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Feasibility study

D3.7: Application and recommendations for simulator based trainings on „eco-driving“ with clean vehicles - EU-Project ACTUATE

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Advanced Training and Education for Safe Eco-driving of Clean Vehicles

Application and recommendations for simulator based trainings on „eco-driving“ with clean vehicles - EU-Project ACTUATE

Content

Introduction:

ACTUATE (Advanced Training and Education for Safe Eco-driving of Clean Vehicles) was a project of the EU's Intelligent Energy Europe Programme. Funded through the Executive Agency for Small and Medium-sized Enterprises (EASME), the aim of ACTUATE was to develop, test and implement advanced driver training and education concepts for safe eco-driving in the public transport sector.

This feasibility study was awarded to analyse illustration facilities and to publish recommendations for technical and organisational requirements for simulator-based safe eco-driving trainings for clean vehicles (trolley-/hybrid bus, tram).

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1. Summary

The following is a summary of the possibilities for a simulator-based training for safe and economical driving (Ecodrive) for electric driven vehicles in the public transport sector.

After discussing previous experiences on simulator-based trainings for drivers of railways, light railways, trams and Subway some technical and didactic approaches are presented. The goal is to create a technical and didactic-methodological basis for making decisions for sustainable and cost-effective implementation of trainings measures elaborated in the framework of the project ACTUATE. The cost of 4 types of simulators in different variant are calculated to support decision makers, whether a simulator is a cost-effective investigation.

2. Simulators for initial and continuing training of drivers of rail vehicles

In contrast to the education and training of drivers of road vehicles (trucks, buses, cars), the use of simulators for training of drivers for rail vehicles has established in Europe since the early 1990s on a significant level.

Both operators of full-railways and operators of public transport are using this training medium. The mains reasons for the use of simulation technology in the education and training are:

1. High investment costs for modern train or light rail systems do not allow a provision of original equipment for education and training in the required extensive.
2. The usage of the route network as a result of a high frequency rates contrasts the efforts of a driving school
3. A standardized initial and continuing training according modern professional pedagogies and demand-oriented teaching methodological and didactic implementation is increasingly seen as a success factor in quality-assured business concepts.

3. Simulator based training for drivers in the public transport sector

With the beginning of the 1990s, the German railway (Deutsche Bahn) dealt with questions about the simulator-based training of locomotive and train drivers. Today there are 17 simulators as a permanent tool used in standard training and regular continuing training for the abovementioned target group. The mid-1990s led the Munich subway to have the first simulator for the training of subway train crews in Germany. Over a period of about 10 years, between 1995 and 2005, further transport companies restructured their initial and further training for the drivers by integrating the usage of simulators.

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These include Stuttgarter Straßenbahnen AG (SSB), Berlin Transport Services (BVG tram and BVG subway), Hamburger Hochbahn AG (HHA), Nuremberg Transport company (VAG subway and bus). Training simulators for Karlsruhe Transport Authority (VBK / AVG) and for Wiener Linien (WL) are in the feed.

From the perspective of today we can look on 20 years of experiences of using simulator based training in public transport area. All types of common electrically powered rail vehicles were simulated. To a lesser extent experiences on the simulation of diesel-powered vehicles are available. All reputable simulator manufacturers companies can demonstrate relevant references. For trolley and hybrid buses no simulators are currently known, but it may be assumed that such systems can be realized in a similar manner as for railways or busses (diesel drive).

4. Concepts of Simulators

Simulator concepts for training purposes should be primarily adjusted on the needs of the Company, the trainer and the trainee. This requires a thorough needs analysis.

A simulator-based training is successful

- if the training objectives are clearly defined
- if the didactic requirements are met
- if a convincing training concept is present
- if the training is economically feasible
- and if the simulator does what is required

The needs analysis and the precise formulation of the mission objectives and goals of the training are based on a demand-driven simulator concept. This concerns not only the technical and didactic aspect of performance but also the cost aspect.

Classification of simulators

In the early 1960th the usage of the simulation launched with flight training both in the civilian and military sector. Maritime and ground-based simulations followed. Since that time various classifications of simulators have emerged depending on the objectives. They substantially carry out the training requirements of aviation. From a simple procedure trainer, over cockpit and navigation trainer, to the so called "Full Flight" simulators the whole spectrum is covered. This differentiation is mainly due economic factors and training efficiency because it makes economically no sense to train simple action procedures in a full flight simulator. To ensure worldwide comparable qualifications e.g. for safety reasons, standards were created by American, European and other regulatory authorities that define minimum qualifications. As in the aviation sector simulator training is mandatory for training, license extension, etc., it is necessary to certify the simulator by the responsible national authorities.

The simulators differ in various classes in both the structural fidelity simulations, the features and quality of movement and perspective applications as well as in the efficiency

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and scope of the software components. The features correspond to the different training requirements.

The following classifications of the Federal Aviation Administration (FAA), is an example how in the United States “Full Flight simulators“ (FFS) are differentiated. .

