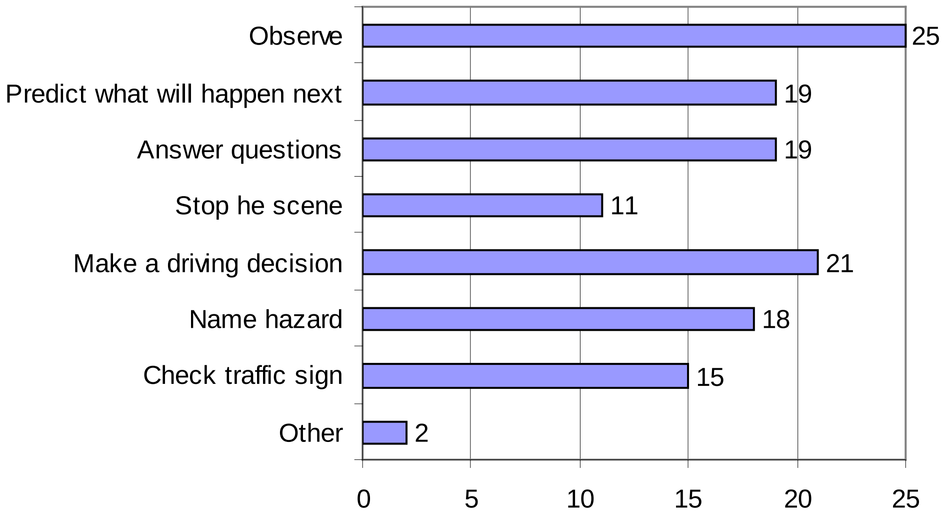


Figure 2.5: Actions required from the trainee[9].

Figure 6 illustrates the output modalities use by the reviewed MMTs. All tools utilize video, with use of pictures and text coming second (n= 21) and third (n=20). Animation is the least frequently used output modality (n= 15), which is probably due to the high costs of animation. The majority (n= 11) of the training tools described use a mixture of five output modalities to maximize the likelihood that training contents are absorbed; eight use four modalities, followed by three with three and another three make use of only one output modality.

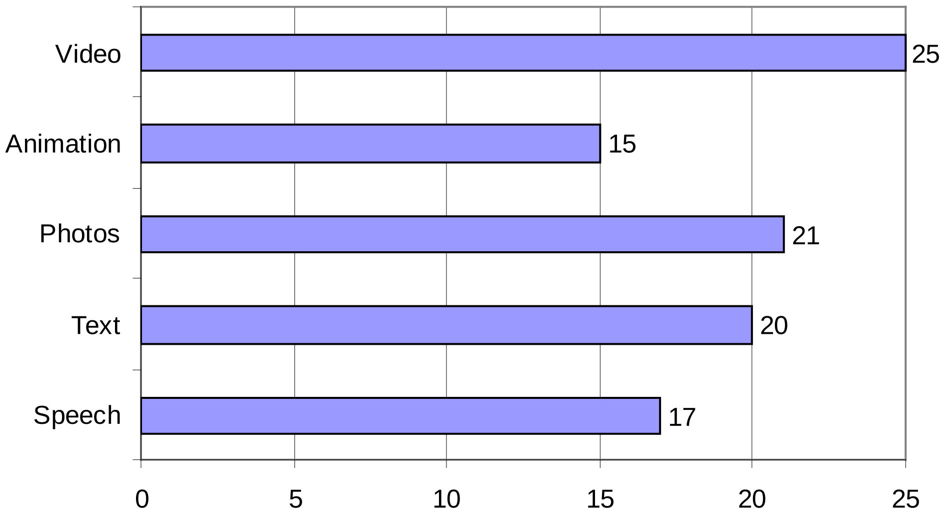


Figure 2.6: Output modalities for the reviewed driver training tools.

Respondents were asked about the feedback modalities of the 25 multimedia tools reviewed. All MMTs displayed the correct answer or correct choice to the trainee, followed by showing existing hazards and providing the trainee's scores (both 69.6%). Illustrating the consequences of behaviour was the least frequently used feedback mode (60.9%). The "other" category included the presentation of textual information to the trainees.

[9] Number of MMTs requiring each of the listed actions

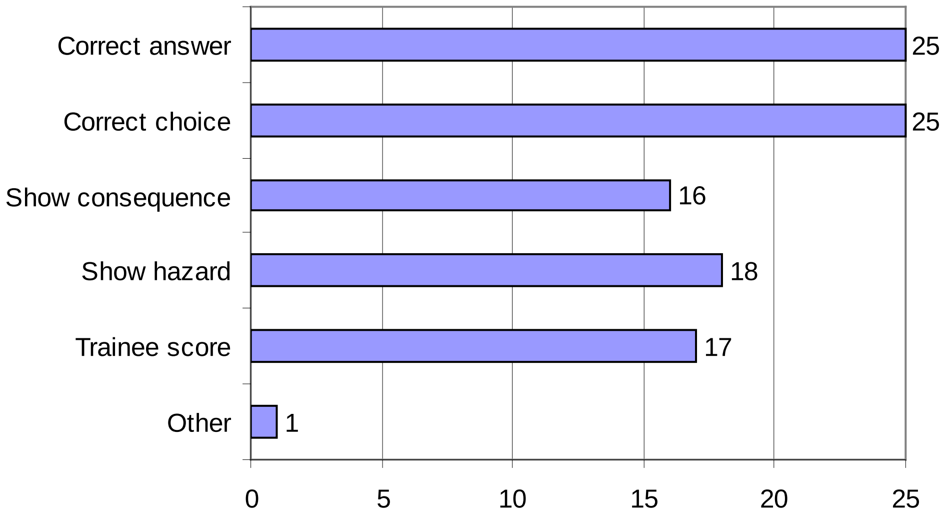


Figure 2.7: Feedback modality for the reviewed driver training tools.

Only four of the reviewed multimedia tools were known to have been evaluated. For the remaining 21 tools evaluation results were not available.

2.3 Driving Simulators

Thirteen organisations specified the cost of their simulator, seven did not. The average price of the simulators was €135,000 (median value) with a minimum price of €12,048 and a maximum of €1,200,000. Thirteen out of the 20 simulators featured a motion system; those which did not come with a motion system had a median cost of €37,500, while those which had motion systems had a median cost of €205,000[10]. The high simulator costs must certainly be seen as associated with the provision of a motion system (see also Table 4).

[10] Six of the simulators with motion systems did not specify their cost, therefore this median may be inaccurate; however, it would seem reasonable to assume that these simulators would be roughly equivalent in cost to the others equipped with motion systems.

Table 5: Simulator costs and presence/absence of motion systems in the 13 simulator for which information on costs was provided.

Prices of simulators with motion system	Price of simulators without motion system
€30,000.00	€12,048.00
€128,000.00	€21,000.00
€135,000.00	€37,000.00
€187,000.00	€37,500.00
€200,000.00	€67,900.00
€300,000.00	
€500,000.00	
€1,200,000.00	

The great majority of simulators described are driving simulators. However, there were three exceptions: one AR/VR Simulator operated by the Centre Ricerche FIAT (CRF) and two mobile units (operated by Doron Precision System and Krauss-Maffeï Wegman). Simulators were typically owned outright (11 of those who's ownership status was reported were owned outright). The operator and the simulator family Green Dino was reported to be operated under various ownership arrangements (leased, hire per use and owned-outright). The ownership status of AutoSim, a low cost simulator used in Spanish driving schools was not specified, probably because the ownership arrangements vary between the driving schools using it. The ownership status of the remaining six simulators was unclear.

Twelve out of 20 training tools had a car as a simulated ego-vehicle. Four simulators could additionally simulate emergency driving conditions to normal car driving conditions. A total of five simulators could use busses as their ego-vehicle (one simulator only used busses as an ego-vehicle) whilst another nine could simulate a truck as the ego-vehicle. No simulators reported using motorcycles as ego-vehicle.

In fifteen out of eighteen (two missing values) simulators one trainee could be trained at the time. The emergency vehicle simulator operated by the Bavarian Police Force allowed a second trainee to be trained as a co-driver at a special training station outside the simulator (for reasons of simulator sickness) but with a view of the same road environment as the driver and radio communication with the driver. The Green Dino simulator allows multi-user training. The Singapore Safety Driving Centre Ltd. described that up to seven trainees could simultaneously use the simulator and THALES in the Netherlands reported an even higher figure of eight trainees.

Only one simulator was not used to teach novice drivers; seventeen out of the twenty simulators also targeted experienced drivers (e.g. truck drivers). Seven of the reviewed simulators could be used for instructor training and six could be used for the training of elderly drivers. Finally, six simulators could be used for the training of disabled drivers (see also Figure 8).

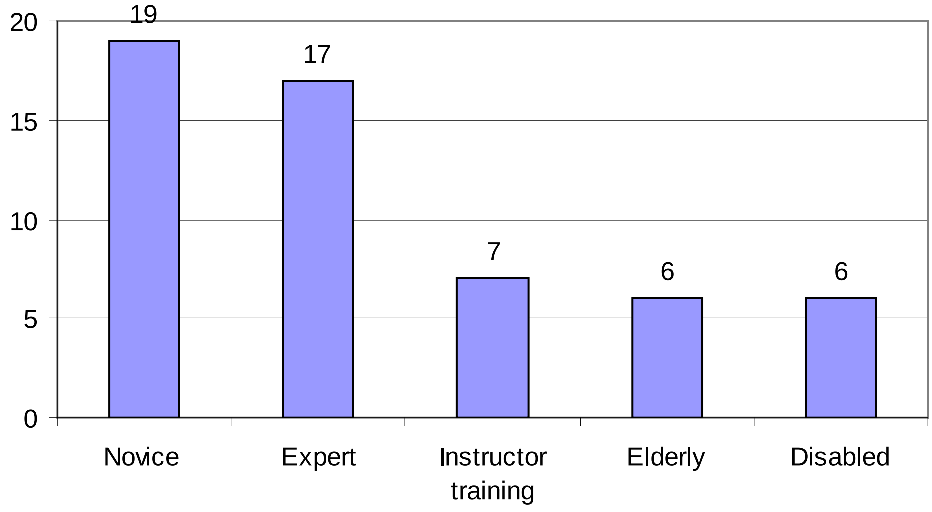


Figure 2.8: Training target group for the 20 simulators reviewed.

As can be seen in Figure 9, the majority of the simulators had strong focus on the lower two levels of the GADGET matrix. The strategic and life goals levels of the matrix (levels three and four) were addressed by eight and four simulators respectively. The four simulators addressing the top level of the GADGET matrix were a Swedish simulator operated by Trafikcenter Scantec AB, a simulator owned by the Singapore Ministry of Defence, a portable simulator operated by an the US firm Drive Square LLC and a German simulator operated by the Bavarian Police Force.

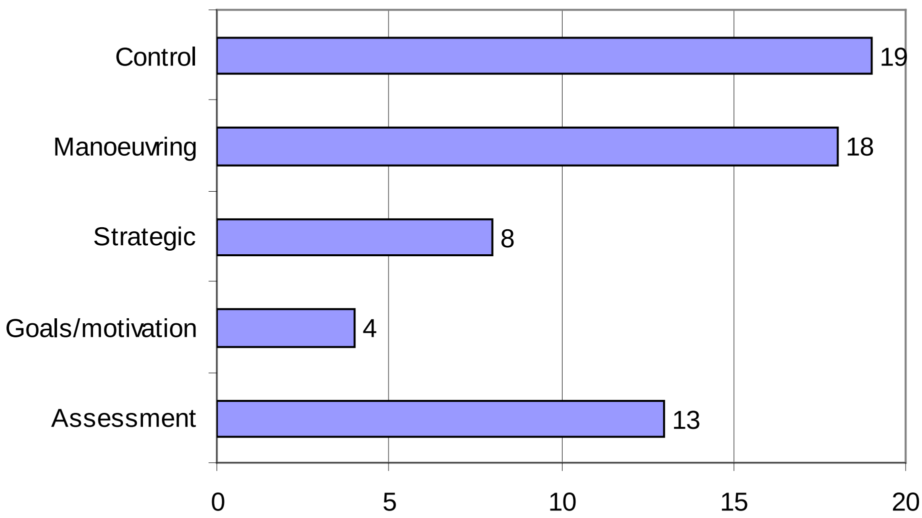


Figure 2.9: Focus of the simulator-based driver training provided in the 20 reviewed simulators.

The physical fidelity of the reviewed simulators overall seemed to be high, with most of the tools being equipped with realistic vehicle instrumentation, mirrors and cab. Control aids such as active vehicle safety systems (ABS, ACC etc.) were less frequent with only six out of the 20 simulators being fitted with them (see Figure 10).

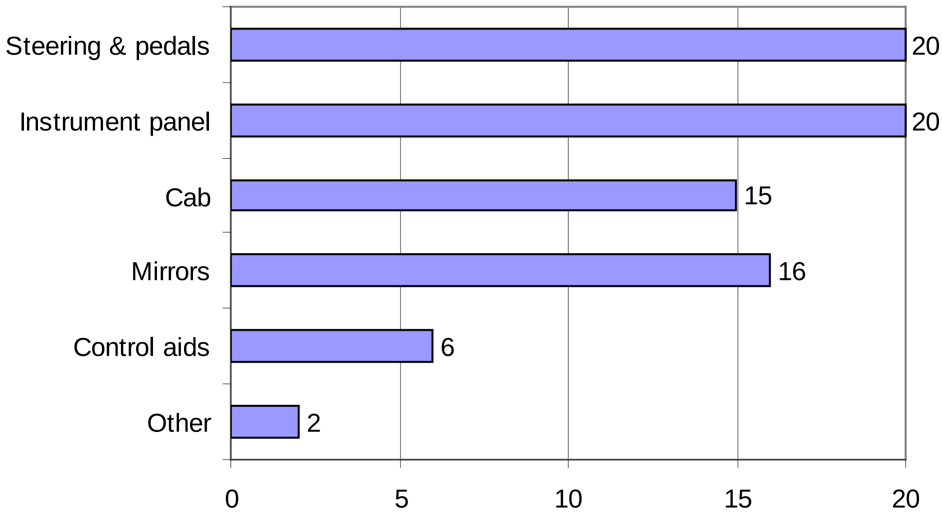


Figure 2.10: Simulated vehicle elements included in the twenty reviewed simulators.

With one exception all simulators used a computer-generated visual system. Selected system characteristics are tabulated in Table 6. Information provided on the technical details of the simulators was partial; therefore, only selected variables are reported here.

Table 6: Reviewed simulators and characteristics of their visual systems.

Simulator name	*Number of channels*	*Field of view*	*Update rate*	*Resolution*
AutoSim	Missing	Missing	Missing	Missing
Smart Simulator	5	180	30 frames per second	1024 x 768 pixel, colour depth 24 Bit
Emergency Driving Simulator	7+3 mirrors	210	60 Hz	Missing
Training and Research driving Simulator	3	180	20-30 Hz	2x800x600 side 1x 1024x768 front
Dutch Driving Simulator	3+3 mirrors	108	100-120 Hz	1400x1050
CRF Advanced Driving Simulator	6	270	50 Hz	3072x1024
Fahrsimulator F10PF	3	120	Max. 300 Hz	800x600
Wheel loader, digger machine, crane	Several	Not specified	Not specified	Not specified
TRUST 3000	5	180x 60	60 Hz	1400x1050
TRUST 5000	3+3 mirrors	210	60 Hz	1280x1024
TRUST 800	5	180+48 left	Missing	Missing
DS-600	3-8	180-360	60 Hz	Missing
Mobile Simulator Safety Training	5	Missing	Missing	Missing
STIsim400	3	180	Missing	1024x768
TranSim VS Driver Training Simulator	3	180	70 Hz	1024x768
460 Truck	8	240	70 Hz	Missing
Truck Driver Trainer	Missing	Missing	Missing	Missing
EF-X	3	30x120	Missing	640x480
Portable In-Vehicle Driving Simulator	1	360	60 Hz	800x600
Honda Driving Simulator	6	Drivers view, read, side	Immediate	Missing

Twelve of the 20 reviewed simulators provided rear mirrors views and fifteen provided side mirrors views. The visual transport delay was only specified for nine of the ten simulators and ranged from 50 ms (two simulators) to 150ms.

The majority of training tools were capable of simulating a range of weather and light conditions (see Figure 11 and Figure 12). Eleven of the 20 simulators were capable of varying road friction in connection with environment/weather conditions.

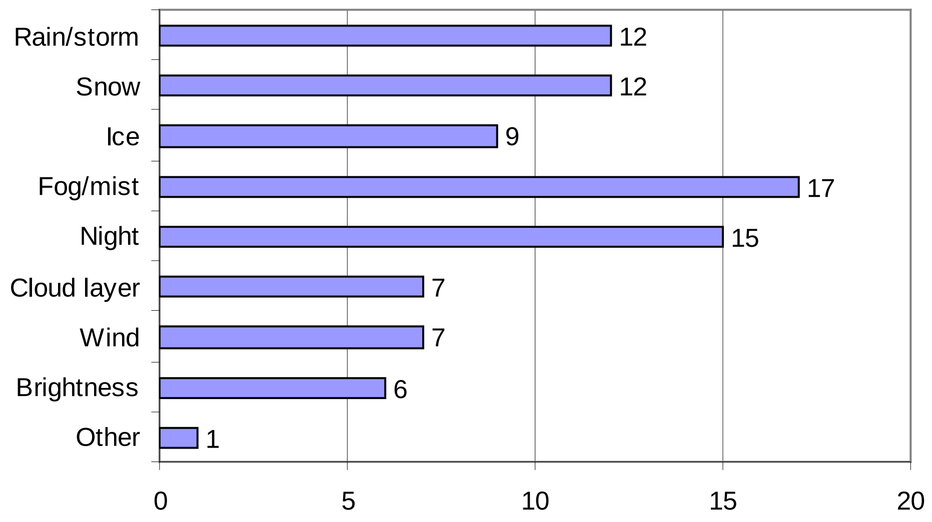


Figure 2.11: Simulated weather conditions in the twenty training tools reviewed.

The two ‘other’ responses in Figure 12 included the simulation of blue lights in the Bavarian emergency driving simulator and the provision of dead angle mirrors as well as front and rear end cameras on the Thales 3000 truck simulator.

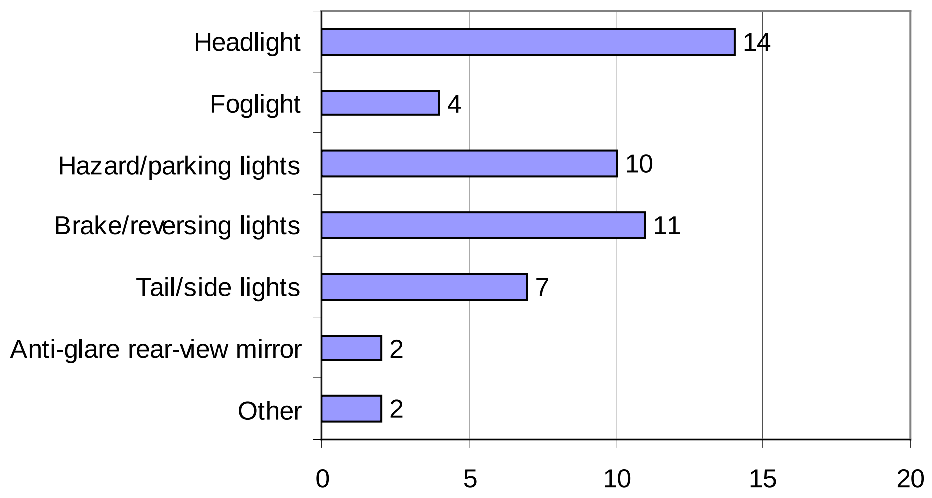


Figure 2.12: Simulated light features in the ten reviewed simulators.

Seven of the reviewed training tools had fixed databases with a mean 115km road network (min= 3km, max= 400km, std. 138km).

All twenty simulators provided motorway sections for training purposes and only one did not also provide urban road environments. Rural roads could be simulated in eighteen of the 20 training tools. Simulation of industrial areas and dual carriageways was considerably less frequent (see Figure 13). The ‘other’ option included road environment features such as mountain roads, skid pads, unmade roads and speed restricted areas (10-30 km/h).

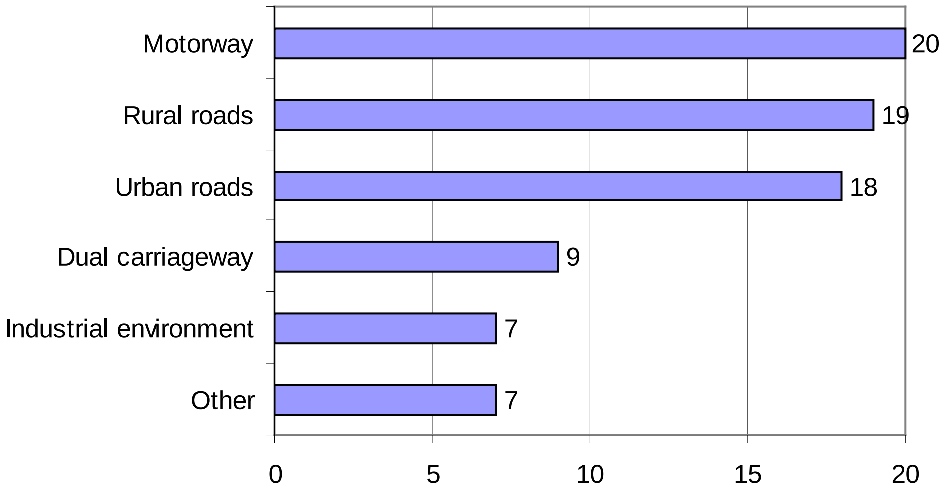


Figure 2.13: Available road environments in the twenty reviewed training simulators.

Figure 14 illustrates the available static road features in the 20 reviewed training simulators. Whereas bridges, serpentines and hills can be simulated by eleven of the 20 tools, road features such as rail crossings or depot areas are less frequently provided in the simulation environment.

