



ITERATE

IT for Error Remediation And Trapping Emergencies

Description of Unified Model of Driver behaviour (UMD) and definition of key parameters for specific application to different surface transport domains of application

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The ITERATE project

This report is produced within the European project ITERATE (IT for Error Remediation And Trapping Emergencies), Grant agreement number 218496. The project started the 1st of January 2009 and will end 31st of December 2011.

The objective of ITERATE is to develop and validate a unified model of driver behaviour (UMD) and driver interaction with innovative technologies in emergency situations. This model will 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.

Such a unified model of driver behaviour will be of great use when designing innovative technologies since it will allow for assessment and tuning of the systems in a safe and controllable environment without actually putting them to use in real traffic. At the concept stage, the model could guide designers in identifying potential problem areas whilst at the prototype stage, the model could inform on the scenarios to be used in system evaluation. In this way the systems will be better adapted to the drivers before being available on the market and will provide better support to the driver in emergency situations. Along the same lines, the model could be of use for authorities as a guide in assessing and approving innovative technologies without performing extensive simulator experiments or large scale field trials.

ITERATE is based on the assumption that the underlying factors influencing human behaviour such as age, gender, culture etc. are constant between transport modes. This assumption allows for a unified model of driver behaviour, applicable to all surface transport modes, to be developed. This will be done within ITERATE and the model can be used to improve design and safety assessment of innovative technologies and make it possible to adapt these technologies to the abilities, needs, driving style and capacity of the individual driver. The model will also provide a useful tool for authorities to assess ITS which is missing today.

The project consortium consists of seven partners:

Statens väg och Transportforskningsinstitut (VTI) Sweden; University of Leeds (UNIVLEEDS) UK; University of Valenciennes (UNIVAL) France; Kite Solutions s.n.c.(Kite) Italy; Ben Gurion University (BGU) Israel; Chalmers University (Chalmers) Sweden; MTO Psykologi (MTO) Sweden

For more information regarding the project please see <http://www.iterate-project.eu/>

I hope you will enjoy this and all other deliverables produced within the ITERATE project. If you seek more information or have questions don't hesitate to contact me.

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List of abbreviations

| | |
|---------|---|
| ADAS | Advanced Driver Assistance Systems |
| AIDE | Adaptive Integrated Driver-vehicle InterfacE |
| ATC | Automatic Train Control |
| ATP | Automatic Train Protection |
| AWS | Automatic Warning System |
| BR | Barrier Removal |
| DMI | Driver Machine Interface |
| DVE | Driver – Vehicle – Environment |
| DVED | Driver – Vehicle – Environment - Driver assistance system |
| EEG | Electro Encephalo Gram |
| ERSO | European Road Safety Observatory |
| ERTMS | European Railways Traffic Management System |
| ETSC | European Transport Safety Council |
| FDW | Following Distance Warning |
| FHWA | Federal Highway Administration |
| HASTE | Human machine interface And the Safety of Traffic in Europe |
| HUD | Head Up Display |
| ISA | Intelligent Speed Adaptation |
| ITERATE | IT for Error Remediation And Trapping Emergencies |
| ITS | Intelligent Transport Systems |
| IVIS | In Vehicle Information System |
| JDVS | Joint Driver- Vehicle System |
| KSS | Karolinska Sleepiness Scale |
| LOC | Locus Of Control |
| OECD | Organization for Economic Cooperation and Development |
| PDT | Peripheral Detection Task |
| RCW | Reverse Collision Warning |
| ROSPA | Royal Society for the Prevention of Accidents |
| RT | Reaction Time |
| SA | Situation Awareness |
| SOFI | Swedish Occupational Fatigue Inventory |
| SPAD | Signals Passed At Danger |
| SS | Sensation Seeking |
| SSS | Sensation Seeking Scale |
| SWAT | Subjective Workload Assessment Scale |
| TCI | Task Capacity Interface |
| TLX | Task Load Index |
| TPWS | Train Protection and Warning System |

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EXECUTIVE SUMMARY

The first work package (WP1) contains a critical review and synthesis of human behaviour models of drivers of road vehicles, trains and maritime vessels (ships). Based on this review a reference model of Driver–Vehicle–Environment is developed. A variety of approaches to modeling driver behaviour are possible as options. The literature review covers the more widely cited of these. Generally, these might be categorized as either '*Descriptive*' models which can only describe the driving task in terms of what the driver has to do or '*Functional*' models which are able to explain and predict drivers' performance in demanding situations and drivers' behaviour in typical ones. It seems that the optimal approach might be a hybrid of several types of models. In recent years, a variety of driver support and information management systems have been designed and implemented with the objective of improving safety as well as performance of vehicles. While the crucial issues at a technical level have been mostly solved, their consequences for driver behaviour remain to be fully explained. To reach this goal predictive models of the interaction of the driver with the vehicle and the environment are necessary. The aim of the European Project AIDE was to integrate all in vehicle support and information systems in a harmonized user interface (Saad, 2006). The ITERATE project will take this further by developing it into a unified driver model that is also applicable to other transport domains.

The first deliverable in this work package (D1.1) presented a critical review of Driver-Vehicle-Environment (DVE) models and most relevant drivers' parameters and variables to be implemented in such models, in different surface transport modes and in different safety critical situations. The aim of this deliverable (D1.2), succeeding D1.1 is to describe and detail the Unified Model of Driver behaviour (UMD), define the environmental parameters to be implemented and their relationships with the driver variables. The proposed model will be used to support design and safety assessment of innovative technologies and make it possible to adapt these technologies to the abilities, needs, driving style and capacity of the individual drivers. The model will also present the environmental parameters, different road and traffic scenarios with different weather and visibility conditions to be simulated in the test phases. The scenarios of traffic that are independent of the activities carried out by the vehicle and driver will be simulated. The model is simplified in the sense that traffic conditions (density, complexity) are not sensitive to the 'test' driver and vehicle behaviour, but remain fixed in a given trial. Thus, within the constraints of this pioneering effort, only the behaviour of the test driver is variable, while the environment and vehicle are defined as parameters with fixed values.

The environmental parameters will consider driving behaviour and performance from the point of view of how drivers perceive, attend, etc. environmental situations to make choices and respond to those situations. The aim is to model how these situations are related to errors, reaction time and risk factors. Particular attention will be paid to the identification of the most risky and critical scenarios; Safety-critical situations that may require emergency actions such as: Obstacle avoidance or gap judgment in passing manoeuvres. Therefore, the DVE model should include those parameters from the environment which drivers indicate as the most attention demanding. The environmental parameters will be synthesized into a preliminary joint DVE model.

1. INTRODUCTION

Using transportation is an everyday practice, a lived experience characteristic of the modern world, but one that is basically taken for granted. People are using different transportation modes such as cars, buses, trains, ships or aircrafts. Driving is central to the lives and deaths of many (Lee, 2008). Road traffic injuries are consistently one of the top three causes of death for people aged between 5-44 years. More than 1.2 million people die on the world's roads every year, and as many as 50 million others are injured (World health statistics, 2008).

Hundreds of articles on driving and driver behaviours have been published during the past years. Lee (2008), in his "Fifty Years of Driving Safety Research" review, claims that substantial improvements in driving safety were seen within the past 50 years; Whether as a result of improved crash-worthiness and passive safety systems (e.g. airbags) or active safety systems (e.g. collision warnings) which promise substantial safety benefits by enhancing driver performance and behaviour so drivers avoid crashes. However, these benefits will be realized only if drivers rely on these systems appropriately and if these systems help drivers behave more safely. Likewise, responding to persistent safety problems, such as alcohol, fatigue, and the emerging problem of distraction, will require systems that improve driver behaviour. A shift in societal norms with regard to what constitutes acceptable behaviour substantially reduced alcohol-related crashes, and a similar response may be needed to address dangerous driver behaviour associated with fatigue and distraction, as well as to further reduce alcohol-related crashes. Technology, particularly which monitors driver behaviour and shares this information could play an important role in changing norms and the driving culture. To a large extent, current and past research has explored similar themes and concepts. Many articles published in the first 25 years focused on issues such as driver impairment, individual differences, and perceptual limits. Articles published in the past 25 years address similar issues but also point toward vehicle technology that can exacerbate or mitigate the negative effect of these issues (Lee, 2008).

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 reality that they actually observe.

In the 1970s, major studies in the United States (Treat et al., 1977) and the United Kingdom (Sabey and Staughton, 1975) identified factors associated with large samples of crashes. The research groups, which were unaware of each other's activities, obtained remarkably similar findings. The US study found the road user to be the sole factor in 57% of crashes, the Environment in 3%, and the vehicle in 2%; the corresponding values from the UK study were 65%, 2%, and 2%, respectively. The road user was identified as a sole or contributing factor in 94% of crashes in the US study and in 95% of crashes in the UK study. The road environment was identified as a causal factor in 31% of crashes in the US study and in 27% of crashes in the UK study. (See figure 1)

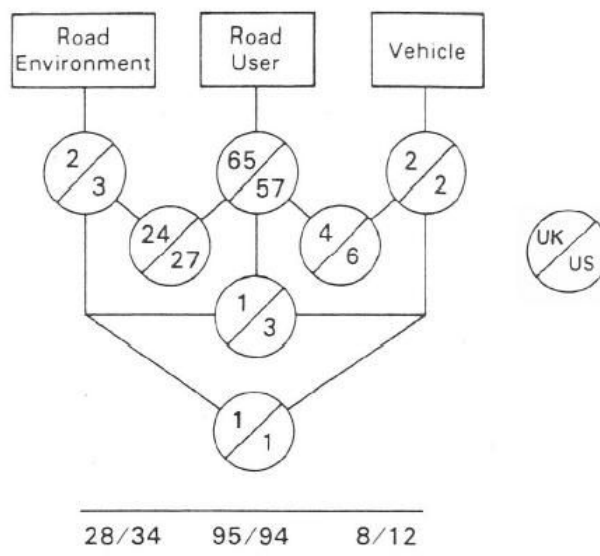


Figure 1 –Road user, Environment & Vehicle contribution to crashes

Treat et al. (1977) found that among the environmental causal factors, view obstructions are the most frequent. Ranking second was slick roads. (Ranking third among the specific environmental causal factors was the special/transient hazards category. Ranking fourth was design problems. Ranking fifth was control hindrances. Ranking sixth was the inadequate signs and signals category. Avoidance obstructions were the seventh-ranking environmental factor. Ranking eighth was ambient vision limitations, Ranking ninth was maintenance problems and Ranking tenth was camouflage effect). Except for the first two factors all the other eight factors had less than 2%.

