Improved realism and improved utility of driving simulators: are they mutually exclusive?

Andrew M. Parkes
Transport Research Laboratory (TRL),
Wokingham, Berkshire, England

This paper traces some of the developments in driving simulators since the 1960's. A distinction is drawn between *degree of simulation* and *fidelity of simulation* and poses questions about the future direction of technological development. The notion of *essential realism* was introduced in the 1970s in aviation simulation, but many of the lessons learned in that domain seem to be overlooked in driving simulation development. As the current push for improved face validity of driving performance parameters and the apparent realism of visual databases continues, it is possible to lose sight of the purpose of simulation within the training environment. This paper draws attention to the need to develop visual databases and road traffic scenarios that are derived from an analysis of training needs, not from the starting point of recreation of real world scenes. Examples of alternative approaches are given, and the implications discussed within the context of the current EC Directive on training.

BACKGROUND

Following the lead set by the aviation industry, simulators have been developed for both research and training for road vehicle drivers. Lee (2004) gives examples including the Iowa State driving simulator from 1958 that linked an vehicle cab mock-up to a scaled physical terrain model allowing the driver to control actions in a rudimentary road layout. Since then there have been many different technical innovations including video of real scenes and more recently, computer generated environments. In 1996 a report of the Federal Highway Administration detailed a scoping study on commercial motor vehicle driving simulator technology. It cited an earlier 1991 special issue of Heavy Duty Trucking that claimed

> *" Cost-effective training simulators are becoming technologically possible - there have been astounding leaps in computer graphics and realism - at the same time the driver shortage and the Commercial Driver License (CDL) are forcing the trucking industry to seek more effective methods for driver training, selection and screening".*

Some outside the industry might view it as surprising that, given the size of the trucking industry in the US and Europe, and the optimism displayed over ten years ago, there are relatively few commercial truck simulators in existence, and little consensus on the content of any curriculum delivery.

Indeed, the intervening period since the FHWA study has seen continued technological development in simulators, particularly in visual database rendering, but very patchy uptake and development of simulation facilities for commercial truck driver training. From a world-wide perspective a clear lead has been taken by France and the Netherlands (Grognet 2004), but even in those countries there is neither the capacity to introduce simulation components to all drivers undergoing current training, nor to satisfy any potential increase in demand. There appear to be four 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, the current requirements
- Some people get ill in simulators

One might conclude that to date there has been a rather hard-to-identify *carrot*, and a complete absence of any *stick* to encourage widespread development and uptake of synthetic training. The commercial truck sector is very different to military ground vehicle, or aviation, sectors, where the presence of cost-benefit models, accreditation and certification bodies, and agreed curricula are evident. There has been a general assumption that simulators (or more correctly, *synthetic trainers*) will probably eventually become widespread as computer costs come down and power increases, but the freight industry and the driver training industry is so fragmented in Europe, there is little to encourage early adopters of the technology.

The picture, in Europe at least, may soon change. The European Commission Directive on Training for Professional Drivers (EU Commission 2001, and adopted by European Parliament in April 2003) stipulates that all persons wishing to drive Large Goods Vehicles (LGVs) in excess of 7.5 tonnes in a professional capacity, will have to undergo training for, and obtain, a vocational Certificate of Professional Competence (CPC) further to the LGV licence. The directive provides a framework for licence acquisition, testing and further skills development.

The total length of *full basic training* in the proposal is 420 hours (12 weeks of 35 hours each). For *minimum basic training* this will be 280 hours. Each trainee driver must drive for at least 20 hours individually in a vehicle of the category concerned. This new Directive is of paramount importance to the training and simulation industries, because for the first time, explicit reference is made to simulators for both training and testing.

Each driver may drive for a maximum of eight hours of the 20 hours of individual training:

"*…on special terrain or on top-of-the-range simulators so as to assess training in rational driving based on safety regulations, in particular with regard to vehicle handling in different road conditions and the way they change with different atmospheric conditions and the time of day or night.*" (European Parliament 2003, p24).

This wording does not go so far as to say that training *should* include simulation, nor that the time devoted to such training *should* be eight hours, nor does it *recommend* simulation; but for the first time, it allows the possibility.

