SCOTSIM: An Evaluation Of The Effectiveness Of Two Truck Simulators For Professional Driver Training

by N. Reed, A. M. Parkes, C. Peacock, B. Lang, and L. Rehm

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Executive summary

The SCOTSIM project, funded by the Scottish Road Haulage Modernisation Fund, conducted research into the viability of state-of-the-art driving simulation techniques in training professional truck drivers in advanced skills of fuel efficiency, vehicle sympathy and hazard awareness.

Although several countries in the EU have truck simulators available for licence acquisition and continuing professional development training there was little published knowledge available to inform the Scottish haulage and training industries of the real benefits and commercial opportunities. The need for research and objective data of direct relevance to Scotland had been brought into focus by the recent EU Directive on professional driver training which allows high specification simulators to be used for part of the training and assessment process from 2009 onwards. The SCOTSIM project sought to:

- Procure commission and validate two state-of-the art truck simulators; one to be housed at a fixed location in the Scottish central belt area; and one to be mobile so that it could visit multiple locations in the regions (Oban, Inverness, Aberdeen, Dundee and Dumfries).
- Ensure heavy involvement of stakeholders in discussions of the nature of the training, recruitment of appropriate trainees, and appraisal of simulation as a training delivery mechanism
- Adopt SAFED-style principles in the delivery of training and the assessment of trainees
- Work closely with the simulator technology provider to establish an advanced automatic assessment system that made best use of the simulator capabilities
- Provide 700 trainees with a detailed programme of training exercises, and measure any changes in driving style and performance
- Through this process, establish a training competence that could form the basis of commercial training in Scotland.

Two simulators were commissioned (the TRUST 5000 at Bellshill, and the mobile TRUST 3000), and over 700 drivers were trained in the first main phases of the project. The training was not part of any other programme of classroom or real road instruction. Instead it was offered as a half-day session that included introduction to the simulator process and familiarisation with simulated driving, followed by an initial assessment drive. This was followed by a period of instruction and then a further assessment drive.

Results showed an average improvement between the two assessment drives of:

- time taken to complete the drives reduced by 10.6%,
- reduction in number of gear changes of 20.8%,
- and a reduction in fuel usage of 11.4%.

This showed that better driving style resulted in fuel savings and less wear and tear on the vehicle, but this did not come at the cost of reduced efficiency. It did not take longer for the drivers to complete the routes. Younger drivers with between one and five years experience received the greatest benefit, and were most receptive to the new style of training. Applying statistical confidence limits to the fuel usage figure we obtain a 95% lower bound limit of a 9.71% reduction. This means there is a less than one in twenty chance that if the whole population of drivers that the trainees came from were exposed to the same training that the benefit seen would be less than 9.71%. These results are very encouraging and helps form the basis for cost-benefit and cost effectiveness comparisons.

Using the figure of 11.4% fuel usage improvement the following cost benefit can be derived.

Table 1. Calculation of savings related to decreased fuel consumption due to provision of simulator training for drivers

Parameter	Measure
Average distance travelled (km)	61,380
Current fuel price (£)	0.923
Fuel consumption before simulator training (l/100 km)	35.0
Fuel consumption considering reported 11.4% improvement (l/100 km)	31.4
Fuel used before simulator training (l)	21,483
Fuel used after simulator training (l)	19,034
Annual fuel savings (l)	2,449
Annual cost savings due to decrease in fuel used (£)	2,260
CO_2 savings (tonnes)	7.10

The calculation is based on several simple assumptions about training transfer to real world situations and the maintenance of any effect over time. Such assumptions will need to be verified in the future, but the scale of the potential savings in fuel and emissions appears substantial.

The subjective opinions of the trainees were sought regarding the effectiveness and realism of the simulator training, with overwhelmingly positive results. However significant problems of simulator sickness were associated with the initial configurations of the simulators, and unacceptable numbers of trainees withdrew from the process and failed to complete all stages of the training (24.6%). Considerable effort was spent on improvements to the road database and the performance of the motion system on both simulators in order to reduce the problems. Background data on the attitudes and demographic details of drivers was also examined in order to derive criteria that could be used to exclude those drivers likely to experience problems. The combination of these measures has reduced simulator sickness drop out rate to around 5%, a figure considered as around the industry norm in the rest of Europe.

In addition to the research phase involving over 700 drivers, further work was undertaken to develop four additional training modules to meet the particular needs of the Scottish haulage industry. A series of workshops were held at Bellshill with industry representatives, academics and the Driving Standards Agency to refine and verify module content. These modules focused on: hazard perception, driver attitude, slow speed manoeuvres and emergency manoeuvres. All modules have been completed and are available on both simulators.

All of the project research objectives were met.

1 Introduction

1.1 Background to the project

Simulation is used widely in the aviation industry and with military land vehicles to train both novices and experienced operators. The benefits are well accepted, and for certain applications simulator training is a key and necessary component. Truck drivers need to be highly skilled and can be responsible for very valuable, and at times dangerous, loads, and although they need to operate in a complex and highly dynamic traffic environment, advanced simulator technology for training is not widespread. There appear to be three fundamental reasons for the relatively slow adoption of simulation as a key component of professional truck driver training:

- A lack of documented evidence showing a clear benefit of simulation training over traditional on-road and test track methods
- A concern over the economics of providing high technology facilities and the attendant high costs of entry to the area
- A concern from the drivers that such training will be additional to, rather than replace parts of, any current requirements

There have been few systematic research projects that have attempted to provide objective evidence of benefit derived from synthetic training, though some helpful information has emerged, and a consistent picture is developing. Welles and Holdsworth (2000) refer to hazard perception training with a particular US police force leading to reductions in intersection accidents of around 74%, and overall accident reduction of around 24% in a six-month period following training. Hornung, Rothlisberger, and Stampfli (2001) report success in fuel efficiency (of up to 15%) and 'comfortable driving style' for car drivers undergoing simulator-based training. More recently Dolan, Rupp, Allen, Strayer, and Drews (2003) presented evidence from a fuel management simulation study that tracked 40 truck drivers through a two-hour training programme, and later for a six-month follow up. Drivers were given specific training in the operational and tactical aspects of appropriate gear selection in a medium fidelity simulator. Results indicated an average 2.8% improvement, with over 7% being indicated for those drivers with a poor pre-training record.

The most recent study (Parkes & Reed, 2005) reported the findings of the TruckSim project where simulator training led to real road fuel savings of 15.7%. Each of these studies reinforces the potential of simulators to be effective training tools for truck driver training. However, it is also necessary to understand whether simulation can be a cost effective training delivery mechanism, and whether there are any drawbacks that might influence decisions about widespread introduction.

The Safe And Fuel Efficient Driving (SAFED) standard has emerged as a well-known programme of training for experienced truck drivers. The training is based on real road assessment, and involved trainees completing an initial drive under the observation of an instructor who is able to rate performance on 17 indicators. The trainee then receives tailored instruction that covers any areas of weakness, and performance is then reassessed via another observed real road drive. A composite score is then derived from performance on both assessment drives and a score and feedback can be given to the trainee. In the SCOTSIM programme it was decided to adopt a similar approach. With valuable input from the Driving Standards Agency, VTL of the Netherlands, and Ritchie’s Training Centre in Scotland, a set of training scenarios were developed that would draw out the important principles of safe and fuel efficient driving. Performance in these scenarios could be scored on the same 17 indicators. The intention was not simply to translate SAFED to the simulator, but rather to take it as an example of best practice in real road training and use it as a model to guide the provision of simulator based training.

It was felt important to use the simulators as more than surrogate road vehicles. Simulation falls short of the ability to recreate reality. It is not possible to create visual scenes of the same complexity as in real traffic, nor is it possible in any simulator to create exactly the same ride feel as that of a real vehicle. This can be seen as a weakness, though current state of the art simulators can provide a compelling immersive experience that produces driver behaviour very closely matched to that seen in real vehicles in equivalent scenarios. Though the simulation is a reduced version of reality, the ability to control and repeat the presentation of events and traffic and weather conditions, and to measure with great precision factors such as speed, lane position, distance from other vehicles, and have perfect knowledge of the use of the controls in the vehicle, are strengths that allow a level of analysis far beyond that available within a normal training vehicle. So, though the training lesson might be equivalent in the road vehicle and the simulator, it should be recognised that the delivery can be different. In the simulator, training can be more concentrated and as such take a shorter time, and because measurement can be more accurate, feedback to the driver can be more detailed.

It was decided in this programme to take the 17 SAFED indicators and work closely with the simulator technology provider to explore to what extent the simulators could reliably assess performance through an automated scoring system. The potential benefits of establishing such a system would be to give the trainer detailed and objective information to tailor further training. It could also lead to economies of scale, with one trainer overseeing several simulators simultaneously.

This programme was of an ambitious scale, with the aim to introduce large numbers of Scottish drivers to simulation training. This necessitated close involvement of the Scottish haulage industry at all stages from project inception in order to ensure the training provision was seen of sufficient value and interest to justify active inclusion of drivers for training.

1.2 Objectives

The SCOTSIM project is an initiative funded through the Scottish Road Haulage Modernisation Fund that sought to expand current knowledge through the following objectives:

- Procure, commission, and validate two state-of-the art truck simulators; one to be housed at a fixed location in the Scottish central belt area; and one to be mobile so that it could visit multiple locations in the regions.
- Ensure heavy involvement of stakeholders in discussions of the nature of the training, recruitment of appropriate trainees, and appraisal of simulation as a training delivery mechanism
- Adopt fuel efficient and safe driving principles in the delivery of training and the assessment of trainees
- Work closely with the simulator technology provider to establish an advanced automatic assessment system that made best use of the simulator capabilities
- Provide 700 trainees with a detailed programme of training exercises, and measure any changes in driving style and performance
- Through this process, establish a training competence that could form the basis of commercial training in Scotland.

It must be emphasised that this was a research project that was conducted within the real commercial constraints of the Scottish haulage industry, and within the tight timescales required by the Scottish Executive.

2 Procurement and Recruitment

A key element for the delivery of the project was the procurement of a high fidelity, full mission truck simulation equipment that could be commissioned and delivered within the relatively short project timescales. TRL drew on previous experience gained during the procurement of a similar simulator facility as part of the TruckSim project to develop detailed functional specifications for two high fidelity truck simulators – one fixed and one mobile. The specifications were used as part of a formal Official Journal of the European Communities (OJEC) procurement process to identify technology solutions that represented best value for the project.

Thales were considered by TRL to have the strongest technical solution and to have most clearly tailored their tender to the particular requirements of the SCOTSIM project. They were recommended to the Scottish Executive as the preferred bidder. Given Thales' previous experience and the relatively small amount of new engineering work needed to produce a right-hand-drive variant, their proposal was seen as low risk. They were also the only short-listed supplier building simulators for both fixed locations and for mobile systems. Thales made considerable effort to make appropriate links to leading UK graphics modellers and to Abertay University to ensure a genuine Scottish look and feel to the proposed training exercises.

2.1 Technical specification of SCOTSIM training components

The SCOTSIM project included specification and procurement of a mobile and a fixed simulator. Both simulators were provided by Thales and go under the acronym TRUST (TRUck Simulator for Training). The mobile unit, the TRUST 3000 (T3000), and the fixed unit, the TRUST 5000 (T5000), were derived from the continental left-hand-drive version of the system. The main modifications were made to the truck cab and to the virtual driving environment, the so-called database, to adapt them for UK regulations.

Both simulators are based on the same technology. However, there is one major difference. On the T5000 both the cabin and the visual system are installed on the motion platform (Flying screen concept) whereas on the mobile T3000 simulator the screens of the visual system are mounted on the floor, independent from the motion platform. The T5000 is a development from the T3000 in line with the technical requirements for the SCOTSIM project. The changes allow for more movement of the motion plat form and thus higher acceleration cues to the driver, which can be beneficial for driving on unpaved roads or for emergency manoeuvres.

The main components of the system are the following:

- Driver cab
- Motion platform
- Visual and audio system
- Control and review stations
- Computer system and software
- Trailer of the mobile T3000 simulator

The following sections describe the technical specification of the different system components in more detail.

Figure 2.1 Fixed T5000 simulator

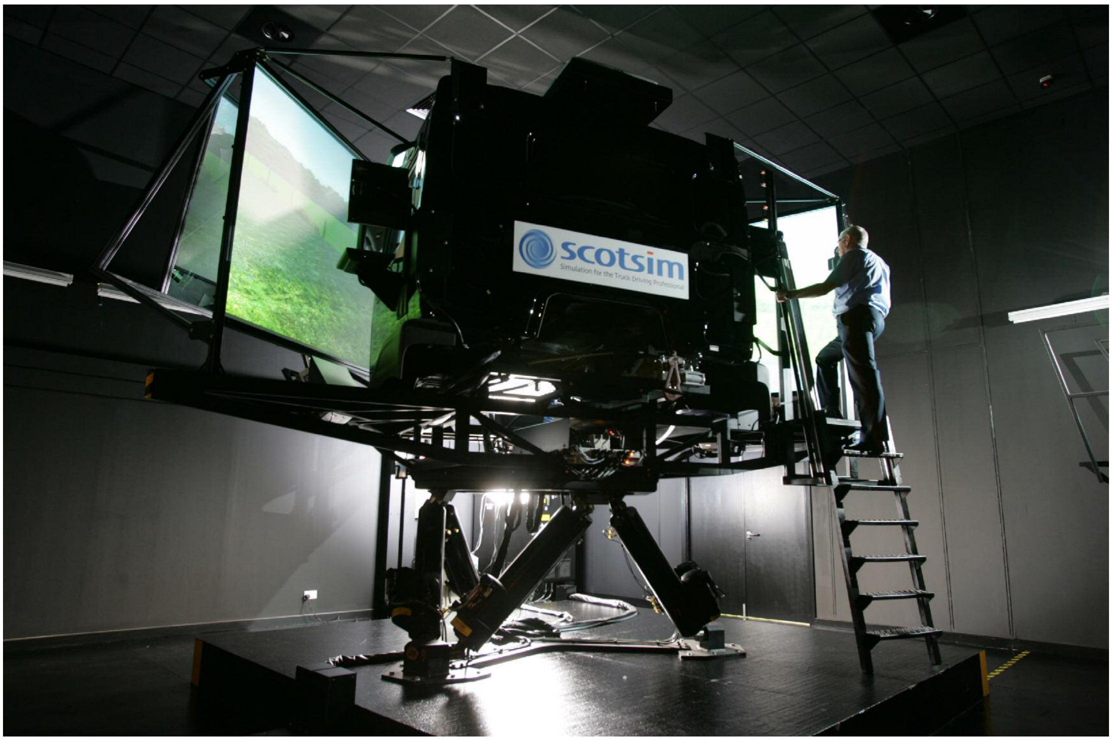


Figure 2.2 Mobile T3000 simulator in training mode

2.1.1 Driver cab

The driver cab on both simulators is the distribution version of Renault Commercial Vehicle's Premium truck cab. The cab has been converted for use in a simulator and all instruments and controls have been interfaced with the simulator's computer system. All the dashboard controls work in the same way as in a real truck. The system also generates force feedback for the controls such as steering wheel, pedals and gear stick.

Figure 2.3 The driver's cab

2.1.2 Motion system

The simulation of the truck's motion and acceleration is created by an electric motion system supplied by American manufacturer Moog. The system offers six degrees of freedom (pitch; roll; yaw; heave; surge; sway).

2.1.2.1 TRUST 3000 motion system

The following table shows the technical characteristics of the motion system used in the TRUST 3000 mobile simulator.

Table 2.2 Characteristics of the TRUST 3000 motion system

Degree of Freedom	Excursion	Acceleration
Pitch	±16°	±500°/s²
Roll	±16°	±500°/s²
Yaw	±16°	±500°/s²
Heave	±0.15m	±5m/s²
Surge	±0.20m	±6m/s²
Sway	±0.20m	±6m/s²

2.1.2.2 *TRUST 5000 motion system*

The motion system of the TRUST 5000 fixed simulator was adapted in order to allow for the screens of the visual system to be mounted onto the motion platform. The system was also supplied by Moog but comes at a higher specification and can carry a payload of more than double that of the motion system used by the TRUST 3000. The following tables show the technical characteristics of the motion system used in the fixed simulator:

Table 2.3 Characteristics of the TRUST 5000 motion system

Degree of Freedom	Excursion	Acceleration
Pitch	±16°	±250°/s²
Roll	±16°	±250°/s²
Yaw	±16°	±250°/s²
Heave	±0.25m	±7m/s²
Surge	±0.30m	±7m/s²
Sway	±0.30m	±7m/s²

2.1.3 Visual and audio system

The visual system uses three video channels to generate the front view with a 180° horizontal forward field of view. An additional three video channels provide images to allow normal use of the rear view and kerb view mirrors.

The images are created by Thales' real time, 3D image generator (IG) system which is also used on a variety of Thales aircraft and helicopter simulators. For the purpose of the SCOTSIM project the standard Thales IG has been improved to the following specification:

- 60 Hz refresh rate
- 1280 × 1024 pixels resolution per channel
- up to 24 sub-pixels anti-aliasing

The three front channels are powered by three Evans & Sutherland *simFUSION* imaging computers. Two Intel processor based PCs with high-end graphics boards control the other channels.

The audio system simulates the following noises:

- Engine
- Aerodynamic and friction noises
- Pneumatic noises of the braking system
- Vehicle noise of other road users
- Indicators

2.1.4 Instructor and review stations

The instructor station is the trainer's workplace. It consists of a visual system with three PCs. The video front channel and the rear-view mirrors are displayed on three TFT flat screens. From here training sessions are controlled by selecting simulation exercises and driving conditions such as time of the day, visibility, weather etc. The trainee vehicle's location and that of other road users' can be monitored in the database on a digital map. The instructor has access to all functions in a Microsoft Windows environment.

The instructor station also allows for an off-line review of training sessions and playback of recorded exercises. In addition to the instructor station the fixed simulator has an independent review station in a separate room. This allows for higher trainee throughput rates as training on the simulator and training review is possible in parallel. The design of the review station is identical to the instructor station. It is linked to the fixed simulator by a high speed data link.

Figure 2.4 TRUST Instructor's station

2.1.5 Computer system and software

In addition to the image generation system the simulator uses two more Intel Pentium based PCs to run the traffic and vehicle software. All computers use Windows Professional 2000 as Operating System and are networked via Ethernet connections. The simulation specific software has been designed and programmed using C, C++, and the OpenGL graphics library. It includes the following components:

- **Traffic Software** – This module is a multi-agent software program that controls the behaviour of all vehicles in the simulation including their speed and route.
- **Vehicle Model** – The vehicle model software calculates vehicle dynamics for a tractor unit, a rigid lorry, and various combinations of articulated vehicle. The model also encompasses various load types.
- **Database** – The virtual driving environment in a simulator is called the database. For the purpose of the SCOTSIM project the existing Thales database has been improved in terms of realism and adapted to provide terrain representative of Scotland and for UK driving regulations. The SCOTSIM database has been developed to allow for creation of a variety of training scenarios including a range of roads, highways, urban situations and manoeuvring areas. It includes approximately 112 square miles of roads.

Figure 2.5 Screenshot of the SCOTSIM database

- **Independent Review Station** – As part of the fixed simulator setup, an independent review station is located in a separate room. This allows for higher trainee throughput rates as training on the simulator and training review is possible in parallel. The use of the review station is very similar to the instructor station in review mode. It is linked to the fixed simulator by a high speed data link. The review station is built around a set of PCs able to playback simulation and to re-compute 3D images in real time.
- **Exercise Creation Tool (CREX) –** CREX is a stand-alone tool installed on the review station and allows the creation and modification of training exercises on the SCOTSIM simulator. A copy has also been installed on the TRUST 3000 instructor station.
- **Debriefing Tool –** This tool allows comparison between two instances of the same exercise, such as before and after training or comparison with a best practice drive. It looks at performance indicators such as duration of exercise, average speed, number of gear changes and fuel consumption.
- **Data storage –** On each simulator the performed exercise evaluations are recorded in a local TRAMS (TRAining Management System) database. The TRAMS database allows the operator to select, review, print and archive selected record data for any student. Each simulator is equipped for local storage of up to two hundred full exercise replays, of which each can be 30 minutes long. The simulation computers are equipped with a CD (re-)writer for archiving data.

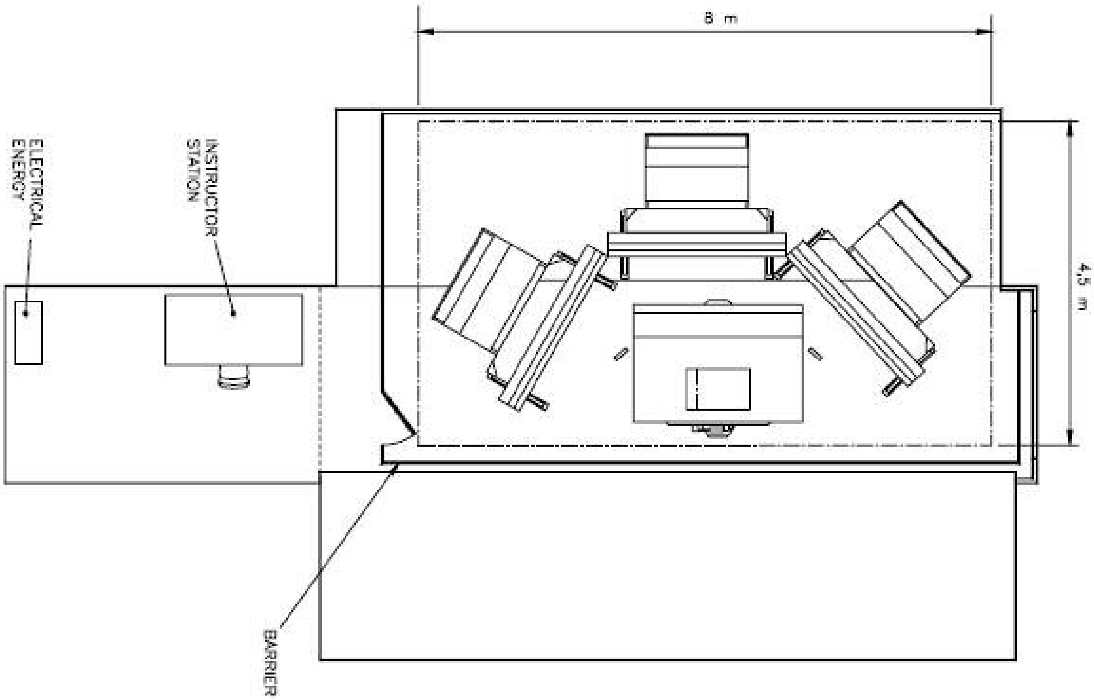
2.1.6 *Trailer of the mobile T3000 simulator*

The TRUST 3000 simulator is installed in a semi-trailer. Both sides of the trailer are withdrawn for transport and deployed for training. The unit was supplied by French trailer manufacturer, Toutenkamion.

The trailer has the following dimensions:

- Length: 13.5m
- Width in transport mode: 2.55m
- Width in training mode: Approximately 7m (9m including access steps)
- Height: 4.2m
- Length including tractor unit: 16.5 m
- Weight including tractor unit: Approximately 20 tons

Figure 2.6 Footprint of the trailer in training mode



Opening of the trailer and setup of the simulator from transport to training mode takes between one and two hours for a trained person. The opening process is supported by a hydraulic system.

Power to the simulator is either supplied via a 380 Volts/60A 3-phase plug or via the trailer mounted diesel generator. The generator has been supplied by German manufacturer Deutz and is installed on the front of trailer. The capacity of the diesel tank is 500 litres.

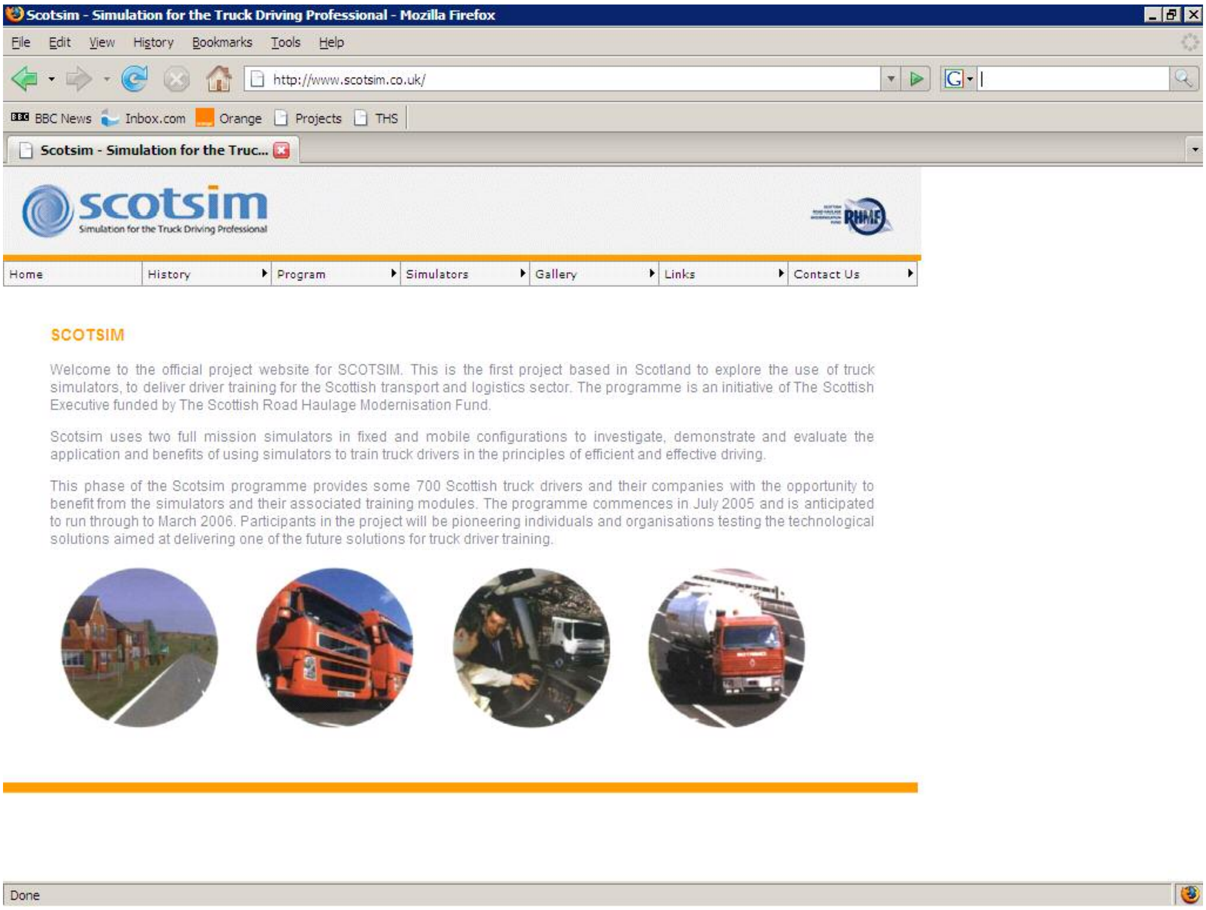
Figure 2.7 Mobile T3000 simulator in transport mode

2.2 Marketing and driver recruitment

2.2.1 Marketing

Marketing activities included the development of a bespoke website (www.scotsim.co.uk) for the purposes of the project. This was used to provide information for potential participants about the SCOTSIM project and offered the possibility of securing bookings for training online. Figure 2.8 shows a screenshot of the website homepage.