Another research investigating a total of 5,471 crashes during the period July 3, 2005, to December 31, 2007, have been used as a sample to obtain national estimates reported in a National Motor Vehicle Crash Causation Survey (NHTSA, 2008). Break down of case vehicles, based on the number of travel lanes and roadway flow show that of the estimated 3,894,983 case vehicles, about 52% were involved in crashes on roadways with three or more lanes, about 46% on roadways with two lanes, and a very small percentage (2.6%) in single-lane crashes. Similarly, about 62% of all case vehicles were on roadways that were not physically divided, 34% were on divided roadways, and a small percentage (4.9%) on one-way roadway.

Atmospheric and natural lighting conditions have been coded for crashes as well. Breakdown of crashes based on atmospheric conditions showed that most (74%) of the crashes occurred in clear weather, about 18% when it was cloudy, and about 9% in rainy conditions. Breakdown of crashes by natural lighting condition showed that a majority (71%) of the crashes occurred in daylight. About 13% of the crashes occurred in dark conditions, and about 10 % occurred when it was dark but lighted. The low percentage of crashes occurring at dawn or dark could be attributed to the fact that the NMVCCS sample only covered crashes occurring between 6 a.m. and midnight.

Among crashes, in which the critical reason was attributed to roadway or atmospheric conditions about 75% were related to roadway conditions, such as slick roads, view obstruction, signs and signals, road design, etc. This consisted of about 50% crashes in which the critical reason was attributed to slick roads in contrast with view obstruction that accounted for only 11.6%, and signs and signals that accounted for 2.7%. In addition, in 8.4% of the environment-related crashes, the critical reason was the weather condition, the most frequent (4.4%) being fog/rain/snow. Glare as a critical reason accounted for about 16% of the environment-related crashes.

Any adverse roadway condition is likely to increase the crash risk, while 16.3% of the estimated 3,894,983 case vehicles, had at least one roadway-related factor, whereas in the case of 83.6 % vehicles there was no roadway-related factor. Roadway condition (wet, slick surface, etc.) was the most common (12.2%) condition. Roadway view obstruction due to design, object, or other vehicle was relatively higher (2.1%) than the roadway geometry (1.0%), narrow shoulder or road (0.7%), and traffic sign (0.3%).

Dingus et al. (2006), in the 100 car study had parsed the crashes, near-crashes, and incidents into 18 conflict categories. These conflict categories, e.g. conflict with either a lead, adjacent or following vehicle, Single-vehicle conflict, Conflict with an obstacle in roadway or with other road user, are found in many crash databases and provide a common, consistent method to stratify the data. Within each conflict type there were factors that precipitated the event, contributed to the event, and were associated with the event.

The infrastructure category includes the factors that were fixed and did not change with the Environment: Trafficway flow: one-way traffic and divided roadway, Traffic control device: traffic signal and yield sign, Locality: interstate and residential areas, Roadway alignment or road profile: straight, level, curve, and hillcrest and Relation to junction: intersection and entrance/exit ramp.

The Driving environment consists of conditions that change on a daily or hourly basis; Surface condition: wet and snowy, Lighting: streetlamps and daylight, Traffic density: stable flow, restricted speed, and restricted flow and Atmospheric conditions: clear and raining.

Results for the *single-vehicle crashes* revealed that infrastructure and driving environment were considered to be contributing factors in 29% of the crashes; Weather and visibility was a factor in 8% of the crashes, roadway alignment was a factor in 13% of the crashes, and roadway delineation was a factor in the remaining 8% of the crashes. Glare was considered a contributing factor in two of the crashes (one was due to sunlight and the other was reflected glare). Another crash was due to a visual obstruction. The infrastructure and driving environment were considered to be a contributing factor in 23% of the *single vehicle near-crashes*. Roadway alignment (14%) was the biggest contributor in this category. Weather and visibility was a factor in 4% of the near-crashes, and road sight distance was a factor in one near-crash. Glare (4%) was considered a contributing factor in two of the crashes. An additional near-crash was due to a visual obstruction. As for the *single vehicle incidents* the infrastructure and driving environment were considered to be a contributing factor in 10% of the. Roadway delineation (6%) was the biggest contributor in this category. Weather and visibility was a factor in 2% of the incidents. Roadway alignment was a factor in two incidents, and road sight distance was a factor in one incident. Glare (4%) was considered a contributing factor in 7 incidents, with 5 being due to sunlight and two being due to headlamps. An additional incident was due to visual obstruction due to a hill or curve.

In the case of *Lead-Vehicle Crashes*, when an interaction occurred between the subject vehicle and the vehicle directly in front of it, the Environmental factors were not judged to be a strong contributing factor, with only one crash being due to weather and visibility. This is somewhat surprising when reviewing the associated factors, which indicated that over 40% of the crashes included inclement weather and wet or snowy surface conditions. Not surprisingly, traffic flow was fairly strongly associated with the lead-vehicle crashes, with only 33% being in free flow conditions. The infrastructure associated with the crashes was straight and level in most of the crashes (87%), with one third of the crashes being intersection related. A single crash indicated that reflected glare was a contributing factor. In the case of *Lead-Vehicle Near-Crashes*, none of the driving environment factors were identified as contributing, and only 1 percent of the infrastructure factors were

identified as contributing. Three near-crashes identified road delineation as a contributing factor. Weather was not as strongly associated with the near-crashes as with the crashes, with only 8% of the near-crashes including inclement weather and 12% including wet surface conditions. Only 21 of the near-crashes were identified as free-flow traffic, again showing the prevalence of heavy traffic as an associative factor for lead-vehicle conflicts. As in the crashes, the road was straight and level in most of the lead-vehicle near-crashes (87%). Approximately 22% of the lead-vehicle near-crashes were intersection-related. As for the *lead-Vehicle Incidents*; none of the driving environment factors were identified as contributing, and only one crash infrastructure factor (i.e., roadway delineation) was identified as contributing. Weather was not a large associated factor, with no inclement weather and only two wet surface associated conditions. Only 4 of the 12 crashes were in free flow conditions. Roadway alignment may have played a role, with 42% of the crashes being on curves. Two-thirds of the crashes were intersection-related.

The road infrastructure conveys a wealth of information that guides drivers' activity and their interactions with others in situ (explicitly through devices such as road signs and road markings, and implicitly by means of environmental context and road layout, for example). In the broadest sense, the road environment comprises the vehicle, the road infrastructure and other road users. It also includes the rules that govern the use of the road infrastructure and interactions with other road users. For this specific context of DVE modeling, the concept of the environment makes reference to any external conditions and surroundings to the vehicle, that is to say, road, traffic and weather & Visibility conditions. (AIDE D1.1.4)

Inadequate conditions of causal factors such as; confusing layout, misleading signage, poor road surface condition and confusing rules / regulations or environmental conditions e.g. weather and lighting, can potentially impact road user behaviour and performance in a way that can potentially lead to road user errors being made (Stanton et al., 2009).

The objective of this project is to use research from the different transportation domains and to use the differences and similarities between the domains to develop a unified model for driver performance / behaviour in safety critical situations which could be used across transportation modes. The focus is on creating a structured model that can be used in real time, in particular with an operator assistance system to (1) monitor driver state and performance, (2) predict how momentary risk is changing, (3) anticipate problem situations and (4) in response adjust the behaviour of in-vehicle information systems and driver assistance systems and feedback to the driver. The driver model would therefore be the major component of a larger model supervising the interaction among driver, vehicle and the traffic and road environment.

The first work package of ITERATE (WP1) started with a critical review and synthesis of existing models of human behaviour for drivers of road vehicles, trains and vessels (D1.1). Based on this review a model of Driver-Vehicle-Environment is proposed identifying elements that can be used to predict momentary risk. This document consists of the following sections; Dependent variables - Predictable quantities that represent driver performance measured by errors and reaction time and also driver behaviour measured by comprehension of risky vs. safety situations. Factors influencing driving safety - in our modelling architecture these factors are: Attitude and personality, Experience, Driver state, Task demand and Culture and The selected driver independent variables are: Sensation seeking, Hazard perception skills, Fatigue, Subjective workload and Country. The first two sections are overlapping D1.1. This document provides also Task Analysis principles to be applied within the scenarios which will be detailed in WP3. Furthermore, Environmental Parameters influencing driving safety (Road / Track / Fairway characteristics and traffic scenarios with different visibility conditions)

and their interaction with the selected driver variables, as it will be implemented in the ITERATE simulation tool, are described. As the focus of the model and simulation is mainly on the Driver, this Deliverable contains only short descriptions of the vehicle model.

The model will be built by considering driving behaviour and performance from the point of view of how drivers perceive, attend, etc. environmental situations to make choices and respond to those situations. The aim is to model how these situations are related to errors, reaction time and risk factors. Therefore, the DVE model should include those parameters from the environment which drivers indicate as the most attention demanding. A conceptual model, in its most general version, is presented in Figure 2. According to this model the ADAS can serve both as a sensor of driver, vehicle, and environmental states AND as an activator of interventions that affect the driver, vehicle, and environment. More specific versions are described below for the two vehicle systems that will be evaluated by all partners (cars and trains) and the two technological interventions that have been selected for evaluation in this study (Collision avoidance and Speed management).

