The ITERATE project final report

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Executive summary (1 Page)

In recent years, a variety of drive/ support and information management systems have been designed and implemented with the objective of improving safety as well as the performance of vehicles. While the crucial issues at a technical level have been mostly solved their consequences on driver activity remains open and needs to be fully explained. Of particular importance are their effects on driver behaviour and strategies, and their impact on the operation and safety of the traffic system. Thus, the main objective for the ITERATE project was to develop a unified model of driver behaviour (UMD) and the driver's interaction with different support systems. The model should be applicable to all surface transport modes (road, rail and water) and include key operator factors (e.g. personality, experience, workload, and driver state) that capture a broad range of behaviour. The underlying assumption was that limited set of human factors could be used to model driver behaviour independent of transport mode. A comprehensive state of the art review of driver modelling efforts was initially carried out in the project. The most suitable model was found to be a model developed within the past AIDE project. This motivational model was further developed so that the output was behaviour, error propensity and reaction time. Furthermore, a feedback mechanism was added to cater for adaptive behaviour. This work is extensively described in two deliverables. An inventory of driver support systems was used to select support systems (with a similar function in the three selected transport modes) to be tested in a large scale simulator experiments. This work is described in two separate deliverables (inventory & selection). The first experiment including car and train driver was carefully planned in order to harmonise the actual performance of the experiments which included six test sites and several test leaders and almost 300 test drivers. Two identical portable simulators for car and train driving were constructed within the project. The two simulators were circulated between partners in five different countries in order to conduct a cross-cultural experiment aiming to test the UMD model. Main effects were found for workload, culture and gender and interaction effects between culture and gender, personality and workload, personality and experience. Driver state (fatigue) did not have any effect which probably was due to too low level of fatigue. Thus, it was concluded that the UMD model could capture driver behaviour with the selected set of factors even if it was found that gender (not included in the model) was a factor that should be included in the future. Furthermore, two large scale advanced simulators were used to validate the results from the portable simulators. It was also found that the small scale portable simulators provided comparable results as the more advanced simulator. The results are described in a deliverable. The UMD model also constituted a foundation for developing a numerical simulation of driver behaviour. The human factors in the UMD model were handled as variables in the simulation and a generic function with these variables was developed and some basic constants were determined rather ad hoc. The SiMUD (the numerical simulation tool) was developed in parallel to the experiments and simulation results were compared to experimental results across transport modes (using regression analysis) and were found to be quite satisfactory and deviations were used to improve the simulation. This work is described in three deliverables with complimentary information together with experimental results. Finally, three new experiments were carried out in order to validate the UMD model in terms of predicting behaviour. The first was aimed at testing that the model was applicable also to the shipping domain. A full scale bridge simulator was used for the experiment and the results were satisfactory considering the differences between land and water transports. Furthermore, an experiment in an advanced car driving simulator with new driver support systems illustrated the validity of both the UMD model and the simulation tool, i.e. changes in a human factor yielded the same results e.g. high sensation seeker tend to drive at a higher speed then low sensation seeking driver. Similar results were achieved for train drivers using a different train simulator (compared to previous experiment). Thus, it was concluded that even if the UMD model needs further development (e.g. take gender into account) as well as the simulation tool (i.e. introduction of non-linear regression). The validation activities are described in two separate deliverables. All experimental data have been collected and organised in a database owned and maintained by the consortium. A MoU which regulates the exploitation of the database have been signed by the contractors. The database will be publicly available in 2014. The ITERATE work has been extensively presented at conferences, workshops and also appears in a book, proceeding from a workshop organised in the project. The dissemination work (website, logo, workshops, newsletters, business plan etc.) are described in six deliverables. There is also a final report which summaries the work conducted in ITERATE.

Project context and objectives (4 pages)

The development of driver support systems has flourished over the last couple of years and they have improved both safety and the performance of vehicles. For road traffic we can see Collision Avoidance Systems (CAS), Lane Departure Warning Systems (LDWS), Speed Limiters, Adaptive Cruise Control (ACC) and many more systems in increasingly numbers on the road. A similar development can be seen for both rail and maritime transport where European Rail Transport Management System (ERTMS) is being introduced for trains and adaptive autopilots, speed pilots, ECDIS (electronic chart display and information system) and AIS (Automatic Identification System) are introduced at sea.

Technically the systems are highly developed and sophisticated, even to that extent that autonomous driving is round the corner. What still is lagging behind is advanced, valid, reliable and cost efficient methods to be used in development and testing of the systems. Of particular interest are these new systems effects on driver behaviour and strategies and their impact on the traffic system; a topic that has been of great concern amongst researchers and traffic safety analysis for several years (Michon, 1993; Parkes and Franzen, 1993; Noy, 1997). This is where driver models can play a substantial role since they allow for testing various systems settings on a large variety of drivers such as drivers of different culture, different experience, different personality and under varying workload. Driver models can also play a big role in various stages of system development since they for instance allow for different settings or timings of a system to be tested at an early stage as well as testing prototypes close to production, or even for authorities to test systems before they are approved for market introduction. In the long term there also exists the potential to have the model running in real time as a "co-driver" or driving assistant. It could therefore warn the driver when the risk level becomes too high, help to manage risk by monitoring and managing driver workload, and even trigger automatic system response when the situation is considered to be unmanageable by the driver.

The identification of crucial behavioural modelling and adaptation aspects associated with the use of the new support systems has already been researched within a number of European Projects such as AIDE, ROADSENSE, MODURBAN, MODTRAIN, UGTMS. However, their integration in Driver-Vehicle-Environment (DVE) models and simulations for supporting design and safety assessment processes only just begun.

The ITERATE objective was to take state of the art in this research area further by developing and validating a Unified Model of Driver behaviour (UMD), applicable to all surface transport modes. The UMD shall encompass dynamic driver-vehicle-environment interactions in terms of theoretical architectures, adaptation and influencing factors, parameters and variables affecting behaviour in normal and critical situations. This model should be applicable to and validated for all the surface transport modes. Drivers' age, gender, education and experience and culture (whether regional or company/organisational) are factors that will be considered together with influences from the environment and the vehicle. The theoretical architecture developed in ITERATE was interpreted into numerical algorithms which were implemented in a simulation software (SiMUD) that enable fast and reliable representations of DVE interactions.

Main project results (max 25 pages)

There were nine work packages (WP) including Management and Dissemination within the project spanning from development of the theoretical model as well as the numerical simulation to experimental work feeding the models with data to calibrate against as well as experiments to show that the UMD developed is valid, The main project results (WP1 – 7) will be presented work package by work package in the following.

Driver behaviour modelling (WP1)

Driving a vehicle may be described as a dynamic control task in which the driver has to select relevant information from a vast array of mainly visual inputs to make decisions and execute appropriate control responses. Although there are occasions when the driver has to react to some unexpected event, in general, drivers execute planned actions which are shaped by their expectations of the unfolding road, pedestrian and traffic scenario in front of them and the road geometry and surroundings that they actually observe.

One classification of the different models is offered in Figure 1. We can divide all models into two major categories: descriptive and functional.

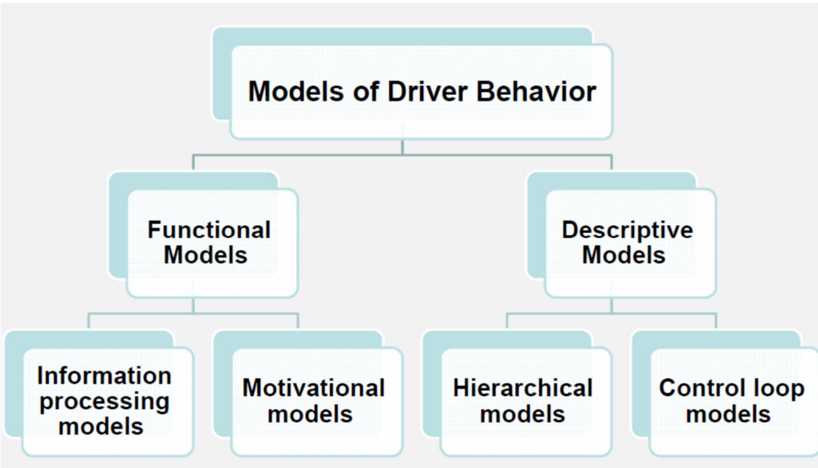


Figure 1 A classification of models of driver behaviour

Descriptive models focus on what the drivers do. These models attempt to describe the entire driving task or some components of it in terms of what the driver has to do. A major feature of such models is that they are not predictive, but are instead analytical. **Hierarchical models** incorporating behaviours at different levels and **control loop models** of operational performance serve as a framework for other models and theories. Driving behaviour can be seen as a behavioural hierarchy. There are several differences between varieties of hierarchical models, but generally they all divide driving behaviour into three levels: the lowest level is an operational, control level. The second level is a tactical, vehicle manoeuvring level referring to how traffic situations are mastered. The third and highest level is a planning or strategic level.

Functional models, which include motivational models and information-processing models, are more likely to help understand complex tasks such as driving. Existing models are largely subjective and based on self-report scales. They strongly emphasize the driver's cognitive state and have incorporated important behavioural change concepts such as motivation, or risk assessment. **Information processing models** consist of different stages, which include perception, decision, response selection, and response execution. Each stage is assumed to perform some transformation of data and to take some time for its completion. The driver in such models is described as a passive information transmission channel, which performs different acts within capacity limitations. **Motivational models** focus on "what the driver actually does" in a given traffic situation rather than on the level of driving skill. Motivational models aim to describe how the driver manages risk or task difficulty. The main assumptions of these models were that driving is self-paced and that drivers select the amount of risk they are willing to tolerate in any given situation. The driver is seen as an active decision maker or information seeker, rather than the passive responder implicit in many information-processing models.

The focus in the ITERATE project is on creating a structured model that can be used in real time, in particular by a driver assistance system to monitor driver state and performance, predict how momentary risk changes, and anticipate problem situations and in response adjust the behaviour of in-vehicle information systems and driver assistance systems and also adjust feedback to the driver. Thus, the AIDE model was identified as the most appropriate starting point for developing an Unified Model of Driver behaviour (UMD). The general objective of the European Project AIDE (Adaptive Integrated Driver-vehicle InterfacE) was to generate the knowledge and develop methodologies and human-machine interface technologies required for safe and efficient integration of Advanced Driver Assistance Systems (ADAS), In-vehicle Information Systems (IVIS) and nomadic devices (e.g. mobile phones, personal digital assistants and other portable computing devices) into the driving environment. Specifically, to develop and validate a generic Adaptive Integrated Driver-vehicle Interface that employs innovative concepts and technologies in order to maximize the efficiency and hence the safety benefits of advanced driver assistance systems; to minimize the level of workload and distraction imposed by in-vehicle information systems and nomad devices and to enable the potential benefits of new in-vehicle technologies and nomad devices in terms of allowing greater mobility and comfort, without compromising safety.

