COMPETITIVE AND SUSTAINABLE GROWTH
(GROWTH) PROGRAMME

TRAINER

System for driver **Tr**aining and **A**ssessment using **In**teractive **E**valuation tools and **R**eliable methodologies

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List of Abbreviations

Abbreviation	Explanation
ABS	Antilock brake system
DTSI CM	Driver Training and Safety Institute, Carnegie Mellon, a non-profit subsidiary of Carnegie Mellon University, PA USA.
GADGET	Guarding Automobile Drivers through Guidance, Education and Teaching (GADGET). A project initiated and partly financed by the EU commission
LCD	Liquid Crystal Display
OECD	Organisation for Economic Co-operation and Development

Index

List of Figures

List of Tables

Abstract

The present truck and bus driver training simulator feasibility study was based on the question: is it feasible to develop a new training methodology utilising low cost and medium cost simulators for truck and bus driver training? The answer is yes. The simulator fidelity is not the issue. The only really important factors for successful training is that the simulator delay is acceptably short and that the simulator can project rear view mirrors. The outcome is however, highly dependent on the curriculum content. There are not many truck and bus driver training simulators operating on the market, and very few of them have provided us with data on the simulators, as well as on their curricula. The present study is, hence, a more theoretical study. Future studies in the field of truck and bus driver-training in simulators should focus on whether actual training effects are present, with respect to training efficiency, as well as to the traffic safety impact of simulator training.

This study is based on the assumption that maybe the TRAINER concept could be used not only for car driver training, but also for truck and bus driver training. We have tried to describe from a theoretical point of view **what** we should aim at, **why** we want to do it and **how** it may be done. This approach is the old traditional didactical triangulation, which I found suitable for this purpose. We also tried to include a questionnaire-based survey of existing truck and bus driver training simulators into the **how**-section of the report. The relevant study is not a full benchmarking, but rather examples of existing simulators, in order to provide the reader with a picture of what is there already on the market.

Also a subchapter about technical requirements for truck and bus driving simulators has been written for non-engineers, as well as the rest of the report, and provides a clear picture of what is essential when discussing the feasibility of simulator usage in truck and bus driver training. A lot of statistics from both bus and truck driver accidents are included in this report.

This Deliverable is structured in accordance to the didactic triangulation: **what?, why?** and **how?**. The reason for using this model is that a truck driver training simulator feasibility study should take a starting point in defining what should be made, before trying to evaluate reasons for doing it and the methods. Hence, this reports first chapter focuses on the objectives of this report, i.e. **"what?".** After that the reasons for driver training in simulators are discussed, i.e. **"why?"** simulation. Finally, the means to achieve the goals are studied and analysed, i.e. **"how"** can this be done?

Chapter 1: Truck driver training simulator feasibility study; **what** are we aiming at?

Based upon the relevant needs found earlier in the TRAINER project and the experience acquired by the TRAINER consortium in developing, constructing and working with low and medium cost driving simulators, as well as multimedia tools, for driver training, the feasibility to develop also a truck driver training simulator will be examined in this Deliverable. This means that there will be a lot of references to earlier findings and previous deliverables from the project. The reader is thus advised to get acquainted with the TRAINER website (http://www.trainer.iao.fhg.de/), from which most of the references can be downloaded. However, a brief summary of the technical objectives and achievements are presented here:

The TRAINER objectives are:

- To develop a new cost-effective Pan-European driver training methodology, which will pay significant attention to the enhancement of risk awareness of learners drivers. It will also familiarise them with emerging Advanced Driver Assistance Systems, like ABS, but also Adaptive Cruise Control, Navigation aids, etc.
- To develop a methodology to assess and support driver's cognitive skills.
- To ***develop a new interactive multimedia training tool*** in 8 languages to support driver training and assessment in strategic and manoeuvring tasks (theoretical driver training improvement), to familiarise novice drivers with the basic principles of driving tasks and to provide a better understanding of risks.
- To develop a ***low cost and enhanced reliability stationary driving simulator*** (4 prototypes) to support driver training and assessment in manoeuvring and control tasks for practical driver training in driving schools, based to the maximum extent on existing elements from the market.
- To develop a ***medium cost and high performance semi-dynamic driving simulator*** (4 prototypes) to support specific needs of selected driver cohorts (novice drivers with enhanced knowledge problems, re-training of drivers in high-risk groups), extending the previous one (visual field up to 180^{o} and simulation of lateral transient forces effect into the horizontal direction)
- To develop new training and assessment criteria and methodologies, tools to capture them and a normative driver behaviour database, to allow trainers to monitor driver training and authorities to extract statistical data concerning driver training.
- To verify the above methodology and assess the effect on risk awareness enhancement of learners drivers through tests with 30 novice drivers (and an equal control group) in 4 European countries.
- To provide recommendations and best practice guidelines for the adoption of common European driver training and assessment framework.

A truck driver-training simulator has for natural reasons other demands than a driver-training simulator for cars. But does it also have other demands than a driver-training simulator for bus drivers would have? The answer may be both "yes" and "no". On the one hand buses are heavy vehicles, as well as trucks, demanding a specific knowledge on how to drive this type of vehicles. Moreover, certain types of driver licences are usually required, as for trucks. In addition, nearly all who obtain those driver licences do it for their profession, not for their personal reasons. Hence, the requirements for bus driving and truck driving may be regarded similar. On the other hand, driving a bus is often done in congested city traffic, sometimes under heavy pressure from tight time schedules and varied passenger demands, features that are necessarily not applicable on truck driving. Furthermore, driving a bus is rarely done with the addition of a trailer or a semi trailer, a feature necessary to practice for truck drivers.

To summarise, there are many similarities between truck driver training and bus driver training, but also certain obvious differences. However, this report will include driver training from the bus driver perspective, as well, although the main focus will be on truck driver training simulation. Throughout the report we will refer to "truck and bus driver-training" unless something is specific for bus drivers only, which will then be denoted as such.

One of the main characteristics of the TRAINER project is that it is aiming to introduce a new driver training methodology based on scientific knowledge about novice drivers needs. Hence, novice drivers' accident involvement has been examined in relation to driver-training curricula in different European countries. Based on the identified needs and the curricula, gaps were identified (Hoeschen et al., 2001). For this purpose a theoretical model for driver training was found to be essential to introduce into the TRAINER project, in order to find a structure of the curricula contents. The GADGET matrix (Hatakka, Keskinen, Gregersen, & Glad, 1999) was chosen, due to the fact that it was developed on the same scientific basis as was the basis for the TRAINER project. The model can briefly be described as follows:

The GADGET-matrix is based on the assumption that the driving task may be described as a hierarchy. The idea of the hierarchical approach is that abilities and preconditions in a higher level influence the demand and preconditions on a lower level. The most important feature of the GADGET matrix in comparison to other models, e.g. the Michon model (Michon, 1985) is the addition of a fourth level relating to personal preconditions and ambitions in life in general, which have shown to be of great importance for driving and road safety. The four levels are:

- Goals for life and skills for living.
- Goals and context of driving.
- Mastering traffic situations.
- Vehicle manoeuvring.

The highest level refers to personal motives and tendencies in a broader perspective. This level is based on the knowledge that lifestyles, social background, gender, age and other individual preconditions have an influence on attitudes, driving behaviour and accident involvement.

On the next level, the focus is on the goals behind driving and context in which driving is performed. The focus is on why, where, when and with whom driving is carried out. Examples on more detailed aspects are the choice between car and bus; daytime or night time driving, rush-hours or not, decision to drive under the influence of alcohol, fatigue or stress etc., all in relation to purpose of the trip.

The next level is about mastering driving in traffic situations, which are defined as more limited than the driving context above. A driver must be able to adjust his/her driving in accordance with the constant changes in traffic, for example in junctions, when overtaking or when encountering unprotected road users. To be able to identify potential hazards in traffic is also on this level. Driver education and training is traditionally focusing this level.

The bottom level is focusing on the vehicle, its construction and how it is manoeuvred. To know how to start, shift gears and stop the car good enough to be able to use the car in traffic belongs to this level, as well as more complex evasive manoeuvres, reducing skids on low friction and understanding the laws of nature. The functioning and benefits of injury preventive systems, such as seat belts and airbags, also belong here.

A safe driver is, however, not only skilled but also aware of risks and of own abilities and preconditions. In order to cover these different dimensions the matrix includes three dimensions as follows:

- Knowledge and skills.
- Risk increasing factors.
- Self-assessment.

The content of the first column describes the knowledge and skills that a driver needs for driving under normal circumstances, that is, on the lower hierarchical levels how to manoeuvre the car, how to drive in traffic and what rules must be followed. On the higher levels the column relates to how trips should be planned and how personal preconditions may influence behaviour and safety.

In the second column about risk increasing factors the focus is on awareness of aspects of traffic and life that can be associated with higher risk. On the basic level it may be worn-out tyres, poor brakes, lack of routine in performing basic manoeuvring etc. Higher in the hierarchy the column refers to risky driving in darkness, on low friction, among unprotected road users, excessive speeding, mental overload etc. It also relates to dangerous motives and risk increasing aspects of lifestyle and personality.

The third column is about how the driver is assessing his/her own situation on the four levels. It points out the calibration of own skills on the basic levels and awareness of own personal preconditions and tendencies, as well as abilities in decision making about trips and in life in general on the upper levels. The GADGET matrix is shown in Table 1.

Table 1: The GADGET-matrix (Hatakka et al., 1999)

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

The cells in the matrix thus define frames for definition of detailed competencies that is needed in order to be a safe driver. The matrix may be used for defining educational goals and educational content in driver education and training. The suggestion from the constructors of the matrix is that driver training strives at covering as much as possible of the whole matrix, not only the lower leftmost cells that traditionally are covered. In the TRAINER project the matrix is used for definition of educational content as a base for development of new educational methods and applications.

Could this theoretical model also be sufficient for truck driver training? The answer to this question must be based on scientific evidence, as is done in the TRAINER project. Accidents, or as sometimes preferred by authors; crashes [1], need to be analysed. Moreover, also incidents [2], i.e. non-collision events resulting in casualties, need to be analysed (Falkmer & Törnros, 2001). This is especially important for bus driver training. In addition, current truck driver-training curricula in simulators should be mapped; analysed and driver-training needs and relevant gaps should be identified.

In this report, these analyses will be performed and reported in the chapters “Truck driver training simulator feasibility study; **why** are we aiming at this goal?” and “Truck driver training simulator feasibility study; **how** are we achieving this goal?”.

A truck driver training simulator feasibility study should also include the relevant technical specifications, the cost and expected benefit for such a simulator. The TRAINER conceptual framework (Falkmer & Gregersen, 2001) will constitute the base for the feasibility study, i.e. a low cost simulator at approximately the cost of a training vehicle and a medium cost simulator of approximately three training vehicles. This part of the report is presented in the chapter “Truck driver training simulator feasibility study; **how** are we achieving this goal?”.

To summarise; We are obliged to perform a truck driver training simulator feasibility study, in order to assess whether the TRAINER conceptual framework is transferable to truck and bus driver - training in simulators, as well. The framework has three major features that make the TRAINER project unique;
1, it is based on scientific knowledge concerning novice drivers’ needs
2, it utilise the GADGET matrix
3, the educational tools are a low cost simulator and a medium cost simulator

We will include bus driver training in the truck driver training simulator feasibility study, but not as a separate part, due to the fact that a lot of driver training for bus drivers and truck drivers is similar.

[1] The word accident conveys a sense that the losses incurred are due to fate and devoid of predictability, while the word crash indicates a in a simple factual way of describing what is observed in nearly all cases (Evans, 1991) (page 8).
[2] Incidents are also defined as high risk situations or near accident situations, definitions that by no means contradict the definition presented here.

Chapter 2: Truck driver training simulator feasibility study; **why** are we aiming at this goal?

Lack of harmonisation

Driver training in Europe suffers from lack of harmonisation (Groot, Vandenberghe, Aershot, & Bekiaris, 2001). This is true for truck and bus driver training, as well. The bus and trucking industry is constantly influenced by external factors (OECD, 1996). For example, national and trans national structures that are formed (e.g. EU, and NAFTA) and developed, fuel economy, environmental protection, infrastructure privatisation and economic deregulation. At the same time driver licensing procedures are literally different in each country with respect to demands, as well as costs. When assessing the licensing procedures (or lack of procedures) the OECD expert group concluded that many serious licensing issues remained to be addressed, namely (OECD, 1996):

- the need for a rigid test on the physical and mental ability of drivers at the time of application and renewal of licenses;
- mandatory training prior to the licensing;
- the potential of graduated licensing for drivers of heavy freight vehicles;
- the worth of demerit points for drivers of heavy freight vehicles.

A harmonisation of the licensing procedures, e.g. based on TRAINER conceptual framework, would probably be positive as it simplifies the licensing procedures and allows comparable measures between countries. Furthermore, harmonisation leads to the possibility to compete between companies with different origin countries.

To improve road safety

The vehicle fleet in the OECD countries varies a lot. In
Figure 1 this is displayed for 17 countries.

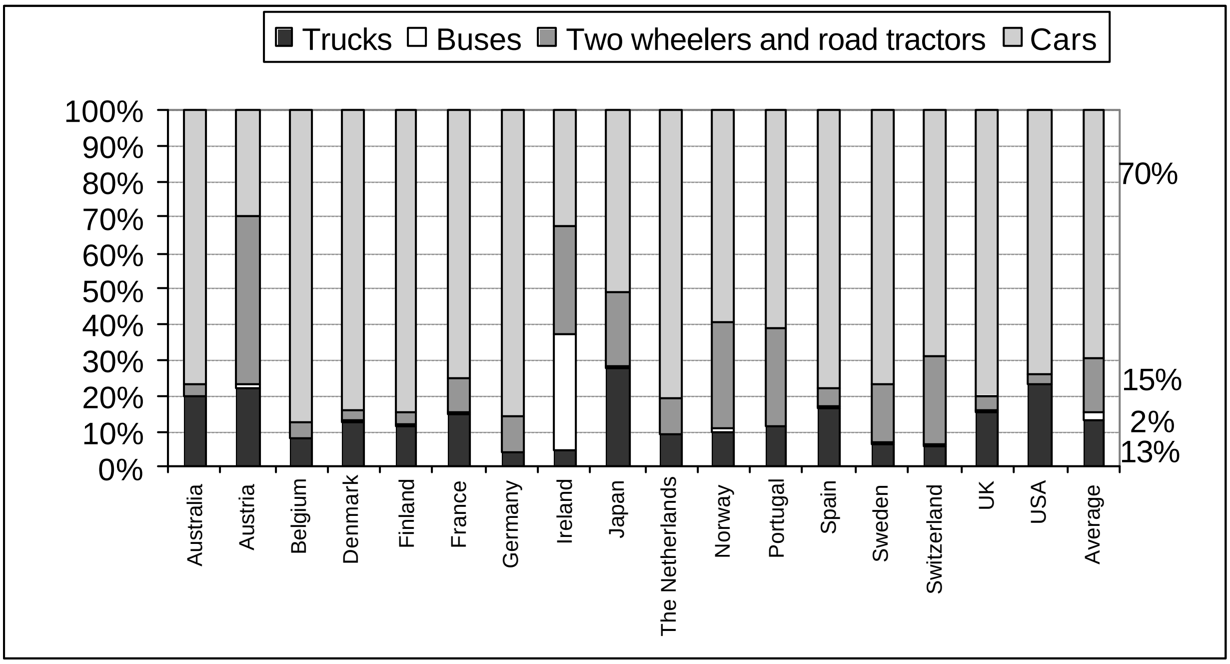

Figure 1: Registered vehicle types per country as a percentage of the total number of road vehicles (OECD, 1996). Please, note that when buses represent less than 0.5% of the vehicle fleet, no white section of the bars becomes visible.