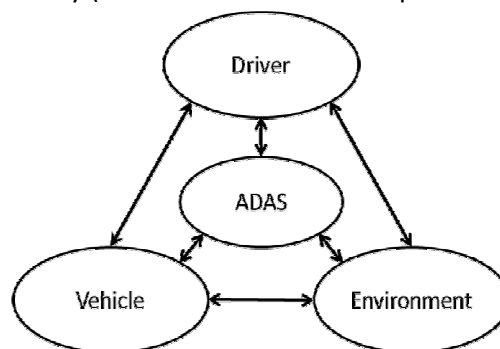


Figure 2 – DVE (A) model

Concerning the car framework, we can learn about drivers' behaviour by their actions and observations including the interactions with the environmental parameters, the vehicle model and ADAS. See figure 2 for schematic interactions.

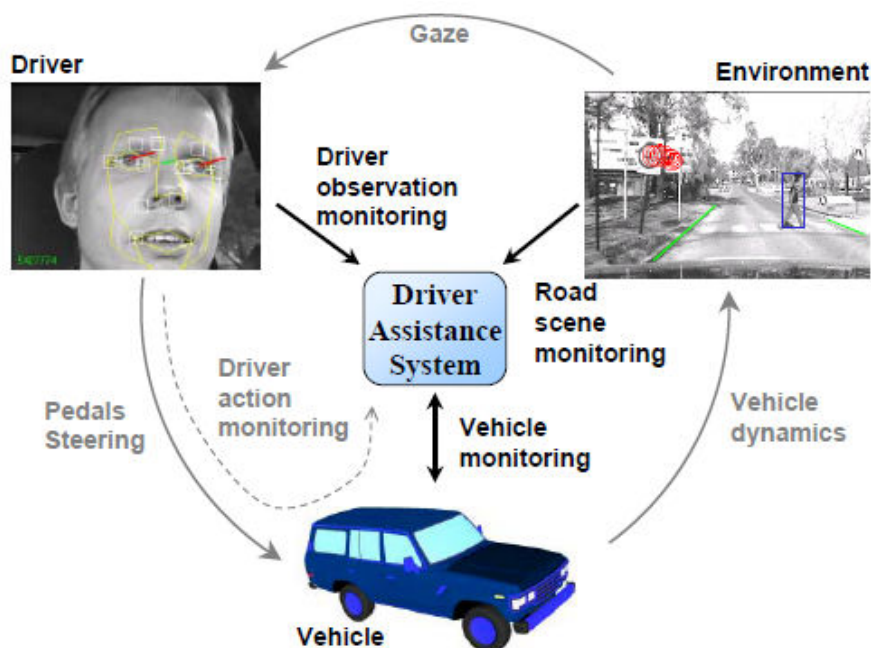


Figure 2a - DVED (from Fletcher et al., 2005)

The train driver has a smaller degree of freedom during driving. He has no control on the direction of the vehicle; but can act on the velocity of the vehicle. However parameters introduced in the DVED can be used for describing the interactions (see Figure 3).

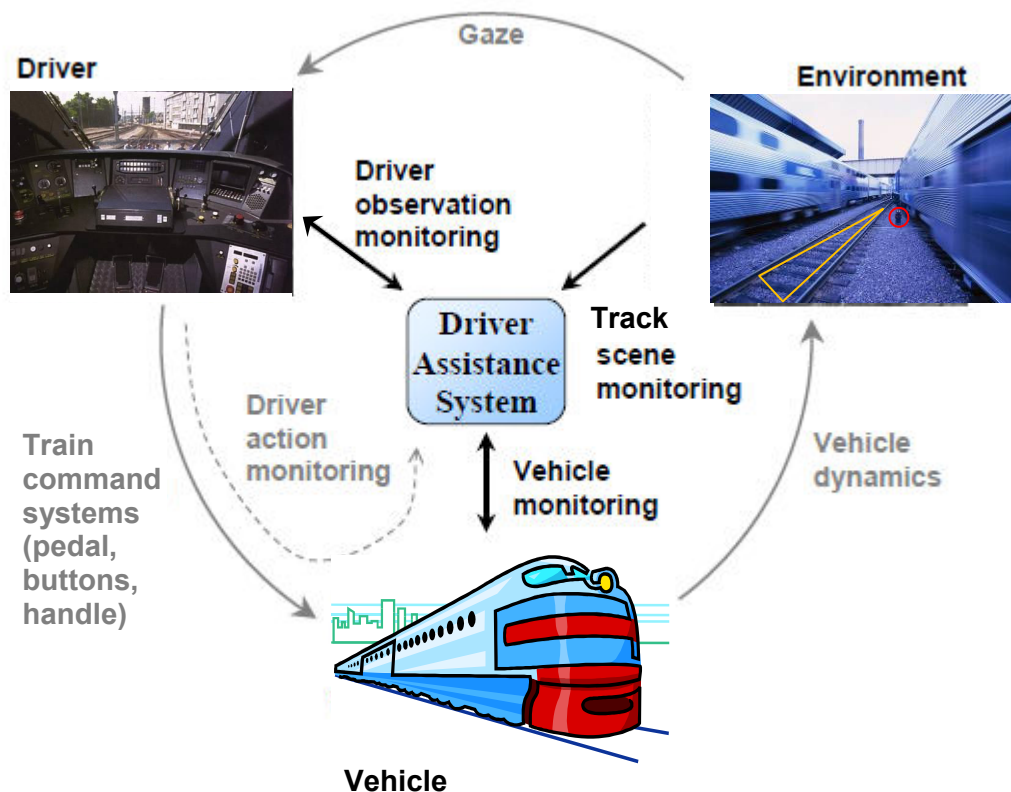


Figure 2b– Proposal of adaptation of the DVED for train domain

Modifications were introduced in the model proposed by Fletcher (Fletcher et al., 2005):

The "Driver observation monitoring" in the train corresponds to the use of the Driver's Safety Device, which indicates no problem concerning the driver state. The driver is able controlling the train commands yet. For these reason the picture representing the Driver is not the driver himself, but it is the command board on which is the button he pushes to acknowledge his ability in driving.

The one-way arrow linking The Driver Assistance System and the Driver was changed by a double arrow. In the train cabin, the Driver Assistance System are in charge of warning the driver about a change of signalling (AWS, ...) or about an over-speed of the train (ATP, ..), for example.

2. DEPENDENT VARIABLES

When discussing safe or unsafe driving behaviour the dependent variable most frequently used are accidents. Traffic safety is often equalled to the inverse of accidents. However, traffic safety is more than the mere absence of accidents. Ranney (1994) argued that "we must go beyond accidents if we are to understand driving behaviour". In this project we decided to focus on three dependent variables that represent driver performance measured by errors and reaction time and also driver behaviour measured by comprehension of risky vs. safety situations.

2.1 Error propensity (slips, lapses, mistakes, violations)

Various taxonomies of human error have been proposed. Within the literature on human error, three perspectives currently dominate. These are Norman's (1981) error categorization, Reason's (1990) slips, lapses, mistakes and violations classification and Rasmussen's (1986) skill, rule and knowledge error classification (Stanton, 2009).

Slips and **lapses** are defined by behaviours related to attentional failures and memory failures which might impact driver safety (Wickens, 2008). Both **slips** and **lapses** are examples of where the action was unintended; either inattention (e.g., failing to perform at critical moments, especially when the driver intends to do something unusual – such as deviating from the normal route on the way home from work) or over attention (e.g., performing at the wrong moments). **Slips** relate more directly to psychomotor components of driving at the operational level of control and refer to events in which the planned action would have achieved the desired goal; the right intention is incorrectly executed, e.g. when a driver who plans to push the brake pedal to slow down inadvertently pushes the accelerator pedal, the intention was correct but the execution was erroneous. While, **Lapses** represent the failure to carry out any action at all, errors based on forgetfulness (e.g. a driver forgetting to turn off the lights when departing the car, although fully intended to do so). Lapses are of particular relevance to roadway accidents as they reflect errors in skill based or automatic behaviours (Reason, 1990, Ranney, 1994). On the contrary, **mistakes** occur when driver intentionally performs an action that is wrong (e.g. when a driver decides to accelerate when the right action would have been to brake or slow down), as a result of limitations in perception, memory and cognition. **Mistakes** initiate at the planning level, rather than the execution level and are likely to precipitate inappropriate manoeuvring decisions. Although both rule- and knowledge-based **mistakes** characterize intentions that are not suitable for the situation, there are some differences between the two. Rule-based **mistakes** tend to be made with confidence (misapplication of a good procedure, e.g. performing a task that has been successful before in a particular context), while knowledge-based **mistakes** are more likely to appear in a situation in which rules are not applicable and the operator becomes less certain (application of a bad procedure, e.g. performing a task that is "unsuitable, inelegant or inadvisable" at the most basic level). The knowledge-based **mistakes** will also involve much more conscious effort, and the chances of making a **mistake** while functioning at this level are higher than they are at a rule-based level since there are so many more ways in which information acquisition and integration may fail (Reason, 1990, 1997). Reason (1990) defines the term **violations** as "deliberate deviations from those practices deemed necessary to maintain the safe operation of a potentially hazardous system" (p.195). In the case of driving this would be deliberate deviations from accepted procedures, standards and rules of safe driving (i.e. speeding), and research has shown that these **violations** are statistically associated with enhanced crash involvement (Lindgren et al., 2007). Comparing **violations** with errors, Reason (1990) states that errors should be related to the individual cognitive processes while **violations** concern the social text in which they occur. Errors may therefore be minimized by retraining, memory aids and better human-machine interfaces. **Violation**, on the other hand, should possibly be dealt with by trying to

change users' attitudes, beliefs and norms, and by improving the overall safety culture (Lindgren et al., 2007). See figure 4 for error classification.