Figure 2.8 SCOTSIM website homepage

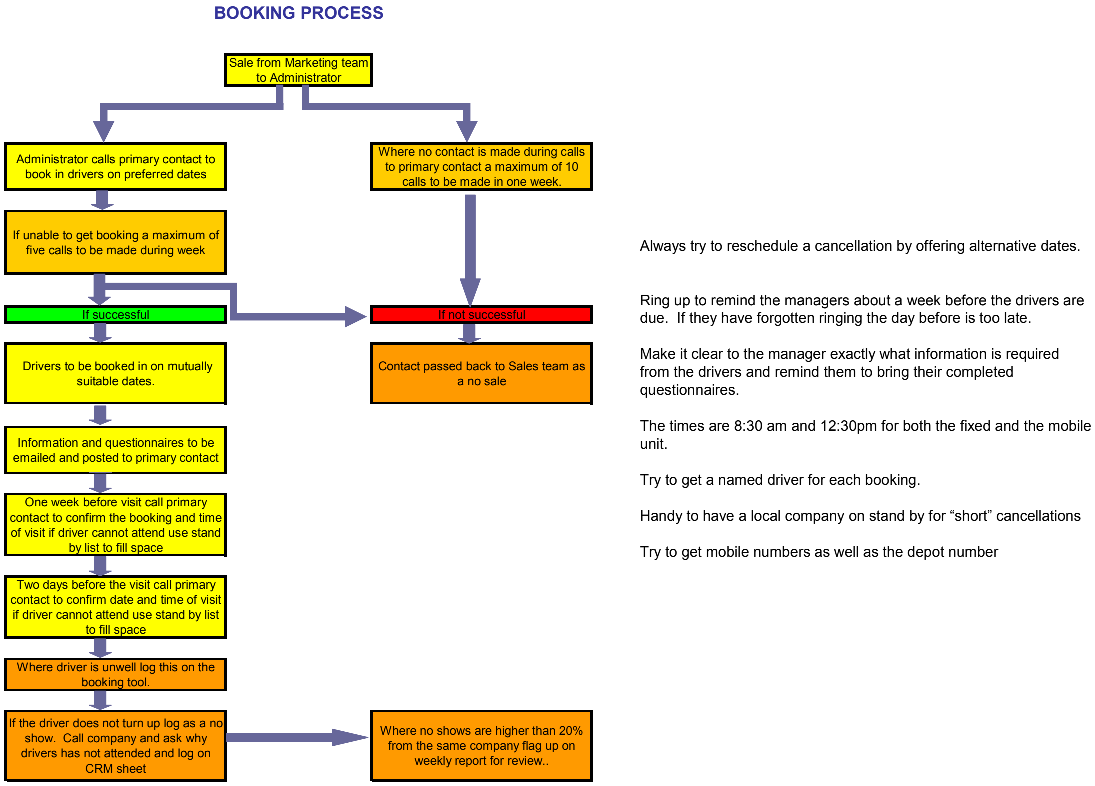


Examples of other marketing materials are shown in Appendix A.

2.2.2 Driver recruitment

Drivers were recruited to participate in driver training on SCOTSIM primarily by a combination of telephone calls made to previous contacts in the Scottish haulage industry from within the project team and by cold calls to other Scottish logistics companies. Recruited drivers were added to a booking tool to track driver throughput. Figure 2.9 shows the recruitment process.

Figure 2.9 SCOTSIM Driver booking process



2.3 Facilities and locations

2.3.1 Fixed location simulation centre (T5000)

TRL conducted a thorough search of suitable locations to find an appropriate site for the fixed location simulator (T5000). The majority of properties visited by TRL were unsuitable for the purpose of the project. The primary distinguishing features between the different facilities relate to the following components:

- Proximity to logistics companies in the central belt
- Easy of access
- Size of the property
- General appearance of the estate and the surround environment.
- Profile of the other tenants on the site.

Although TRL initially anticipated producing a shortlist of 3-5 properties which would be suitable for the project, this was not possible. In total TRL identified only one industrial estate, Strathclyde Business Park, that could potentially accommodate the SCOTSIM simulation centre (see Appendix B for the specification used to establish viable locations). The estate has very good access from the A8, is maintained to high standards and houses a good mixture of tenants including some technology companies. The site chosen was of sufficient size to house the mobile simulator and this flexibility was considered beneficial for maintenance/repair activities as well as providing safe storage if necessary.

Figure 2.10 shows the exterior of the facility whilst figures 2.11 and 2.12 show the appearance of the SCOTSIM facility before and after preparation for use.

Figure 2.10 Exterior and parking outside the SCOTSIM facility

Figure 2.11 Interior of the SCOTSIM facility on acquisition

Figure 2.12 Interior of the hall at the SCOTSIM facility

2.3.2 Mobile simulator (T3000)

The T3000 is essentially a self-contained simulation centre and can therefore operate at any (flat) location. However, there were important considerations when deciding where the T3000 should be deployed. A specification for the mobile sites was developed. This document was based on Thales' technical documentation and on experience gathered during both the TruckSim project and the identification of the site in Bellshill. The following criteria were applied during the process:

- **Space:** The site must be sufficiently large to house the simulator without interfering with on-site operations. The operating area must measure at least 20m × 12m, have a solid and even surface and at least 4.2m headroom.
- **Proximity to drivers:** The site should be located close to the project's target group, HGV drivers (e.g. in or close to a distribution centre, an industrial estate etc.).
- **Coverage:** The sites selected should expose SCOTSIM to as a large a proportion of drivers on the Scottish mainland as possible.
- **Facilities:** Facilities such as water, toilets or catering should be available on-site or nearby
- **Parking:** Two drivers per day will attend training on the mobile simulator. Some of them are likely to travel with their HGV. Therefore some HGV parking is likely to be required.
- **Security:** The operating area should be hazard-free and secure, ideally fenced with security on-site or CCTV
- **Access:** The site must be easily accessible with an HGV
- **Marketing potential:** Ideally the site would allow for hosting a simulator-launch-event with some visitors and local media present.
- **Neutrality:** A commercially neutral site would be preferable.

Potential sites were identified through a variety of channels, making use of the local knowledge of:

- Industry Advisory Group(IAG) members
- Companies that were approached to deliver simulator training

- Ritchie's Training Centre
- Heriot-Watt University
- Local Councils
- Highlands and Islands Enterprise
- Scottish Executive property division

Discussions with those institutions led to a shortlist including sites of the following nature:

- Territorial Army Barracks
- VOSA HGV Testing Sites
- Council owned sites
- Truck Parks
- Sites of Haulage Companies
- Sites of Training Companies
- Scottish Executive Office sites
- Other sites

The following sites were selected to accommodate the mobile simulator:

- **Oban** (*Oban Fire Station)*
- **Inverness** *(Army Barracks)*
- **Aberdeen** *(Army Barracks)*
- **Dundee** *(Army Barracks)*
- **Dumfries** *(Nithcree Training)*

Oban Fire Station was chosen for its modernity, security, and space for the simulator and parking. Toilets are on site and the station is located very close to Oban's industrial estate where a number of potential project participants were located.

The Army Barracks in Inverness, Aberdeen and Dundee are very secure, offered lots of space for housing the simulator and parking and have toilets and some kitchen facilities on site. Scheduling of on-site operations at the barracks resulted in safe usage of the simulator during the weekdays of operation.

Nithcree Training have a safe and secure site in the heart of a Dumfries industrial estate in close proximity to various potential project participants. Toilets are on site and space for parking is available.

2.4 Training supplier

Ritchie's Training Centre, based in Glasgow, were selected to provide the driver trainers required to deliver the simulator training as part of the SCOTSIM programme. The specification used to select the training provider is shown in Appendix C. Ritchies is one of Scotland's leading commercial vehicle driver training companies and committed its principal driver instructors to the SCOTSIM project.

In addition to selection of an appropriate training centre, appropriate training staff were required. In addition to being properly qualified truck drivers with the ability to drive the mobile system, plus being a professional truck driver trainer/instructor, TRL required that candidates had a rudimentary knowledge of and interest in the following areas:

- Mechanics
- Electricity
- Computers

It was determined that these abilities would help the instructors to become familiar with the simulator systems, in maintenance of the simulator equipment, and in the diagnosis of any faults that should arise.

3 Simulator training method

3.1 Training method: Phase I

Drivers experienced the same half day training process at the mobile (T3000) and fixed (T5000) simulator facilities. Aside from the technical differences between the T3000 and the T5000, there were two active trainers on the fixed system enabling training of four drivers per day. On the mobile system only one driver trainer was present so that a maximum of two drivers were trained per day (see training schedules shown in Appendix E).

3.1.1 Training staff

The staff responsible for delivering driver training were qualified trainers contracted from Ritchie's Training Centre. In addition to their truck driver training qualifications, each of the driver trainers underwent training to be able to train drivers to the Safe and Fuel Efficient Driving (SAFED) standard. They also visited the Thales technical centre in Cergy, France, to experience a one week training course in the operation and maintenance of the simulator equipment.

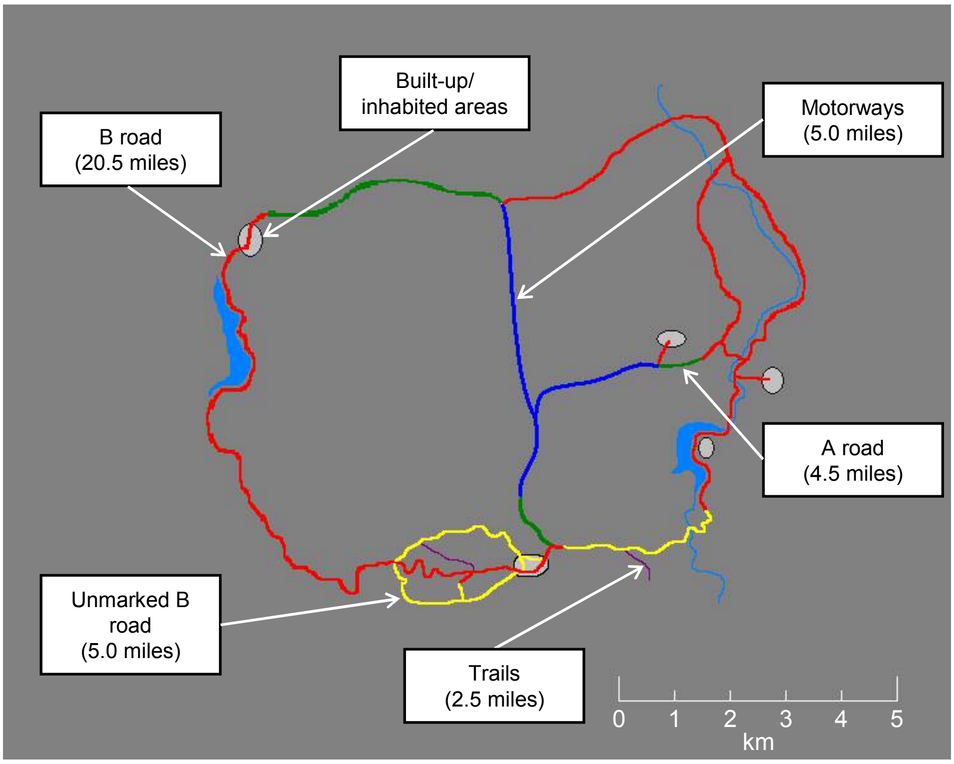
3.1.2 Simulator database

The simulator database refers to the 'virtual world' in which the training exercises are created. The database measures 112 square miles (14 × 8 miles) and consists of the following road types

Motorway:	2 × 3.65m lanes with 3.30m hard shoulder in each direction with central reserve (5 miles)
A-road:	2 × 3.65m lanes in each direction with central reserve (5 miles)
B-road:	1 × 3.65m lane in each direction (22 miles)
Minor road:	Unmarked 7.3m lane (10.5 miles)
Trails:	Unmade roads (2.5 miles)
Cobbled roads:	In villages/town (1 mile)

Figure 3.1 shows a map view of the SCOTSIM database.

Figure 3.1. Map of the SCOTSIM database



3.1.3 Exercise creation

An *'exercise'* is created in SCOTSIM as one element within a *'sequence'* of exercises. A set of sequences is known as a *'cursus'* (course) on the system. For the SCOTSIM training programme, the cursus consisted of one sequence of exercises that contained the familiarisation route and the four training exercises (described in 3.1.6).

3.1.4 Exercise parameters

The vehicle driven throughout was a fully loaded rigid vehicle (gross vehicle weight 26 tonnes). The vehicle has a manually operated gearbox with sixteen forward gears and one reverse gear. The exercises were run in a simulated clear daytime environment.

For each exercise drivers, were given instructions on the route to follow by automated voice messages trigger at appropriate locations through the route. The voice message system used text-to-speech software, programmed with the correct voice instructions as verified by the qualified trainers from Ritchie's Training Centre.

3.1.5 Scoring

The aim of the programme was for drivers' performance to be evaluated by an automated driver assessment system. This monitored how drivers were controlling the simulated vehicle and compared their performance to pre-determined benchmarks set by novice and expert drivers to calculate ratings of their performance in eleven different criteria, based on those set out in the Safe And Fuel Efficient Driving (SAFED) standard. Section 4 gives a full description of development of the automated assessment system. Technical difficulties resulted in this software being finalised at the end of the training programme. However, each driver was assessed over the course of each drive by the trainer who scored their performance in each of the seventeen criteria that comprise the SAFED standard. The seventeen SAFED criteria are:

1) Acceleration and Cruise Control
2) Braking (including engine/exhaust brake)
3) Clutch Control
4) Driving Position/Seat Belt
5) Road and Weather Conditions
6) Steering
7) Gear Selection and Use
8) Hazard Perception and Prioritisation
9) Speed
10) Lane Discipline and Positioning
11) Making Progress and Planning
12) Use of Mirrors and Blind Spots
13) Use of Signals
14) Overtaking
15) Vehicle Sympathy
16) Driver's Attitude/Technique
17) Reaction to Road Markings and Signs

Under the SAFED training regime, the driver trainer is required to score the driver's performance on three point scale, from 'Good' (G) through 'Fair' (F) to 'Unsatisfactory' (U). For the purposes of this research programme, the phrase 'Unsatisfactory' was deemed too confrontational and was replaced with the phrase 'In need of development' (D). In the SAFED course, a rating of G in a criterion gives a score of 0 faults; F gives 1 fault; and U gives 3 faults[1]. The fault scores across all criteria are summed across both drives to give the final score. If a driver scores 17 faults or less over the course of the two drives, they are deemed to have achieved a 'Pass with distinction'. A score of more than 17 but no more than 34 is awarded an 'Ordinary pass' whilst a score of 35 or greater is deemed a 'Fail'. These scores were taken for drivers in the SCOTSIM programme but drivers were not awarded pass/fail marks.

3.1.6 Exercise descriptions

3.1.6.1 Familiarisation

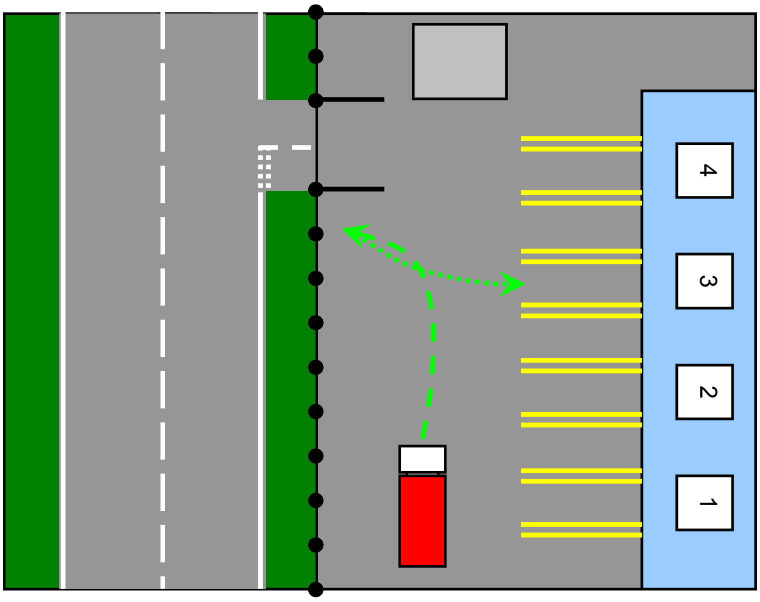
In the Familiarisation exercise, drivers were required to complete a short unchallenging drive in the simulator in order to become acquainted with the vehicle controls and to get used to driving in the virtual environment. No performance measures were collected during this familiarisation period. This drive lasted around five minutes after which the driver was required to take a short break. If they felt comfortable with driving the simulator, they would then proceed to the training drives.

[1] The 'faults' awarded to do not necessarily reflect the number of mistakes made by the driver in that criterion but the score is designed to reflect the severity of the mistakes made.

3.1.6.2 Distribution Centre

The first exercise on which the drivers were assessed required them to reverse the vehicle up to a loading bay in a simulated distribution centre (as shown in figure 3.1) and then exit the distribution centre through the main gate. The manoeuvre required a short drive forwards followed by the reverse up to the bay wall.

Figure 3.2. Top-down view of the manoeuvre required in the reversing exercise.



As the driver completed the reverse a pedestrian crossed behind the driven vehicle such that the driver had to stop to allow the pedestrian to cross safely. Once the pedestrian had walked across to safety, the reverse could be completed. Once the driver had parked the vehicle, after a short time, they were instructed that their vehicle had been loaded and they could proceed out of the distribution centre. Pulling out of the distribution required the negotiation of some light traffic. After driving a short distance, drivers were asked to stop behind a broken down vehicle, thus completing the exercise. Total distance driven within the exercise was approximately 0.5 miles and was typically completed within four to six minutes.

3.1.6.3 Village

In the Village exercise, the trainee was required to drive along a rural B-road with light oncoming traffic. The exercise started on approach to a village. On entering the village, the speed limit changed from the national speed limit to 30mph. At a point within the village a pedestrian was triggered to walk across the path of the driven vehicle. A driver demonstrating good hazard awareness would slow and be able to stop in good time before reaching the pedestrian. A driver travelling too fast would run the risk of hitting the pedestrian.

Having driven through the village, the route returned a more rural setting and the national speed limit was restored. After a short distance, the road narrowed from two lanes to a single track. The oncoming traffic was such that if the driven vehicle was travelling too fast the driver would be required to slow and wait for the oncoming traffic. Once again, a driver demonstrating good planning skills would slow steadily as the road narrowed such that the traffic would clear and forward momentum could be retained. The truck then had to be driven through a narrow tunnel and negotiate a cyclist that was attempting to pass at the same time. Driven carefully, the tunnel and cyclist could be cleared with ease.

Once through the tunnel, the single track road continued with sweeping bends on which a broken down vehicle was parked and had to be avoided. After a time, the road widened and became a two-lane rural A-road. On approach to a roundabout, a vehicle malfunction was triggered such that the engine overheated. This illuminated warning signals on the vehicle instrument panel to which the correct response from the driver was to pull over safely to the side of the road. Drivers ignoring or failing to notice the warning signals were instructed by the trainer to stop. The total distance driven within this exercise was approximately 3.8 miles and was typically completed within ten to thirteen minutes.

3.1.6.4 Highway

In the Highway exercise, participants started on a dual-carriageway A-road with two lanes in either direction. After a short distance, a hard shoulder was added such that the road became a motorway. After driving a short distance driving on the motorway, drivers were required to leave the motorway using a slip road that led to traffic light controlled roundabout. The timing of the traffic light sequence on the entry to the roundabout is controlled such that drivers who approach steadily will be able to continue making progress without having to come to a stop. Drivers who travel too quickly on the slip road will have to stop at the traffic lights, thereby wasting fuel whilst stationary and accelerating away from the traffic lights to continue the drive. The exit from the roundabout to which drivers were directed leads to another motorway. Having safely merged onto the motorway, the drivers had to catch and overtake a slow moving lorry. Shortly after the overtaking manoeuvre had been completed, the driver encountered a traffic jam in which the driver had to wait for a short time before the problem cleared allowing the driver to continue. The driver then left the motorway at the next exit leading to a roundabout and turned off the roundabout, completing the Highway exercise. The total distance driven within this exercise was approximately 2.7 miles and was typically completed within six to eight minutes.

3.1.6.5 Town

In the Town exercise, participants started on an A-road at the national speed limit approaching a town. At the entrance to the town, the speed limit reduced to 30mph. The driver was then guided along a route around the town along which the driver had to negotiate a number of different urban manoeuvres including a pedestrian using a zebra crossing, overtaking two cyclists, negotiating mini-roundabouts, and dealing with a car running through a red light. In the final manoeuvre, the driver had to reverse down a pedestrianised precinct to a delivery point. The total distance driven within this exercise was approximately 1.5 miles and was typically completed within eight to eleven minutes.

The total distance driven across the four exercises was approximately 8.5 miles. After completing the four exercises, each participant was given feedback on their performance and training advice by the instructor. They were then required to complete the four exercises a second time (‘Drive 2’) to demonstrate the skills that they have been taught. Comparison could then be made across drive 1 and drive 2 to investigate any improvements in performance.

3.1.7 Questionnaires

Through the training process, participants were required to complete questionnaires to record a number of different details about their background, their driving behaviour, and their subjective experience of the simulator and of the simulator training experience as a whole. The questionnaires completed are listed below (see Appendix D to view the questionnaires):

- *Pre-drive questionnaire*

  This required participants to state their age, driving experience, enjoyment and confidence with regard to driving, accident and training history, the type of vehicle they usually drive, self-ratings of ability, and some health-related questions.

- *Pre-drive SSQ*

  The Simulator Sickness Questionnaire (SSQ) was created by Kennedy, Lane, Berbaum, & Lilienthal (1993) and is commonly used in research and training to assess participants' subjective levels of sickness arising due to their experience in a simulated environment. Trainees in the SCOTSIM programme were required to complete this questionnaire before any simulation training had occurred to register any sickness that drivers were experiencing prior to participation. The severity for each of a number of different symptoms is rated on a four-point scale. The ratings are compiled into an overall SSQ score.

- *Attitudes towards simulation*

  This questionnaire required participants to state their level of experience with computers and technology and to rate their agreement with a number of statements relating to the use of technology e.g. "I seem to have difficulties with most video players I have tried to program"; "Computers are good aids to learning".

- *Post-drive questionnaire*

  In this questionnaire, participants rated the realism of various aspects of the simulation and required them to express their overall opinion of the SCOTSIM training experience.

- *Exercise questionnaire*

  This required participants to indicate how useful, interesting, and intuitive each exercise was. They were also able to state how they thought each exercise should be changed if they felt it could be improved.

- *Post-drive SSQ*

  At the end of their simulator drives, participants were again asked to complete the SSQ. By comparison of the pre-drive SSQ score with the post-drive SSQ score, it was possible to determine how much the simulator had contributed to any feelings of sickness.

3.2 Training method: Phase II

3.2.1 Additional drivers

TRL were contracted to train 700 drivers as part of the original contract issued by the Scottish Executive. In phase I of the project, 641 drivers participated in simulator training. Therefore, an additional group of drivers was required to fulfil the contract. These drivers underwent exactly the same process as described for phase I.

3.2.2 New training modules

TRL were commissioned to develop new training modules for SCOTSIM, beyond those developed for the phase I training process. This required close liaison with industry representatives, training providers and trade associations. A one-day workshop was held to establish the training modules that would be most desirable and could provide the greatest benefit. Organisations represented at the workshop included the Driving Standards Agency (DSA), the Freight Transport Association (FTA), the Road Haulage Association (RHA), Skills for Logistics, and Scotland-based companies with large numbers of commercial vehicle drivers. Through the workshop, TRL facilitated discussion groups to identify the four training modules that stakeholders regarded as particularly important for truck drivers in Scotland.

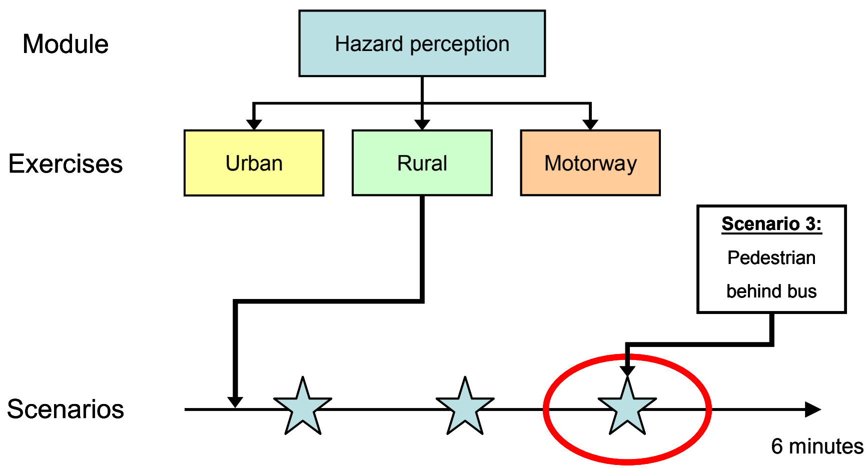
The four modules selected for consequent development and implementation in the simulator were:

1. Hazard perception

2. Driver attitudes
3. Slow manoeuvring
4. Emergency manoeuvres

It was agreed that each of the modules should contain approximately four exercises of 5-10 minutes duration, resulting in approximately 20-30 minutes of driving per module. Within each exercise the truck driver would have to drive along a fixed route and negotiate a number of training scenarios that resulted from particular configurations of the traffic environment (see Figure 3.3).

Figure 3.3 Schematic set-up of the Hazard Perception module.



The following provides a brief overview on each of the four modules, including training objectives, description of exercises, training scenarios and assessment criteria.