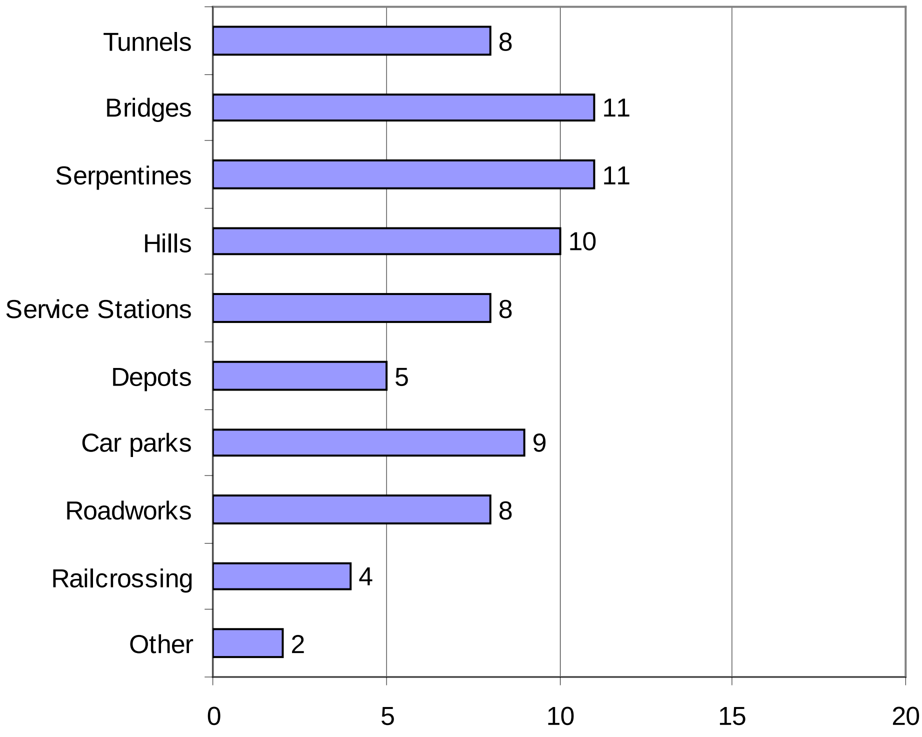


Figure 2.14: Static road features available in the twenty reviewed simulators.

Nine of the twenty reviewed training tools specified the maximum number of other dynamic road users that could be simulated in the visual range of the trainee driver. On average 34 other road users could be simulated (std= 26.25) with a minimum of 3 and a maximum of 80. Figure 15 illustrates the types of dynamic road users that could be simulated by the 20 reviewed driving simulators.

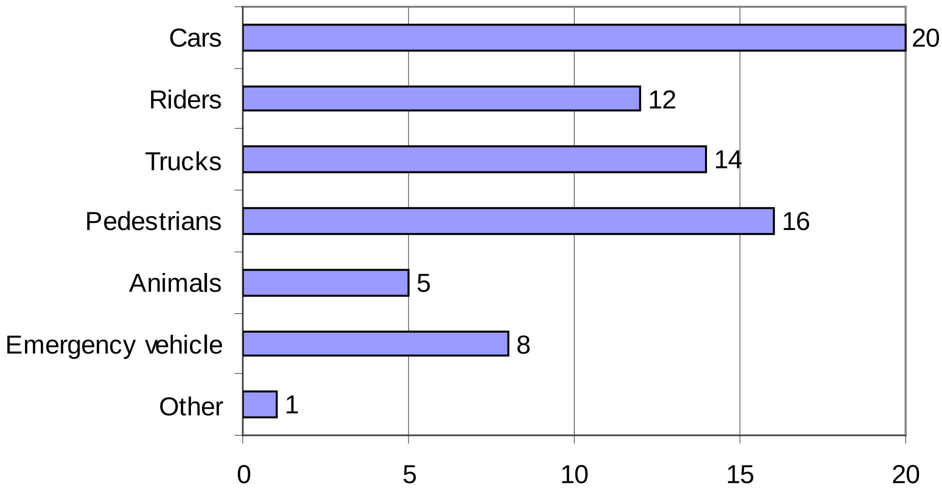


Figure 2.15: Road users that can be simulated by the 20 reviewed training tools.

Traffic densities could be modified in eleven of the 20 reviewed training tools. In those same eleven simulators it was also possible to modify the behaviour patterns of those other dynamic road users. Respondents were asked to describe those changes in the behaviour profile of those ambient road users. Some of the behaviours described were:

- Aggressive, defensive, law abiding, reaction belonging to the driving-style of the emergency driver;
- Mediocre type of behaviour;
- Response time, speed;
- Behaviour of participants is determined by basic parameters like target headway, safety distance, maximum and minimum acceleration;
- Annoying behaviour, in order to generate critical situations;
- Red light running, not stopping at line, etc.;
- Highly flexible programming of driver behaviour of autonomous vehicle;
- Speed, avoiding collision, driving through red light, changing lanes;
- Aggressive drivers, law breakers.

Simulated sounds included engine sounds in all ten simulators, tyre sounds (11), wind (9) and other sounds (10), including the sounds of other road users (3), sirens (2) and rain drops hitting the windscreen in the ego vehicle (1).

The type of transmission and drive system used varied. As can be seen in Figure 16, six simulators used manual transmission, four used automatic, one used a sequential transmission and eight could vary their transmission system.

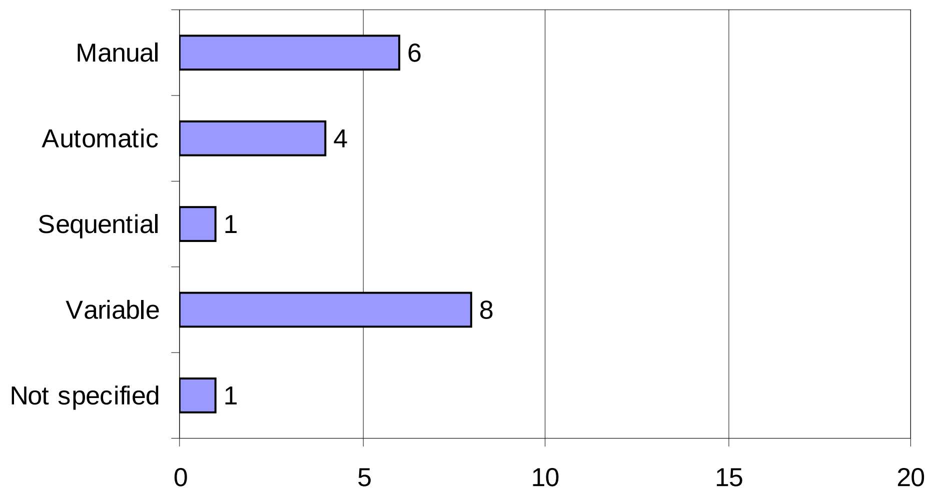


Figure 2.16: Transmission types simulated.

Five simulators used front-wheel drive, five used rear-wheel drive, four could alter their drive system and six did not report their drive system.

Malfunctions could be simulated in seven of the simulators, eight could not simulate malfunctions and five did not respond (or marked the question as not applicable).

When asked if their training simulators accommodated driving aids such as power steering and ABS, eight reported that they could. Figure 17 describes the frequency of the various features present:

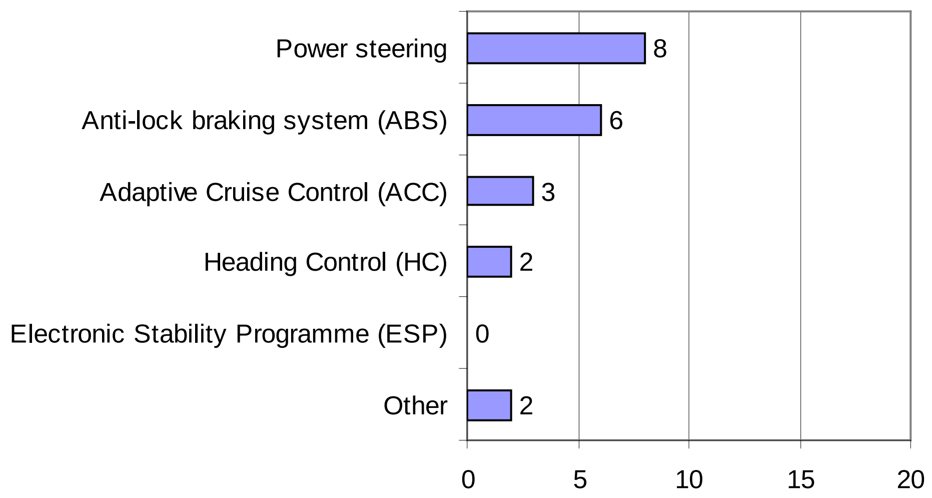


Figure 2.17: Frequency of driver aids.

The means by which feedback for the trainee was provided were also addressed in the questionnaire. A large majority of simulators featured a replay function, indeed, only one tool was reported as not possessing this feature (there were four cases where the presence or absence of a replay function was not reported).

Twelve of the 20 training tools depended on the simulator to view the replay; six could either watch the replay at the simulator or a satellite station, with a further two only displaying replays via satellite stations. Nearly all replays could be viewed from either the driver's perspective, or a 'birds-eye' perspective. Five simulators were also able to view the replay from another driver's perspective. Assessment of the trainee's performance could be carried out by both the trainer and the simulator in eight cases, by the simulator only in five cases and just once by the instructor alone.

To further explore the degree to which each simulator satisfies the four levels of the GADGET matrix (something which was first addressed in by Figure 9 on page 29), the questionnaire included a section detailing training goals which relate to the matrix's various levels. For four of the 20 simulators data on the coverage of learning goals was not available.

In agreement with the findings of Figure 9, the great majority of simulators comprehensively addressed the first two levels of the matrix (vehicle manoeuvring and mastery of traffic situations, respectively). The only notable exceptions were the "use of new car control aids" training goal (from the vehicle manoeuvring level) and the "reacting to in-vehicle information systems" training goal (from the mastery of traffic situations level) where only five and four simulators, respectively, covered these training goals.

With respect to levels three and four of the GADGET matrix (driving goals and context, and goals for life and skills for living), only few of these learning goals were addressed by the reviewed simulators.

Figure 18 describes the number of simulators which covered the third level of the GADGET matrix (driving goals and context). As can be seen, nine out of the 16 completed questionnaires included the "safety issues" learning goal, making this clearly the most common learning goal of this level of the matrix. The remaining goals were covered much less frequent, ranging from zero responses for "maintenance of the vehicle" and "first aid" to six responses for "determination of trip goals, route and modal choice". "Loading of the trailer" received zero responses and was not part of the learning goals for any of the nine reviewed tools that were capable of simulating a truck as ego-vehicle.

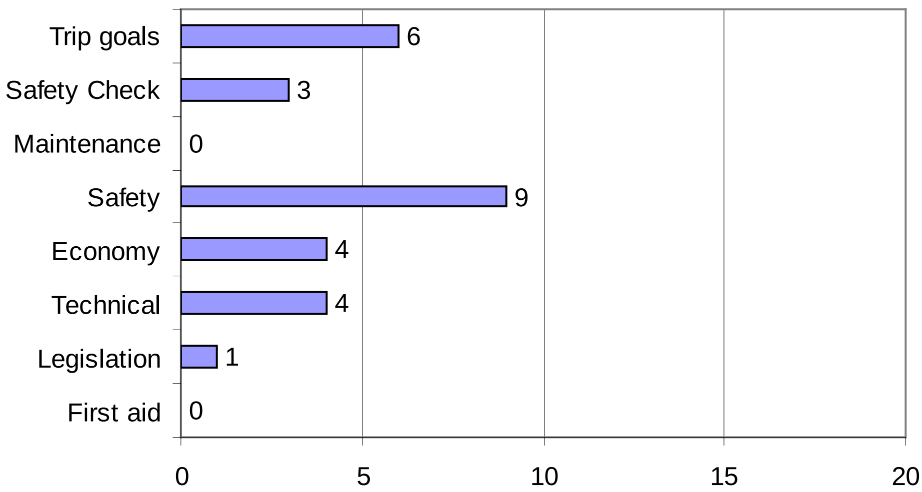


Figure 2.18: Number of simulators which address level three of the GADGET matrix[11].

The highest level of the GADGET matrix, goals for life and skills for living, was broken down into three learning goals, none of which were addressed by the majority of the reviewed simulators. The learning goals of "relation between age/gender and driving style", and "relation between personality, lifestyle and driving style" were only included in one simulator each, and the learning goal of "relation between social norms, values, motives and driving style" was addressed by three simulators.

When asked if there had been any evaluation of the simulator, there were only six replies which confirmed their simulator had been evaluated. Some of the replies included one from the BBP which described how an instructor compared the performance of trainees to that of experienced drivers. The evaluation of TRL's truck simulator included 841 drivers who had completed tests for fuel efficiency and safety training.

There were eight responses which confirmed that motion sickness had been investigated in the driving simulators reviewed, however, the provision of sickness rates were the exception rather than the rule. Reported sickness rates ranged from 0% to 80%, with a mode of 5% (two simulators). Of

[11] driving goals and context

course, direct comparisons between these figures are fraught with difficulties as the measurement of motion-sickness may have differed between simulators.

When asked to describe their experiences with their simulators, over half of the respondents offered brief replies. Some selected quotes were:

> *"…the interest that have been shown from Driving schools, shows that it can have a very positive impact if used in a fair number of training schools."*
>
> *"Improved defensive [driving] and anticipation"*
>
> *"Use of the simulator has demonstrated that drivers learn driving techniques to help them improve their fuel efficiency and safety. Validation studies are now required to test how well these learned techniques transfer to real world driving."*
>
> *"Because of the positive results by novice drivers and by experienced drivers: fewer accidents, damage and less fuel consumption the DS-600 is an exceptional simulator for the price."*
>
> *"Usage of an actual vehicle as part of a simulator increases face validity of the simulator presumably resulting in a better transfer of skills."*
>
> *"The simulator is beneficial to training emergency driving. So far driver training was restricted to close course training without other road users present."*

Few problems were reported, but those that were typically concerned either technical faults or motion-sickness related issues. One simulator did mention the need for more "finely graded difficulty gradients" and the need for greater fidelity.

Several responses offered suggestions as to how their simulators could be improved. Some technical improvements ranged from the use of faster computers to aid performance, increasing image quality, to access to the simulators raw data as an output, rather than having to use the simulators inbuilt analysis tools. Other improvements were related to the training scenarios, specifically the desire for more scenarios, more flexible use of pedestrians and other vehicles, and improvements to the scenario generation tool.

Finally, respondents were given a chance to relay any general comments. The low cost of AutoSim was highlighted as a strength due to it being affordable for many driving schools whose trainees learning process would benefit despite the relatively low level of simulation. The portable nature of the Drive Square LLC was highlighted as a factor which can lead to "multi-site use, leading to higher simulator utilization, resulting in lower costs per simulation hour". TRL described how the Trust 5000 simulator "…now represents a mature and commercially viable truck training tool". A Thales representative believes "that simulation is the best option to train novice drivers as well as experienced truck drivers. It's a perfect system to show the trainees how to solve things and where and what his problems are and to confront him with his shortcomings".

3 SIMULATOR GAPS AND BEST PRACTICE SOLUTIONS

The questionnaire survey on driving simulators currently in use for the training of various driver cohorts including novice drivers and professional drivers on various vehicles including cars, buses, trucks, motorcycles and emergency vehicles identified 20 simulators in Europe and overseas. With an average cost of €135,000 (median value) and more than half (65%) of the simulators featuring a motion system the sample of simulators reviewed are at the higher end of the market. The sample of the simulators has a negative skew when categorised into low-cost simulators with up to €10,000, medium-cost simulators with up to €30,000 and high-cost simulators above € 30,000 as suggested within the TRAINER project (Deliverable No 2.1) and not a single simulator falls in the "low-cost" category. The affordability of simulators as portrayed in this deliverable to a wider audience including driving schools or similar stakeholders is limited and further considerations to cost and cost-effectiveness are given in later chapters.

At the same time less expensive driving simulators (mostly those without motion systems) tend to be able to cater for a wider range of trainee groups could even be more inclusive as they allow disabled or elderly trainees to access the simulator more easily.

Simulator-based training is still limited in its provision for multiple user training: 15 of the 20 reviewed tools would only accommodate one driver at the time. Thus the efficiency of simulator training currently does not derive from its ability to train several students at the time, but from its ability to provide controlled learning situations to one trainee and thus by reducing training time per student. Future developments should focus on the integration of multiple users in a shared virtual environment.

The findings on availability and interactivity of other road users showed considerable differences in the sample of reviewed simulators. On average 34 other dynamic road users could be simulated (std= 26.25) with a minimum of 3 and a maximum of 80. In just over half of the simulators the modification of traffic densities was possible. Additionally the behaviour of dynamic other road users could be influenced, mostly to simulate aggressive behaviour in order to trigger critical situations. The behaviour of other road users and their believable responses to the driver's input are crucial elements for the successful training of complex traffic scenarios and higher order skills such as hazard perception. This also includes the capability to simulate a sufficient number of dynamic road users to create realistic and believable traffic streams that the trainee needs to negotiate with. The degree to which the behaviour of simulated road users is believable is difficult to determine by questionnaire. The importance of this variable is discussed in a later chapter.

Fifteen of the driving simulators had a replay function that allowed trainee and instructor to review the drive. In 12 simulators this had to be done on the simulator; Seven out of 20 tools gave a choice of viewing the replay on the simulator or on a satellite station and a further two used dedicated satellite stations only. Whilst the possibility of reviewing selected scenes and discussing specific examples of good and bad driving performance is important for training success, the lack of a separate replay station in most of the simulators reviewed means a loss of training efficiency by blocking the resource. Automatic export of drive videos to satellite replay stations is available on some simulators and is good practice that should be implemented in more training tools.

Despite considerable developments in automatic scoring systems, the driving instructor is still an important figure in assessing trainee performance. In eight of all reviewed tools trainee performance was assessed by the instructor and the simulator versus in five of all cases by the simulator only. Open comments indicated that access to the raw data stored by the simulator would be preferable to a processed result sheet. Transparency of the criteria used by a simulator in the assessment process is of great importance.

Most of the drive videos were available from driver's view or bird's-eye perspective. Especially for the training of young novice drivers the implementation of further perspectives in the replay, such as the view of other road users involved in critical driving scenarios (e.g. pedestrian crossing the road) would be beneficial for the development of an understanding of other road users' perspectives and for the development of safe driving attitudes. This last point touches on the question of how driving simulators are currently used for training purposes and how this may change in future: the questionnaire data showed a strong dominance of learning goals situated on lower level of the GADGET matrix in the simulator-based training process.

As a consequence of the limitations of early simulators training has traditionally focussed on controlling and simple manoeuvring tasks. With increasing computer power and simultaneously decreasing prices for IT capabilities more complex training scenarios become available and simulator provide increasingly sophisticated interactive traffic scenarios.

The set-up of simulator training, however, often still seems to be a mere translation of on-road driving lessons into the virtual worlds. Therefore the lack of coverage of the highest levels of the GADGET matrix (strategic and motivational driving goals) may not only be explained by the technical inability of the simulator, but rather by the absence of an in-vehicle training format that would successfully address these variables. In the future more thought must be given to the development of appropriate course ware and training formats and settings (e.g. including peers in the training process). This could for instance include the development of driving tasks on the strategic level (e.g. plan a trip in the simulator to a specified location) or could address personal attitudes and motivations by allowing/triggering trainees to disclose them in the training process.

Finally, more and robust evaluation studies on simulator-based driving are urgently needed. Only six of the reviewed driving simulators had been evaluated according to the questionnaire responses. Available evaluation studies included pre-post comparisons after fuel efficiency and safety training as well as comparisons of novice drivers' performance with expert drivers. To successfully promote simulator-based driving training, evaluation studies on transfer of training would be vital in demonstrating the benefits of simulators to a wide – and often sceptic- range of stakeholders.

Most survey respondents felt that the simulator they use fulfilled their requirements. Suggestions for improvement included most frequently the creation of additional scenarios and greater scope for modifying dynamic other road user behaviour.

3.1 Appropriateness of current training tools per training need

The main problems of novice or candidate drivers are dealt with in relation to the four levels of the GADGET matrix (Hatakka et al., 1999). For each level, the problems focus on different driving responsibilities. A more detailed analysis could be follow an analytical driving responsibilities model, such as of the model developed by McKnight and Adams (1970), which distinguishes 1,700 driving tasks. However, such an approach is very detailed and theoretical to be used during driver training. An alternative conceptualization of the driving task has been suggested by Bekiaris et al. (2003) with the DRIVABILITY model (see Figure 19 below).

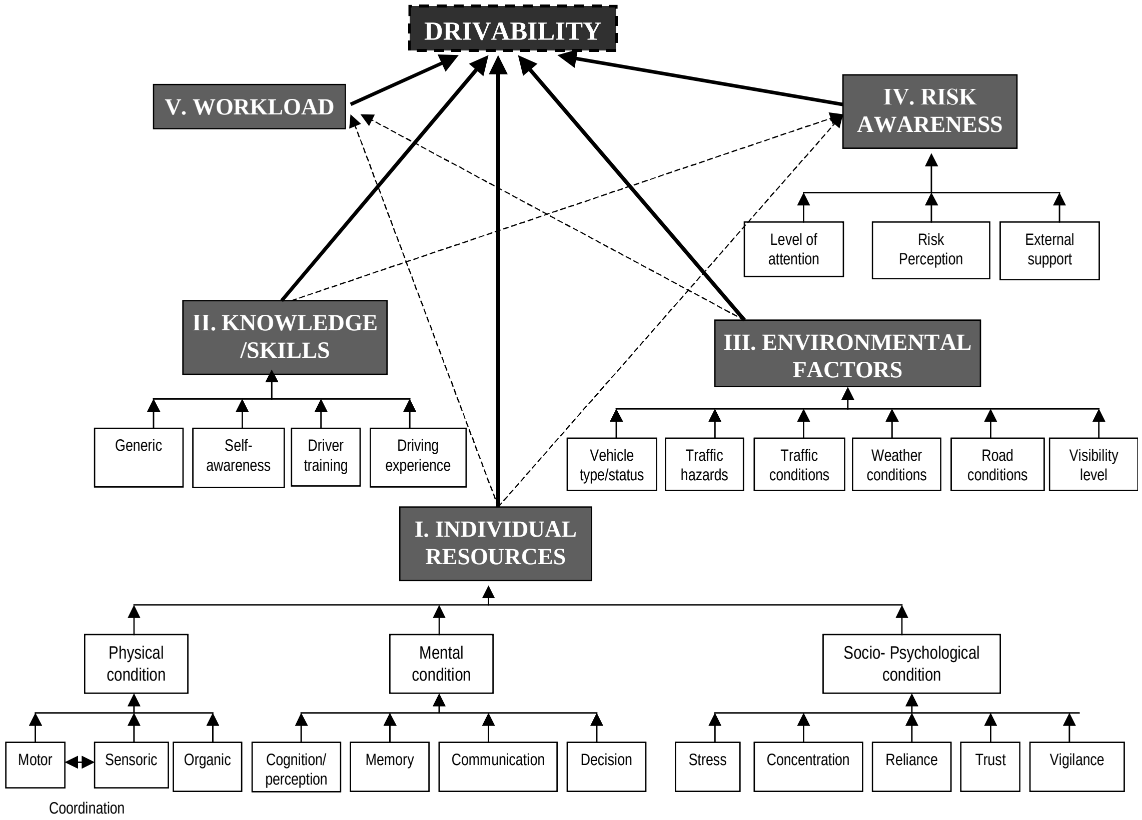


Figure 3.1: Contributors to DRIVABILITY.