The ITERATE Unified Model of Driver Behaviour (UMD)

It is important to develop a modelling architecture that will be appropriate for a UMD in different surface transport systems and to identify specific parameters and variables that will enable the characterization of the modelling architecture to specific applications. It is crucial to include in the applications, a vehicle model and environmental parameters that represent different (risky and critical) traffic scenarios simulated in the test phases of the project. In order to be a useful tool, the selected model should include as inputs, factors that have been shown to influence risk, risk-taking and errors. The selected driver variables described above are:

- *Sensation Seeking* (representing attitudes/personality) - especially relevant for the road vehicles. For other transport modes this is of lesser relevance because the operators of these modes professional drivers who are recruited under restrict conditions and therefore the presence of sensation seekers among these drivers can be mitigated. Personality traits may have negative influence on driving performance. Most articles show statistically significant but moderate correlations between sensation seeking and some aspects of risky driving.
- *Hazard perception Skills* (representing experience) – relevant to all modes of transport. Hazard perception skills have been found to correlate with crash risk.
- *Fatigue* (representing driver state) - relevant to all modes of transport. To have greater control over the level of fatigue, and to reduce the costs of the experiments, we will only use task induced fatigue (using a monotonous task or 'time-on-task') in the model validation studies. Monotony of road environment has an adverse effect on driver performance and fatigue caused by driving in complex roads has a large impact on driving behaviour.
- *Subjective workload* (representing task demands) – also important within all transport modes, Task demand arises from a combination of environmental features (complexity of traffic, weather, and light conditions), other road users' behaviours, and characteristics of the vehicle; not necessarily in the same level of importance for the different transport modes.
- *Country* (representing culture) - Common to all transport modes, Most Studies dealing with cross-cultural differences in driving found significant effects on behaviour and performance variables.

There are, of course, some differences between the different transport modes concerning these parameters, but they seem to be sufficient to give a reasonable cover of most of the important and relevant factors.

In the proposed model, the driver, as the most flexible component, often finds it necessary to modify his or her behaviour in order to correct for various degradations in the environment. These may be due to weather, topography or design. It is important to investigate how much do 'human indirect causes' (i.e., conditions and states) affect the driver's ability to overcome the environmental hazards posed by the environmental factors. In most studies some common factors pertaining to the road infrastructure or the driving environment conditions were found to be critical. These conditions include roads slick with rain/ice or other debris, obstructions to the driver's vision attributable to inadequate highway design, poor signage, and poor infrastructure maintenance. It is important to develop a unified model of DVE which will evaluate the effects of the selected environmental factors on the driver model and the corresponding driver behaviour and performance, in order to understand how to avoid errors and crashes. We have selected the most salient variables that (1) have been shown to influence risk, risk-taking, and errors, (2) can be implemented within the model simulation, and (3) are relevant to at least one of the three transport modes – cars, trains & maritime vessels. The selected parameters and variables described in this document are: Road/Track /Fairway – type, alignment, view obstruction, surface conditions, Traffic – density and mix, and Visibility – rain/snow/fog, light conditions.

A Literature review on the joint effects of selected driver variables and selected environmental parameters on driving performance and behaviour reveals some important effects that need to be implemented within the DVE model and be part of the scenarios to be implemented within the simulations. We did not find any empirical studies that investigated the effects of weather, roadway geometry, and traffic density on drivers with different personality characteristics; specifically high- and low sensation seekers. While weather is often claimed to be responsible for inter-country variations in culture, we did not find any studies that investigated the differential effects of the selected environmental parameters on drivers from different cultures.

With regard to experience and hazard perception skills, novice drivers are over-involved in accidents relative to experienced drivers when driving on poorly designed roads, and when encountering view obstructions. On the other hand, education does not seem to improve the driver's ability to better interpret driving conditions (e.g. slippery road). Novices are also significantly slower in perceiving of hazards at night than during the daytime.

Curves are more demanding than straight roads in terms of reaction time and lateral control, and unexpected hazardous situations affect subjective workload more than curves. In high density traffic changing lanes increases strain; whereas in low density the maximal strain is reached during the planning phase. Driving in a mixed steam of traffic makes merging into traffic more mentally demanding. The effect of weather conditions (clear/foggy) on workload is limited because drivers adapt their driving behaviour in bad weather by reducing speed. Mental effort increases when the motorway lighting is switched off.

Fatigue increases when traffic density is low, visibility is poor, and the drive is monotonous. Fatigue induced by underload is greater on divided roads and in monotonous drives (with an interesting order effect where drivers feel more fatigue when transferring from heavy traffic in urban roads to light traffic in monotonous rural roads than vice versa). Driving longer routes induces higher degrees of sleepiness than driving on shorter routes repeatedly or driving in heavy traffic and dense areas. Time of day effect on fatigue was found in late-night to early-morning hours (2:00 – 6:00). Autumn was the time of year when most of the drivers considered sleepiness to be most disturbing followed by the winter.

To consider all of these factors simultaneously we propose the Unified Model of Driving illustrated in Figure 3. In this model driving behaviour or performance of each driver are governed by the relatively stable factors of culture, attitudes and personality, and experience. These factors interact with and influence the driver's state, that can be affected by various impairing factors such as fatigue and alcohol/drug intoxication. The driver's state is also influenced by (and can influence) the task demands. The environment has an effect on at least three of the driver parameters that are included in the model: it can determine the much of the task demands (e.g., coping with heavy traffic), the driver state (monotonous drives induce fatigue), and the driver's experience (some environments may be novel to some drivers, such as coping with icy roads). The in-vehicle systems ("system" in the model) receive inputs from the environment but also respond to the drivers' actions. Depending on their level of intervention they can either alert the driver to impending dangers or actually affect the vehicle response to cope with these dangers.

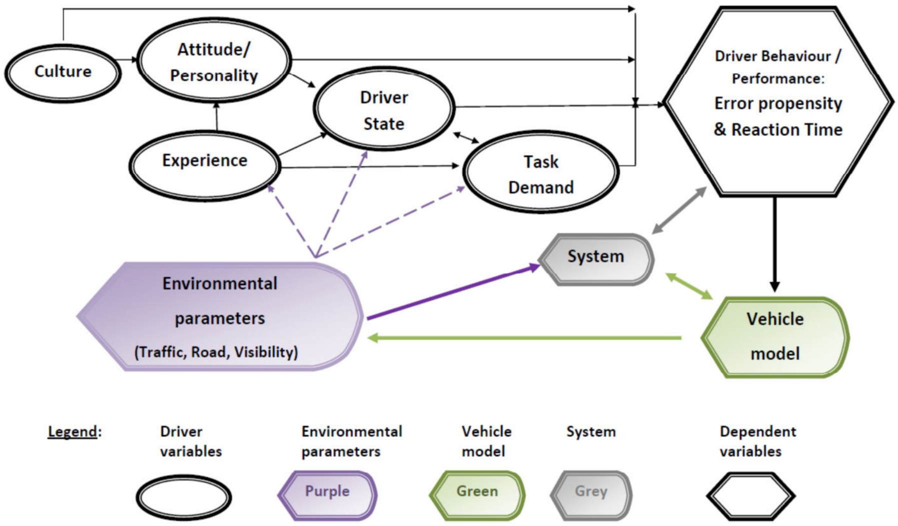


Figure 3 The ITERATE Unified Model of Driver behaviour (UMD)

Although the theoretical model was designed to be generic for all surface transport modes the simulations was in a first step created for road and rail transport. This includes development, the first experimental stage of the project and tuning of the model based on experimental data. It was then adapted to maritime transport and validated for all three modes.

Methodology (WP2 – 4)

Selection of operator support systems (WP2)

A review of operator support systems was carried out with the aim to identify systems that have significant effects on operator performance and operator interaction with the vehicles (car, train and ship). The goal was to investigate a range of prevailing systems rather than an exhausting review of all available systems on the market. The review was performed in a systematic format, which included a description of the system/technology and a tabular categorisation of system functionality and characteristics in terms of the following perspectives:

- task requirements of the operator, with respect to strategic, manoeuvring and controlling elements of the task;
- level of automation, ranging from non-automation (e.g. information provision only) to full automation (e.g. operator's task becomes monitoring only);
- timeframe with respect to the occurrence of event and to operator response; and
- the ability to handle the switch between manual and automated operation.

Support functionalities and systems reviewed at this stage are depicted in Table 1. It is worth noting that, for rail transport, due to their difference in environmental settings and thereby demands on the operator, a distinction was made between tramway and subway, and inter-city trains.

Table 1 List of reviewed operator support systems

Mode	Functionality	System
Road vehicles	Support of longitudinal control of the vehicle	Forward Collision Warning (FCW) Cruise Control (CC) Intelligent speed adaptation (ISA)

Mode	Functionality	System
	Support of lateral control of the vehicle	Lane Departure Warning (LDW) Blind Spot Information System (BLIS)
	Provision of feedback on operator performance	Fuel Efficiency Advisor (FEA) Driver status monitoring systems
Ship	Support of navigation tasks	Radar Electronic chart display and information system (ECDIS)
	Support of steering tasks	Autopilot Speed pilot
	Classification of ship's identifies	Automatic identification systems (AIS)
	Alter and information provision	Global Maritime Distress and Safety System (GMDSS)
Subways	Support for forward control, speed control and braking tasks	Automatic Train Protection (ATP) Overlap device Distance-To-Go
	Monitor operator state	Driver's safety device (DSD)
Tramways	Support for forward control, speed control and braking tasks	Over speed device
	Information management	Board Assistance System for Exploitation (SAE)
	Monitor operator state	Driver's safety device (DSD)
Inter-city trains	Integrated support	Automatic Warning System (AWS) and Train Protection and Warning System (TPWS) The European Train Control System (ETCS) Automatic Train Protection (ATP)

The review process synthesised these 26 support systems into five categories:

- Support for navigation and maintaining position: especially the ship systems provide a lot of support for navigation (e.g. the ECDIS), which is one of the major tasks of vessel pilots, given the degrees of freedom a ship has. For road vehicles, support is mainly to stay within certain boundaries, such as the lateral position support (e.g. the LDW system). For trains, planning information makes it possible for the driver to adjust speed and driving style, e.g. if the train is running late and there is a slow-running train ahead there is still no need to driving close to ceiling speed to try to make up for delays.
- Support for maintaining (or changing) speed: all modes of transport have systems that provide this kind of support; e.g. the ISA system for road vehicles, the speed pilot for ships, and the ATP system for trains.
- Support for detecting and avoiding obstacles: this is again of importance for all transport modes. Objects can be very far, such as the identification of other vessels at a large distance, or near (e.g. the radar), such as other vehicles in the blind spot (e.g. the BLIS). Often a combination of detection, identification and avoidance support is offered (e.g. a FCW system with brake function). For avoidance, this means that there is an overlap with speed management and navigation support.
- Information systems: all modes have a variety of information systems that supports the operator in decision making. The support systems discussed for ship and rail operators in particular provide a lot of information, not only needed for the "driving" task (e.g. the chat plotter for ships and the ETCS for high speed trains), but also for other purposes, such as supervision of passengers (e.g. the SAE for light rails).
- Driver state detection: such a function has been made use in all modes of surface transport, albeit operated in slight different ways; some systems provide warning (e.g. driver state

monitoring systems for road vehicles) while others intervene the task of driving the vehicle as well (e.g. the DSD system for trains).

Operator support systems are often rather complex and provide more than one kind of functionality. This is especially the case for rail and ship transport modes. It is sometimes hard to separate the different functionalities. A system may provide information on the vehicle status, give warnings if a potentially dangerous situation is detected and take action if the operator does not react quickly enough. Most systems reviewed operate on several levels of automation, and provide support in different time frames.