3.2.2.1 The Hazard Perception module

The Hazard Perception module consists of four exercises: rural roads, urban roads, and two motorway exercises. Hazards are situations where a driver may have to brake or to take avoiding action. The training scenarios within the Hazard Perception module broadly fall into three different categories:

1. Entry of another object into the path of the driven vehicle
2. Unexpected actions of the vehicle in the front
3. Hazardous actions of oncoming traffic.

A safe driver anticipates situations in which hazards are likely to occur and modifies his driving such that the potential hazard is avoided.

The training goal for the Hazard Perception module is thus the early recognition of potentially dangerous situations in traffic and anticipation of possible situation developments. This requires knowledge of typical risks associated with particular road environments.

- In the rural environment: the presence of cyclists or slow moving vehicles such as tractors in front.
- In the urban environment: sudden stops or turns of vehicles in front of the trainee, turns of oncoming traffic crossing the trainee’s way or pedestrians crossing the trainee’s way. Early perception of hazards is aggravated by the high density of buildings and other road users.
- On the motorway: sudden occurrences of obstacles in the trainee’s way, e.g. traffic jams or broken down vehicles

Specifically the truck driver should learn to reduce his speed when approaching situations where visibility is poor (e.g. bends or fog), to only pass (moving) obstacles if a safe distance to them can be kept and visibility ahead is good and to communicate the driving intention by appropriate use of the indicators.

Hazard perception can be measured in terms of response to hazard. This includes the response time to specific hazards (that is the latency of response to the beginning of the hazardous events) or the number of hazards detected. The safe truck driver will react timely to hazards by reducing his speed or waiting for the hazard to pass. In driving past the hazard he will keep a sufficient distance to the hazard. The assessment of trainee performance is in part automatically monitored by the simulator but will also form part of the feedback session with the trainer at the review station.

There are four exercises within the Hazard Perception module:

- *Overtaking*
- *City drive*
- *Motorway 1*
- *Motorway 2*

3.2.2.2 The Driver Attitude module

The Driver Attitude module consists of four exercises: motorway, urban roads, highway to village, and rural roads. The module focuses on demonstrating to the trainee that not all road users always behave as expected or desired and that the adoption of a driving style that is tolerant of the errors of other road users is beneficial in terms of safety as well as the trainee's own stress levels.

The training scenarios within the Driver Attitude module broadly fall into three different categories:

1. Illicit entry of another road user into the path of the driven vehicle
2. Failure of other road users to indicate driving intention appropriately
3. Obstacles in the path of the ego vehicle that hinder the trainee's progress.

The module's difficulty could be further increased by setting a time limit for the completion of the course that is unrealistic in such as way that it will not allow the trainee to master all exercises in a safe way. As tight timescales are a phenomenon typically experienced in the haulage industry this measure would add to the face validity of the training scenario.

A safe driver demonstrates a driving style that is courteous and error-tolerant of other road user's mistakes. The safe driver remains calm even if hindered in his own progress and successfully interacts with other road users.

The training goal for the Driver Attitude module is to give other road users sufficient space to carry out safely their intended driving manoeuvres; to refrain from carrying out driving manoeuvres that could endanger other road users or block emergency services' way and to communicate driving intentions appropriately.

The automatic assessment of good driver attitudes should includes the appropriate use of indicators when turning or overtaking to communicate the driving intention to other road users. Good driving attitudes should also be reflected in a resource-friendly, anticipatory driving style that plans ahead and avoids harsh acceleration or deceleration. Approach speeds should be low and the distance that the trainee leaves to waiting vehicles ahead should be sufficiently large as not to pressurise the vehicle in front.

The debrief session should focus on occurrences of agitation, aggression or stress that the trainee might have displayed during the exercises. The trainer should discuss with the trainee that other road users' behaviour is probabilistic rather than deterministic and thus requires an error-tolerant driving style.

There are four exercises within the Driver Attitude module:

- *Country roads*
- *City drive*[2]
- *Motorway*
- *A-road*

3.2.2.3 The Emergency Manoeuvres module

The Emergency Manoeuvres module consists of four exercises: motorway, urban roads and adverse weather condition on rural roads.

The training scenarios within the Emergency Manoeuvres module broadly fall into three different categories:

1. Unexpected actions from vehicles in the front
2. Failure of essential parts of the driven vehicle
3. Hazardous weather/road conditions that require the driver to take action.

The motorway exercise is designed in such a way as to expose the trainee to situations where he is unlikely to control the truck sufficiently to avoid jack-knife or roll-over. The second exercise on urban roads requires the driver to deal safely with situations of technical defect. The third exercise, adverse weather conditions on rural roads, allows the driver to avoid emergency manoeuvres, if he has adapted this driving style sufficiently to the prevailing weather conditions.

In the Emergency Manoeuvres module the trainee should learn that his skills, even if highly developed, are unlikely to prevent him from avoiding an accident in certain situations. Overconfidence in one's driving skills is frequently associated with the adoption of riskier driving styles and so this is tackled in these exercises. A driver must also be able to adapt his driving to the prevailing weather conditions in order to maintain control of the vehicle at all times.

Successful avoidance of truck rollover is a readily available assessment criterion. For other exercises, stable control of the truck must be monitored. This will include the monitoring of speed reductions in adverse weather, the lateral position of the truck on the road, and the keeping of a safe distance to other road users.

There are five exercises within the Emergency Manoeuvres module:

- *Escape lane*
- *Avoidance manoeuvres*
- *Accident avoidance*
- *Icy A-road*
- *Rollover avoidance*

3.2.2.4 The Slow Speed Manoeuvres module

The Slow Speed Manoeuvres module consists of four exercises: At the depot, urban environment, rural environment and motorway environment.

The training scenarios within the Slow Speed Manoeuvres module broadly fall into two different categories:

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[2] The City drive in the Driver Attitude module is the same as that in the Hazard Perception module. It was felt that the challenges to Hazard Perception in the City drive were also applicable as challenges to Driver Attitude.

1. Manoeuvring around static obstacles or road features, e.g. turns or loading bays
2. Manoeuvring the truck in road environments where vulnerable road users are present

The first exercise, at the depot, requires the driver to move in and out of a depot area and to reverse the truck into a loading bay. He is required to make a choice as to where to safely turn his truck and return to the depot. Exercise two requires the driver to manoeuvre safely in built-up areas and roads that are narrowed by the presence of parked cars. Exercise three and four, the rural and motorway exercise, focus on overtaking slow vehicles, turning off roundabouts and merging with slow traffic.

A safe driver is aware of the limitations of visibility in the truck and watches out for vulnerable road users, especially during turning and reversing manoeuvres.

The aims of the slow manoeuvring module are to increase the trainee's awareness of vulnerable road users in particular traffic environments such as depot areas or built-up areas, where blind spots during reversing or turning make it particularly difficult to see them. The trainee should furthermore use his mirrors appropriately and position the truck on the road.

Successful avoidance of accidents with (vulnerable) road users such as pedestrians or bicyclists or with static objects such as parked cars will be a readily available assessment criterion for the first exercise. In depot areas where pedestrians are present, the trainee should not continue the manoeuvre when the pedestrian is in a blind spot from his truck.

Further assessment criteria will be the correct positioning of the truck in loading bay, when taking turns or negotiating roundabouts.

There are five exercises within the Slow Speed Manoeuvres module:

- *Depot manoeuvres*
- *City manoeuvres 1*
- *Rural manoeuvres*
- *Right turn manoeuvres*
- *City manoeuvres 2*

3.2.3 Enhanced familiarisation and application of screening criteria

Two different techniques were tested to investigate whether they might cause a reduction in the incidence of simulator sickness among participants in the SCOTSIM driver training programme. The first technique was to enhance drivers' familiarisation with the training facilities and the simulator equipment by inviting participants to a short evening session at the facility for an introduction to the

The second technique was to apply screening criteria to the drivers recruited to participate in the training programme, based on elements within the Attitudes to Simulation questionnaire that were found to be correlated with simulator sickness (see section 5.2.5). The questionnaire used for driver screening is shown at the end of Appendix D. In recruiting drivers for this process, drivers had to fulfil successfully a number of criteria as listed in the questionnaire

Drivers in phases I and II completed a familiarisation drive and then repeated the four training exercises twice. In this evaluation process, drivers did not complete the full training day. Participants were only required to complete the familiarisation drive and one instance of each of the four exercises. This is termed the 'half process' and enabled more drivers to be tested in the available time period.

4 Development of the SCOTSIM Automated Driver Assessment System

This section outlines the work performed by TRL and Thales in the development of the automated driver assessment system used to evaluate driver performance on the training exercises created for phase 1 of the SCOTSIM project, commissioned by the Scottish Executive. It serves to identify within the sample of drivers trained during the project where opportunities and deficiencies arise when applying automated scoring techniques at the boundaries of current simulation technologies.

In phase 1 of the project, there was a requirement for 700 professional truck drivers working for companies based in Scotland to undergo driver training using two full mission, high fidelity truck simulators supplied by Thales. The TRUST 5000 simulator operates at a dedicated facility located in Bellshill, near Glasgow, whilst the TRUST 3000 is housed within a truck trailer unit that was taken to various sites around mainland Scotland. The main technical difference between the two units is that the TRUST 3000 is surrounded by fixed screens whereas the TRUST 5000 uses flying screens and a larger scale motion system.

The simulator training provided in the SCOTSIM programme was designed primarily to improve safety and fuel efficiency. Early within the project definition it was decided to maximise the industry recognition of the SAFED brand and whilst not delivering SAFED training on the simulators (they provide arguably more powerful analytical tools) the principles which govern that training regime would where possible be integrated into the simulator training modules.

The Safe and Fuel Efficient Driving (SAFED) standard was designed in 2003 under the Freight Best Practice programme for the Department for Transport. Its aim was to improve the driving techniques of professional Large Goods Vehicle (LGV) drivers. The training exercises developed for the simulator were therefore based around the principles set out in the SAFED standard.

The requirement for a coherent scoring system delivering outputs to support trainer interventions has always been viewed as crucial within the SCOTSIM project. There are a number of reasons for this, not the least being to reduce the variability of trainer interpretation, to minimise the argument from a trainee that an instructor has been biased and fundamental to the technology is the capability to capture and retain performance measurement within discrete criteria at a level that driver trainers are unlikely to be able to replicate.

One ambition for the project was to analyse to what degree machine and man (simulator and trainer) scoring could be synchronised. In order to achieve appropriate analysis of measurements and to produce an automated SAFED scoring system, it was acknowledged that significant adaptations were likely to be required to Thales' standard scoring mechanisms and techniques.

4.1 SAFED training

Under the SAFED protocol, trainees complete a baseline drive of around one hour accompanied by a suitably qualified instructor, typically in their own vehicle. After the baseline drive, trainees are given feedback on their performance by the instructor and classroom training is given in best practice driving techniques for safe and fuel efficient driving. Trainees are then given the opportunity to demonstrate the skills that they have been taught in a second drive on the same route as the first. In each drive, objective and subjective measures are taken. The objective measures are the fuel used, the number of gear changes, and the time taken to complete the route. The instructor provides the subjective assessment, scoring the trainee on seventeen different criteria:

Table 4.1 The seventeen elements assessed in the SAFED standard

1.	Acceleration and Cruise Control	10.	Lane Discipline and Positioning
2.	Braking (including engine/exhaust brake)	11.	Making Progress and Planning
3.	Clutch Control	12.	Use of Mirrors and Blind Spots
4.	Driving Position/Seat Belt	13.	Use of Signals
5.	Road and Weather Conditions	14.	Overtaking
6.	Steering	15.	Vehicle Sympathy
7.	Gear Selection and Use	16.	Driver's Attitude/Technique
8.	Hazard Perception and Prioritisation	17.	Reaction to Road Markings and Signs
9.	Speed		

In each drive, the instructor scores the candidate on a three point scale:

G: Good (zero faults allocated)

F: Fair (one fault allocated)

U: Unsatisfactory (three faults allocated)[3]

The overall score is based on the sum of faults accumulated across the two drives (the number of faults allocated does not necessarily correspond to the number of faults observed in each criterion). A trainee is considered to have passed the course if they achieve fewer than 35 faults. A score of 17 faults or fewer achieves a 'Pass with Distinction'.

4.2 Applying Safe and Fuel Efficient principles to simulator training

At the outset of the project, it was apparent that simulator technology would not be appropriate for the data capture and assessment of four of the seventeen criteria listed in Table E1 above. The criteria that would not be assessed by an automated process were 4, 5, 12, and 16. Driving position and use of the seat belt cannot be evaluated using the data recorded in simulator exercises but are relatively easy for an appropriately trained instructor to appraise. The simulated road available in which to create exercises is largely an ideal surface and whilst it is possible to vary the weather conditions within exercises, for reasons of practicality, this was not done in the SCOTSIM exercises. Consequently, evaluation of driving performance in this criterion using simulator data cannot be considered useful. Technology exists that enables a driver's eye gaze direction to be determined and this would enable the use of mirrors to be evaluated very effectively. However, in the absence of this technology, a driver's use of mirrors can be assessed more effectively by a suitably trained instructor. This left thirteen of the seventeen SAFED elements that it was believed could be assessed automatically using the data recorded from the training simulators.

Four training exercises (plus a familiarisation drive) were developed as part of the SCOTSIM project and constructed to test drivers on a wide range of driving skills. These were developed by Thales on the instruction of TRL with input from a variety of stakeholders including DSA, Ritchies Training Centre (the Scottish truck driver training company providing trainers and expertise for the project), VTL (a Dutch truck driver training company with long experience with Thales simulation equipment).

The exercises were as follows:

[3] For the purposes of the SCOTSIM programme, the 'U' rating (Unsatisfactory) was changed to 'D' to mean 'In need of Development' since this phrase was deemed less confrontational for use within a research programme.

(i) Industrial exercise (approximately 5 minutes)

This exercise was based in a depot and required the trainee to reverse the vehicle into a loading bay taking care to avoid pedestrians, exit the depot, and make progress on a rural B-road for a short time.

(ii) Village exercise (approximately 10 minutes)

This exercise was based on rural roads with sweeping bends, some shallow gradients, and some single track roads. Trainees were challenged by unexpected pedestrian events and vulnerable road users. The exercise was ended by a triggered vehicle malfunction that caused the simulated vehicle to overheat, thus requiring the driver to stop.

(iii) Highway exercise (approximately 7 minutes)

This exercise was based on dual carriageways and motorways and required the trainee to overtake a slow moving vehicle, manage motorway junctions, and negotiate a traffic jam.

(iv) City exercise (approximately 9 minutes)

This exercise was based in a built up environment requiring the trainee to negotiate tight turns and busy junctions. It included unexpected events and vulnerable road users and ended with a reversing manoeuvre into a pedestrianised precinct.

Each exercise is constructed of a number of different tasks e.g.

Task 1: position vehicle ahead of parking bay;

Task 2: reverse into parking bay;

Task 3: pull out of parking bay

Task 4: etc…

The simulator can assess drivers on **global** or **local** criteria:

A **global** criterion is measured over the course of the entire exercise e.g. total fuel used in the exercise;

A **local** criterion is assessed only over the course of a task, e.g. a local criterion to keep speed below 30mph during a task that starts at a 30mph speed limit sign and continues through a village until the national speed limit is restored.

The criteria on which drivers would be assessed in each task and exercise were determined in a consultative process with stakeholders. In total, 335 evaluation criteria were set across the four exercises.

Once the driver assessment criteria were established for each of the simulator exercises, these were allocated into the seventeen criteria set out in the SAFED standard, again in consultation with stakeholders.

For example assessment criteria that related to compliance with speed limits were allocated to SAFED criterion 9, Speed. If appropriate, assessment criteria could be allocated to more than one SAFED criterion, e.g. number of gear changes was allocated to SAFED criterion 7, Gear Selection and Use; to SAFED criterion 11, Making Progress and Planning; and to SAFED criterion 15; Vehicle Sympathy.

The number of assessment criteria that were set against each SAFED criterion is shown in Table 4.2.

Table 4.2 The allocation of the automated assessment criteria to the SAFED elements

SAFED element	Description	Number of automated assessment criteria in SCOTSIM exercises
1.	Acceleration and Cruise Control	61
2.	Braking (including engine/exhaust brake)	35
3.	Clutch Control	37
4.	Driving Position/Seat Belt	N/A
5.	Road and Weather Conditions	N/A
6.	Steering	13
7.	Gear Selection and Use	28
8.	Hazard Perception and Prioritisation	40
9.	Speed	51
10.	Lane Discipline and Positioning	45
11.	Making Progress and Planning	52
12.	Use of Mirrors and Blind Spots	N/A
13.	Use of Signals	21
14.	Overtaking	11
15.	Vehicle Sympathy	43
16.	Driver's Attitude/Technique	N/A
17.	Reaction to Road Markings and Signs	16
Total		453

Note that the total number of criteria across all SAFED elements (453) is greater than the total number of evaluation criteria stated earlier (335). This is because some of the evaluation criteria are allocated to more than one of the SAFED elements.

4.3 Scoring system calibration process

The aim of the automated scoring system was for a driver's performance in the simulator to be evaluated by the system in the same way that a trained instructor would have evaluated that drive.

Therefore, the relevance of each evaluation criterion within each SAFED element to the score (G/F/D) given by a trained instructor in that element had to be investigated.

The Thales TRUST evaluation system rates performance on an evaluation criterion on a scale between -10 and 10 where a score of 10 indicates perfect performance and a score of -10 indicates that performance was poor. For a batch of drives completed in the SCOTSIM programme, the scores for each of the evaluation criteria were correlated with the G/F/D score given by the trainer.

Thales chose to use a correlation procedure for this operation and following consultation with TRL, it was decided that the Spearman's rank correlation protocol should be applied.

When designing the exercises, a training expert analysis was conducted to generate a matrix that linked each TRUST evaluation to the relevant SAFED criterion. This link was refined through a calibration process that used the Spearman's rank correlation coefficient between the TRUST assessment and the scores provided by human examiner as a weighting. When a close correlation exists between the TRUST assessment and the trainer assessment, that TRUST assessment can be considered to be very significant in the score awarded by the trainer. Therefore, the correlation coefficient gives a high weighting to such a criterion. Conversely, when a low correlation is found, this provides a low weighting because that TRUST assessment can be considered to be less influential in the overall score awarded by the trainer.

Where trainers scored all drivers identically or where the TRUST assessments did not distinguish between drivers, a zero weighting was applied such that non-discriminant scores were not taken into account in the award of the overall mark by the system. Furthermore, when only two classes of score were observed, either in the TRUST assessment or for scores given by the trainers, the discriminant information is poorer than when there are 3 classes or more. Under these circumstances, the Spearman's rank correlation coefficient used as the weighting has been divided by 2 to optimise the calibration.

The SCOTSIM result is the weighted average of all the elementary scorings weighted as defined above. This gives a unique mark per student per SAFED element. Finally, to give the G/F/D statement to the trainee, it is necessary to define the score boundaries between the G, F, and D score categories. To get obtain these limits, Thales investigated the analysed batch of trainees to find the score boundary values that would give the greatest accuracy between the respective scores given by TRUST and the trainers. These limits integrated into the automatic SCOTSIM assessment process.

TRL determined that a practical minimum level of agreement between the score given by the automated system and trainer scores for a given SAFED element was 70%. This would mean that out of 100 scores within that element, the system and the trainer would give exactly the same G/F/D score on at least 70 occasions.

In addition, there should be a minimal number of occasions where the simulator score completely differs from that given by the trainer, i.e. if the trainer gives a score of G then the system should not give a score of U and if the trainer gives a score of U then the system should not give a score of G.

Table 4.3 shows the performance of the Thales scoring system on a batch of 75 drivers (and therefore 2 × 75 = 150 instances of each exercise) that completed the SCOTSIM programmes in the first three months of 2006.

Table 4.3 Accuracy of the automated scoring system in matching trainer scores (criteria that reach an acceptable level of accuracy are highlighted in green)

SAFED element	Description	Accuracy	Two marks inaccuracy
1.	Acceleration and Cruise Control	72%	1%
2.	Braking (including engine/exhaust brake)	59%	4%
3.	Clutch Control	65%	1%
4.	Driving Position/Seat Belt		
5.	Road and Weather Conditions		
6.	Steering	67%	2%
7.	Gear Selection and Use	73%	2%
8.	Hazard Perception and Prioritisation	74%	9%
9.	Speed	62%	13%
10.	Lane Discipline and Positioning	60%	5%
11.	Making Progress and Planning	72%	4%
12.	Use of Mirrors and Blind Spots		
13.	Use of Signals	60%	1%
14.	Overtaking	64%	13%
15.	Vehicle Sympathy	71%	4%
16.	Driver's Attitude/Technique		
17.	Reaction to Road Markings and Signs	75%	9%

Table 4.3 shows that for six of the thirteen criteria, an acceptable level of agreement was attained between the automated system and the trainer scores.

A previous analysis of this kind using 178 drives demonstrated that an acceptable level was also attained in SAFED element 2. It is unclear why accuracy in this analysis fell to a lower level but this prior performance led to the acceptance of the system for SAFED element 2.

Investigations were undertaken between TRL and Thales to decide how to proceed with the items for which the automated system appeared incapable of reaching a sufficient level of agreement with the trainer scores. It was concluded that beyond items for which the automated system is sufficiently accurate, the remaining items can be separated into two categories.

The first category is those items for which the assessment made by a human examiner is likely to encompass issues that are difficult or impossible to detect in the data-streams produced by the simulator. These items are comparable to the issues such as Driving Position and Driver's Attitude that were rejected initially.

The first item for which this is true is Steering (6). The guide to driver assessment within the SAFED standard document refers to the correct positioning of the driver's hands on the steering wheel as one of the key metrics and since this cannot be assessed by the simulator, the item must be rejected.

The second item falling into this category is Overtaking (14). It was decided that there are tactical decisions that a driver makes when overtaking that whilst not impossible it would be very hard to assess using the simulator data as it is captured in its current form. This is compounded by the limited number of occasions where the driver is required to perform an overtaking manoeuvre within the current simulator exercises. For the future development of the technology it has been concluded that there are approaches that merit investigation to understand the opportunity provided by capturing more appropriate data. However within the scope of this phase of the SCOTSIM the timeframes and resources available create technical constraints.

The second category of items is those items in which the vigilance that the simulator is able to achieve is perhaps greater than that of a human examiner.

The items for which this is true are Clutch Control (3), Speed (9), Lane Discipline and Positioning (10), and Use of Signals (13).

In assessing performance in these criteria, a human examiner may observe behaviour for a short period before coming to a judgement about performance that would only be changed if the trainee makes a glaring error. A simulator is able to parse data constantly to detect any low level mistakes that may be missed by a human examiner.

Whilst the judgement reached by the human examiner may be more valid in terms of overall driving style appropriate to the driving task, the simulator assessment is also a meaningful contribution to the evaluation of the driver.

Table 4.4 summarises the status of the automated scoring system.

Table 4.4 Categorisation of the scoring elements based upon utility of the automated scoring system

Category 1 *Agreement between simulator and trainer*	**Category 2** *Disagreement between simulator and trainer but meaningful assessment by simulator*	**Category 3** *Simulator not suited to assessment (in current configuration)*
1. Acceleration and Cruise Control	3. Clutch Control	4. Driving Position/Seat Belt
2. Braking	9. Speed	5. Road and Weather Conditions
7. Gear Selection and Use	10. Lane Discipline and Positioning	6. Steering
8. Hazard Perception and Prioritisation	13. Use of Signals	12. Use of Mirrors and Blind Spots
11. Making Progress and Planning		14. Overtaking
15. Vehicle Sympathy		16. Driver's Attitude/Technique
17. Reaction to Road Signs and Markings		

For implementation of the automated scoring system, Category 1 items have been implemented and will provide an automated score of driver performance that should match the score that would be given by a trained instructor.

For category 2 items, there is no requirement to match the score given by an instructor. Consequently, for those items the score will be based upon an average TRUST scoring made within each relevant criterion. G and D trainees are defined as the 20% lowest and highest marks in the studied batch of trainees.

For category 3 items, the simulator will provide no automated assessment of performance and feedback must therefore be provided by the instructor.

4.4 TRL validation of scoring system calibration

In addition to the work completed by Thales in establishing the link between the automated assessments and trainer scores, TRL called upon internal statistical experts to conduct an investigation into this procedure to ensure that the most appropriate and statistically rigorous techniques were applied.

Rather than use correlation to establish the link between automated scores and trainer scores, a discriminant function analysis was conducted. This determines the variables which discriminate between groups and in this case, picks out the assessment criteria that discriminate between the three scoring levels (G/F/D) for each SAFED element.

The TRL analysis gave results that were broadly similar to those demonstrated by Thales' approach using correlation, suggesting that the Thales approach was appropriate for the purposes of the automated scoring system.

TRL also conducted a brief investigation into the intra- and inter-trainer variability in scores given to trainees in the SCOTSIM programme. This revealed that there was cause for concern over the acceptance of trainer scores as the 'gold standard' by which the automated system should be judged and demonstrated that even with perfect assessment criteria and a precisely calibrated automated scoring system, it would be impossible to achieve perfect agreement between the automated process and a human examiner.

TRL and Thales agreed that one approach to mitigating the differences would be to increase the trainer awareness of the discrete assessment criteria on which the simulator scores were based. Scoring consistency, both between trainers and the system and between trainers themselves would be anticipated to improve.

5 Results

5.1 Analysis and evaluation of training: Phase I

The results described in the following section refer to the drivers trained as part of the phase I training process that took place between August 29, 2005 and April 27, 2006.

5.1.1 Participant profile

5.1.1.1 Age, sex, and experience

Table 5.1 Age and experience profile of drivers attending the SCOTSIM training programme

	Driver age (years)	Years as professional truck driver
N	640	627
Mean	41.7	13.9
Minimum	18	0
Maximum	72	45
SD	9.57	10.4

Of the 641 participants, there were 635 males (99.1%) and 6 females (0.9%). Participants were drawn from 86 companies based in Scotland, some supplying more than 30 drivers.

5.1.1.2 Age and experience groups

Table 5.2 Frequency tables for age and experience groups for drivers attending the SCOTSIM training programme

	Driver age group			Experience as professional truck driver group	
Years	Count	%		Count	%
25 and under	37	5.8%	up to 1 year	67	10.7%
26 to 40	253	39.5%	1 to 5 years	88	14.0%
41 to 55	293	45.8%	6 to 10 years	124	19.8%
56 and over	57	8.9%	more than 10 years	348	55.5%
Total	640	100.0%	Total	627	100.0%

5.1.2 Driver drop-out

Simulator sickness is a condition with symptoms similar to motion sickness and occurs for some users when experiencing apparent motion through a virtual environment. Table 5.3 shows the number of drivers that dropped out of the programme due to symptoms of simulator sickness. The table is broken down by driver age group and simulator.