Today, driver training focuses mainly on the acquisition of knowledge for the control of the vehicle and manoeuvre development. The strategic level, as well as behavioural issues and goals for life, are not covered, or are covered only theoretically, not only due to lack of knowledge of several trainers, but also due to inappropriateness of existing training methodologies. For this reason, there is a lack of proper training for driving complex or dangerous manoeuvres (for their avoidance). Also, as stated in TRAINER Deliverable 2.1 (2001), future driver training should take into account or intensify the training of perceptual and cognitive skills, i.e. scanning skills, and hazard detection. With regard to the GADGET matrix, the driving task should be understood as a task involving decisional and motivational aspects. Higher level skills (i.e. strategic and behavioural) play an important role in the involvement of novice drivers in accidents as clearly stated by recent research literature, as well as by those experts participating in the TRAINER workshop: Novice drivers can have superior manoeuvring skills and still have many crashes. Teaching scanning and anticipating as well as self-evaluation skills appear to be promising ways to reduce accident rates of novice drivers.

Developing behaviour-related and strategic skills and knowledge are the most important tasks training tools should be used for to achieve driver improvement. In parallel, tools may be used for the lower levels of the GADGET matrix, too, but only if combined with the higher levels. Below, the appropriateness of current training tools per GADGET matrix level (see Table 7) and per level and contributions of the DRIVABILITY (Bekiaris et al., 2003) model (see Table 8 and Table 9) are presented.

Table 7: Appropriateness of current training tools per GADGET model level[12].

Hierarchy levels[13]	*MMT*	*Driving Simulator*
Control level	The multimedia tools are not appropriate for this level and they can only offer supplementary general information (e.g. what the driver should check before he/she starts the vehicle, vehicle maintenance, etc.).	The driving simulators may be useful for the training of basic controls, before the candidate driver uses a real vehicle. The final training should, however, still be realized with a real car.
Manoeuvres level	The multimedia tools are useful only if they have the ability of presentation of interactive scenarios, where critical manoeuvres and traffic scenarios are demonstrated and the trainee has to identify possible dangers, to predict a situation, etc.	The driving simulators are very useful for the training of hazard awareness and avoidance. Training in the simulator should not be directed at improving driving skills in dangerous situations as this may give the trainee a false feeling of control and result in an overestimation of his/ her skills.
Strategic level	The multimedia tools are useful in presenting the relevant information, through text, video, etc.	The driving simulator can provide training on professionals' driving tasks or in-vehicle support systems, but can also be used to demonstrate the effects of alcohol, fatigue, mobile phones use, known versus unknown routes etc. on driving performance.
Behavioural level	The multimedia tools may provide information that initiates reflection on behavioural issues.	The driving simulators may offer a trial tool of relevant parameters, such as passenger influence, time pressure, etc.

12 Bekiaris et al. 2007
13 of GADGET model

Table 8: Appropriateness of current training tools per level of the DRIVABILITY model[14].

Levels of DRIVABILITY model	*MMT*	*Driving simulator*
Safety	The multimedia tools can offer useful material (video from collision tests, diagrams, etc.) in order to show to the trainee the main risks for traffic safety.	The simulators are the most important tools for promoting the training for safe driving, since they allow the driver to experience several risks (such as aquaplaning, bad visibility conditions, etc.) and to obtain the relevant experience with no danger and with much less cost.
Comfort	The multimedia tools allow the trainee to repeat every part of the course and to practice at his/her home, without needing to keep notes. Also, the trainer can ask the trainees to do additional training at home and to test them when and where he/she wishes.	The simulators allow training of the main vehicle controls, without being in a real car, leading to increased comfort for the trainer.
Environment	The multimedia tools support the training and the understanding the concept of ecological/economical driving.	The simulators allow training on economical/ ecological driving and allow immediate presentation of economic/ecologic gain to the trainee. As simulators can replace training of the basic vehicle controls in real vehicles, they reduce the environmental pollution due to traffic reduction.
Health	The training tools provide information for the avoidance of driving under the influence of alcohol, use of medication and drugs as well as other general health issues.	Relevant scenarios can be tested in simulators. The greatest health benefit of simulator training is achieved by reducing the number of traffic accidents and increasing safety.
Occupation	The extended use of the new training tools is expected to lead to the development of a new market, resulting in new working places.	
Quality of life	The new training tools include training issues on the driver behaviour. If such issues can be realized, they may lead to the improvement of the quality of life of the trainee.	

[14] Bekiaris et al. 2007

Table 9: Appropriateness of current training tools per contributor of DRIVABILITY model[15].

Main contributors to DRIVABILITY model	*MMT*	*Driving simulator*
I - Individual resources	The multimedia tools provide important information for the meaning of certain social-psychological factors (stress, vigilance, concentration, etc.) that influence the driving ability.	The simulators help in the improvement of the physical situation in relation to driving, and mainly the ability of coordination of the relevant movements, but also of some related intellectual parameters (e.g. communication with other road users).
II - Knowledge/ skills	The multimedia tools provide a lot of information about driving.	The simulators provide additional practical knowledge, related to experience from driving, and to the self-esteem of the driver.
III - Environmental factors	The multimedia tools provide, through appropriate material, a good summary of the consequences of the bad environmental factors (e.g. night, low vision, etc.) while driving.	The simulators provide the possibility of training under various environmental conditions, including extreme cases (ice, night without road lighting, special road types with gravel, sand, etc.).
IV - Risk awareness	The multimedia tools give useful information on possible risks and especially those that consist of interactive scenarios of detecting dangerous situations.	The simulators comprise the only tool that allows for the recognition of a number of risks and the increase of the level of detection of risks of the trainee with the safety and comfort of an off road environment.
V - Workload	Multimedia tools do not affect driver workload directly but can inform the trainee on the effects that engaging in secondary tasks whilst driving will have.	In simulators it is possible to demonstrate to the driver what effects engaging in secondary tasks can have on attention and consequently, driving performance (e.g. speaking on the mobile phone, detailed set-up of the CD player, etc. while driving). Modification of driver workload are possible through inclusion of secondary tasks such as a passenger speaking to the driver or the need to maintain radio communication during emergency driving

15 Bekiaris et al. 2007

4 BENCHMARKING OF MULTIMEDIA TOOLS

4.1 Clustering of multimedia tools

Among the new, innovative training tools for driver training, are the multimedia tools that are used in the theoretical part of training. Such tools have been widely used during the last 10 years for various applications, but mainly for training and educational purposes. The most common materials used in such tools are:

- Pictures;
- Video;
- Animations;
- Sounds and acoustical messages.

Different user categories have different preferences and needs, e.g. the needs vary among users with high and low PC literacy. Thus, users with high PC experience, mainly young users, prefer rich multimedia material when they are being trained for a certain issue. This is because a simple book, manual or training tool (consisting only of text and some pictures) is common and is frequently perceived as boring training tool. On the contrary, when multimedia material is added, the same application becomes more “live’ and attractive to the users.

In addition, with the multimedia, the degree of understanding increases. This is true for driver training, since “live” examples can be given for every case of traffic incidents, either with video or animations.

When there are users with limited or no knowledge on PC use, simple training material is required, since richer material can cause confusion. This is true for older persons that don’t know how to use a PC and who have limited knowledge to new technologies in general, resulting in difficulty in understanding complicated PC-based courses.

More advanced tools use multimedia that allow interaction with the user, resulting in an even more live connection of the trainee with the training tool and further increasing his/her interest for training.

Multimedia material can be used, during exercises and testing procedure as well as for more general training.

The following clustering of the multimedia tools that are currently in the market is based on a survey that was performed in the framework of the EC TRAINER project (Deliverable 2.1, 2001). In addition, it has been enriched by data from web sites of the developers and literature research that were studied within ‘ADIRITO’ which is a national Greek project.

The clustering is based on the interaction level between the user, the tool and the task required by the user (e.g. simple observation of scenarios, active participation, etc.). In particular, the interaction of the users with the training software can be distinguished in three types, as follows:

- No interaction;
- Answering of questions;
- Prediction and progress of scenario, determination of risks.

It has to be noted that the multimedia tools discussed below, are only indicative for the specific clustering categories. Their selection is random.

4.2 Multimedia tools that do not require any task by the user

Tools for which the user is not required to take any action, apart from watching the screen, belong to this category. Usually, such tools are used solely by the trainers and they decide the pace of the course and the rate of change of each screen.

Below are some pictures of the German tool ‘SCAN & TEACH’. This tool is only used by the trainers, and the trainees do not interact with it. Its role is to enrich the training with pictures, text and video. The lack of interaction is a negative aspect in most related tools that are available in the market as it results in a lack of training of perception and risk awareness.

Figure 4.1: Pictures from the multimedia training tool SCAN&TEACH[16].

4.3 Multimedia tools based on answering of questions

Questions maybe presented to the user by various means (apart from text), such as pictures, videos, acoustic messages, etc. The user is usually required to select the correct answer from a multiple choice or to select “Yes/No”, or “Correct/Wrong”. More rarely, the user is asked to enter his/her reply which consists usually of numbers, in order that the software understands if the reply is correct or wrong.

As examples of this category, two similar Dutch training programs can be mentioned, namely ZEBRA and VEKABEST. The trainee is asked to answer by ‘yes’ or ‘no’. The questions are supported by pictures and text.

[16] used in training schools in Germany

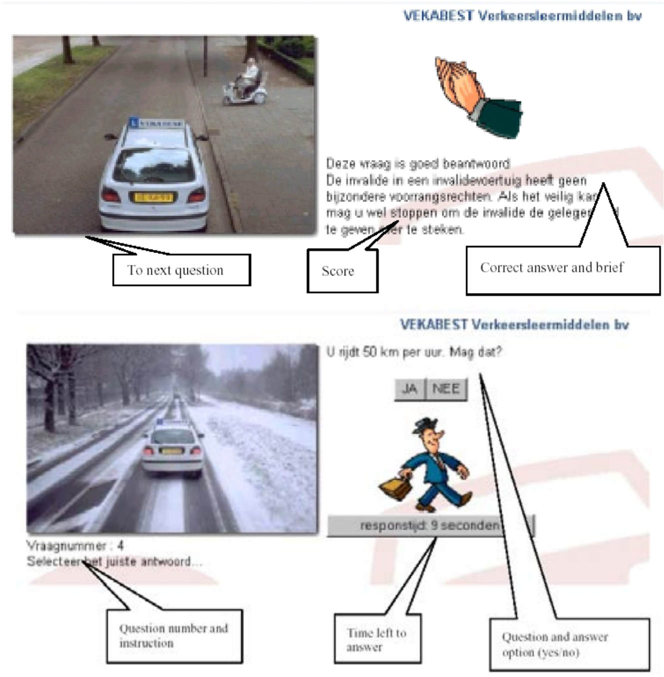


Figure 4.2: Snapshots from the Dutch multimedia tool ZEBRA.

Another training tool that belongs to the same category is the Swedish Bonniers Traffiscola, which is intended to be used both in the driving school and in the trainees' home. The user has a passive role in this software tool: he/she has to observe the progress of the scenario and then answer questions. The trainees do not get a sequence of driving in which they have to react to, they do not have to make decisions relevant to driving and they do not have to foresee or determine dangers.

Figure 4.3: Screenshots form the Swedish multimedia training tool Bonniers Traffiscola.

4.4 Multimedia tools that require prediction of traffic incidents and risks estimation

This category includes software training tools that allow the user to be actively involved in the theoretical training. Apart from the simple answering of questions, the estimation of traffic incidents is required, as well as the identification of drivers' mistakes, the decision of the correct action and the recognition of possible risks. The risks include, among others, vehicles in critical distance and in dangerous spots, vehicles that do not maintain the safety distance, vehicles that come from the traffic travelling in the opposite direction with dangerous behaviour, children, pedestrians, animals that appear suddenly, cars that merge into traffic after parking position, behaviour in roads that are closed due to road works, etc.

Such programs may involve the trainee either as external observer or as driver, which may change per scenario. It has to be noted that even if some tools allow interaction with the trainee, they may differ substantially in the quality and the price. In other words, they cannot be considered as having the same value; this depends on the certain parameters that have to be examined, such as the scenarios that they include the training material, the duration, etc.

An example tool that falls into this category is the multimedia tool that was developed in the framework of TRAINER (European Union co-funded project). Its' aim is the support of the theoretical training of candidate drivers. Most of its scenarios allow interaction of the user in various ways.

The 'Interactief Defensief Autorijden' is a Belgian tool that was developed by an insurance company that plays a role in accident prevention. Its' aim is to inform the drivers about traffic safety and to try to convince them to drive safely. This tool has been designed to be used from home and the order of the courses is based on the Belgian driving training rules. It involves the user at a high level since in almost all the scenarios he/she has to observe and predict their progress, reply to questions, make decisions relevant to driving and identify risks.

Figure 4.4: Screenshots from the Belgian multimedia training tool Interactief Defensief Autorijden.

The next example is the Belgian training tool 'Feu Vert'. It is designed to be used by trainees, who have a satisfactory knowledge of using Windows. It involves the user at a high level, by observing the scenarios, predicting progress, answering questions, etc.

Figure 4.5: Screenshots from the Belgian training tool Feu Vert.

The last example of this category is the American Driver 'Zed', which has been designed and developed by the AAA Foundation, a USA organization for traffic safety, in cooperation with major public bodies. The application 'DRIVER-ZED' is available for two driver categories: 'experienced' and 'novice' drivers (below 20 years old). The user chooses a virtual trainer (among four persons) who gives advice during the course of the program.

Figure 4.6: Virtual trainer selection screen of the American multimedia tool Driver Zed.

As in the above products, the tracking of risks within a time-limit is required by the user. The user observes a scene (simulation) and when it stops he/she has to answer a question, by selecting the correct answer. Then the program presents the consequences of his/her selection. In some scenarios, the application tries to measure the users' ability to predict the reaction of the nearby vehicles in a given situation, enriching in this way their experience in assessing their actions in relation to the consequences over the other road users.

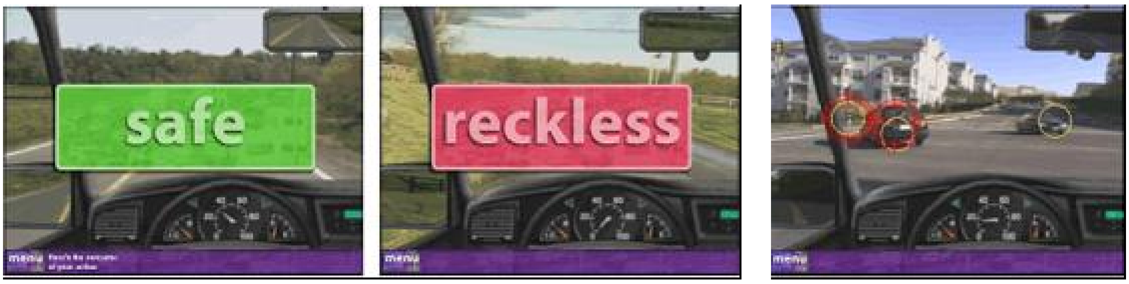


Figure 4.7: Screenshots from the American multimedia tool Driver Zed.

4.5 Alternative clustering of multimedia tools

An alternative clustering of support tools for the theoretical training is possible, based on different characteristics. An important characteristic is the user type and the environment for which each tool is intended. More specifically, the following clustering is possible:

- Multimedia training tools for use by the trainee either in his/her home (distance learning) or in the training school;
- Multimedia training tools for use solely in the training school;
- Multimedia training tools for use solely in the home (distance learning).

However, the above categorization is subjective and, in general, it is preferable that a driver instructor is present during the training, so that the trainee converse directly with the trainer in case of difficulty or for any question that might arise. Also, the trainer can check and correct the trainee if they have misunderstood something. This can be realised either with the trainer being present either in the same room or by some other media (e.g. through the internet or teleconference).

Yet another alternative categorisation is based on the way of using the tool, as listed below:

- Multimedia training tools that operate on a PC;
- Multimedia training tools that operate on a driving simulator;
- Multimedia training tools that operate on a TV monitor.

Finally, a list with various characteristics of such training tools follows next, based on which a clustering can be attempted, depending on the aim of the study:

- Based on input devices (mouse, keypad, mouse and keypad, TV control, etc.);
- Based on the content of the tools, according to the GADGET matrix, i.e. if each tool contains scenarios that cover the four levels;
- Based on the presentation means (video, pictures, sound, etc.) that it is composed of;
- Based on the content of its output (presentation of the correct/wrong answers, scoring, etc.);
- Based on the scenarios characteristics that are supported (night, accident, static traffic, rural roads, urban roads, motorway, etc.)

4.6 Classification of multi-media tools

The 25 multimedia tools collated in this report were clustered into three groups following the recommendations for the clustering of multimedia tools made in the previous chapter. The chapter discussed the importance that high level skill acquisition (strategic and behavioural skills) plays in reducing the accident rate of novice drivers. Therefore the best training tools should incorporate techniques to help drivers develop behavioural and strategic skills.

The GADGET matrix provides a basis for the clustering of tools according to levels covered by a given multimedia tool. The four levels of the GADGET matrix are listed below in order of importance (i.e. the highest level training first and the lowest last):

4. Goal for life and skills for living (Goals) (Highest Level);
3. Driving goals and context (Strategy) (High);
2. Mastery of traffic situations (Master) (Low);
1. Vehicle manoeuvring (Basic) (Lowest Level).

The data gathering questionnaire asked the focus of the driver training that the tool provided according to the GADGET matrix [(a) Influence of general goals and motives in life on driving; (b) Strategic/ trip-related driving tasks; (c) Basic control and manoeuvring; (d) Basic control and manoeuvring]. Each tool has therefore been classified according to the level of training provided. Each tool could cover one or more level of training. The tools have been clustered into three levels:

- Top Level (cluster 1);
- Middle level (cluster 2);
- Lower Level (cluster 3).

In order for a tool to be classified as 'top level' it was required to satisfy one of the following criteria:

- Cover all four levels of driver training;
- Cover the two highest levels of the GADGET matrix (Goals and Strategy);
- Cover one of the highest levels of training and both the lower levels of training (Goal or strategy and Mastery and Vehicle manoeuvring).

In order for a tool to be classified as 'middle level' it was required to satisfy the following criteria:

- Cover at least one of the higher levels of training (Goals and Strategy) as well as one of the lower levels of training (Mastery, Vehicle Manoeuvring).

In order for a tool to be classified as 'bottom level' it was required to satisfy one of the following criteria:

- Provide at least one of the lower levels of training (Mastery, Vehicle manoeuvring).

In the table below shows the result of the classification of the 25 media tools clustered according to the GADGET matrix.

Table 10: Clustering of the 25 reviewed multi-media tools.

cluster 1	The Police Driver's Course on Advanced Driving
	The Official Guide to Hazard Perception
	SCAN & TEACH
	Driving Skills
	TK 2000
	Korkortstest
	Interactief Defensief Autorijden
	De nieuwe Rijes
	Vection and HyperDrive
cluster 2	What If? The Official Guide to Boosting Rider Awareness
	What If? The Official Guide to Boosting Driver Awareness
	Simulation of Emergency Driving
	Emergency Driving
	INFORMED MMT
	SEVIAL
	ZEBRA
cluster 3	The Official Theory Test for Drivers of Large Vehicles
	BOB MMT
	Feu Vert pour le permis de conduire
	Multimedia Training for Students
	Vagmarken
	Bonniers Traficskola 3
	Mijn Rijbewijs zonder omwegen
	En god hjalp med teorin
	Klik op de weg/E op weg

5 CONSIDERATIONS FOR THE USE OF SIMULATION IN TRAINING

In order to better appreciate the complexity of simulation provision, there follows three discussions of factors that impinge on the utility and cost effectiveness of simulator based training.

5.1 Factors influencing training uptake and transfer of learning

5.1.1 Introduction

Everyday traffic has become more and more dangerous due to higher volumes of traffic, more roadwork and more traffic jams. Statistics show that especially novice drivers are overrepresented in particular types of crashes (e.g. Maycock, 2002) and could thus benefit from more training. Simulator training have the potential to deliver the further training required by novice drivers and other driver cohorts. However, to have a maximum training effect, some psychological learning principles should be followed throughout the training process.

In the following, the learning process is described and explained, followed by the discussion of learning transfer, which demonstrates the success of the training tool. Lastly, some general points like simulator sickness, influence of pre-training or length of one training session will be mentioned.

The aim of this report is to give an overview on the theoretical knowledge required to construct a successful simulator training program.

5.1.2 The learning process

There is no single definition learning. The definition of learning that is the basis to this report is that *"learning is an enduring change in the mechanics of behaviour involving specific stimuli and/or responses that results from prior experience with those or similar stimuli and responses"* (Domjan, 2003).