Communality of support systems across modes was considered at two dimensions: the functionality of system itself, and the interaction between the system and the operator.

Considering common functionalities of systems across modes, the five categories identified at the first stage were then narrowed down to three functionalities: those providing support for speed management, systems for detecting and avoiding obstacles, and those for monitoring operator state. Systems supporting navigation and maintaining position are not very relevant for rail transport. Systems for information provision are widely used, but are very diverse; therefore it is difficult to find communalities. These systems area also not always directly related to the task of driving the vehicle. Table 2 depicts the selected system at this stage.

Table 2 Refined selection of operator support systems

	System functionality		
	Speed management	**Collision avoidance**	**Operator state monitoring**
Car	Intelligent Speed Adaptation (ISA)	Forward Collision Warning (FCW)	Driver State monitoring (DS)
Train	Automatic Train Protection (ATP)	Automatic Warning System (AWS)	Driver’s Safety Device (DSD)
Ship	Speed Pilot and Electronic Chart Display and Information System (ECDIS)	Radar and Automatic Radar Plotting Aid (ARPA)	Dead Man Alarm / Watch Alarm

The interaction between support system and operator took into account the five operator parameters built into the ITERATE UMD model that were considered influential of operator performance. Hypotheses were developed for examining the effects of system functionality on operator performance. A template was used for systematically formulating hypotheses on each of the nine support systems listed in Table 2. The hypothesis template consisted of the following items:

- Input: the variables sensation-seeking, hazard perception skills (high and low experience), fatigue, high and low workload.
- The pathway: the mechanism by which the input influences the outcome (risk increase or decrease). For example: sensation seekers have a higher tolerance for risk and thus ignore warnings.
- Effect on operator’s interaction with the system: describing what the operator would do when interacting with the system, considering input as an attribute. For example, a sensation seeker would respond later to a warning.
- Effect on the system functionality: how the system would behave given the operator’s behaviour. For example, if more warnings are ignored, the system would intervene.
- The risk potential: whether it is hypothesised that the risk for safety would increase or decrease.
- Example scenario: describing a typical situation in which the operator would behave in the hypothesised way and the system would react as expected.

Over 200 hypotheses were produced for the nine systems, which were analysed for communality. A set of global hypotheses for each system across the modes and across the systems was identified:

H1. Sensation-seeking operators adopt (or choose) shorter warning thresholds.

H2. Sensation-seeking operators will behave in such a way that more warnings will be triggered.
H3. Sensation-seeking operators will seek stimulation to cope with monotonous situations.
H4. Experienced operators will receive fewer warnings than inexperienced operators.
H5. Fatigued operators will rely on the system to warn them about a critical situation.
H6. Operators will receive more warnings when fatigued than when alert.
H7. Fatigued operators will have less situational awareness than alert operators.
H8. Fatigued operators may compensate for their fatigue by increasing the safety margin.
H9. Operators will receive more warnings when under low workload.
H10. Operators will receive more warnings when under high workload.

Each global hypothesis was further developed at a detailed level, and for each an example scenario was developed. It was noted where a hypothesis was not relevant to a particular mode. During this process, it was observed that operator state monitoring generally did not function in a similar way across the modes. Therefore speed management and collision avoidance were selected as candidate functionalities for realisation in the subsequent simulator experiments, with the focus placed on warning as opposed to intervention functionality. System functionalities for different modes were also adapted where appropriate at the design stage of the project facilitating comparison of experimental results across modes. Table 3 depicts the support functionalities implemented in the experimental work.

Table 3 Final selection of operator support systems

	System functionality	
	Speed management	**Collision avoidance**
Car	Warning ISA	FCW
Train	ETSC speed warning	
Ship	ISA-like warning	Integrated in ARPA Radar screen

Experimental design (WP3)

This process consisted of four major steps:

- a comprehensive review of the measurements for the five operator parameters
- development of experimental scenarios
- specification of experiment protocols
- specification of simulators

A comprehensive review was carried out for identification of feasible approaches to measuring the five operator parameters included in the ITERATE model (UMD); i.e. personality, operator state, experience, workload, and culture. An inventory of definitions and measurements of these parameters was made. Different measurement methods, such as questionnaires, tests, and psycho-physiological measures were summarised and advantages and disadvantages were discussed.

A template was used for development of scenarios facilitating comparability across modes. The template consisted of the following elements:

- Situation in which the system would be active (for example, change in speed limit)
- The characteristics and state of the operators (for example, experienced drivers, or drivers with high workload induced by means of a secondary task)
- The trigger: the event that would trigger an action from the system (for example, a speed limit sign)
- The expected reaction from the operator on the trigger and on the systems' warning (for example, the driver does not pay attention to the sign and only reduces speed after the warning)
- Environmental conditions, such as traffic, weather and light conditions, and type of road or track (for example, low traffic density, night time, rural road)

- Measures to be taken before, during and after the experiment, to determine the effect of the scenario or to establish the level of one of the parameters. The measures may be driving related, measured automatically by the simulator, measured by the experimenter or the participant may give a subjective opinion. For example, number of warnings received, amount of deceleration, reaction time, questionnaire on sensation seeking, subjective workload rating on a scale.

For the speed management systems 24 scenarios were developed for cars, 12 for trains, and 6 for ships. For collision avoidance systems 21 scenarios were developed for cars, 14 for trains, and 6 for ships. There were relatively fewer scenarios developed for trains and ships because the operator's tasks are much more restricted and regulated than the car driving task; i.e. the train drivers and ship pilots are less flexible in reaction options for a given situation. The scenarios were analysed and reviewed for common characteristics. Scenarios sharing the same types of environment were identified, which facilitated comparability across modes.

The five parameters in the UMD model were realised in the experiments as independent variables and were implemented in various ways.

- Personality: this was represented by sensation-seek tendency and was measured by the Brief Sensation Seeking Scale (BSSS). This was used as an *ad hoc* between-subject variable.
- Experience: this was measured by the number of years hold a valid licence. This was used as an *a priori* between-subject factor. There were two levels: experienced and novice. The cut-off point of experience varied according to modes.
- Operator state: this was measured by the Karolinska Sleepiness Scale (KSS). Fatigue was systematically introduced by a 25-min monitoring task and the "post-lunch dip". This was used as an *a priori* between-subject factor. There were two levels: fatigued and non-fatigued.
- Workload: this was manipulated by the presence as well as complexity of secondary tasks. This was used as an *a priori* within-subject factor. There were three levels: low, medium and high workload.
- Culture: this was represented by country, and was used as an *ad hoc* between-subject factor.

It was planned to recruit 32 participants per mode, per site. The following factors were fully counterbalanced across all participants per site:

- Experience
- Operator state
- Gender
- Order of support systems offered (i.e. speed management or collision avoidance)

It is worth noting that operator state was not manipulated in the ship experiments, following a pilot test which concluded that the 25-min monitoring task did not reliably affect participating deck officers' sleepiness state. The experiment routes are summarised in Table 4.

Table 4 Description of experiment routes

Mode	Experiment route
Car	ISA was implemented through a 32-km rural single-carriageway road consisting straight and curve sections with various speed limits. FCW was implemented through a 47-km two-lane motorway.
Train	The ETSC system was active throughout the 110-km track consisting of 11 stations and various speed limits.
Ship	Navigation through open water and passage in harbour area. Various speed limits applied.

The experiment also featured a PC-based hazard perception test and a web-based questionnaire.

The ITERATE project made use of existing simulators (e.g. the car and train simulators at VTI, the car simulator at Leeds, the train simulator at Valenciennes, and the ship simulator at Chalmers), but also developed a portable simulator with an inter-changeable control interface between car and train. Two identical portable simulators were built within the project. One was used for data collection in Sweden and Italy; the other one for data collection in the UK, France, and Israel. The portable simulator consisted of the following major components:

- HP Z400 workstation running Windows 7
- Samsung 40" wide-screen 1920x1080 monitor. Primary screen.
- ViewSonic 15" wide-screen 1366x768 monitor. Secondary screen.
- Logitech G27 steering wheel and pedals for the car.
- RailDriver for the train. A low-cost alternative to a 'professional' control.
- A GameRacer seat with mounting points for the wheel and train controller..

Experimental procedure – common approach (WP4)

It was decided that all partners should use the same hardware and software in their experiments with the portable simulators. Thus, the simulators were shipped between the partners in specially made wooden boxes together with detailed instructions for how to assemble the simulators. Assembling was a quite simple task which took less than an hour to complete. However, sending the simulators between countries was not always simple and delays were caused by customs regulations and carrier mishaps. Thus, it was found that freight insurance is important to consider and to plan for delays.
A remote control software (LogMeIn) was used to adapt (e.g. change of language) and if needed control the simulator software once it was assembled. Instructions were also given on how to setup room lighting, control sufficient space and sound levels. An ordinary office room was adequate but the test leader required a place to supervise the experiment without disturbing the participants.
Common selection criteria for participants were specified to ensure as far as possible identical experiments. Questionnaires and instructions to subjects were translated and checked for consistency. SPSS Dimensions Net ® was used to set up web based questionnaires in the different languages used. All questionnaire data was collected in a common database located at VTI in Sweden. Furthermore, common experimental protocols were developed in order to minimize the influence of irrelevant factors on the experimental results. Finally, driving behaviour data collected in the simulators were uploaded to a FTP server at VTI to ensure backup and accessibility for other partners to data. In summary it can be concluded that conducting identical experiments is not always straightforward but need careful preparations, common understanding and takes time. But it is possible to do it which ITERATE proved even if it was not always perfect. ITERATE is unique in this aspect.

Experimental results (WP5)

The ITERATE simulator experiments are unique in the sense that common scenarios were run on a common portable car/train driving platform as well as on full scale train and car driving simulators. Two identical portable driving simulator platforms were circulated among the project partners across five countries allowing a large number of participants to take part in the experiments.

Experimental design

A mixed design with four between factors (*Culture, Experience, Driver state,* and *Personality*) and one within factor (workload) was applied for all experiments. Culture was included as a factor with 5 levels represented by the five countries (Sweden, England, France, Italy and Israel) as cultural differences (even within Europe) has shown to be of importance. Experience was a factor with two levels (novice and experienced) determined by the number of years active as a train driver or the number of years holding a car driving licence. Fatigue was also a factor with two levels (alert, fatigued) with the post lunch dip as the fatigue condition. Personality in terms of sensation seeking (measured by the Brief Sensation Seeking Scale (BSSS)) was not actually controlled for by screening subjects but rather by forming groups of drivers based on BSSS scores. Workload was manipulated by a secondary counting backwards task in three difficulty levels (low, medium and high). Workload and fatigue manipulations had been tried out in pilot experiments.