As shown in
Figure 1 the percentage of vehicles that are trucks and buses does not exceed 15% of the vehicle fleet on average. One exception is the vehicle fleet on Ireland, in which 33% of the vehicles are buses. If trucks are added, 38% of the vehicles are heavy vehicles. This extreme percentage of heavy vehicles is not common. On average 13.1% (SD 6.9) of the vehicle fleet in the examined countries are trucks and 2.3% (SD 7.8) are buses. If Ireland is not included, 0.4% (SD 0.2) of the vehicle fleet are buses, while 13.7% (SD 6.8) are trucks. Hence, buses constitute only a very limited part of the vehicle fleet.

Trucks are over represented in fatal accidents/crashes. Although trucks represent 13.1 % (SD 6.9) of the vehicles in the above mentioned 17 countries, they account for 3-5% involvement in ac accidents/crashes annually but are involved in >10% of all fatal accidents/crashes (OECD, 1996). Moreover, they are involved in about 5% of all accidents/crashes that only includes property damage. Truck accidents/crashes account for >15% of total road accident/crash costs. The aggressiveness due to the mass of the vehicles is singularly important, especially in head-on collisions (Huttula, 1994). However, compilations and analyses of statistical data on heavy freight vehicles accidents/crashes presents considerable difficulties and usually yields very limited substantive conclusions (OECD, 1996). This statement is confirmed by Nilsson, who explicitly states that *"The main conclusion is however that comparison of fatality and injury rates must be done for homogeneous environments and road user groups and not for whole countries and all road user groups, as the distribution and composition of traffic in different environments must be taken into consideration."* p 17 (Nilsson, 1997), which can explain the variation in fatality rates per million vehicle miles between different literature sources.

Nilsson has nevertheless used data from the OECD countries to calculate fatality risks for different categories of road users. The fatality rate for truck drivers per million km, i.e. 0.0025-0.0045, is about half of the rate for car occupants, i.e. 0.004-0.016. As a comparison it can be mentioned that fatality rate for pedestrians, cyclists, mopedists and motorcyclists ranges from 0.03-0.06 up to 0.11, i.e. approximately a ten folded risk. These figures may also be expressed in the number of loops around the planet earth per fatality. One loop is 40,000 km and one million km represent 25 loops. For a truck driver this means that he/she may drive 5,500-10,000 loops per fatality and truck drivers drive on average approximately two loops per year. Taking into account the number of truck drivers per year and their average driven kilometres, i.e. the frequency exposure, this means that in the examined OECD countries one out of 2,750-5,000 of the truck drivers each year will be killed in a road accident/crash. However, the exposure measure for truck drivers is difficult to determine precisely, due to the fact that the classification of lorries differs between the countries and that data gathering by questionnaires is a rather crude method for this particular group of road users. Nevertheless, the presented figures suggests that truck drivers are exposed to the inherent risks connected to road transportation, but to a lesser degree than drivers of cars. Moreover, this assumption may be valid for bus drivers, as well.

Accident/crash data from Sweden is presented below in order to provide an example of what truck and bus drivers are exposed to in a homogeneous environment. Data for 1997-99 are compiled. However, it should be noted that in Sweden trucks are divided into light trucks and heavy trucks. The former is defined as trucks weighing less than 3.5 tonnes, and, consequently the latter weighs 3.5 tonnes or more. Based on this subdivision a comparison can be made on the occurrence of accidents/crashes between the two groups, as is presented in Figure 2

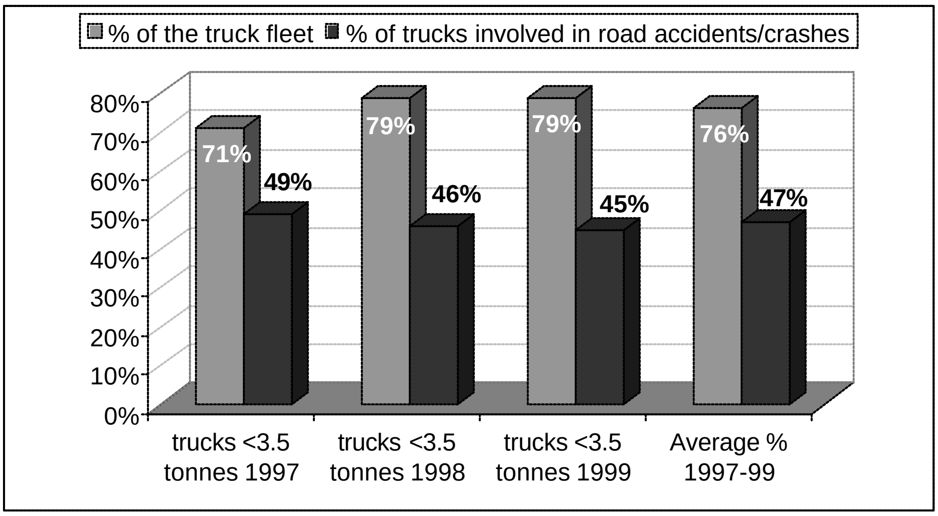

Figure 2: Accident/crash involvement versus occurrence of Swedish light trucks (data from SNRA for 1997-1999).

Heavy trucks are comparatively more often involved in accidents/crashes than light trucks. While light trucks constitutes on average 76% of the truck fleet, they are only involved in 47% of the accidents/crashes. Hence, heavy trucks constitute only 24% of the truck fleet but are involved in 53% of the accidents/crashes, as can be deducted from Figure 2. A further analysis of these data reveal that trucks weighing more than 20 tonnes are 3-4 times as likely to be involved in an accident/crash as a light truck. Apparently the weight and, hence, the size of the vehicle have some relation to traffic safety.

On the other hand occupants of heavy trucks are less likely to be killed in accidents/crashes but more likely to be slightly injured than light truck occupants and other road users, as shown in Figure 3.

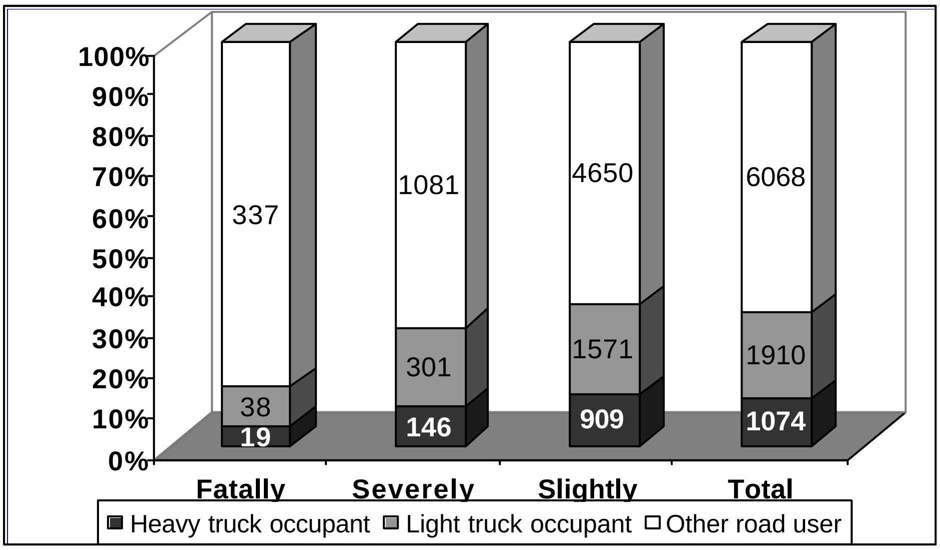

Figure 3: Accident/crash injury severity with respect to different categories of vehicle occupants (SNRA data 1997-99).

As shown in Figure 2 and Figure 3, truck drivers in heavy trucks are more often involved in accidents/crashes but less likely to be killed or severely injured from them, than drivers of light trucks. This finding is confirmed by American data on 47,093 fatalities in 1988 (Evans, 1991), from which it can be concluded that occupants in heavy trucks account for only 2.1% of all fatalities, i.e. far less than expected with respect to the percentage of heavy trucks and their annual mileage.

The safety belt usage in fatal accidents/crashes was examined for the period 1997-2000 in Sweden (SNRA data) and it was found that of all killed truck drivers in heavy trucks 70% did not wear safety belts and for 18% safety belt usage was unknown. The corresponding figures for light trucks were 61% and 17% respectively. In cars the corresponding figures are 34% and 9% respectively, i.e. a significantly more frequent usage of safety belts than among truck drivers.

Figures for occupants and non-occupants killed or injured in truck and bus accidents/crashes in different European countries 1987-1991 (Persson & Ödegaard, 1995) are presented in Table 2:

Table 2: Occupants and non-occupants killed or injured in truck and bus accidents/crashes compared to other vehicle types in four different European countries for 1987-1991 (Persson & Ödegaard, 1995).

Country	**Occupants killed** per 10^9 km	**Non-occupants killed** per 10^9 km	**Occupants injured** per 10^9 km	**Non-occupants injured** per 10^9 km
		TRUCKS		
Sweden	5.6	25.5	172.6	330.2
Finland	4.9	28.5	89.4	138.0
UK	2.8	11.0	182.4	366.2
Germany	3.6	17.7	209.8	320.7
		BUSES		
Sweden	1.4	39.2	264.9	560.8
Finland	1.7	30.4	118.3	154.8
UK	5.3	26.4	1779.3	869.1
Germany	3.6	31.9	1303.3	771.9
		CARS		
Sweden	8.4	2.9	251.2	80.5
Finland	10.5	3.9	173.2	41.8
UK	6.2	4.4	536.1	267.6
Germany	11.4	4.8	705.5	233.8
		MOTORCYCLES		
Sweden	52.8	10.0	1334.3	207.1
Finland	116.6	26.7	1843.3	188.3
UK	97.4	17.4	4728.3	717.6
Germany	132.6	12.8	5591.2	249.0

As shown in Table 2, motorcycles, and cars to some extent, primarily pose a threat to the occupants of these vehicles, whereas trucks and buses primarily pose a threat to the non-occupants, that is, the other road users.

What are the main accidents/crashes causes then? Not much data can be found in international literature for truck accidents/crashes, with respect to causalities. Swedish data does not provide an answer[3]. However, in a Finish study (Häkkänen & Summala, 2001) investigating the causality factor in 337 fatal two-vehicle accidents, it was found that in 16% of the cases the truck drivers were principally responsible. Moreover, younger driver age and driving during evening hours were significant predictors of being principally responsible. In addition, the probability of being principally responsible for the accident/crash increased by a factor of over three if the driver had a chronic illness. Furthermore, driver experience has a significant impact on accident/crash involvement (OECD, 1996). The risk of being involved in a road accident/crash is inversely proportional to the truck driver's experience.

[3] In Sweden it is possible to register a car as a truck if only certain measures are taken. Accident/crash data does not provide an answer on the weight of the truck involved in a specific accident/crash and, hence, these data are not sufficient for the purpose of this report.

There are also some American data. “Human error” was believed to be the main reason (in 75% of the cases) for accidents/crashes involving trucks (OECD, 1996). In a study performed on truck accidents/crashes in Michigan, USA (Lyles, Campbell, Blower, & Stamatiadis, 1991), it was concluded that the most consistent factor associated with truck accident/crash rate was the roadway class. Urban accident/crash rates were lower than rural rates. Moreover, night rates were lower than day rates for casualties but lower for all accidents/crashes. Trucks were also found to be more likely than non-trucks to be involved in multiple vehicle accidents/crashes, 79% of truck involved accidents/crashes involved two or more vehicles versus about 57% of non-truck-involved accidents.

American data from bus accidents/crashes do also provide a picture of accidents/crashes and their causes. In the U.S. most of the accidents/crashes occur between intersections, i.e. while driving in the traffic, and a frequent event is rear-end collisions. The second most common place is at intersections while accidents/crashes in loading zones is the third most common place, being almost as common as intersections accidents/crashes (King, 1996). However, this survey was s not a total survey in the U.S. but merely a sample of bus accident drawn from transit companies of different sizes. Thus, this information should be handled with care.

In N.Y. a seven-year investigation on probable accident causes for the bus accidents was performed (N.Y.State.Pub.Transp.Saf.Board, 1994). The results are presented in Figure 4

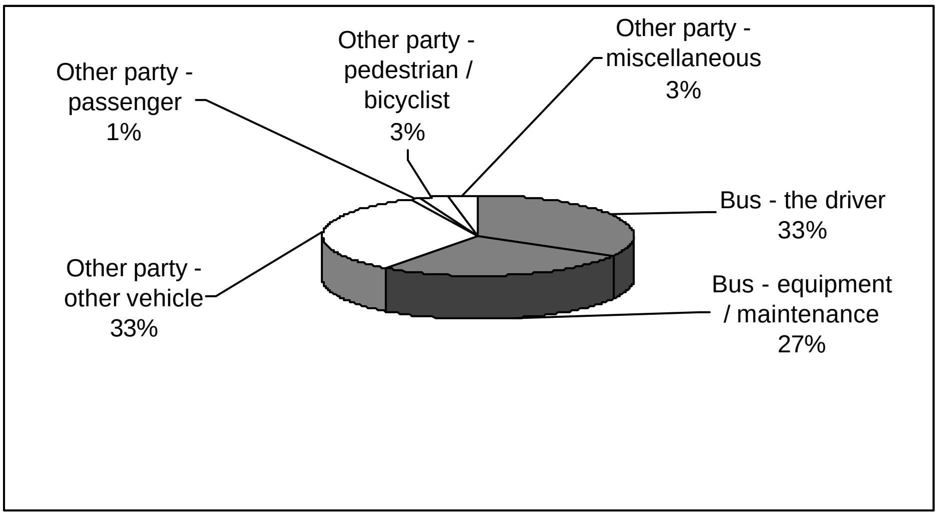

Figure 4: Bus probable accident/crash cause categories from a New York investigation of accident over the years 1988-1994 (N.Y.State.Pub.Transp.Saf.Board, 1994).

From the data presented in Figure 4, it was concluded that the driver, the bus and other party represented more or less a third of the causes each. The driver probable accidents/crashes, i.e. 33% of the accidents/crashes causes were scrutinized further. The results are presented in Figure 5.