Table 5.3 Driver drop-out due to simulator sickness broken down by age group and simulator type

Simulator	Driver age group	N	N dropped out	% drop-out
T5000	25 and under	24	4	16.7
	26 to 40	185	27	14.6
	41 to 55	213	57	26.8
	56 and over	42	12	28.6
	Total	464	100	21.6
T3000	25 and under	13	1	7.69
	26 to 40	64	21	32.8
	41 to 55	78	28	35.9
	56 and over	14	5	35.7
	Total	169	55	32.5
Total	25 and under	37	5	13.5
	26 to 40	249	48	19.3
	41 to 55	291	85	29.2
	56 and over	56	17	30.4
	Total	633	155	24.5

Table 5.3 shows that the T3000 had a significantly higher level of simulator sickness with nearly one in three drivers unable to complete the training programme due to symptoms of simulator sickness. It is also apparent that drivers in the younger age groups appear to be less susceptible to simulator sickness. This could be for physiological reasons such as better eyesight or for psychological reasons whereby younger drivers are more tolerant of the technology and therefore less stressed during training on the simulator. More detailed analysis of the incidence of simulator sickness and steps taken to reduce its occurrence can be found in section 6.

5.1.3 Effect of training

The fuel used, number of gear changes and time taken to complete the exercises were recorded and used to compare performance across drives 1 and 2. Table 5.4(a) shows how these measures changed for all drivers that completed drives 1 and 2, whilst Table 5.4(b) shows the mean percentage changes in each measure and the 95% confidence interval on that mean percentage change. The 95% confidence interval is a measure of data variance and indicates the upper and lower values within which the true mean value lies.

Table 5.4(a) Mean performance in drives 1 and 2

	Time taken (sec)		Number of gear changes		Fuel used (litres)	
	Drive 1	**Drive 2**	**Drive 1**	**Drive 2**	**Drive 1**	**Drive 2**
N	448	448	448	448	448	448
Mean	2007	1794	109	86	1.92	1.68
SD	203.2	122.3	31.9	21.2	0.39	0.26
Overall % change	Down 10.6%		Down 20.8%		Down 12.5%	

Table 5.4(b) Mean percentage change across drivers in measures between drives 1 and 2

		Time taken (sec)	Number of gear changes	Fuel used (litres)
	N	448	448	448
	Mean % improvement	9.98%	15.6%	10.8%
95% Confidence Interval	Lower bound	10.8%	18.7%	12.0%
	Upper bound	9.18%	12.4%	9.71%

Table 5.4(a) shows how participants on average achieved significant reductions in time taken, number of gear changes, and fuel used. Table 5.4(b) shows that the confidence intervals are tight for the changes in Time taken and Fuel used but wider for the percentage change in the number of gear changes.

The difference between the *overall* percentage changes reported in table 5.4(a) and the *mean* percentage change reported in table 5.4(b) are due to the different methods of calculation. The percentage change values reported in table 5.4(a) are found by calculating the percentage difference between the mean values in drive 1 and drive 2 for all drivers in phase I. The percentage change values reported in table 5.4(b) are found by calculating the percentage change for each driver drive 1 and drive 2 and taking a mean of the percentage change values for all drivers in phase I. In each case, a negative percentage value means an improvement (less time, fewer gear changes, less fuel) so these figures the sign on each value was reversed to give a more intuitive percentage *improvement* value.

Figure 5.1 shows how the percentage improvement between the two drives for all participants who completed both drives, broken down by the experience level of the participant.

Figure 5.1 Percentage improvement in the time taken, number of gear changes, and fuel used in completing drives 1 and 2

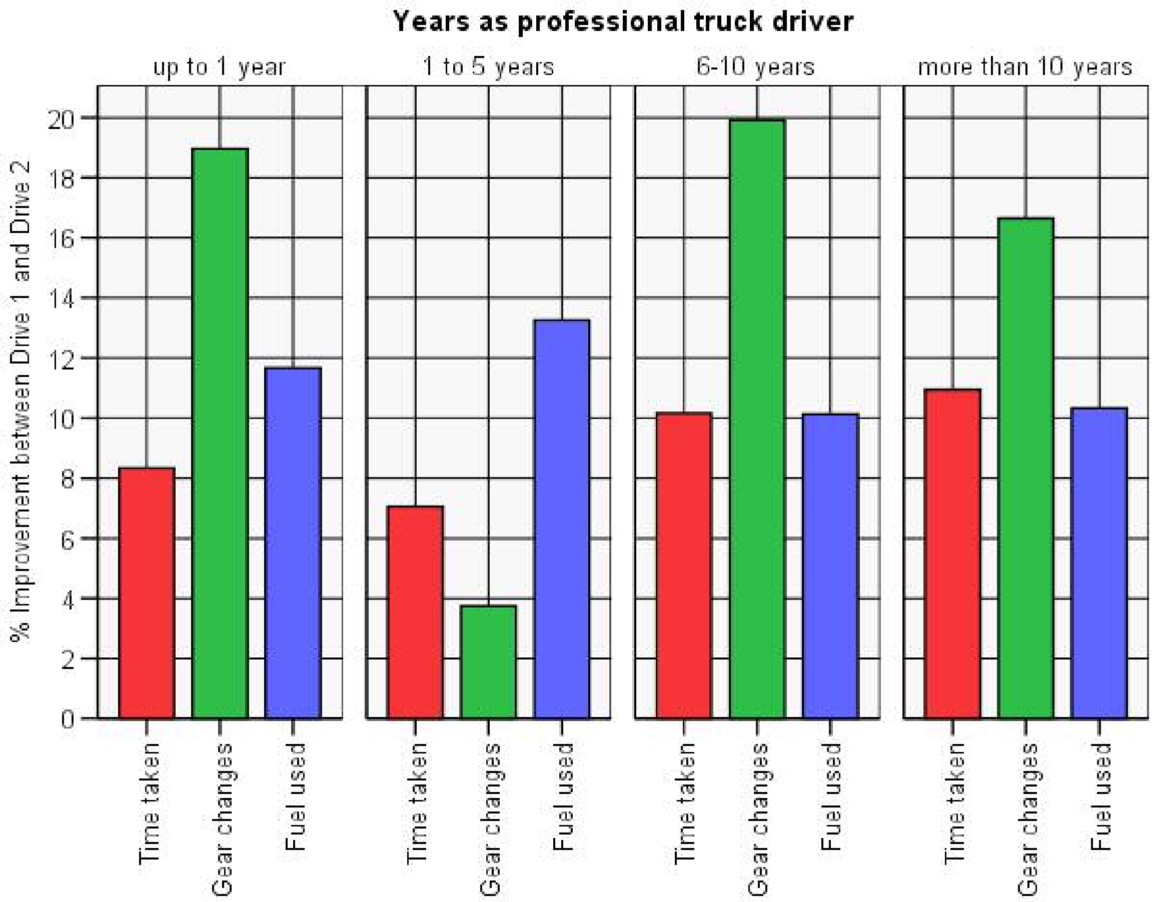


Figure 5.1 shows that drivers from all experience groups tended to show significant improvements in their performance in drive 2, recording faster completion times, fewer gear changes, and reduced fuel consumption. Interestingly, the 1-5 years experience group showed the smallest reduction in the time taken to complete the exercises and in number of gear changes made but they also made the largest improvement in fuel consumption. In other groups, the improvements in performance were relatively consistent.

5.1.4 SAFED scores

The trainer responsible for each driver monitored their performance and scored them on the seventeen SAFED criteria. The road/weather conditions (SAFED criterion 5) did not change through the route so all drivers were awarded G in that criterion.

5.1.4.1 Drive 1

In drive 1, the most common SAFED criterion on which drivers score a mark of D was 7 (Gear Selection and Use) where 65.8% (N = 518) of drivers were awarded the lowest rating. The next lowest scores were in criteria 1 (Acceleration and Cruise Control) and 8 (Hazard Perception and Prioritisation) where 56.9% (N = 518) and 52.9% (N = 518) of drivers were awarded the lowest mark. The highest scores in relevant driving criteria were achieved on SAFED criterion 17 (Reaction to Road Markings and Signs) in which 71.9% (N = 513) of drivers were awarded a ‘G’ rating. The mean overall SAFED score for drive 1 was 20.3 (N = 513; SD = 8.42).

5.1.4.2 Drive 2

In drive 2, drivers showed significantly improved SAFED scores. The most common criterion on which to pick up a score of D was 10 (Lane Discipline and Positioning) where 12.6% (N = 467) of drivers scored the lowest mark. Highest scores in driving criteria were achieved in criterion 14 (Overtaking) where 92.0% (N = 427) achieved a 'G' rating. The mean total SAFED score for drivers in drive 2 was 6.72 (N = 462; SD = 4.03). This is clearly significantly lower than their scores in drive 1, confirmed by a paired-samples t-test ($t(456) = 45.3$; $p \ll 0.001$).

5.1.4.3 Overall scores

Drivers' mean total SAFED score for both drives was 28.0 (N = 457; SD = 10.3). Allocating pass marks according to the SAFED standard, 73 drivers (16.0%) would have achieved a 'Pass with distinction; 263 drivers (57.5%) would have achieved an 'Ordinary pass'; and 121 drivers (26.5%) would have scored a 'Fail' mark. Drivers frequently ended up in the 'Fail' category because they picked up many faults in their first drive, making it very difficult or impossible to achieve a pass mark. Indeed, 30 drivers scored 34 faults or more in their first drive alone. The poor scores recorded in drive 1 may be attributable to drivers being unfamiliar with the simulator technology.

5.1.5 *Subjective experience*

Participants were required to complete a number of questionnaires as part of the training programme. This section summarises their responses.

5.1.5.1 Learning experience

Figure 5.2 shows participants' average level of agreement with a number of different statements relating to their learning experience in the truck simulators.

Figure 5.2 Mean level of agreement with a number of statements relating to drivers' learning experience

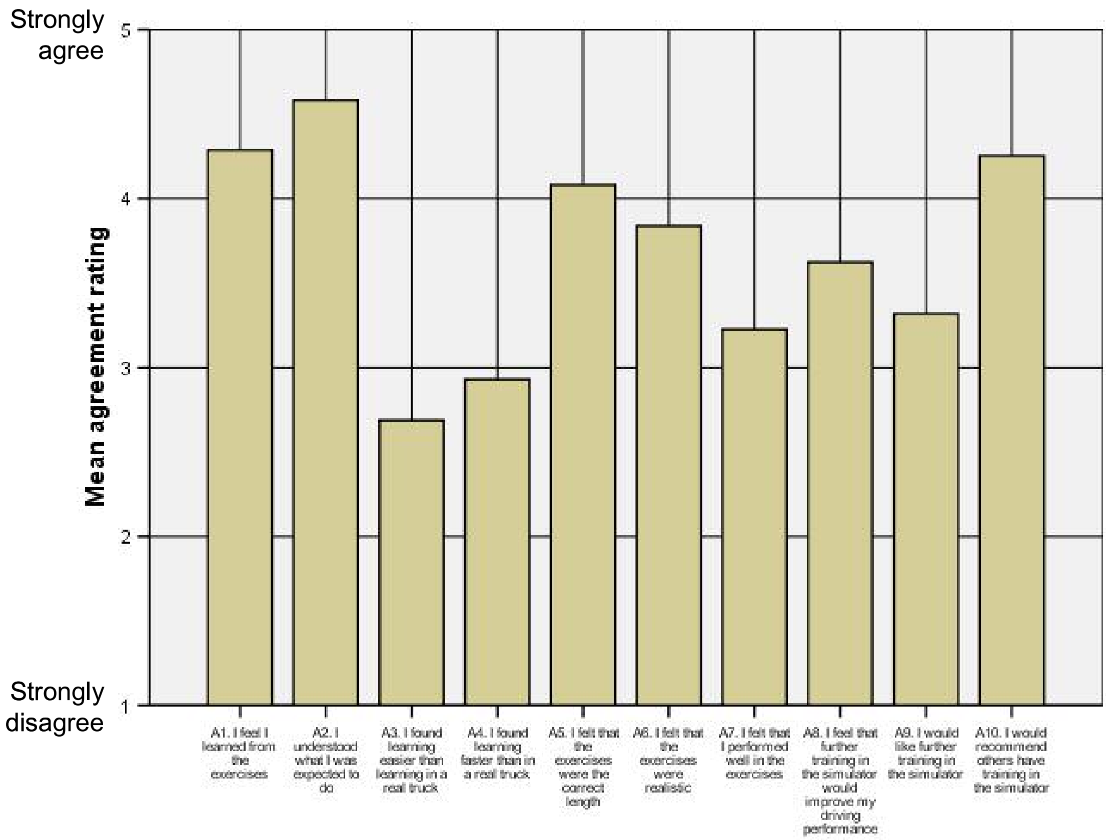


Figure 5.2 shows that drivers felt that they learned from their experience in the simulator and would be keen to recommend simulator training to others. The lowest rated item was agreement with the statement "I found it easier than learning in a real truck". Given the new circumstances under which the training was conducted, this is unsurprising. However, there is not overwhelming disagreement with this statement, suggesting that drivers typically did not find it much more difficult than learning in a real truck.

5.1.5.2 Similarity of the simulator to a real truck

Figure 5.3 shows how drivers rated the similarity of the simulator vehicle to a real truck.

Figure 5.3 Mean rating of similarity between the simulator and a real truck for a number of different items

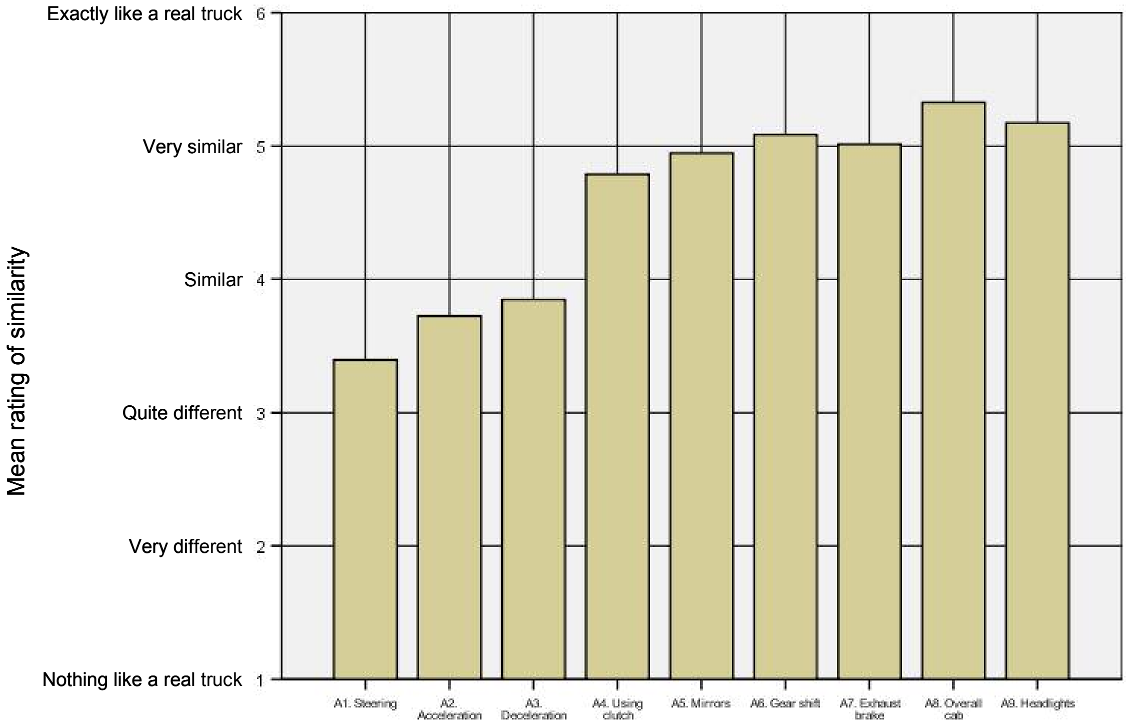


Figure 5.3 shows that drivers rated the steering as the least realistic item with acceleration and deceleration also given relatively low ratings. The low ratings for these items reflect the limitations of the motion system to provide the driver with the expected acceleration cues. Incidentally, the ratings for the T3000 and the T5000 (with a larger scale motion system) for these items did not differ. For each of the other items the similarity of the simulator to a real truck is rated highly.

5.1.5.3 Experience on the day

Figure 5.4 shows how drivers rated their experience of the SCOTSIM training programme.

Figure 5.4 Mean rating of aspects of the training programme

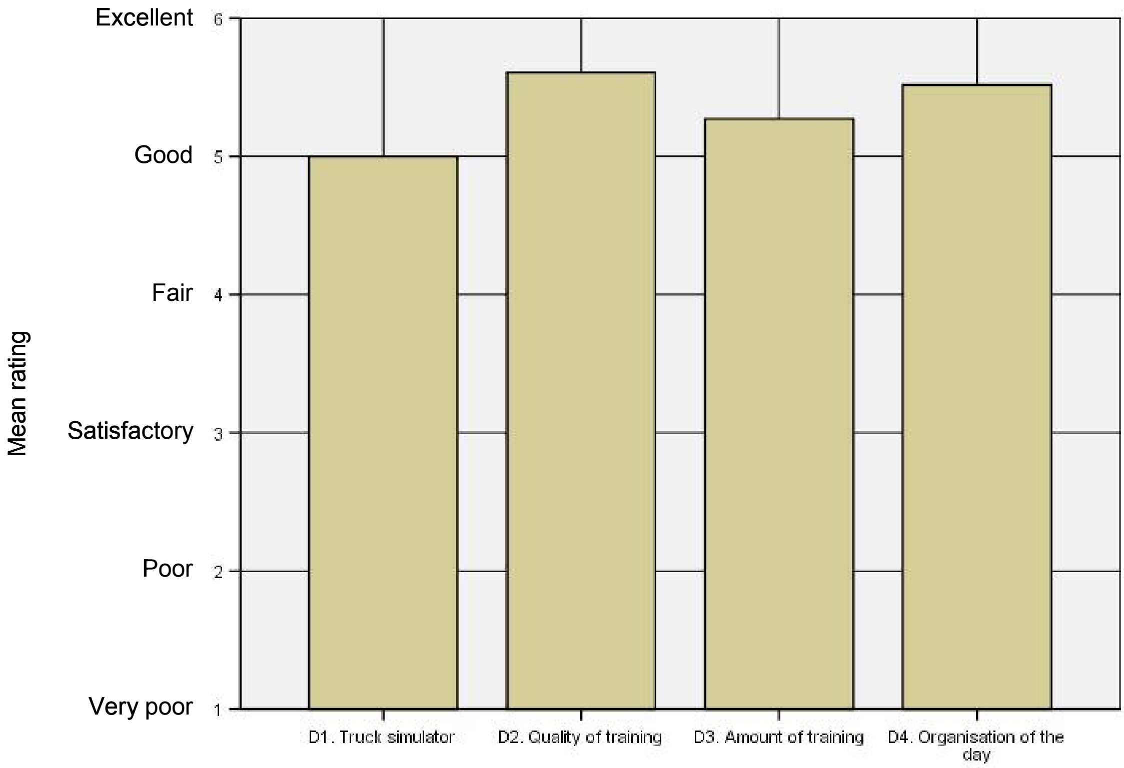


Figure 5.4 shows that participants rated all aspects of the training programme highly with the simulator, the quality and amount of training, and the organisation of the day all achieving mean ratings between the 'Good' and 'Excellent' categories. The simulator achieves the lowest of the ratings given and this is to be expected given the discomfort that some of the participants felt caused by simulator sickness. Yet the rating for the simulator is still relatively high, indicating the positive feelings participants had towards the simulator technology. Again no statistical difference was observed between the ratings given for drivers on the T5000 and those on the T3000.

5.1.6 Summary

The SCOTSIM project recruited 641 professional commercial vehicle drivers as part of the phase 1 training programme. These participants came with a wide range of backgrounds and experience levels. The main flaw in the programme was the incidence of simulator sickness which resulted in the withdrawal of nearly one quarter of participants from the programme due to feelings of discomfort caused by the simulator. However, following completion of phase 1, steps were taken to reduce this drop-out rate.

Drivers demonstrated significant improvements in their driving performance between drives 1 and 2, suggesting that the training and feedback given by the trainer was having some effect. Drivers achieved significant fuel savings whilst also reducing the time taken to complete the exercise. A proportion of that improvement may be due to participants becoming more familiar with the simulator technology however, the margin of improvement suggests that drivers were demonstrating better driving practices. If the skills learned in the simulator transfer to behind the wheel of drivers' real vehicles (as has been shown in other studies e.g. Parkes & Reed, 2005), then the value of the simulator training will be realised.

Participants were largely positive about their training experience. The similarity between the simulator and a real truck was highly rated. The only elements to receive low ratings were the steering and acceleration/deceleration forces. These items are influenced by the limitations of the motion system which, without making hugely expensive and impractical modifications, is unable to provide drivers with forces that more closely represent those that would be experienced on the real road. In all other aspects, the simulators' similarity to a real truck was relatively highly rated. Finally, drivers appeared to rate highly their experience on the day, reporting the simulator, the quality/amount of training, and the organisation of the day as 'Good' to 'Excellent'.

5.2 Revised training protocols: Phase II

The results described in the following section refer to the drivers trained as part of the phase II training process that took place between August 24, 2006 and November 10, 2006.

5.2.1 Participant profile

5.2.1.1 Age, sex, and experience

Table 5.5 Age and experience profile of drivers attending the SCOTSIM training programme in phase II

	Driver age (years)	Years as professional truck driver
N	69	68
Mean	40.4	11.6
Minimum	22	0
Maximum	63	41
SD	9.21	10.7

Of the 69 participants, there were 68 males (98.6%) and 1 female (1.4%). Independent-samples t-tests confirm that there were no significant differences in the age, sex, and experience profiles of the 69 participants in phase II when compared to the 641 drivers recruited in phase I.

5.2.1.2 Age and experience groups

Table 5.6 Frequency tables for age and experience groups for drivers attending the SCOTSIM training programme in phase II

Years	Driver age group			Experience as professional truck driver group	
	Count	%		Count	%
25 and under	4	5.8%	up to 1 year	18	26.5%
26 to 40	31	44.9%	1 to 5 years	9	13.2%
41 to 55	29	42.0%	6 to 10 years	9	13.2%
56 and over	5	7.2%	more than 10 years	32	47.1%
Total	69	100.0%	Total	68	100.0%

Table 5.6 shows that the numbers of drivers within each age group match approximately those in phase I. In terms of experience, the least experienced driver group represents a greater proportion of drivers than in phase I with a lower percentage of drivers from each of the two highest experience categories.

5.2.2 Driver drop-out

The drop out rates in phase II were virtually identical to those in phase I, with a around one in three drivers dropping out on the T3000 (33.3%) and approximately one in five drivers dropping out on the T5000 (21.4%). The overall drop-out rate was 26.1%. However, calculation of the post-drive SSQ scores shows that reported sickness levels were down by more than 30% in phase II, significantly lower than the scores observed in phase I. The implications of the reduction in SSQ scores are discussed in section 5.3.

5.2.3 Effect of training

As in phase I, the fuel used, number of gear changes and time taken to complete the exercises were recorded and used to compare performance across drives 1 and 2. Table 5.7(a) shows these measures changed for all drivers that completed drives 1 and 2 in phase II, whilst table 5.7(b) shows the mean percentage changes across drives for each measure with 95% confidence intervals.

Table 5.7(a) Mean performance in drives 1 and 2 for drivers in Phase II

	Time taken (sec)		Number of gear changes		Fuel used (litres)	
	Drive 1	Drive 2	Drive 1	Drive 2	Drive 1	Drive 2
N	49	49	49	49	49	49
Mean	1963	1778	112	86	1.91	1.60
SD	153.7	99.8	26.7	17.9	0.34	0.18
% change	Down 9.42%		Down 23.2%		Down 16.2%	

Table 5.7(b) Mean percentage change across drivers in measures between drives 1 and 2 in Phase II

		Time taken (sec)	Number of gear changes	Fuel used (litres)
	N	49	49	49
	Mean % change	-9.06%	-20.4%	-14.2%
95% Confidence Interval	Lower bound	-10.8%	-25.9%	-17.8%
	Upper bound	-7.30%	-15.0%	-10.7%

Tables 5.7(a) and (b) show how participants achieved significant reductions in time taken, number of gear changes, and fuel used in the exercises. Table 5.7(b) indicates that the confidence intervals were larger for phase II drivers but this is to be expected with a sample size that is one tenth the size of that available in phase I. The reductions in each measure for phase I drivers were of similar magnitude and the mean percentage changes for each measure in phase I are within the confidence intervals observed in phase II. Table 5.8 shows the mean percentage change for each measure between drives 1 and 2 for all drivers in phases I and II.

Table 5.8 Mean percentage change across drivers in measures between drives 1 and 2 in Phases I and II

		Time taken (sec)	Number of gear changes	Fuel used (litres)
	N	510	510	510
	Mean % change	-10.1%	-16.3%	-11.4%
95% Confidence Interval	Lower bound	-10.9%	-19.1%	-12.5%
	Upper bound	-9.21%	-13.4%	-10.3%

Figure 5.5 compares how these measures changed between the two drives across phases I and II for all participants who completed both drives, broken down by the experience level of the participant.