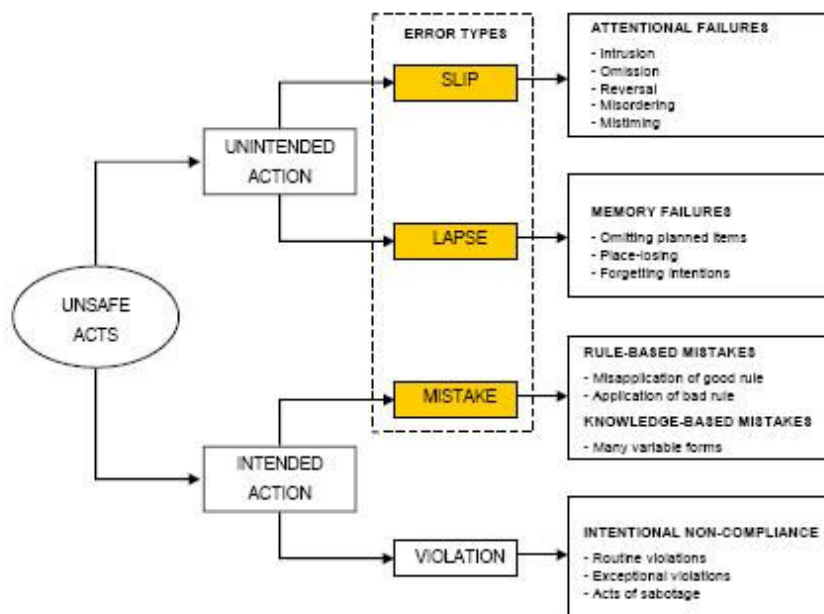


Figure 3 – classification of unsafe acts (Reason, 1990 in Weller et al., 2006)

2.2 Transformations of Reaction time to discrete events

Often, the terms "reaction time" and "response time" are used interchangeably, but reaction time is always a part of the response time. Reaction time is also called perception-reaction time. The total reaction time can be split into three components : (1) mental processing time (the time required for the driver to perceive the sensory input and to decide on a response), (2) movement time (the time used to perform the programmed movement, such as lifting the foot from the accelerator and touching the brake), and (3) device response time (the time the physical device takes to execute its response, such as the time needed to stop the car after brake engagement). Because the mental processing time is an internal quantity that cannot be measured directly and objectively without a physical response, it is usually measured jointly with movement time (Setti et al., 2006)

Brake reaction time (RT) is a parameter of driving behaviour that has not only attracted the interest of researchers but is also of great importance in road design and accident litigation process. Among other things, brake RT is used in assessing stopping sight distance, which determines road design required for a certain design speed. In accident litigation, the legal process often tends to determine whether the participant driver reacted to the impending collision within "acceptable" time, in which acceptability is established from a certain percentile of RT distribution thought to represent the driver population (or relevant fraction of it) in relevant conditions. (Summala, 2000)

2.3 Projection of current situation to risky vs. safe situation

Endsley (1995) defines situation awareness as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status to the near future" (Endsley, 1995, p. 36 in Shinar, 2007) Loss of situation awareness has been found to be a significant causal factor in accidents and incidents in transportation domains. (Stanton, 2009)

We intend to investigate the effects of the selected independent variables on the 3rd level of SA meaning the projection of current situation to risky vs. safe driving behaviours. See figure 5

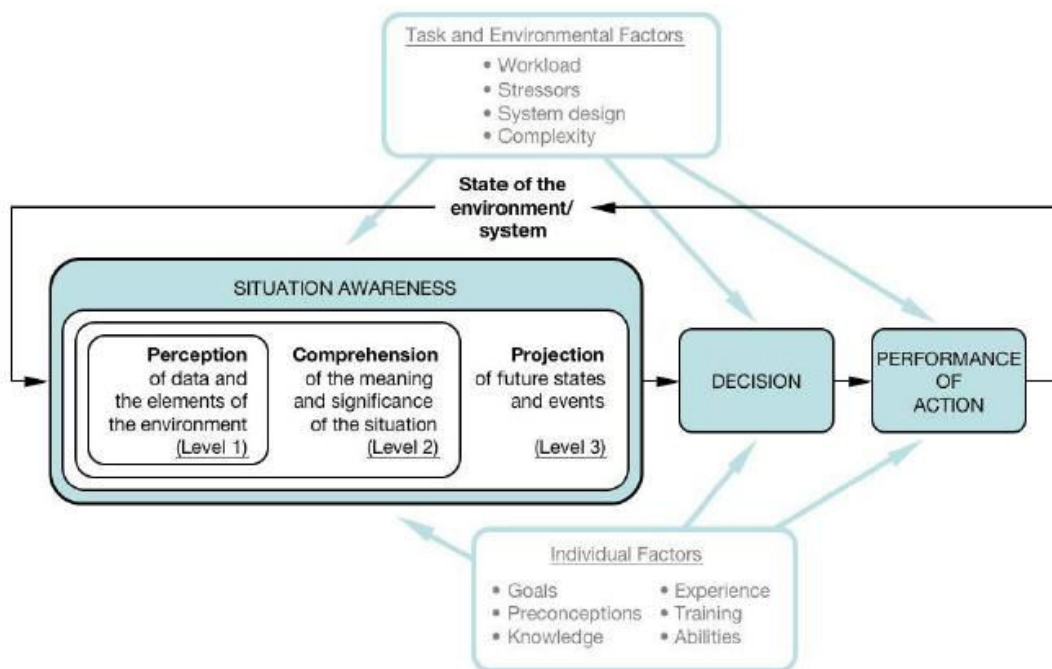


Figure 4 – Model of situation awareness (Endsley, 1995 in Jin, 2008)

3. FACTORS INFLUENCING DRIVING SAFETY & SELECTED DRIVER VARIABLES

3.1 Attitudes/ personality

Attitudes / Personality mean a complex mental state involving beliefs, feelings, values and dispositions to act in certain ways. These are static parameters that affect the input data of the driver model (i.e., their values do not change during the dynamic simulation of a case study) associated with each driver (Cacciabue & Carsten, 2009).

Research of road accidents began a hundred years ago, and, as it developed, it clarified the dominant role of human characteristics, whether paying insufficient attention or erring in processing information and in decision-making (see e.g., Shinar, 1978). A large proportion of the studies and theories developed in the past to understand these factors emphasized the relationship between personal characteristics and driver behaviour (Elvik and Vaa, 2004 in Factor et al., 2007). These studies dealt principally with various personality components that lead to accident proneness, risk-taking, and driving over the speed limit. Other studies analyzed attention disorders while driving, the effect of fatigue, aggressive and violent driving, gap acceptance for crossing intersections, and more (Factor et al., 2007).

3.1.1 Sensation Seeking

Several authors (Jonah et al. 2001; Rudin-Brown and Noy 2003; Rudin-Brown and Parker 2004 in Cacciabue & Saad, 2008) have put the emphasis on some general personality traits, such as “sensation seeking” and “locus of control”. These personality traits are assumed to influence, more or less directly, the occurrence of behavioural adaptation either through a general tendency for risk compensation (for “high sensation seekers”) or a propensity to manifest over-reliance in automation (for “external LOC”) (Cacciabue & Saad, 2008).

sensation Seeking is defined as "seeking of varied, novel, complex and intense sensations and experiences and the willingness to take physical, social, legal and financial risk for the sake of such experience" (Zuckerman, 1994). Some publications showed physiological correlations with sensation seeking (Jonah, 1997, Zuckerman, 1994) it is operationally defined in terms of scores on questionnaires namely the Sensation Seeking Scale (SSS-V Zuckerman, 1994) or the Arnett Inventory of Sensation Seeking (AISS, Arnett, 1994). Most articles show correlation between Sensation Seeking & some aspects of risky driving. (Weller et al., 2006)

The search concerning sensation seeking identified no scientific articles as regard to train driving. The search revealed that the topic has been identified and discussed in the area of driver selection and recruitment and that train drivers (e.g. RSSB, 2006) should not be sensation-seekers and risk-takers was identified as a selection criteria. The conclusion was to avoid sensation seekers because train drivers must tolerate long periods of low stimulation without seeking thrills or taking risks. This discussion can also be related to the fact that drivers must tolerate monotony and work situations with little stimulation without trying to engage in risk behaviors to increase simulation. Drivers must also be able to cope with highly irregular working hours. These issues were discussed in results from the TRAIN-project (Kecklund et al., 2001). An important issue is however, that the automatic safety systems such as ATC and ERTMS, restricts the drivers actions to a large extent and thus prevents sensation-seeking behavior. Research on driver selection criteria has been identified as an important research topic in the railway domain.

No research has been found in shipping and the maritime domain considering sensation seeking, which is assumed to have a natural explanation. Most studies performed are aimed to penetrate other issues and aspects of commercial professional shipping where sensation seeking is not an issue. However, as high-speed boats, such as rib-boats, water jets etc., are becoming more available for the consumer and adventure/recreation market the assumption is that this will change in the near future, given the existing legislation in Europe. For example, in Sweden have the Swedish Maritime Administration noticed the issue, even though no action have been taken (Dahlman, et al., 2008).