The new Directive goes even further. It opens the way for simulation to play a part in the practical element of the driving test. It states that the basic elements of the practical test must have a duration of at least 90 minutes. This practical test may be supplemented by an assessment taking place on special terrain or on a top-of-the-range simulator.

"The duration of this optional test is not fixed. Should the driver undergo such a test, its duration may be deducted from the 90 minutes….but the time deducted may not exceed 30 minutes" (op.cit. p25)

So, simulation is seen as a viable medium for testing and early skills development for novice drivers. However, the Training Directive is also concerned with the skill set of existing experienced drivers. A driver who has obtained his or her licence must undergo 35 hours of continuous training every 5 years.

"….*Such periodic training may be provided, in part, on top-of-the-range simulators*" (op.cit. p27).

The current wording poses some problems, for as yet, there is no satisfactory consensus view on the definition of *top-of-the-range*. It begs the question; who will be the arbiter and monitor of such a distinction?

According to the Directive, basic vocational training is divided into three areas:

- Advanced training in rational driving based on safety rules
- Compliance with regulations
- Health, safety, service and logistics

In addition there are other areas of direct relevance to possible simulator training. These relate to:

- road traffic regulations
- ergonomic principles
- behaviour in an emergency situation:

This shows where simulation, and synthetic training in general, could provide a valuable role, but it does not *prescribe* exactly which elements may be suitable, nor *proscribe* those that are unsuitable. The introduction of compulsory basic, and continuous training, will require a large increase in capacity in the training industry. As the industry expands there is a general expectation that simulation will become more common, and could eventually be a core component of the curricula. However, it could be a mistake to assume that simply because simulators are widespread, successful, and necessary in aviation or military ground vehicle applications, that they will be similarly well accepted and suitable for truck driver training.

The review by Williges, Roscoe and Williges (1973), pondered the then 50-year history of flight simulation, and concluded that '*….many issues concerning ground based flight simulators and trainers remain unanswered'*. Many concerns remain in aviation, and most remain to be addressed at all in a systematic fashion in the truck industry.

The possible benefits of simulation are clear. There is potential for: control of the training environment, repeatability of specific combinations of features, objective performance scoring, cost reduction and consistent on-line tutorial delivery. The training environment can also be more effective than the real world due to the ability to remove unessential elements from any particular scenario; and safer, due to the lack of physical risk, no matter how catastrophic the performance failure.

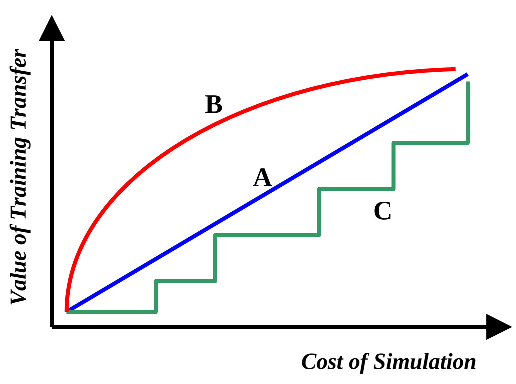
However, potential operators of training simulators need to know the following:

- what can they really do?
- how much will they cost?
- what new skills will trainers need?
- how will they be accredited?
- how should simulators be used within a wider curriculum?

The problem at present is that, whilst there are several convincing high-fidelity truck simulation systems available, there are very few answers available to the last of the questions above. There is little known in relation to truck driving, and little that is directly transferable from aviation, that can inform discussion of what should be delivered in a simulation training package, nor how the costs and benefits might compare to real road training. Information exists, but at present it is difficult to find.

The figure below attempts to demonstrate the current dilemma. In an ideal world we might hope there would be a clear linear relationship between the cost of a particular simulation system and the value of the training transfer that could be derived (line A). In reality, the relationship is likely to be less than straightforward.

Figure1. Models of Fidelity v. cost of simulation.



There is certainly a strong suspicion it may become increasingly expensive to add fidelity as one moves along the line (B), and added expenditure may result in diminishing returns on investment. In practice there are many go/no go decisions to be made in simulator specification, and so a step function (line C) may be more realistic. Decisions such as whether to include a motion system, or to include multiple channel projection systems, or to include sophisticated three-dimension sound rendering, all require jumps in technology provision that have substantial cost implications.