Figure 5.5 Percentage improvement in the time taken, number of gear changes, and fuel used in completing drives 1 and 2

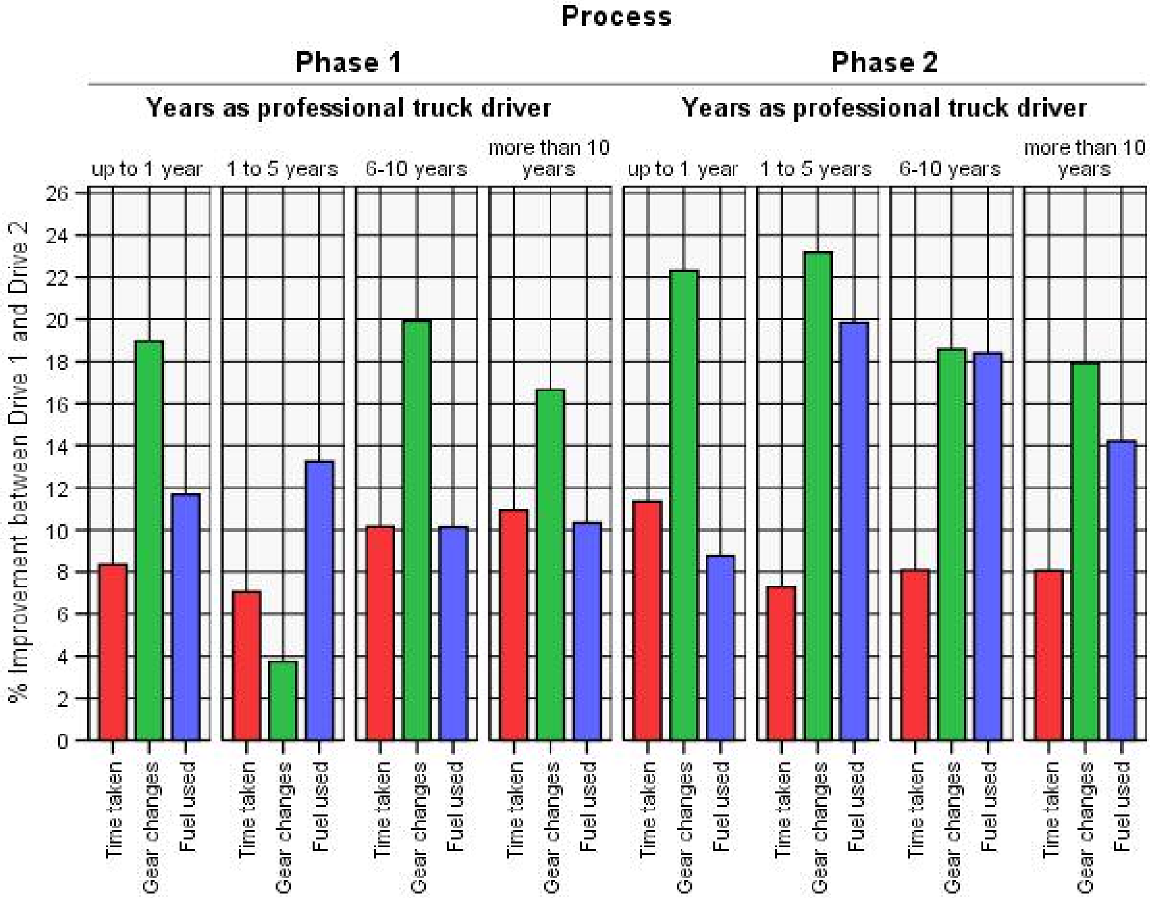


Figure 5.5 shows that drivers in phase II tended to make bigger percentage improvements in the number of gear changes made within the exercise. Drivers in phase II improved to the same level as drivers in phase I in terms of number of gear changes. It is also apparent that drivers in the three more experienced categories made bigger percentage fuel savings than drivers in phase I. Performance in drive 1 is essentially the same across phases I and II so this effect is due to drivers completing drive 2 even more fuel efficiently in phase II. As in phase I, the 1-5 years experience group showed the smallest improvement in the time taken to complete the exercises and made the largest improvement in fuel consumption but unlike phase I, this group also made the largest percentage improvement in the number of gear changes made.

5.2.4 SAFED scores

In phase II, the profile of the SAFED scores achieved by drivers were largely similar to those observed in phase I but a lower overall standard was observed. In drive 1, drivers performed least well in SAFED criterion 7 (Gear Selection and Use) and best in SAFED criterion 17 (Reaction to Road Markings and Signs). The mean SAFED score in drive 1 for drivers in phase II was slightly higher than in phase I at 25.3 (N = 44; SD = 5.49). In drive 2, drivers again showed significantly improved performance. However, unlike phase I, it was criterion 15 (Vehicle Sympathy) in which drivers achieved the best scores. The mean total SAFED score for drive 2 in phase II was 10.1 (N = 41; SD = 4.43). No drivers would have achieved a “Pass with distinction’ in phase II but 17 drivers (41.5%) would have achieved an ‘Ordinary pass’, whilst 24 drivers (58.5%) would have failed the course. Again, it is poor performance in drive 1 that hampered drivers’ chances of achieving a pass mark and this is perhaps a significant problem with the construction of the SAFED scoring system in that drivers can have failed the course before they have received any tuition. The difference in driver ratings between phase I and phase II may also reflect inter-rater differences.

5.2.5 Subjective experience

Participants were required to complete a number of questionnaires as part of the training programme. This section summarises their responses.

5.2.5.1 Learning experience

Figure 5.6 shows participants' average level of agreement with a number of different statements relating to their learning experience in the truck simulators.

Figure 5.6 Mean level of agreement with a number of statements relating to drivers' learning experience in phase II

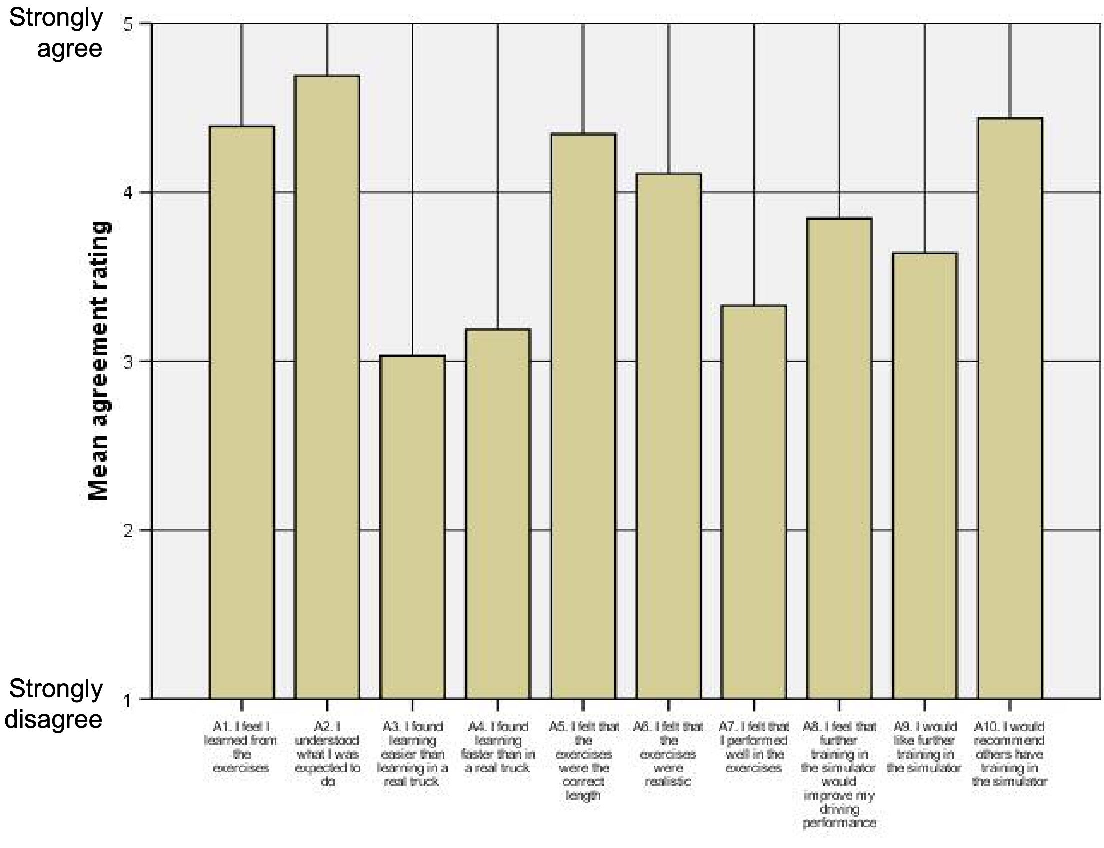


Figure 5.6 shows that drivers' response in phase II were very similar to those observed in phase I (see figure 5.2). Drivers again reported that they felt they learned from their experience in the simulator and would be keen to recommend simulator training to others. As in phase 1, the lowest rated item was agreement with the statement "I found it easier than learning in a real truck" but the level of agreement with this statement is still closer to agreement than disagreement.

5.2.5.2 Similarity of the simulator to a real truck

The ratings given by drivers in phase II to the similarity of the simulator to a real truck in various criteria were very similar to those observed of drivers in phase I. Again, drivers rated the steering as the least realistic item with acceleration and deceleration also given relatively low ratings. For each of the other items the similarity of the simulator to a real truck is rated highly.

5.2.5.3 *Experience on the day*

Figure 5.7 shows how drivers rated their experience of the SCOTSIM training programme.

Figure 5.7 Mean rating of aspects of the training programme in phase II

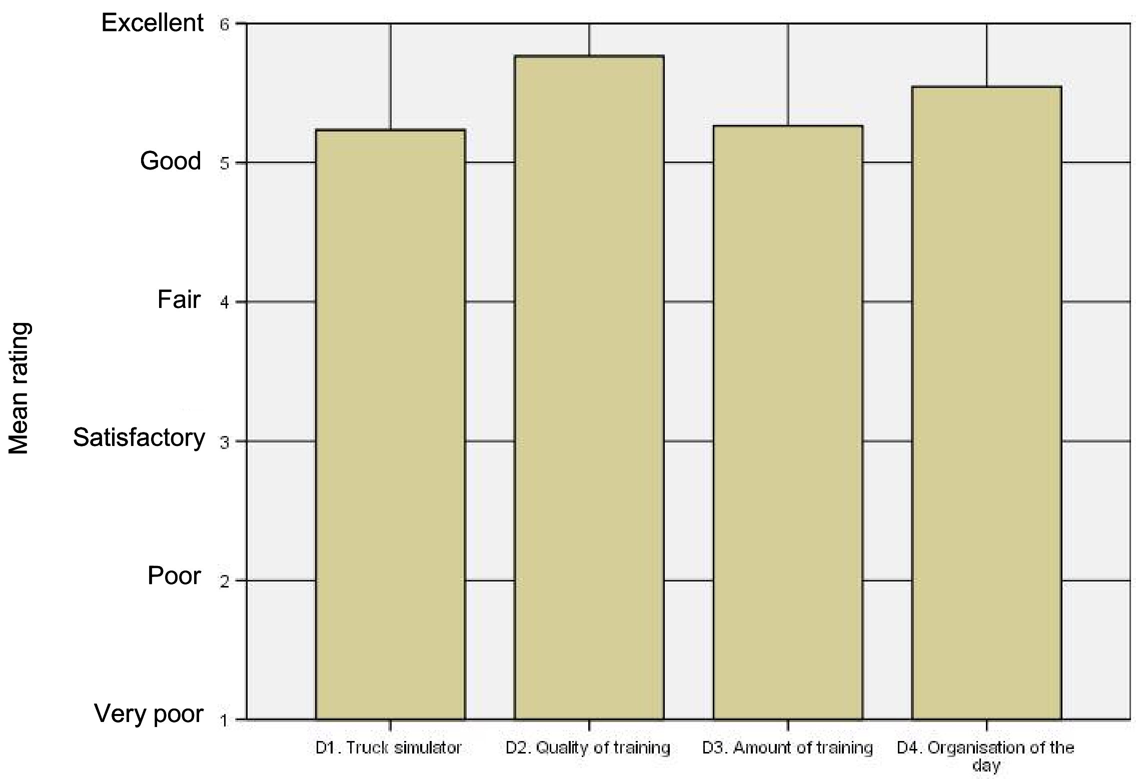


Figure 5.7 shows that participants in phase II again rated all aspects of the training programme highly with the simulator, the quality and amount of training, and the organisation of the day all achieving mean ratings between the ‘Good’ and ‘Excellent’ categories. Compared to phase I, drivers rated the truck simulator and quality of training even higher than in phase I, in fact an independent samples t-test confirms that for the quality of training item this difference was significant ($t(685) = -2.171$; $p = 0.030$). This suggests that within phase II, the training process had become further refined to a very high standard.

5.2.6 Summary

The drivers recruited in phase II fulfilled the contractual requirement to deliver 700 drivers through the SCOTSIM training programme. However, it was useful to compare the performance and opinions of this additional batch of drivers to those recorded in phase I to assess whether the training process had changed in any way. Results demonstrated that drivers in phase II improved their performance following simulator training by similar amounts as drivers in phase I. It was also found that technical revisions to the simulator technology had caused the reported sickness level to fall considerably. Phase II participants reported that the quality of the training process was even higher than was reported by drivers in phase I, possibly due to the trainers becoming more experienced with using the simulator technology and the general simulator training process.

5.3 Trainer variability

The variation in SAFED scores and pass rate observed between phase I and phase II suggested that it would be of interest to conduct an analysis of the variability in scores awarded by the different trainers in the SCOTSIM programme. Table 5.9 shows the frequency of pass marks awarded by the different trainers across phases I and II.

Table 5.9 Frequency of pass marks awarded by examiners in phases I and II of the SCOTSIM training programme.

Trainer		Pass with distinction	Ordinary pass	Fail	Total
1	Count	3	37	12	52
	%	5.8%	71.2%	23.1%	100.0%
2	Count	0	4	9	13
	%	0.0%	30.8%	69.2%	100.0%
3	Count	5	90	61	156
	%	3.2%	57.7%	39.1%	100.0%
4	Count	49	80	8	137
	%	35.8%	58.4%	5.8%	100.0%
5	Count	10	40	36	86
	%	11.6%	46.5%	41.9%	100.0%
6	Count	5	7	3	15
	%	33.3%	46.7%	20.0%	100.0%

It is clear from table 5.9 that there is significant variation in the ratings given by different examiners in the SCOTSIM training programme. A key comparison is between trainers 3 and 4, who had the highest driver throughput. Since trainers 3 and 4 each trained more than 100 drivers each, it could be expected that driver ability would be normally distributed across the drivers assigned to each trainer. However, there is a significant difference in the frequency of the pass marks awarded whereby 4 appears to have a higher pass award rate than 3. The disparity in pass marks awarded is too large to be explained by variation in the drivers for which each examiner was responsible and would suggest that each examiner had distinctly different scoring protocols, despite all trainers involved being trained to the SAFED standard before commencing training on the SCOTSIM programme.

Table 5.10 shows the mean scores awarded by trainers 3 and 4 in drive 1 and drive 2.

Table 5.10 Mean scores awarded in drive 1 and drive 2 of phases I and II by trainers JM and KD

	Trainer	N	Mean fault score	SD
Drive 1	3	158	24.3	6.51
	4	177	14.0	6.65
Drive 2	3	149	8.86	4.05
	4	139	5.59	3.29
Total score	3	149	33.0	9.19
	4	137	21.4	8.14

Table 5.10 shows that trainer 3 awarded higher fault scores both drives, particularly in drive 1. Trainer 3's mean total fault score was 33.0. This is one point below the threshold for passing the course, thus explaining the high proportion of fail marks awarded by trainer 3. Independent-samples t-tests confirm that the comparison between scores awarded by trainers 3 and 4 in drive 1, drive 2, and overall differed significantly (Drive 1: $t(333) = 14.3$; $p < 0.001$); Drive 2: $t(286) = 7.48$; $p < 0.001$; Total score: $t(284) = 11.2$; $p < 0.001$).

Tables 5.9 and 5.10 are not intended to indicate that one trainer has more astute judgement than another but to demonstrate the variability that can exist in the judgement of experienced and qualified driver trainers.

5.4 Revised training protocols: Module Evaluation

Four new modules were created to expand the range of skills on which rivers could be trained using SCOTSIM. These were the Hazard Perception; Driver Attitude; Slow Speed Manoeuvres; and Emergency Manoeuvres modules. A module consisted of four or five exercises, each with a different training purpose. A small sample of drivers were recruited to validate the modules and to provide some subjective feedback on the learning potential of each new module.

5.4.1 Participant profile

5.4.1.1 Age and experience

Thirty-three drivers were recruited to take part in the module evaluation. Each was randomly assigned to a different module.

Table 5.9 Age and experience profile of drivers participating in the module evaluation programme

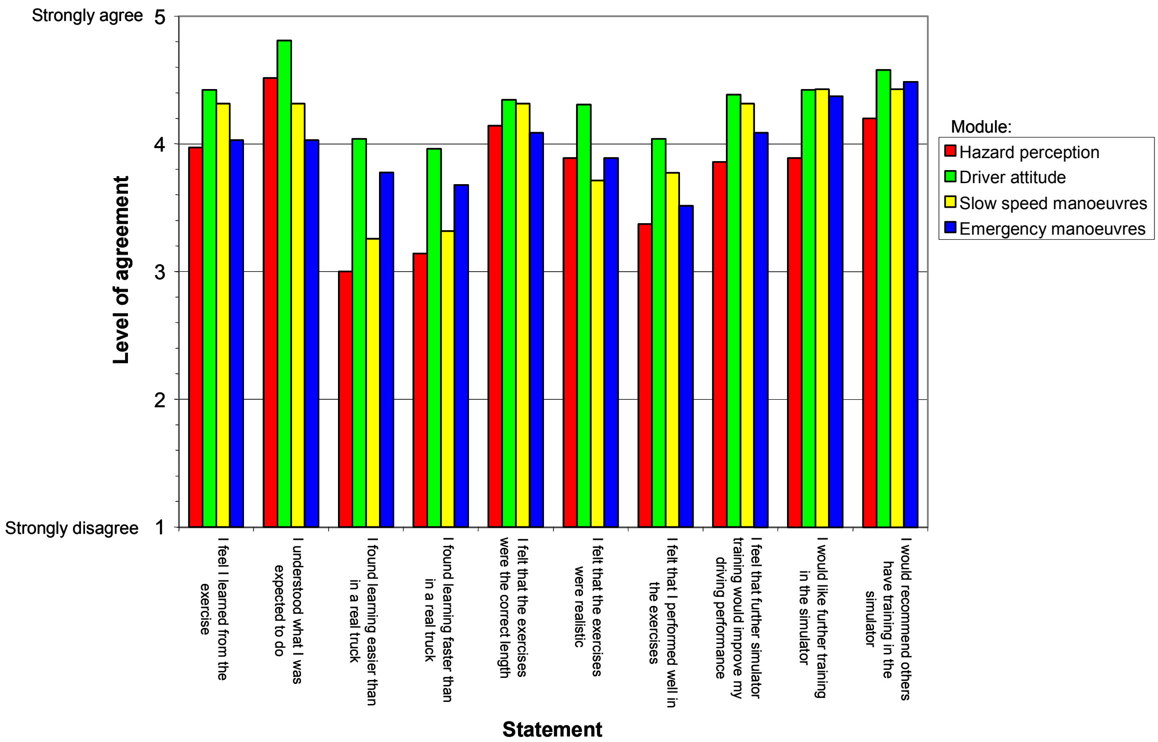
	Driver age (years)	Years as professional truck driver
N	31	29
Mean	32.4	5.37
Minimum	19	0
Maximum	47	21
SD	9.39	6.94

Table 5.9 demonstrates that the drivers used to assess the modules were considerably younger than the drivers participating in the main training programme and had less experience as professional commercial vehicle drivers. This is useful as inexperienced drivers are likely to be the target for such training courses. However, the views of experienced drivers who have attained the required skills would have been useful.

5.4.2 Subjective views of the new modules

Participants filled in a questionnaire after each exercise within their assigned module asking them to state their agreement with a number of statements. Figure 5.8 shows the mean level of agreement with each statement with items combined across modules.

Figure 5.8 Mean agreement with a number of statements relating to each exercise within each new module



Since a high level of agreement with each statement indicates a positive response towards the exercise, figure 5.9 demonstrates that all of the modules were reasonably well received by the participating drivers. The Hazard Perception exercises appear to achieve the lowest scores whilst the Driver Attitude module achieved the highest scores. All modules scored over four out of five when drivers were asked whether they would recommend others have simulator training based on their experience of the exercises/module. Similarly, high agreement scores were achieved by all modules in drivers' responses to the statements "I feel I learned from the exercise", "I understood what I was expected to do", and "I felt that the exercises were the correct length". These results suggest that drivers found that the modules were appropriate for driver training and would help drivers to improve their skills. Interestingly, all modules scored three or greater (indicating positive agreement) in relation to the statements "I found learning easier than in a real truck" and "I found learning faster than in a real truck". This would suggest that drivers felt that simulation was appropriate for the tasks in which they were being trained.

6 Driver drop-out and the incidence of simulator sickness

6.1 Introduction

This section serves to define simulator sickness, report its observed incidence through phase I of the SCOTSIM training programme, and to describe countermeasures taken to reduce its occurrence and the result of their application.

Simulator technology is well established in the aircraft industry for pilot training. It offers the trainee the opportunity to experience (potentially dangerous) training scenarios repeatedly in a safe environment where performance can be studied and reviewed with a high degree of accuracy. With the increased availability of low cost computer technology capable of displaying realistic virtual environments and managing complex vehicle dynamics calculations, simulators are now being used for training in other domains such as road vehicles. However, an important problem that to some degree afflicts all simulators based on virtual environments is simulator sickness (sometimes called simulator adaptation syndrome).

Symptoms of simulator sickness can include eye strain, headache, pallor, sweating, dryness of mouth, fullness of stomach, disorientation, vertigo, dizziness, nausea, and vomiting. The accumulation of these symptoms can be sufficient to cause participants to withdraw from exposure to the simulation.

In the SCOTSIM project, the requirement was to provide simulator training for 700 professional truck drivers based in Scotland using two full mission truck simulators. The training objective of the programme was to improve drivers' fuel efficiency and to encourage safe driving habits. The simulator equipment was procured from Thales and comprised two related systems. The TRUST 3000 (T3000) was housed in an expandable trailer unit and was therefore mobile, providing training at various locations around the Scottish mainland. The TRUST 5000 (T5000) was installed at a fixed facility in Bellshill, near Glasgow, Scotland. The one major technical difference between the simulators is that the screens of the T3000 visual system are mounted on the floor, independent from the motion platform, whereas on the T5000, both the cabin and the visual system are installed on the motion platform. In all other aspects the operation of the simulators was identical.

As discussed, simulator sickness is an unavoidable side effect of apparent self motion through a virtual environment for a proportion of the population. It was therefore important to monitor its occurrence and where possible take steps to minimise the severity of symptoms.

6.2 Observed effects

There were two key measures of simulator sickness. The first was simply a measure of the number of drivers who were unable to continue with the training programme due to discomfort caused by the simulator. These are termed 'drop-outs'. The second was a subjective measure of sickness recorded using a standard and validated questionnaire. All drivers participating in the simulator training programme were required to complete the Simulator Sickness Questionnaire (SSQ) introduced by Kennedy, Lane, Berbaum, & Lilienthal (1993) before and after driving the simulators (questionnaire used is shown in Appendix D). In the SSQ, participants are required to rate the severity of a number of different symptoms on a four point scale: 'None'; 'Slight'; 'Moderate'; 'Severe'. An SSQ score can then be calculated from the responses where a higher score indicates more severe symptoms of sickness. The results for the two simulators are reported separately as they are based on different motion platforms and visual systems.

6.2.1 Driver drop-out

Table 6.1 shows the overall percentage drop-out rate observed on the T5000 and the T3000.

Table 6.1 The percentage drop-out rate of participants caused by simulator sickness in phase I of the SCOTSIM driver training programme

	T5000		T3000		Overall	
	N	%	N	%	N	%
Completed	364	78.4%	114	67.1%	478	75.4%
Dropped out	100	21.6%	56	32.9%	156	24.6%
Total	464	100.0%	170	100.0%	634	100.0%

Table 6.1 shows that there was a significantly higher drop out rate on the T3000, with approximately one in three drivers unable to complete the programme. On the T5000, the drop-out rate was nearer one in five participants.

6.2.2 Effect of T5000 motion system failure on SSQ and driver drop-out

A technical fault caused the motion system to be inoperative on the T5000 for approximately six weeks between September and October 2005. The simulator exercises could still be driven therefore training continued but the driver did not experience the motion cues that the system should provide. This allowed comparison of sickness rates with and without an active motion system. Table 6.2 shows the post-drive SSQ scores and percentage drop-out rates for drives completed on the T5000 with and without the motion system.

Table 6.2 Comparison of post drive SSQ scores and percentage drop-out rate of participant experiencing an active or inactive motion system on the T5000

	Motion status	N	Mean	SD
Post drive SSQ score	Active	350	27.6	35.4
	Inactive	96	18.2	25.6
% Drop-out rate	Active	363	24.0	42.7
	Inactive	101	12.9	33.7

Table 6.2 shows that both SSQ scores and drop-out rates were considerably lower when the motion system was inactive. This result suggests that the motion cuing system was not providing drivers with the appropriate motion cues to correspond to the visual changes that they were observing, leading to feelings of discomfort and sickness.

6.2.3 Effect of change to exercise order on SSQ and driver drop-out

From the start of the training programme at the end of August 2005 through to February 8, 2006, all trainees completed drives in the order Industrial; Village; Highway; City. It became clear that of the four training scenarios, the Village exercise was causing the most problems in terms of sickness. The decision was therefore taken to change the order of the drives such that drivers completed the Industrial and the Highway exercises first, then took a short rest break, then completed the Village exercise, then took another short rest break before completing the City exercise. This revised order was introduced to give trainees a longer period in the simulator (and therefore greater familiarisation with the technology) before tackling the Village exercise plus the addition of rest breaks to allow drivers greater time to recover between exercises. The Village exercise takes the longest time to complete of the four exercises and entails many sweeping bends and changes of gradient. This combination of features is possibly the reason for the high frequency of drop-out observed in the

Village exercise. It was anticipated that this combination of changes would reduce drop-out rates. Table 6.3 compares the SSQ scores and drop-out rates with the original and revised orders of exercise.

Table 6.3 Comparison of the post drive SSQ scores and percentage drop-out rate of participants experiencing the original and revised exercise orders

	Exercise order	N	Mean	SD
Post drive SSQ score	Original order	434	27.2	33.6
	Revised order	164	21.8	31.7
% Drop-out rate	Original order	467	24.4	43.0
	Revised order	167	25.2	43.5

Table 6.3 shows that despite participants reporting lower average SSQ scores in the revised order, drop-out rates were in fact very similar.

6.2.4 Correlations with SSQ and driver drop-out

To understand the factors contributing to the observed sickness rates, multi-factorial Pearson correlation procedure was performed to investigate which factors were strongly correlated with high SSQ scores and driver drop-out for drivers in phase I of the training programme. The first result was that drivers' SSQ scores were unsurprisingly highly positively correlated with drop-out ($N = 592$; $r = 0.60$; $p < 0.001$). Furthermore, drivers' age also showed a significant positive correlation with drop-out ($N = 633$; $r = 0.12$; $p = 0.003$). Four of the health characteristics showed positive correlations with drop-out. The strongest correlation was where the participant reported suffering from motion sickness ($N = 633$; $r = 0.32$; $p < 0.001$). There were also weak but significant correlations between driver drop-out and drivers who reported suffering with (respectively) migraine ($N = 633$; $r = 0.079$; $p = 0.047$), claustrophobia ($N = 634$; $r = 0.13$; $p = 0.001$), and brain damage ($N = 634$; $r = 0.080$; $p = 0.045$).