3.1.2 Effect of sensation seeking on the dependent variables

The model of Rudin-Brown and Noy (2002), proposes that behavioural adaptation to new in-vehicle systems will be influenced by personality in the form of locus of control and sensation seeking as well as by trust in the system. (See figure 6) this model offers the prospect of predicting the direction and relative magnitude of adaptation effects. (Carsten, 2009)

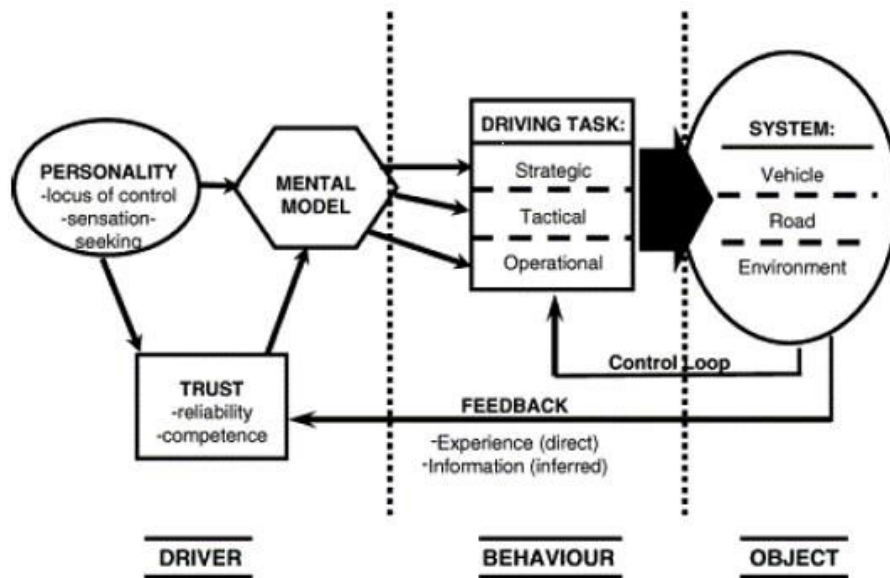


Figure 5 - Qualitative model of BA (Rudin-Brown & Noy, 2002)

Personality and driving behaviour have strong correlations (Sümer, Lajunen & Ozkan, 2005). Jonah (1997) argued that most studies found significant positive relations between SS and aspects of aggressive and risky driving (e.g. driving while impaired, speeding, following too closely) see for example Dahlen & White, 2006. Sensation-seeking significantly predict violations (Schwebel et al., 2006, 2007, Machin and Sankey, 2006, 2008). Furthermore, high sensation seekers with high level of attention are more likely to have a higher number of traffic violations and errors (Ayvaşık et al., 2007). The sensation seeking variables (thrill & adventure and disinhibition) had significant indirect influence on accidents and offences mediated by the violations and mistakes factors (Rimmo & Aberg, 1999). SS explain the variance of the tendency to take risks occasionally less well than the tendency to take risks frequently (Desrichard & Denari, 2005).

3.2 Experience

Experience is the accumulation of knowledge or skills that result from direct participation in the driving activity; static parameters that affect the input data of the driver model (do not change during the dynamic simulation of a case study) associated with each driver (Cacciabue & Carsten, 2009).

For any given situation, a novice driver must, under the time constraints of driving, be able to quickly select the cues that are indicative of a hazard, integrate them into holistic patterns, comprehend their implications, project how the situation may evolve into a potential accident, and select the necessary action from his or her repertoire of driving behaviours. The more experience a driver has, the greater the repertoire of situations and schemata he or she has in long term memory. Thus, with experience the driver learns to effectively select the cues to attend to, quickly perceive their meanings, and on the basis of these cues quickly identify the situation and project its implications into the immediate future. Using scripts built through past experience this driver then controls the vehicle in a very effective manner. This mode of driving is very effective because behaviours are guided by partial information that has been previously organized into complete situations which in turn are linked to pre-established behaviour sequences. Thus, much of the driving can be automated, and when a totally unexpected hazard (e.g. one never encountered before) is encountered the driver still has spare capacity to deal with it. The novice driver, in contrast, does not

have all of these benefits of experience and therefore must attend to more stimuli, which necessitate slower driving in environments that are not as complex in order to build up the necessary skills and repertoire of experiences. As this driver accumulates experience, more and more of the driving scene is recognized through schemata and more and more of the behaviour is automated; allowing the driver to better attend to other driving tasks, or to time-share the driving with non-driving tasks. (Shinar, 2007) Yet, the issue whether driving experience provides better performance when the driver engages in use of in-vehicle systems is debatable. In general, it can be concluded that driver Situation Awareness increases with experience as static knowledge will increase for predicting future driving environment states and deciding on driving actions (Jin, 2008). However, McKenna and Crick (1997) concluded that a secondary auditory-verbal task had a detrimental effect on hazard perception for both novice and experienced drivers. Sagberg and Bjørnskau (2006) conversely found that increased mental load imposed by a mental arithmetic task resulted in impaired hazard perception only for the male novice drivers, and not for drivers in general. The discrepancy may be due to differences in the difficulty of the secondary task. McKenna and Farrand (1999) found that both experienced and inexperienced drivers suffered considerable interference to their hazard perception skills in the presence of a secondary speech task. Interestingly, the more experienced drivers suffered greater interference. Apparently, hazard perception is demanding and when attention is drawn to other tasks, the ability to detect hazards will decrease. The improvement of hazard perception skills may be a result of learning to identify situations in combination with automation of other driving tasks, thus reducing the mental workload and leaving more mental capacity for the hazard detection task. It would appear that the more you have, the more you have to lose. In terms of hazard perception skills the secondary speech task converted the experienced drivers into poor novices (McKenna, 2006). While both experience and age are important, research indicates that experience is clearly more important than age in determining the relative risk levels of young drivers. Risk levels for both young males and females are extremely high immediately following licensing for solo driving, but reduce significantly in the first six to 12 months. Risks then reduce more gradually in line with experience over the remainder of the first two to three years of solo driving. However, it does take that long – i.e. two or three years at least – before risk levels for young drivers approach the levels of older drivers (OECD, 2006). In the train domain, Barrier removal (BR) is a safety-related violation, and it can be analyzed in terms of benefits, costs, and potential deficits. The proposed method can be used, on the one hand, to foresee/predict the possibility level of a new/changed barrier (prospective analysis), and on the other hand, to synthetically regroup/rearrange the BR of a given human-machine system (retrospective analysis) (Zhang et al., 2004). A reinforced iterative formalism to learn from intentional human errors called barrier removal and from uncertainty on human-error parameters has been proposed (Vanderhaegen et al., 2009). The iterative learning formalism is based on human action formalism that interprets the barrier removal in terms of consequences, i.e. benefits, costs and potential dangers or deficits. Two functions are required: the similarity function to search a known case closed to the input case for which the human action has to be predicted and a reinforcement function to reinforce links between similar known cases. This reinforced iterative formalism is applied to a railway simulation from which the prediction of barrier removal is based on subjective data. We applied both these methods to the BR analysis on twenty people who participated in the simulator experiment as ‘traffic controllers’. They came from different countries, had different educational levels and different regional performance characteristics.

Another experimental protocol was run on the COR&GEST platform which involves a miniature railway structure on which several trains can move. It integrates both a supervision interfaces to manage remotely signals and devices such as points and a driving interface for each train. Seven inexperienced human operators behaviour were studied during the train driving activities with or without any technical failure occurrence (Vanderhaegen, 2009). The occurrence of barrier removals or of disturbances makes some human operators more aware of the danger or the performance control.

3.2.1 Hazard perception skills

There is an increased interest in driver's ability to detect hazards during the last decade. Hazard perception (HP) skills include discovering, recognizing and reacting to potentially dangerous situations (OECD, 2006). Hazard perception ability has been found to correlate with crash risk (Smith et al., 2009) and is a critical skill that distinguishes experienced drivers from novice drivers (Horswill and McKenna, 2004). Experience is a key influence on hazard perception, independent of age (Ahopalo, 1987 cited in OECD, 2006).

Although young drivers perform better than older drivers on visual and motor skill tasks, they crash more frequently during the first few years of driving, which may reflect underdeveloped hazard perception skills. The most cited article published in 'Human Factors' concerning driving safety showed that novice drivers scan the road differently than experienced drivers do (Mourant & Rockwell, 1972 in Lee, 2008), indicating that different search strategies are being used by these groups, which influence their steering control. Lee (2008) argue that examination of driver eye movements confirms these findings by showing that the eye movements of inexperienced drivers focus more on guiding lateral control than on hazard detection, leading to diminished hazard awareness that may increase novice drivers' crash risk (Lee, 2008).

Typically, measuring hazard perception latencies (reaction time) and/or assessments of the degree of perceived hazard associated with various traffic scenes includes either simulated photographs/pictures or 'animated' hazards in scenario-based video clips/ films, however, seldom with real-life traffic situations (Sagberg & Bjørnskau, 2006, Sümer et al., 2007).

Concerning train driving the concept of hazard perception skills was applied in a quite broad sense, including for example strategies used to manage the allocate attention and to perform the driving task. Drivers' allocation of attention was found to be influenced by the aspect of the approaching signal and the aspect of the signal just passed (e.g. Elliott et. al., 2007, Merat, et. al., 2009). This will influence the driver's ability to detect hazards because the driver can be assumed to be more vigilant if a restrictive signal aspect has been passed.

Route knowledge has been identified as important for the driving task (e.g. Luther, 2007). Some studies showed that a driver machine interface which is not well designed will increase subjective workload and also time to take action (e.g. Gibson et al., 2007, McLeod et al., 2005). These factors are important for the drivers' timely identification and prediction of hazards.

Other studies have shown that high level of automation decrease vigilance (e.g. Spring et al., 2009) and that time at task give vigilance decrements. Decreased vigilance will probably have a negative effect on hazard perception skills.