Method

Car drivers drove with support systems that would warn if speeding and or driving too close to a lead vehicle, train drivers had a system that showed current maximum allowed speed and warned if driving too fast. A selection of earlier formulated hypotheses was tested e.g.:

- Experienced drivers will drive faster but receive fewer warnings from the support system (speed and distance)
- High sensation seekers will drive faster than low sensation seekers and get more warnings
- Fatigued drivers will drive slower than alert drivers but rely on the system to warn and get more warnings
- Low workload would result in higher speed, while low and high workload in curves would provide more warnings

Simulators

The three different types of simulators used in the experiments are depicted in Figure 2. Two identical simple mobile simulators were circulated among partners to minimize the difference between test sites. Two advanced simulators (a large scale motion-base car simulator in Leeds, Great Britain, and a train simulator with a mock-up of a train driver's cab at VTI, Sweden) were also used as reference to determine if simple simulators yield the same results as more complex ones. Simulator software and driving tasks were the same independent of simulator. Participants were though not the same (between subject design).

Figure 2 Simulators used (top left - small scale car simulator, top right - small scale train simulator, bottom left – full scale car simulator, bottom right . full scale train simulator)

Participants

In total 183 car divers and 110 train operators participated in the simulator experiments (Table 5 and Table 6). The distribution was not ideal, i.e. few female train drivers, few novices, few French train drivers. The target was 16 in each cell. However, in total 76% of the target was reached.

Table 5 Distribution of car drivers with respect to Country, Gender, Experience, and Driver state.

Country	*Number*	*Gender*		*Experience*		*State*	
		Female	*Male*	*Experienced*	*Novice*	*Alert*	*Fatigue*
France	32	7	25	16	16	16	16

Great Britain	30	15	15	16	14	15	15
Israel	31	16	15	16	15	16	15
Italy	27	11	16	20	7	16	11
Sweden	34	16	18	26	8	14	20
Total mobile simulator	**154**	**65**	**89**	**94**	**60**	**77**	**77**
Advanced simulator GB	29	17	12	15	14	14	15
Grand total	**183**	**82**	**101**	**109**	**74**	**91**	**92**

Table 6 Distribution of train drivers with respect to Country, Gender, Experience, and Driver state

Country	*Number*	*Gender*		*Experience*		*State*	
		Female	*Male*	*Experienced*	*Novice*	*Alert*	*Fatigue*
France	6	0	6	6		4	2
Great Britain	19	3	16	11	8	10	9
Israel	14	0	14	11	3	7	7
Italy	18	1	17	16	2	8	10
Sweden	21	1	20	16	5	10	11
Total mobile simulator	**78**	**5**	**73**	**60**	**18**	**39**	**39**
Advanced simulator SE	32	4	28	21	11	16	16
Grand total	**110**	**9**	**101**	**81**	**29**	**55**	**55**

Driving tasks

The car driving task was divided in two parts, driving on a two-lane rural road with an Intelligent Speed Adaptation System (ISA) and motorway driving with a Forward Collision Warning System (FCW). The ISA part of the car experiment included negotiating speed limit changes and sharp curves, as well as driving through villages and a school zone. In the FCW condition, the driver encountered events with a lane changing truck, a road work with a lane drop, the sudden braking of a car in front and breakdown of a downstream vehicle. However, it turned out that in most cases the FCW situations were not critical enough for the warning to be triggered. Thus, the results from this part are excluded in this paper but can be found in in the project deliverable (Forsman et al., 2011).

During the train driving experiment, the driver interacted with a simplified version of the European Rail Traffic Management System (ERTMS) called ETCS (European Train Control System) which provided information to the driver concerning speed management. Participants drove approx. 80 minutes according to a given timetable. The scenario included several changes in speed and nine stations with stops. Speed changes and station stops included different speed alignments, i.e. slopes, and levels of permitted speeds.

Performance indicators

During normal car driving and driving through curves, school zone and villages, the performance indicators were mean speed and number of warnings. When approaching curves, villages and a school, the performance indicators were spot speeds at certain locations before the curve/village/school, mean speed passing a village or school zone and number of warnings. Performance indicators for the train drivers were speed deviations from permitted speed at station stops and speed reduction events. Furthermore, warning duration (due to over speed) was also used as a dependent variable.

Car drivers

For most measures during normal driving and driving through curves, four of the main factors were significant: *Country, Gender*, *Workload,* and *Subject*. The significant effect of subject was expected since it is known from previous experience that there are large individual differences of different subjects in driver performance. The only significant interaction effects were *Country * gender* during normal driving and *Sensation Seeker * Workload* at curve sign, entry and apex.

The mean speed levels for different countries are shown in Table 7. The signed speed limit was 80 km/h both at normal driving and through curves. It can be seen that during normal driving, the drivers from Israel had the relatively highest mean speed and drivers from Italy the lowest. When driving through curves, drivers from Israel had the highest speed at curve sign, but at curve entry they tend to slow down and through the curve (apex) they have among the lowest speeds. The Swedish drivers tended to have among the lowest speeds at all spots in the curves.

Table 7 Analysis of variance – adjusted mean values, mean speed at normal driving and speed at various locations in relations to curves (km/h)

	Normal driving	*Speed through curves*			
Country	***Mean speed***	***Mean speed***	***At sign***	***Entry***	***Apex***
GB	73.47	57.30	72.42	55.09	57.97
SE	75.50	57.16	72.07	53.46	57.88
FR	75.93	62.14	74.79	60.76	62.55
IT	71.58	61.82	72.09	61.42	63.68
IL	76.27	57.12	76.55	58.36	57.68

Table 8 shows that during normal driving, male drivers drove more than 2 km/h faster than female drivers. At curves the difference is even larger, male drivers drove about 4 km/h faster than female drivers.

Table 8 Analysis of variance – adjusted mean values for gender (km/h)

	Normal driving	*Speed through curves*			
Gender	***Mean speed***	***Mean speed***	***At sign***	***Entry***	***Apex***
Female	73.41	56.27	71.24	55.08	57.14
Male	75.59	61.14	75.36	59.64	61.98

There were minor differences between men and women in Great Britain, Sweden and France, while in Italy and Israel male drivers drove considerably faster than women, see Figure 3.

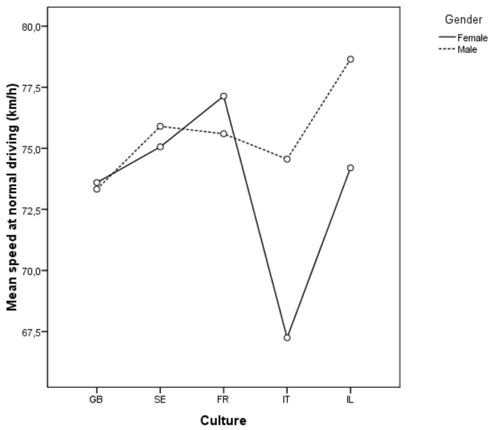


Figure 3 Adjusted mean speed for Country and Gender at normal driving (km/h).

Table 9 shows that during normal driving and high workload the speeds were about 2 km/h lower than at low and medium workload. Through curves (mean speed, entry and apex) there was a tendency that the speeds were higher at high workload.

Table 9 Analysis of variance – adjusted mean values for workload (km/h)

	Normal driving	*Speed through curves*			
Workload	***Mean speed***	***Mean speed***	***At sign***	***Entry***	***Apex***

Low	75.79	58.33	75.10	56.16	58.85
Medium	75.11	58.96	72.04	57.62	59.74
High	73.08	59.88	73.65	59.30	61.15

In Figure 4, adjusted mean speeds for workload and sensation seekers at curve entry are shown. The difference between high and low sensation seekers was smaller during high workload. There were similar tendencies for speeds at the other locations were spot speeds were measured. When the number of warnings was analysed similar results as those for speeds were obtained.

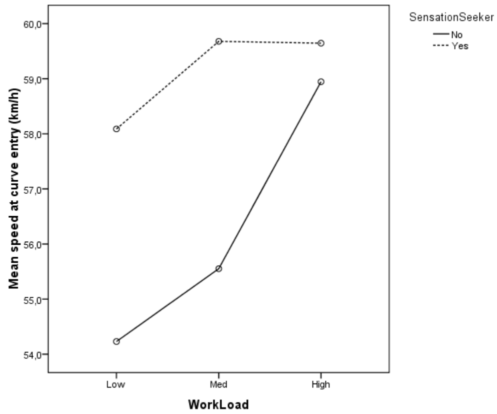


Figure 4 Adjusted mean speeds for Workload and Sensation Seekers at curve entry (km/h)

Speed behaviour through villages and school zones were also studied. Only results from the villages are included here, but the results were similar at school zones. When driving through the village, *Country, Order* and *Subject* are the main factor effects that are significant at sign visible and entry of village. When studying the mean speed through village, *Country* was the only significant main effect. At the spot where the village-sign was visible, the interaction effects *Country * Experience* and *Sensation Seeker * Experience* were significant. The mean speed levels for different countries and at various locations in relation to the village are shown in Table 10. The drivers from Israel have the highest speeds and drivers from Sweden, Italy and Great Britain tend to drive slower, French drivers are in between. Looking at the first column in table 6, showing the mean speed through the village (speed limit 50 km/h) for drivers from different countries, drivers from Great Britain and Italy drove at about 46 km/h while drivers from Israel had a mean speed close to 53 km/h. Table 11 shows that, similar to normal driving and driving through curves, male drivers tend to drive faster than female drivers.

Table 10 At villages: analysis of variance – adjusted mean values for different countries (km/h)

	Speed at villages			
Country	***Mean speed***	***Sign visible***	***Entry***	***Apex***
GB	45.72	70.15	51.66	53.03
SE	47.29	70.55	51.35	56.81
FR	48.95	73.18	55.01	60.35
IT	45.70	68.54	53.20	54.79
IL	52.73	77.17	61.07	60.02

Table 11 At villages, analysis of variance – adjusted mean values for gender (km/h)

	Speed at villages			
Gender	***Mean speed***	***Sign visible***	***Entry***	***Apex***
Female	47.15	70.85	53.13	55.44
Male	48.86	72.82	55.39	58.35

Figure 5 shows the adjusted mean speeds through the villages. There were minor differences in speed choice between novice and experienced drivers in all countries except for Israel. In Israel, the mean speeds through villages were about 10 km/h higher for experienced than novice drivers.

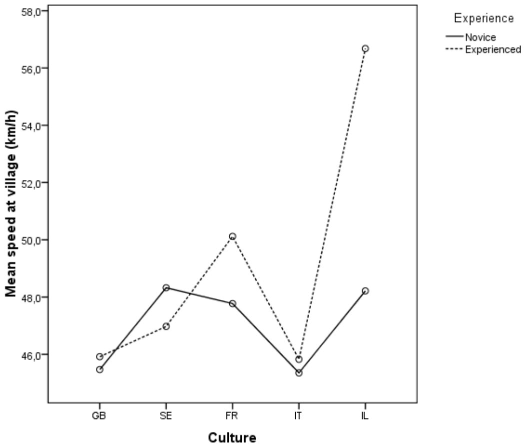


Figure 5 Adjusted mean speed for Culture and Experience - mean speed through village

The adjusted mean speeds where village sign was visible for *Sensation Seeker* and experience are illustrated in Figure 6. If classified as a sensation seeker, experienced drivers had a higher speed than novice, but if classified as a non-sensation seeker, novice drivers had higher speeds than experienced.