Drivers also completed a questionnaire that asked them to rate their agreement with each of 18 statements relating to the use of technology. Agreement was measured on six point scale (1-6) where a score of 1 indicated that the driver completely disagreed with the statement and a score of 6 indicated that the driver completely agreed with the statement. Correlations were taken between participants' agreement with these statements and SSQ scores and with driver drop-out. Eight of the statements showed significant correlations. These are shown in table 6.4. Note that correlations with statements that are generally positive towards technology are negative and correlations with statements that are generally negative towards technology are positive.

Table 6.4 Statements in the Attitudes to Technology questionnaire that show significant correlations with either SSQ or driver drop-out

Statement	Correlation with SSQ score			Correlation with driver drop-out		
	N	r	p	N	r	p
"I enjoy watching widescreen TV"	578	-0.083	0.045		NS	
"I am very unsure of my abilities to play computer games"	583	0.117	0.005	618	0.084	0.038
"I seem to have difficulties with most video players I have tried to program"		NS		619	0.080	0.046
"I am very confident in my abilities to use different technical equipment"		NS		622	-0.097	0.016
"I would rather that we did not have to learn how to use computers"		NS		620	0.114	0.005
"I always seem to have problems when trying to use computers"	587	0.094	0.023	622	0.113	0.005
"Playing computer games is something I rarely enjoy"	578	0.108	0.009		NS	
"I don't consider myself a competent player of computer games"	583	0.111	0.007		NS	

Table 6.4 shows that the significant correlations, though weak, are all in the direction where a driver who has a negative attitude towards technology is more likely to report a high SSQ or drop-out of the simulator training programme.

6.2.5 Screening criteria

The items that showed significant correlations with either SSQ or drop-out were used to generate screening criteria that could be applied to drivers wishing to participate in a simulator training programme. These were evaluated by applying them retrospectively to the 641 drivers participating in the training programme. For drivers' age, the threshold was set at 60 years, such that drivers aged 60 years and over would be excluded from participation. This excluded 16 drivers from the original dataset. For the health criteria, if a driver reported any of the conditions that were correlated with drop-out, then they were excluded. This meant that 92 drivers who reported suffering from motion sickness were excluded; 27 participants who reported suffering from migraine were excluded; 6 participants who reported suffering from claustrophobia were excluded; and 8 participants that reported suffering from brain damage were excluded. Finally, scores from the eight questions that showed significant correlations with SSQ score and/or driver drop-out were aggregated such that if a drivers' total agreement scores with the statements (measured on the 1-6 scale) was below a threshold score of 20, the driver would be excluded from the analysis . This resulted in the exclusion of 33 participants in the retrospective analysis.

Sufficient data were available to apply the exclusion criteria to 625 of the 641 participants in the training programme and resulted in the (retrospective) elimination of 149 participants (23.8%) from the training programme. Table 9 shows the drop-out rate for the included and excluded participants.

Table 6.5 Driver drop-out rate and mean post-drive SSQ score observed for participants included and those excluded using the exclusion criteria

Driver group	N	Completed	Drop-out	% drop-out	Mean SSQ
Included	476	397	79	16.6%	20.9
Excluded	149	74	75	50.3%	43.2

Table 6.5 shows that for drivers who are considered eligible for simulator training based on these exclusion criteria, the drop-out rate has fallen from the original overall rate of 24.6% to 16.6%. However, for the excluded drivers the drop-out rate exceeds 50% with drivers reporting higher SSQ scores more than double those reported by the included group. An independent samples t-test across the included/excluded groups shows that the differences in drop-out rate ($t(623) = 8.83$; $p < 0.001$) and post-drive SSQ score ($t(588) = 7.06$; $p < 0.001$) are highly significant.

6.3 Simulator Sickness Countermeasures

6.3.1 Simulator technical updates

At the end of the first phase of driver training, TRL requested that simulation experts from Thales UK conduct a full and independent audit of both the visual and motion systems of the T5000 and T3000, in order to reduce the observed sickness rates. This audit resulted in improved motion cuing algorithms, including a corrected centre of rotation on the T3000 and a corrected height of centre of rotation of motion on the T5000. Tests confirmed that the latency between control inputs and response of the visual and motion systems were within acceptable levels.

Analyses were performed on the sickness levels observed for a sample of 54 drivers that had completed the SCOTSIM training programme in phase II, after the technical revisions were completed (30 on the T5000; 24 on the T3000). This allowed limited analysis of the effect of the technical updates. SSQ scores on the T5000 were reduced by 31.2% whilst SSQ scores on the T3000 were reduced by 34.8%. The drop-out rate on both simulators was also reduced but the sample size was too small to confirm whether this is statistically significant.

To investigate what effect such a reduction in SSQ would have on drop-out rate, SSQ scores from the original batch of drivers were analysed to find what the estimated threshold SSQ score was above which drivers would drop-out from the programme. It was found that if SSQ scores were reduced by a margin of 30% (as is suggested by the new data following the technical updates to the simulators), only 13.2% of drivers would have recorded an SSQ score that exceeded the estimated drop-out threshold. This result suggests that the technical revisions have significantly improved the cues provided by the motion system resulting in reduced feelings of discomfort for drivers.

6.3.2 Enhanced familiarisation and screening processes updates

A study was conducted to investigate how SSQ scores and driver drop-out might be reduced by improving the familiarisation processes that drivers experience before driving the simulators and by introducing a more rigorous screening process of trainees wishing to participate in simulator training.

The enhanced familiarisation process consisted of an evening when trainees attended the simulator facility and one of the driving instructors explained the purpose of the simulator training programme. Trainees were able to ask any questions they had regarding training and/or the simulators themselves and had the opportunity to the simulator in action. It was anticipated that attendance at this event would reduce drivers' anxiety before participating in simulator training and therefore lead to a reduction in the occurrence of simulator sickness.

As part of the original SCOTSIM training programme, participants were required to complete a number of questionnaires. Statistical analysis was conducted on responses to these questionnaires to find the factors that were correlated with high SSQ scores and driver drop-out. Factors that were strongly linked to SSQ or drop-out (see 6.2.5) became the screening criteria for participation in the programme. In this research phase, drivers who wished to attend but met one or more of the exclusion criteria were not allowed to participate in the programme. Screening was conducted by telephone questionnaire (see Appendix D).

Table 6.6 shows the observed SSQ scores and comparative percentage drop out rate for drivers not screened or familiarised against those that experienced either/both of the interventions. It should be noted that drivers completed the half process

Table 6.6 SSQ scores and drop-out rate for drivers screened and/or familiarised

Process		Driver age (years)	Total SSQ score due to simulator experience	Drop out rate
Not screened or familiarised	N	30	27	30
	Mean	47.1	18.3	6 (20%)
Screened	N	20	20	20
	Mean	42.6	3.18	1 (5%)
Familiarised	N	15	14	15
	Mean	33.7	12.8	0 (0%)
Screened and Familiarised	N	15	15	15
	Mean	33.1	5.24	1 (7%)

Table 6.6 shows that both the additional processes appear to cause a reduction in reported SSQ levels and driver drop-out rate. A relatively small sample was used so it would be hard to derive conclusive evidence based on the numbers of drivers dropping out of the programme. However, there are consistent reductions in reported SSQ for each intervention type. The lowest reported mean SSQ scores are for drivers who have been screened. Therefore it would seem that this is the most important component of the enhanced recruitment process. Recruiting drivers to attend an additional familiarisation process at the simulator facility proved a challenging task and it does not appear to cause a significant benefit over and above that achieved by applying the screening process. It would be particularly difficult for drivers coming long distances across Scotland to attend the familiarisation session. It is therefore recommended that the screening criteria and not the enhanced familiarisation procedures would benefit future research and training programmes.

6.4 New modules

New exercises were created in addition to those already within the original SCOTSIM training programme. These exercises were not tested extensively for their propensity to cause simulator sickness within the scope of work conducted by TRL. However, they are shorter in duration than the training exercises created within the original training programme and they adhere to lessons that have been learned about the positions within the available SCOTSIM database where it is most appropriate to create exercises. It is therefore anticipated that sickness symptoms shall be no worse than those observed with the original exercises.

7 Cost-Benefit Analysis of SCOTSIM simulator training

Parkes and Reed (2005) found that fuel efficiency benefits observed through a training programme conducted on a full mission, high fidelity truck simulator were translated to real world driving performance and that the fuel efficiency improvements were of similar magnitude as that observed on the simulator. The magnitude of the improvement in fuel efficiency observed in the SCOTSIM training programme is slightly larger than that observed in Parkes and Reed (2005). It would therefore be of interest to determine what cost benefits may be accrued by the application of such a training programme base on the results observed in the Parkes and Reed study and the improvements in fuel efficiency achieved by drivers in the SCOTSIM training programme.

7.1 Cost-Benefit Analysis

Cost Benefit Analysis (CBA) aims to understand the value of all the benefits in a process less that of all costs to specified constraints. It is vital to set out the parameters of the CBA. These were as follows:

- The base case for the comparison
- Groups that would be affected by the implementation of the project
- The costs and benefits to be included into the analysis
- Interest rates that should be used for discounting of future benefits and costs to obtain the present value
- Relevant constraints e.g. willingness to pay, budget constraints
- The comparison should be made between the companies that have no driver training arrangement and those providing simulator training.
- Four main customer groups were defined for the analysis:
    - Drivers
    - Employers
    - Society
    - Government
- A simplified CBA structure was applied where costs and benefits were defined as ‘in-cash’ or ‘in-kind’.
- Based on the mean age of the participants in the SCOTSIM training programme (41.5 years; N = 808), a 3.5% discounting rate was applied to costs and benefits incurred over the period of 24 years (assuming that drivers retire at the age of 65 and the effect of training remains unchanged over the discounting period)

The calculations in this section are based on an amalgamation of data from phases I and II of the SCOTSIM training programme. The average fuel efficiency improvement observed between drives 1 and 2 in the training programme was a reduction in fuel used of 11.4% (N = 525, 95% confidence interval lower bound = 10.3%; upper bound = 12.5%). This is comparable with the 11% improvement achieved in the Parkes and Reed study observed of drivers following three simulator training episodes. By measuring drivers fuel efficiency before and after simulator training, Parkes and Reed were able to evaluate the transfer of training from simulator to real world and found that drivers who had experienced simulator training achieved a 15.7% improvement in fuel efficiency compared to a matched control sample of drivers. In the absence of comparable pre- and post-training data, it must be assumed that drivers in the SCOTSIM attain an improvement of 11.4% in the real world following simulator training.

Drivers participating in the SCOTSIM training programme were asked to indicate their annual mileage completed as a commercial vehicle driver from one of four options. The results are shown in table 7.1.

Table 7.1 Annual mileage reported by drivers participating in the SCOTSIM training programme

Annual mileage as commercial vehicle driver	Count	%
< 20,000	263	33.5%
20-50,000	303	38.5%
50-80,000	150	19.1%
> 80,000	70	8.9%
Total	786	100.0%

Taking the midpoint of each category (and 100,000 miles as the midpoint of the largest category), it is possible to derive an estimate of drivers' annual mileage of 38,140 miles (61,380km). The current average diesel fuel price per litre is £0.923/litre[4], including £0.5327/litre in fuel duties for conventional diesel fuel. Fuel consumption of the driven vehicle was assumed to be 35l/100km (8.07mpg), approximating that of an articulated goods vehicle. The cost savings related to decrease in fuel consumption are shown in Table 7.2.

Table 7.2 Calculation of savings related to decreased fuel consumption due to provision of simulator training for drivers

Parameter	Measure
Average distance travelled (km)	61,380
Current fuel price (£)	0.923
Fuel consumption before simulator training (l/100 km)	35.0
Fuel consumption considering reported 11.4% improvement (l/100 km)	31.4
Fuel used before simulator training (l)	21,483
Fuel used after simulator training (l)	19,034
Annual fuel savings (l)	2,449
Annual cost savings due to decrease in fuel used (£)	2,260
CO_2 savings (tonnes)	7.10

Discounting the monetary savings over the period of 24 years will lead to an estimated cumulative saving of £37,120 in fuel cost as well as 117tonnes of CO_2 saved over the same period. A drivers' increased fuel efficiency is going to result in reduced fuel costs. Lower expenditure on fuel shall result in reduced revenue raised by the UK Government through fuel duties. The total loss sustained through increased fuel efficiency was calculated to be £21,423 over the period of 24 years.

The cost of training is represented by the opportunity cost of a driver's time spent in training. A driver typically works 48 hours per week, corresponding to 9.6 hours per day of a 5-day working week with an average industry hourly rate for professional HGV driver of £8.18. Participating drivers had to

[4] Fuel price data was obtained from the fuel price reports published by the AA.

make one half day visit to a simulator facility and it is assumed that each participants made a return trip of 150km on the day of training making the journey by car at an average fuel consumption of 8l/100km (29.4mpg) with an average petrol fuel cost of £0.889/litre. Each company also incurs the cost of replacing a driver for the time spent in training. This is difficult to estimate correctly as different companies may tackle this problem in different ways such as scheduling other drivers to cover shifts or recruiting agency drivers. For the purposes of this CBA, it has been assumed that they pay an equivalent hourly rate to a replacement driver for the same time period.

The costs incurred by the commercial companies due to sending their drivers to undertake simulator training are presented in Table 7.3.

Table 7.3 Calculation of savings costs incurred by companies in submitting drivers for simulator training

Cost/Units	Value
Labour cost for trainee (£)	39.26
Labour cost for replacement driver (£)	39.26
Transportation cost (£)	10.67
Total costs per driver (£)	89.19

Table 7.4 shows the overall results of the CBA.

Table 7.4 Overall Cost benefit analysis

Parameter	Value
First year benefit (£)	2,260
First year cost (£)	89.19
Total cost benefit for the first year (£)	2,171

Tables 7.3 and 7.4 do not include any cost incurred by the trainee's company to pay for the training received. The cost benefit that companies could achieve by sending their drivers on such a course

The fuel consumption of the vehicle used will have a big impact on the possible annual saving. Figure 7.1 shows how the annual fuel cost savings varies with the fuel consumption of the vehicle.

Figure 7.1 Graph to show estimated annual fuel cost saving against the fuel efficiency of the vehicle

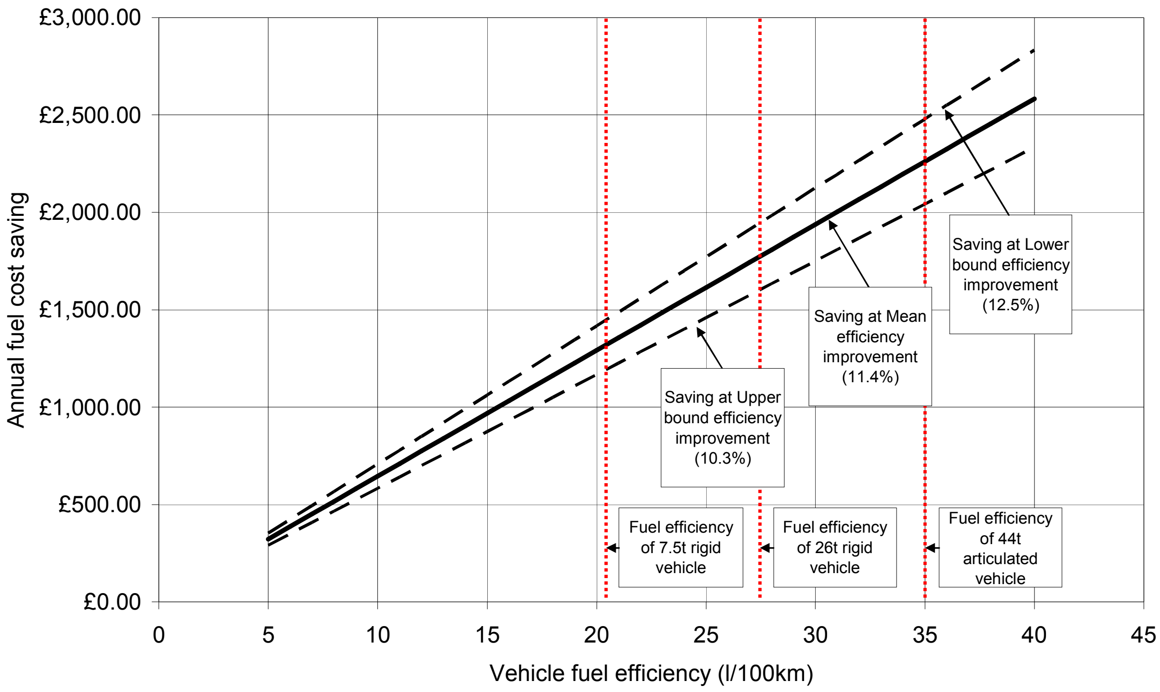


Figure 7.1 illustrates the difference in fuel cost saving that could be achieved between different vehicle types (assuming each vehicle covers the same annual mileage). A driver of a 7.5t lorry who achieved an 11.4% improvement in fuel efficiency could save around £1,300 whereas the driver of a 44t articulated vehicle could save more than £2,200.

7.2 Discussion

This limited CBA gives a simplistic demonstration of the estimated fuel cost savings that could be achieved if the fuel efficiency improvements observed of drivers in the simulator were to be translated exactly to real world driving and maintained over a year and over the remainder of a driver's career. The results suggest that employers could make significant fuel cost savings if drivers were to undergo simulator training. However, a number of assumptions were in the CBA that could affect the results. Firstly, the CBA assumed that the 11.4% mean fuel efficiency improvement observed in the simulator would transfer directly to real world driving. Parkes and Reed (2005) found that an 11% improvement observed over the course of three training episodes in a full-mission truck simulator caused a 15.7% improvement in real world fuel efficiency. Therefore, the assumption made in this CBA of an exact translation of the improvement shown in the simulator to real world driving could be seen as conservative. However, without the research required to establish the level of transfer of skills learned in SCOTSIM to the real world, the assumption must remain.

The CBA also assumes that the 11.4% fuel efficiency improvement is retained over the year and over the remainder of the drivers' career. In reality, it is likely that after the immediate post-training improvement in fuel efficiency, drivers would show some decline in performance level as bad habits return and trained skills are forgotten. Research into the longevity of the training effect would be of interest; not only to refine the CBA but also to determine the optimal fuel efficiency training frequency.

An analysis of the effect of simulator training on accident rate reduction should cover the decrease in the number and severity of accidents caused by commercial vehicles and the associated decrease in fuel used by other road users and increased productivity resulting from reduced congestion due to accidents. Furthermore, a lower accident rate would reduce absenteeism due injuries sustained in accidents and increase the productive life span of the vehicle itself. In addition, insurance premiums are directly connected to the accident rates. These will therefore be affected should simulator driver training cause the accident rates to change in either direction. Other costs that will be affected by change in accident rates are administration costs and customer satisfaction levels together with vehicle downtime and repairs costs. Detecting changes to accident rates as a result of driver training is difficult to achieve because fortunately, accidents are relatively rare. Consequently, the sample size needs to be large and the duration of measurement needs to be long making the realisation of such studies difficult. One possibility that may assist in studies of this nature is the increased market penetration of vehicle safety systems such as electronic stability protection and electronic brake-force distribution that intervene when the system detects conditions that suggest the vehicle is at risk of an accident. If telematics systems could report how often these systems are typically activated before and after a safety training course, it may provide a measure of the safety level of the driver.

The fuel price has fluctuated considerably over the last five years. Any future increase in fuel cost will cause a commensurate increase in the cost-benefit of fuel efficiency training. In a highly competitive market, haulage companies and fleet operations tend to conduct their business with very narrow profit margins. If fuel costs jeopardise these margins, improved driver efficiency through simulator training may help to restore the balance.

While some costs have been identified for the purpose of this analysis it is important to note that the cost of training was set to zero. However, the future cost of simulator training for truck drivers will depend on a number of factors, such as the operational cost of running the simulator, labour costs, etc. These costs will decrease the received savings from the simulator training in the first year.

An additional consideration is the effect of driver training on the technical aspects of vehicle operations. Improved driving techniques can lengthen useful vehicle life by reducing attrition rates and reduce maintenance costs. This may also increase vehicle resale value and lower administrative costs.

User groups affected by the project:

Drivers: One of the main benefits expected to arise from driver training for drivers themselves is increased awareness of the vehicle and consequently decrease in accident rates. The decrease in accident rates can improve the absenteeism records and drivers' perception of the job while bringing the medical bills down and increasing the productive working time within the industry. At the same time training is normally seen as a strong motivator for the employees to stay with the same company and may increase drivers' esteem and job satisfaction.

Employers: Many of the benefits to a driver have related benefits for their employer (reduced absenteeism, greater job satisfaction, reduced accident rates). However, pragmatism dictates that probably the most important factor for the employer is the cost benefit of the training process. Depending on the level of transfer to real world driving and the future cost of the training process, it would appear that simulator training may offer companies the potential to make savings in their fuel costs, which typically account for a significant proportion of a company's expenditure.

Society: Society can potentially benefit from a reduction in CO_2 and NOx emissions due to improved fuel efficiency. Further research could investigate the financial implications of decreased fuel consumption and health improvements within society. If driver training were to cause a reduction in accidents, society would benefit through a reduction in injuries/fatalities and through a reduction in congestion caused by accidents.

Government: The Government would potentially experience a loss of revenue due to reduced fuel usage by vehicles because of more efficient driving practices. However, this would potentially be far outweighed by increased productivity due to companies achieving reduced fuel costs and a reduction in the level of congestion caused by accidents.

The CBA of the SCOTSIM training programme demonstrates clear benefit to commercial companies and other groups from truck driver training using simulator technology. However, this should only be seen as a guideline because the CBA was necessarily based on assumptions about drivers' behaviour, the transfer of the SCOTSIM training to real world driving, and longevity of the training effect in the absence of the research required to establish these factors. Furthermore, the CBA did not include possible savings in insurance premiums through provision of training and reduction in accident frequency, nor could the possible benefits of improved driver recruitment and retention rates be included. However, as a starting point, the CBA of the SCOTSIM training programme suggests that drivers attending and their employers derived a clear cost benefit from the training experience.

8 Conclusions for the SCOTSIM programme

Two state-of-the-art truck simulators were commissioned successfully for Scotland. A realistic road environment was created with appropriate Scottish look and feel; and training exercises were created that industry experts agreed delivered the required principles of safe and fuel efficient driving. A programme of training was established that led to the assessment of over 700 drivers. Comparisons of performance after training to that shown in an initial assessment drive indicated a substantial training effect. Time taken to complete the required tasks reduced, as did the number of gear changes made and the amount of fuel used. Trainees were happy with the design and organisation of the training and provided positive feedback about the realism of the driving experience and the tasks involved.

This project has enabled TRL and Thales to work together to develop an automatic assessment system that can score performance on the majority of the indicators used in SAFED training, with the benefit of being objective and accurate. This project has demonstrated that there is considerable variability in ratings of trainee performance produced by different experienced trainers, even when there is complete standardisation of the driving tasks for all trainees. Automation of aspects of the assessment has clear potential to harmonise results and provide a more equitable process.

A further success of the project was the involvement of the Scottish haulage industry and other stakeholders in the development of additional training modules of value to future training. These modules have been through a three stage validation process, including testing with around 90 drivers and provide a strong basis for commercial development of simulation training provision.

Timescales were very ambitious for this project, and the period available for specification, production, delivery and testing of the two systems was far shorter than would normally be undertaken by the technical supplier to the training industry. Given that the TRUST 5000 system was a unique one-off design, and that the TRUST 3000 though a standard offering in Europe, also needed to be translated to a right hand drive variant, it is not surprising that technical problems at times interrupted the smooth delivery of the training schedule. Of particular concern during the main phases of the project was the number of trainees who were unable to complete all of their sessions due to various degrees of simulator sickness. From the point of view of developing a commercial system, drop-out rates of around 25% were totally unacceptable, and considerable effort was diverted to establishing causes and potential remedies.

This challenge is probably the biggest facing the simulation training community. If we accept that a proportion of drivers are unable to adapt to simulated environments, it is not appropriate to have training policies that require individuals to have simulator training as a necessary stage of development, nor would it be appropriate to prescribe simulators for all assessments. Simulation therefore remains an addition and possible alternative to traditional behind the wheel training that can be seen to be highly beneficial for the majority of students, but will remain inaccessible to a proportion. How large that proportion is will be a function of the physical health of the driving population, and their age profiles and attitudes to new technology. It will also be a function of the technical sophistication of the simulator and the level of demand of the driving tasks introduced.

During the SCOTSIM project adaptations were made to the road database, the vehicle dynamics models, and the performance characteristics of the motion rendering systems to ameliorate as far as possible disturbance to the drivers caused by a mismatch or delay in responses of the simulator to their input controls. Considerable effort was also employed in investigating which personal characteristics of the driver were the best predictors of likely simulator sickness. These findings were coupled with continued improvement in the organisation of the training provision and the introduction to the simulation process. Taking all these approaches together has resulted in a final drop-out rate across the two simulators of around 5%. It would be entirely possible to reduce that rate even further by having stricter exclusion criteria for the drivers and a reduction in the difficulty of the driving task s during the training exercises, but then there would be debate about the potential training value of tasks that become too far removed from real driving experiences. Clearly a drive on completely flat terrain, involving no other traffic, turns, or stopping and starting manoeuvres would be very unlikely to cause simulator sickness in even the most prone individual. However, there would be very little training opportunity left within such tightly prescribed environments. The current drop out rate of around 5% seems to compare favourably with those experienced by other simulator operators in Europe, particularly so given that the SCOTSIM driving modules involve sweeping bends, significant gradient changes, and urban traffic manoeuvres.

The approach taken in this project has demonstrated the value of simulation-based Continuing Professional Development (CPD) training. It was not possible to investigate the potential of the systems for novice training leading to licence acquisition. Given that trainees likely to undertake licence acquisition training would tend to be younger and more accepting of such new technologies, their success rates and adaptation to the environment are likely to be high.

The project has shown the technology is suitable for delivering CPD training, and the results obtained show considerable change in driver behaviour. The outline cost-benefit case appears compelling, but further work would be needed to test the cost effectiveness of such simulated CPD training in comparison to traditional behind-the-wheel training or any other learning environment.

9 Recommendations

A programme of training was devised that followed the principles of the SAFED programme, but no direct comparison was made with the outcome of that behind-the-wheel training scheme. It would be of interest to compare results obtained on SAFED for a similar population of trainees.