- ***FAA FFS Level A*** - *A motion system is required with at least three degrees of freedom. Airplanes only.*
- ***FAA FFS Level B*** - *Requires three axis motion and a higher-fidelity aerodynamic model than does Level A. The lowest level of helicopter flight simulator.*
- ***FAA FFS Level* C** - *Requires* a *motion platform with all six degrees of freedom. Also lower transport delay (latency) over levels A* & *B. The visual system must have an outside-world horizontal field of view of at least* 75 *degrees for each pilot.*
- ***FAA FFS Level D*** - *The highest level of FFS qualification currently available. Requirements are for Level* C *with additions. The motion platform must have all six degrees of freedom, and the visual system must have an outside-world horizontal field of view of at least 150 degrees, with* a *Collimated (distant focus) display. Realistic sounds in the cockpit are required, as well as a number of special motion and visual effects.*

A similar classification unfortunately has not been established for the simulator based training of rail vehicles drivers.

Looking at simulator concepts in most cases the focus is on hardware architecture and the simulated functionality of the object to be simulated. There is no universally agreed definition, but in practice different architectures have evolved, that are easy to distinguish.

type of simulator	Description of requirements and functionalities
Full-mission simulator	Closed type cabins faithful reproduction, accurate / realistic equipment, motion platform (3-6 DOF), functionally faithful recreation
Full cabin simulator	Closed type cabins faithful reproduction, accurate / realistic equipment, no motion platform, seat-movement, functionally faithful recreation
Generic simulator	Closed neutral cabins reproduction, learning topic related equipment, functional reproduction, seat movement
Procedure simulator	Open form, realistic simulation of the driver's workplace, seat movement, vehicle-specific function simulation, learning objectives related equipment with control and display instruments.
Desktop simulator	Simple simulation of a driver's workplace or individual user modules, learning objectives related equipment with control and display elements, functional logic software control, neutral or vehicle specific

Table 1: Types of Simulators – Description of requirements and functionality

Examples of different types of Simulators:

Figure 1 and 2: Full cabin simulators (1. generation): BVG-Tram (left), SSB-AG Stadtbahn (right), view presentation via projection, 6 DOF electromechanical moving system

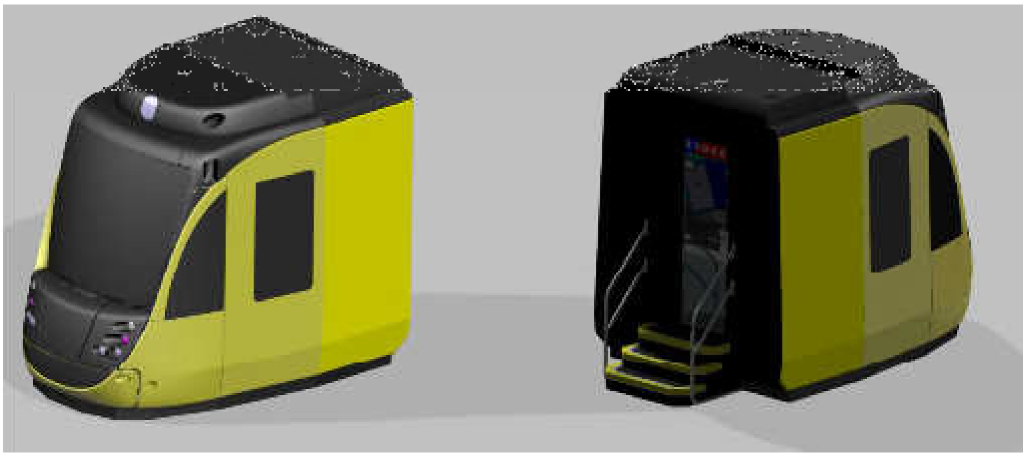

Figure 3: Full cabin simulator 2. generation, VBK Stadtbahn, view presentation via monitors, seat shaker

Figure 4: procedure trainer, VBK/AVG, view presentation via large screen monitor, seat shaker, side controls and indicators as touch Panel

Figure 5: Desktopsimulator (Source: http://www.railway-news.com/gallery/infrastructure-signalling-and-train-control/metro-train-driver-desktop-simulator)

The simulators in the 1990s (1st generation, Figure 1 and 2) were mostly "full-scope simulators" that is realistic cabin reproduction, realistic representations of the function and safety logic, external view between 60 ° and 180 ° (horizontal field of view) and a 6 DOF motion system. The visual representation was made with one or several projectors. Simulators of this type are suitable for training in complex, operationally relevant processes and procedures. A few simulators have been realized without moving system. This normally was liable to the training objectives for which a moving system was not decisive. Of course in this cases, the absence of a 6 DOF motion simulation lowered costs for both the simulation system and the required infrastructure.

The full-scope simulators of the 2nd generation (Fig. 3) are equipped with an exterior visual representation on large screen monitors and mostly renounce the 6 DOF motion. The required movement impulses are routed by technical devices directly in or on the driver's seat. As the simulators 1st generation 2nd generation simulators cover also the entire functional and dynamic requirements. The advantage is obvious, less investment and lower infrastructure costs.