It is important to remember that not a change in behaviour is evidence for learning but a change in the mechanics of behaviour. Someone might behave differently in a certain situation due to various context factors. For the simulator implementation, this means that it has to be ensured that the trainee shows the right behaviour not only in the simulator due to the context "simulator", but also outside the simulator in real traffic. The aim is not a different behaviour of the trainee inside the simulator but a change in behaviour whenever he or she drives.

The learning process can be divided into the "learn-phase" and the "can-phase". The "learn-phase" is the phase in which information is gathered and saved. The learning success can be seen in the "can-phase" (Marek, J., 1983). The information is retrieved and certain behaviour is performed. When the trainee starts training with the simulator, he or she has already gained theoretical knowledge about driving. In the majority of cases also has already driven a car. Thus, the trainee might think that he or she is already in the "can-phase" although he or she is still in the "learn-phase" because he or she cannot react correctly and in-time in all situations. The simulator training should show him that there are skills still to be acquired and help him to learn them. Therefore, the simulator training should be divided into different modules and the trainee should only proceed to the next module after having completed the previous one successfully. So, when starting a module the trainee is in the "learn-phase" and will gradually change into the direction of the "can-phase". When reaching the "can-phase", the module is completed and the trainee can move on to another module.

Most driving students think that with getting their driver licence, they have reached the "can-phase". However, they are still in the "learn-phase". Various EU-countries have introduced "attended driving" which extends the learning time after finishing driving school training. The trainee is allowed to drive but only in an experienced driver's company. This gives the trainee the chance to practice and gain experience.

5.1.3 Model learning

Often we do not have to make certain experiences ourselves to learn the best behaviour for a particular situation. We have seen the outcome of other peoples' actions and we are able to draw our conclusions from it. This is known as model learning. Model learning describes learning through observing and imitating or avoiding the observed behaviour. Imitation depends on five variables:

1. If the outcome is positive or the behaviour is rewarded, the behaviour is more likely to be imitated. The imitator hopes to be rewarded, too – either by the success of the behaviour and its outcome (in this case the outcome is the behaviour) or by someone else;
2. The social status of the observed person is important, too. Behaviour is more likely to be imitated if the performing person is popular, friendly, of high status, pretty or seems to be competent;
3. The duration of contact with the performing person and, thus, the length of the observation;
4. The similarity of the observer and performer is of high importance;
5. The emotional bond between observer and performer.

In driving we have positive short-term outcomes and positive long-term outcomes. A positive short-term outcome is accident avoidance, while a positive long-term outcome is a decrease in car insurance costs. In the driving simulator we can only use the short-term outcomes. The trainee might experience an accident in the simulator if he or she does not brake in time, but if he or she does, an accident is avoided. While driving in the simulator, the trainee should be able to observe more than just one car in front of him and one car behind him. Thus, an accident could happen in front of him during the simulator session to let him see the consequences. The person having the accident should be similar to the trainee in age, gender and, as far as it can be seen, appearance. Also, the car should be similar in age and type of car. While the emotional bond between the trainee and other traffic participants has to be neglected in the simulator training, other drivers could be celebrities who show the trainee the right traffic behaviour.

Summed up, to apply model learning to the simulator, other drivers should be similar to the trainee and his car. By observing the model and his wrong and right doing, the trainee should find out right and wrong behaviour.

It should be considered that model learning also occurs if the trainer discusses the performance of another trainee (or other trainees) within a group-session: The simulation drive could be followed by a group session, if more than one trainee participates simultaneously in simulator training. The trainer could discuss one ore more mistakes of other trainees with help of the replay function and give hints for better performance and better behaviour within certain simulation situations. If the trainee is aware about the mistakes of others (maybe also of his own mistakes) he or she should learn to change his mechanics of behaviour and show better performance in future simulation sessions.

5.1.4 Learning transfer

The success of the simulator training can be measured with the trainee's on-road performance after completing the simulator training. On-road performance after the training should be better than before the training if the training was successful and better than without training (compared to other drivers). Learning transfer is the ability to transfer behaviour to another situation. In this case, the aim is that the trainee applies the learned behaviour from the simulator to on-road traffic. Transfer means the application of skills in situations that differ from the original learning context. If a skill is applied during a simulator session, but is not applied in real driving situations, there is no transfer. The best conditions for a successful learning transfer are: The trainee understands the given information. This makes it easier to save and recall the information and behave correctly. Most information needed for driving should already be known before starting the simulator training due to theoretical and contingent practical lessons. However, using the knowledge and experiencing the causes when neglecting certain rules, helps to understand the rules. A driver is more likely to stick to rules that he or she understands than to rules that he or she does not value, e.g. most speeders think that a speed limit is useless.

Transfer will be poor when learner drivers do not understand why they have to execute a task in a certain way. The simulator environment is a reduction of the reality. Learning in a reduced reality may help to speed up the acquisition of skills because it makes it easier for learner drivers as they can focus on the core of the skill. It is known that it is easier to learn in a simplified environment at first. However, later in training, those, who had started in a complex environment straight from the beginning, learned faster (Vlakveld, W.P., 2005). Because of this and the fact that transfer is poor when the training conditions clearly differ from reality Groeger (2000) thinks that with regard to road safety, the use of driver simulators (with poor realistic environment) in basic driver training could be counter productive. He says: "With regard to driving, and especially learning to drive, the findings from studies of transfer of training suggest that training drivers on actual roads, rather than under more simplified track or simulator conditions, offer the best chance of learners transferring what they have learned during training to the situations they will later encounter when driving alone."

Considering both Vlakveld (2005) and Groeger (2000), it can be seen that a good simulator with a realistic simulation is needed to have the aimed success. Simulators need to convey a good image of everyday traffic in all its facets like amount of traffic, behaviour of other traffic participants, roadwork, etc. The simulator should neither show an idealistic image of traffic (e.g. every participant behaves correctly, only few traffic, no roadwork, no unclear situations) nor an exaggerated image. The more realistic the simulator displays everyday traffic, the more realistic the simulated situations are the higher is the probability that the trainee’s transfer is successful.

Apart from understanding the rules and keeping to them, it is important to automate certain driving skills like gearing, breaking, blinker giving. If a driver does not have to think about what he or she is doing, he or she has more capacities to concentrate on the traffic around him and is able to react faster.

Table 11: Types of Transfer (Barnard et al., 2001).

Transfer	Explanation	
Positive transfer	1. Extent to which trainees have acquired knowledge, skills and attitudes, which can be applied effectively in work practice 2. Previously acquired knowledge, skills and attitudes facilitate the learning of new knowledge, skills and attitudes	Baldwin & Ford, 1988; Jelsma, 1989
Negative transfer	1. Extent to which an undesired effect occurs after following a course 2. Previously acquired knowledge, skills and attitudes hinder the acquisition of new knowledge, skills and attitudes	Baldwin & Ford, 1988; Jelsma, 1989; Gick & Holyoak, 1987; Patrick, 1992
Far transfer	Transfer when the initial learning task and the subsequent tasks to be learned differ substantially	Gick & Holyoak, 1987; Gielen, 1995; Tannenbaum & Yukl, 1992
Near transfer	Transfer when the initial learning task and the subsequent tasks to be learned differ only slightly or not at all	Gick & Holyoak, 1987; Gielen, 1995; Tannenbaum & Yukl, 1992
Low-road transfer	Transfer based on intensive and varied training, and occurring by means of automatic use of acquired knowledge and skills in a new context	Salomon & Perkins, 1990
High-road transfer	Transfer based on consciously abstracting of already acquired knowledge and skills from one context to another	Salomon & Perkins, 1990
General transfer	The trainee acquired certain working methods, knowledge and skills which can be used in tasks other than the original learning task	Gick & Holyoak, 1987
Specific transfer	The learning task is so specific that no transfer can be expected to other tasks	Gick & Holyoak, 1987
Horizontal transfer	Transfer from one task to another	Patrick, 1992
Vertical transfer	Transfer within a certain task, with growing expertise	Patrick, 1992

As can be seen in Table 11, there are several types of transfer. A positive transfer, of course, is wanted. If the simulator is good and conveys a good image of everyday traffic, a near transfer should take place as well. Low-road transfer covers the automating of different skills. Since one aim of the simulator is the automating of basic driving skills like gearing or steering, this type of transfer is wanted. High-road transfer is wanted as well since each traffic situation is unique and, thus, the trainee can only learn ways to deal with unclear situations.

5.1.5 Feedback

Barnard et al. (2001) underlie the importance of individual feedback. They differentiate between the input, throughput and output of trainee and trainer. The trainee is expected to look at the learning material before the course (input). During the training, he or she should think about applying the newly learned content to another situation. In this case, the trainee should know how to transfer the just-learned to real traffic. After the training, the trainee should try to maintain contact to either fellow-trainees or talk with peers about traffic and certain driving manoeuvres. The trainer on the other side has to organise the training and determine the training needs beforehand. Throughout the session, the trainer should motivate the trainee and coach the learning and “unlearning” process (e.g. identifying and sidelining interfering knowledge and skills). After the training the trainer gives follow-up support and positive feedback.

As Parush et al. (2002) pointed out „simulation-based learning must be supported by a reviewing mechanism if self-learning (i.e. without a human instructor) is performed“. The reviewing mechanism can either be an instructor who talks with the trainee about his performance and tells him what he or she has done wrong and gives him advice at how to improve. A further option is that the simulator itself has a so-called review-function. Best would be a combination of both, because if the trainee does not see what he or she has done wrong, the review-function alone is of no use. This enables the trainee to view his prior performance from a different view and helps the trainer to judge the performance of the trainee in detail and discuss ways to improve the performance in certain situations. Thus, trainee and instructor should view his performance together and give their opinion (based on a standardised estimation of the performance) on it. Further, the instructor helps the trainee to improve by giving him advice.

The discussion about the simulator drive could also be a group discussion. The advantages of group discussions are that the trainees can learn from the mistakes that someone else has made. Also, it is known that interaction increases the 'critical concept learning' (Damon, 1984). Group discussion leads to a deeper elaboration of the simulated scenarios and, thus, to more understanding (Webb, 1989). It is not known whether group learning is effective for all learners, e.g. some believe that a good person is held back by a weaker person (Allen, 1991). However, as mentioned above, group discussion will definitely lead to a deeper examination of the tasks and, thus, a better understanding of the rules. (Webb, 1989). And, in the simulator the trainee has to deal with the scenario alone since he or she will be drive alone on the road as well. In on-road driving lessons there often is another trainee present who is sometimes asked by the driving instructor to comment on the driver's driving style and behaviour. This can be seen similar to the group discussions above. Also, the group discussions after the simulator training will deal with the use of theoretical knowledge and, thus, this will be discussed to refresh the trainees' theoretical knowledge. Theory lessons in driving school are always group lessons due to the reasons above and they have been shown effective. It can not exactly be said how big the group should be. However, it can be said that the group should not be too small because then there are only a few opinions on a certain topic. It should not be too big, either, because then it is easier for someone to draw back from the discussion.

Interactivity plays an important role in learning. Three main interactions in learning can be described: interaction with other trainees, interaction with the teacher and interaction with the content (Moore, 1989; Schrum & Berge, 1997). Interaction with the teacher is important because he or she is able to judge the trainee's performance and give feedback. Interaction with other trainees or with the teacher can be initiated by both sides while interaction with the content is usually initiated by the trainee. However, with an interactive programme, interaction can also be initiated by the programme (Schär & Krueger, 2000). Due to this, an interactive programme is able to guide the trainee. Evans & Gibbons (in press) found out that an interactive-added computer-based learning system increases either the depth of learning or the depth of understanding. Either way, subjects trained with an interactive system were significantly better than subjects trained without an interactive system.

5.1.6 General considerations

5.1.6.1 Simulator sickness

Some users of virtual environments experience adverse effects known as simulator sickness. Common symptoms are generally grouped into (a) nausea, (b) oculomotor discomfort, and (3) disorientation.

The cause for simulator sickness has not been clearly identified. However, it is believed that simulator sickness is caused due to a discrepancy between the experienced motion and the actual motion.

Hoffmann, Krüger and Buld (2003) found out that there are no significant gender or age differences although the tendency for simulator sickness is highest for young women while the tendency for men over 50 is lowest. They also found out that the best way to avoid simulator sickness is when the participant is fit (e.g. not tired, not overhang etc.). They developed a training to avoid simulator sickness which will be explained in chapter 5.1.6.2. "Duration of simulator sessions" since the duration of the sessions has a major influence on simulator sickness and simulator sickness can be avoided by starting with short sessions and gradually extend them.

5.1.6.2 Duration of the simulator sessions

An on-road training session is usually 45 or 90 minutes long. Due to simulator sickness, the simulator sessions should be shorter. You should begin with a few minutes to test whether the trainee gets along. If someone becomes ill very quickly, he or she should train only a few minutes. If someone doesn't becomes ill, he or she should train longer.

Simulator sickness can be reduced by adaptation through training. Due to individual differences, there is no master plan on how to reduce simulator sickness. However, Hoffmann, Krüger and Buld (2003) developed a training plan after studying participants and their driving simulator experience. The persons tested for the development of the training plan had to deal with scenarios which are believed to cause simulator sickness and especially nausea. In between the sessions the participants are questioned about their physical state and they are able to go outside.

The first drive should last about 8-10 minutes and should give the participant the possibility to get to know the simulator and its handling. Since the used driving simulator was automatic, the subjects could concentrate on steering and breaking and did not have to worry about gearing. The second drive deals with acceleration and breaking in more detail and this drive can be up to 12 minutes long. The third drive is similar to the second drive in content, but longer (12-15 minutes). The fourth drive is a so-called “free drive” since the subject must choose the speed he or she drives at. In the first three drives, the participants were told which speed to drive at. This drive is about 10-15 minutes long. The fifth drive then is the test drive and should be 20-25 minutes long. This drive includes all the scenarios that the participant could practice in the preceding fourth drives. After the training, 80 of the tested 108 subjects were able to do simulator training without experiencing simulator sickness. However, it should be considered that none of the subjects suffered severe simulator sickness at the start.

Anyway, the concept of starting with short sessions that gradually become longer and more complex can be copied. This gives the subjects the chance to slowly adapt to the simulator environment and try out if they suffer simulator sickness. Hoffmann, Krüger and Buld (2003) also found out that the physical and mental state of the person plays a role and these can differ from one day to another. It is important that the participants' feels fit.

One driving school organisation in the Netherlands especially uses driving simulators for condensed driver training programmes. In these condensed programmes, learner drivers train all day long during consecutive days. From various experiments (not related to driving) it is known that this also has an effect on the speed of skill acquisition and retention. This is the so called spacing effect. Baddeley & Longang (1978) carried out a study regarding the training schedules for the training of postman to work with a new sorting machine. They examined four different training schedules, ranging from 1 hour of practice per day (spaced) to 4 hours of practice per day (massed). The learning speed (plotted as keystrokes per minute as a function of hours of practice) was the best for the group that trained during 4 consecutive hours (massed training) and the worst for the group that trained only one hour per day (the spaced group). However retention after completion of the full training programme appeared to be much worse for the postmen that had trained in the massed training condition than that of the postmen that had trained in the spaced training condition.

This shows that too much training leads to good results at first view but due to the low retention to quite a bad result. Thus, too much training only leads to good adaptation to the simulator. Regarding this learning fact and the facts about simulator sickness mentioned above, it can be seen that simulator training should be short, but effective.

5.1.7 Conclusion

To give an insight into the learn theories that should be regarded when planning simulator training this report focused on the theory of model learning. Apart from this theory, different studies and their results were acknowledged.

Although there are only a few studies dealing with the use of car simulators, there are broader studies concerning flying simulators or learning in general that were focused on in this report.

When planning simulator sessions, it is important to think about simulator sickness. Thus, one session should not be too long and the duration of the sessions should gradually become longer – starting with only a few minutes. Apart from simulator sickness, this point is important because if a trainee trains too often in the simulator, retention is low and he or she might not be able to transfer the learned content to real traffic.

The scenarios itself for the simulator should be as realistic as possible to make a maximum of transfer possible. The problem however is that some motions cannot easily be simulated which makes some manoeuvres unrealistic. Thus, the simulator training should aim at automating skills like steering, breaking or gearing since it is difficult to train higher order skills. If skills like steering, breaking or gearing are automated, the trainee has more capacities to deal with complex traffic situations. The scenarios should get more complex with each session. It is important that the first scenarios are rather easy because the trainee needs to adapt to the simulator and its handling. The scenarios should gradually become more difficult and more complex.

Feedback is always important. Integrating feedback and model learning leads to the implementation of group learning. Feedback should be given by an instructor who is also able to reason why the trainee has behaved in a certain way in a specific situation. The simulator should have a review function. In the group sessions, the group can view manoeuvres that each of the participants has driven and talk about what was good and what needs improvement. The group can profit from and help each other.

Overall, it can be said that more research on the use of car simulators and factors influencing training uptake is needed.

5.2 Motion rendering in simulation

5.2.1 Human perception of the vehicle movements

In a truck as well as in other transportation platforms, every vehicle movement of translation and rotation stimulates the driver's sense of balance through the ear's vestibular system synchronized with visual and audio information.

Basically we can consider that the driver has the sensation of moving forwards because his environment is moving past him in the opposite direction.

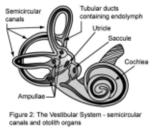
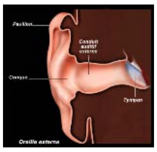
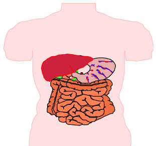
For example when passengers are waiting in a train and a second train starts alongside they usually sense that their own train is moving back. The lacks of reference marks in the environment cause a false perception.

Simulation attempts to use this property to reproduce the sense of driving without moving the driver's cabin by simply running a film at speed in the opposite direction. It is important to trick all the driver's senses if he or she is to be taken in. The immersion of the driver's senses is of prime importance to deceive him properly.

Studies conducted by several researchers have proved this can be difficult:

- The information of the vehicle acceleration is partly given by the ear's vestibular system. This information is subjective and relative, and generally depends on the perception of the individual.
- The eye perceives the position and speed information in absolute values from the height and the distance and relative values for the passing pictures. The eye's performance varies between individuals. Lastly peripheral vision is far less efficient than the frontal vision; for example unidentified lateral movements are perceived as shadows and can cause fright and unexpected reactions (e.g. when a fast motorcycle is overtaking the driver).
- The body itself through the bones and the muscles, for example through the feet, also gives a sense of acceleration, a sense of equilibrium, etc. to the brain.

Table 12: Driver's sense of perception.

Sense		*Perception*	*Ranking importance*
Eyesight		Position and speed in frontal view	1 (main human captor)
Ear vestibular system		Acceleration	2 (equilibrium captor)
Hearing		Relative position, bearing	3 (need of coherence)
Body		Swaying, acceleration, etc.	Others (weariness, diet, mood…)
Brain		Automatic treatment of the information, information gathering, comparison with known situations, recognition, correction and evaluation Automatic self-balance process with the spinal column etc.	Others (more complex than that)

Conflicts of perception can appear in a simulator, which delivers false incoherent or incomplete information to the driver's brain. Age, gender and numerous personal capacities have an influence on the driver's environmental perception.

5.2.2 Motion rendering contribution

The core objective of motion rendering in simulation is to give the correct driving sensation to the student without developing simulator sickness.

The motion can contribute very effectively to the acceleration and speed perception and to the credibility of the experience.

For example the professional driver, who drives his truck on a day-to-day basis, will also react with difficulty if he or she cannot sense his usual vehicle behaviour. he or she needs to adapt more than a beginner, who will take to the simulator environment more quickly as a new different driving reference. Motion in a truck simulator contributes to drivers' perception of immersion in the simulator; so the motion gives to the simulator a better fidelity rating.

There are two strategies, which can be applied, to simulate the environment for the driver. The first one is not to immerse the student in the simulator environment. For example very few people are sick with videogames. The second one in the contrary is to propose a faithful simulation environment. In this case motion rendering becomes of prime importance to produce a faked acceleration and speed and to reduce potential simulator sickness. A well-designed motion system can stimulate the student accurately so that he or she learns.

This strategy is quite successful, for example, in aircraft simulators, which have the Level D certification that means an equivalence of flying a real aircraft. Some criteria must be applied, for example:

- The dynamic simulation system errors must be reduced to allow the synchronization of the visual and hearing perception with the body and vestibular system. Experience tells that it is better to give motion command timing advance over the physical sensation.
- The simulation system must reduce the acceleration parasites, which give rotations of the head and movements of the thorax to the student.
- A fresh cabin environment helps reduce the heat of the internal ear and makes it easier to fight against simulator sickness.
- It is better to have high-spirited students than anxious drivers: anxiety leads to simulator sickness; motion makes it more fun and reduces anxiety and consequently reduces sickness.

When road vehicles are considered, the road surface contact makes more complex rendering the motion. The feeling of the vehicle jolting depends of the road itself, the vehicle suspension, transmission, tires, etc. and how much the driver knows his vehicle (i.e. its vehicle empathy). The lightness and the power of the vehicle make the road movement more abrupt.

While using an accurate modelling of the vehicle characteristics, to give a good illusion of driving and an appropriate sensation to the driver, the following factors have been taken into account:

The vestibular system, which is sensitive to short angular acceleration, could be stimulated in pitching, rolling and twisting.

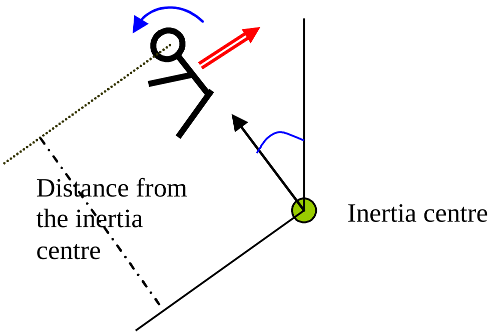
The body captors, which are sensitive to tilt and linear or long angular acceleration, could also be stimulated in pitching and rolling.

Understanding of rendering the vehicle motion

The common problem is to stimulate the driver accurately without interference (i.e parasitic forces) in the system in movement. The system to be considered is composed of the pilot cabin and the motion system itself. Let's illustrate the problem.

Regarding the pitching, the driver feels a force due to the vehicle mass inertia, which depends also on the vehicle turning circle. The vestibular system detects the angular acceleration, which is independent of the gyration.