This study focused on improvements in the simulator, but was not able to make any direct estimates of a transfer of training principles to the real road. Previous work (Parkes and Reed 2005) showed a very similar improvement in fuel efficiency as a result of training and assessment in a top-of-the-range truck simulator (11.4%), but was also able to demonstrate via access to the real road fuel records of trainees that their average improvement in the real road setting was even higher at 15.7%. It would be of great interest to measure the fuel performance of drivers that had undertaken the SCOTSIM training and compare them to records from similar driver who had not been able to engage in the programme.

Although an important development in this project was the major advance in automation of the assessment process, an important lesson learnt was the key role of experienced and enthusiastic trainers. In this project the training team had to take on many extra responsibilities and learn many new skills in a short period. The simulators require significant skills and knowledge for successful operation and first line maintenance, and the aptitudes and attitudes necessary for success may not be those always seen in traditional trainers. Any group taking simulation training through to a commercial process will need to devote particular attention to trainer recruitment and development.

This research has shown that safe and fuel efficient training can be delivered in a simulated setting, but within the constraints of the project it was not possible to address other delivery mechanisms in a structured way to determine an optimum blend of simulation, road vehicle and classroom teaching. For future comprehensive CPD in line with the European Directive and for licence acquisition training it is likely to be efficient and cost effective to deliver only those training principles in a simulator that are shown to be dangerous or inefficient in other traditional formats. Further work is required to establish this optimum blend.

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Appendix A. Marketing materials

Figure A1. Letterhead paper

scotsim
Simulation for the Truck Driving Professional

8 Dunlin Court
Strathclyde Business Park
Bellshill
ML4 3NH

Tel: 0845 606 6532
Fax: 0845 606 6534
Email: info@scotsim.co.uk

Web: www.scotsim.co.uk

26 April, 2005

Sandi Goddard
Goddard Delaney
41 Great Guildford Street
Bankside
London
SE1 0ES

Dear Sandi

Re: Scotsim Letterhead Test

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Yours sincerely

Lisa Miller

Figure A2. SCOTSIM leaflet

What should I do next?

If you feel you or your company would benefit from taking part in the Scotsim initiative we look forward to hearing from you.

The project has slots for some 700 drivers to undertake training at our fixed location at Bellshill or at the various regional locations the mobile simulator will visit.

Mobile locations and dates are identified on the project website: www.scotsim.co.uk.

Participating drivers must be qualified C or C+E licence holders and either:

- Novice drivers - with less than 1 year experience; or
- Experienced drivers - with more than 10 years driving experience; or
- Experienced drivers - with more than 10 years driving experience and some evidence of poor driving habits

The programme commences in July 2005 and participation will be based on a 'first come, first served' basis.

Companies can indicate commitment to the programme or book individual drivers by contacting us by phone, e-mail and mail, or via the on-line booking system on the website.

To find out more see our website
www.scotsim.co.uk

"Our business will definitely benefit from this exciting project"

Simon Wilson
National Training Manager HSEQ
Exel Industrial and Special Products

Driver Development

Committed to improving your journey

Scotsim
8 Dunlin Court
Strathclyde Business Park
Bellshill
ML4 3NH

Tel: 0845 606 6532
Fax: 0845 606 6534
Email: info@scotsim.co.uk
Web: www.scotsim.co.uk

scotsim
Simulation for the Truck Driving Professional

Simulators: what should I know?

Training pilots in simulators has been common practice for many years. Professional truck drivers can now benefit from training in similar systems. In Europe and North America innovative logistics and transport companies increasingly use simulators to aid recruitment and to improve the skills of their drivers.

It is crucial that drivers from logistics and transport companies in Scotland have access to similar high-end simulators to ensure that efficient and safe driving skills can be developed throughout their own sector.

The Scottish Executive via the Scottish Road Haulage Modernisation Fund is undertaking a programme to evaluate how truck simulators can be used to deliver driver training in Scotland.

The Scotsim project is designed to research how simulators can be used to deliver fuel efficient and safer driving practices in the real world.

Simulators create a near-real environment. The vehicle cab and the outside world are reproduced with sufficient accuracy that drivers feel they are sitting in their own cab.

Vehicles and pedestrians act and produce the same problems and challenges for truck drivers as those in the real world.

Trucking companies and drivers participating in Scotsim will be pacesetters, supporting the introduction of truck simulation training for the Truck Driving Professional.

What are the key benefits?

The new generation of full mission truck simulators, combined with appropriate training, provide companies with opportunities to introduce new and innovative approaches to achieving professional driver development.

Fuel: Truck simulators assist transport companies to maximise the productivity of their drivers and vehicles. Research is demonstrating that truck simulator training is now beginning to deliver significant benefits for fuel efficient driving practices.

Safety: It is now possible to place drivers in situations which would be too dangerous to demonstrate in the real world. Simulated environments mean that icy roads, inappropriate driving behaviour and other scenarios can all be demonstrated with no damage to equipment or risk to drivers and other road users.

Measurement: Driver actions and performance such as acceleration, braking, gear changing are all constantly monitored by multiple sensors delivering objective rather than subjective insight into individual driver skills.

Reports: Tailored performance printouts mean drivers can be provided with tangible results of their driving behaviour.

Repetition: Simulators can demonstrate and repeat identical scenarios over and over again enabling trainees to understand fully the consequences of their actions.

What's the advantage for me?

Scotsim gives some 700 Scottish drivers and their companies a chance to assess the benefits and opportunities of this new technology. All this without the direct cost of paying for simulator training. Participants will receive reports on their individual driving performance and advice on techniques to improve their driving skills.

Companies will be able to assess how truck simulator training could contribute to driver recruitment, staff retention and improved driver skills.

The Scotsim project offers the chance to:

- Understand a new and innovative training technology
- Learn techniques for fuel efficient and safe driving
- Access both fixed and mobile simulators in a number of Scottish locations
- Review personal driving skills and understand which elements can be improved or polished
- Remove the need for dedicated company vehicles or trailers from the training process
- Evaluate new approaches to achieving conformance to future EU Training Directives
- Gain insight into safe driving practice in scenarios with no risk to driver, vehicle or other road users.

Figure A3. SCOTSIM folder cover

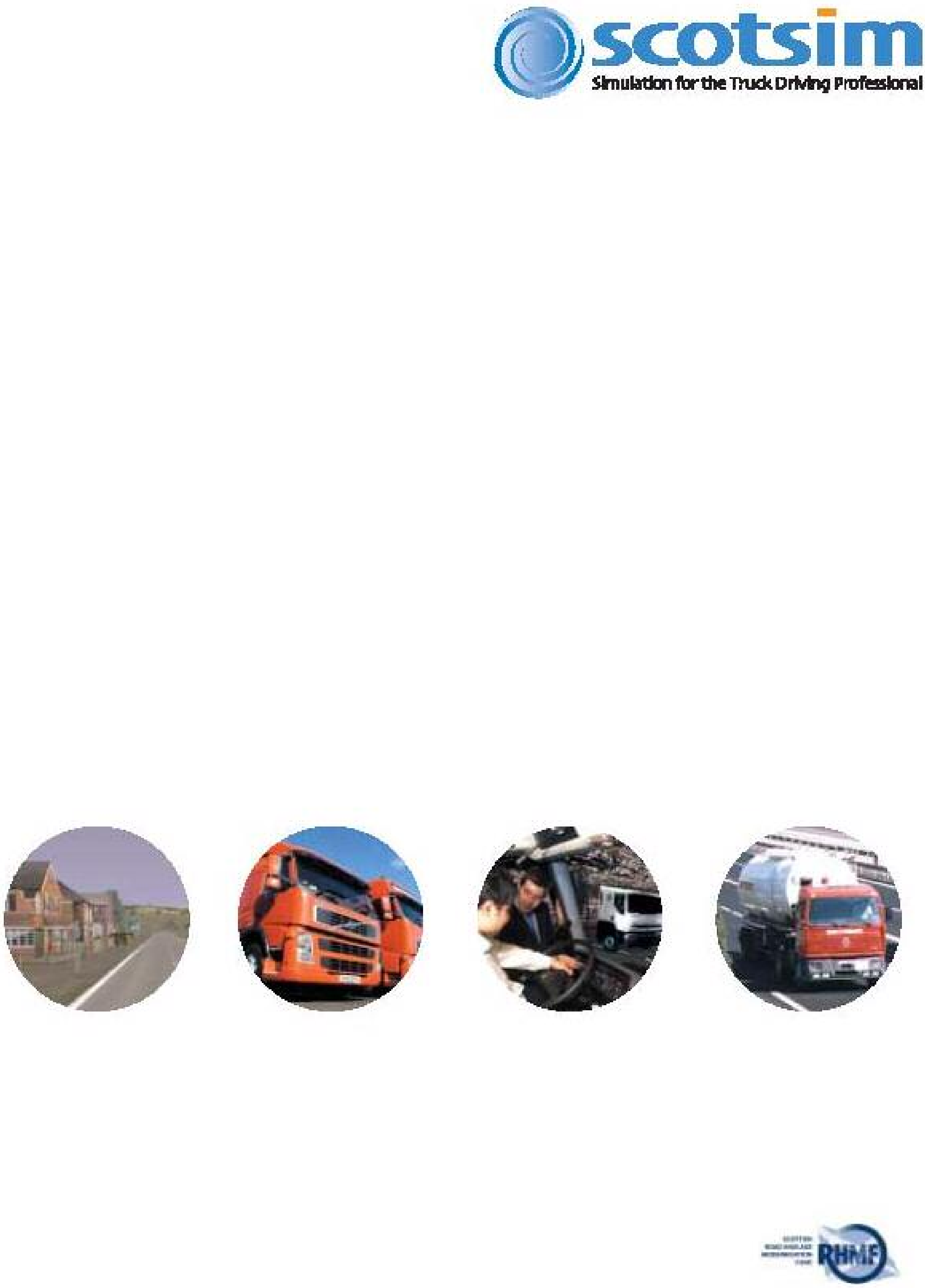
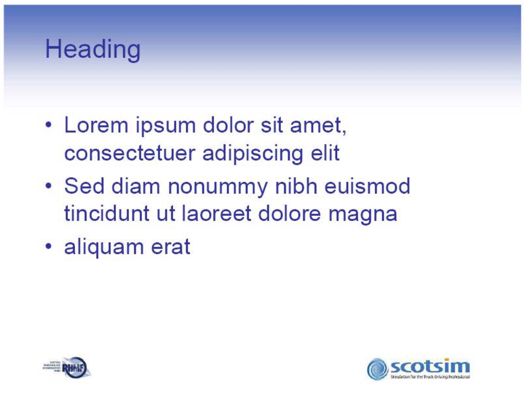
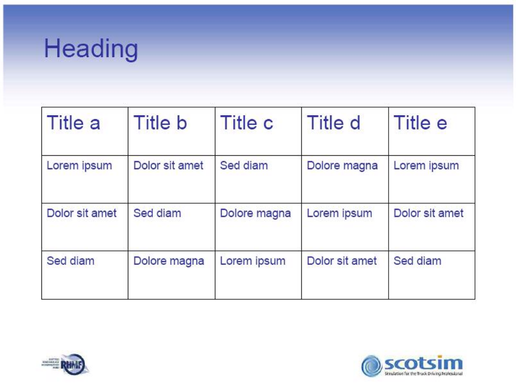
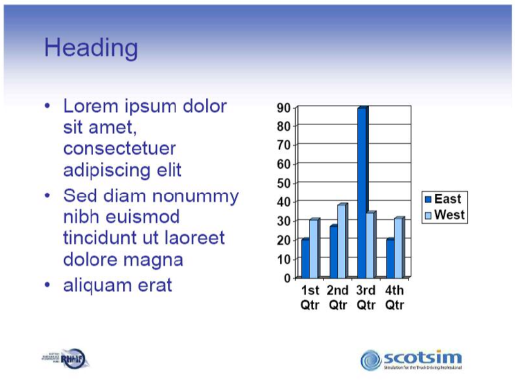


Figure A4. Example slides from Microsoft PowerPoint SCOTSIM presentation template







Appendix B. SCOTSIM facility specification

B.1 Specification used for the fixed simulator facility location

SCOTTISH TRUCK DRIVER TRAINING SIMULATOR

Site specification

1. Introduction

The TRUCKSIM project in England has demonstrated the feasibility of synthetic training for truck drivers and shown a high level of acceptability, in principle, by the target trainees. The project has covered a wide range of possible training objectives as an investigation of the potential of the technology in Scotland. This project intends to take advantage of that preliminary work and move forward in order to deliver focused and verified training.

Project Overview
The Scottish Executive has appointed TRL as Programme Manager to specify, procure, host, evaluate and research the potential for simulator technology to support truck driver training.

Two forms of full mission simulation training equipment will be procured - one a fixed variant, the other a mobile. Both will be capable of delivering identical minimum training functionality.

The fixed variant will be located in Scotland's Central belt area. Its precise location is still to be determined. The Mobile will be used at five potentially six locations (dependent on demand) during the course of the programme. These locations are likely to include the following:

1. Inverness
2. Aberdeen
3. Fort William
4. Dumfries
5. Berwick area

It is anticipated that the mobile variant will be present at each location for a minimum of 1 week up to a maximum of 4 weeks. Its duration is, of course, highly dependent on the number of drivers secured at each location.

It is envisaged that the mobile unit, when not operated at one of the locations mentioned above, will either be parked or operated at the site of the TRL Scotland fixed simulator.

To assist in the research, it is anticipated that over 700 commercial vehicle drivers will need to attend during a nine month period starting in mid summer 2005 until end of March 2006. Each driver will receive training according to the SAFED training standard.

To support a successful outcome of the project, it is anticipated that it will be necessary to establish a simulation training centre that provides easy access, good transport connection and an image of professionalism to industry stakeholders and participants.

The venue should help position simulator technology as a high tech tool which provides innovative solutions and highlight its ability to deliver pragmatic solutions for the industry based on saving money and improving performance.

2. REQUIREMENT

It is anticipated that the Scottish truck simulator site will be required to have the following specification in order to provide an appropriate facility to house world class training equipment. This is not only essential to successful training but also to support the marketing and branding of the system.

2.1 Location:
An analysis of the operators' licenses and heavy goods vehicles registrations in Scotland shows that the vast majority of HGV operators are based in the Glasgow area. The Simulation centre should therefore be located east of Glasgow to allow good access for visitors from Edinburgh, ideally with very good access to the M74 and M8 motorways.

2.2 Timeframes:
The building should be available at **the latest by 1 February 2004**
The lease has to run **until at least 30 March 2006** but there is potential for a permanent operation of the simulator at the site.

2.3 Building specification:
Please note that the specifications in this document are minimum requirements. Also the lease needs to allow for any modification necessary to convert the building into a simulation centre!

The building should ideally comprise of the following areas which are explained in more detail below:

- Simulator area
- Control room
- Parking/operation area for the mobile simulator
- Debrief area
- Computer Based Training area
- Research staff and installation team space
- Trainee management area
- Reception area
- Kitchen area Washing, toilet and restroom facilities
- Meeting rooms
- Parking

and have the following characteristics:

- **Ease of access** for participants of the research programme. This includes dedicated parking areas for those who require them and mobility access. There should be clear access to the reception area where dedicated staff will show participants to the Simulation Centre.
- The centre should have its **own dedicated secure entrance**.
- **Self contained**. The Centre should be self contained with all simulator areas, trainee management area, refreshment area, research staff areas and so on, in one secure location.
- **Service and freight access** for up to 40 ft trailers.
- **Modern service provision**. Power, IT and communications should be new is possible and be designed to accommodate modern requirements.
- **Ease of exit** in case of emergency
- **Safety and Security.** The building should have CCTV, an alarm system, fire alarm and fire extinguishers.

TRL understands that it will be difficult to identify a site that provides all of the above. A certain amount of refurbishment and modification will be required to transfer a prospective site into the required state.

Simulator area

This section describes the requirements for the area that will house the simulator itself and the trainer station.

Figure 1 shows the minimum space requirements of the simulator hall and the control room.

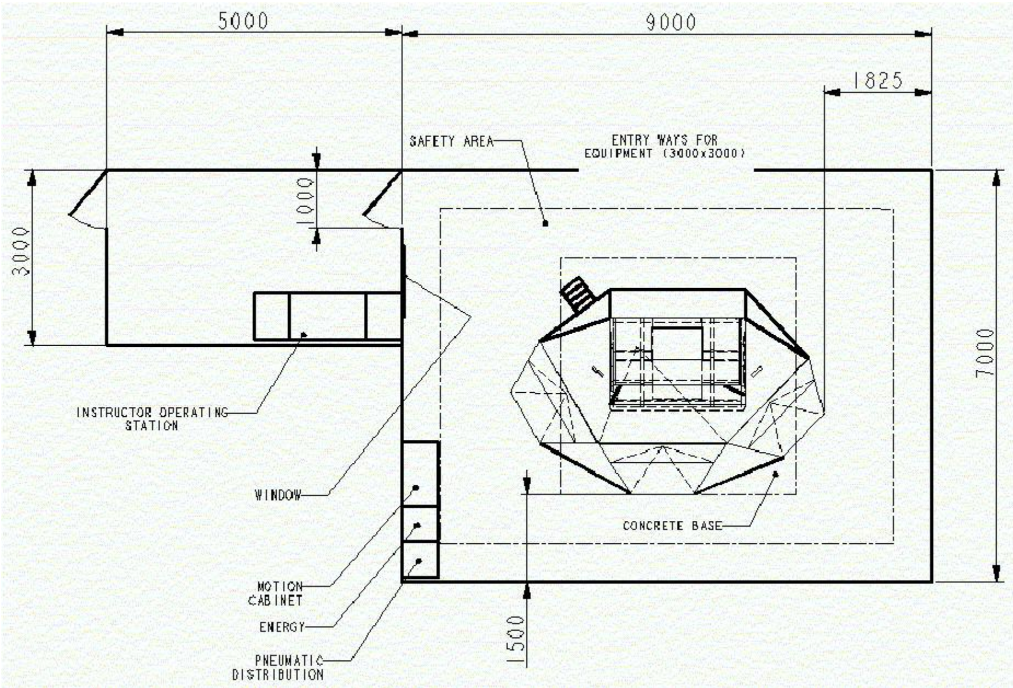


Figure 1: Minimum space requirements of the simulator hall and control room

Dimensions:

- The simulator will require an area of approximately 9x7 metres (the simulator envelope is 8x6 metres with a recommended 0.5 metres space all around)
- Ceiling height: ≥ 5 m
- It is recommended that the simulator room and the instructor's room are contiguous to keep inter-connecting wiring length less than 30 metres.

Floor characteristics (concrete base) for the motion system of the simulator:

- 4 x 4 metres x 0.30 m deep
- Concrete must be a class 25MPa grid reinforced concrete
- Surface flatness: 2 mm max. per square metre.

Access:

- The hall that will accommodate the Trainee Station must be accessible to a fork lift truck (fork + hoist arm) having a load capability of 3 Tonnes.
- The minimum dimensions of the access door are 3 m x 3 m and compatible with the driver's compartment handling facilities.

Other:

- 3 phase power supply is required, 400V +6-10%
- Frequency 50Hz +- 1Hz
- The simulator area has to be lighting and temperature controlled (aircon with approximately

12-15 kw)
- A compressed air source is required close to the driver's cabin

Control room
The control room has to be adjacent to the simulator area allowing direct viewing of all trials.

- 5x3 metres.
- ceiling height ≥ 2.50 m
- A 1m wide door is necessary between the trainee station and the Instructor Station Room to allow easy installation of the Instructor Operating Station
- It is recommended that the room is fitted with a raised floor with the following specification:
  - height H: 30 cm d H d 40 cm,
  - removable slabs 60 x 60 cm,
  - Surface flatness : 2 mm max per square meter,
  - allowable evenly distributed loads t 400 daN/m²,
  - allowable loads on a single point: t 100 daN/5 x 5 cm,
  - punching resistance: 40 daN/cm²,
  - static-free finishing.
  - Openings will be made in the raised floor underneath the Instructor Operating Station and the computers (dimension of each opening: ¼ slab).

Parking/operation area for the mobile simulator
When the mobile simulator is not operated at a remote site it should either be securely parked or operated in the main simulator building. Space required for this is approximately 20 x 7 metres. The access gate has to have a minimum width of 3 metres and 4 metres height. The mobile simulator area should be adjacent to the main simulator hall to facilitate parallel operation of both simulators.

Debrief area
This area should measure approximately the same as the control room (Minimum size 15m^2) and have the same characteristics.

Computer Based Training area
This area should be big enough to host two computer work stations (Minimum size 15m^2).

Research staff and installation team space
This area will require desks, filing space, communications, IT connections and so on, but also provide easy interaction with the Operations Team and the Project Managers (Minimum size 15m^2).

Trainee management area
In this area trainees should have the possibility to relax, have refreshments and complete questionnaires (Minimum size 10m^2).

Meeting rooms
A range of meeting and conference facilities should be included for visitors that the Scottish Executive or the Marketing Team wish to bring to the simulator (Minimum size 20m^2).

Kitchen area, washing, toilet and restroom facilities
Separate toilets for male and female staff, trainees and visitors; a small kitchen area for the preparation of refreshments, coffee, sandwiches etc.

Reception area for registration of visitors

Parking
There should be approximately 10 parking bays for trainers, trainees and visitors. Ideally also some truck parking facilities should be available as some trainees may travel to the simulation centre by

HGV.

Table 1: Summary of space requirements

Area	Size (m^2)
Simulator area	63
Control room	15
Parking/operation area for the mobile simulator	140
Debrief area	15
Computer based training room	15
Research staff and installation team space	15
Trainee management area	10
Reception area	10
Meeting rooms	20
Parking	10 Spaces
Kitchen and restroom facilities	

Industrial Space	(orange)
Office Space	(green)

Total Industrial	**203**
Total Office	**100**

2.4 Surveys to be undertaken prior to lease

- Roof survey
- Floor survey
- Asbestos type II survey
- Power survey

3. Refurbishment activities

This section provides an overview of what activities presumably (depending on the identified property) need to be installed or refurbished in order to use the building as a simulation centre:

General refurbishment

- New carpet throughout in line with branding
- Replacement light switches and sockets
- Increase number of sockets throughout building
- Increase number of telephone sockets
- Cat5 Data cables brought into building CAT5
- Replace lighting
- New heating system
- Intrusion and fire alarm systems linked to security if possible
- Possible replacement of foundations, this depends on the applicability of floor in place
- Refurbishment of toilets
- New tea/coffee point
- Replace and/or hide heating and water systems
- Hide all 3 phase power units
- Monitor power supply to ensure it is adequate
- Install black curtains to shield off simulator
- Potentially put up branded curtains to cover the walls

- Potentially we need to build walls to put up pictures
- Clean brickwork and repaint outside in line with branding

Furniture and office equipment
- Conference table – 12 chair
- White board 2 x 2 at least
- Flip chart
- Projection system
- 12 office chairs
- 7 office tables
- Waiting area build

Signs
- Sign over door
- Sign indicating parking areas
- Sign on motorway exit

Layout
- Rest area close to exit to outside.
- Design to prevent too much crossover and interaction.
- False ceiling in other areas (nice to have).
- A demountable wall may be a option for the launch event

3. Type of Contract

TRL aims for a "turnkey contract", i.e. the building owner/agent should undertake all necessary modifications to convert the building into a simulation centre and start the lease once TRL can move in.

TRL will only identify the facility on behalf of the Scottish Executive who will then take out the lease and leave the building to TRL for "beneficial use".

4. Misc

- Planning permission will be needed for separate signposts and illuminated signs on the building.
- Area should have good Safety/security records, no Hazchem sites in the proximity, and not be prone to flooding.
- Insurance should be reduced by installing a good fire warning system.

For further queries contact project manager

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Appendix C. SCOTSIM training supplier specification

REQUIREMENT

Scope of supply

The following represents the core components of supply for the training supplier:

A. Provision of high quality commercial vehicle trainers for both fixed and mobile solutions.

B. Sufficient qualified trainers to meet the rostering requirements of leave, sickness and other associated issues

C. Provision of training centre administration

D. Interaction with technology provider

E. Input into the training modules and their application in Scotland

F. Sufficient staff commitment to ensure the trainers have received appropriate technology training to maintain the systems.

G. Commercial activity to market the project to potential users

H. Other issues

The core components of supply are detailed below:

A. DRIVER TRAINING

Experienced truck driver trainers are essential to manage the students during their visit. Whilst the modules will be pre-scripted with built in pedagogical packages, there will still be the potential for students to make mistakes or to misunderstand the instructions on a particular route.

The experienced trainers will need to step in at these stages and make decisions about whether to move the student on to a different module and provide remedial training at a later stage, or to abandon that module, and so on. Particularly when dealing with experienced drivers, possibly with poor driving records, the trainers may wish to add to instructions from the system and so on in real time.

Credibility in the exercise can only be maximised if the students acknowledge the domain expertise of the trainers. The following will be expected of the training supplier:

- Trainers dedicated to the programme will need to demonstrate a willingness to participate in the project, be technically interested in the concept and have suitable patience to work with new, untested equipment.
- Trainers will need to be self starting particularly with the remote mobile solution equally they will be expected to be able to make formal reporting to appropriate time frames throughout the programme.
- It will be essential that trainers dedicated to the project will need to be SAFED trained and versed in SAFED principals.
- The trainers will be ambassadors to the project, TRL and the organisation they represent. They will therefore need to demonstrate the appropriate degree of professionalism in both appearance and conduct that befits this unique training experience
- Flexibility to manage both fixed and mobile simulation

  Trainers are expected to be of the highest quality, as trainees brought to the programme are likely to feature high standard drivers.

Trainee profile

For the purposes of research, three groups of qualified C and or C+E license holders will be recruited to the programme to receive training. These are categorised as:

- Novice - recently gaining licence at either C or C+E and holding license for less than a year
- Experienced (10 yrs +) - identified by management as 'good' drivers

  Experienced (10 yrs +) - identified as 'poor' drivers (accident record or poor fuel economy).

Training elements

The technical supplier will provide a sophisticated database containing rural, urban and motorway environments, comparable to Scottish roads. Requirements for three test scenarios that have the same route and traffic elements, but which remove the possibility of the driver remembering specific elements from one drive to the next, and acting accordingly will also be specified.

Each 30-minute session will be defined to allow the measurement of the following elements (based on SAFED principles):

1. Acceleration and cruise control
2. Braking
3. Clutch control
4. Driving position and seat belt
5. Road and weather conditions
6. Steering
7. Gear selection and use
8. Hazard perception
9. Lane discipline
10. Speed
11. Making progress and planning
12. Use of mirrors
13. Use of signals
14. Overtaking
15. Vehicle sympathy
16. Driver attitude
17. Reaction to signals and road markings.