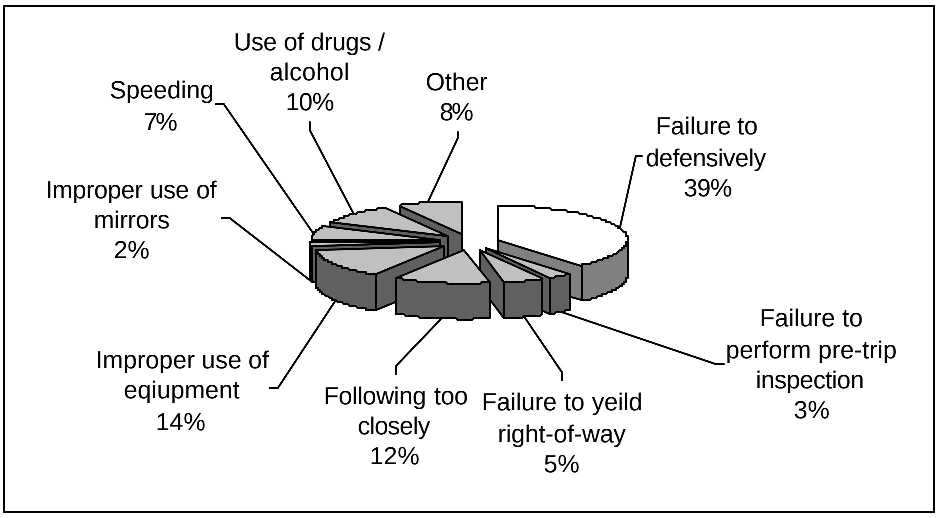

Figure 5: Bus driver probable accident-cause types from a New York investigation of accident over the years 1988-1994 (N.Y.State.Pub.Transp.Saf.Board, 1994).

As shown in Figure 5, the major cause for bus driver related accidents was failure to drive defensively. It should, however, be kept in mind that Figure 5 only represents the bus driver probable part of the accidents, i.e. 33% according to Figure 4. If the 27% labelled as “Bus - equipment/maintenance” causes in Figure 4 are further analysed the following figure can be shown to illustrate the results.

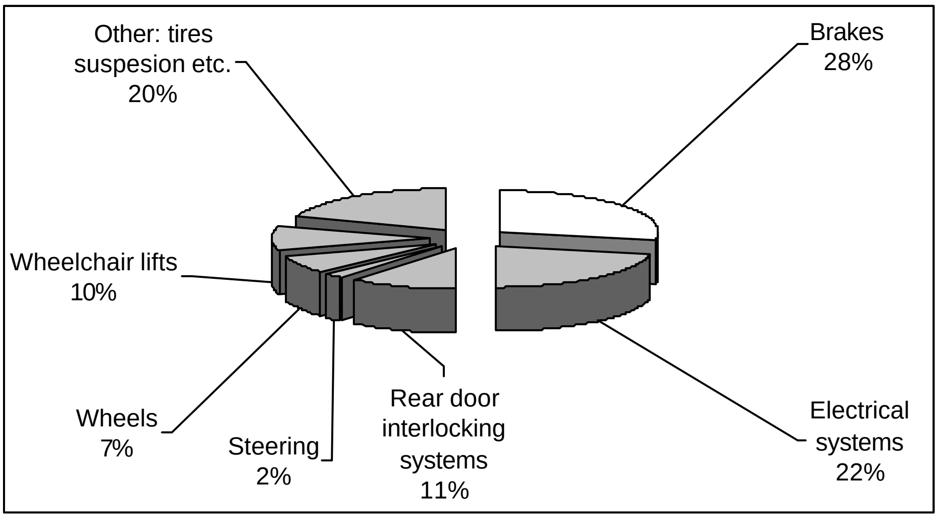

Figure 6: Bus equipment probable accident cause type (N.Y.State.Pub.Transp.Saf.Board, 1994).

As shown in Figure 6, the most common “equipment/maintenance” accident/crash causes were insufficiently functioning brakes, electrical systems and tires, suspensions etc. In total, this means that approximately 8% (i.e. 28% of 27%) of the accident/crash causes could be attributed to defective brakes. For trucks this figure is only 3% (OECD, 1996).

Data are insufficient with respect to truck driver accidents/crash causes. Police records are often inconclusive and ambiguous, e.g. "…speed too fast for conditions" (OECD, 1996). Another often stated reason is "driver fatigue and lack of training in operating the vehicle". However, the latter assumption was not confirmed by Häkkänen and Summala (2001) who claimed that only 2% of the truck drivers in their accident investigation were estimated to have fallen asleep while driving just prior to the accident /crash. Furthermore, only 4% altogether of the truck drivers had been tired prior to the accident. Hence, the results are somewhat ambiguous with respect to the impact of fatigue on truck accidents/crashes.

Bus accidents/crashes are not frequent events. In the U.S. accidents/crashes involving buses only accounts for 1 % of the total costs for crashes (Miller et al., 1991). Truck crashes are, however, more frequent as previously mentioned. The cost of truck crashes is also generally higher (OECD, 1996). Moreover, accidents/crashes involving buses are the least expensive crashes, while accidents/crashes involving any type of trucks are more expensive, as shown in Figure 7

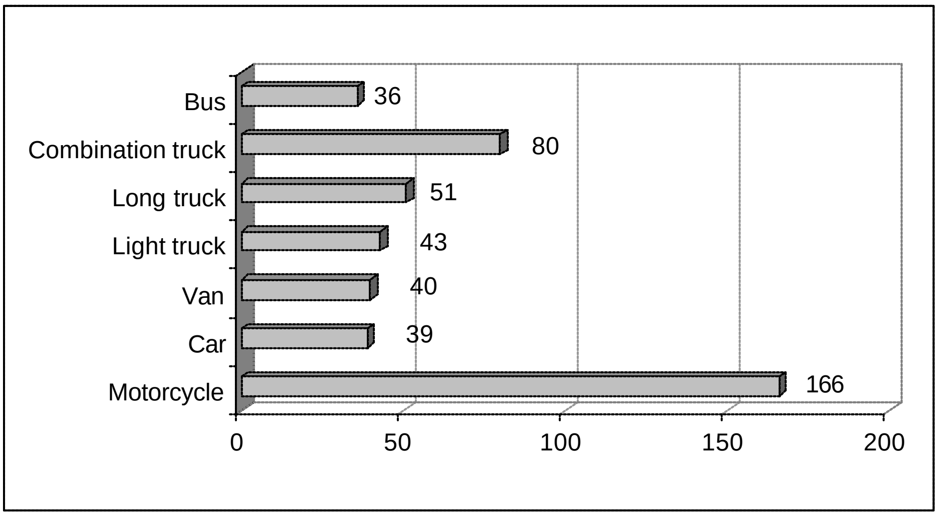

Figure 7: The comprehensive crash costs by vehicle type in U.S. 1998, in 1,000 U.S. $ (Miller et al., 1991).

As shown in Figure 7, the cost for each bus crash is lower than for any other type of vehicle. Nevertheless, in the same study (Miller et al., 1991) it was estimated that counting the comprehensive, as well as the human capital costs for bus highway crashes in comparison to other vehicle type crashes, ended up in finding bus crashes as the second most expensive vehicle type of crashes, as shown in Figure 8.

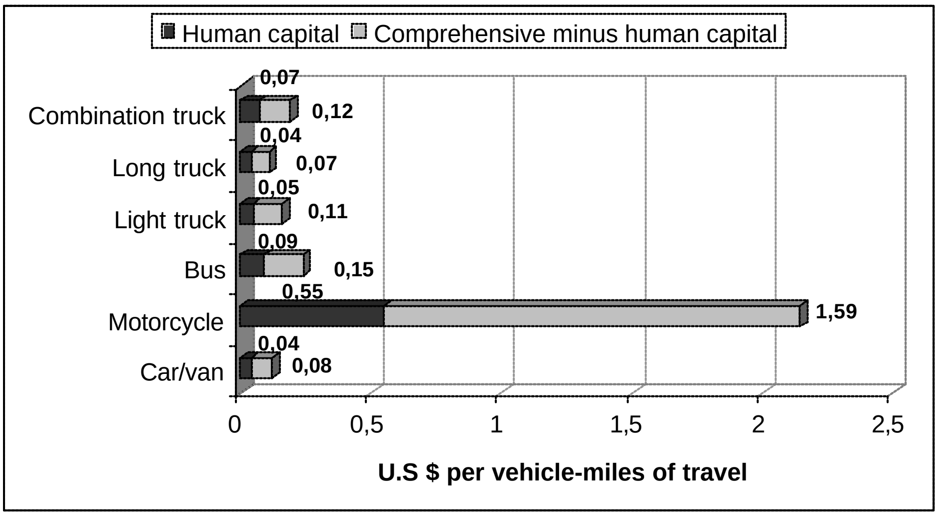

Figure 8: Comprehensive and human capital costs/unit of exposure by vehicle type (Miller et al., 1991).

As shown in Figure 8, apart form the obvious motorcycle problem, bus crashes was suggested to be possible intervention targets (Miller et al., 1991).

To summarise: Trucks and buses represents on average 15% of the vehicle fleet. Trucks drivers are among the "safest drivers", truck accidents/crashes only account for 3-5% involvement in accidents/crashes annually but are involved in >10% of all fatal crashes. Heavy trucks are comparatively more often involved in accidents/crashes than light trucks. Trucks and buses primarily pose a threat to the non-occupants, that is, the other road users. Lack of defensive driving and driving experience, type of roadway, and nighttime driving are factors of importance for understanding truck and bus driver accidents/crashes.

Truck driver population

Road transport activities in European Union yielded 6.5 million jobs in 1995[4]. Of these 6.5 million jobs 76 % were jobs in driving, i.e. ~ 4.9 million jobs. There were about 3.5 million professional drivers of heavy vehicles in the EU in 1998 and about the same amount in North America (Horn & Tardif, 1999). The employment market for truck drivers shares the characteristics of the employment market for workers in general. Access is easy, and the only requirement is that the person holds a driver licence for heavy vehicles. This also implies that drivers leave the companies easily. It is not unusual with an annual turnover of 30% of the work force. In America there are fleets that have seen a 100% turnover ratio in one year (Horn & Tardif, 1999). In the EU countries the annual turnover rate is lower. Approximately 14-16% of the drivers leave the transport sector annually, i.e. ~ 750,000 drivers that need to be replaced each year (OECD, 1996). The average length of a career as driver is 12-13 years. Moreover, not all who hold a driver licence for heavy vehicles use them in their professional every day work. For example, in Norway, 25-30% of those holding a heavy freight vehicle licence use it to earn a living. In Australia, the corresponding figure is 23%. In France, there

[4] At that time there were only 11 member states in the European Union.

are 3 holders of heavy freight vehicle licence per every job vacancy in the trucking industry (Horn & Tardif, 1999). Hence, there is a constant shortage of licensed truck drivers (OECD, 1996).

Taken together this calls for a lot of truck driver training, in all the OECD countries.

Truck and bus driver training

As stated previously, the risk of being involved in a road accident/crash is inversely proportional to the truck driver's experience (OECD, 1996). This is confirmed by a Norwegian study (Nygård & Tellnes, 1994) on bus and truck drivers' accident/crash involvement in 1993, as shown in Figure 9.

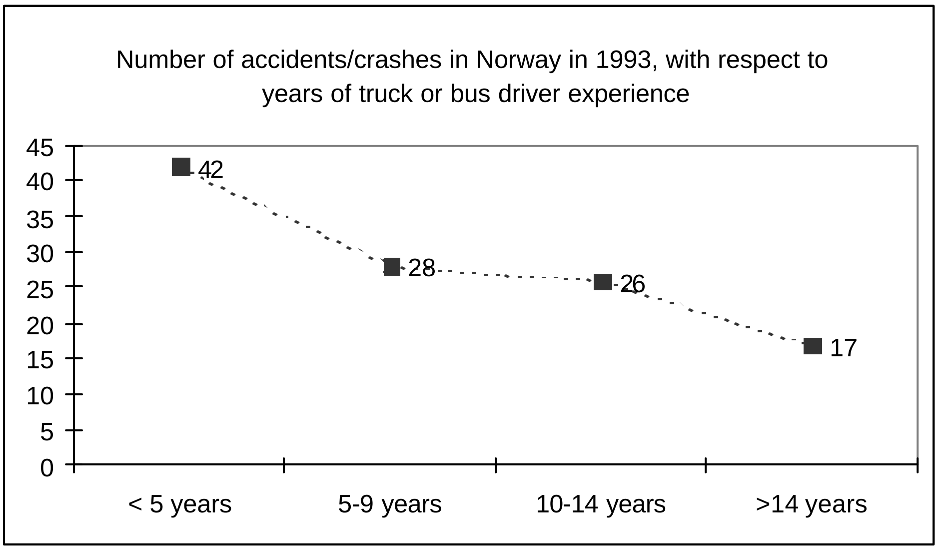

Figure 9: Number of accidents/crashes in Norway in 1993, with respect to years of truck or bus driver experience (Nygård & Tellnes, 1994).

As, shown in Figure 9, driver experience has a significant impact on accident/crash involvement for truck and bus drivers. However, this is not something unique for these two categories of drivers (Maycock, Lockwood, & Lester, 1991). The very same pattern is true for car drivers as well, as shown in Figure 10.

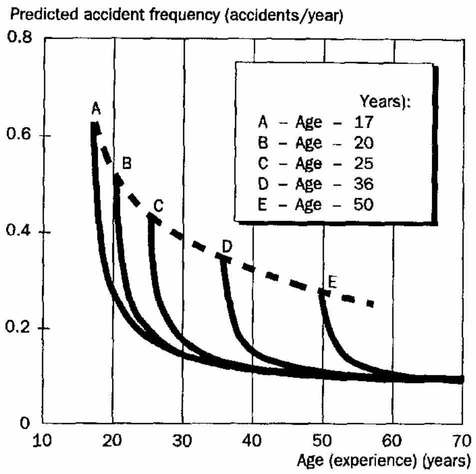

Figure 10: Predicted accident frequency with age (Maycock et al., 1991).

As shown in Figure 10, not only experience, but also age has an influence on accident/crash involvement. However, it is not all that easy to separate the two factors, when examining truck and bus drivers' accident/crash involvement. For truck and bus drivers, a minimum age limit of 18 years is set in all countries (OECD, 1996). For heavy trucks, i.e. weighing >7.5 tonnes, the age limit is 21 (EC regulation 91/439/EEC and 3820/85). In the U.S. a minimum age is set at 21 for driving vehicles weighing more than 10,000 lbs, i.e. approximately 2 tonnes. This means that novice truck and bus drivers probably are somewhat older than car drivers, but in principal this age difference is not that great to jeopardize the validity of the Maycock et al. curve in Figure 10.

The Maycock et al. study includes both men and women, but truck and bus drivers are predominantly male. Young men are highly over represented in accidents/crashes, as shown in Figure 11.