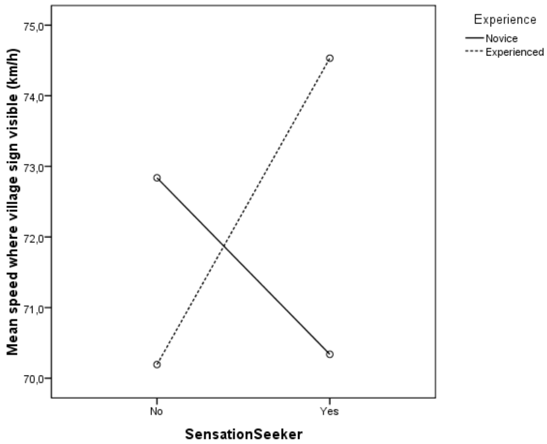


Figure 6 Adjusted mean speed for Sensation Seeker and Experience where village sign visible

Car drivers – small scale portable simulator versus full scale simulator

Data from both types of car simulators were incorporated in the same model (only drivers from Great Britain). In general, two of the main factors turned out significant: *simulator* and *workload*. None of the interaction effects with simulator were significant. This means that it does not seem that for example becoming more experienced, fatigued, changing workload etc. affects the behaviour in the portable simulator differently than in the full scale simulator. In Table 12, adjusted mean speeds for the two simulator types are shown. The mean speed during normal driving and driving through curves is about 3-4 km/h higher in the full scale simulator compared to the portable one. The speed difference between the portable and full motion simulator is almost 9 km/h at curve entry and about 3 km/h at curve apex and exit.

Table 12 Analysis of variance – adjusted mean values for simulator type (km/h)

	Normal driving	***Speed through curves***			
Type of simulator	***Mean speed***	***Mean speed***	***At sign***	***Entry***	***Apex***
Portable	72.77	57.13	72.27	54.93	57.76

Full motion	75.96	61.00	74.81	63.30	60.60

Train drivers

Speed reduction events occurred during two in principle different situations, at station stops and during driving (no stop). Five speed metrics were used; spot speed when information on future new speed limit was given (PI), mean speed during approach to new speed limit (SI), spot speed at initiation of speed reduction (PII), mean speed during speed reduction (SII), and speed at event end (PIII). Furthermore, warning duration during speed reductions and station stops was also used in the analysis. Gender was not included in the analysis as there were so few female train drivers.

It was found that during station stops three of the main factors were significant: *Sensation Seeker* (PI, SI, PII), *country* (All except PIII) and *workload* (All metrics). For some of the metrics there were significant interactions: *Country * Workload* (PI), *Experience * Country* (PI), *and Experience * Sensation Seeker* (PIII). Furthermore, for speed reduction while driving two main factors were significant: *country* (All except PI*)*, *Workload* (PII). Interactions were found for: *Experience * Country* (PII, SII, PIII), *Country * Workload* (SI), and *Experience * Workload* (SI). See Figure 7 and Figure 8 for some results.

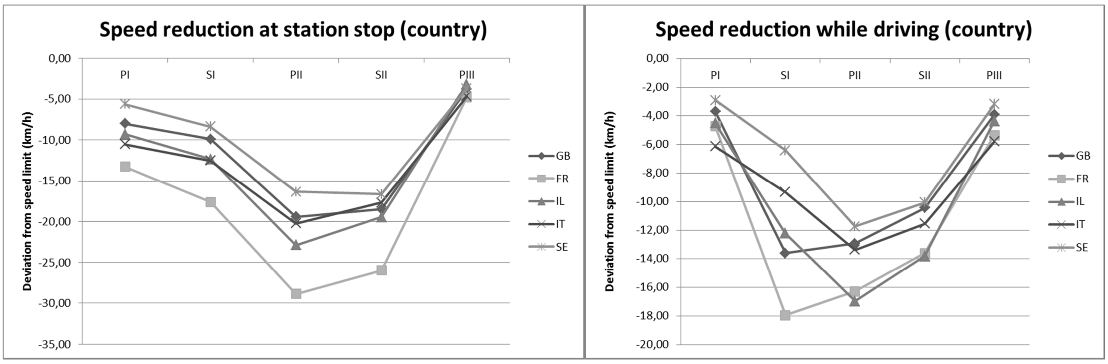


Figure 7 Adjusted mean deviation from speed limit per country (low value closer to the limit) during station stop (left panel) and while driving (km/h)

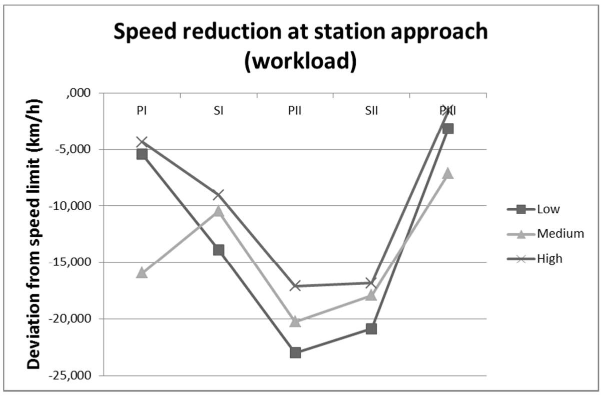


Figure 8 Adjusted mean deviation from speed limit for Workload (low value closer to the limit) during station stop (km/h)

Warnings were given if the driver was over speed limit. Thus, it was considered interesting to include warning duration (seconds/km) in the analysis. Four metrics were used: total warning duration for all conditions, warning duration during speed reduction for station stops, warning duration during speed reduction while driving and warning duration for station stops. There were main effects of *Experience (speed reduction while driving)*, *Country* and *Workload (not speed reduction for station stops)*. Furthermore, there were significant interactions between *Experience * Country (three metrics)* and *Experience * Sensation Seeker (one metric).*

Figure 9 depicture some differences between countries e.g. Israeli train drivers experienced in total the longest duration of warnings and of warnings and also during station stops. Train drivers from Great Britain and Italy encountered the longest warning duration during speed reduction for station stops. It can also be seen that French and Swedish train drivers evoked the least warnings.

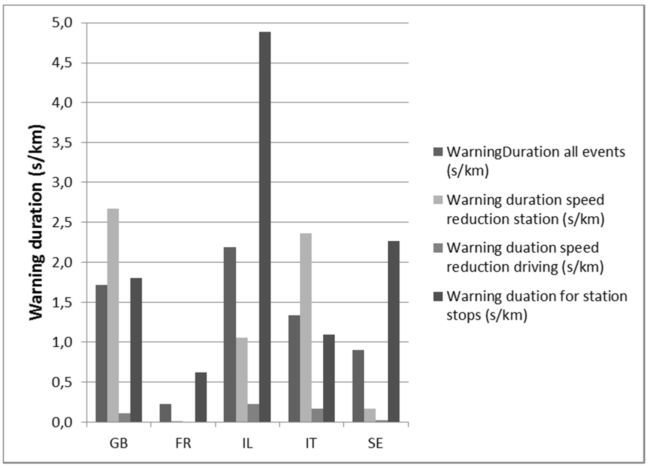


Figure 9 Adjusted mean warning duration (seconds/km) per country

Figure 10 show warning durations under the three workload conditions (low, medium and high) for the four situations. The warning duration was under high workload compared to low and medium for three of the four situations. However, the difference in warning duration during speed reduction while driving seems much less.

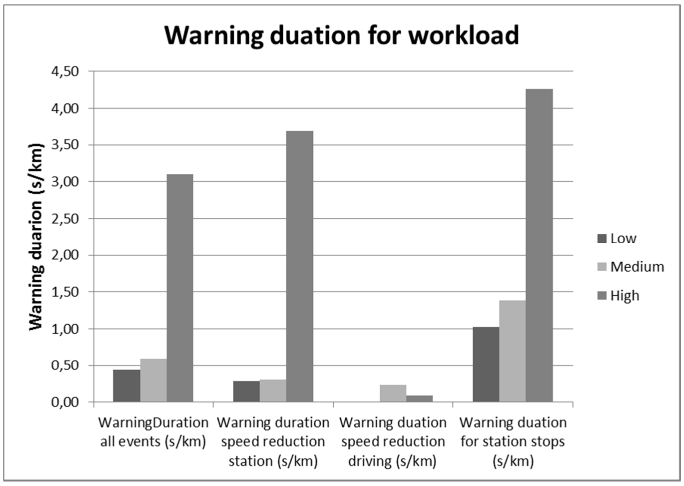


Figure 10 Adjusted mean warning duration for workload

Train drivers – small scale portable simulator versus full scale simulator

Finally, the comparison between the small scale train simulator and the full scale simulator revealed no significant differences between the simulators with respect to speed performance. Only Swedish train drivers were included in this analysis. In total 53 professional drivers were included. Concerning warning durations it was found that drivers in the full scale simulator had warnings with significantly longer durations when considering the total drive but not for the specific events (i.e. speed reductions). The rationale behind this does not seem self-evident and call for further analysis. In general, there were no interaction effects found between type of simulator and other factors. Thus, no major differences between the two simulator types were observed within the context they were used here.

The numerical simulation of UMD (WP6)

The numerical simulation of the UMD was developed within Work Package 6. The ITERATE framework distinguishes between UMD, SiMUD and DVESim:

- UMD (Unified Model of Driver) is the theoretical model or framework that describes the basic relationships that enable to represent the behaviour and cognitive performances of a human being in controlling a vehicle.
- SiMUD (Simulation of the Unified model Driver) is the actual implementation in a numerical set of expressions and software implementation tool of the UMD theoretical representation. This is the main engine of the simulator and supervises its execution.
- DVESim (Driver Vehicle and Environment Simulator) is the software platform that enables the representation of the interactions between a SiMUD and the rest of the “actors” involved in a scenario development. These are namely: the actual vehicle in control by the “driver” (a car, train or ship) and the environment and its dynamic evolution in terms of traffic (i.e., other vehicles, cars, trains and ships) and the surface system (road, rail and maritime surface).

The development of the software in a modular structure implies some particular issues that are worth consideration:

- A modular approach increases extensibility the software usability, supporting on one side the development of other possible components and features and on the other the reuse of the code in future applications.
- The software code is kept separate, following a rationale that reflects maintenance needs and architectural choices.
- Although the outcome of the project is a single model of the driver/operator, different models are needed to perform the simulation, such as: models of the different kind of vehicles and environments, which are mutually exclusive during the execution of the simulation. Developing them in dedicated modules is a choice that meets both logical and functionality requirements.
- For each simulation running, only the chosen modules are loaded and executed, avoiding the wasting of memory by unneeded instructions and data.

On the other side, some drawback and difficulties have to be dealt with, namely:

- The software shows a greater degree of complexity and has to manage typical issues and problems of module integration both during coding and at runtime (dependencies, compatibility, dynamic loading and unloading).
- In order to be correctly loaded and executed, modules must provide their functionalities through a well-defined single interface common for all. The interface must be defined in the early stage of design and particular attention has to be dedicated to this task, as further modification to the interface might have strong repercussions on the rest of the program and large modification to the code might be needed.

Software Configuration, Execution and Architecture

DVESim is configured by a XML file. Its syntax is defined by a proper XSD file. The file has a very simple structure and includes twos kinds of information:

- Global parameters of the simulation, such as length and time step interval.
- Modules to load and path of their configuration files.