Drivers' incomplete understanding of the automatic functions due to inadequate DMI design makes it difficult to maintain adequate situation awareness when automation takes over (e.g., Harms, et al., 1996, Olsson, 2001). Skill-based, reactive behavior is then applied in response to warning signals

and sounds and sometimes only the warning signal is cancelled without the driver performing the safety braking task (e.g. McLeod et al., 2005). Several studies have shown that driver behavior is adapted to the behavior of the warnings and support systems. For example McLeod et al. (2005) showed that AWS increased the risk of Signals Passed at Danger (SPAD). An ATC system with insufficient DMI promotes a reactive driving style (e.g. Olsson, 2001).

Two different driving styles, reactive and proactive could be identified (Jansson, et al., 2005). The proactive style is characterized by development of situational awareness and route knowledge used to predict situations which can occur further down the line. The reactive style is characterized by awaiting signs and signals, e.g. warning sounds from ATC before acting. Dorrian et al. (2007) has also showed that drivers switched from a proactive to a reactive driving style with increased sleepiness and fatigue and that the braking behavior was less efficient. More research is needed to confirm the findings presented in the studies presented above.

In the maritime domain, few studies have studied hazard perception as a separate concept. Some studies look at closely related concepts, such as a high-speed navigation field study (Dahlman, J., Forsman, F., Sjörs, A., Lützhöft, M., Falkmer, T. 2008) and an interview study with maritime pilots (Darbra, Crawford, Haley, & Morrison, 2007). The high-speed navigation study used two levels of experience (expert and novice) and two runs through the navigated track (at high and lower speed). Measures taken were eye-tracking and observations. The results show that fixation durations became shorter in the high speed condition but there was no significant difference in fixation duration between novice and experienced across both conditions. It was also found that experienced navigators rely more on environmental cues and the paper chart and less on other navigational aids compared to the less experienced.

3.2.2 Effect of hazard perception skills on the dependent variables

Several studies have shown that experienced and expert drivers detect hazards better (e.g. McKenna and Crick, 1991 and 1994 in OECD, 2006) and faster (Sümer, 2007, Klauer et al., 2008, Horswill et al., 2008, Smith et al., 2009) than novice drivers. However, others did not report such differences (e.g., Borowsky et al., 2007; Sagberg & Bjornskau, 2006).

Experienced drivers are better than novice drivers at detecting far hazards (Brown, 1982 in Shinar, 2007, Drummond, 1996 in OECD, 2006). Drummond (2000) found that poor hazard perception was associated with increased risk of fatal or serious crashes but not minor crashes or crashes overall, especially during the first year post-test. Renge (1998 in OECD, 2006) found significant correlations between high hazard perception scores and high risk rating of the situations and between high hazard perception scores and lower speed choice. Grayson (1998, cited in OECD, 2006) found that drivers who were rated by driving examiners "as being attentive, safe, and skilful drivers, and as having good anticipation and good speed setting abilities" on the road tended to have faster response times in a hazard perception test. Watts and Quimby (1979 in OECD, 2006) found a significant correlation between drivers' reaction time to hazards and their road crash frequency over the previous three years, McKenna and Crick (1991 in OECD, 2006) found that those with a higher number of crashes over the previous two years were worse at the hazard perception test, after taking into consideration the effects of age and mileage. Quimby *et al.* (1981, 1986) and Maycock *et al.* (1991) also showed that hazard perception skills relate to potential for crashes, especially for inexperienced drivers. (OECD, 2006)

McKenna and Horswill (2006) have shown that appropriate hazard perception training not only improves the time to detect hazards it also results in a reduction in risk taking as indexed by speed choices. Borowsky et al. (2007) argued that experienced drivers learn to avoid hazards to which inexperienced drivers must respond. When the hazard was imminent all drivers responded at the same time.

Results from studies of incident reports related to train driving show that errors at the skill and rule-based level were the most common (e.g. Edkins et. al., 1997). Sustained attentions were the most salient factors contributing to accidents, in particular inattentiveness to railway signals. This can be due to unfavourable work environment and is probably related to the high degree of monotony in the train driver's work. The latter cause has been identified in other studies (e.g. Kecklund, 2001).

A study of SPAD occurrences (van der Flier and Schoonman, 1988) showed that the most frequently mentioned hazard was that the signal was situated behind a bend. Most SPADs took place near stations and most with arriving trains. The direct cause was often that the signal was overlooked.

3.3 Driver state (impairment level)

Driver state is the driver physical and mental ability to drive (fatigue, sleepiness etc.), a set of dynamic parameters representing aspects of the driver relevant for the human-machine interaction (AIDE D1.1.3), and subjective dynamic parameter resulting from DVE interaction (Cacciabue & Carsten, 2009).

Lee (2008) argued that alcohol and fatigue impair performance and undermine driving safety. Although the numbers of crashes and incidents attributed to alcohol and drug use is decreasing, they probably remain a significant causal factor as long as alcohol and drug abuse remain common among the population at large (Ranney et al., 2000). Drugs & Alcohol have a generally deleterious effect on performance; usually it lengthened reaction times and cognitive processing times. Incidence of alcohol involvement in accidents has been researched for many years, and has been found to be substantial. Medical Conditions – people with disabilities who drive represent a small but growing portion of the population as technology advances in the field of adaptive equipment. Studies and data show that such driver's performance is indistinguishable from the general driving population. Although there are doubtless a number of people on the highways with illnesses or conditions for which driving is contraindicated, they are probably not enough of these to account for them in any traffic flow models (Koppa, 2003).

Because the inclusion of an experiment using alcohol/drugs requires a more complex Institutional Review Board process - that varies among countries - we decided not to include this variable in the model validation evaluations.

Fatigue represents a less prominent safety problem that may be underreported because; unlike with alcohol or drugs, no forensic test can measure its presence. Researchers attribute between 2% and 25% of car crashes to fatigue (Lee, 2008). Karrer et al. (2004) argued that scientific definitions of fatigue are still unsatisfactory; it could be due to the ambiguity of the term "fatigue", used for different phenomena resulting from different factors. The literature offers different terms for fatigue, such as: 'sleepiness', 'drowsiness', 'micro sleeps', 'attention', 'alertness', 'vigilance', 'performance variability', 'error vulnerability' which are used more or less synonymously. Next section will detail the term of 'fatigue' and its synonyms and explain the relevant term in this project. Considerably, the degree to which impairment influences driving performance reflects driver behaviour -drivers choose to compromise their ability to drive safely by driving while impaired. As a

consequence, influencing driver response to impairments may require cultural changes regarding norms of acceptable behaviour (Lee, 2008).

Fatigue remains a major factor in all transportation modes. Companies increasingly have fewer employees working longer hours to increase corporate productivity and personal income. The resulting longer work shifts may provide sufficient sleep time; however, rest periods may not promote uninterrupted sleep if they are not synchronized with the employee's circadian rhythm. This is a particular problem for both operating and maintenance staff in maritime, highway, and rail freight transportation, where work scheduling is keyed to customers' needs, equipment reliability, and weather. Here technology shows great promise. Positive train control may improve schedule regularity. Alertness detection technologies (e.g., PERCLOS, an automated camera-drowsy driver detection device) have the potential to reliably monitor operator alertness. The Global Positioning System provides the potential for enhanced monitoring of adherence to hours of-service rules (Ranney, 2000).

3.3.1 Fatigue

Van den Berg & Landstrom (2006) illuminated a serious problem with respect to sleepiness and traffic. The number of drivers with experiences of sleepiness is high. Their study supports a number of previous studies (ROSPA, 2001). Almost one-third of the drivers occasionally had to fight sleepiness while driving and about 8% of the drivers reported occasional head nodding/drops while driving. This must be considered as a serious traffic problem. The same conclusion could be drawn from the result that more than one-fifth of the drivers occasionally or more often had to stop their driving due to sleepiness.

Fatigue has three dimensions (Shinar, 2007) (1) Bodily changes, such as reductions in physiological potentials and neuron-muscular capabilities, (2) Performance changes, such as output and reaction time and (3) Subjective sensations, such as feelings of tiredness and sleepiness.

While Fatigue has been associated with task performance which can be relieved by changing the task, **Sleepiness** can be defined as the amount of perceived 'sleep pressure' (Vöhringer-Kuhnt et al., 2005) or the neurobiological need / physiological 'drive' for sleep (European Road Safety Observatory, 2006) typically measured in terms of sleep loss, time awake, etc. Moreover, **Drowsiness** is defined as a reduction of concentration (Vöhringer-Kuhnt et al., 2005) or as a transitional state from waking to sleeping and its further development can lead to sleepiness and then actual sleep to occur (Campagne et al., 2004) and **Tiredness** has no consensual definition and could mean lack of energy and initiative, which can be improved by rest, not necessarily by sleep (Mathis & Hess, 2009).

Saxby et al. (2007) support the theory of active and passive fatigue (Desmond and Hancock, 2001). Active fatigue results from the physical demands that are imposed upon drivers such as steering and acceleration changes, whereas passive fatigue results from underload driving tasks and monotony. While active fatigue appears to be characterized by symptoms of distress, passive fatigue appears primarily to elicit task disengagement, mental confusion and distractibility.

Fatigue can be caused by either **State induced** - sleep deprivation such as: lack of sleep, poor sleep or sleep demands induced by the internal body clock, or **Task induced** as a result of a monotonous task or 'time-on-task' (European Road Safety Observatory, 2006). To have greater control over the level of fatigue, and to reduce the costs of the experiments, we will only use task induced fatigue in the model validation studies.