The requirement of representing the entire technical function and dynamic power profile of the simulated train arises from the desire to shift as much content as possible on the training simulator. However, if as a result from the needs analysis shows that only a small scope of the training should be done in the simulator or the company only requests specific aspects to be trained on the simulator, such systems can be developed specifically for these needs. An Example for this is the so-called procedure trainer (Fig. 4), which in turn of course may be build quit complex.

Modern desktop simulators cover most areas of the requested simulation (part-task training). Part-task training results less to cost reasons, but from realizing that training of complex action sequences can be made simpler, by focusing on meaningful aspects and in further steps to add more and more different tasks. Part simulators are optimized to a specific training goal and need correspondingly a lower financial investment. They relieve complex full-scope simulators from simpler training tasks. Eco Driving can be understood as part of a complex target sequence, so that for this training goal in principle a part task simulation is an adequate solution.

But with all the efficiency of modern training simulators it must be said that they cannot replace the use of original vehicle in total, but with a much lesser extent. A simulator is a simulator and not an original vehicle in a real world.

5. Training targets

Mostly the training goals are determined by operationally relevant content. For example this includes controlling operational processes in regular and failure conditions, fault management, riding in adverse environmental conditions, etc. Key aspects depend on the training level the simulator is used for. Basic training, continuing education, special training, etc. may be mentioned here as an example. As important prerequisites for a successful simulator training shall apply:

- a realistic as possible reproduction of the driver's workplace (based on the learning objective scope)
- a realistic as possible reproduction of logic functions of the vehicle,
- a realistic as possible reproduction of driving behavior,
- a realistic as possible reproduction of vehicle and vehicle noise,
- an adequate reproduction of traffic environment
- embedding of the simulator in a methodical didactical training concept, that is tailored to target group and learning objectives
- a didactic periphery, that cause a real added value in comparison to a training only with a real vehicle

6. Eco Driving as topic of a simulator based training

Basically so far public transport companies concentrate on ensuring a trouble-free operating procedure when using simulators for training.

Under the term "energy-saving driving" there was ever paid attention to the corresponding manner of driving. Energy-efficient driving was doing superficially understood as a "skill". Eco-driving in our modern understanding, is less understood as a psychomotor skill rather than a mental performance. Currently considered to be the most sustainable success factors for a successful driving following the Eco-driving rules are the attitude and conviction of the driver.

For developing training according to the purposes of systematic training planning methodical and didactical aspects has to be considered. Therefore the training objective has to be broken down to specific learning targets. For the training objective Eco Driving it quickly becomes clear that this is a complex learning target and must be differentiated. The units can be classified according to categories of learning target

- cognitive
- affective
- psychomotor

Each categories of learning target requires its own methodology to determine the optimal learning settings to set. In the case of "Eco Driving" the units can be assigned as follows

- **Cognitive aspect**: understanding the physical relationships that are important for energy saving while driving a train/trolley-bus. Knowing the basic rules of an energy-saving driving style (see "golden rules" for road vehicles).
- **Affective aspect**: to be convinced that energy-efficient driving is a personal, active contribution to the company's profitability and for environmental protection.
- **Psychomotor aspect**: to control the vehicle with the necessary sensitivity (acceleration, deceleration, stop, etc.) according to basic rules of EcoDriving.

Boundaries between the categories of learning target species are of course fluently, anyway only merging the individual components can ensure success.

The psychomotor part is of course the domain of the simulator. Here, the fusion of the components is accomplished.

6.1. Requirements for the simulation

Hardware and software provide the technical basis for a successful training. To practice and realistically train the psychomotor learning goal part "driving skills" drivability and operation of the vehicle (speed control unit or accelerator) must come very close to the real vehicle behavior. In addition, the representation of the outside world the driver shall provide the information he needs for a reasonable intervention in the driving progress. This information includes for example, the speed indicator, the timely recognition of light and semaphore signals, estimating distances to a stop point or an obstacle, topographical characteristics of the route, assessment of the track or road conditions, the behavior of other road users, etc.

Operation / Handling

Switches, Buttons, Displays: Usually are depicted as original components or on touch monitors. If it is required to have a feeling for pressure points or restoring forces original parts are mandatory.

Vehicle Model

This software module maps the logic function and the failure behavior of the vehicle. Therefore manufacturer's documentation and user manuals are used.