So what *degree*, and *fidelity*, of simulation are necessary for effective training of truck drivers? For maximum *face validity* of a truck simulator it would be necessary to specify the highest *degree* and *fidelity* available within a particular budget. But if the training has to be cost-effective when compared to traditional real world training, budgets will be constrained and a compromise might be needed in the views of *top-of-the-range* facilities. At present there is little information available to enable perfect choices between expenditure on a particular motion system instead of on a particular visual system, or even sound and vibration system. Can we even say that motion is necessary for successful training?

The aviation literature provides a range of views. Some have suggested that because experienced pilots often rely on motion rather than instrument readings, motion becomes more important as experience level increases (Briggs and Wiener 1959, cited in Williges et al). Similarly it might be argued that experienced truck drivers rely more on motion, sound and vibration rather than dashboard displays to judge the performance of the vehicle, whereas novice drivers might derive substantial benefit from systems that focus on instrument display. Thus some training lessons appropriate for novice drivers might be conducted on part-task trainers (see figure 2), but advanced skill based lessons would require a motion component. If we decide motion is important, then fidelity must be addressed. Poor motion systems might not only have a negative transfer of training to real world situations, they will also lead to increased levels of simulation sickness.

Figure 2. An example of a high-fidelity part-task trainer

There are some very high fidelity full-mission simulators in existence (see Figure 3), and whilst demonstrating that current and prospective technology can provide a dynamic and involving driving experience, such levels of sophistication come at a financial cost which may be unrealistic for the mass training market. However, the prospective European Directive wording refers to *top-of-the-range*. Herein lies the difficulty. Not only may simulators that can be described as top-of-the-range, or high-end, possibly be over specified, and out of the range of prospective users; the use of such terms implies that only systems that achieve some kind of high face- and performance-validity can have merit and value in training. There is, as yet, no distinction between full-mission and part-task simulators, nor acknowledgement that realism (isomorphism with real road training) may not be necessary or even desirable in all circumstances.

Figure 3 The National Advanced Driving Simulator, Iowa, USA

Similar arguments might surround the fidelity of visual databases. The simple view is that they need to be as realistic as possible. However from a training perspective that may not be correct. Certainly in terms of resolution, field of view, brightness, contrast and refresh rates there seems value to having higher fidelity. However it might be argued that the content of the visual scene itself does not have to be high fidelity (if that means close to photo-realistic representation of a real scene). There may be value in taking unimportant elements out of a visual scene, allowing the driver to concentrate on elements salient to the training objective without distraction. Anyone involved in visual database development knows that there is a distinct law of diminishing returns (line B) to further expenditure beyond a certain point.

Williges et al. proposed the notion of *essential realism*, relating not to what might be regarded as essential for improved face validity, but instead, essential to the particular training requirements under consideration. Indeed, face validity is the *bête noir* of training system specification, as it will always demand the highest feasible feature set. Instead, there are three important elements that should drive decisions on simulation provision within the training process:

- The efficiency and acceptability of the learning in the simulator
- The transfer of the learning to the real world
- The retention of skills or knowledge learned.

Lee (2004) posed a number of interesting questions about simulator development and concluded that the pursuit of higher levels of fidelity in simulation may not be adequate, or even desirable. The reasons being that increased fidelity can undermine scenario control, limit data collection, dilute training potential, and increase likelihood of causing simulator sickness. For example, if a simulation is able to provide a highly realistic and complex urban environment and a busy traffic situation; it may be a highly impressive demonstration if the state of the art of the simulation industry, but may force the driver to attend to elements peripheral to the current training objective. If the driver is supposed to focus on responding to a particular signal in the scene, a complex environment may present a number of competing signals and it would be difficult for the trainer to be certain which prompted the response by the driver. Taking extraneous noise from the scene (removing competing signals) would allow the particular behaviour or skill to be developed effectively and efficiently. The skill can then be later validated in a more complex and realistic environment, whether that is in a simulator on the real road.