Scoring and evaluation of trainees

Each of the 17 elements above can be scored for each of the baseline and training drives. A model will be produced that allows the trainer to rate each element on a three point scale, allowing an aggregate score to be derived for each drive. The next step would be to compare the overall score of the trainee to some agreed criterion. If it is agreed to follow a model very similar to the current SAFED approach, then each element is rated good, fair or unsatisfactory and given a score of 0, 1 or 3 accordingly.

In SAFED there are only two drives, and a simple composite is calculated for the two scores. The trainee is then rated as a pass with distinction if less than a total of 18 points are scored; a pass if between 18 and 34 are scored, and a fail if the score is higher.

We anticipate a similar approach, though clearly as we have three drives, the exact nature of the algorithm will be different.

It should be noted that we will also require the technology provider to configure their system such that certain objective measures can also be calculated. As a minimum these will include time to complete task, distance covered, number of gear selections and apparent fuel usage. We will then also derive a MPG figure for each run, and also note other safety relevant parameters to give an overall score for the session.

Preliminary curriculum development and consistency checks

The approach to be taken has the potential weaknesses of relying on subjective opinion of the trainer, and on the arbitrary nature of any scoring procedure. There will not be time to resolve these issues satisfactorily if we wait until on-site acceptance tests, following delivery of the technical system.

To support the curriculum development, the TRUCKSIM facility at TRL Crowthorne will be used to resolve these issues independent of the technical supply schedule.

TRUCKSIM and its existing databases will be used during the period September to November 2004. Existing scenario creation tools will also be implemented to develop appropriate draft 30 minute drives. TRL will invite input from DSA and the training supplier at this stage. Draft background questionnaires and evaluation material will also be generated. With DSA in attendance, piloting of the drives with around 4 drivers will be undertaken.

The draft scenarios will then be refined on the basis of the pilots and 'destruction tested' with experienced driver trainers.

The next stage of piloting will involve a number of trainers reviewing a number of live and pre-recorded drives in the simulator and scoring them accordingly. Checks will be made to gauge the consistency of scoring. If the approach is regarded as having sufficient concurrent and content validity, and reliable scoring is produced, we will go to a further level of testing using around 20 additional drivers. This should be a sufficient number to allow a consensus to be reached on performance levels and for firm criteria to be set for the pass/fail algorithm to be used in the full training period. It has the additional benefit of allowing a very full specification document to be generated for the technical supplier to ensure that all necessary elements are included in both the databases and also the data capture systems well in advance of proposed delivery dates.

A trainer supplier representative will be expected to join in this process by attending the curriculum development workshop and joining in with some of the training and piloting at the TRL site in Crowthorne.

We have scheduled December 2004 as the target for producing a deliverable report that will detail the approach taken and the resulting curriculum, courseware and scoring procedures.

Training session operating model

The following will represent the core activities undertaken by the truck driver trainer:

1. Provide training sessions of around 190 minutes in duration per trainee.
2. Provide introduction and health and safety checks
3. Introduce trainee to the simulator, demonstrate main controls and familiarisation with the gear selection system
4. Enable a short free run exercise with the trainee to allow familiarisation of vehicle handling characteristics and perform simple manoeuvres so that normal driving behaviour can be demonstrated
5. Remove trainee from simulator

6. Introduce trainee to a 15 minute hazard perception training session on a PC (the driver is given on-line feedback about performance. The session is both useful in its own right as an introduction to hazard awareness, but also serves as a useful introduction to synthetic training and evaluation, and makes the transition to testing in the main simulator less daunting).
7. Reintroduce the driver to the simulator in order to complete a 30 minute 'baseline' drive
8. Provide feedback based on the system's automatic scoring regime and on observation by the trainer
9. Provide a further two 'training drives' each with appropriate feedback from the trainer
10. Total time spent in the simulator is expected to be 100 minutes.
11. The training session is completed with the trainee having opportunity to provide feedback on their physical condition following the simulator sessions, their views on the appropriateness of the training and recommendations for any improvements.
12. The trainer will conclude the session by calculating a performance score for the trainee, and if appropriate, award a pass certificate for the course.
13. The trainer will be proactive in mitigating and reducing any potential problems created by motion sickness
14. Experience has shown that culturally many companies participating in the English programme have not positioned the experience that will be gained as a positive programme for individual drivers. The trainer will therefore be proactive in positing the training experience.

Duration

The total amount of time spent in the simulator is around 100 minutes, with the main evaluation based on 3 x 30 minute drives (baseline, and two training sessions). These 30 minute sessions have been chosen for several reasons

- Any more than 30 minutes without break in a simulator environment is not advisable for students who are not regular users of such systems, as the potential for experiencing symptoms of simulator sickness will increase after this period.
- 90 minutes total drive time compares favourably with the current SAFED scheme which gives each trainee around 120 minutes drive time in a real vehicle.
- The approach of a baseline drive for comparison with training allows direct objective scoring to be introduced and enables a structured review of concurrent and content validity, and reliability of the system.

Delivery

Training is to be delivered on a one-on-one basis. Drivers are to go through the sessions as individuals in order to focus the training and quality of tuition.

Training will commence shortly after the technical provider has successfully delivered the simulators. It is anticipated that the fixed simulator will be delivered first in mid summer 2005, and the mobile several weeks later. Therefore the degree of training cover will be staged to accommodate the fixed simulator trainees and then the mobile.

It is anticipated that there will be a need for 2 trainers to operate the fixed facility from mid June to early March and 1 trainer to operate the mobile facility from October to early March. Because of leave etc there is likely to be a team of trainers who will deliver the training over the period.

Trainer Selection

The driver trainer has a critical role to play in the delivery of a successful programme. Additionally training of the trainer to use and operate the simulator represents a considerable investment and as such the selection of suitable individuals is crucial. As such the following criteria must be met before an individual will be accepted as suitable for programme.

- Trainer must be DSA registered. Evidence of this registration must be supplied
- A detailed Curriculum Vitae for each individual proposed must be supplied
- A reference for each individual must be supplied. This is particularly relevant for individuals who have worked for the training supplier for less than 5 years
- Demonstrable ability in the use of IT equipment. A suitable assessment of current IT ability is currently being developed by TRL.
- Suitable aptitude and personality. This will be assessed using UK accredited aptitude and personality tests. These will undertaken by TRL's Human Resources department

TRL reserve the right to reject a proposed trainer if these selection criteria indicate that they will be unsuitable for the programme.

In addition to the above items TRL require the training supplier to submit formal statements detailing the following:

- Official replacement procedure in the event of rejection of one or more of the proposed t trainers
- Detailed statement of intent for the approved trainers for the duration of the project. Items to cover include;
    - o the trainer's base for the duration of the training period (June 05 – March 06),
    - o procedures for provision of replacement trainer in the event of illness, leave etc,
    - o training company's proposed replacement policy for the approved trainers, to manage the training company's existing business activities, for the duration of the training period (June 05 – March 06).

It should be noted that in the event of an approved trained trainer being unable or unwilling to continue with the programme, the costs of training a replacement will be borne by the training provider.

B. TRAINING ADMINISTRATION

The fixed simulator is to be based within the Scottish central belt. The training centre that will be developed for the fixed simulator is likely to accommodate not only trainees but also visitors and stakeholders from the road haulage industry, prominent figures and the media.

In addition to the provision of suitably qualified driver trainers, the training supplier is to also provide training centre administration. This may partly be covered by the trainers but also partly covered by administration effort based at the training supplier's premises. This is seen as a part time activity by staff involved in normal training administration.

The requirement is to:

- work with the TRL marketing and sales teams to ensure that every effort has been made for drivers to attend both the fixed and mobile simulator each day of operation
- liaise with TRL's Scottish marketing representatives to establish planned visits by non-trainees
- ensure that a visitor schedule is maintained and that visitors are met, briefed and given a brief tour of the facilities
- prepare daily schedules of activity for the fixed simulator so that trainers understand which types of drivers are attending and for them to prepare the appropriate training course.

prepare daily schedules of activity for the mobile simulator so that trainers understand which types of drivers are attending and for them to prepare the appropriate training course.

- for the fixed simulator prepare trainee packs, assist with their completion, retrieve data feedback forms, undertake data entry of forms
- provide sufficient stocks of trainee packs for the mobile simulator and manage inbound data collected from the mobile simulator.

liaise with TRL regarding the management of all driver records

The training supplier is also to make provision for:

- cleaning and maintenance support to ensure that the centre is always maintained to the highest possible standards. The centre must always portray a professional, clean, hygienic appearance.

Administrator Selection

Similar to the driver trainer, the training administrator has an equally critical role to play in the delivery of a successful programme. It is important that the selected individual has the correct level of experience and aptitude to perform this role. As such the following criteria must be met before an individual will be accepted as suitable for programme.

- A detailed Curriculum Vitae for the individual proposed must be supplied

A reference for the individual must be supplied.

Relevant experience.

Demonstrable ability in the use of IT equipment particularly relating to the use of standard office software. A suitable assessment of current IT ability is currently being developed by TRL.

- Suitable aptitude and personality. This will be assessed using UK accredited aptitude and personality tests. These will undertaken by TRL's Human Resources department

TRL reserve the right to reject a proposed administrator if these selection criteria indicate that they will be unsuitable for the programme.

C. INTERACTION WITH TECHNOLOGY PROVIDER

The technical supplier will deliver not only the hardware and operational software components but also a functional simulator with pre-programmed SAFED training exercises already installed.

To assist the technical supplier develop these exercises, TRL will work together with the training supplier and other appropriate stakeholders (e.g. DSA) to define the processes for specific SAFED training criteria. Much of the development work will be undertaken at TRL Headquarters in Crowthorne Berkshire over a three month period starting with a SAFED training workshop in September 2004. The training supplier will be expected to be involved throughout this period with attendance of an appropriate representative at Crowthorne for the scenario development workshop.

The technical supplier will also be obliged to train identified individuals from TRL and the training supplier in the operation and functionality of the systems.

- For the Fixed simulator, this will be for 5 days and take place in Cergy the technical supplier's premises near Paris and cover user training and first level maintenance training

Additional training for the mobile simulator will take place at the Fixed Simulator site in Scotland and will be 2 days mobile user training and 2 days trailer user training.

It is expected that by the time the systems are installed, all training scenarios will be operational at the start of the live training period, scheduled for mid summer 2005.

D. OTHER ISSUES

Reporting

The training supplier's representatives engaged on the project will report to TRL's project manager Pat Hayes.

Value add

It is recognized that this programme can offer considerable benefit and kudos to those organizations closely associated with it. This programme is provides clear opportunities for the training supplier being overtly involved. The training supplier is encouraged to identify methods or processes through which it could add value to ensuring the programme is a success.

Launch of Simulators in Scotland

There will be a press launch of the simulator in summer 2005. The premises and simulator will be opened by a Scottish Minister or senior industry figure. The training supplier's representatives will assist in preparation for the launch and will be available for driving and demonstrating the simulator to visitors.

Industry advisory group

An industry advisory group will be formed in Scotland in order to allow industry stakeholders to feedback their thoughts on the training programme. This will be an invited non-remunerative body. It is likely that senior representatives of the training supplier will be invited to be make presentations to the advisory group when appropriate. The function of this advisory group is to support rather than steer the programme, therefore representation must be at an appropriate level.

Training Records Management

All driver records will be transferred to TRL either electronically or physically, depending on the technological solution available. These records will be treated as confidential information. All correspondence and data gained within this project will be handled within data protection legalization, therefore appropriate confidentiality must be maintained.

The working day

The length of the working day will be sufficient to deliver the training required and associated start up and close down activities.

Maintenance

The simulators will require some first line maintenance and checking on a regular basis. This will be within the capabilities of the training staff. Other faults will be reported to TRL and/or the technical provider as agreed. Additionally, trainers will be expected to perform basic operational, deployment and diagnostic routines in order to operate the simulators. The training supplier should ensure that proposed staff will be prepared and capable of undertaking these basic tasks.

Innovation

While there are many prescriptive requirements in this specification, TRL is keen to accept innovative ideas on the training process and other ways of working.

Invoicing

Invoices are to TRL accounting quoting the appropriate TRL purchase order number. For further queries contact project manager Patrick Hayes - jhayes@trl.co.uk

Supporting documents

- Copy of the SAFED standard is available at http://www.safed.org.uk/About.htm

  Also an overview of the driver trainer requirements and maintenance responsibilities for operating the simulators is attached to assist the training supplier identify appropriate personnel to be involved in the research programme.

Appendix D. Questionnaires

In the following pages, examples of each of the questionnaires used in the SCOTSIM training programme are shown. They are:

Pre-drive questionnaire

Pre-drive SSQ

Attitudes towards simulation questionnaire

Post-drive questionnaire

Exercise questionnaire

Post-drive SSQ

SSQ stands for Simulator Sickness Questionnaire and was a tool developed by Kennedy, Lane, Berbaum, & Lilienthal (1993). It is commonly used in research and training to assess participants' subjective levels of sickness as a result of their experience in a simulated environment.

The final questionnaire shown in this appendix is that used for the driver screening as part of phase II.

`For office use only

Participant Number: ________________ Date of Trial: _____/_____/_________

SCOTSIM study

SECTION A DRIVER PROFILE

Note:

- All information on this form is confidential.
- It will be stored securely at TRL.
- No information will be used by other projects at TRL.
- No individuals will be identified in reports.

A1. Name

A2. What was your age at your last birthday?

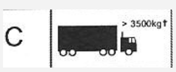
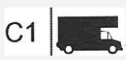
A3. Are you Male or Female (tick)?

Male		*Female*	

A4. How many years have you held a full driving licence?

A5. How many years experience as a professional truck driver do you have?

A7. What commercial vehicle licences do you hold?

	Licence held? (tick)	*How long? (years)*		*Licence held? (tick)*	*How long? (years)*
					
					

SECTION B

YOUR DRIVING

(Please circle the number that you feel is most appropriate)

B1. In general, do you enjoy driving?

Completely dislike driving										***Thoroughly enjoy driving***
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*

B2. When working, on how many days do you drive in a typical week?

Never							***Everyday***
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*

B4. In general, how confident do you feel when driving a car?

Very unsure										***Very confident***
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*

B5. How confident do you feel when driving a commercial vehicle?

Very unsure										***Very confident***
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*

SECTION C YOUR RECORD					
C1. For how many years have you been with your current employer?					
C2. How many hours of driver training have you received in the last…					
(a)…1 year?			*(b)…3 years?*		
C3. How many accidents (of any kind) have you had in the last…					
(a)…1 year?			*(b)…3 years?*		
C4. Which body type do you usually drive?					
Rigid			*Articulated (including draw-bar)*		
C5. Which type of gearbox does the commercial vehicle you most commonly use have?					
Manual		*Semi-automatic*		*Automatic*	
C6. Which type of load do you normally carry?					
Solid			*Liquid*		
Hanging			*Other*		
C7. How many LGV miles do you drive in an average year?					
Less than 20,000			*50-80,000*		
20-50,000			*More than 80,000*		

SECTION D DRIVING ABILITIES										
Please rate your skills in the following categories (0: very bad, 10: very good):										
D1. Adapting to a new vehicle										
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
D2. Fuel efficient driving										
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
D3. Low speed manoeuvres including reversing										
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
D4. Speed management										
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
D5. Driving in poor weather conditions										
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
D6. Judging gaps at junctions										
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
D7. Driving in high speed curves										
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
D8. Knowledge of driving theory										
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
D9. Anticipating hazards										
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*

SECTION E HEALTH SCREENING		
Before you can be scheduled for this study you are required to complete these health related questions. This is because some pre-existing health conditions may exclude you from participation in this study.		
Please answer the following question. If you tick yes for any questions please describe in the section below (include frequency of symptoms, type of symptoms and medication)		
E1. Have you ever suffered or been diagnosed with:	Yes	No
a) Any inner ear problems, dizziness, vertigo or balance problems?		
b) Diabetes or hypoglycaemia for which insulin is required?		
c) A respiratory disorder or shortness of breath?		
d) With a mood problem or psychiatric disorder?		
e) Motion sickness e.g. in ships, vehicles, fairground rides?		
f) A history of migraine headaches?		
g) A history of claustrophobia?		
h) Any serious or terminal illness?		
i) Do you suffer from a heart condition (e.g. heart attack, angina or irregular heart rhythm)?		
j) Have you suffered from a stroke, tumour, head injury or infection?		
k) Have you ever been diagnosed with seizures or epilepsy?		
l) Any other health problems which affect driving?		
Please give details:		
E2. Are you taking any other medication? If yes detail below.	Yes	No
E3. If you are female, is there any possibility that you are pregnant?	Yes	No

<u>End of Questionnaire</u>

Thank you very much for your participation in this study.

Before you begin driving the truck simulator, do you have any of the following feelings?

(Please tick the appropriate box for each symptom.)

	None	Slight	Moderate	Severe
General Discomfort				
Fatigue				
Headache				
Eyestrain				
Difficulty focusing				
Increased salivation				
Sweating				
Nausea				
Difficulty concentrating				
Fullness of head				
Blurred vision				
Dizzy (eyes open)				
Dizzy (eyes shut)				
Vertigo				
Stomach awareness				
Burping				

It may not be a good idea to take part if you are feeling unwell or tired. We want you to enjoy your time with us.

<u>End of Questionnaire</u>

To be completed by TRL
Participant Number: ________________ Date of Trial: _____/_____/_________
SCOTSIM study
Note: The questionnaire is divided into two parts. In Section A you are asked to provide some basic background information about yourself and your experience of computers and computer games, if any. Section B aims to get more detailed information by asking you to indicate the extent to which you agree or disagree with a number of statements provided. • All information on this form is confidential. • It will be stored securely at TRL. • No information will be used by other projects at TRL. • No individuals will be identified in reports.

SECTION A BACKGROUND INFORMATION									
Please tick the box that most accurately describes your experience with computers									
A1. Please describe your level of experience with computers?									
None		*Very limited*		*Some experience*		*Quite a lot*		*Extensive*	
A2. Do you have access to a personal computer or game console?									
Yes		*No*							
If "Yes" please provide details									
A3. Do you own a personal computer or game console?									
Yes		*No*							
If "Yes" please provide details									

SECTION B ATTITUDES TO TECHNOLOGY						
Please circle the number that is most appropriate to you						
	Strongly Disagree	*Moderately Disagree*	*Slightly Disagree*	*Slightly Agree*	*Moderately Agree*	*Strongly Agree*
B1. I enjoy watching widescreen television	1	2	3	4	5	6
B2. I am very unsure of my abilities to play computer games.	1	2	3	4	5	6
B3. I seem to have difficulties with most video players I have tried to program.	1	2	3	4	5	6
B4. Simulation games frighten me.	1	2	3	4	5	6
B5. I enjoy playing computer games.	1	2	3	4	5	6
B6. I find computers get in the way of learning.	1	2	3	4	5	6
B7. I often have difficulties when trying to learn how to use a new system such as a video, camcorder or DVD player.	1	2	3	4	5	6
B8. I am very confident in my abilities to use different technical equipment.	1	2	3	4	5	6
B9. At times I find computer games very confusing.	1	2	3	4	5	6
B10. I would rather that we did not have to learn how to use computers.	1	2	3	4	5	6
B11. I usually find it easy to learn how to play a new computer game.	1	2	3	4	5	6

	Strongly Disagree	Moderately Disagree	Slightly Disagree	Slightly Agree	Moderately Agree	Strongly Agree
B12. Using computers makes learning more interesting.	1	2	3	4	5	6
B13. I always seem to have problems when trying to use computers.	1	2	3	4	5	6
B14. Some computer packages definitely make learning easier.	1	2	3	4	5	6
B15. Playing computer games is something I rarely enjoy.	1	2	3	4	5	6
B16. Computers are good aids to learning.	1	2	3	4	5	6
B17. As far as arcade games go, I don't consider myself to be very competent.	1	2	3	4	5	6
B18. I find playing computer games very frustrating.	1	2	3	4	5	6

End of Questionnaire

To be completed by TRL

Participant Number: _________________ Date of Trial: _____/_____/_________

SCOTSIM study

Note:

One of the aims of today is to evaluate the effectiveness of this truck simulator in the use of truck driver training.

Please complete the following sections to tell us about your views of the simulator in terms of its handling and realism.

We are also interested in your views of the quality of the training that can be provided through simulation and what aspects, if any, could be improved for future training.

- All information on this form is confidential.
- It will be stored securely at TRL.
- No information will be used by other projects at TRL.
- No individuals will be identified in reports.

SECTION A SIMILARITY TO DRIVING A TRUCK						
Please tick the box that you feel is most appropriate						
	Exactly like driving a truck	*Very similar*	*Similar*	*Quite different*	*Very different*	*Not at all like driving a truck*
A1. Steering						
A2. Acceleration						
A3. Deceleration						
A4. Using Clutch						
A5. Mirrors						
A6. Gear shift						
A7. Exhaust brake						
A8. Overall cab						
A9. Headlights						
A10. Did the change from your usual cab to the simulator cab affect your learning in any way?						
Yes			*No*			
If "Yes" please provide details:						
A11. Do you have any further comments on the similarity of the simulator to driving a truck?						

SECTION B THE VISUAL DRIVING ENVIRONMENT						
Please tick the box that you feel is most appropriate						
	Very Poor	*Poor*	*Satisfact ory*	*Fair*	*Good*	*Excellent*
B1. Clarity of the display						
B2. Brightness of the display						
B3. Traffic signs and signals						
B4. Display in the mirrors						
B5. Realism of the scenery						
B6. Behaviour of other traffic						
B7. Realism of cyclists and pedestrians						
B8. Realism of road layouts						
B9. Overall driving environment						

B10. Did the quality and/or realism of the visual driving environment affect how easy it was to drive in the truck simulator?			
Yes		*No*	
If "Yes" please provide details:			

B11. What aspects of the visual driving environment do you think were missing that could have made it easier to learn?

SECTION C REALISM OF TRUCK SIMULATOR HANDLING						
Please tick the box that you feel is most appropriate						
	Exactly like driving a truck	*Very similar*	*Similar*	*Quite different*	*Very different*	*Not at all like driving a truck*
C1. Controlling speed						
C2. Controlling in turn						
C3. Changing gears						
C4. Service/foot braking						
C5. Exhaust braking						
C6. Signal turns/ lane changing						
C7. Handling difficult driving situations						
C8. Seeing the road and other users						
C9. Driving the truck in general						
C10. Do you have any further comments on the realism of the truck simulator handling?						

SECTION D OVERALL OPINION OF THE DAY						
Please tick the box that you think is most appropriate						
	Very Poor	*Poor*	*Satisfact ory*	*Fair*	*Good*	*Excellent*
D1. Truck simulator						
D2. Quality of training						
D3. Amount of training						
D4. Organisation of the day						
D5. Do you have any further comments about the overall strengths and weaknesses of the training day?						

<u>End of Questionnaire</u>

To be completed by TRL

Participant Number: ________________ Date of Trial: _____/_____/_________

SCOTSIM study

SECTION A

YOUR LEARNING EXPERIENCE

Note:

- All information on this form is confidential.
- It will be stored securely at TRL.
- No information will be used by other projects at TRL.
- No individuals will be identified in reports.

Please circle the number that you feel is most appropriate

	Strongly Disagree				*Strongly Agree*
A1. I feel I learned from the exercises	1	2	3	4	5
A2. I understood what I was expected to do.	1	2	3	4	5
A3. I found learning easier than learning in a real truck	1	2	3	4	5
A4. I found learning faster than learning in a real truck	1	2	3	4	5
A5. I felt that the exercises were the correct length	1	2	3	4	5
A6. I felt that the exercises were realistic	1	2	3	4	5
A7. I felt that I performed well in the exercises	1	2	3	4	5
A8. I feel that further training in the simulator would improve my driving performance	1	2	3	4	5
A9. I would like further training in the simulator	1	2	3	4	5
A10. I would recommend others have training in the simulator	1	2	3	4	5

SECTION B YOUR COMMENTS AND RECOMMENDATIONS
B1. Things I think should be added to the exercise
B2. Things I think should be removed from the exercise
B3. Things I think should be done to improve the exercise

End of Questionnaire

Having driven the truck simulator, do you have any of the following feelings?

(Please tick the appropriate box for each symptom.)

	None	Slight	Moderate	Severe
General Discomfort				
Fatigue				
Headache				
Eyestrain				
Difficulty focusing				
Increased salivation				
Sweating				
Nausea				
Difficulty concentrating				
Fullness of head				
Blurred vision				
Dizzy (eyes open)				
Dizzy (eyes shut)				
Vertigo				
Stomach awareness				
Burping				

End of Questionnaire

SCOTSIM screening criteria

Telephone questionnaire

I am going to ask you a number of questions to assess whether you conform with our criteria to participate in a discrete research study using the SCOTSIM truck simulators. Please answer the following questions as honestly as possible. Your answers will remain confidential and will be anonymised within the study itself.

There are no right or wrong answers.

Health questions

1. Are you aged over 60?
2. Have you ever had any form of brain damage?
3. Do you suffer from motion sickness (as a passenger in a car, fairground rides, ferry crossings)?
4. Do you suffer from migraine headaches?
5. Do you suffer from claustrophobia?

Health questions 1-6: **<u>Exclude if driver answers yes to any of questions 1-6.</u>**

Previous experience questions

1. Have you heard about the experience of other drivers using SCOTSIM?
2. (If yes to 1) Would you say that has put you off using a simulator for driver training?

Previous experience questions: **<u>Exclude if driver answers yes to BOTH questions 1 & 2.</u>**

Attitudes to simulation questions

"I am going to read a number of statements; you must rate how strongly you agree with the statement on a scale from 1 to 6.

If you strongly AGREE with the statement, you should answer '6'.

If you strongly DISAGREE with the statement, you should answer '1'.

Or give an answer somewhere in between as appropriate."

	Statement	**Response**
1	I enjoy watching widescreen TV	
2	I am very sure of my abilities when playing computer games	
3	I have no difficulties programming a video recorder	
4	I am very confident in my abilities to use different technical equipment	
5	I would like to learn how to use computers	
6	I rarely have problems when using computers	
7	Playing computer games is something I usually enjoy	
8	I consider myself a competent player of arcade games	
	Total	

Attitudes to simulation questions: **<u>Exclude if total score is 21 or less</u>**

If excluded:
Thank you very much for your time. I am sorry to say that based on your answers it appears that your profile is not appropriate for the current research study. This does not mean that you cannot participate in future simulator training and, with your consent, we would like to keep your details for possible participation in future studies.

Appendix E. Training schedules

Figure G1. Training schedules for T5000 and T3000