Dynamics model

The dynamic model depicts the dynamic behavior of the vehicle. For this different complex software modules are on the market. The modules in general can parametrized. The simpler the structure, the more general is their dynamic behavior. As a basis for the representation of the dynamics of the vehicle a generally accepted, tunable to the mass distribution of the respective configuration of the vehicle is to choose. Different parameters should be considered in relation to the train characteristics such as engine, axle distribution, engine torque, acceleration graphs, etc.
With regard to the training goal "eco-driving" the dynamic model generates a speed-track-diagram with reference to the relevant parameters. This diagram is displayed to the driver graphically and is analyzable in an appropriate manner for further analyses of driving behavior. To what extent the parameters used must relate on a particular vehicle has to be seen. For training purposes approximate values should be sufficient. Graphical representations or numeric consumption indicators can be displayed for the driver on additional displays.
The aim of the training simulation is not the exact calculation of the speed-track-diagram, but rather, it will seek to clarify the driver the impact of his driving style. Changes in driving style must be expressed in various forms of speed-track-diagram.

The dynamic model (depending on requirements) also delivers current energy consumption and regenerative values of CO_2 consumption or energy recuperation.

Route Database

The route database is divided into different modules. These modules contain all the information relevant to emulate the outside world.

Track data: intended to provide information about the route such as decline, incline, curve radius, distances, speed limits, sensors for the control command, etc. This module provides, i.e., the location-related parameters for the dynamic model

Data for the outside world: This module contains all relevant information about outside world to be generated in the visual system. A distinction is made between specific or typical reproduction. The more specific a reproduction is the more complex the design and the higher the cost are. If there are very different topographies within a route network, the cost of a site-specific replication can be quite high. With regard to the learning goal eco-driving, it may be sufficient to develop a didactically reduced, fictional route network, which allows to apply the rules described in the principles of eco-driving and experiencing the effects of a change in driving style.

Visual representation

The driver as an active element in the control circuit receives relevant information from the outside world and reacts with an appropriate response as input into the control circuit. The more differentiated the visual perception of the outside world is, the more differentiated his reactions can be. The visual representation has a high value as a source of information.

Depending on the operating conditions the relevance of the horizontal viewing angle must be evaluated. This is influence i.e. if the vehicle moves on its own track or within the normal street, are there interactions with individuals or does the vehicle only move in a tunnel. For a tunnel operating a horizontal viewing angle of 60° is sufficient whilst on the road 200° will be relevant.

The quality of the visual representation needs to ensure early detection and identification of light and semaphore signals, the early detection of braking and holding points, etc. The external view also includes the representation of the different weather conditions, i.e. a change in the coefficient of friction affects the braking performance.

Vehicle and road noise have to be realistic and presented in accordance with the impressions of the outer world.

6.2. Requirements for the didactic peripheral

The didactic periphery of the simulator prepares data in an appropriate manner that is necessary to understand the processes and presents and records this data.

Preferably the progress of used time and distance is graphically edited and displayed, e.g. as speed-time-diagram. Curves can be prepared as summaries or with individual parameters. The graphs must be presented in a way that individual events can be viewed in isolation, such as a stop with subsequent acceleration. The advantages of using regenerative braking can be represented numerically or graphically as an energy flow diagram.

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The raw data for the power consumption or for energy recovery are taken from the simulated electronic control system. If the MMI display is prepared to indicate various values about the power usage it should be like in the original. If necessary the information must be provided more didactically for better understanding.

As a basis for the representation of the graphs data can be used, that is stored in the dynamic model (torque, acceleration, deceleration, energy requirements). The characteristic curves can be implemented specific for the vehicle, or if they are not obtained from the manufacturer, be used from typical vehicle data.

In the vehicle equipped with advanced driver assistance systems to improve energy efficiency, this has to be included in the simulation. Their influence must be precisely traceable in didactic diagrams.

Instructor / Trainer choose in advance what data or events have to be prepared and displayed. Experience shows that not everything that can be provided needs to be displayed.

All used data used for representation of performance during a running exercise should also be stored in a file that contains the whole exercise. This documentation is usually the basis for the exercise debriefing. Normally trainings are organized in groups the simulator should have the opportunity to have separate displays outside the simulation for observers “Übungsmitschau”. Here the other group members can watch the ride of their colleagues. All views and viewing of the vehicle as well as other values showing numerical consumption, position, gas pedal, brake pedal, etc., are also available at the “Übungsmitschau”. The status of all controls is also displayed. If necessary, other displays such as longitudinal and lateral acceleration, even if not in the original vehicle available, can be realized.

6.3. Training concept

An important lesson from the past 20 years simulator-based training is the integration of the simulator into a training concept with determined statements about target and target-group. A systematic planning of training on the principles of "Instructional Design" provides the methodological didactic framework. With the basis of this experience you can ask, which role plays the simulator in a didactically planned training concept. It quickly becomes clear that even if it is an important role, it does not play the key role. Especially not when the actual learning target is highly affective pronounced.

It is estimated that about 70% of the learning process play outside of the simulator, the impulse is however triggered in the simulator. Here, the simulator offers the opportunity to check effects of changes in behavior and to experience its effects directly, e.g. comparing consumption values. Documented divergences from a desired set point can be analyzed, discussed and evaluated by the coach and the whole training group. Beside the simulator itself a specially qualified instructor (for using simulators) plays a major role. In optimal case the driver immediately recognizes immediately why he has not reached the desired value and can run the exercise again with modified behavior under comparable conditions. This lays the foundation for sustainable behavior change. Understanding of the basic interrelations, insight into the interplay of the relevant factors and knowledge of the control options form the basis on which the simulator provides the practical implications.