The felt force would be reduced while minimizing the distance from the system inertia centre. In this way the force induced by the simulator appears to be the natural force induced by the vehicle.



Therefore it's a complex constraint to be able to move and adjust the inertia centre of the system. There is in particular a limitation due to the performance of the motion system itself linked to weight because of its capability to stimulate the cabin.

That's why the hexapod or Stewart Platform is a good solution. With a good synchronisation of the six actuators this produces the sensation of a movement 'near the driver's head' in order to limit the sickness and to give the most accurate sensation. This system can produce a translated virtual pitching movement.

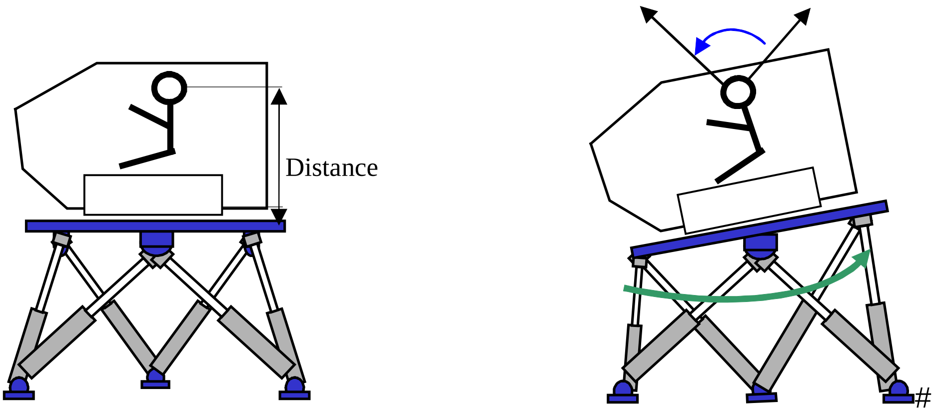


Figure 5.1: Rendering motion with a hexapod solution.

We can apply the same principle for the rolling and the twisting, combined with the horizontal, lateral and up & down translation forces.

The length of the jacks increases with the capability of deflection of the driver head. For example for 4° of pure rotation, the required jack stroke is 1.5 meters with a pilot head 2.5 meters above the motion platform (in blue in the figure). And the hexapod motion system is 2 meters high in neutral position.

This solution can be enhanced with the integration of the jacks on the cabin, if the cabin is not too large. This solution is applied for example for the cross-country vehicles to obtain an 8° rotation rate around the head of the driver and better vertical translation capability. This configuration reduces also the distance between the head of the driver and the centre of the motion system.

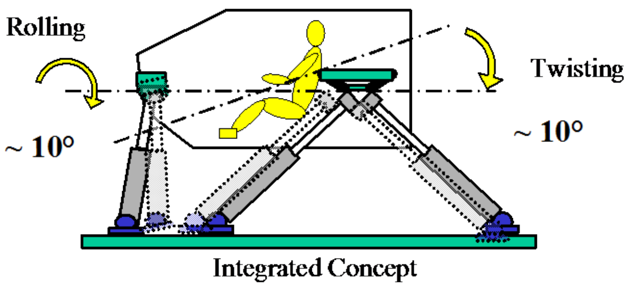


Figure 5.2: Integrated hexapod solution.

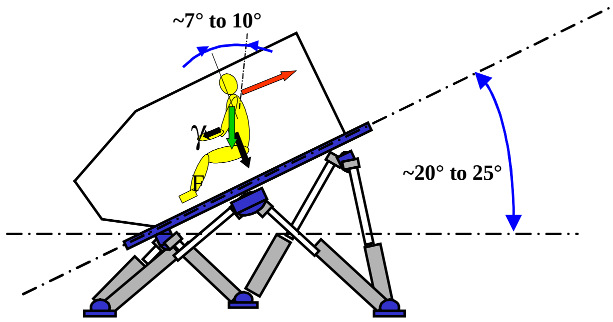


Figure 5.3: Cross country jacks deflection.

In a cabin placed on top of the motion platform the deflection of the jacks would be more important: around 20° to 25° to obtain the 7° to 10° head rotation; by contrast the integrated hexapod solution moves with the same rotation angles and is better at getting rid of parasitic forces.

So to render vehicle motion is not an easy task. It requires not only good design of the system, which consists in the vehicle cabin and the motion hardware, but also software modelling of effort and the vehicle behaviour too, which is able to compute the response of the vehicle when it is stimulated by the synthetic terrain.

Thales has designed its own hexapod systems to take into account the different masses of the simulator on-board elements. The main characteristics regarding the jack are its stroke length and supported mass, its angular amplitude (°), speed (°/s) and acceleration (°/s2) with regard to the pitching θ, rolling ρ and yawning ϕ associated with the X-Y-Z shifting range (mm), speed (mm/s) and acceleration (mm/ s2).

5.2.3 Motion simulation solutions

The motion device proposed by Thales, which is able to prevent the delivery of false information to the driver, is commonly a hexapod-based solution with six degrees of freedom. So it is not perfect especially in regard to acceleration, because the classic simulation to create a faked acceleration is roughly to incline the cabin, which may not be really effective for the body captors for example.

This mechanism could be enhanced with a pair of orthogonal rails in order to simulate the longitudinal and lateral acceleration, which could be particularly strong for a light vehicle. But the high price of this combination of movement currently makes this solution impracticable. For example car Manufacturers Renault uses this kind of motion rendering only on one simulator prototype. The speed of the double rail movement reaction and the combined activity of the rails are of prime importance to render a good sensation.

In particular the longitudinal and lateral rail amplitude limits the driving performance: the lateral rail allows you to simulate the car displacement on two road lanes while the longitudinal rail reduces by ten the average acceleration or braking distance, mainly because the simulator mechanism to be effective must be of reasonable size.

There is also some “washing up” to do to reinitialise the vehicle position after the braking or acceleration displacement: this has to be taken in to account when building up driving scenarios.

For the driving simulators the usually small available customer budget can limit the success of this strategy: However experience shows that a large diffusion of the simulators can counterbalance the fact that the investment capacity is small.

For example there is not much twisting and lateral acceleration for a truck at low speed on road or driving manoeuvres, where characteristics are limited to one or two power axles and a small turning circle. Sensation of vehicle braking and acceleration are moderate because of the important wheelbase and the inertia of the vehicle. So the simplest motion system can be applied to a heavy vehicle like a truck or a bus.

Indeed there are many examples of small motion systems under the driver seat. See opposite the US three-axis Force Dynamics 301 motion platform, which is designed for automotive purposes to reproduce physically engine vibrations, pavement texture, and high frequency suspension vibrations with appropriate software.

5.2.4 Lessons Learned

The fidelity of the visual system has the most impact on the sorts of driving tasks that could be used in training in a driving simulator.

Most lessons learnt have been learned from the production of simulators for tanks, because over a period of 20 years there are more than 400 installed tank systems for various kinds of tanks. However THALES through its customers with 42 truck simulators installed in Europe has acquired a major in-the-field experience.

Regarding the road driving or the cross-country for multi-power axles wheeled or tracked vehicles; the driver is completely satisfied by the sensation of pitching, rolling and swaying. However a very few characteristics regarding some tracked vehicles could not be rendered properly by the motion system.

Measurement of rendering the vehicle motion was expressed by qualitative analysis of the movement breakdown on the different degrees on freedom and also by the amplitude of the driver's thorax movement.

The flexibility of the vehicle's suspension is also very well perceived.

Five degrees of freedom are very comfortable: the lateral free-degree is non significant because the sensation feels like swaying or rolling for the driver, but the equilibrium and the momentum of the jack-mounted systems requires a sixth jack. For vehicles with a low dynamic, a three-pod motion system would be enough.

For the truck the hexapod was chosen mainly for the restitution of the braking sensation.

- The important criteria, which militate in favour of the motion, are the perception capabilities of:
- The truck load on the moving off;
- The jerks when shifting the gear;
- The braking;
- The changing of direction;
- The road overlay, potholes, kerbs etc.;
- Some mechanical breakdown such as puncture.

Sickness induced by motion remains a problem on some configuration, because it also depends mainly of the elapsed time between the student actions and the visual cues. Motion is only a part of the system.

5.2.5 Analysis of the interest for motion rendering through the assessment capability

The truck simulator is able to supply lot of measures during an exercise. These measures are designed for the instructor assessment of the student; they show the skill in controlling the vehicle, the respect of the traffic rules, the ability to be positioned correctly in the traffic and overtaking skill. The driver sensation must be accurate to consider the measures representative of the real driver's skills.

In fact the motion permits the trainee to feel the road to sense the real road conditions, such as the potholes, the kerbs, the verges, etc.; trainees can sense also a flat tire. This road sensation is very useful to better integrate the road environment through the vehicle behaviour. The trainee can accelerate and brake progressively; he or she is able to discern the vehicle turning circle, the mass and its main rigid or articulated truck characteristics and he or she can experience how it could be dangerous to adopt too high a speed at a roundabout and the risk of tipping over. The motion is the essential complement of the visual display allowing the student to integrate the vehicle parameters and especially its cinematic effects, the road environment and the controls and their effects such as the braking, the clutch and accelerator pedals, the gear and the wheel.

The table below shows the importance of the measure regarding the use of a motion in the simulator.

Table 13: Example of positioning data of demonstrator with motion.

TRAIN-ALL Demonstrators *The motion enhances the fidelity level of the simulator = 5 or is useless for the simulator fidelity = 1*	Motorcycle simulator prototype	Truck simulator prototype	Emergency vehicle simulator prototype	Passenger car simulator prototype	Immersive simulator prototype	Multi purpose driving simulator
Acceleration & braking feeling	5	5	4	2	3	2
Speed feeling	3	3	2	2	3	2
Trajectory depiction	3	2	2	1	3	1
Clutching jerks feeling	3	2	2	1	3	1
Position in traffic	1	2	4	4	3	4
Traffic violation rules	1	1	3	2	3	4
Overtaking in the traffic	3	3	4	4	3	4
Defensive driving	1	2	5	4	3	4
Economic driving	1	1	1	3	1	4

This table has to be reviewed by the partners. Is the “Overtaking in the traffic” activity training needs a motion system on the simulator? “3” indicates an average response, because it’s better to have it.

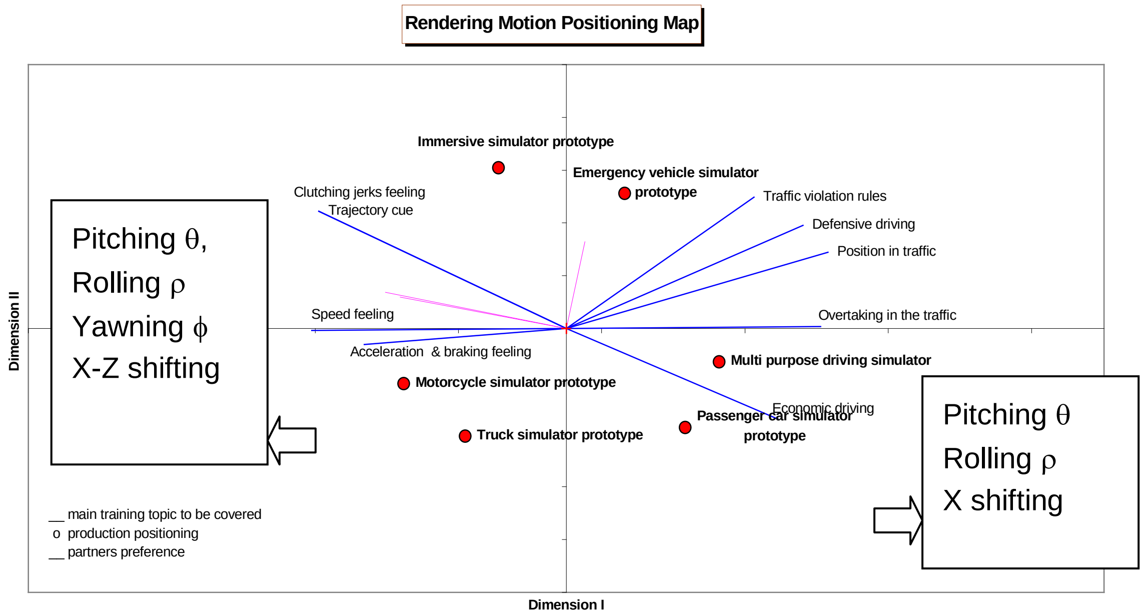
The next table shows the interest for each partner regarding the necessity of a motion system integrated in the TRAIN-ALL demonstrators. For example UP doesn’t have any preference.

Table 14: Example of preference data of demonstrator with motion.

Demonstrators	Motorcycle simulator prototype	Truck simulator prototype	Emergency vehicle simulator prototype	Passenger simulator prototype	Immersive simulator prototype	Multi purpose driving simulator
THALES	5	4	3	1	4	1
CERTH/HIT	2	4	4	3	4	3
CRF	5	4	4	3	4	2
UP	4	4	4	4	4	4

With a positioning analysis the next figure presents a map perception of rendering the vehicle motion through the main training topics to be covered in regard of the different TRAIN-ALL demonstrators. On this map the partner’s preferences are also indicated.

Figure 5.4: Positioning analysis.



The pair-wise distance between the different topics directly indicate the "perceived similarities" between any pair of topics. Map Vectors in pink or in blue indicate the strength of the preference or the production and its main product attributes corresponding to the different topics. The motion use for Motorcycle and Truck simulators are more oriented on the machine control-command difficulties and for multipurpose driving or car simulators it could be wise to use motion for economic driving or defensive driving.

This analysis could provide the requirements for the degrees of freedom, which must be simulated for the different types of simulators.

5.3 Influence of future ADAS on future training requirements

5.3.1 Introduction to ADAS

ADAS have in common the idea to improve a safer driving, providing preliminarily information to the drivers on situations which could occur in brief time horizon (as collision avoidance systems or blind spot), supporting them in case of poor environmental perception (as night vision or ACC), contributing to keep the driving task in the safer way (as lane keeping). They point in the direction of a priority to which public opinion and authorities address a high relevance, when the innovation in car domain is discussed: to have new functions which support accidents and fatalities reduction.

Some ADAS are nowadays already available on the market, but we are only in the beginning of this exploitation. The first one to be introduced on the market was the ACC (Adaptive Cruise Control). ACC is an extension of ordinary Cruise Control, since it keeps not only the vehicle velocity at a predefined value, but also the distance (headway) from a front vehicle. It was introduced firstly in Japan and then in Europe in 1998. Another ADAS is the Night Vision, which has been introduced in USA in 2000. Typically, it consists in an IR camera with associated a Head Up Display (HUD), in order to improve the vision of external scene during night-time. Finally, the Frontal Collision Warning (FCW) and the Lane Departure Warning (LDW) are two systems available in USA for trucks and in Europe also on cars. FCW is a system able to alert drivers about dangerous obstacles (e.g. a vehicle too much slower and/or too close respect to the host-vehicle and inside its trajectory); LDW is a system able to alert drivers in case of unintentional lane departure.

The following table summarizes the main radar/camera/GPS based systems.

Table 15: Overview of radar, camera, GPS-based systems.

System	*Description*
ACC + Stop & Go	The ACC and Stop & Go establish a virtual link with the frontal vehicle via a radar-based technology and keep both vehicles within a safe distance. In traffic conditions as in a queue, the Stop & Go automatically drive the vehicle timely providing vehicles' stops and small movements.
Lane Departure Warning	If certain thresholds (like distance, time to lane crossing) allow a prediction of a lane departure this system warns the driver by means of acoustic, optic or haptic feedback.
Frontal Collision Warning	The driver is warned if a potential collision is detected via radar-based technology
Collision Avoidance	This system has an extended functionality compared to the Frontal Collision Warning. An autonomous intervention takes over the control of the vehicle in critical situations, in order to avoid an accident.
Lane Keeping Assistant	The function of this system includes the lane detection and the feedback to the driver if he/she is leaving a defined trajectory within the lane. An active steering wheel can help the driver with a force feedback to keep on this trajectory. The lane is detected by a video image processing system.
Blind Spot Monitoring	This function detects if a vehicle is present in the so-called "blind spot" area when the vehicle is starting a lane change and/or overtaking manoeuvres. A camera is placed into the left rear-mirror and once the incoming vehicle is recognised, a warning is issued to the driver.
Night Vision	Based on camera techniques like near or far infrared, it allows enhancing the perception of the driver in the dark light conditions.
Lane Change Assistant	Before and during a dangerous lane change process, the lane change assistant will warn the driver. Several stages of such a system are possible from the pure warning to even haptic feedback at the steering wheel to help the driver following a lane change trajectory.
Curve & Speed Limit Info	These systems inform the driver about speed limits and the recommended speed in curves. Possibly the necessary information can be take from digital maps, image processing communication systems between vehicles and infrastructure.

Currently, the introduction of this kind of system involves prototypes or mainly luxury cars, or trucks, but there are many other systems that are more widely integrated in common vehicles, such as ABS (Anti-lock Braking System), EBD (Electronic Brake-force Distribution), ASR (Anti Schlupf Regierung – Acceleration Skid Control), ESP (Electronic Stability Programme), BAS (Brake Assist System).

As a consequence of this increasing technologies integration, the role of human beings is changing as well, since human operators will have more and more a task of supervisors and monitors of procedures, performed automatically by "technologies".

It is to be noted that without a proper grounding, there is for the driver the risk of overestimate the ability of the ADAS to handle every situation; in other terms, the driver, not experienced enough, could feel himself out of the control loop, forgetting that the responsibility of the driving remains always in his hands. It's a pity, because a wider knowledge of the ADAS, a greater awareness about their current limits and a bit of training in their use could allow the driver to benefit by all what technologies are, anyway, currently able to offer.

In this context, great efforts will be needed on one hand in the design of more and more usable HMIs, and on the other hand in a deeper and deeper drivers' knowledge of the ADAS functionalities and algorithms and in a more and more effective training on the use of such a systems.

5.3.2 Future training requirements

There are many aspects that future training curricula will have to consider, from the point of view of an increasing ADAS integration. One aspect is the safe and easy human – ADAS interaction. Of course ADAS should have better and better interfaces, but also the driver will have to understand deeply the meaning of all the initial ADAS settings and all those are made when the vehicle is running. he or she will have to learn how to interact safely with all the input interfaces, and how to interpret all the lights, icons, acoustic and haptic warnings, up to ADAS active interventions.

A second aspect is related to the ability that a driver should have to recognise a possible system failure, and to cope with such an eventuality.

A third, but not less remarkable, aspect is the advisability for the driver to know the basic principles about how ADAS work, which are the optimal scenarios for each ADAS, and above all, which are the critical scenarios, for which the driver should expect a reduced functionality or even some mistakes (false alarms / interventions and missing or delayed alarms / interventions).

In order to better understand this latter issue, in the following is instanced the ACC Stop & Go system with some of its relevant critical scenarios.

The ACC Stop & Go can be seen as a typical evolution of the current ACC system. The main objective is to offer the customer longitudinal support on a vehicle guidance level at low vehicle speeds all the way up to zero velocity. The support is offered to alleviate the driver from strenuous tasks and strain of routine processes such as accelerating, decelerating and stopping while maintaining proper spacing with the surrounding vehicles in an environment characterized by a congested traffic flow. The ACC Stop & Go comprises at least the following functions:

- Remain safe distance to preceding vehicle(s);
- Slow down behind decelerating vehicle, eventually make a full stop;
- Slow down and stop behind stopped vehicles;
- Autonomous “GO” when stopped behind vehicle;
- “GO” when initiated by driver in case no preceding vehicles are present;
- Control vehicle speed (up to set speed) when no preceding vehicles are present;
- Manage standstill condition even on slopes;
- Manage near cut-ins from adjacent lanes comfortably;
- Recognize and manage lane changes initiated by the driver;
- Harmonize perturbed traffic flows;
- Inform drive when system limits are reached;
- Switch off when brake pedal is activated;
- Limit vehicle speed when set-speed has been reached;
- Adjust headway according to driver preference.

The range in front of the own car can be typically organised into three regions: near range region up to about 10 m, mid range between 10 m and up to about 50 m and far range above 50 m distance. The near region is covered by a very wide angle of view to detect cut in objects very early. The mid range region covers typically three lanes at a distance of about 10 m. The far range sensor should cover an angle of about ±10°. For each of these three regions there is a suitable radar sensor.

The ACC Stop & Go, just as every radar based system, has some problems of false alarms with tunnels, bridges, signs, underpasses and overpasses; this because of the lack of angular vertical resolution of the sensor. In addition to these typical (well known) situations, ACC Stop & Go sometimes presents some other problems, such as:

When the own car is still in a straight, and is approaching a bend, some objects in the bend outside the lane, or even outside the road, can be detected erroneously if they are in the estimated own vehicle trajectory; then a false alarm will be issued.

A motorcyclist driving between the own vehicle and a vehicle ahead with a varying distance to the own could not be detected, with a consequent risk for the motorcyclist.

If the own car is stopped behind a vehicle, the latter restarts and there is a pedestrian still crossing the road between the two cars, the system could not detect the pedestrian and start performing an autonomous “GO”.

Every kind of low speed manoeuvre related to a lane change of the own car when there are many other vehicles surrounding it, or to a cut-in or cut-out manoeuvre of vehicles ahead could cause problems in the detection of the environment

5.3.3 Conclusion

The goal of “White Paper of European Transport Policies” (EU 2001) is to reach a 50% of road fatalities reduction within 2010. In order to achieve this goal, a big effort in safety research has been made, and is still demanded. The recent introduction of ADAS can give a strong contribution to obtain the aforementioned objectives. In order to make such devices as friendly and safe as possible, big improvements have been done, even from the cognitive ergonomics point of view. The “Human Centred Design” approach has been adopted in order to make HMI (together with their information management logics) more and more intelligent and usable, but a suitable driver training which would give him a full mastery of ADAS functionalities would be strongly recommended as well.

As the on-board ADAS integration trend is increasing, it is no more acceptable not to take into account, during the training and assessment of a driver, also the knowledge of such a systems and the ability in using them.

Trying the ADAS settings, HMI and limitations in a driving simulator can lead the learning process to better results and in shorter time (thanks to the use of ad hoc scenarios). Above all it will lead also to a better awareness about the fact that the responsibility of the driving task still remain, in every conditions, in the hands of the driver.