Reports are emerging that point to cost-benefits of simulation training. Welles and Holdsworth (2000) reviewed features necessary to successful training in a range of commercial simulators and concluded that "…data to date, although sketchy, anecdotal or very preliminary, provides strong suggestion that driving simulators ….can reduce accidents, improve driver proficiency and safety awareness, and reduce fleet operations and maintenance costs". They refer to hazard perception training with a particular 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.

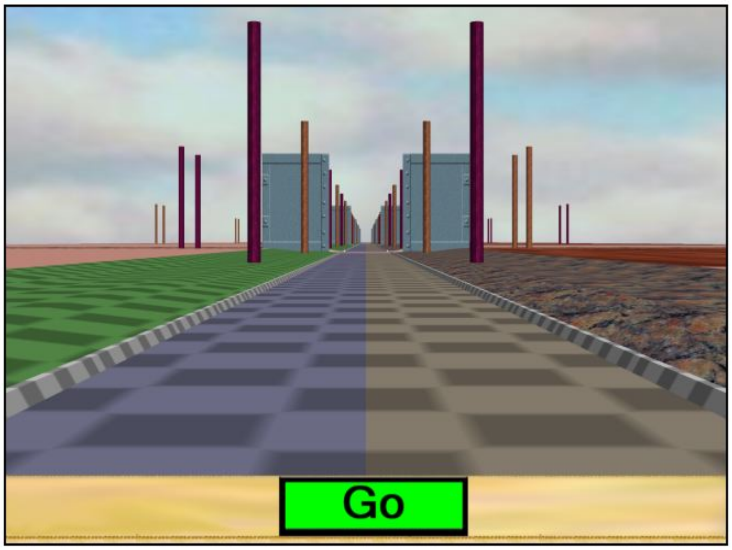
More recently Dolan, Rupp, Allen, Strayer and Drews (2003) presented evidence from a fuel management simulation study which tracked 40 drivers through a two-hour training programme, and later for a six-month follow up. Drivers were given specific training in the operational and tactical aspects of appropriate 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.

Such reports are encouraging, but do not take us far toward a minimum specification for systems that can provide a similar transfer of training benefit. There is a wealth of anecdotal experience that shows that road environments are difficult to model in simulators. Buildings and road signs have sharp edges, and road markings use white lines. At current typical screen resolutions such scenes are prone to highlight aliasing and peripheral flicker, and text on signs will appear blurred. The number of polygons needing to be processed in a photo-realistic scene may also mean that simulators run at close to their processing limits and consequently display slow refresh rates.

One of the important skills in database creation is optimisation for the run time environment to ensure that the scene can be processed efficiently. However, the starting point is usually taking realistic road layouts and scenes and making adjustments to levels of detail and so on to make them usable, rather than coming from the other direction of taking what is known about cognitive processing, perceptions of speed and distance and producing an environment that includes salient information that allows training principles to be demonstrated, but which may be far removed from conventional views of realistic road scenes. Rizzo et al (2002) have demonstrated an interesting concept with a database road scene created specifically to host experiments with cognitively impaired participants and their judgments of speed and distance. The experiment involved a large number of braking manoeuvres in a short space of time; and if conducted in a computer road scene of 'traditional' aspect would have been highly likely to promote high levels of simulator sickness. However, the specially constructed road environment which used aspects of colour, tint, texture, and object obscuration coding to produce a driving environment which lacked face validity (apparent realism) but provided very high utility for the research team.

Accurate data could be collected from a large number of participants with very minimal problems of simulator sickness.

Figure 4. Example of stylised road scene from Rizzo et al 2002



The road scene above is clearly an extreme example, but in being so, serves to illustrate the point that utility has been maximized by careful consideration of the particular requirements of the task under consideration.

Technological developments of simulators will continue as manufacturers seek to develop products for the marketplace and seek commercial advantage through performance improvement. However, improvements in computers and projectors, or motion systems, in themselves will not lead to a dramatic upswing in usage. A focus on *essential realism* is needed, and the main area for this is in the look and feel of the road scene databases. Such road scenes and scenarios must be developed that support the ability of the driver to interpret salient information without overloading the visual system with unnecessary information. The road scene must be a comfortable place for training to take place.

Face validity, the *bête noir* of simulation development, must assume a lower priority for users, if real progress is to be made.

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