Accordingly a training unit needs to be created which yields this basis

- transfer of knowledge about technical relationships
- rules (golden rules) for the application
- review within the simulator

A good proven schedule that has been used successful in the conventional Eco-Drive Train for car driver and truck driver is the following:

1. Introduction
2. Initial drive (data collection, current status)
3. Subject information on eco-driving (golden rules, etc.)
4. Second Drive (data collection, data comparison)
5. Debriefing

6.4. Exemplary Training module

For the training on the simulator, the number of participants from a maximum of 6 riders has proved to be practicable. Since a significant aspect of the simulator training is to observe the behavior of all the other drivers a higher number of drivers would lead to not acceptable observation times. Therefore the training is designed as a one-day seminar for 8 participants. A larger number would require another coach, because the groups must be separated. Through targeted monitoring of specific driving behavior (speed, engine speed, gear changes, stops, acceleration, etc.), the entire group is involved in each simulator ride. The limitation to 8 participants is often referred as uneconomical, in chapter 7 this is focused more. In this example qualitative and quantitative aspects are taken into consideration.

Time	Topic	Method	Remarks
08:00 – 08:15	Welcome / Overview / Organisational	FlipChart / prepared papers	
08:15 – 08:45	Round of introduction	individual each participant	e.g. collecting expectations
08:45 – 08:50	Explaining the simulator	Trainer – at the simulator	
08:50 – 09:30	familiarization drive	Each student e.g. 4-5 min.	Easy to drive task
09:30 – 09:45	Break		
09:45 – 11.00	Driving the first ride	Each student about 10 min.	Observing tasks for other students
11:00 – 12:30	Eco driving - Golden rules	Elaboration of the golden rules in small groups	Group work,discussions
12:30 – 13:00	Break		
13:00 –13:15	Golden rules	Repeating	
13:15 – 14:15	Driving experience	Students have different tasks (golden rules) driving the simulator	Observing – Evaluating
14:15 – 14:30	Break		
14:30 – 15:40	Driving the second ride	Each student about 10 min. including individual debriefing	Observing tasks for other students
15:40 – 16:00	Conclusions	Lessons learned	

Table 2: Example for training using a simulator

6.5. Excercise scenarios

Exercise scenarios define the framework data of one specific simulation exercise, in which the driver has to cope with the well-defined task of driving. Only for basic demands standardized training scenarios are imaginable. As a general rule the scenarios will be developed specific by each company due to their operational, traffic and weather-related conditions. Each company will define specific scenarios depending on route requirements to which the driver should apply the learned practices, but complete realism is not necessarily required. The key is to make the route requirements so that dealing with the typical modes of electric vehicles such as acceleration, insistence, coasting and braking can be practiced in a variety of ways. This is about the application of the theory developed in the block "golden rules"[1] for energy-efficient driving and to review the central statements of the theory lessons. So there is obviously a difference if the driver believes the instructor (or not) that even with fuel-efficient driving the timetable can be met, or whether he actually experience it on the simulator himself.

7. Cost considerations

Consideration on cost aspects of a simulator-based training lead to several cost blocks.

When training is performed personnel costs for the students and the trainer must be added and simulator costs must be adapted to the use in the training.

The following aspects focus onto the simulator itself.

1. Investment for the simulator
2. Investment for further didactical tools (depending on the concept)
3. Infrastructure costs
4. Operating costs
5. Maintenance / Update

To 1: Investment for the simulator

The cost of a simulator cannot name as a lump sum. Influence from too many parameters has to be considered. As experience from 2 currently tendering procedures and the evaluation of 6 offers the following as a guideline figures can be given as average values:

type of simulator	Cost aspects
Full cabin simulator, viewing system with large monitor, seat shaker, Übungsmitschau, 30 km track data base	Range: 650.000 € to 1.440.000 € Ø 1.000.000 €
Procedure simulator, Open form, realistic simulation of the driver's workplace, seat movement, vehicle-specific function simulation, learning objectives related equipment with control and display instruments (without data base)	Range: 150.000 € to 350.000 € Ø 250.000 €

Table 3: Different types of Simulator – cost aspects

Serious desktop simulators operate in a range of 30.000 to 80.000 €

[1] http://www.actuate-ecodriving.eu/fileadmin/user_upload/ACTUATE_Training_Material_Broschure_Trolley.pdf

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To 2: Investment for further didactical tools

Other teaching aids are e.g.:

- Equipment for classroom (Smart board, Beamer),
- Learning materials like CBT/WBT and necessary Hardware (Computer, Notebook etc.)

When integrating simulators into to training, also Computer Based training is often used to impart knowledge. On the market there are some programs available that can support the training by self-learning of the participants during the training, for preparing the training or in the post-phase for a sustainable behavioral change .