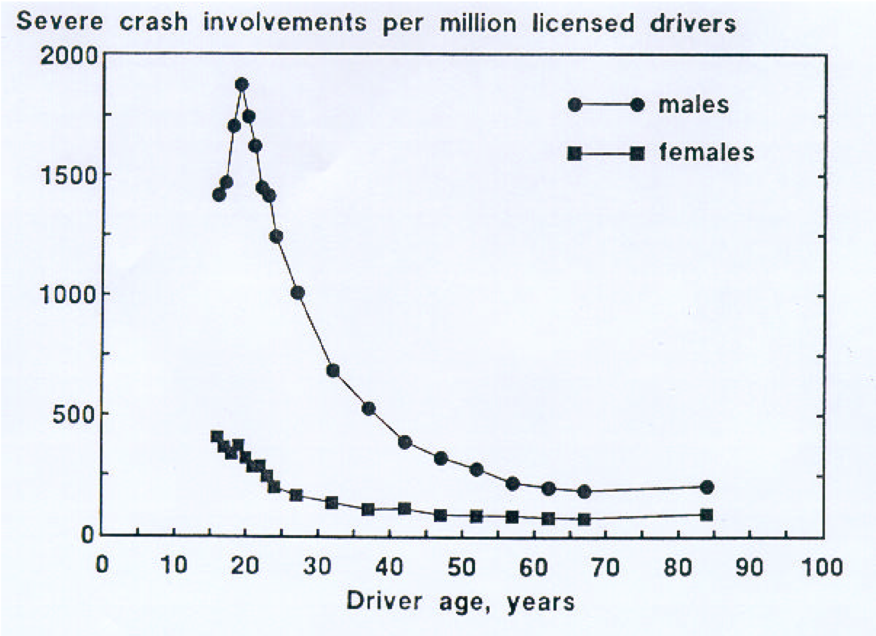

Figure 11: Estimated driver involvements (all motorized vehicles) per million licensed drivers in accidents/crashes of sufficient severity to kill 80-year-old male drivers versus sex and age (Evans, 1991).

Men drive more kilometres on average than women (Evans, 1991). But even if exposure, i.e. the number of kilometres driven, is used as an independent factor, instead of the number of licensed drivers, the general pattern remains, as shown in Figure 12.

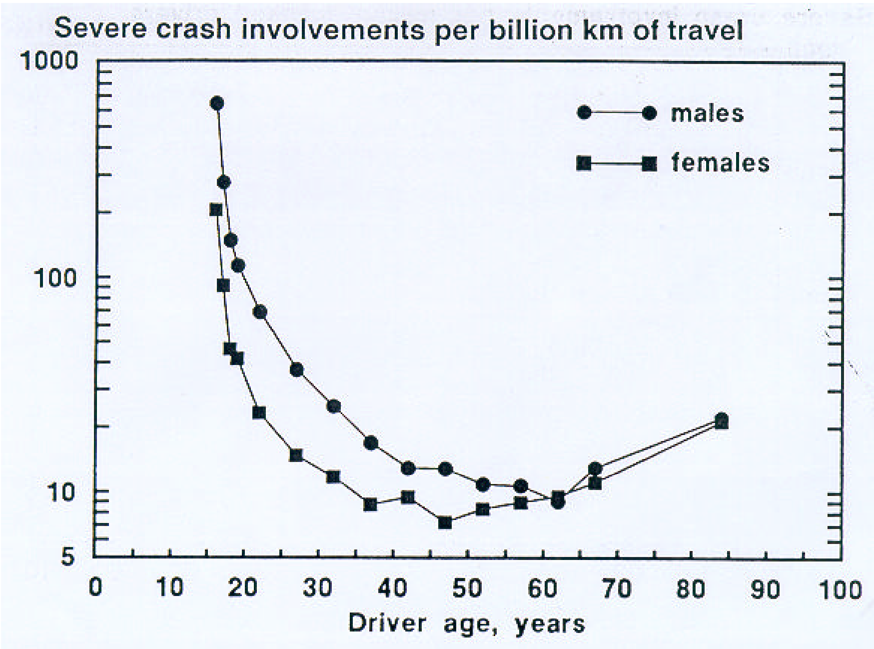

Figure 12: Estimated driver involvements (all motorized vehicles) per billion kilometres of travel in accidents/crashes of sufficient severity to kill 80-year-old male drivers versus sex and age (Evans, 1991).

It may be concluded that driver experience is crucial for safe truck and bus driving. Apparently, for truck and bus drivers, learning to drive takes place on the job (OECD, 1996). The question arises as to whether more of the necessary experience could be gathered by the student during driver training instead? This question, in turn, leads to the issue of what are the training objectives for truck and bus driver training?

Training objectives for truck and bus driver training

The objectives for truck and bus driver training can be found by studying the training curricula and the European Union directive on driver's licensing for truck divers. The directive includes the following categories: ***General, Knowledge, Driver skills, & Driver behaviour,*** i.e. the same as for car drivers. These requirements s are:

General

The truck driver must be able to:

- recognise traffic dangers and assess their seriousness;
- have sufficient command of his vehicle not to create dangerous situations and to react appropriately when dangerous situations occur;
- comply with road traffic regulations;
- detect any major faults in his vehicle and have them corrected in an appropriate fashion;
- take account of all the factors affecting driver behaviour, e.g. alcohol, fatigue, poor eyesight, etc., so as to retain full use of his faculties;
- help ensure the safety of all road users.

Knowledge

Truck drivers must be able to demonstrate their knowledge and understanding in the following fields:

- importance of alertness and attitudes to other road users;
- mechanical aspects of their vehicle;
- principles concerning the observance of safe distances between vehicles and braking distances under various weather and road conditions;
- perception, judgement and decision-making, especially reaction time, as well as changes in driving behaviour due to the influence of alcohol, drugs and medical products;
- specific risk factors related to the lack of experience of other road users;
- risks involved in the driving of various types of vehicles and the different fields of view for the drivers of these vehicles;
- driving risk factors related to various road conditions;
- characteristics of various types of roads;
- vehicle safety equipment and in particular the use of seat belts;
- rules regarding the use of a vehicle in relation to the environment;
- road safety regulations and in particular road signs including markings;
- rules concerning the administrative documents required for the operation of the vehicle;
- general rules specifying the behaviour of the driver in the case of an accident;
- safety factors relating to the vehicle and the persons on-board.

Driver skills

Drivers must be able to:

- check the conditions of the tires, lights, reflectors, steering, brakes, direction indicators and audible warning device;
- adjust the seat as necessary:
- adjust the rear-view mirrors and seat belts;
- check that the doors are closed.

Drivers must be able to use the vehicle controls, namely:

- steering wheel;
- accelerator;
- clutch;
- gears;
- handbrake and footbrake.

Drivers must be able to:

- start the engine and move the vehicle smoothly;
- accelerate to a suitable speed while maintaining a straight course, including during gear changes;
- adjust speed to negotiate left or right turns at junctions while maintaining control of the vehicle;
- reverse in a straight line and reverse right or left around a corner while keeping within the correct traffic lane;
- turn the vehicle to face the opposite direction using forward and reverse gears;
- brake accurately to a full stop and if needed by performing an emergency stop;
- park a vehicle and leave a parking place both in forward and reverse gears, on a flat, downhill and uphill surface.

Driver behaviour

Drivers must be able to perform all the usual manoeuvres in complete safety in normal traffic situations:

- observe road alignment, markings, signs and potential or actual risks;
- communicate with other road users;
- react appropriately in actual risk situations;
- comply with road traffic regulations and the instructions of the police;
- show due respect for other road users.

Drivers must also have the following skills in traffic situations:

- move from the kerb and/or from a parking place;
- drive a vehicle correctly positioned on the road, adjusting speed to traffic conditions;
- keep the right distances between vehicles;
- change lanes;
- pass parked or stationary vehicles and obstacles;
- meet on-coming vehicles, including in confined spaces;
- overtake in various situations;
- approach and cross level crossings;
- approach and cross junctions;
- turn right and left at junctions or to leave the carriageway.

In addition to the above presented requirements truck drivers must also demonstrate theoretical and practical knowledge and sound understanding in the following areas, shown in Table 3:

Table 3: The 1991 European Union directive on Driver's licensing, with respect to the specific rules for heavy freight vehicle drivers (OECD, 1996).

Rules specific to heavy freight vehicle drivers (EU).	
Knowledge & sound understanding in:	**Drivers must be capable of:**
• Effect of wind on the course of the vehicle. • Rules on vehicle weight and dimension • Rules on driving hours, rest periods and use of on board monitoring devices, etc. • Principles of braking systems and speed governors. • Precaution to be taken regarding splash and spray when overtaking other vehicles. • Reading a map. • Know the safety factors related to vehicle loading	• Checking the power-assisted braking and steering systems. • Using various braking systems. • Using speed reduction systems other than brakes. • Adjusting the course of the vehicle when turning to allow for the length of the vehicle and its overhang. • Coupling and uncoupling the trailer and semi-trailer from the tractor.

As can be seen in Table 3 and in the above presented requirements, only a certain part of the Gadget matrix, presented in Table 1, is covered. One way to illustrate this is presented in Figure 13.

	Knowledge and skill	Risk increasing aspects	Self assessment
Preconditions and ambitions for life	**R**elations lifestyle, age, group etc. and driving behaviour	**S**ensation seeking **G**roup norms Peer pressure	**I**ntrospective competence **O**wn preconditions **I**mpulse control
Transport and driving	**M**odal choice **C**hoice of time **R**ole of motives	**A**lcohol, fatigue **L**ow friction **R**ush hours	**O**wn motives influencing choices **S**elf-critical thinking
Driving in traffic	**T**raffic rules **C**o-operation **H**azard perception **A**utomatization	**D**isobeying rules **C**lose-following **L**ow friction **V**ulnerable r.u.	**C**alibration of driving skill
Vehicle construction and control	**C**ar functioning **P**rotection systems **V**ehicle control **P**hysical laws	**N**o seatbelts **B**reakdown of vehicle systems **W**orn-out tyres	**C**alibration of car-control skill

Figure 13: The EU directive on Driver's licensing content in relation to the Gadget matrix (Hatakka et al., 1999). The inner circle represents the focus of the directive, while the outer circle represents the enlarged view on driver education, as was suggested by the GADGET project.

Based on the truck and bus driver accident/crash analyses, it may be discussed whether also driver training for these categories of drivers should include all the aspects presented in Figure 13, or just those indicated by the inner circle. A tentative hypothesis is that by utilising the Gadget matrix in the truck and bus driver training, an increase of "safer" novice truck and bus drivers will come.

As shown in Table 3, both theoretical and practical knowledge should be taught to the truck and bus driver student. Practically there are three different "arenas" to use for this training. For natural reasons the purely theoretical training can be done in an ordinary classroom. Some of it may also be performed in the training vehicle while practising. The practical training is usually performed in the "early" stages of the education at a "range", i.e. closed course driving. Later on in the education street driving becomes more frequent. In order to estimate the proportion of these three "arenas", truck driver training programme curriculum hours offered by 24 U.S. private training schools were examined. The average number of training hours was 267 (SD 62). The results are presented in Figure 14.

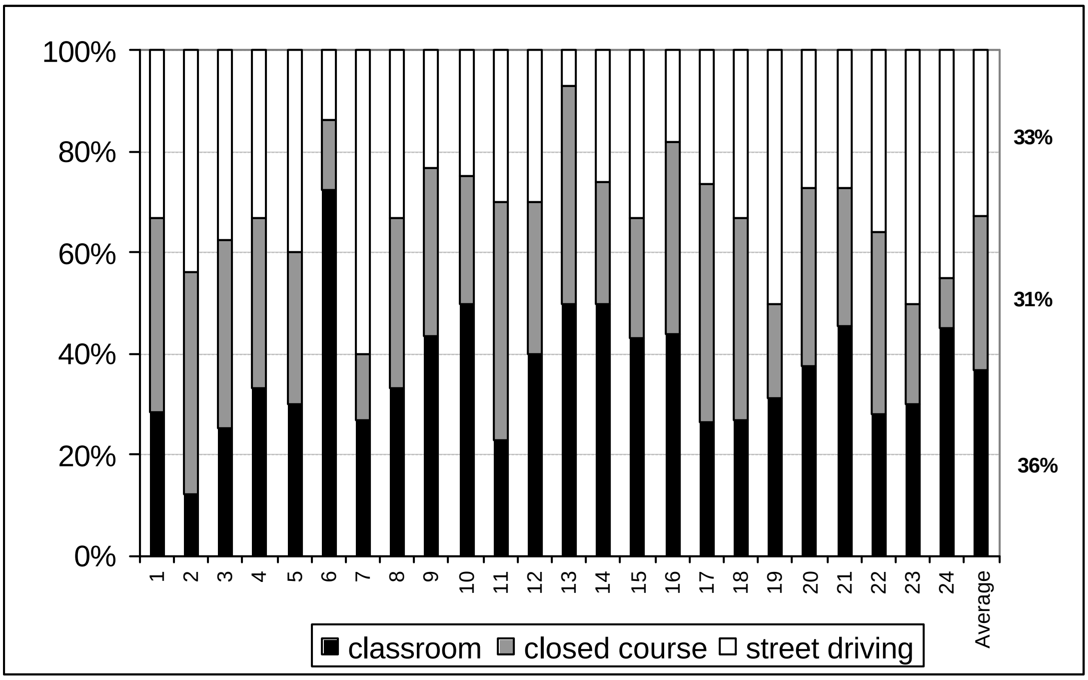

Figure 14: Truck driver training programme curriculum hours with respect to different training "arenas", offered by 24 U.S. private training schools, and the average (OECD, 1996).

As shown in Figure 14 there were great variances with respect to the number of curriculum hours spent in the different "arenas", but there were no significant differences from a statistical point of view in their average values.
The hours ranged as follows:

- Classroom 12-73% (Average-36%)
- Closed course 10-47% (Average-31%)
- Street 7-60% (Average-33%)

As also shown in Figure 14, approximately a third of the curriculum hours were spent in the classroom, and two thirds in the vehicle. Around half of the training hours in the vehicle were spent on the streets, i.e. 91 hours on average.

A comparison with EU can be made. In the EU countries more extensive curriculum than the American ones are common (OECD, 1996). Some countries have obligatory training hours and some have not. Also other systems are present; e.g. the U.K. has a certification of drivers by the Driver Instructors Association, i.e. not a governmental institution. The conclusion from the EU countries is that there is no harmonisation with respect to this issue.

So what is the content of the different curricula, i.e. what is being taught? After studying the different curricula it must be concluded that it is almost impossible to compare contents due to different labelling and categorisation of the different tasks (OECD, 1996). The variation in the number of hours offered by the schools is enormous (Horn & Tardif, 1999). Generally, a private school will offer a 150 hours curriculum while a non-profit school may offer up to a 700 hours curriculum.

Observations and commentary techniques play an important role in the education. The vehicle used for the practical part of the training usually have extra seats behind the driver so that 3 or 4 students can be at the same time in the same vehicle (Horn & Tardif, 1999).

In the present Deliverable the focus is on the curricula content taught in closed course area ("range") driving and street driving, due to the fact that the aim is to do a truck and bus driver training **simulator** feasibility study. A simulator is probably not the optimal tool for teaching pure driving theory.

Training in a simulator?

Truck driver training has remained, generally speaking, low tech (Horn & Tardif, 1999). The vast majority of training is done utilising traditional teaching methods. The teachers' experience and intimate knowledge of the trucking and bus industry is regarded far more important than any other training aid. However, training simulators have started to be used in some schools. This remains an exception, due to the fact that the bus and trucking industry and the private training schools do not have the funds to pay for these tools. Especially since many of them are regarded as additional, and not facilitating, tools. But, as stated in the **"What?"** – chapter, this study focuses on a simulators ranging from the price of one training vehicle to maximum three training vehicles. The basic idea is to buy a simulator instead of an additional training vehicle. In that sense, a low cost simulator may have a better acceptance rate among users than the more expensive ones.