Three physiological correlates of fatigue have been studied quite extensively: heart rate variability (HRV), blinking behaviour, and electro-encephalogram (EEG) recordings from the skull (Shinar, 2007). One of the most popular subjective measures of perceived fatigue related to the driving task is the Swedish Occupational Fatigue Inventory (SOFI) one more is the Dundee Stress State Questionnaire (DSSQ; Matthews & Desmond, 1998) assess transient states associated with stress, arousal, and fatigue, and reflect the multidimensionality of these states, how changes in task engagement (and presumably boredom) vary with the cognitive demands of the task (Matthews & Desmond, 1998, Saxby, 2007). Furthermore, the Karolinska Sleepiness Scale (KSS) is the only scale for sleepiness that has been validated in the driving context. KSS is a nine-grade scale (1 very alert and 9 very sleepy) that refers to perceived level of sleepiness (Lützhöft et al., 2007)

In the railway domain, studies of train drivers has shown that the highly irregular work hours are associated with very shorter sleep and increased sleepiness. This is due to a high proportion of early morning shifts (starting before 6.00 a.m.) and short breaks between shifts. High prevalence of severe sleepiness during early morning shifts has been reported in several studies (e.g. Härma et al., 2002, Ingre et al., 2008). Sleep quality and quantity was worse when not sleeping at home (Ingre, 2000, Jay et al., 2006, Lamond et al., 2005). Train drivers also report higher level of symptoms of insomnia compared to day-time workers but also to other shift-work groups (e.g. Ingre, et al., 2004, Hack et al., 2006). Sleepiness effects “driving style”, with more reactive “driving style” and “cognitive disengagement” with high level of sleepiness (e.g. Dorrian et. al., 2006). Long drives with no stops, combined with monotonous task increase sleepiness. (Ingre et. al, 2004)

Of the independent variables mentioned here, fatigue is probably the one which has received most attention in the marine domain. In commercial shipping over long distances fatigue is both task induced and state induced. For high speed boats, short haul shipping and leisure boats sleep deprivation may be of higher magnitude than task induced fatigue. The working situation of personnel on commercial ships is often characterized by long shift work periods, which include night-time work. The major national and international organizations concerned with shipping have become aware that fatigue is a critical problem for safe and efficient shipping, and have adopted legislations and resolutions to limit for example working hours of ship personnel (Gander, 2005; IMO, 1993; Smith, et al., 2006) .Lack of sleep is not the only factor responsible for fatigue, improper sleep quality on board is as well of importance. It has to be noted that although fatigue is receiving much attention, the number of recent field studies onboard ships is still very limited. Methods used to measure fatigue include psycho physiological measurements, standardized questionnaires, performance, and sleep logs, etc. Often the shift system (number of hours of work versus number of hour of sleep) is found to be accountable for the severity of fatigue experienced, which is not surprising, as more work and less sleep will cause higher fatigue levels. The effects of circadian rhythm are as well known: personnel working during late night hours often display higher levels of fatigue.

3.3.2 Effect of fatigue on the dependent variables

Studies have shown that lack of sleep, low sleep quality or excessive daytime sleepiness is significant predictors of driver fatigue as well as fatigue-related crashes (Van den Berg & Landstrom, 2006). Driving at times of the day that would normally be spent sleeping, or driving for prolonged periods are also associated with increased crash risk. Other studies have examined personality-related (e.g. sensation seeking and extraversion) showing an association between high levels of these factors and

greater propensity towards driver fatigue. Stress and its contribution to fatigue have also been extensively examined in the past and are well recognized in the literature. The impact of stress on fatigue is complex and person specific, as individual factors such as coping style, personality traits and social support all play a role in moderating the extent to which stress is experienced (see for more details in Strahan et al., 2008)

Several studies have shown that fatigue contributes to crash risk by significantly increasing reaction times especially in emergency situations and by influencing driving behaviour & performance - drivers perform worse on attention-based tasks when sleep-deprived e.g. are slower in hazards perception (ERSO, 2006, Strahan, et al., 2008). Time on task had also a significant effect on EEG indices, indicating a progressive worsening of driver's vigilance level (Campagne et al., 2004). Furthermore, fatigue reduces information processing ability and the accuracy of short-term memory (ERSO, 2006).

Nearly all studies investigating factors contributing to driver fatigue involve monotonous road environments and/or straight roads and low traffic density. Monotony of road environment (very few stimuli e.g. only rows of trees or intermittent background scenery) has an adverse effect on driver performance (Saxby, 2007) but fatigue caused by driving in complex road had the greatest impact on driving behaviour (Liu & Wu, 2009).

In the railway domain, there is very strong scientific evidence from all parts of the world to state the negative effects on train drivers' performance during night shifts and on early morning shifts due to sleepiness (fatigue). This has been shown in all types of studies; in simulator, case studies, and studies of incident reports, using objective measures as well as questionnaires and sleep diaries. There is also an interaction between early morning shifts and time at task (Ingre et al., 2004). Studies have also reported severe sleepiness common during night shift with missed stop signal and sign of speed reduction (Torsvall et. al. 1987).

Drivers showing symptoms of insomnia had also been involved in incidents and accidents more often than drivers without such symptoms (Ingre et al, 2000). Younger train drivers had a greater risk for severe sleepiness than older drivers (Härma et al., 2002).

A survey of in depth accident report showed that about one third of the accidents stress and fatigue seem to have been contributory factors (Kecklund, et.al., 1999). Results from studies of SPADs and incident reports has shown that accident risk grew with increased consecutive driving hours and doubled that of the first hour after four consecutive hours of driving (Kecklund, et.al., 1999). For example van der Flier and Schoonman, (1988) showed that many SPADs, signals passed at danger, occurred between 6 am and 8 am. The probability of error was highest during the second and third hour of the shift, to then drop towards the end of the shift.

Stress, sleepiness, fatigue and sleep disturbances were related to a higher frequency of self-reported, work-related errors. Sleepiness and lack of job motivation were the most important factors explaining serious mistakes at work (Ingre et al. 2000).

Simulator studies showed that fatigue effected performance during speed restrictions (Dorrian, et al., 2006). Drivers with high fatigue levels used the brake less in three downhill conditions. Results suggest that there are certain types of track section where fatigue is most likely to have serious effect. The results suggest that highly fatigued drivers do not engage in compensatory braking behavior and may become disengaged from the driving task. Results suggest a switch from well-planned, prospective driving style to more reactive, less efficient pattern of train interaction while fatigued. At high fatigue levels, errors involving a failure to act (errors of omission) increased,

whereas incorrect responses (errors of commission) decreased. The term “cognitive disengagement” is used as an explanation.

Very few studies have been performed in the maritime domain in modern time. The number of crew members has been reduced quite drastically in the last decades, in combination with much new technology in the control rooms, which invalidates much of the older research studies. However, there is no reason to assume seafarers reacting any differently than other “drivers” to fatigue. The difference is that they cannot “stop the vehicle”, nor is there always anyone else rested that can relieve them. Even though the ship moves quite slowly into risky situations it moves quite slowly getting out of them as well. The rest regulations are international and watch systems do not take into account recent sleep research; (e.g. the need for at least 6 hours of sleep and the non-additional character of sleep periods, 4+4 hours do not equal an 8-hour period of sleep).

Most existing and available information is derived from different national maritime accident investigation boards. Unfortunately do the investigation boards use different methods for documentation, making comparison difficult (Ek et al., 2000; Håvold, 2000, Moreby, 1991).

3.4 Task demand (workload)

Task demand is the demands of the process of achieving a specific and measurable goal using a prescribed method. This parameter can be subjective and/or objective, dynamic parameter resulting from DVE interaction (Cacciabue and Carsten, 2009).

Workload is defined as the amount of information-processing resources used per time unit, for task performance (Wickens and Hollands, 2000 cited in Patten et al., 2006). A similar definition used elsewhere in this project is that workload is the rate of activity supplied by the operator in order to perform the task (Sperandio, 1972). When the activity measure used reflects all the effort allocated to the task, the two measures are identical.

From a Human Factors perspective, the driver and his task should be the focus of modeling safe traffic and transport systems, because the match between the car drivers' capabilities and the demands of the actual driving task determines the outcome in terms of a more or less safe driving behaviour. This relationship has been modeled by Fuller (2000, 2005), who called it the task-capability interface model (TCI) of the driving process. Driver capability is limited by personal competence (experience, training and constitutional factors, such as age, perceptual acuity) and shaped by momentary variations in driver states (e.g. fatigue, alcohol, time pressure).

The resulting balance of the comparison of task demand and driver capability is projected on an axis between control and collision, thus relating the task conception to safety considerations, i.e. the interface between the demands of the driving task to achieve a safe outcome and what the driver is momentarily able to do will lead to more or less safe driver actions and thus will have an impact on road traffic safety. (Fastenmeier & Gstalter, 2007)

In the railway domain studies have been carried out concerning train driver workload but also on train traffic controller workload. Studies of driver workload has shown that subjective mental workload could be reduced by improving the DMI, although this has only been tested with small scale DMI's, not with complex displays such as ERTMS (Scott & Gibson, 2009, Young & Grenier, 2009). Another small-scale experiment showed that a HUD displays could have a positive effect and reduce mental load (Davies et al., 2009). These results indicate that new support systems or presentations can have a positive effect but this must be more thoroughly tested. The introduction of ERTMS will provide

the drivers with considerably more information and automatic support functions and this will be a very important area for human factors research in the railway domain in the forthcoming years.

Results also indicate that experienced drivers have different strategies than novice drivers, and look at different information. This may have an effect on mental load. Different situations effects workload, for example is load high when entering a station area (Gillis, 2007), and attention must be switched between tasks.

APRECIH (French acronym for Preliminary Analysis of Consequences of Human Unreliability) is a generic method to analyse the consequences of human unreliability on system safety and to generate a set of design recommendations to increase system safety regarding both off-line and on-line human error prevention supports (Vanderhaegen, 1999). System functions have to be identified and human's role to achieve them is defined in terms of procedures, *i.e.* lists of tasks to be performed in work contexts during normal and abnormal system functioning. A failed task can be caused by three behavioural dysfunction factors: an acquisition related failure, a problem solving related failure and/or an action related failure. A consequence analysis consists of identifying scenarios of human unreliability. Work has been extended to a non-probabilistic approach, ACIH, which aims at identifying both tolerable and intolerable sets of human behavioural degradations, which may affect the system safety (Vanderhaegen, 2001). These methods have been applied to the rail system.