To 3: Infrastructure

Infrastructure costs relate to the installation site of the simulator, as well as other rooms for technical equipment, a classroom and possibly staff rooms.

To 4: Operating costs

Operating costs are only cost of electricity, beside the obligatory personnel costs.

To 5: Maintenance / Updates

For a simulator system it makes sense to have a regular maintenance concept. After the expiration of the warranty maintenance work should be carried out at least once a year. By self-performing a part of the maintenance costs can be reduced.

Experience shows that regular maintenance costs have to be planned, e.g. for content adjustments due to changes in requirements for the simulation software (e.g. changed traffic light circuit, altered performance of the vehicle). Over a period of 5 years an amount of 20% of the procurement cost should be provided for major upgrades.

7.1. Cost model for different scenarios using a simulator for eco-driving training

To make cost model easy to handle a reduction on only a few parameters is useful, especially when different scenarios can be compared. Therefore the cost model leaves all parameters aside, which do not have a strong influence on the decision whether the costs of a scenario speak more for or rather against the simulator use. Examples are cost of premises or general administrative expenses.

The following decisions were made:

The calculation is performed for 4 simulator types:

(A)	Desktop simulator	=	80.000 €
(B)	Procedure simulator	=	300.000 €
(C)	Generic simulator	=	500.000 €
(D)	Full-Cabin simulator	=	1.000.000 €

Costs for maintenance and yearly updates and adjustments are set to 5 % each year.

The costs per usage of the simulator is calculated to one as if the simulator can be used 1.600 hours in average a year (S1) and to the other as if the simulator is only used for the eco-driving training (S2).

The costs per usage of the simulator is calculated to one as if the simulator is only used for the eco-driving training and to the other as if the simulator can be used 1.600 hours in average a year. The second case is realistic for more complex simulator that allows having a broader usage than only for EcoDriving.

Three variations of the number of drivers are determined to meet the range from small to big companies: 100 / 500 / 1.500 driver. (variant 1 to 3)

Reflecting the personnel costs that vary strong in different countries the model contains driver costs per hour from 6.20 € (A1.personnel cost low) and 35.0 € (A2.personnel cost high). The costs for trainer are set equivalent to 9.10 € (B1) and 45.00 € (B2).

The number of drivers per training session is set to 8 drivers.

The costs for energy consumption is taken from the project partner in Leipzig, with about 9.350 € per year.

Fuel savings are calculated for 3%, 4.5% and 6%, where the middle value is near to the overall calculated savings within the ACTUATE Project.

7.2. Results cost calculation

The table on the last page shows the results; after all relevant data from section 7.1 is put into an Excel-sheet.

There are 4 rows of total cost result. Result 1 and 2 with personnel cost low und Result 3 and 4 with personnel cost high. Result 1 and 3 have the overall cost, when the simulator can be used also for other training and Result 2 and 4 show the cost if the simulator is only used for EcoDriving training.

The values for savings are given for the sake of completeness in all alternatives.

Alternative A: Desktop simulator

Total cost	Variant 1 100 driver	Variant 2 500 driver	Variant 3 1.500 driver
Result 1: overall costs for training	6.620,00 €	33.100,00 €	99.300,00 €
Result 2: overall costs for training (Sim only for EcoDriving)	17.870,00 €	41.350,00 €	100.050,00 €
Result 3: overall costs for training	33.250,00 €	166.250,00 €	498.750,00 €
Result 4: overall costs for training (Sim only for EcoDriving)	44.500,00 €	174.500,00 €	499.500,00 €
Savings:			
3.0% savings per year	28.050 €	140.250 €	420.750 €
4.5 % savings per year	42.075 €	210.375 €	631.125 €
6.0 % savings per year	56.100 €	280.500 €	841.500 €

Table 4: results cost calculation desktop simulator

The results show that with low personnel cost (Result 1+2) for all variant the cost of a simulator based training is even lower than the lowest expected yearly savings from 3 %. Result 3 and 4 show that with savings about 4.5 % that using a simulator lead to lower training costs than the expected savings.

Alternative B: Procedure simulator

Total cost	Variant 1 100 driver	Variant 2 500 driver	Variant 3 1.500 driver
Result 1: overall costs for training	8.682,50 €	43.412,50 €	130.237,50 €
Result 2: overall costs for training (Sim only for EcoDriving)	50.870,00 €	74.350,00 €	133.050,00 €
Result 3: overall costs for training	35.312,50 €	176.562,50 €	529.687,50 €
Result 4: overall costs for training (Sim only for EcoDriving)	77.500,00 €	207.500,00 €	532.500,00 €
Savings:			
3.0% savings per year	28.050 €	140.250 €	420.750 €
4.5 % savings per year	42.075 €	210.375 €	631.125 €
6.0 % savings per year	56.100 €	280.500 €	841.500 €

Table 5: results cost calculation procedure simulator

The overall costs of Result 1 are in all variants lower than the expected savings. Result 2 needs with 100 driver 4.5 % saving to reach the break even, the other variant need lower savings. Result 3 shows that a small company with high personnel cost need about 4.5% savings and with a simulator only for EcoDriving will in the first year (Result 4) not reach the break-even. For variant 2 and 3 the break-even with high personnel cost (Result 3+4) can be reached between 4.5 und 6.0%. Of course the savings go on in the following years, so that on the long run total savings can be achieved.