6 BENCHMARKING OF DRIVING SIMUALTORS

6.1 Rationale for classification

To allow classification and benchmarking of the driving simulators identified in the questionnaire survey, important variables and parameters for the description of simulators were identified through review of relevant literature, including various EU-project deliverables such as the TRAINER deliverables and other classification approaches for training tools.

Categorisation of training devices is a standard procedure, e.g. in the aviation industry. Flight Simulators are categorised into four bands, A, B, C and D according to the prescriptions of JAR-STD 1A.025 (Requirements for Flight Simulators (qualified) on or after 1 April 1998). The directive published by the Joint Aviation Authorities (JAAT) states that

> *"(a) Any flight simulator submitted for initial evaluation on or after 1 April 1998, will be evaluated against (applicable) JAR-STD 1A criteria for Qualification Levels A, B, C or D. (Recurrent) evaluations of a flight simulator will be based on the same version of JAR-STD 1A, which was applicable for its initial evaluation. An upgrade will be based on the currently applicable version of JAR-STD 1A)".*

According to this directive, flight simulators are assessed in those areas which are essential to completing the flight crew member training and checking process, including:

- Longitudinal, lateral and directional handling qualities;
- Performance on the surface and in the air;
- Specific operations where applicable;
- Flight deck configuration;
- Functioning during normal, abnormal, emergency and, where applicable, non-normal operation;
- Instructor station function and simulator control; and
- Certain additional requirements depending on the Qualification Level and the installed equipment.

The Authority must be notified of changes in the operation or configuration of qualified flight simulators, including amongst others relocation, software and hardware modification as these may affect the categorisation of the flight simulator.

The directive specifies minimal technical requirements for simulators qualifying for JAA Level A, B, C and D with A being the lowest and D being the highest level of technical complexity of the flight simulator. Certain requirements in the categorisation system must be supported with a statement of compliance (SOC) and, in some designated cases, an objective test.

A banding system for the driving simulators identified in the questionnaire survey was developed in the style of the flight simulator banding, including five levels, with level A being the lowest and level E being the highest level of complexity of the driving simulator. The banding of the driving simulators identified in the questionnaire survey was carried out on the basis of the information made available by the stakeholders in the questionnaire. This meant that simulators that were not described in full in the questionnaire may have received a lower banding than necessary as the required information was missing.

Five bands were identified rather than the four used in aviation because the technology clusters had different distinguishing characteristics. Most notable the aviation classification does not consider the very basic technology cluster of TRAIN-ALL Band A, but for driver training this could be an important component of the curriculum, and can be distinguished from other multi-media tools in that it has the important characteristic of demanding the student to take direct interactive control of a simulated vehicle in a traffic environment.

The suggested banding does not include all variables deemed relevant for a comprehensive benchmarking of driving simulators. Instead it rather focuses on a few main variables that allow a rough classification of simulators under scrutiny in terms of their technical complexity. The suggested variables for simulator banding were all covered in the questionnaire survey on driver training simulators and include:

- Replication of vehicle features (e.g. controls, cab, sounds, kinaesthetic feedback);
- Visual system (single versus multi-channel projection and field of view (FOV));
- Motion rendition (none, basic, 6 and 8 degrees of freedom);
- Interactivity/number of simulated road users (low (L), medium (M), high (H));
- Sophistication of the simulated road environment, including road layouts and environmental conditions (low (L), medium (M), high (H));
- Breadth of learning opportunities provided, e.g. complexity of training scenarios, changeability of underlying vehicle model and possibility to add driver assistance systems.

The sophistication of the simulated road environment was operationalised as the sum of simulated road environments (e.g. motorway or urban), the simulated road features (e.g. bridges or tunnels), simulated weather conditions (e.g. rain or night) and simulated lights (e.g. headlights or reversing lights). A maximum of 32 simulated road environment conditions could be obtained in the simulator questionnaire. A score of up to 10 was defined as low (L), between 11 and 20 was regarded as medium (M) and a score between 21 and 32 was regarded as high (H).

The complexity of available training scenarios was computed from the number of selected training goals on the manoeuvring level (second level of the GADGET matrix) a simulator could cover. The simulator questionnaire required respondents to specify which out of a total of 29 manoeuvring goals the training tool they described could cover. Nine of the training goals from the manoeuvring level were selected for the assessment if a simulator was capable of covering complex manoeuvring tasks. These learning goals included the explicit interaction with other road users rather than the mere negotiation with static road environment features. The selection of items for the assessment is in line with the requirement from the EU driver training literature for a stronger focus of simulator training on higher order skills. Table 16 shows the nine selected manoeuvring tasks.

Table 16: Complex manoeuvring tasks on GADGET level 2.

1	Visual scanning
2	Overtaking/passing
3	Entering/leaving the traffic
4	Hazard perception
5	Driving techniques in critical situations
6	Defensive/ anticipating driving
7	Reacting to other vehicles
8	Reacting to pedestrians, cyclists and other vulnerable road users
9	Negotiating intersections, junctions and roundabouts

A score of up to three complex scenarios was defined as low (L), between four and six was regarded as medium (M) and a score between seven and nine was regarded as high (H) with regards to the coverage of complex manoeuvring scenarios.

Typically, for low band simulators most variables would assume low (L) values, whereas training devices in the higher bands would be characterised by high (H) values on most variables. As the suggested simulator banding includes a number of variables and at the same time simulators can vary considerably in their capabilities, a perfect fit between banding criteria and simulator features is unlikely. The suggested banding approach allocates a simulator to the band it has the greatest overlap with on the basis of the existing information. It is also important to note that the suggested simulator banding is based on technical complexity of the driving simulators and does not imply a "fit for purpose" judgement of the training tool itself. Low band simulators may be very appropriate for achieving their intended training goals, e.g. if the training goal is the familiarisation with car controls the simulator will not be required to feature a sophisticated behaviour model of the simulated road users. Cost- benefit considerations are part of a more sophisticated classification suggested in a later chapter. The table following gives a brief description of the general technical requirements associated with the five bands and the learning targets that are attainable with simulators representative of the five bands.

Table: Overview of posited parameter values for five simulator bands.

Qualification Level	*General technical requirements*	*Learning targets*
A	The lowest level of driving simulator technical complexity The driving simulator enables the user to navigate the ego-vehicle through a populated road environment displayed on a single channel screen. Rear and side mirror views may not be provided. The movements (vertical and lateral) of the ego-vehicle are controlled by the use of a mock steering wheel and pedals or by joy-stick. Kinaesthetic feedback for driving controls is not provided. The driving simulation does not include realistic gearshifts, a vehicle cabin or a motion system. Changes of the underlying vehicle model are not possible or very limited. The interactivity of simulated road users is low. Low number of simulated road environments and environmental conditions	Suitable for: Awareness raising, visual familiarisation with road environments, or simple entertainment (may have value in promoting life goals and strategic issues)
B	As for Level A plus: Provision of car controls, including pedals, gearshift, steering wheel Provision of an artificial vehicle cab The road environment is displayed on a single visual channel Side or rear mirror views may not be provided No motion system provided Limited number and interactivity of simulated other road users Limited number and realism of simulated road environments and environmental conditions	As for Level A plus: Familiarisation with vehicle controls and procedures possible. Compliance with some rules of the road.
C	As for Level B plus: Realistic feel of car controls (e.g. pedal or steering wheel resistance) A motion system may be provided Wider FOV through multi-channel projection often provided Greater number and realism of simulated road user behaviour Training of more complex driving scenarios possible	As for Level B plus: Training of simple manoeuvring tasks in small number of road environments possible; and some tactical decision making in simple

Qualification Level	*General technical requirements*	*Learning targets*
		traffic
D	The second highest level of driving simulator complexity As for Level C plus: Provision of realistic vehicle cab Multi channel visual system with provision of rear and side mirror views 6 Degree of freedom motion system provided Larger number and realism of simulated road environments and environmental conditions Behaviour of other road users can be influenced High degree of interactivity with simulated road users provided Change of underlying vehicle model possible Addition of ADAS possible	As for Level C plus: Training of complex manoeuvring tasks including interaction with other road users, hazard perception, and eco-driving
E	The highest level of driving simulator complexity As for Level D plus: 6 Degrees of freedom plus extended x and y motion system (rails) provided Training with highly complex training scenarios with high level of interactivity between road users	As for Level D plus: Wider range of complex manoeuvring tasks recreated adequately due to availability of more comprehensive motion rendering

6.2 Classification of reviewed simulators into bands

- **Band A**

None of the reviewed simulators was classified as a band A simulator. Figure 31 provides example pictures of Band A applications.

Figure 6.1: Examples of Band A simulators.

The examples above include computer games and are obviously not presented as training devices, however they demonstrate that compelling simulations of driving can be provided to be used on either generic PC technology, or on bespoke vehicle bucks that whilst lacking face validity can provide an engaging driving experience.

- **Band B**

Seven of the twenty reviewed driving simulators were classed as band B driving simulators. These included (1) AutoSim, (2) the CRF Advanced Driving Simulator, (3) Oryx Simulation's Wheel loader/ digger machine/ crane, (4) the STIsim 400, (5) the TranSim VS Driver Training Simulator, (6) Doron Precision System's 460 Truck simulator and (7) Faros EF-X. Whereas the first three simulators were genuinely classed as band B simulators, the information provided on STIsim 400, TranSim VS, 460 Truck simulator and Faros EF-X was insufficient to make a definite decision on the appropriate banding.

Pictures were not available for the CRF and the Oryx simulator; pictures of the remaining five simulators are displayed in Figure 32 to Figure 35: STIsim 400.

Figure 6.2: AutoSim, an example of a B band driving simulator.

This simulator was put in the B band because of insufficient information to confirm a higher classification.

Figure 6.3: Doron Precision System's 460 truck simulator.

This simulator was put in the B band because of insufficient information to confirm a higher classification.

Figure 6.4: Faros EF-X simulator.

This simulator was put in the B band because of insufficient information to confirm a higher classification.

Figure 6.5: STIsim 400.

This simulator was put in the B band because of insufficient information to confirm a higher classification.

Figure 6.6: TranSim VS Driver Training Simulator.

- **Band C**

  Seven of the twenty reviewed driving simulators were classed as band C driving simulators. These included (1) FOERST's Smart Simulator, (2) Green Dino's Dutch Driving Simulator, (3) FOERST's Fahrsimulator F10PF, (4) Lockheed Martin's Truck Driver Trainer, (5) Honda' s Driving Simulator, (6) Drive Square's Portable in-vehicle driving simulator and (7) Krauss Maffeï Wegmann's Mobile Simulator. As information on the Krauss Maffeï Wegmann simulator was incomplete the banding of this simulator is conservative.

  Pictures were not available for FOERST's Smart Simulator, Honda's Driving Simulator or Drive Square's portable simulator. Pictures of the remaining five simulators are displayed in Figure 37 to Figure 39.

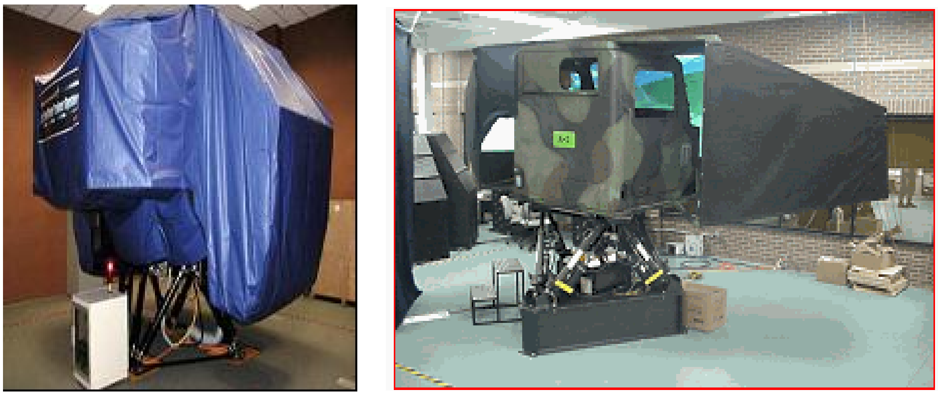


Figure 6.7: Lockheed Martin

Figure 6.8: FOERST's Fahrsimulator F10PF

Figure 6.9: Green Dino's Dutch Driving Simulator

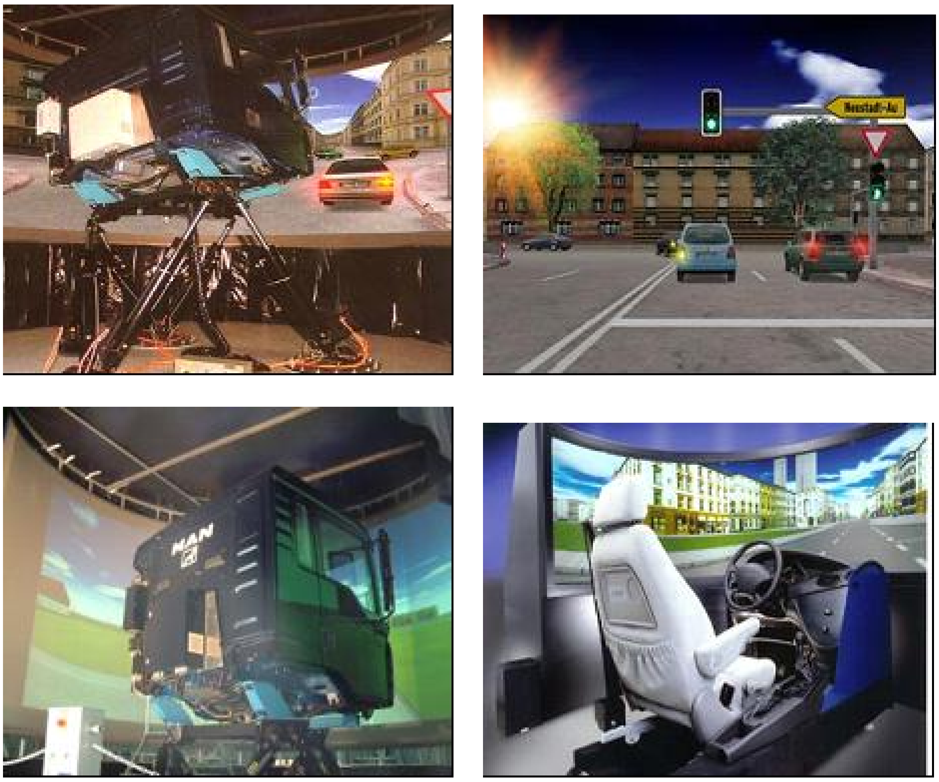


Figure 6.10: KMW

- **Band D**

  Six of the twenty reviewed driving simulators were classed as band D driving simulators. These included (1) Rheinmetall Defence Electronics Emergency Driving simulator, (2) WIVW's Training and Research Simulator, (3) DriveSafety's DS 600, (4) Thales' TRUST 3000, (5) Thales Trust 5000 simulator and (6) Thales Trust 800 simulator.

Figure 6.11: Thales' Trust 3000 Simulator, an example of a D band driving simulator.

Figure 6.12: RDE's Emergency Driving simulator

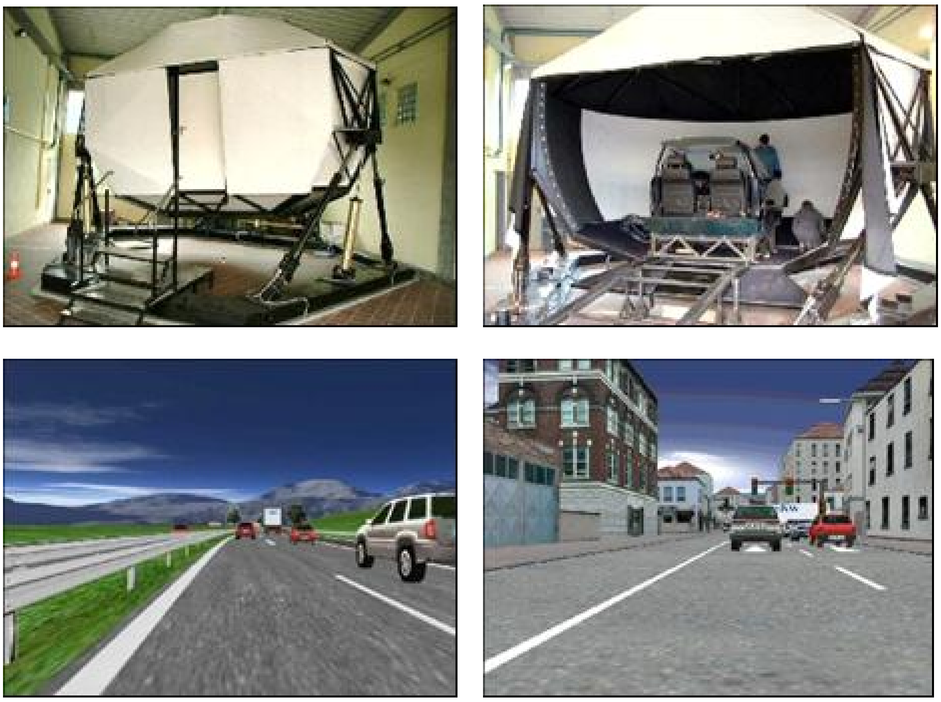


Figure 6.13: WIVW's Training and research simulator

Figure 6.14: DriveSafety's DS 600

- **Band E**
  None of the reviewed simulators fulfilled the criteria for the E band. This required highly sophisticated scenario modelling, a six degree motion system plus extended X and Y motion and highly interactive and realistic behaviour of simulated road users.

Figure 6.15: Examples of band E driving simulators (NADS, Daimler Dasa).

6.3 Suggestions for further classification of simulators

The classification of simulators on the basis of a limited number of variables indicating technical complexity of a given driving simulator allows an immediate allocation judgement; however, it is not appropriate to fully describe the properties, capabilities, effectiveness and the realism of a given training device. For a more comprehensive benchmarking of simulators the consideration of a larger range of variables is necessary. These variables include manifest as well as less tangible characteristics of a simulator training device. It would also be necessary to make a more direct link to specific training scenarios and the prescription of minimum and optimum criteria.

Whilst there is intuitive appeal to such an approach which might for example provide, in a matrix format, the links between levels of sub goals of the GADGET matrix with particular simulator characteristics, the derivation of minimal and optimal technical performance lacks an evidence base. For example, we might consider the specific case of GADGET training goal *'Mastery of traffic situations*' (see Table 2) and the sub-goal *'distance to others/safety margins'*. We might be encouraged to think of which type of visual system a simulator should have, or which motion system (if any), or what type of traffic generation routine would be appropriate. But while a particular expert might feel confident to express a view, given an explicit scenario description for a training module that addressed *'distance to others/safety margins'* of what a minimum system should look like, it is also likely that any other expert might take a markedly different view. At present there is insufficient public domain evidence of the effectiveness of any particular type of simulator configuration in promoting realistic behaviour in the training task, and more importantly, in promoting useful levels of transfer of training to real world situations. Without this evidence a matrix based approach is invalid at present.

7 DISCUSSION

There is no single dimension or attribute that allows a straightforward and non-controversial classification of multi-media devices or driving simulators. Technology is advancing, and stakeholder expectations of systems are developing, not least because there is a general awareness of the developments being made in entertainment systems and in military grade synthetic training. As shown, there are many subsystems within even the most basic simulation training device. Simple, level A devices will employ a visual display, some form of manual input device, and a task presented within an traffic environment. As we move up the scale of face validity and complexity, motion, sound, and vibration are introduced, and the realism of the dynamic driving task increases. The fact that different systems may have strengths in one area but weaknesses in others, compared to systems of roughly similar price and training aim, means that a classification which takes a technology focus struggles to provide distinct immutable classes.

The assignment of simulators to the bands A to E in this report is not intended to be definitive, nor should it be viewed as having importance beyond that of providing a worked example of how such a system might operate if full information was available for each system under consideration. Within the TRAIN-ALL project the intention is to further refine the classification in the light of experience and consensus gained through efforts in other work packages. In particular it should be noted that the importance of the classification and benchmarking exercise, is to move towards a point where a clear view of what level of simulation is required to deliver particular training lessons adequately can be expressed.

In order that purchasers of simulator-based training can have confidence that they will receive value, they will need to know the curriculum is to be delivered through the appropriate training medium. That implies a clear knowledge that the particular system has been accredited as appropriate. Thus this report has described an important preliminary step towards an acceptable classification system, but a greater integration with the output of work packages that consider the benchmarking of training curricula will be required.

Future consideration will be needed of how to accommodate forthcoming developments in advanced vehicle displays and controls (head up displays, voice activated controls etc), and also systems such as navigation, adaptive cruise control, collision avoidance, vision enhancement and so on. It may not be the case that interaction with advanced systems can only be trained on the most sophisticated levels of simulator.

The most obvious gap identified in the review has been related to the highest levels of the GDE matrix. At present simulators, and to a lesser extent, multi media systems, are focused on providing the opportunity for training in skill-level operational control and for tactical decision making in terms of responses to potential hazards in the road environment. They have not been developed with strategic level decision making in mind (mode and route choice for example), yet these aspects will form an increasing component of future training programmes.

It is also likely that some forms of training, for example of emergency service drivers, will require increasing emphasis on direct participation by the trainer in the form of manipulation and control of other road users (drivers or pedestrians) in the road scene. At present there are very few systems that allow the trainer direct control of other vehicles in the road scene via a separate instructor station.

This benchmarking review has been limited by the number of respondents and the comprehensiveness of the information they were willing to supply. As such it can only be regarded as a partial survey of all the systems that are currently being used to varying degrees for novice licence acquisition and for continuing professional development training. However the range of multi media systems and driving simulators reviewed has been of sufficient size for clear trends to be determined.

It is of course quite understandable that system suppliers can be unwilling to disclose performance data to third parties, and often giving precise details of costs is difficult as pricing will be heavily dependent on factors additional to the main simulator hardware. That said, it was also notable that very few simulators have undergone a rigorous and transparent validation process, and it can be difficult for purchasers to understand in advance the level of realism of the driving experience to be derived from the various configurations available.