Modules have distinct configuration files and their specific behaviour is not defined in the main configuration file of DVESim. Instead, their parameterisation and starting conditions are coded in their own configuration files. This approach determines a sort of hierarchy of configuration files. DVESim is executed from a command line. It does not depend on a Graphical User Interface (GUI) to manage the simulation or to show results. It executes a purely computational task, and therefore it does not show windows or expect any kind of input from the user. The rationale is to speed up computation and time of the simulation in order to make possible the automation of execution and the generation of data corresponding to a wide range of scenarios, having different starting conditions. Basic visualization of trends of main variables can be performed separately on the database of outputs. In other words, the results of a simulation are stored in log files in text format. These data, stored in such simple and standard format, can be easily used as input by other applications of various type scope which might include: Graphical rendering of the simulation; Computation of the generated data;

Plotting of graphics; and Comparison with results of other tests. A synthetic view of the software architecture and the interactions of its main components are shown in Figure 11.

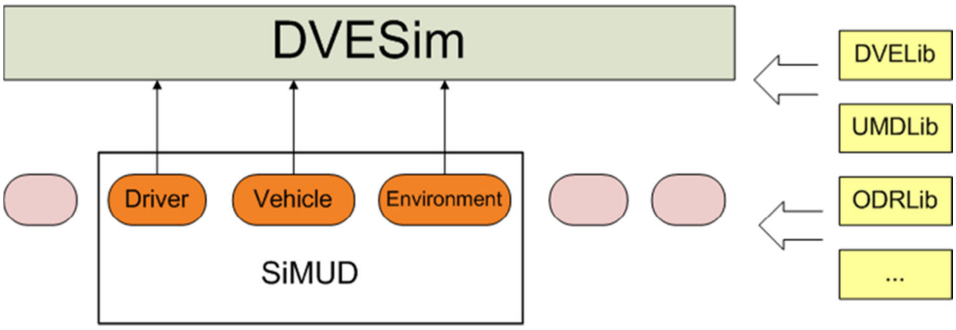


Figure 11 Architecture of DVESim and its components

The main types of components are: "Main executable", "Dynamic libraries" and "Static libraries". The Main executable is the main engine of the simulator (DVESim) and is responsible for the correct behaviour of the simulation and for the interaction of the models. The Dynamic libraries are loaded at runtime and include the models that need to be instantiated. The Static libraries provide basic functions and common data types that can be shared among all the components such as DVELib, or just in some particular components such as UMDLib used in SiMUD modules and ODRLib, used to represent the road.

Runtime behaviour

The steps executed by the program during a simulation are as follows:

1. DVESim parses its configuration file and detects what modules must be loaded and the path of their configuration files.
2. Modules are loaded and models instantiated. The configuration files of the modules are parsed and the models are initialised accordingly. Models are linked together so they can interact.
5. The simulation loop is started and is performed until end conditions are met. Modules are unloaded and the simulation ends.

During the simulation loop (Figure 12) each model updates its current status, and computes its next status. Then the time is increased. The status of a model depends on the status of other models. For examples, to compute the *steering angle,* the vehicle model reads the *desired steering angle* of the driver model, and to compute the *desired speed* the driver model reads the *visibility* of the environment; to compute the *speed*, the vehicle reads the *friction* environment. From a logical point of view, the driver collects data from the vehicle and environment models and actively carries out actions to change the own and vehicle status. As an example, the driver can decide to undertake a different task or pressing the accelerator pedal of the vehicle.

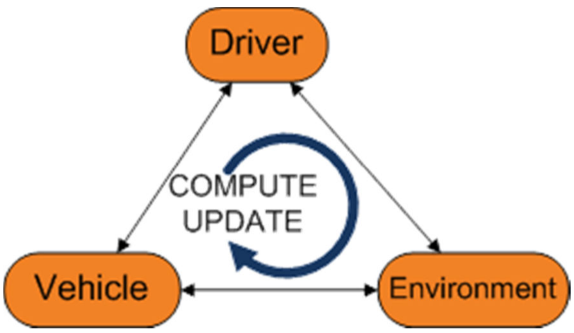


Figure 12 DVESim loop

Final version of the numerical model of the UMD

The Unified Model of Driver behaviour (UMD), developed within ITERATE and derived from a comprehensive literature search and several workshops on the topic within the project consortium, accounts for the factors that have been shown to influence risk, risk-taking and errors of “drivers”. These factors, handled as variables for the model and for the experiments, are:

- Attitudes/personality (ATT) (Sensation Seeking) - especially relevant for the road vehicles, whereas for other transport modes this variable is of less relevant.
- Experience (EXP) (Hazard Perception Skills) – relevant to all modes of transport. Hazard perception skills have been found to correlate to EXP with crash risk.
- Driver State (DS) (Fatigue) – relevant to all modes of transport. Monotony has an adverse effect on performance and fatigue has the greatest impact on behaviour.
- Task Demand (TD) (Subjective workload) – also important within all transport modes, arises out of a combination of environmental features (complexity of traffic, weather, and light conditions), other people’s behaviour, and characteristics of the vehicle.
- Culture (CULT) (Country) - common to all transport modes, deals with cross cultural differences found significant effect on behaviour and performance variables.

The Simulation concepts - F correlations

In order to implement the Simulation of the Unified model Driver (SiMUD) in the overall DVESim software platform, it is necessary to consider the cognitive functions and processes that generate the actions of the driver. These are implemented in the simulation in a quite simple architecture that attempts to capture the complex and realistic descriptive driver behaviour, i.e., a driver is affected by personal attitudes, motivational aspects, workload, etc. Moreover, the overall requirements of the simulation are of being predictive and fast running, accounting eventually also for dynamic interactions, human errors, and adaptive behaviour. The basic assumption of the simulation approach is that a generic expression (F_i) can be considered and utilized throughout the simulation to characterise all essential quantities associated to driver behaviour, e.g., speed, gas and brake activities, distances from obstacles and leading vehicles, stop and start performances etc. The functions F_i take the following form:

$$F_i = K_i(CULT) + \alpha_i(CULT) * C_1(ATT, EXP) + \gamma_i(CULT) * C_2(DS) + \beta_i(CULT) * C_3(TD) \quad \textbf{EQ. 1}$$

Assumptions:

- The initial values assigned to the constants C1, C2 and C3 have been selected on the basis that common sense behaviour would result from the application of the proposed **F** functions in absence of the effect of the term *Ki* and the coefficients *αi*, *βi*, and *γi.* In other words, common sense expected behaviour of a driver is obtained when the term *Ki* and the coefficients *αi*, *βi*, and *γi* are set to the value 1 and the resulting functions **F** are applied in SiMUD for evaluating driver behaviour.
- It has also been assumed that the constant C1 is independent of experience in the case of sensation seeking, whereas it is associated to experience in the case of a prudent attitude.
- CULT is considered separately and is not intended to have a numeric value, but is instead used to identify the nationality of the driver.

These basic assumptions have generated the subsequent evaluations of the constants C1, C2 and C3:

- The following discrete values of the parameters have been associated to different types of driver characteristics and contextual and personal conditions (Table 13).

Table 13 Basic constants affecting driver behaviour

ATT	0 = Prudent		1/8 = Sensation Seeker
EXP	-1/8 = Novice		1/8= Experienced
DS	1/8 = Alert		-1/8 = Fatigued
TD	1/8 = Low	0 = Medium	-1/8 = High

- The quantities C_1, C_2, and C_3 depend on the characteristics of the driver:

$$if \rightarrow ATT = 1/8 \Rightarrow C_1(ATT, EXP) = 1/4$$
$$if \rightarrow ATT = 0 \Rightarrow C_1(ATT, EXP) = EXP$$
$$C_2(DS) = DS$$
$$C_3(TD) = TD$$

- The constant term K_i and the coefficients α_i, β_i, and γ_i enable to differentiate between drivers according to their culture and, within cultures, to their personal characteristics.

Some formulas utilized in the SiMUD are shown in Table 14. The left side of the equations contains the quantity calculated, while the right side shows the expression containing the function F_i, generated from the experimental tests. The value 1.6 for the evaluation of the intended distance has been assigned from the literature.

Table 14 Some formulas utilized in the SiMUD simulation

Automotive domain formulas	Rail domain formulas
$v_{intended\text{-}car} = F_{car-int-speed} \cdot v_{max\text{-}allowed\text{-}car}$	$v_{intended\text{-}train} = F_{train-int-speed} \cdot v_{max\text{-}allowed\text{-}train}$
$reaction\_distance_{car} = \frac{visibility}{F_{car-react-dist}}$	$reaction\_distance_{train} = \frac{visibility}{F_{train-react-dist}}$
$intended\_distance_{car} = \frac{1.6 * speed_{car}}{F_{car-int-dist}}$	$acc = F_{train\text{-}cruise\text{-}acc} \cdot \left(1 - \frac{speed_{train}}{inten\_speed}\right)$

As an example, according to the above discussion on the assumptions and the formulas utilised, in the case of $v_{intended\text{-}car}$, the maximum and minimum value of the speed of the vehicle, in absence of the effect of the term *Ki* and the coefficients *αi*, *βi*, and *γi,* would be:

- Maximum $v_{intended\text{-}car}$ would result, independently of Culture, for a driver “sensation seeker” (ATT = 1/8 => C_1 = 1/4), Alert (DS = C_2 = 1/8), with Low Task Demand (TD = C_3 = 1/8):

$$v_{intended\text{-}car} = 1{,}5 \cdot v_{max\text{-}allowed\text{-}car}$$

- Minimum $v_{intended\text{-}car}$ would result, independently of Culture, for a “novice prudent driver” (ATT = 0 and EXP = -1/8 => C_1 = -1/8), Fatigued (DS = C_2 = -1/8), with High Task Demand (TD = C_3 = -1/8):

$$v_{intended\text{-}car} = 0{,}625 \cdot v_{max\text{-}allowed\text{-}car}$$

Refinement and tuning based on the experiments

The final definition of the functions **F**s, the constant term *Ki* and the coefficients *αi*, *βi*, and *γi* have to be determined by interpolating the experimental results with the complete set of formulas as mentioned above. In order to carry out this confrontation and regression analysis, it was necessary to identify the data set of interest for each function $\mathbf{F_i}$. This task included the choice of the scenarios of interest among those available in the experimental tests. In order to be evaluated, each function required:

- A scenario used to evaluate the relevant coefficients.
- The data set, expressed in terms position of the vehicle along the path.
- Particular conditions to satisfy.

Different scenarios were considered for different types of drivers. As an example, for evaluating the coefficients in the case of “desired speed” of car driver, the following type of considerations were made:

- It was necessary to compare the speed of the vehicle with the speed limit on the road. The only eligible scenarios and experimental settings for assessing this variable are the Intelligent Speed Adaptation (ISA) instead of the Frontal Collision Warning (FCW) cases where no speed limit was present.

- Moreover to avoid the effect of dangerous curves on driver performance, only the straight sections of the road are suitable, in the vicinity of schools and inside villages.
- In addition, not all the straight sections have been considered, as the initial and final portions of each section have to be ignored in order to avoid the effects of the deceleration and acceleration at the beginning and the end of speed limit zone. The data that have been considered range from a quarter to three quarters of the straight parts.

Similar reasoning was carried out in relation to the other variables, namely intended distance, reaction distance, gas pedal pressure, brake pedal pressure, etc.