Wachtel (1996) and Decina et al. (Decina, Gish, Staplin, Kirchner, & Wachtel, 1996) have phrased the question of simulation usage or not in training as follows: "Once training objectives are identified; is training on the actual equipment:

1. Possible?
2. Practical?
3. Cost effective?"

Wachtel answers himself by concluding that if the answer on any of the three questions is "No" then simulation offers the best solution.

Truck driving simulation training has many advantages compared to training in vehicles. Simulation training offers (Triggs, 1995):

- Enhanced training efficiency by providing the ability to expose the students to numerous specific training scenarios, with immediate repetition if desired.
- Training control in the simulator as it is possible to specify precisely the type and level of driving task elements and demands.
- Performance measurements on a detailed level, reliably and objectively in order to determine rates of improvement by the training. Furthermore, it is possible to scale individual performance against the trainee population. This is not possible to do out on the road.
- Training feedback that can be provided to the trainee either in real time or afterwards.
- Environment manipulation in a way that is not possible out on the road. Hence, the level of risk can be manipulated systematically.

There are several reports that claim simulation to be an attracting teaching method. For example Grace et al. claim that *".. truck…vehicle simulators can be extremely effective tool for improving driver safety,…training and human factors research"* (Grace et al., 1998). Furthermore, Allen, et al. states that *"..low-cost simulation may offer a way to teach novice drivers how to cope with* *cognitively complex driving hazards."* (Allen et al., 2000). Moreover, in an experiment Laurie et al. found that risk perception training effects from a low-cost simulator (PC) generalizes to an advanced driving simulator (Laurie et al., 1999). So, training transfer effects seem to be present from low cost simulation, but do they transfer to real world driving? So far, no study has been made to prove this. Lack of validation of the training effectiveness appears to be a problematic trend as was noted by Kaptein et al. (Kaptein, Theeuwes, & van der Horst, 1996).

Thus, low cost simulations seem to offer a possibility to be used as a teaching tool, even if only as a PC simulation. Hence, fidelity is not the issue to focus on when it comes to training. Since, as confirmed by a Dutch study; *"In the design of training simulators, too much an emphasis is placed on fidelity. In particular, older studies and studies in the field of engineering …………seem to fail to appreciate the fact that it is not the goal of (training) simulation but the efficient transfer of training. Although these goals are certainly related, they are by no means the same……"*, page 2 (van Emmerik & van Rooij, 1999). Moreover, by deliberately deviating from reality, transfer of training can be enhanced (Roscoe, 1991). The focus may be on a certain task relevant aspect of the simulation without distraction from other stimuli. Especially early in the training process this may be beneficial for the student, in order to lower the overall workload. A low cost "stripped down" simulator may thus be more efficient for training than a full cost simulator (van Emmerik & van Rooij, 1999). Factors that are of importance in deciding what level of physical fidelity a simulator requires include:

- the task,
- student proficiency, and
- the difference between criterion performance and maximum performance.

To conclude; the process of estimating the value of a simulator as a training device may be substantially improved by incorporating the didactic factors in the assessment.

Can simulation also be a more efficient way of training compared to traditional training? One measurement that can be useful in order to answer such a question is the "Student/teacher ratio", i.e. how many students can a teacher teach at the same time given a certain "arena/tool"? In an OECD report (OECD, 1996) the ratios are estimated to be as follows:

- **Classroom:** (an average of 20/1, but rather irrelevant with respect to simulation, due to the fact that not much of the theoretical knowledge teaching may be improved by use of simulation).
- **Closed course:** 4/1 – 15/1 (the latter figure is somewhat surprising, but refers to instructions given in the closed course, which not necessarily imply driving). Could be improved by simulation.
- **Street driving:** 2/1 – 5/1 (in the latter case by use of an extended cabin). This ratio could be significantly approved by use of simulation.

As mentioned earlier classroom training, closed course driving and street driving occupies about a 1/3 of the training hours, each. This means that approximately 50% of all the driving takes place on the streets. Simulation does not only offer a possible higher student/teacher ratio, but also an environmental improvement, i.e. the fewer the practises in the street the less pollution and noise (OECD, 1996). It also implies that less traffic congestions may be the outcome of enhanced use of simulation training. The latter is especially important for bus driver training as this particular training has a component of driving in congested traffic as an essential part of the curriculum.

All this may look like an advertisement for simulation driving training. But are there no drawbacks then?

The industry consensus on the use of simulation is that it is most effective for remedial and advanced truck driver training (Emery, Robin, Knipling, Finn, & Flenger, 1999). However, there exists no hard evidence support for simulation used in any type of training: *"..few, if any, studies assessed whether learning was better with the use of simulation."* (Emery et al., 1999).

Another factor associated with simulation is "simulator sickness" which is a type of motion sickness. It is usually connected to car, air and sea travel (Money, 1970), but also a frequent occurrence in situations involving illusory motion, such as in vehicle simulators (Emery et al., 1999; Kennedy & Frank, 1986). The precise caution is unknown but it is believed to be associated with perceptual and/or sensory mismatch input from the human vestibular and the human visual system (Bles, Bos, de Graf, Groen, & Wertheim, 1998; Förstberg & Ledin, 1996). Although the extent of this mismatch is a contributing factor (Lackner, 1989), the occurrence and severity of simulator sickness is highly individual, and also depending on time and place. Simulator sickness has, for natural reasons, a non-neglectable potential of reducing the pool of training students. More or less every one with a functioning vestibular system is also more or less susceptible, with about 10% of the population being seriously affected (Durlach & Mavor, 1994).

Furthermore, lack of dangerous consequences following high-risk behaviour in the simulator, may result in learning irrelevant or ambiguous cues that later will interfere with correct learning transfer. However, if such an effect is present or not is a matter of debate (Emery et al., 1999).

Chapter 3: Truck driver training simulator feasibility study; **how** can the goals be achieved?

As shown previously in this truck and bus driver training simulator feasibility study, there are several reasons for training in a simulator. The incentives are ranging from pure environmental reasons, public health aspects, over to increased learning efficiency and, in the end, the utilization of a cost effective tool in driver training.

Teaching truck and bus driver training in a simulator is, however, nothing invented by the authors of this Deliverable. There are several truck and/or bus driver-training simulators on the market. New simulators come and old go. Producing a comprehensive list of these simulators is thus a great challenge. Partly because not only the simulators change and become upgraded, but also because the company names may change over time. Furthermore, what used to be a "research simulator" may later on become a "driver-training" simulator, and vice versa. Nevertheless, a list of driver training simulators is included in this report. The reason for this is that all the listed simulator companies have been asked to respond to a questionnaire about their simulators and their curricula. The questionnaire is included in Appendix 1.

Driver training simulators

The listed driver training simulators are chosen from the website:
http://www.inrets.fr/ur/sara/Pg_simus_e.html :

- BEL Bharat Electronics Limited Training simulators (India)
- Bundeswehr (German military forces) driving simulators with original motion system (Dornier and STN) In german.
- CGSD Corp Virtual Reality Driving Simulator
- FAAC DTS Various simulators (some pictures on DTS News page)
- Dr. Ing. Reiner Foerst Gmbh- Various driving simulators.
- Doron Precision - Various driving simulators since 1973.
- Faros - Various training simulators. (updated link)
- GSC - Spanish low cost simulators. (new link)
- Hyperion Technology
- I*SIM Driving simulators and trainer
- Imago Systems Inc Virtual reality system.
- Immersive Tech. Mining Truck simulators.
- Kyungwoo IT Inc. Training driving simulators since 1994 (Korea).
- Monterey Technologies simulator used by australian TAC.

- Simusa Training simulator in Israel.
- Simutech (Germany) low-cost simulators. Swiss site (in german only).
- SoftLab simulator A training driving simulator by a company in Novosibirsk (Russia).
- STN-ATLAS Training simulators.
- Stora Holm A truck simulator (TRaCS) in a swedish training center (details in swedish).
- Systems Technology Inc Low cost driving simulators.
- Tecniduplo - Small portugese simulators.
- TRaCS A truck driving simulator. Designed in an european project, this simulator is in operation in a french training institut (AFT-IFTIM) (in french).
- TRUST similar driving simulator sold by Thales (Thomson Training&Simulation). (updated link)
- Off-road machine simulator A tractor simulator with motion base in Sweden, Lulea University.

Through a Market search, also the following ones were found:

- Oerlikon Contraves AG
- STN ATLAS Elektronik GmbH(AAFR Truck Simulator Developer)
- THALES Training & Simulation
- NTNU/SINTEF
- PTI (Pennsylvania Transportation Institute)
- INRETS
- Carnegie Mellon DTSI
- University of Michigan, Great Lakes Center for Truck Transportation Research

The above list is not all inclusive, as the target of the survey is not a detailed simulator benchmarking but to analyse deeply characteristic examples. To all the above companies a questionnaire was sent (see **Annex 1**) to get the technical characteristics of the simulators. The response rate from the companies to the questionnaire was unexpectedly poor, despite frequent questionnaire reminders. In fact, only three companies responded to the full questionnaire. Several of the companies responded, but did not use the simulator for training purposes, or had not yet developed the curriculum or the necessary procedures. Yet others refused to respond, either due to the fact that they were not members of the target group, i.e. driver-training simulator facilities, or that they regarded their curricula as being part of their business concept and thus not suitable for public exposure. The true reasons remain, however, unknown.

Hence, instead of presenting compiled data on the technical specifications of existing driver-training simulators, as they are generally missing, a theoretical chapter about the technology behind driver training simulators is inserted.

The technology of driver training simulators

Any driving simulator must at least include the following three necessary main components:

- Seat with steering wheel, pedals, gear stick and instruments
- Visual system to show the driver the road and its environment. This must at least show the road in the forward direction with a horizontal angle of at least 40 deg.
- Computer containing a mathematical model of car. The equations of motion of the car are solved in real time.

These parts constitute a closed loop where the driver controls the direction of the car by turning the steering wheel and the speed with the accelerator and the brake pedals. The signals from these control instruments are fed into the computer program that calculates the response of the car, which in turn is displayed in the visual system. The driver sees the result and uses this information for further corrections to keep the desired course. This is the basic loop in which the driver is involved.

In order to help the driver in this control system loop the following responses are normally included in a driving simulator:

- Sound effects to support the speed information like engine sound, wind noise, tire rumble, etc.
- The feel of the control instruments should be similar to that of the real car (accelerator, clutch and brake pedals, as well as the gear stick) but most important is the reaction torque at the steering wheel.
- The driver's seat is situated in a mock-up representing the real car with doors, windscreen, A-pillars and so on, to make the driver comfortable in a normal driver's environment.

The next step to enhance the simulator validity may include:

- A wide-angle visual system showing pictures in rear-facing mirrors and a front view extending over 120 deg.
- A small moving base mainly used for road vibrations transmitted to the car to increase the "road feeling"

A further extension might incorporate:

- An outer moving base to simulate lateral and longitudinal accelerations by a combination of tilt and limited linear motion (hexapods of varying sizes carrying the whole simulator including visual system projectors and screens) or custom-built designs.
- Extension of the linear motion made possible with the hexapod with another linear drive.
- Adding another linear drive making X-Y-motion in the plane possible.

Almost every existing simulator fits somewhere in the above scheme, from the most humble system to the most extravagantly expensive ones. The technical performance varies, however, substantially.

Minimum performance demands

In the preceding paragraph the basic closed loop was defined as the driver-vehicle-response and naturally the simulator components must respond much faster than the response time for the real vehicle does in the real world. Passenger cars normally exhibit a response time (delay between steering wheel input and the response in the form of yaw velocity and lateral acceleration) around 100-150 ms, while trucks may have slightly higher values at 150-250 ms, mainly depending on the load conditions. Thus the simulator itself can only be allowed to add a fraction of these values. It is very important to observe that the simulator delay is an additive effect and must be added to the vehicle response times, degrading the simulation result. A common mistake is to assume that if the inherent delays in the simulator (mainly the computer graphics of the visual system) are of the same magnitude as the vehicle response times the simulator should work fine. This is completely incorrect!

It is well known from control theory that if delay is introduced in the feedback loop the complete system may exhibit instability. It starts to swing more and more violently since the corrections from the feedback loop have wrong phase and tend to augment the signal rather than make it converge to the expected value. Exactly the same behaviour can be observed in a driving simulator if the inherent delay is too long. A simple test is to use a group of people familiar with the real type of vehicle and let them drive the simulator on a road with curves and the simple task is just to follow the road. If anyone in the group starts to oscillate while trying to maintain the course the delay is too long. Surprisingly many simulators in existence fail this simple test. Especially simulators utilising VR-helmets are notorious in this respect since the tracking device for head movements introduces long delays for some reason. It is the author's[5] opinion that simulators failing in this simple test are useless for either research or training, since inherent flaws are destroying the results.

Trucks and heavy vehicle combinations

The earlier remarks are valid in a general sense and concern simulators for both passenger cars and trucks. Heavy vehicles differ from passenger cars in several respects that might be important to highlight in a truck-training simulator:

- Heavy vehicle combinations are large and have a high centre of gravity. The actual size forces the driver to consider the off-tracking problem at low speeds when negotiating sharp corners so that no wheel sets cross the boundaries or touch/damage other vehicles. The high centre of gravity when fully laden makes overturning a hazard to take into consideration for the driver.
- Due to the weight of the vehicle and the relative weakness of the engine the driver constantly has to choose the correct gear ratio out of many possible gears depending on the speed, road slope and other driving conditions.
- The brakes are pneumatic and the driver must practice to economise with compressed air supply when driving downhill or else he will loose the proper function of the brakes.

The first point in this paragraph would then indicate that low speed manoeuvring with high precision should play an important part in a truck simulator program. Going in the forward direction the student should learn to position his vehicle combination in the driving lanes so he can safely

[5] i.e. the author of this sub-chapter, Professor Staffan Nordmark at VTI

negotiate sharp corners and turnarounds even if it means that the combination intrudes into other lanes. The last part is in many cases necessary. In a simulator the teaching process could be improved by showing the student a bird's view of the moving combination on the front screen, with position on the road and distances to boundaries clearly indicated. This is a feature that can be hardly reproduced in the real truck on the road.

The same technique can also be used when practising driving in the reverse direction. For a truck with full trailer or a tractor with semi trailer this procedure demands much training by the student. The bird's view of the combination will prove invaluable in the beginning to clarify and explain to the student the response in the trailer from his steering wheel actions. However the goal is that the student should be able to perform this reverse manoeuvre by looking mainly in the rear-facing mirrors and decide the position of the trailer and truck with this information. Obviously dedicated computer graphics for rear-facing mirrors must be included also at the lowest level of truck simulators since this low speed precision manoeuvring occupies such a big part in the training process.

Another important aspect is the overturning hazard. The student should learn to adapt his speed to the curvature of the road so that the lateral acceleration won't overturn the combination. Also in this case the simulator offers possibilities not normally available in the real truck on the road. The program for the vehicle dynamics constantly calculates the overturning risk for all axles and the result can be displayed on the front screen. The student will then get on-line information on how close he is to overturn and learn to modify his speed in a safe manner. Of course it is important to give the driver all speed cues from the speedometer, noise and engine sounds to road vibrations. A vibration table in the form of a small hexapod would prove beneficial and constitute an important cue.