Alternative C: Generic simulator

Total cost	Variant 1 100 driver	Variant 2 500 driver	Variant 3 1.500 driver
Result 1: overall costs for training	10.557,50 €	52.787,50 €	158.362,50 €
Result 2: overall costs for training (Sim only for EcoDriving)	80.870,00 €	104.350,00 €	163.050,00 €
Result 3: overall costs for training	37.187,50 €	185.937,50 €	557.812,50 €
Result 4: overall costs for training (Sim only for EcoDriving)	107.500,00 €	237.500,00 €	562.500,00 €
Savings:			
3.0% savings per year	28.050 €	140.250 €	420.750 €
4.5 % savings per year	42.075 €	210.375 €	631.125 €
6.0 % savings per year	56.100 €	280.500 €	841.500 €

Table 6: results cost calculation procedure simulator

From Result 3 it can be seen, that in case of high personnel cost the savings should be 4.5%, to reach a break-even in the first year.

Alternative D: Full-Cabin simulator

Total cost	Variant 1 100 driver	Variant 2 500 driver	Variant 3 1.500 driver
Result 1: overall costs for training	15.245,00 €	76.225,00 €	228.675,00 €
Result 2: overall costs for training (Sim only for EcoDriving)	155.870,00 €	179.350,00 €	238.050,00 €
Result 3: overall costs for training	41.875,00 €	209.375,00 €	628.125,00 €
Result 4: overall costs for training (Sim only for EcoDriving)	182.500,00 €	312.500,00 €	637.500,00 €
Savings:			
3.0% savings per year	28.050 €	140.250 €	420.750 €
4.5 % savings per year	42.075 €	210.375 €	631.125 €
6.0 % savings per year	56.100 €	280.500 €	841.500 €

Table 7: results cost calculation procedure simulator

From Result 4 it can be seen, that in case of high personnel cost the number of driver to be trained should be higher than 500 (variant 2) to reach break-even in the first year.

In case of low personnel cost and using the simulator also for other training the break-even is reached even in the variant with only 100 driver.

The following page shows the whole results in an overview.