In the case of train drivers, a similar approach was followed. However, given the differences between the two domains, e.g. no other vehicle is present on the railway, the analysis in the railway was tailored in some aspects, maintaining the same method in order to be able to compare the results. For the desired speed, the actual speed of the train was compared with the speed limit. The sections of tracks in which speed limit remains constant are those of greater interest. Moreover, to avoid the effects of acceleration and deceleration when speed limits occur, the first and the last quarter of the considered section are discarded. The reaction distance was evaluated in relation to the distance from signals at which the driver changes the position of the accelerator or brake pedals. For the cruise situation, because of the differences between the car and train controllers, in order to be able to evaluate the intended cruising speed for the accelerator and brake position, the entire sections of the railway with constant speed limit were selected.

Coefficients of the functions Fi from regression analysis

The amount of data collected in both domains (car and rail) was very extensive and the regression processes demanded a very long time to complete. Not all data were consequently utilised and this has an impact on the correlations and validation. Further steps would be necessary in a subsequent stage of research. In order to overcome this difficulty, a major assumption was made of similarity between the domains enabling to make some of the results obtained in the car driving domain useable, at least in part, for the experiments performed in the train domain. In the case that this assumption is not verified, further data analysis and regression development for the train domain should be carried out for the calculation of more consistent F_i functions, and the correlations for the UMD for the train driving simulation should be handled with particular attention because of this issue. It should be noted that only linear regression analysis was performed. This has led to certain relevant values of standard deviations, as to indicate that a non-linear type of correlation could have been considered in those cases. However, it has been assumed that for this first stage of development of the SiMUD, the results obtained with linear correlations are sufficient to perform simulations and evaluations of different behaviours.

Trasferability and Validity of the iterate model (WP7)

For the UMD model and the simulation tool (SiMUD) to be useful in accordance with the project goals it is of importance that they are applicable to all modes of surface transport and that it is valid in terms of predicting behaviour.

To show that the UMD model is applicable to other modes of surface transport a simulator experiment was carried out at the full scale bridge simulator at Chalmers University aiming to verify that the findings on car and train drivers were applicable to seafarers as well. In addition, the simulation tool was adapted to the shipping domain by applying a vehicle model of a ship and an environment model of the Gothenburg archipelago. This was to verify the technical transferability of the simulation tool.

Extensive simulations were performed in the shipping domain, keeping as many similarities to the train and car experiments as possible. The transferability of the UMD to the shipping domain was ascertained through the application of the model to the new domain (with algorithms reflecting the new vehicle and medium). Anyway, as the first data collection for shipping was conducted in WP7, no further UMD model tuning was conducted, this would be necessary to simulate driver behaviour (with all factors present in the model) in detail. A number of differences between the shipping domain and the other two domains became evident through the experiments, for example that terms such as intended speed, desired distance and gas position may not be used directly for shipping, but need an adaptation to better reflect reality. The relevance of attitude (for example sensation seeking) for the shipping sector cannot be quantified here, since the results only partly confirm the initial assumptions.

The validity of the UMD model and the SiMUD was shown by a new set of experiments with car and train drivers. The SiMUD is based on data from the WP4/WP5 experiments and it has been tuned to that data by a regression analysis so to be able to show that the simulation is valid and applicable to driver behaviour in general, not just a specific data set, new data from new drivers needed to be collected. It can always be argued how to show that a model is valid and what criteria that needs to be fulfilled and the different methods all have their strengths and weaknesses. In this project it was decided that for the theoretical model the parameters chosen should be a significant factor that had an influence on behaviour and that the results from the WP4/WP5 experiments should be repeated. For the SiMUD the criterion was that it should reproduce the same behaviour as was generated on group level in the simulator with real drivers and the main effects should be comparable. So if, for example, sensation seeking drivers (SS) are shown to drive at a higher speed than non SS, then should the modelled SS drive faster as well.

For cars, the differences between the new experiments compared to the previous were that a completely new road was developed and new drivers were selected. The study was also carried out in a driving simulator that was not used in the previous experiments. The studied system however, ISA with curve speed warning is identical to what was used in before. The 48 drivers participating in the experiment were all Swedes so the factor culture was not included. Driver state (fatigue) was also omitted since it had not had any effect in the previous trials. For trains similarly a new simulator with new train drivers on a new track was used. For practical reasons however the system used differed somewhat even though it deals with speed warning and control as well. The drivers included were French and Belgian train and tram drivers so culture was included but fatigue was omitted here as well.

For cars the conclusions from WP5 were that Country, Gender and Workload were significant main effects. For interaction effects Country and Gender as well as Sensation Seeker and Workload were significant on several of the measured points but also Experience and Workload was significant on some points. In WP7 Gender and Workload turned out significant which was the same as in WP5. For interaction effects however Sensation Seeker and Workload did not turn out significant but in addition Experience and Workload as well as Gender and Attitude/personality was significant. This means that the results from WP5 were repeated in terms of main effects while for interaction effects there are some differences. It should be noted however that the interaction effects found did to some degree exist in both experiments even though they did not turn out significant.

The results when comparing the SiMUD with real drivers show that SiMUD managed to replicate the behaviour of the Swedish drivers on a general level in that sense that it choses approximately the same speed, it reduces speed when approaching the curve in a similar level and the behaviour through the curve is also comparable. Comparing the SiMUD output and the real drivers on a more detailed level shows that the SiMUD does predict difference in behaviour due to Attitude/Personality and Task demand/workload. The variation between the compared groups is in general smaller but this is most likely due to the difference between the real drivers used for tuning the model and the real drivers used for testing it.

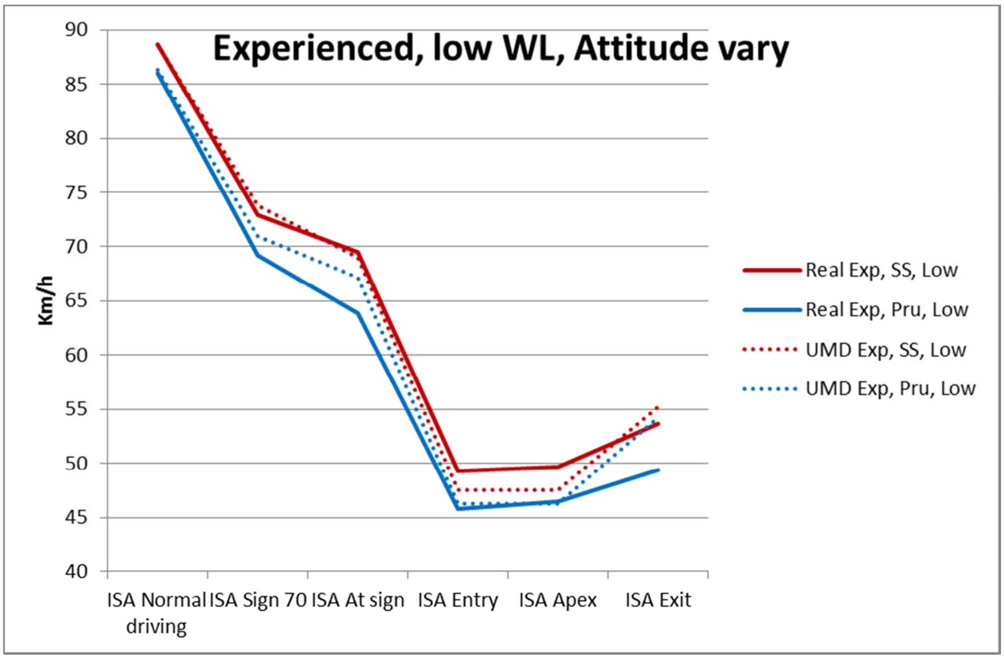


Figure 13 The graph shows a comparison of Swedish, experienced drivers under low workload with varying attitude and their simulated counterparts in SiMUD.

For trains the aim was similarly to show that the UMD and the SiMUD is valid and can be used to predict behaviour of real train drivers. A simulator experiment with 32 test drivers was performed and the results were compared with the SiMUD. The simulator experiment was carried out at University of Valencienne on their COR&GEST platform and the same environment was implemented in the SiMUD. Simulations were carried out for French drivers, experienced and novice, High & Low sensation seekers and workload was varied.

The results show that the SiMUD manages to repeat the behaviour of the French drivers on a general level in that sense that it ”chooses” approximately the same speed profile. The SiMUD driver reduces speed at a later stage closer to the latest possible deceleration point and the braking is smoother. This effect is most likely due to the fact that the portable simulators used to tune the model did not give the same sensation of speed to drivers and so they anticipated a lot and they brake earlier during WP7 experiments.

A conclusion with regard to the train part of the validation compared to the car part is that more tuning of the SiMUD seem to be needed to better fit with experimental platform. This is likely due to the fact that the car simulators used within ITERATE are more developed and are validated against real cars while the train simulators are more on a novel stage and are in need of some further development.

Project potential impact (max 10 pages)

The actual socio-economic impact of the project is hard to estimate as the nature of the project is mostly theoretical and very so close to production and implementation. However, the SiMUD tool has a potential to improve the development of advanced driver support systems and thus contribute to both safety and mobility aspects of driving behaviour. Even if the road fatalities in EU tend to decrease it seems like the target for 2020 (halving the overall number of road deaths starting from 2010) will be hard to reach. Substantial efforts are made not the least in terms of introducing driver support systems with the aim to improve safety. However, the use of driver support system can have unexpected adverse effects depending on variations in driver behaviour. Such effects could be studied by use of the UMD model and the SiMUD tool even if there is a need for further development of both the model and the SiMUD tool. Thus, the ITERATE work could contribute to the development of test methods and tools for safe guarding driver support systems to emerge on the market. There is a demand from industry for tools and methods to test new systems before they put on the market. Furthermore, traffic safety authorities could benefit from the use of a unified model of driver behaviour for assessing and approving innovative technologies without performing extensive simulator experiments or large scale field trials. In this way we believe that ITERATE can contribute to the EU road safety target for 2020 or beyond.

Dissemination

The ITERATE dissemination plan is presented in two deliverables (8.1a and 8.1b) and summaries in the following.

Logo and **website** design was discussed during the kick-off meeting together with leaflet and newsletter. Kite undertook the work and administration of implementing the website (see Figure 14).