The training experience is a function of the characteristics of the trainee, the trainer, and the training delivery system, and the dynamics of the interaction between them. As such, although the content of the trainer function is likely to change in the future as synthetic training becomes more widely adopted, the importance of the trainer as facilitator, mentor and confidant of the trainee will continue, and be particularly important for those trainees who might not be at ease with the technologies involved.

Although the information available for this review was only partial, it shows that benchmarking and classifying in a coherent manner is possible. There appears to be a thriving community in Europe of users and suppliers of multimedia systems and driving simulators, and it is hoped that future developments will lead to continued improvements in training and therefore to the raising of standards for safe and fuel efficient driving.

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9 APPENDIX A TRAIN-ALL Operational GLOSSARY

9.1 Simulation

A simulation is an imitation of some real thing, state of affairs, or process. The act of simulating something generally entails representing certain key characteristics or behaviours of a selected physical or abstract system. A simulation does not necessarily need to incorporate all of the attributes and functions of the real system, but will attempt to provide a meaningful representation of those of immediate interest.

Physical simulation refers to simulation in which physical objects are substituted for the real thing. These physical objects are often chosen because they are smaller or cheaper than the actual object or system.

Interactive simulation is a special kind of physical simulation, often referred to as a human-in-the-loop simulation, in which physical simulations include human operators, such as in a flight simulator or a driving simulator. In practice, modern driving simulators tend to incorporate physical simulations of the vehicle cab and controls and a virtual or synthetic representation of the traffic environment via images presented on some form of display device.

According to Carr (1995), simulation can be distinguished from Virtual Reality in that simulation tries to imitate reality, whereas virtual reality does not necessarily do so, though both are creating a synthetic environment. Often the terms simulator training and synthetic training are used interchangeably in current literature. Using strict definitions, synthetic training could refer to any training where real systems or processes are substituted by non-operational representations. Simulation then becomes a subset of synthetic training.

Lawson et al. (2002) used the phrase “synthetic experience” (SE) encompassing technologies such as virtual environments, teleoperators, and augmented reality, while not excluding other technologically mediated experiences such as interactive flight simulation or non-interactive viewing of moving visual scenes such as wide-screen movies. The term SE may also be applied to the wearing of optical prisms that alter the visual stimulus. According to Lawson et al., the term SE could finally be applied to simulations that allow people to experience non-terrestrial forces or other feelings of body acceleration.

Based on the above, a distinction is made between “simulator training” and “synthetic training” whereby synthetic training may involve the use of simulators but may also incorporate low-fidelity desktop training systems.

9.2 Virtual Reality (VR) and Virtual Environment (VE)

Although Virtual Environment and Virtual Reality are sometimes used synonymously (e.g., Draper, 1998), the term Virtual Environment is generally used to describe the “world” presented to the user. Blade and Padgett (2002) defined VE as a 3-dimensional data set describing an environment based on real-world or abstract objects and data. Wilson (1999) defined VE as a computer generated 3D model, where a participant can interact intuitively in real time with the environment or objects within it, and to some extent have a feeling of actually ‘being there’ (presence).

Virtual Reality, on the other hand, has been used to refer to the technology that presents the stimuli to a user (or participant) (Nichols, 1999; Wilson, 1999). These stimuli are almost always visual, and may include the facility to provide complementary auditory, tactile or olfactory information.

If a VE is interactive the user will have the potential to change the presentation of any one of these sets of information, either merely by viewing it from a different perspective, or by actually changing its content or nature. It is the elements of user movement autonomy and the potential for interaction (i.e. the user’s presence or actions having an effect on the VE) that distinguishes VEs from other similar three dimensional technologies such as Computer Aided Design (CAD) packages, 3D video or multimedia.

It should be mentioned that this definition is appropriate for completely synthetic environments, but does not fully address the definition of an augmented reality system involving both synthetic and real environments. In augmented reality systems, the synthetic environment is used to augment or 'fill-in' information in the real environment, i.e., additional information is overlaid onto the real environment (e.g., a computer generated terrain display that is overlaid onto the real world through head up or head mounted displays). Therefore, it has been suggested by Kalawsky (1993) to append VR/VE definitions with the notion that: "…Virtual reality can be used to augment the real world and compensate for missing sensory information or to enhance the real world in a way that does not normally exist".

9.3 Configurability

Configurability refers to the extent 1) physical aspects of the cockpit and controls or 2) apparent (virtual) vehicle characteristics such as size, axles, load, and Adaptive Driver Assistance Systems.

9.4 Fidelity

Degree to which a Virtual or Synthetic Environment duplicates the appearance and feel of operational equipment (i.e., physical fidelity) and sensory stimulation (i.e., functional fidelity) of the simulated context (Blade and Padgett, 2002).

9.5 Interactivity

The potential for a VE to react to the participant's movements and behaviours (Nichols, 1999).

9.6 Level of the driving task

The driving task has traditionally been divided into three levels of skills and control: strategic (planning), tactical (manoeuvring) and operational (control) (Michon, 1985). The strategic level includes trip planning and the selection of trip goals and route. On the tactical level, sometimes referred to as the manoeuvring level, the driver negotiates prevailing circumstances. It includes, for example, obstacle avoidance, gap acceptance, overtaking, choice of headway during car-following and speed choice. The operational level relates to lateral and longitudinal control of the vehicle.

As pointed out by Hollnagel et al. (2003), the model proposed by Michon implicitly assumed control to reside on one level only at a time. Furthermore, most models describe the driver separately from the car. Hollnagel et al. argued that for models to be of practical value a model of driving must meet two criteria: (1) allow control to exist on several levels simultaneously, and (2) describe the driver and the car as a joint system, rather than as two separate systems. The first criterion simply reflects the fact that both humans and machines routinely pursue several goals at the same time. A driver may, for instance, be involved in maintaining the lateral position of the car, carrying out an overtake manoeuvre, and keeping a "mental" eye on the fuel level and the expected time of arrival. The second criterion recognises that modern cars contain a number of automated functions that in some conditions can take control of the car, while other functions run in the background and thus exist side-by-side with the driver's actions. The couplings and dependencies among these functions determine how easy it is to control the car, and hence, how well the Joint Driver-Vehicle System (JDVS) performs. .

9.7 Level of immersion / presence

Immersion, whether physical or psychological in nature, is intended to instil a sense of belief that one has left the real world and is now "present" in the virtual environment (VE). This notion of being present in the virtual world has been considered central to Virtual Environment endeavours since its conception (Minsky, 1980). Presence is traditionally thought of as the psychological perception of "being in" or "existing in" the VE in which one is immersed (Heeter, 1992; Sheridan, 1992; Steuer, 1992; Witmer and Singer, 1998).

The more immersive a VE experience, often the greater the sense of being part of the experience. There are a number of different types of visual representation (VR) systems allowing for different levels of immersion. A system that presents the visual representation of the Virtual Environment via a conventional computer monitor is a Desktop VR system. Other types of VR systems include HMD VR systems, where the user views the VE on an HMD, and other types of physically or perceptually immersive systems, such as projection or CAVE systems. A desktop VR system is traditionally considered to be “non-immersive”; however, although the user is not physically enveloped in the environment, they may still become psychologically involved in the experience. Therefore a distinction can be made between physical and psychological immersion.

It has been suggested that a sense of presence contributes to the effectiveness of learning, comprehension and insight, performance and transfer of training for users of VEs (e.g. Sheridan, 1992; Held & Durlach, 1992). However, the relationship between presence and performance may be either causal or correlational, and both are likely to be inextricably linked to other factors such as clarity of display, reduction of feedback or sensitivity of input devices (Welch et al., 1996). Even if presence is merely an epiphenomenon of VE technology (Welch et al., 1996) it may well have an effect on user motivation, enjoyment and concentration.

A large number of factors have been suggested to influence presence. These are listed in Table 17.

Table 17: Factors contributing to sense of presence (adapted from Nichols, 1999)

Object Motion Lag	Duration of exposure
Temporal distortions	Ergonomics of gear
Spatial distortions	Realism
Intersensory distortions	Vection
Resolution	System response time
Unimodal distortions	Field of view
Navigation mode	Touch and force feedback
Feedback	Head tracking
Stereopsis (binocular depth cues)	Visual display resolution
Human actors	Virtual personal risk
Colour	Interaction
Scene update rate	Object detail
Spatial frequency	Meaningfulness of experience
Number of polygons in visual field	

9.8 Mission (full, part-task)

Full-mission relates to performing a training program with the most complete simulation possible. The concept of a part-task training is to assess a performance measure in response to a specific task or function. This type of training isolates a single critical function for evaluation in terms of driver behaviour.. However, what part-task simulation may gain in training control it lacks in external validity, i.e., accurate representation of the real world. The fidelity requirements for part-task simulation studies cannot be determined in general. The requirements must be determined on a case-by-case basis depending on the objectives of the training or research.

9.9 Motion rendering

While visual perception is dominant in most driving tasks, vestibular perception plays an important role in vehicle control. Cars can move vigorously, and may exhibit large linear accelerations while accelerating, braking and in curves. Several studies have indicated that vestibular cues have a role in steering, speed control, and braking behaviour (Alm, 1995; Reymond et al., 2001; Wierwille et al., 1983). Motion cueing also prevents subjects from reaching too high and unrealistic decelerations, which are observed in a static simulator (Siegler et al., 2001).

Motion cueing can be obtained thanks to a movement platform which is controlled by a set of electromechanical linear actuators. The fidelity of the motion base ranges from relatively simple 3 degrees of freedom (pitch, roll, heave) motion platforms to more sophisticated hexapod motion platforms generating linear accelerations in the longitudinal, lateral and vertical direction of the vehicle, as well as roll, pitch and yaw angular accelerations. Since hexapod motion platforms do not allow for large linear accelerations to be simulated accurately, several high-end driving simulators rely on large X, Y, X/Y or rotatory motion platforms which allow these cues to be provided to some extent. However, even with these large motion platforms and highly accurate vehicle model, vestibular cues cannot be correctly presented to the driver. This not only holds for driving in extreme conditions, but is a fundamental problem in everyday 90 deg turns as well. Furthermore, inappropriate motion rendering can degrade the driving impression and contribute to simulator sickness (Kennedy et al., 1990).

9.10 Realism of control input / feedback

In the virtual environment of a driving simulator, drivers control vehicle position via inputs in the steering wheel. Ideally, the simulator's steering system should be capable of instructing the driver about the amount of steering correction to apply and of transmitting driver's steering inputs to the vehicle dynamics program during simulation. Since steering is the main control device available to the driver in a driving simulator, driver's performance greatly depends on the quality of the steering torque feedback. Previous literature has extensively reported the importance of the response of steering feedback systems on driver steering activity in driving simulators (Espié et al. 2003; Godthelp, 1985; Takao et al., 1991; Liu and Chang, 1995; Howe et al., 1997; Takehiko et al., 1999; Chen and Ulsoy, 2002). Realism of control input further refers to force feedback on brake, clutch, gear shift, and accelerator pedals and the control of x and y position.

9.11 Realism of traffic events

Traffic is all around us, in large numbers and may occur in complex situations. To be acceptable, computer generated traffic requires accurate reproduction of driving behaviour at the control, the manoeuvring and the strategic level. This implies that each simulated car has its own vehicle model, perception and control model, and decision logic. There are many different traffic models currently in use. Some merely present a car moving over a track, with hardly any interaction. Others are fully interactive and scriptable, and can handle complex situations on multi-lane intersections and roundabouts. Increased realism of traffic has been shown to increase the level of immersion or presence in simulator scenarios and increase behavioural validity in that users are likely to drive in a more realistic and representative manner (Wright et al., 2006). As pointed out by Duraz and Espié (2005), to acquire knowledge and skills concerning mastery of traffic situations, the traffic model is an essential component able to produce a realistic traffic environment.

9.12 Replication of vehicle characteristics

Replication of vehicle characteristics, or physical simulator validity, refers to the degree to which the simulator dynamics and visual system reproduce the vehicle being simulated (Jamson, 1999). Heydinger et al. (1990) define validation as "within some specified operating range of the vehicle, a simulation's predictions of a vehicle's responses agree with the actual measured vehicle's responses to within some specified level of accuracy".

9.13 Simulator sickness

Simulator sickness refers to the condition where users suffer physiological discomfort in the simulator, but not while driving the same manoeuvres in the actual vehicle (Kennedy et al., 1989).

Simulator sickness was initially documented by Havron and Butler in 1957 in a helicopter trainer. It is similar to motion sickness, but can occur without actual motion on behalf of the subject. The most common signs and symptoms resemble those of motion sickness: general discomfort, sweating, headache, disorientation, drowsiness, stomach awareness, nausea, pallor, and dizziness.

The most widely accepted explanation for simulator sickness is sensory conflict due to an unexpected incongruence between the input provided by different sensory systems involved in the computation of self-motion (i.e., visual, vestibular, somatosensory modalities) (Reason & Brand, 1975). For instance, in driving simulators or wide screen cinemas, moving visual scenes ("optic flow") can lead to the feeling that the body is moving ("vection"). This information is different to that provided by the vestibular system and somatosensors, which report that the body is stationary.

Simulator sickness limits the usability and acceptability of simulators (Kennedy et al., 1990). Decreased use may result from users who have experienced symptoms and are unwilling to repeat the experience. Training may be compromised in one of two ways: symptoms in the simulator may distract the user during the simulator session thus interfering with the training process. Secondly, users may adopt behaviours to avoid symptoms in the simulator, which if transferred to the actual vehicle, may be detrimental (negative transfer). Ground safety in terms of exiting the simulator or driving away from the site may be jeopardised by after-effects from the simulator such as postural disequilibrium (ataxia) and flashbacks.

Main factors determining the level of simulator sickness include the field of view, exposure duration, transport lag, visual-vestibular incongruence, and kinematics (Kennedy et al., 1990).

9.14 Sound / vibration

Spatialised sound generation replicating both vehicle and traffic sounds, and vibrations transmitted to the vehicle cabin can significantly enhance the overall realism and validity of a driving simulator.

Wind and engine noise contribute to fatigue in drivers who have logged many hours. Sirens and horns grab their attention away from the task at hand. Traffic noise can affect a driver's state of being and decision-making. Tires squealing are indicators that the vehicle is being pushed towards its handling limits. Several studies have shown that the presence of speed-related sound (e.g., engine noise) increases simulator validity by improving speed perception (McLane & Wierwille, 1975; Panerai et al., 2001) and producing braking profiles closer to real world braking (Pinto et al., 2004). Recently, Riecke et al. (2005) have shown that adding spatialised 3D-sound that moves concordantly with a visual self-motion simulation does not only increase overall presence, but also improves the self-motion sensation itself.

Representation of high frequency motion associated with pavement slab joints, curbs, potholes, and wind buffeting, can be accomplished by the incorporation of a vibrating platform which adds to the realism of the simulation. With regard to flight simulation, Brown (1975) showed that the addition of physical vibration uncorrelated with visual scene motion increased the perceived realism.

9.15 Transfer effectiveness

It is possible to evaluate training effectiveness based on the notion of transfer of training. Transfer of training is the extent to which the simulation system prepares individuals for real world performance (Morrison & Hammon, 2000). A general transfer of training paradigm is the one commonly used in flight simulation, where a trainee is instructed in a flight simulator for a predetermined number of sessions, and then allowed to operate an actual aircraft under the guidance of an experienced pilot. The experienced pilot assesses the performance of the trainee and determines a positive or negative transfer of training (Martin, 1981).

Evaluating the extent to which training with a simulator transfers to the actual task can be measured using a Transfer Effectiveness Evaluation (TEE). Most TEE's involve both a learning experiment and a transfer experiment. Learning experiments are evaluations that quantify the amount of learning resulting from simulation training. The simplest way to evaluate the amount of learning that has taken place is to measure performance prior to training and compare it with performance measures after training has taken place (Morrison & Hammon, op.cit. Parkes & Reed, 2005.). However, a TEE is not complete without the addition of a transfer experiment, which seeks to measure how effectively the training is transferred to the operational equipment. A transfer percentage is then calculated. While learning experiments only evaluate the training effectiveness in the experimental conditions in which they are conducted, transfer experiments attempt to measure performance in real world conditions.

In general, transfer experiments provide more convincing evidence that the simulation system has prepared individuals for a real world scenario. However, some researchers believe that a TEE alone is not sufficient to measure whether transfer of training has actually occurred. Some believe that a transfer percentage does not measure the efficiency for which skills are learned. Therefore, a Cumulative Transfer of Effectiveness Ratio (CTER) can be employed to measure the average number of trials needed to reach standard proficiency on the operational equipment. A CTER of 1.0 indicates that the simulator is just as efficient as training on actual operational equipment, while values above and below 1.0 indicates that the simulator is more or less efficient than the equipment (Morrison & Hammon, op.cit;).

9.16 Vision

Driving is a visually dominant task (Hills 1980), and presenting visual information is an important issue in driving simulators. Visual cues are provided by an image generator (IG), which computes in real-time the textured images of the simulated scenes. Generally, these are projected on a curved screen or one or more flat screens. Alternatively, some simulators use head-mounted displays (HMD). Such configurations usually provide stereoscopic viewing and head movement tracking. However, the field of view is generally limited. It has been found that for correct speed perception, a horizontal field of view of at least 120 deg is needed (Jamson, 2000).

Image quality (in terms of contrast and resolution) will predominantly affect distance and size perception of far objects (Ross 1975), and acuity-mediated tasks such as performing a lane change (e.g. Leibowitz and Owens 1977, Higgins et al. 1998). Lowering the spatial resolution will not affect components of the driving task that are related to peripheral vision, such as lateral control and navigating. On the other hand, lowering the image update rate will predominantly affect peripheral vision and related tasks such as speed estimation and braking.

Previous research has further indicated the importance of image refresh rate and time delay (i.e., the time elapsed between a movement initiated by the driver and the restitution of the corresponding visuals) on driver's performance (Hogema, 1997; Sudarsan et al. 1997). Refresh rates of 60 Hz and higher are usually considered adequate whereas time delays up to 50 ms are acceptable for conventional driving simulators (Dagdelen et al, 2002).

9.17 Cost

Simulation costs are heavily dependent upon the level of fidelity. Driving simulators can be classified as low, medium, and high-cost simulators according to their acquisition cost. This classification is sometimes also referred to as low-level, mid-level, and high-level (Weir and Clark, 1995). Low-level simulators typically consist of a PC or graphics work station, a monitor, and a simple cab with controls. Mid-level simulators include advanced imaging techniques, a large projection screen, a realistic cab, and possibly a simple motion base. High-level simulators typically provide close to a 360-degree field of view and an extensive moving base.

Additional costs include operations and maintenance (O&M) costs that are mostly attributed to database and scenario creating tools upgrades and updates as well as training.

9.18 Cost benefit

A cost-effective simulation could be described as a simulation which fulfils the purpose for which it was designed at a lower expense – both financial and otherwise – than performing the equivalent task in the real world (Pongracic et al., 2005). However, it should be noted that cost-effectiveness can have different meanings in the different areas of simulation, e.g., research or training. The criteria which make a research simulator cost-effective are not necessarily the same as those which make a training simulator cost-effective. Perhaps it is more cost-effective for a research simulator to be reconfigurable, but this would not necessarily be the case for a truck training simulator. The first factor which needs to be determined is what the simulation will be used for. Then, in the context of that criterion, appropriate measures can be constructed.

Cost-effective does not necessarily mean low cost. First of all the use of the simulator has to be effective - it has to achieve its training or research objective. To be cost-effective this should be done at a lower cost compared with using the actual equipment. Lyon (1996) pointed out the following: Low cost simulators can be cost-effective (i) if the alternative is no simulator; (ii) when enough of the training system requirements can be met; or (iii) by augmenting a full mission simulator. High cost simulators can be cost effective when (i) a high percentage of training tasks can be effectively done in simulator at lower cost than in actual vehicle; (ii) a more expensive full simulator provides more complete training than several low-cost simulators; or (iii) a low-cost simulator cannot provide adequate training.

The most commonly used measure of training effectiveness in the literature is the CTER (see also “Transfer effectiveness”). This relates the time saved on the transfer task relative to time spent on training (Westra and Lintern, 1994). CTER values greater than, equal to, and less than one indicate the training task led to positive, none, or negative transfer respectively. A simulator can be said to be cost-effective when it provides a CTER greater than one for an acceptable cost. Su (1984) pointed out that there may be flaws in using CTER as a measure of effectiveness however. To measure a CTER, a control group (one trained only on the actual equipment) is required, but for studies where the equipment in not yet operational, or extremely complex, this cannot be measured.