Simulator design

A revolution has occurred during the recent years with computer costs since powerful PCs with advanced graphics card are available at mass market prices, offering a capacity seldom seen in the most advanced simulators only ten years ago. This means that the computer platform even in the most modest systems can handle quite complex and sophisticated software. There are very limited funds to save by choosing a less powerful PC. The same can also be said about TV-projectors that have dropped drastically in price with the introduction of mass market LCD-projectors. They are not all perfect but can produce a good result at a budget.

The software is still very expensive to develop from scratch and the huge development costs must be written off on the number of simulators planned in a series. This is a dilemma for a small company that wants to recover the development costs on a fairly small series. Thus it is impossible to state any prices for simulators of this type since the numbers produced solely determine the final price.

However, the dedicated hardware will be expensive to build and here no reduction in prices is foreseen. This includes the cab mock-up with driver's seat, instruments, steering wheel, pedals and gear stick. The computers and computer graphics hardware including TV-projectors are not very expensive and can be bought at mass market prices but the cost will not change much due to number of simulators produced.

A **low cost truck driving simulator** should be comprised of a driver's seat with steering wheel and some simple pedals corresponding to clutch, brake and accelerator. The steering wheel should have some active torque motor controlled by the computer while the pedals can be spring-loaded. The gear stick should be original since the student should practice gear patterns extensively. The necessary sound is only engine noise. Two computer graphics channels, one at the front and one rear-facing mirror (on the left side), should be present. A LCD-projector produces the central front image and a small monitor serves as mirror.

A **medium cost truck driving simulator** should be equipped with a correctly sized cab so that the driver gets a correct feeling of the vehicle size compared to the outer world. The torque motor at the steering wheel should be of better quality. The sound quality should be enhanced to include tire and wind noise. More computer graphics channels should be added; 2 more in the forward direction and 1 more small monitor showing the wheels on the left hand side of the vehicle. A small hexapod for road vibrations should also be mounted under the cab.

The software is assumed to be roughly the same at both levels. There is no need to develop two levels of vehicle models when the computer platform is so powerful anyway. The only reduction is in the computer graphics databases (less channels).

To summarise: the technical demands for producing a truck (or) driver training simulator do not exclude simulators built on the basis of the TRAINER concept, i.e. the low cost simulator would be of the same price as one training vehicle, and the medium cost version triple that price. The simulator offers a unique chance to project vehicle positioning from a birds view as a tool in teaching the necessary skills. The simulator delay is, however, crucial for the usefulness of the tool. Too long delay times may jeopardize the whole training. Moreover, due to the fact that reversing is an essential part of the training curricula, rear view mirror simulation is of significant importance for the training.

The cost of existing driver training simulators

As described in the **"What?"** chapter, the cost of a truck and bus driver straining simulator, according to the TRAINER – concept (Falkmer & Gregersen, 2001), is that a low cost simulator should be approximately of the same price as a driver training vehicle, i .e. approximately 90,000 Euros. The cost of a medium cost simulator should accordingly be three times this cost, i.e. 270,000 Euros. How does this estimation correspond to the actual cost of driver training simulators on the market today? Is it too low or approximately the same? The answer is presented in Figure 15.

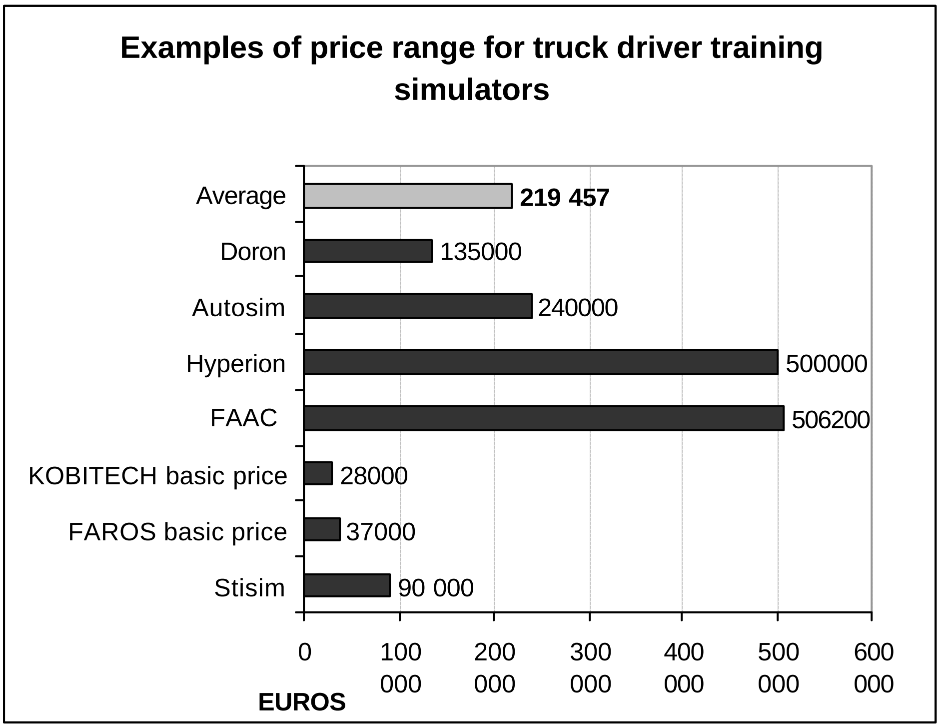

Figure 15: Examples of prices for truck driver training simulators.

As Shown in Figure 15, the average cost of the selection of simulators is close to the estimated cost of the medium simulator, i.e. three times the price of the low cost simulator. It can be noted that the cost of the Stisim-simulator is approximately the same as for a TRAINER concept based mean cost simulator.

The DTSI Carnegie Mellon, Driver Training and Safety Institute example

One example of an American training facility can be shown to illustrate how a truck driver simulator is used. The example is from the DTSI Carnegie Mellon, Driver Training and Safety Institute.

The price of the DTSI CM simulator is 650,000 US $ = 731,250 Euros. The DTSI CM simulator curriculum constitutes an example of a truck driver training curriculum for simulator training. It should be noted that DTSI CM has subdivided the curriculum into 5% and 10% modules, as shown in Figure 16.

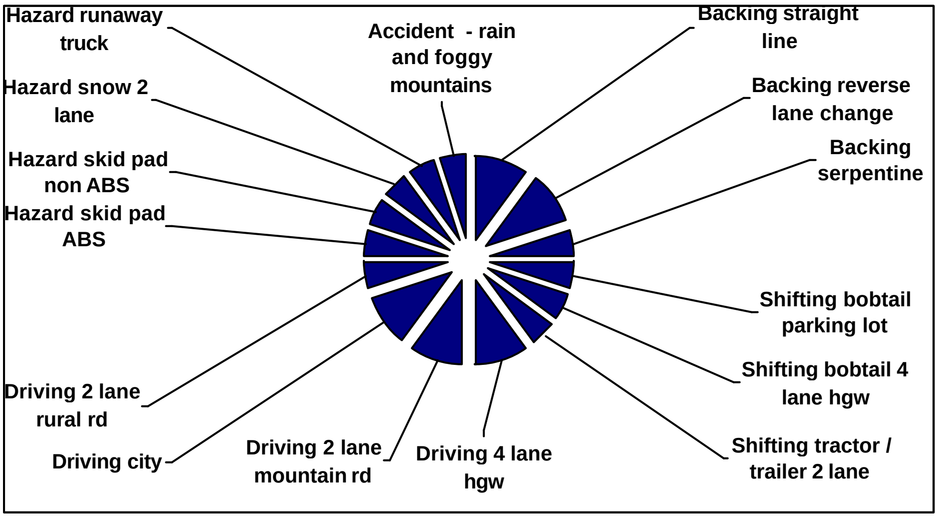

Figure 16: The DTSI CM truck driver training simulator curriculum, based on 5% and 10% modules out of the total 100%.

The education centre at Stora Holm example

One example from Sweden, Stora Holm may also be inserted to provide a picture of what is common practice. The following text is from their web page[6]:

“Stora Holm got its name from the farm, which lies just beside the entrance road. It was earlier used by Volvo as a testing track for cars and trucks. In the middle of the seventies it was taken over by the City Council of Gothenburg. The Traffic Security Committee of Gothenburg then started to use the track as a skidpan for pupils training for their driving licences. In 1992 Bräckegymnasiet, which is a secondary upper school, established education for a Vehicle Engineering Programme, which includes truck driver education, and a Building and Construction Programme. Bräckegymnasiet is also an adult education school where the adults, when passed, receive a practical diploma relating to work. The education in truck driving is comprehensive. The students obtain a rather high skill in different tasks such as; Plant and distribution transport, vehicle combinations, forklift, goods handling, wheel mounted loader, logistics, etc.

In 1996, the Education Committee, the local education authority, started a very exciting project in cooperation with the industry, mainly Volvo Trucks. The project is a Truck Simulator at Stora Holm. A high tech developing project which main purpose is to increase the traffic security and to reduce the impact on the environment during the education. We achieve these benefits by replacing some off the real reality education driving with virtual reality driving in the simulator. Our goal during the projects first year is to let the students drive 10% of their practical education in the simulator. This is the first step towards a "green truck-driving license".

[6] http://transport.storaholm.educ.goteborg.se/info%20in%20english.htm

Figure 17: Stora Holm have implemented the Information Technology as a pedagocical resource. Here is a picture of their truck driver training simulator.

At Stora Holm, the truck driver training curricula is less subdivided than at DTSI CM. It constitutes of the following tasks:

- Braking, gear shifting, which constitutes 50%
- Reversing, 30%
- Lane positioning, handling of dangerous goods, fuel saving i.e. eco driving, etc. 20%

The Swiss military Oerlicon Contraves example

Also a military example of driver-training in a simulator may be inserted, to reflect the variety of fields that this technology may be utilized in. The following presentation is based on the Oerlicon Contraves answer to the questionnaire presented in Appendix 1.

The company is situated in Zürich and has a simulator that utilises a computer based image system, not developed by the company. The following features characterise the simulator:

- It is equipped with rear view images.
- It provides stereophonic feedback sound to the driver.
- It is possible to reproduce precisely, the same scenarios several times.
- It is able to vary the friction of the road surface.
- It is possible to change roads, e.g. urban-, rural - and highways, but it is not possible to vary the curves, i.e. the linearity of the curve.
- It is possible to simulate closed course driving (i.e. range driving).
- It is possible to vary the sight conditions.
- There is a motion system, generating motion feedback to the driver.
- It is possible to vary between different types of heavy vehicles (e.g. bus and truck).
- It is possible to change between front- and rear wheel drive.
- The simulator vehicle is equipped with a gear lever.
- The simulator vehicle has manual gearbox, but not an automatic one.

- There are no passenger seats.
- The simulator vehicle is equipped with servo/power steering, but no cruise control.

The cost of the simulator is 800,000 Euros, i.e. approximately nine times the price of a training vehicle.

With this simulator Oerlicon Contraves trains approximately 1,500 students annually. The students are military personnel. Almost everyone is male, i.e. 99% of the students and 95% of them are younger than 24. No one is older than 40 and none of them was previously unlicensed for cars. However, 95% of them did not have a driving licence for trucks prior to the training. When training bus driving 100% of the students were previously unlicensed for this vehicle type.

The curriculum hours are distributed over the different training “arenas” as shown in Figure 18.

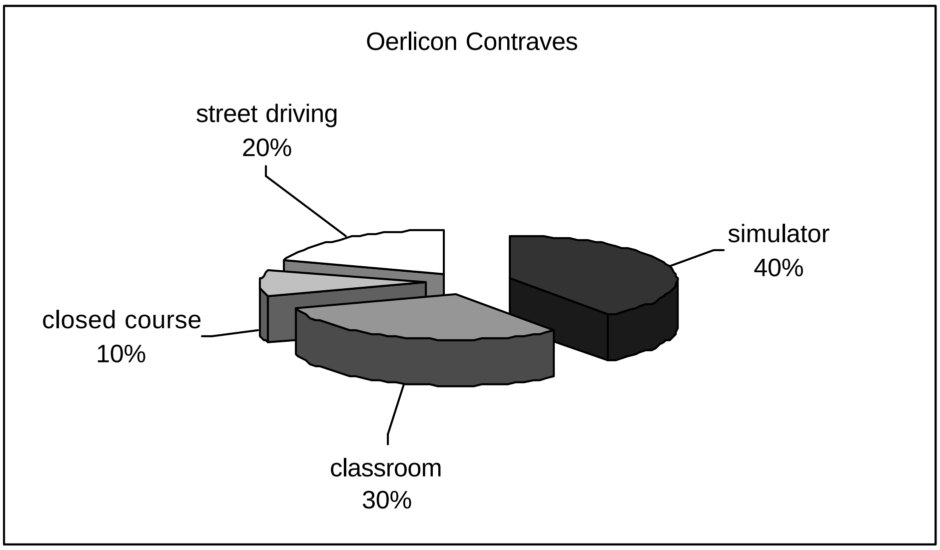

Figure 18: The distribution of curriculum hours at the Oerlicon Contraves training simulator, with respect to the different training “arenas”.

As shown in Figure 18, compared to the results presented in Figure 14, the introduction of simulator training appears to reduce the closed course driving by approximately 20% and street driving by approximately 10%, or more. However, we have no “pre simulator” figures for this particular simulator site and, hence, the presented figures should be handled with care.

The average number of curriculum training hours is 39, distributed as described in Figure 18, plus compulsory 55 hours of additional training for other vehicle types, not included in Figure 18.

The different tasks within the training curricula were practised in the different “arenas”, as presented in Table 4.

Table 4: The different curriculum tasks at the truck driver training at Oerlicon Contraves, presented with respect to the "arena" at which it is trained.

Driver training curricula content as performed by the Swiss army at the Oerlicon Contraves	Practised:			
	In the class room	On the closed course	In the streets	In the simulator
backing straight				X
backing with trailers straight				X
backing with trailers in a curve				X
backing with trailers on a serpentine road				X
shifting			X	X
braking			X	X
using different types of braking systems	X		X	X
use of speed reduction systems other than the brakes	X		X	X
driving on city roads			X	X
driving on rural roads			X	X
driving on highways			X	X
driving on mountain roads			X	X
skidding		X		
skidding and the use of ABS	X			X
runaway truck driving				X
driving in fog				X
driving in snow				X
coupling and uncoupling of trailers		X		
adjusting the driving to vehicle overhang		X		X
rules on vehicle weight and dimensions	X			X
driving hours		**Not practised**		
precautions against spray and splash		**Not practised**		
map reading	X		X	
safety factors related to vehicle loading	X			
driving at night				X
military procedures				X
traffic situations				X
emergency situations				X
economical driving				X
all manoeuvres with/without trailer on drive yard including buildings for docking				X
driving in convoy				X

As shown in Table 4, the use of the simulator is quite extensive with respect to the different tasks.

At present there is no bus driver-training simulator at the Oerlicon Contraves facility, but a concept for a bus simulator is currently under development.

The STN ATLAS Elektronik example

STN ATLAS is one of the major European developers, designers and builders of driving simulators for cars, trucks, trams and also tracked vehicles based on latest technology.

STN ATLAS has won the German Army's design study contest for the transition to truck simulator training, one of the major milestones for the respective upcoming project. Together with many customers STN ATLAS are operating successfully several simulators and train many students per year. The following presentation is based on the STN ATLAS answer to the questionnaire presented in Appendix 1.