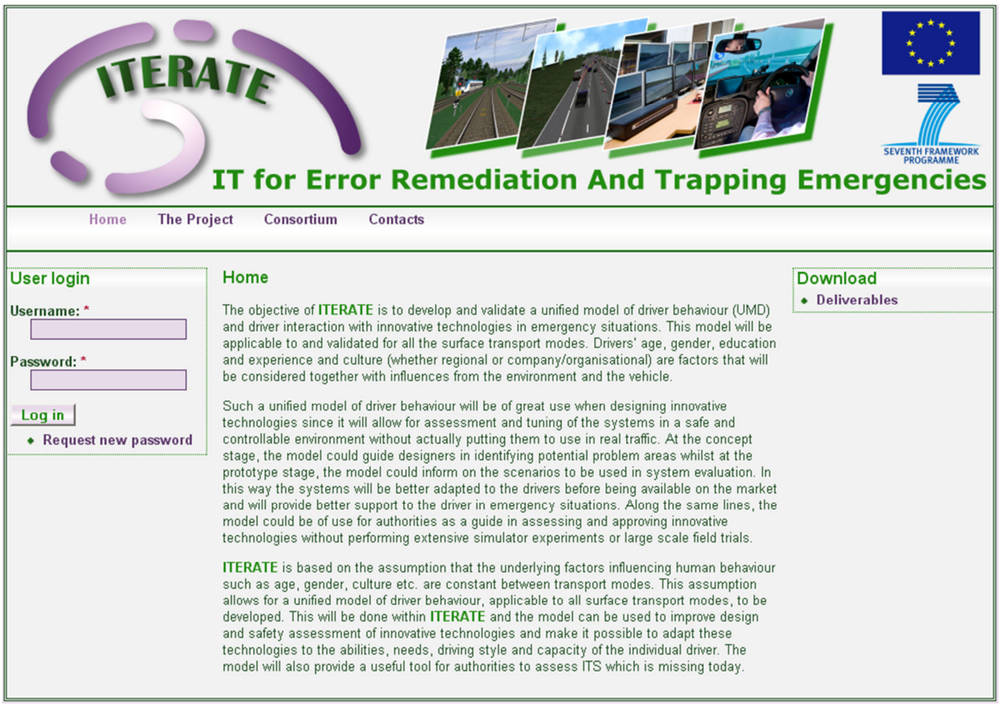


Figure 14 Iterate homepage with project logo(www.iterate-project.eu)

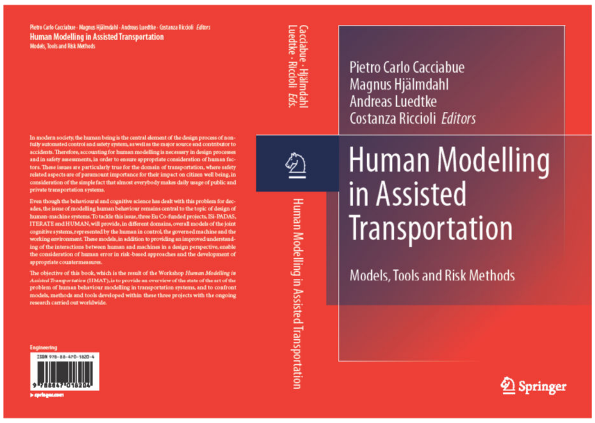
The website has been developed using Drupal CMS (http://www.drupal.org) which is written PHP and utilises a MySQL database. For the graphical theme we did not used one of the several themes freely available but an "ad hoc" theme was designed. The theme colours and layout recall those of the project logo. The website has two areas a public one and a private one. The public area has the purpose of presenting the project and its outcome and to promote the project (e.g. advertising the HMAT conference). Furthermore, it includes information about the project aims, the structure of the project and the Consortium's members. Deliverables with public dissemination level are also available for download.
The private area can be reached by a logging-in procedure with a personal id and password. Contents in this area include a repository for documentation and a calendar showing incoming events. The repository is used to host preliminary versions of official documents (e. g. deliverables) and other working documents. To improve the usability of the private repository the behaviour of Drupal has been slightly modified by implementing a specific module. The calendar is used to organise meeting and other events: days, locations and agendas are published and made available to all the project members. The website development is described in deliverable 8.2.
A total of 5 **Newsletters** have been issued and published on the project public web site, and a final Newsletter will be published after the end of the Project. Thus, in total five newsletters dedicated to the different phases of development of the Project and a "Special Issue" newsletter dedicated to the Conference HMAT-2010.

- The 1st Newsletter was dedicated to the description of the overall Project goals and aims and to the modelling approach proposed as guiding paradigm for the whole Project activity
- The 2nd Newsletter was dedicated to the experimental planning and preparation of the various filed tests, as well as to the description of the "portable "simulator".
- The 3rd newsletter was dedicated to the experimental work and to the data analysis carried out in association to WP 5
- The 4th Newsletter contains the numerical implementation of the Driver Model, as result of WP 6
- The 5th Newsletter, to be published on the web site after closure of the project, will contain the results of the validation exercises and the outcome of the web-conference (Webinar) organised to describe the results of the project to well identified stakeholders.
- The Special Issue Newsletter was dedicated to the Conference HMAT-2010 organised by ITERATE in collaboration with two other EU funded projects of FWP 7 in the domain or Transportation safety and Human Factors, and reported on the overall results of the Conference as well as on the specific contributions of ITETATE.

Workshops: Two workshops were planned in the project. The first workshop was held in 2010 and named "Human Modelling in Assisted Transportation - HMAT". The workshop conducted in collaboration with two other EU funded projects: ISi_PADAS and HUMAN. Furthermore, a couple of national funded projects from Germany and Sweden also presented their work.

- Dates of the workshop: 30 June – 2 July 2010 in Belgirate (Italy).
- Workshop logo and web page was designed and launched on the web. http://www.hmat-ws.eu/
- Ten key-note speakers were invited and present specific lectures.
- Proceedings: The Proceedings was published by Springer (see below)

The Workshop was attended by over 60 participants from all over the world. The conference dealt with the human modelling into design processes and in safety assessments of innovative technologies in highly assisted systems. The HMAT-2010 Workshop offered the opportunity to have fruitful scientific discussions on three main topics:· advanced human models in transportation; Human Errors and Risk Assessment in design processes of assistance systems; Methods and tools to prevent erroneous behaviour to mitigate its consequences. During the HMAT-2010 Workshop, ITERATE partners gave the possibility to all participants to visit the portable car and train simulator utilised inside the project for the empirical experiments. The Abstracts of the papers presented during the conference by Keynotes and by ITERATE Partners are contained in the Special Issue Newsletter, mentioned above.



Cover of Book of HMAT-2010 Conference Proceedings.

The second workshop was organised as a 2 hour webinar and was held in February 2012 with international participation. The agenda included 6 presentations. 90% of the audience remained connected for more than 2 hours. The webinar ended with a discussion. The GoToWebinar service was used for the webinar.

The results of the two workshops have been presented in two deliverables. Deliverable D 8.3a, contains the summary of the most important outcome of 1st ITERATE Workshop, and describes the whole process of planning, preparation and implementation of the Conference, as well as of the results in terms of manuscripts associated to ITERATE. Deliverable D 8.3b contains a summary of the presentations made during the Webinar as well the report of the actual development of the webinar interaction processes.

Publications: In total 26 peer reviewed publications have been produced within ITERATE (references to the publications have been uploaded to the reporting portal. The publications consist of conference papers, journal articles and chapters in edited books/proceedings, in particular HMAT papers in the HMAT book. Furthermore, a number of publications have been planned after the end of the project, in particular:

- A Special Session of "*The 5th International Conference on Traffic and Transport Psychology*" will take place in Groningen, The Netherlands, from August 29-31, 2012" with 4 papers from ITERATE, already planned and accepted for presentation.A
- A Special Issue of the "*Transportation Research Part F: Traffic Psychology and Behaviour*" has been planned and accepted by the Journal Editor. The preparation of the papers is also an on-going activity fully accepted by all involved authors, including non-academic ones.

The final Business plan (D 8.4) has been delivered at the end of the project and addresses how to promote ITERATE outcomes, in terms of technologies and services, to potential recipients, including stakeholders of the transportation domains such as private companies and public administrations.

Project public website and contact details

There is a public website with the address: http://www.iterate-project.eu/ where deliverable and newsletters can be downloaded as described above under dissemination. The consortium consists of 7 partners from 5 countries (Sweden, United Kingdom, France, Italy, Israel). Contact details are shown below.

Contact details for ITERATE per partner/contractor

Beneficiary Number *	Beneficiary name	Contact names	Contact Email	Phone
1	Statens väg och Transportforsknings-institut	Björn Peters Magnus Hjälmdahl	bjorn.peters@vti.se magnus.hjalmdahl@vti.se	+4613204000
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4	Kite Solutions s.n.c.	Carlo Cacciabue	info@kitesolutions.it	+39332789869
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6	Chalmers University	Margareta Lützhöft	margareta.lutzhoft@chalmers.se	+46317721464
7	MTO Psykologi -> MTO Säkerhet	Lena Kecklund	lena.kecklund@mto.se	+46858818898

Consortium logos

Additional information requested by Project Officer (Mr Domanski)

This information was requested by the project officer and has not been included elsewhere. Travel and list of staff involved in the project was reported in the second periodic report. Gender statistics was reported in the electronic reporting tool.

Planned vs. actual use of resources per work package and contractor.

Beneficiary number	Beneficiary short name	Third party	Planned/ Actual/ Use %	WP0	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	Total
1	VTI	0	Planned	8,0	0,5	1,0	6,5	8,0	5,5	1,0	7,5	1,5	39,5
			Actual	8,6	0,8	1,8	5,2	11,1	7,0	0,3	7,8	0,6	43,1
			Use %	107,3%	152,0%	182,0%	80,6%	138,1%	126,5%	31,0%	104,4%	36,7%	109,1%
2	UnivLeeds	0	Planned		2,0	4,0	8,0	8,0	4,0	1,0	5,0	0,0	32,0
			Actual		2,0	4,0	10,1	15,6	4,7	1,2	4,9	0,2	42,6
			Use %		100,0%	100,0%	125,6%	194,4%	117,8%	121,0%	98,6%	#DIVISION/0!	133,3%
3	UniVal	0	Planned		2,0	2,0	4,0	4,0	3,0	1,0	8,0	1,0	25,0
			Actual		2,0	2,0	4,0	4,0	3,0	1,0	8,0	1,0	25,0
			Use %		100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
4	Kite	0	Planned		1,0	0,0	1,0	4,0	3,0	16,0	3,0	6,0	34,0
			Actual		1,3	0,0	1,3	4,7	4,0	22,2	4,0	8,4	45,9
			Use %		133,0%	0,0%	132,0%	118,5%	133,7%	138,6%	133,3%	139,2%	135,1%
5	BGU	0	Planned		9,0	0,0	0,0	4,0	0,0	1,0	2,0	0,0	16,0
			Actual		9,0	0,0	0,0	8,5	0,0	1,2	6,0	0,0	24,7
			Use %		100,0%	0,0%	0,0%	212,5%	0,0%	120,0%	300,0%	0,0%	154,4%
6	Chalmers	0	Planned		2,0	3,0	0,0	0,0	0,0	0,0	7,0	0,0	12,0
			Actual		4,6	3,1	0,0	0,0	0,0	0,0	11,8	0,0	19,4
			Use %		227,5%	103,7%	0,0%	0,0%	0,0%	0,0%	168,3%	0,0%	162,0%
7	MTO	0	Planned		3,0	2,0	0,0	0,0	0,0	0,0	1,0	0,0	6,0
			Actual		1,9	1,7	0,0	0,0	0,0	0,0	1,1	0,0	4,6
			Use %		61,7%	87,0%	0,0%	0,0%	0,0%	0,0%	105,0%	0,0%	77,3%
Total		0	Planned	8,0	19,5	12,0	19,5	28,0	15,5	20,0	33,5	8,5	164,5
			Actual	8,6	21,5	12,7	20,6	43,8	18,7	25,9	43,6	10,1	205,4
			Use %	107,3%	110,2%	105,6%	105,7%	156,6%	120,5%	129,5%	130,1%	118,7%	124,9%