Table 8: overall cost calculation

Cost model using simulator based training in clean vehicles - ACTUTATE												
category		A			B			C			D	
costs of simulator		Desktop simulator			Procedure simulator			Generic simulator			Full-Cabin simulator	
Acquisition costs simulator		80.000,00 €			300.000,00 €			500.000,00 €			1.000.000,00 €	
life cycle (years)		10			10			10			10	
maintenance / update p.a. (5%)		4.000,00 €			15.000,00 €			25.000,00 €			50.000,00 €	
S1 costs with 1.600 h of usage p.a.		7,50 €			28,13 €			46,88 €			93,75 €	
S2 costs simulator usage only for EcoDrive	120,00 €	24,00 €	8,00 €	450,00 €	90,00 €	30,00 €	750,00 €	150,00 €	50,00 €	1.500,00 €	300,00 €	100,00 €
personnel costs	variant 1	variant 2	variant 3	variant 1	variant 2	variant 3	variant 1	variant 2	variant 3	variant 1	variant 2	variant 3
number of participants	100	500	1500	100	500	1500	100	500	1500	100	500	1500
A1. costs per participant per hour in Euro	6,20 €	6,20 €	6,20 €	6,20 €	6,20 €	6,20 €	6,20 €	6,20 €	6,20 €	6,20 €	6,20 €	6,20 €
A2. costs per participant per hour in Euro	35,00 €	35,00 €	35,00 €	35,00 €	35,00 €	35,00 €	35,00 €	35,00 €	35,00 €	35,00 €	35,00 €	35,00 €
B1. costs per Trainer per hour	9,10 €	9,10 €	9,10 €	9,10 €	9,10 €	9,10 €	9,10 €	9,10 €	9,10 €	9,10 €	9,10 €	9,10 €
B2. costs per Trainer per hour	45,00 €	45,00 €	45,00 €	45,00 €	45,00 €	45,00 €	45,00 €	45,00 €	45,00 €	45,00 €	45,00 €	45,00 €
training duration (hours)	8	8	8	8	8	8	8	8	8	8	8	8
number of participants per training session	8	8	8	8	8	8	8	8	8	8	8	8
cost summary												
S1 costs simulator partly using for EcoDriving	750,00 €	3.750,00 €	11.250,00 €	2.812,50 €	14.062,50 €	42.187,50 €	4.687,50 €	23.437,50 €	70.312,50 €	9.375,00 €	46.875,00 €	140.625,00 €
S2 costs simulator only for EcoDriving	12.000,00 €	12.000,00 €	12.000,00 €	45.000,00 €	45.000,00 €	45.000,00 €	75.000,00 €	75.000,00 €	75.000,00 €	150.000,00 €	150.000,00 €	150.000,00 €
personnel costs low												
A1. costs of participants	4.960,00 €	24.800,00 €	74.400,00 €	4.960,00 €	24.800,00 €	74.400,00 €	4.960,00 €	24.800,00 €	74.400,00 €	4.960,00 €	24.800,00 €	74.400,00 €
B1. costs of trainer	910,00 €	4.550,00 €	13.650,00 €	910,00 €	4.550,00 €	13.650,00 €	910,00 €	4.550,00 €	13.650,00 €	910,00 €	4.550,00 €	13.650,00 €
Total cost (personnel cost low)												
Result 1: S1+A1+B1 overall costs for training	6.620,00 €	33.100,00 €	99.300,00 €	8.682,50 €	43.412,50 €	130.237,50 €	10.557,50 €	52.787,50 €	158.362,50 €	15.245,00 €	76.225,00 €	228.675,00 €
Result 2: S2+A1+B1 overall costs for training	17.870,00 €	41.350,00 €	100.050,00 €	50.870,00 €	74.350,00 €	133.050,00 €	80.870,00 €	104.350,00 €	163.050,00 €	155.870,00 €	179.350,00 €	238.050,00 €
personnel costs high												
A2. Kosten TN für Schulungen	28.000,00 €	140.000,00 €	420.000,00 €	28.000,00 €	140.000,00 €	420.000,00 €	28.000,00 €	140.000,00 €	420.000,00 €	28.000,00 €	140.000,00 €	420.000,00 €
B2. Kosten Trainer für Schulungen	4.500,00 €	22.500,00 €	67.500,00 €	4.500,00 €	22.500,00 €	67.500,00 €	4.500,00 €	22.500,00 €	67.500,00 €	4.500,00 €	22.500,00 €	67.500,00 €
Total cost (personnel cost high)												
Result 3: S1+A2+B2 overall costs for training	33.250,00 €	166.250,00 €	498.750,00 €	35.312,50 €	176.562,50 €	529.687,50 €	37.187,50 €	185.937,50 €	557.812,50 €	41.875,00 €	209.375,00 €	628.125,00 €
Result 4: S2+A2+B2 overall costs for training	44.500,00 €	174.500,00 €	499.500,00 €	77.500,00 €	207.500,00 €	532.500,00 €	107.500,00 €	237.500,00 €	562.500,00 €	182.500,00 €	312.500,00 €	637.500,00 €
fuel consuption / savings												
energy consumption per driver per year		9.350,00 €			9.350,00 €			9.350,00 €			9.350,00 €	
energy consumption all driver per year	935.000 €	4.675.000 €	14.025.000 €	935.000 €	4.675.000 €	14.025.000 €	935.000 €	4.675.000 €	14.025.000 €	935.000 €	4.675.000 €	14.025.000 €
X1. 3.0% savings per year	28.050 €	140.250 €	420.750 €	28.050 €	140.250 €	420.750 €	28.050 €	140.250 €	420.750 €	28.050 €	140.250 €	420.750 €
X2. 4.5 % savings per year	42.075 €	210.375 €	631.125 €	42.075 €	210.375 €	631.125 €	42.075 €	210.375 €	631.125 €	42.075 €	210.375 €	631.125 €
X3. 6.0 % savings per year	56.100 €	280.500 €	841.500 €	56.100 €	280.500 €	841.500 €	56.100 €	280.500 €	841.500 €	56.100 €	280.500 €	841.500 €

8. Conclusions

The investigation shows generally that training using simulators is valuable. The conditions for a successful training must be well defined and in many cases the costs are suitable in comparison to the achievable savings.

Main aspects are:

- Using simulators is a proven method for vehicle training.
- EcoDriving is a good topic to be trained on a simulator, even a desktop simulator can be used to achieve pedagogical and didactical pre-defined goals.
- Especially when using as simulator a well-designed training is essential.
- Different types of simulator are qualified to be used for EcoDriving training, depending on the goals. Higher sophisticated simulator can be used for goals other than EcoDrive focus.

But of course, in most cases the cost for integrating simulation in the training process does not make the training cheaper than a traditional training at a first glance. Costs for simulator are always an add-on, compared to traditional training. Only when subsidizing original vehicles by simulator you can achieve savings. But to have only this view on using simulators for training it is often overlooked that there are some non-quantifiable aspects as:

- Companies can strengthen their image (modern, fuel saving)
- More intensive training than with traditional methods and thereby more being ready to adopt the driving style (sustainable change in behavior)
- Save the vehicles (less wear and tear)
- Avoid accidents

When analyzing the costs and benefits as fuel savings, then even if simulator based training is more cost extensive than traditional training, in a lot of cases the savings from a simulator based EcoDriving training are higher than the costs incurred.