10 APPENDIX B Simulator technical specifications

No	Manufacturer	Product name	Year			Band
1	GSC Grupo de Simulacion de Conduccion	AutoSim	2001	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Variety of other road users & interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios: Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y N N N N L L L N N	B
2	FOERST	Smart Simulator	2007	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios: Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y Y Y N Y Y M M N N	C
3	Rheinmetall Defence Electronics	Emergency Driving Simulator	2001	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios:	Y Y Y Y Y H M H	D

No	Manufacturer	Product name	Year			Band
				Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y N	
4	Green Dino	Dutch Driving Simulator	2007	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios: Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y Y Y Y N M M H N N	C
5	WIVW GmbH	Training and Research driving Simulator	2000	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios: Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y Y Y Y Y H M H Y Y	D
6	CRF Virtual Reality	CRF Advanced Driving Simulator	2002	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios:	Y N N Y Y L L N/A	B

No	Manufacturer	Product name	Year			Band
				Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y N	
7	FOERST	Fahrsimulator F10PF	2002	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios: Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y N Y Y Y M M M N Y	C
8	Oryx Simulation	Wheel loader, digger machine, crane	2005	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios: Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y Y Y Y Y L L M N N	B
9	Thales	TRUST 3000	2006	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios:	Y Y Y Y Y M H H	D

No	Manufacturer	Product name	Year			Band
				Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y Y	
10	Thales	TRUST 5000	2005	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios: Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y Y Y Y Y M H H Y Y	D
11	Thales	TRUST 800	2000	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios: Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y Y Y Y Y M H H Y Y	D
12	DriveSafety	DS 600	2006	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios:	Y Y Y Y Y M H H	D

No	Manufacturer	Product name	Year			Band
				Change of underlying vehicle model possible: Addition of driver assistance systems possible:	N Y	
13	Krauss Maffei Wegmann	Mobile Simulator Safety Training	2006	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios: Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y Y Y Y Y N/A N/A N/A N N	C Higher banding may be possible; available information not sufficient
14	System technology Incorporated	STIsim 400	2003	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios: Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y Y Y Y N N/A N/A N/A N/A N/A	B Higher banding may be possible; available information not sufficient
15	MPRI (L3COM)	TranSim VS Driver Training Simulator	2006	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios:	Y N N Y N N/A M N/A	B Higher banding may be possible; available information not sufficient

No	Manufacturer	Product name	Year			Band
				Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y N/A	
16	Doron Precision System	460 Truck		Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios: Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y N Y Y N N/A L N/A Y Y	B Higher banding may be possible; available information not sufficient
17	Lockheed Martin	Truck Driver Trainer	2001	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios: Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y Y Y N/A Y N/A M H Y N	C
18	Faros	EF-X		Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios:	Y N Y Y N N/A L L	B

No	Manufacturer	Product name	Year			Band
				Change of underlying vehicle model possible: Addition of driver assistance systems possible:	N N	
19	Honda	Honda Driving Simulator	2001	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios: Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y Y Y Y Y L M H N N	C
20	Drive Square LLC	Portable in-vehicle driving simulator	2006	Provision of realistic car controls (pedals, gearshift, steering wheel): Provision of realistic vehicle cab: Rear or side mirror views: Multi-channel visual system: Provision of motion system: Degree of interactivity: Sophistication of simulated road environment: Training of complex manoeuvring scenarios: Change of underlying vehicle model possible: Addition of driver assistance systems possible:	Y Y Y N N H M H Y N	C

11 APPENDIX C Questionnaires used in surveys

11.1 Questionnaire template for existing tools and technologies for computer-based driver training

To whom it may concern,

We, the Transport Research Laboratory (TRL), an independent research company, currently work as part of a consortium of renowned European partners on the EU project TRAIN-ALL. The project aims to develop a computer-based training system for different land-based driver cohorts, which integrates multimedia tools, driving simulation, virtual reality simulation and on-board vehicle sensors. As a result of the project activities new simulation tools as well as guidelines, standards, certification and accreditation procedures will be developed for motorcycle riders, car drivers (novice and emergency drivers) and truck drivers.

To inform the development of simulators and multimedia tools at pan-European level, we want to identify tools currently used to derive and share good practice recommendations.

We have developed a questionnaire on multimedia tools and driving simulators that are currently used for the training or assessment of various driver cohorts. If you use a multimedia tool or driving simulator in your training process, please take the time to complete the questionnaire and help us with our research.

The questionnaire covers multimedia tools in the first section and driving simulators in the second section. If you have access or use more than one training tool, please complete one questionnaire per tool described. If the requested information on the tools used is not available to you, please leave the questionnaire item blank.

Please return the completed questionnaire and email or post it back to

Britta Lang
Transport Research Laboratory (TRL)
Nine Mile Ride
Wokingham
Berkshire, RG40 3GA
UK
E-mail: blang@trl. co.uk

Thank you very much for your help with our research!

11.2 Contact information for the organisation that answers this questionnaire

Country: ____

Name of the authority/organisation: ____

City/local area: ____

Contact phone: ____

Contact E-mail: ____

Please note:
If you have more than one multimedia tool or simulator please complete one questionnaire for each tool and for each simulator you wish to describe. Thank you.

11.3 Questions on the multimedia tool used

11.3.1 Background information

(1) Name of manufacturer/provider: ______________________________________

(2) Product name: ____

(3) Version: ____

(4) Year: ____

(5) Product price *(please specify currency)*: ___________________________ € / £ / $

(6) Vehicle type the multimedia training is aimed at *(please tick all that apply)*

- ☐1 Car
- ☐2 Motorcycle
- ☐3 Bus / coach
- ☐4 Truck
- ☐5 Emergency vehicle
- ☐6 Other: ________________________________

(7) Number of trainees that can be taught at the same time: ____________________

(8) Training target group (please tick all that apply)

- ☐1 Novice drivers
- ☐2 Experienced drivers
- ☐3 Driving instructors

☐4 Elderly drivers
☐5 Drivers with disabilities

(9) Focus of the multimedia driver training *(please tick all that apply)*

☐1 Basic control and manoeuvring
☐2 Mastery of traffic situations
☐3 Strategic/ trip-related driving tasks
☐4 Influence of general goals and motives in life on driving
☐5 Driver assessment
☐6 Other: ________________________________

(10) Format of the multimedia training *(please tick the appropriate box)*

☐1 Video
☐2 CD-ROM
☐3 DVD
☐4 Floppy disc
☐5 Simulator
☐6 Other: ________________________________

(11) System requirements *(please tick all that apply)*

☐1 Personal Computer / Mac
☐2 Video player and screen
☐3 MPEG card or AVI
☐4 Soundcard
☐5 Internal memory
☐6 Other: ________________________________

(12) Software platform

☐1 Windows 95 or higher
☐2 Other: ________________________________

(13) Browser compatibility (only if multimedia tool is interactive website)

☐1 Internet Explorer
☐2 Netscape Navigator
☐3 Mozilla Firefox

☐4 Opera

☐5 Other: ____________________________________

(14) Mode of use

☐1 Use by the trainee alone at home

☐2 Demonstration tool for the instructor during the lesson (no student involvement

☐3 Use by the trainee at the driving school

☐4 Other: ____________________________________

(15) Input devices

☐1 Computer mouse

☐2 Keyboard

☐3 Other: ____________________________________

(16) Actions required from multimedia tool user *(please tick all that apply)*

☐1 Observe

☐2 Predict what will happen next

☐3 Answer questions

☐4 Stop the scene

☐5 Make a driving decision

☐6 Name hazards

☐7 Check traffic signs

☐8 Other: ____________________________________

(17) Output modality *(please tick all that apply)*

☐1 Video

☐2 Animation

☐3 Photos

☐4 Text

☐5 Speech

☐6 Other: ____________________________________

(18) Feedback *(please tick all that apply)*

☐1 Showing the right answer

☐2 Showing the right choice

☐3 Showing consequences (what would have happened)

☐4 Showing existing hazards

☐5 Trainee's score

☐6 Other: ____________________________________

11.3.2 Evaluation of the multimedia tool

(1) Have any evaluation studies been carried out on the multimedia tool? ☐1 Yes ☐2 No ☐3 Don't know

If yes, please describe the study design and specify the sample sizes involved.

(2) Are any evaluation results available in the public domain? ☐1 Yes ☐2 No ☐3 Don't know

If yes, please specify where the evaluation results are available:

11.3.3 Experience with the multimedia tool

(1) How has the use of the multimedia tool you have described in this questionnaire affected the efficiency of the driver training in your opinion?

Please use this space to provide a short answer.

(2) Have you ever experienced any problems in training with the multimedia tool you have described in this questionnaire?

Please use this space to provide a short answer.

(3) Do you think that the multimedia tool you have described in this questionnaire could be improved in any way?

Please use this space to provide a short answer.

11.3.4 Any other items

Please use this space to provide comments.

End of questionnaire on multimedia tool

11.4 Questions on the simulator used

11.4.1 Background information

(1) Name of manufacturer/provider: ________________________________

(2) Product name: ________________________________

(3) Version: ________________________________

(4) Year: ________________________________

(5) Product price *(please specify currency)*: ______________________ € / £ / $

(6) Please specify what type of driving simulator you are describing in this questionnaire

- ☐1 Driving simulator
- ☐2 AR/ VR simulator
- ☐3 Ambient simulator
- ☐4 Mobile unit

(7) What is the ownership status of the simulator? *(please tick appropriate box)*

- ☐1 Leased
- ☐2 Hire (payment per time of use)
- ☐3 Hire (payment per client)
- ☐4 Owned outright
- ☐5 Other: ________________________________

(8) Simulated training ego-vehicle type *(please tick all that apply)*

- ☐1 Car
- ☐2 Motorcycle

☐3 Bus / coach

☐4 Truck

☐5 Emergency vehicle

☐6 Other: ______________________________

(9) Number of trainees that can be taught at the same time: ____________

(10) Training target group *(please tick all that apply)*

☐1 Novice drivers

☐2 Experienced drivers

☐3 Driving instructors

☐4 Elderly drivers

☐5 Drivers with disabilities

(11) Focus of the simulator-based driver training *(please tick all that apply)*

☐1 Basic control and manoeuvring

☐2 Mastery of traffic situations

☐3 Strategic/ trip-related driving tasks

☐4 Influence of general goals and motives in life on driving

☐5 Driver assessment

☐6 Other______________________________

11.4.2 Simulator characteristics

(1) Which cockpit elements are included? *(Please tick all that apply)*

☐1 Steering wheel, gear, clutch, brake & accelerator pedals

☐2 Instrument panels

☐3 Correctly sized cab

☐3 Mirrors

☐4 Control aids (ABS, ACC, etc.)

☐5 Other: ______________________________

Visual system characteristics

Is the visual system (please tick all that apply)

(2)

- ☐1 Computer-generated
- ☐2 Video-based
- ☐3 Other: ____

If the visual system is based on computer-generated image projection

(3)

Total number of channels: ______________________
Available images: ____________________________
Field of View: _______________________________
Visibility range: ______________________________
Update and display rate: ______________________
Computation and display resolution: ___________
Triangles throughput: _________________________
Visual transport delay: _______________________
Relocation time within the database: ___________
Host link: __________________________________

(4)

Which of the following weather/ light conditions can be simulated?
(Please tick all that apply)

- ☐1 Rain / Storm
- ☐2 Snow
- ☐3 Ice
- ☐4 Fog / mist
- ☐5 Night
- ☐6 Cloud layer
- ☐7 Wind: ________________
- ☐8 Brightness: ___________
- ☐7 Other: _______________

(5)

Which of the following weather/ light conditions can be simulated?
(Please tick all that apply)

- ☐1 (Dipped) Headlights
- ☐2 Foglight
- ☐3 Hazard lights / Parking lights
- ☐4 Brake lights / reversing light
- ☐5 Tail lights / Sidelights
- ☐6 Anti-glare rear-view mirror
- ☐7 Others: ______________

If possible, please provide the following information on picture quality:

(6) Translucency: _______________________________

Anti-aliasing: ______________________________
Colours number: ___________________________
Occultation method: ________________________
Shading: ________________________________

(7) Are rear mirrors provided? ☐1 Yes ☐2 No

(8) Are side mirrors provided? ☐1 Yes ☐2 No

Motion system characteristics

(9) Is a motion system included? ☐1 Yes ☐2 No

(10) What system weight is applied on the motion: ____________________________

(11) If this data is available, please specify the performance characteristics of the motion system:

Degree of Freedom		Range	Speed	Acceleration
Pitching	θ	________	________	________
Rolling	ρ	________	________	________
Yawning	ϕ	________	________	________
X shifting	X	________	________	________
Y shifting	Y	________	________	________
Z shifting	Z	________	________	________

(12) Database characteristics *(please tick the appropriate box)*

☐1 Fixed database (road network cannot easily be modified)
☐2 Flexible database

(13) If the database is fixed, please specify the size of the database (km road network): _____________ km

(14) Simulated road environments *(please tick all that apply)*

☐1 Motorway / Highways
☐2 Rural roads (country and village environment)
☐3 Urban roads
☐4 Dual carriageway
☐5 industrial environment
☐6 Other: ______________________________________

(15) Can road friction be varied in the simulator? ☐1 Yes ☐2 No

(16) Simulated road features *(please tick all that apply)*

☐1 Tunnel
☐2 Bridges

- ☐3 Serpentines
- ☐4 Hills
- ☐5 Service stations
- ☐6 Depot areas
- ☐7 Car parks
- ☐8 Road works
- ☐9 Railroad crossing
- ☐11 Other: ____________________

(17) Simulated dynamic ambient road users *(please tick all that apply)*

- ☐1 Cars
- ☐2 Motorcycles, bicycles
- ☐3 Trucks, buses
- ☐4 Pedestrians
- ☐5 Animals
- ☐6 Emergency vehicles (fire fighter, police, ambulance)
- ☐7 Other characters: ____________________

(18) Maximum number of dynamic ambient road users that can be simulated in the visual range of the trainee driver: ____________________

(19) Can traffic densities be modified? ☐1 Yes ☐2 No

(20) Can behaviour profiles of ambient road users be modified? ☐1 Yes ☐2 No

If yes, please describe available behaviour profiles (e.g. aggressive, law-abiding etc.):

____

Is multi-user training possible (e.g. two trainees controlling different ego-vehicles in a shared road environment)? ☐1 Yes ☐2 No

Audio system characteristics

(21) Is engine noise simulated? ☐1 Yes ☐2 No

(22) Is tyre noise simulated? ☐1 Yes ☐2 No

(23) Is wind noise simulated? ☐1 Yes ☐2 No

(24) Is other noise simulated? ☐1 Yes ☐2 No

If yes, please specify: ____________________

(25) Is the sound-system stereophonic? ☐1 Yes ☐2 No

Communication facilities

(26) Is instructor – student communication included? ☐1 Yes ☐2 No

(27) Is student – co-driver communication included? ☐1 Yes ☐2 No

Simulated vehicle characteristics *(please tick all that apply in each row)*

(28) ☐1 Manual gearbox ☐2 Automatic transmission

(29) ☐1 Front wheel drive ☐2 Rear wheel drive ☐3 Four wheel drive

Are the following modifications possible? *(please tick appropriate box in each row)*

(30)	Simulation of trailer?	☐1 Yes	☐2 No	☐3 N/a
(31)	Simulation of different loads?	☐1 Yes	☐2 No	☐3 N/a
(32)	Can the underlying vehicle model be changed (e.g. change from bus to truck)?	☐1 Yes	☐2 No	☐3 N/a
(33)	Simulation of vehicle malfunctions (e.g. tyre blow-out or roll-over)	☐1 Yes	☐2 No	☐3 N/a
(34)	Are driver assistance systems included?	☐1 Yes	☐2 No	

(35) If yes, please tick all systems that can be simulated:

☐1 Power steering
☐2 Anti-lock braking system (ABS)
☐3 Adaptive Cruise Control (ACC)
☐4 Heading Control (HC)
☐5 Electronic Stability Programme (ESP)
☐6 Other: ______________________________

11.4.2.1 Feedback facilities

(1) Does the simulator have a replay function? ☐1 Yes ☐2 No

(2) Can drive replays be watched *(please tick all that apply)*

☐1 At the simulator
☐2 At a separate satellite station?

(3) If a satellite replay station is used are drive replays exported to the replay station

☐1 Automatically
☐2 Manually by the instructor
☐3 Other: ______________________________

(4) Can the drive replays be watched from *(please tick all that apply)*

☐1 The driver's view
☐2 From bird's eye view
☐3 From other road users' view
☐4 Other: ______________________________

(5) Is the assessment of the trainee carried out

☐1 Solely by the instructor
☐2 Solely by the simulator
☐3 By the instructor and the simulator
☐4 Other : ______________________________

11.4.2.2 Training scenarios

(1) Is there a maximum number of training scenarios? ☐1 Yes ☐2 No

(2) Are training scenarios activated by
- ☐1 Hitting a geographic marker
- ☐2 Hitting a time criterion
- ☐3 Other: ______________________________

(3) Are there any training scenarios that would be desirable but are not supported by the simulator? ☐1 Yes ☐2 No

If yes, please specify:

11.4.3 Training goals

The following matrix aims at identifying what training goals can be covered in the driver training with the specific simulator you are using. Please go through the list of the training goals that relate to the four levels of the GADGET matrix and tick all training goals that are currently covered in the specific training the simulator is currently used for.

GADGET level of training goal	*No*	*Description*	*Simulator*
Vehicle control goals	1	Start up and stop	☐a1
	2	Knowing how to hold and turn the wheel	☐a2
	3	Knowing how to use the different mirrors	☐a3
	4	Shifting gears	☐a4
	5	Accelerating/decelerating	☐a5
	6	Steering/ lane following	☐a6
	7	Moving along respecting road marks	☐a7
	8	Braking/stopping	☐a8
	9	Use of new car control aids	☐a9
Manoeuvring training goals	10	Driving in country and village environment	☐b1
	11	Driving in industrial environment	☐b2
	12	Driving in urban traffic	☐b3
	13	Driving on highways	☐b4
	14	Driving on motorways	☐b5
	15	Approach/ exit of motorways	☐b6
	16	Negotiating intersections, junctions and roundabouts	☐b7
	17	Negotiating hills/ slopes and curves	☐b8

GADGET level of training goal	No	Description	Simulator
	18	Negotiating railroad crossing, bridges, tunnels	☐b9
	19	Parking	☐b10
	20	Reversing	☐b11
	21	Turning manoeuvres	☐b12
	22	Following and tailgating (not)	☐b13
	23	Lane changing	☐b14
	24	Overtaking / passing	☐b15
	25	Driving at high speed	☐b16
	26	Reacting to other vehicles	☐b17
	27	Reacting to pedestrians, cyclist (weak actors)	☐b18
	28	Reacting to traffic regulations, traffic signs	☐b19
	29	Reacting to road direction signs	☐b20
	30	Reacting to in-vehicle information systems[17]	☐b21
	31	Visual scanning	☐b22
	32	Hazard perception	☐b23
	33	Driving techniques in critical situation[18]	☐b24
	34	Defensive/ anticipating driving	☐b25
	35	Economic/ environmental friendly driving style	☐b26
	36	Entering/leaving the traffic	☐b27
	37	Skid control	☐b28
	38	Road surface/ obstacles	☐b29
	39	Railroad crossings, bridges, tunnels	☐b30
Strategic training goals	40	Determination of trip goals, route and modal choice	☐c1
	41	Technical / Safety check of the vehicle before start	☐c2
	42	Loading of the trailer	☐c3
	43	Maintenance of the vehicle	☐c4
	44	Safety issues	☐c5
	45	Economic and environmental issues	☐c6
	46	Technical issues related to control / support	☐c7

[17] GPS navigation equipment, etc.
[18] Emergency braking, obstacle avoidance, etc.

GADGET level of training goal	*No*	*Description*	*Simulator*
		system	
	47	Legislative issues related to licensing	☐c8
	48	First aid	☐c9
Training goals for personal life style/ values	49	Relation between age/ gender and driving style	☐d1
	50	Relation between social norms, value, motives and driving style	☐d2
	51	Relation between personality, lifestyle and driving style	☐d3

11.4.4 Evaluation of the simulator

(1) Have any evaluation studies been carried out on the simulator? ☐1 Yes ☐2 No ☐3 Don't know

If yes, please describe the study design and specify the sample sizes involved.

(2) Are any evaluation results available in the public domain? ☐1 Yes ☐2 No ☐3 Don't know

If yes, please specify where the evaluation results are available

(3) Has the sickness rates in simulator trainees been investigated? ☐1 Yes ☐2 No ☐3 Don't know

If yes, please describe what sickness rates have been found.

11.4.5 Experience with the simulator

(1) How has the use of the simulator you have described in this questionnaire affected the efficiency of the driver training in your opinion?

Please use this space to provide a short answer.

(2) Have you ever experienced any problems in training with the simulator you have described in this questionnaire?

Please use this space to provide a short answer.

(3) Do you think that the simulator you have described in this questionnaire could be improved in any way?

Please use this space to provide a short answer.

11.4.6 Any other items

Please use this space to provide comments.

End of questionnaire on driving simulator

11.5 Questions on neurological batteries used

11.5.1 Background information

(1) Name of manufacturer/provider: ______________________________

(2) Product name: ______________________________

(3) Version: ______________________________

(4) Year: ______________________________

(5) Product price *(please specify currency)*: ______________________ €/£/$

(6) Training target group (please tick all that apply)

- ☐1 Novice drivers
- ☐2 Experienced drivers
- ☐3 Driving instructors
- ☐4 Elderly drivers
- ☐5 Drivers with disabilities

(7) Number of physiological tests it can conduct (please tick all that apply)

- ☐1 Executive Control
- ☐2 Active Virtual Field
- ☐3 Alertness
- ☐4 Distractibility
- ☐5 Divided Attention
- ☐6 Flexibility
- ☐7 Go/no go

☐8 Visual Scanning

☐9 Schuhfried

☐4 Wiener Test System

☐5 Other: ______________________________

(8) Format of the multimedia tools supported (please tick the appropriate box)

☐1 Video

☐2 CD-ROM

☐3 DVD

☐4 Floppy disc

☐5 Simulator

☐6 Other: ______________________________

(9) Video formats supported: ______________________________

(10) System requirements (please tick all that apply)

☐1 Personal Computer / Mac

☐2 Video player and screen

☐3 MPEG card or AVI

☐4 Soundcard

☐5 Internal memory

☐6 Other: ______________________________

(11) Software platform

☐1 Windows 95 or higher

☐2 Other: ______________________________

(12) Software with which it was designed: ______________________________

(13) Input devices

☐1 Computer mouse

☐2 Keyboard

☐3 Other: ______________________________

(14) Actions required from multimedia tool user (please tick all that apply)

☐1 Observe

☐2 Predict what will happen next

☐3 Answer questions

☐4 Stop the scene

☐5 Make a driving decision

☐6 Name hazards

☐7 Check traffic signs

☐8 Other: ______________________________

(15) Output modality (please tick all that apply and specify output data)

☐1 Video ______________________________

☐2 Animation ______________________________

☐3 Photos ______________________________

☐4 Text______________________________

☐5 Speech ______________________________

☐6 Other: ______________________________

(16) Feedback (please tick all that apply)

☐1 Showing the right answer

☐2 Showing the right choice

☐3 Showing consequences (what would have happened)

☐4 Showing existing hazards

☐5 Trainee's score

☐6 Other: ______________________________

11.5.2 Evaluation of the neurological batteries

(1) Have any evaluation studies been carried out on the physiological batteries? ☐1 Yes ☐2 No

If yes, please describe the study design and specify the sample sizes involved.

(2) Are any evaluation results available in the public domain? ☐1 Yes ☐2 No

If yes, please specify where the evaluation results are available.

Other Items

Please use this space to provide comments.

End of questionnaire on neurological test batteries