The company is situated in Bremen and has a simulator that utilises a computer based image system, developed by the company. The following features characterises the simulator:

- It is equipped with rear view images
- It has stereophonic feedback sound to the driver
- It is possible to reproduce precisely, the same scenarios several times
- It is possible to vary the friction of the road surface
- It is possible to change roads, e.g. urban-, rural - and highways, but it is not possible to vary the curves, i.e. the linearity of the curve
- It is possible to simulate closed course driving (i.e. range driving)
- It is possible to vary the sight conditions
- There is a motion system, generating motion feedback to the driver
- It is possible to vary between different types of heavy vehicles (e.g. bus and truck)
- It is possible to change between front- and rear wheel drive
- The simulator vehicle is equipped with a gear lever
- The simulator vehicle has both manual and automatic gearbox and it is possible to interchange
- There are no passenger seats
- The simulator vehicle is equipped with servo/power steering, and cruise control may be added.

The cost of the simulator is unknown, basically because it may be customised.

With this simulator STN ATLAS train approximately 1,000 students annually. Most students are male, i.e. 90% of the students and 80% of them are younger than 24. Only 2% are older than 40 and 10% of them are previously unlicensed for cars. However, all of them do not have a driving licence for trucks prior to the training. When training bus driving all of the students were previously unlicensed for this vehicle type, as well. All the given figures in this paragraph are estimated figures.

The curriculum hours are distributed over the different training “arenas” as shown in Figure 19

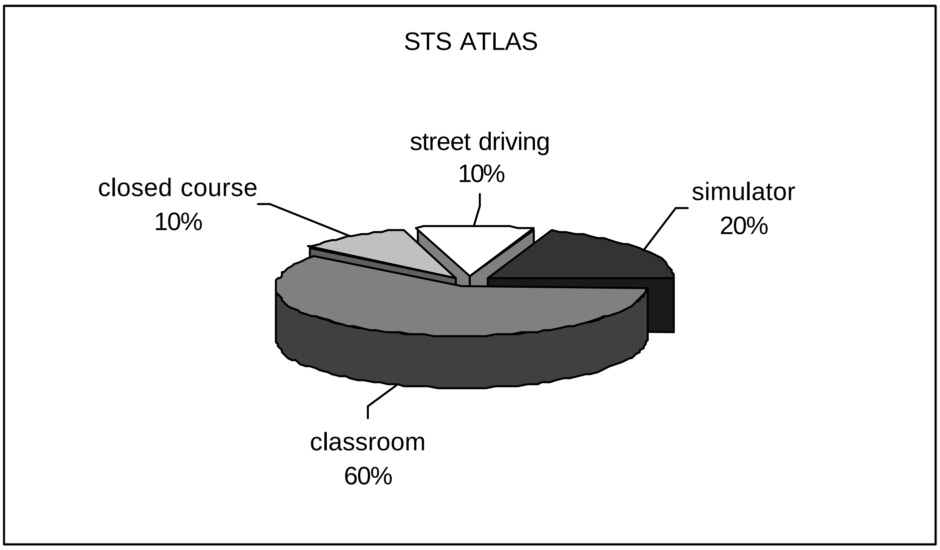

Figure 19: The distribution of curriculum hours at the STS ATLAS training simulator, with respect to the different training "arenas".

As shown in Figure 19, compared to the results presented in Figure 14, the introduction of simulator training appears to reduce the closed course driving and street driving by approximately 20%. However, we have no "pre simulator" figures for this particular simulator site and, hence, the presented figures should be handled with care.

The average number of training hours is 185.

The standardised driver training curriculum tasks were practised in the different "arenas", as presented in Table 5, with variances taken into account the individual skills.

Table 5: The different curriculum tasks at the truck driver training at STN ATLAS , presented with respect to the "arena" at which it is trained. The tasks written in bold italics are non-compulsory tasks

Driver training curricula content as performed by the STN ATLAS	Practised:			
	In the class room	On the closed course	In the streets	In the simulator
backing straight				X
backing with trailers straight				X
backing with trailers in a curve				X
backing with trailers on a serpentine road				X
shifting			X	X
braking			X	X
using different types of braking systems			X	
use of speed reduction systems other than the brakes			X	X
driving on city roads			X	X
driving on rural roads			X	X
driving on highways			X	X
driving on mountain roads			X	X
skidding	X			X
skidding and the use of ABS	X			X
runaway truck driving				X
driving in fog	X			X
driving in snow	X			X
coupling and uncoupling of trailers	X			
adjusting the driving to vehicle overhang	X			
rules on vehicle weight and dimensions	X			
driving hours	X			
precautions against spray and splash	X			
map reading	X	X	X	X
safety factors related to vehicle loading	X			X

As shown in Table 5, the use of the simulator is quite extensive with respect to the different tasks.

The AFT-IFTIM example

The following information is taken from the AFT-IFTIM web page.

AFT-IFTIM is one of the leaders in vocational training for transport and logistics in Europe. With 1,400 employees and training staff and 22,000 member companies, AFT-IFTIM is the French and European leader in vocational training in transport and logistics.

AFT-IFTIM training is designed for:

- truck, coach and bus drivers
- transport and logistics technicians
- national and international freight forwarders
- transport and logistics managers
- company directors

The AFT-IFTIM skills are:

- transport and logistics training
- teacher training, management of small transport companies
- conception of training programmes
- creation of transport and logistics training centres
- technical assistance
- teaching materials and equipment (multimedia and simulator)

Resources

- 6 interregional centres and 70 training centres
- 615 training vehicles, 250 fork lift trucks, 15 heavy lifting plant
- 9 mobile teaching units
- « Global » Logistics Assistance consultancy

In 1995, AFT-IFTIM trained 105,700 people, including 22,000 students in further education. The organisation works in close partnership with professional bodies in the transport (AFTRI, CLTI, FFOCT, FNTR, FNTV, UTP, and others) and logistics sector (FEDIMAG-DLRSNUG-AUTF-CGI-FCD-SIMMA) and with the French ministries of transport, employment, education and defence. AFT-IFTIM is member of the Eurotra network and has taken part in numerous training programs and projects in Argentina, Brazil, Canada, North Africa and Eastern Europe.

The company is situated in Paris among other places and has a simulator that utilises a computer based image system, not developed by the company. The following features characterises the simulator:

- It is equipped with rear view images
- It has monophonic feedback sound to the driver
- It is possible to reproduce precisely, the same scenarios several times
- It is not possible to vary the friction of the road surface
- It is possible to change roads, e.g. urban-, rural - and highways, and it is possible to vary the curves, i.e. the linearity of the curve, as well
- It is possible to simulate closed course driving (i.e. range driving)
- It is possible to vary the sight conditions
- There is a motion system, generating motion feedback to the driver
- It is possible to vary between different types of heavy vehicles (e.g. bus and truck)
- It is not possible to change from rear to front wheel drive, since front wheel drive is

not an option

- The simulator vehicle is equipped with a gear lever
- The simulator vehicle has a manual but not an automatic gearbox
- There are two passenger seats
- The simulator vehicle is equipped with servo/power steering, but no cruise control

The company does not present the cost of the simulator.

With this simulator AFT-IFTIM train approximately 200 students annually. Most students are male, i.e. 95% of the students and 65% of them are younger than 24. None of them are previously unlicensed for cars. However, 40% of them do not have a driving licence for trucks prior to the training.

The truck driver training curriculum hours are distributed over the different training “arenas” as shown in Figure 20. There is no training for bus drivers at AFT-IFTIM .

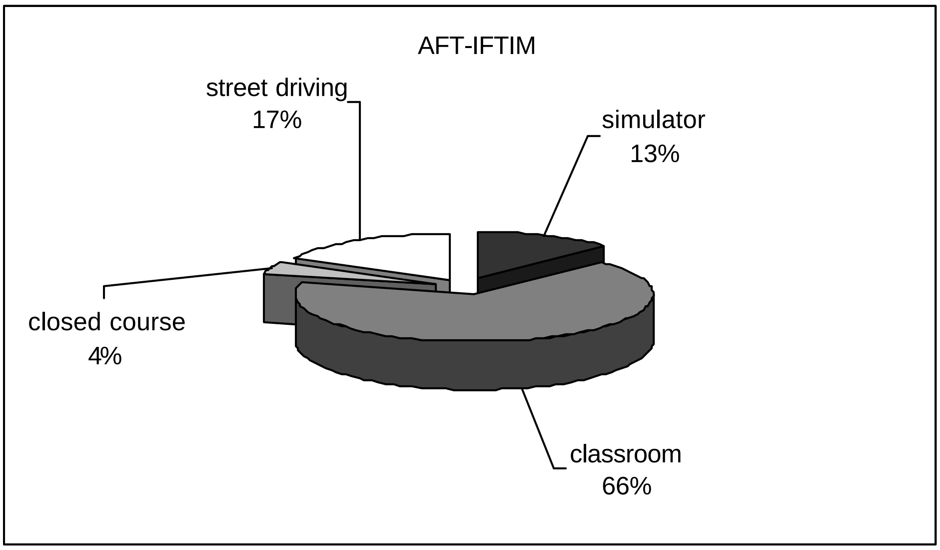

Figure 20: The distribution of curriculum hours at the AFT-IFTIM training simulator, with respect to the different training “arenas”.

As shown in Figure 20, compared to the results presented in Figure 14, the introduction of simulator training appears to reduce the closed course driving and street driving by approximately 40%. However, we have no “pre simulator” figures for this particular simulator site and, hence, the presented figures should be handled with care. Moreover, AFT-IFTIM students are trained in classrooms 66% of the curriculum hours, a percentage figure that must be regarded as significantly higher than on average.

The average number of training hours is 125.

The standardised driver training curriculum tasks were practised in the different "arenas", as presented in Table 6.

Table 6: The different curriculum tasks at the truck driver training at AFT-IFTIM, presented with respect to the "arena" at which it is trained.

Truck driver training curricula content as performed by the AFT-IFTIM	Practised:			
	In the class room	On the closed course	In the streets	In the simulator
backing straight		X		X
backing with trailers straight		X		X
backing with trailers in a curve		X		X
backing with trailers on a serpentine road		X		X
shifting	X	X		X
braking	X	X	X	X
using different types of braking systems	X	X	X	X
use of speed reduction systems other than the brakes	X		X	X
driving on city roads	X		X	X
driving on rural roads	X		X	X
driving on highways	X		X	X
driving on mountain roads	X		X	(X)
Skidding (snow covered road)	X		X	
skidding and the use of ABS	X		X	X
runaway truck driving			X	
driving in fog	X		X	(X)
driving in snow	X		X	(X)
coupling and uncoupling of trailers	X	X		
adjusting the driving to vehicle overhang	X			
rules on vehicle weight and dimensions	X		X	
driving hours	X			
precautions against spray and splash	**Not practiced**			
map reading	X			X
safety factors related to vehicle loading	X			

As shown in Table 6, the use of the simulator is quite extensive with respect to the different tasks.

The Geiersbach Consult Unternehmensberatung GmbH example

The Geiersbach Consult Unternehmensberatung GmbH used to have two educational centres in Germany for training truck drivers, using training in simulators as a didactic tool. They used simulators developed by AITEC at a price of 1.3 million Euros per piece. Both Geiersbach Consult Unternehmensberatung GmbH and AITEC are presently not existing on the market. The below presented data are thus from previous conditions but they, nevertheless provide a picture of how this truck driver simulator training was done.

The company utilised a computer based image system, not developed by AITEC. The following features characterises the simulator:

- It was equipped with rear view images
- It had stereophonic feedback sound to the driver
- It was not possible to reproduce precisely, the same scenarios several times
- It was possible to vary the friction of the road surface
- It was possible to change roads, e.g. urban-, rural - and highways, and it is possible to vary the curves, i.e. the linearity of the curve, as well
- It was possible to simulate closed course driving (i.e. range driving)
- It was not possible to vary the sight conditions
- There was a motion system, generating motion feedback to the driver
- It was not possible to vary between different types of heavy vehicles (e.g. bus and truck)
- It was not possible to change from rear to front wheel drive, since front wheel drive was not an option
- The simulator vehicle was equipped with a gear lever
- The simulator vehicle had a manual but not an automatic gearbox
- There was one passenger seat
- The simulator vehicle was equipped with servo/power steering, and a cruise control

The Geiersbach Consult Unternehmensberatung GmbH trained approximately 300 students annually. Most students were male, i.e. 95% of the students and 10% of them were younger than 24, and 65% of them were younger than 40 years of age. All of them were professional drivers, i.e. this was so called post-licensing training.

The truck driver training curriculum hours are distributed over the different training “arenas” as shown in Figure 21. There is no training for bus drivers at Geiersbach Consult Unternehmensberatung GmbH.

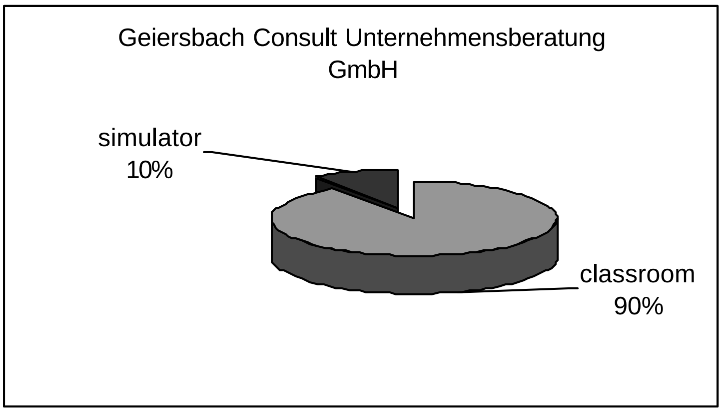

Figure 21: The distribution of curriculum hours at the Geiersbach Consult Unternehmensberatung GmbH, with respect to the different training “arenas”.

The average number of this post licensing training hours was only 8.

The standardised driver training curriculum tasks were practised in the different “arenas”, as presented in Table 7

Table 7: The different curriculum tasks at the truck driver training at Geiersbach Consult Unternehmensberatung GmbH, presented with respect to the “arena” at which it was trained.

Truck driver training curricula content as performed by the AFT-IFTIM	Practised:			
	In the class room	On the closed course	In the streets	In the simulator
backing straight				X
backing with trailers straight				X
backing with trailers in a curve				X
backing with trailers on a serpentine road				X
shifting				X
braking				X
using different types of braking systems		**Not practised**		
use of speed reduction systems other than the brakes				X
driving on city roads				X
driving on rural roads				X
driving on highways				X
driving on mountain roads				X
Skidding (snow covered road)	X			
skidding and the use of ABS	X			
runaway truck driving				
driving in fog				X
driving in snow				X
coupling and uncoupling of trailers		**Not practised**		
adjusting the driving to vehicle overhang		**Not practised**		
rules on vehicle weight and dimensions	X			
driving hours	X			
precautions against spray and splash		**Not practiced**		
map reading		**Not practised**		
safety factors related to vehicle loading	X			

Apart from the above-mentioned tasks, also driving and distance keeping at a railroad crossing are practised. As shown in Table 7 the use of the simulator is quite extensive with respect to the different tasks, but not to the same extent as in the other examples of training facilities, presented previously.

The TRAINER concept extension to the truck/ bus simulator domain

The TRAINER concept is a suitable concept also for producing a low cost truck and bus driver-training simulator. There are several reasons to support this statement.

The technical demands of a truck and bus driver-training simulator are possible to be met within the price range of one training vehicle, i.e. the price of the low cost simulator. However, the presence of rear view mirror simulation and sufficiently short simulator delay is crucial for the usefulness of such a simulator. Whether the medium cost concept is as applicable as the low cost concept is however, doubtful. The addition of a moving base may not be all that cost-effective.

A part of the TRAINER concepts (as briefly described in the **"what"** chapter) and one of its objectives is to develop a new cost-effective pan-European driver training methodology. Truck and bus driver training suffers from the same lack of harmonisation in the EU countries as other types of driver education. Due to the fact that the EU market is a common market it is of special importance to harmonise the demands within the union, in order to make competition between commercial companies in the truck and bus driving business fair. Moreover, drivers of heavy vehicles in the EU are already driving on foreign roads as part of their daily work. The demands on these drivers are that they shall understand and comply with the different, un-harmonised rules and regulations within the EU countries while driving there. This also includes rules and regulations not immediately connected to traffic, such as working hours, handling of dangerous goods, etc. A harmonisation of heavy vehicle driver training is one of the major issues in the OECD report on truck driver training from 1996 (OECD, 1996).

A development of a new pan-European truck and bus driver training methodology is of course a huge task. It involves at least 750,000 students annually, most certainly more, since this calculation was for the 1996 conditions, i.e. with only 11 states in the EU. It also includes a lot of implementation work within the different countries, both on a governmental level and on a driving school level. Nevertheless, it seems feasible to introduce a new methodology for the same reason, i.e. the turnover rate is high or extremely high in the truck driving business. A high turnover rate means that the new methodology content will have an impact relatively soon in time. Unfortunately the turnover rate in the bus driving business is unknown, but it may be anticipated that it is approximately the same as in the truck driving business. Furthermore, in the figure of 750,000 new drivers annually, bus drivers are not included. This means that the potential for professional driver training in the EU countries is even higher that the given figures.

There is a potential for enhanced road safety with the introduction of a new pan European truck and bus driver-training concept. The most essential part here is not the simulator tool per se, but the development and implementation of a new driving curriculum. Heavy vehicles, i.e. in this Deliverable trucks and buses, are involved in less accidents/crashes than other vehicle types, relative to their frequencies on the road. However, when accidents/crashes occur they tend to become fatal more often than for other vehicle types involved. Furthermore, due to the mass and weight trucks and buses are extremely aggressive towards the second part in an accident/crash. Hence, it is fairly safe to be a bus driver/passenger or a truck driver, but less safe to be a road user involved in an accident/crash with one of those two types of vehicles. It becomes even less safe in the case of trucks carrying dangerous goods. Fortunately this type of accident/crash is not common. When trucks are subdivided into light and heavy trucks it turns out that heavy trucks are more involved in accidents/crashes. Apparently, the size, the weight and the manoeuvrability of these heavy trucks have a relation to accident/crash involvement. Exactly what this relation is remains unknown, but a speculation may be that vehicle dynamics and the drivers' estimation of their own skills are contributing factors. However, fatigue, a casual factor that recently has drawn a lot of attention, does not seem to be of high relevance in this case. Furthermore, vehicle maintenance or technical deficits do not contribute significantly to accidents/crashes. Instead what is referred to as "human error" is the most frequent accident/crash causation. This fact is an argument for increased, and harmonised truck and bus driver training.

Regarding drivers in general it is well known that young drivers overestimate their driving skill more than older drivers. Furthermore, they are not familiar with the actual dynamics of their vehicle, which define, for example, the minimum stopping distance in a certain speed. Traditionally, driver training has focused on vehicle control skills and traffic rules without reaching far enough in the efforts to provide risk awareness and other higher order skills. The risk awareness problem is included in driver training in many countries but rather in a theoretical way, included in textbooks, and is not covered in practical training. This reasoning, which was one of the reasons for launching the TRAINER project, is also applicable on truck and bus driver training. Novice truck and bus drivers are involved in more accidents/crashes than experienced truck and bus drivers. Taking into account that those novice drivers are predominantly male and young, the problem of accident involvement is probably not caused by lack of perceptual or motor skills. On the contrary, those skills are probably not the peak point of the novice drivers' abilities. Instead, experience seems to be the factor that can predict accident involvement. One essential part of experience in general, as well as with respect to driving, is to acknowledge your own skills and limitations. Although heavy vehicle driver training on average is six times longer or more than car driver training (Gregersen et al., 2000), thus yielding driving experience, still "most of the learning is done on the job" (OECD, 1996). An extension of driver training, combined with the utilization of the curriculum content, described in the upper most left corners of the GADGET matrix, may, however, reduce the "learning on the job" part in favour of learning under safe conditions. Safety is, of course, further enhanced if street driving is replaced by simulator training.

Replacing street driving with simulator training is an attractive option, not only from a traffic safety perspective, but also from an environmental perspective. Practicing in the streets generates pollution. Moreover, a lot of practicing will take place in already congested traffic environments, i.e. a further increase of pollution due to traffic congestions per se. The potential of such replacement is, at maximum, somewhere near a third of all curricula hours and approximately half of the practical curricula hours of the training. However, in reality it will probably be less, due to the fact that training in real world environment is still quite attractive for the students, despite potential traffic congestions and, thus, real world practice, i.e. street driving, may become a means of competition between different driver training companies.

Training in a simulator that costs the same as one training vehicle is a cost effective measurement. Moreover, simulator training has several other positive features, such as enhanced training efficiency, increased training control, reliable and objective performance measurements, enhanced training feedback in real time or afterwards, and the possibility of environment manipulation, i.e. the level of risk. So why is not the truck and bus driver training market full of training simulators?

One reason may, of course, simply be general conservatism. *"We train the way we have always trained, and it has work for nn years."* However, claiming that companies strive for maximum profits, missing such a cost effective tool as a training simulator does not seem plausible. Instead the reason may be that it remains to be proven that the use of simulator in truck and bus driver training actually transfers to safer driving in real traffic environments. So far, no study has been conducted to scientifically evaluate if such a transfer does take place. Such a controlled study would require an economically strong conductor and will take time, due to the rareness of accidents/crashes. As part of the TRAINER project a traffic safety impact pilot should be performed to evaluate if the use of the TRAINER low and medium cost simulators in driver training have any impact on traffic safety (Falkmer & Gregersen, 2001). A similar one would be possible to perform if also a truck and bus equivalent to the TRAINER tools will be developed. For the desired European Union harmonisation of truck and bus driver training, such a tool and project would come in handy.

Within this Deliverable there is no detailed analysis on existing driver training simulators driving curricula and simulator features. Despite an ambitious dissemination procedure, many companies either did not answer the questionnaires or found them impropriate due to the fact that the companies did not use their simulators as trainings devices. An assumption can be made that those companies that actually do train truck and bus drivers in a simulator are not willing to give part of their concept, i.e. the curricula and the simulator features, for free to the open market. At the same time it is bad PR to state this as an answer to the questionnaire. Instead, the companies chose not to answer at all. Still, several examples and replies were given, to provide a good knowledge basis for the Deliverable.

Future studies in the field of truck and bus driver-training in simulators should focus on whether actual training effects are present, with respect to training efficiency, i.e. a more quantitative measurement, as well as to traffic safety impact, i.e. a more qualitative measurement. Such a study should be based on random sampled groups from a homogeneous population, divided into an experimental and a control group. They should follow an identical curriculum. The experimental group should then be trained with the use of the simulator while the other group should do it traditionally, i.e. without the aid of simulator training. The results are then compared with respect to different types of measurements, relevant to driver performance as well as to driver behaviour (Evans, 1991). An example of such an experimental design is presented in the pilot plans for the TRAINER project (Falkmer & Gregersen, 2001).

Conclusions

The present truck and bus driver training simulator feasibility study was based on the question: is it feasible to develop a new training methodology utilising low cost and medium cost simulators for truck and bus driver training? The answer is yes. The outcome is highly dependent on the curriculum content. A truck driver-training simulator should:

- Not necessarily be of high fidelity, due to the fact that generalisation effects from a low cost simulator to other situations can be expected to be present.
- Instead of high fidelity the technical requirements are that the simulator delay is acceptably low and that rear view mirror simulation is included.
- The driver-training curriculum for the simulator part of the training should focus on tasks normally performed by street driving and closed course driving.
- Training truck and bus drivers in a simulator could increase training efficiency, i.e. to increase the Student/Teacher ratio.
- Training truck and bus drivers in a simulator could also be beneficial for traffic safety in a longer perspective, for example by improved training for hazardous situations.
- Training truck and bus drivers in a simulator could finally be environmentally justifiable because of less street practice, combined with eco driving.

While several of the above stated arguments for truck and bus driver training in a simulator are arguments that could be regarded as positive from a marketing point of view, many of them are sound arguments from a governmental aspect, as well.

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Appendix 1: The questionnaire

Dear Respondent,

This is a questionnaire concerning truck and bus driver training and the use of simulation for this purpose. The reason for us, kindly, asking you to fill it in and send it back to us as soon as possible, is that we are partners in a European Union project TRAINER[7], in which we are performing a Truck Feasibility Study.

We have deliberately tried to make the questionnaire as short and easy to fill in as possible and we are happy to receive your answer by e-mail or regular mail at latest November 10th.

The questionnaire is divided into three sections. The first part is a standard questionnaire concerning the technical aspects of the simulator that is used. If, however, the questions are irrelevant, just tick this column. The second part is short and concerns the students that are involved in the training. The last part is somewhat more extended, and is the most essential as well, and regards various aspects of the training curricula.

If you have any questions, please do not hesitate to give me notice.

Yours sincerely

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[7] More info can be found on the website: http://www.trainer.iao.fhg.de/

Questionnaire part 1

This questionnaire is a <u>standard form</u>, which is directed to a broad range of companies and/or people in some way connected to heavy vehicle driver training simulators. The form uses “Yes”- and “No”-questions and hopefully you can answer all questions without using the “Irrelevant”-column.

Questions concerning the simulator		**Yes**	**No**	**Irrelevant**
1	Is there a computer generated image system?			
2	Is there a video based image system?			
3	Is the image system developed by your company / institution?			
4	Is it equipped with rear view images?			
5	Is there any feedback sound to the driver?			
6	Is the sound-system stereophonic?			
7	Is it possible to reproduce precisely, the same scenarios several times?			
8	Is it possible to vary the friction of the road surface?			
9	Is it possible to change roads (i.e. urban-, rural - and highways)?			
1	Is it possible to simulate closed course driving (i.e. range driving)?			
1	Is it possible to vary the sight conditions?			
1	Is it possible to vary the curves, i.e. the linearity of the curve?			
1	Is there any kind of motion system, generating motion feedback to the driver?			
1 1	Is it possible to vary between different types of heavy vehicles (e.g. bus and lorry)? Is the simulator vehicle front wheel driven?			
1	Is the simulator vehicle rear wheel driven?			
1	Is it possible to change between front- and rear wheel drive?			
1	Is the simulator vehicle equipped with a gear lever?			
1	Does the simulator vehicle have automatic gearbox?			
2	Does the simulator vehicle have manual gearbox?			
2	Is it possible to change between automatic and manual gearbox?			
2	Are there passenger seats?			***No. of seats:***
2	Is the simulator vehicle equipped with servo/power steering?			
2	Is the simulator vehicle equipped with a cruise control?			
For manufacturers (or others with explicit knowledge):				
	Estimated cost for purchase? Standard models approximately (Please specify the right currency, or preferably state the cost in EUROS)			US Dollars EUROS

Questionnaire part 2

This part concerns the student that you train and if you cannot provide exact figures, your best estimation is good enough. Hoverer, please indicate in the "Answer" column if the answer is given by use of exact figures or estimation.

Questions concerning the students		**Answer (estimated or exact)**	**Comments**
	How many students do you train per year (on average)?		
	What percentage of those are male?		
	What percentage of those are under the age of 24?		
	What percentage of those are under the age of 40?		
	What percentage of those are previously unlicensed for car driving?		
	What percentage of those are previously unlicensed for truck driving?		
	What percentage of those are previously unlicensed for bus driving?		

Questionnaire part 3

This part concerns the training curriculum. This is the most essential part of this questionnaire. Please take your time to fill it in. If you have a written curriculum we would appreciate if you could send that as complementary to your answers (i.e. not solely). The questions focus on the curricula used in simulator training, street driving, closed course driving (sometimes called range driving) and the theoretical part.

	Questions concerning the training curriculum	Answer	Comments
	What is the average percentage of the training performed in a simulator?	*(Please note that the answers on questions Nos. 32-35 should add up to 100%)*	
	What is the average percentage of the training performed as street driving?		
	What is the average percentage of the training performed as closed course driving?		
	What is the average percentage of the training performed theoretically?		
	What is the average number of training hours per student of the training performed in a simulator?		
	What is the average number of training hours per student of the training performed as street driving?		
	What is the average number of training hours per student of the training performed as closed course driving?		
	What is the average number of training hours per student of the training performed theoretically?		
	Do you have a standardised driver training curriculum for truck drivers?	Y/N	
	Do you have a standardised driver training curriculum for bus drivers?	Y/N	

	Driver training curricula content…..…………	For bus Y/N	For truck Y/N	Comments	Where is this task trained?			
					In the class room	On the closed course	In the streets	In a simu lator
	Is there a specific task in the curriculum about backing straight?							
	Is there a specific task in the curriculum about backing with trailers straight?							
	Is there a specific task in the curriculum about backing with trailers in a curve? Is there a specific task in the curriculum about backing with trailers on a serpentine road?							

	Is there a specific task in the curriculum about shifting?							
	Is there a specific task in the curriculum about braking?							
	Is there a specific task in the curriculum about using different types of braking systems?							
	Is there a specific task in the curriculum about the use of speed reduction systems other than the brakes?							
	Is there a specific task in the curriculum about driving on city roads?							
	Is there a specific task in the curriculum about driving on rural roads?							
	Is there a specific task in the curriculum about driving on highways?							
	Is there a specific task in the curriculum about driving on mountain roads?							
	Is there a specific task in the curriculum about skidding?							
	Is there a specific task in the curriculum about skidding and the use of ABS?							
	Is there a specific task in the curriculum about runaway truck driving?							
	Is there a specific task in the curriculum about driving in fog?							
	Is there a specific task in the curriculum about driving in snow?							
	Is there a specific task in the curriculum about coupling and uncoupling of trailers?							
	Is there a specific task in the curriculum about adjusting the driving to vehicle overhang?							
	Is there a specific task in the curriculum about rules on vehicle weight and dimensions?							
	Is there a specific task in the curriculum about driving hours?							
	Is there a specific task in the curriculum about precautions against spray and splash							
	Is there a specific task in the curriculum about mapreading							
	Is there a specific task in the curriculum about safety factors related to vehicle loading?							

	Is there a specific task in the curriculum about something not noted in this questionnaire							
	Please describe the tasks that you meant when answering Yes on question 66:							

Thank you for your kind co-operation!