3.4.1 Subjective Workload

The ideal workload situation occurs when “homeostasis” is achieved, which can be described as a balance where coping and adaptation to task demands are optimal. (Saxby, 2007)

Workload or strain might basically be defined as the reaction to demand or stress. The consequences can be either positive or negative (Weller et al., 2006). Strain and performance are important as mediators between the concepts of driving task demand and traffic safety. (Fastenmeier & Gstalter, 2007) see figure 7.

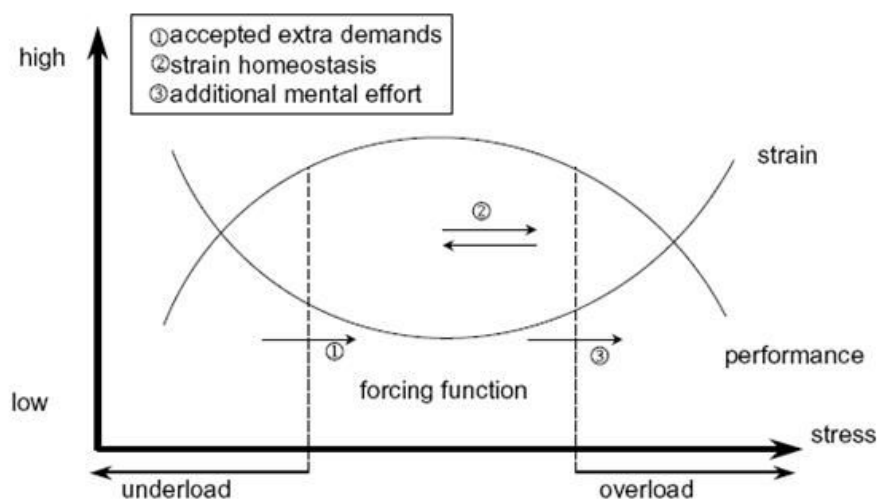


Figure 6- Relationship between stress, strain and performance (Fastenmeier and Gstalter, 2007)
The Driving Task Demand is presumed to be a function of two factors: the roadway baseline requirement and the proximity to the navigation choice point also called “Maneuver Proximity”.
The roadway baseline requirement is a general level of attentional demand that is more or less constant over a section of freeway. It is determined by the nature of the roadway and its features

e.g. geometric, operational, and environmental characteristics. The second factor is an increased demand as the vehicle approaches a navigational choice point which requires a driving maneuver (such as exit areas) and imposing additional load. The reasons for this increased load may have to do with the perceptual and control demands required monitoring conflicting traffic, finding gaps, determining the appropriate lane and speed, executing lane changes, and adjusting speed. It might also be related to increasingly urgent cognitive or emotional factors associated with resolving uncertainty. (Lerner et al., 2003)

The most popular subjective task load indices are the NASA-TLX (Task Load Index), SWAT (Subjective Workload Assessment Scale) & single or simple 'overall workload' question. Recent developed tool, the DALI – Driving Activity Load Index is proposed by Pauzié et al. (2007).

3.4.2 Effect of subjective workload on the dependent variables

As regards the workload associated with the use of driver support systems, workload depends on the characteristics of the systems concerned and the task to be carried out. Workload also depends on drivers' degree of adaptation of the system. (Saad, 2006)

While driving itself can be considered as a loading task, Makishita & Matsunaga (2008) investigated the effect of driving vs. stationary task and also driving with and without mental task on reaction time. They found that both driving and mental task increased reaction time; also, mental task influenced elderly drivers' reaction times significantly.

Some interesting findings regarding workload while using IVIS or ADAS were found. The values of the DALI factors showed significant difference between 4 experimental Sessions (low vs. high task demands with and without IVIS), with an increased level of workload for the driver. this tool allowed in a quick and reliable way to identify the global workload of a given context, and to bring additional precision about the level of load for the vision, the audition, the stress, the attention components for each of these driving contexts (Pauzié et al., 2007). Regan et al. (2005) argued that different ITS (intelligent transport systems) affect workload levels differently (e.g. using RCW or SRB might lower the workload while using ISA or FDW had no effect). Some studies showed that driving performance (e.g. lateral control) decline as visual demand increase, moreover, negative effect of the cognitive task on driving performance (e.g. longitudinal control in car following). Task completion time increase when driving versus while parking but driving in different levels of curvature had no effect on task completion time. Elderly drivers show very risky driving while performing IVIS tasks (Östlund et al., 2004, Tsimhoni et al., 1999, 2001)

Many maritime simulator studies are performed with higher speeds and/or higher workload than normal in order to get measurable results. The generalisability of such studies is doubtful. Even when a study is reasonably realistic, few studies have been made with real seafarers. Subjective workload assessments may be affected or even confounded by a “cultural factor”; in fatigue assessments subjective judgments are consistently lower than measured results. For certain nationalities extreme differences were shown (Chauvin, & Lardjane, 2008; Gould et al., 2009; Hockey et al., 2003).

3.5 Culture

Not only the rules of the road but also social environments, norms and driver behaviour may vary significantly from country to country and have a notable influence on the attitudes and behaviours of drivers. (Lindgren et al., 2007)

Little sociological research has been published on driving or car culture. There are, however, studies that examined the differences in road accident involvement among different social groups. Nevertheless, most such studies are not grounded in sociological theory. Furthermore, researchers often explain their findings as a social or cultural phenomenon without empirically examining their argument. The reason that socio-cultural aspects are not fully explored in studies of road safety is that culture is largely taken for granted, is immersed in experience, and is therefore invisible and difficult to study. Furthermore, cultural analysis is perhaps complex, as there is no agreement on the boundaries of the domain. Factor et al., (2007) investigated the influence of social and cultural characteristics on motor vehicle accidents. Although cultural aspects are difficult to measure and to manipulate, it is possible to investigate the effects of cultural factors on road safety (through simulation and laboratory research). Sociological and anthropological studies assess cultural differences among different groups-differences between nations, and between groups within nations, such as among social classes.

Özkan et al., (2006) claim that each country has its own problems in traffic culture. SARTRE, an acronym for "Social Attitudes to Road Traffic Risk in Europe", is a research project, which aims at studying the opinions and reported behaviours of car drivers throughout Europe. The project is based on ad hoc data collection, which involves a representative questionnaire survey. The main purposes of this project were to describe the state of drivers attitudes and reported behaviours throughout the continent with regard to road traffic risk, to evaluate the range from approval to opposition towards regulations and countermeasures, to search for underlying social or cultural factors leading to various behaviours in term of risk, and lastly to recommend actions to be taken into consideration when improving road safety policies. (SARTRE, 2004)

Organizational culture is typically described as the shared attitudes, values, beliefs and behaviours that occur within an organization (Schein, 1992). Those shared norms and ideas concerning safety culture that is specific to road safety can be considered as fleet safety culture (Strahan et al., 2008)

There is a large body of research literature on the concept of safety culture from all areas of industry (e.g Gadd & Collins, 2002). The review presented in this report has not included safety culture but has focused on cross cultural differences. In the railway domain cross cultural differences and its implications on safety has been an issue for the last ten years in the European railway community due to the fact the European Commission directives on interoperability. A few studies have been conducted concerning cross cultural differences and railway safety. For example the HUSARE project (HUSARE, 2000) examined safety in connection with cross-border traffic, interoperability and international harmonization. Also a method for safety assessment in cross border operation focusing on safety culture has been presented (SINTEF, 2004). This study used the safety culture perspective to address cross cultural differences. Both studies focused on developing methods.

In the maritime domain "culture" is a term full of nuances as it could be found at different levels. The most common and most studied is the dilemma to overcome differences in culture background in aim to harmonize culture differences within a crew, between different ship-owner and their ships (the difference between ships within same company could be considerable, and large ship is almost a world of its own). The outcome from these studies often touches upon the issue of safety in broad terms, i.e. policy standard operation procedure, SOP, etc. It has a natural explanation as many of the investigations performed after incidents often point out lacking communication within crews as one of major "human errors" to an unsafe situation escalating to an undesired event. These studies have usually been performed as ethnographical studies on board ships during longer journeys or as repeat journeys with specific ships in specific areas (Broberg, No date; Ek et al., 2000; Moreby, 1991).

3.5.1 Effect of Culture on the dependent variables

Cultural differences can affect different transport perceptions and cause difficulties in inter driver communication, thus leading to the increased probability of an accident. Culture influences action through shaping a behavioural repertoire or “tool kit” that includes habits, skills, and styles that people employ to build “strategies of action.” Every group has its own “tool kit” and particular cultural characteristics that cause its members to interpret the environment and to make decisions in a particular manner. Accordingly, drivers who belong to different groups might vary in interpreting similar events while driving and, consequently, make conflicting decisions, thereby increasing the risks of their being involved in an accident. (Obviously there are different levels of homogeneity within groups. Yet, it is reasonable to assume that, on average, heterogeneity within groups is smaller than between groups. (Factor et al., 2007)

As was pointed out in SARTRE (2004) in many countries some typical driving habits and widely spread attitudes that might be a serious problem in road safety can be found. But similarities between the countries can be found as well: The majority of drivers in most countries point dangerous driving behaviour to other road users and considers their own behaviour relatively safe. The proportion of drivers who indicated that they experienced aggression towards them (e.g. following too closely, driving through amber lights, dangerous overtaking) is higher than the percentage of drivers that admitted own aggression towards other drivers. Most Studies dealing with cross cultural differences in driving found significant effect on behaviour and performance variables such as: speed choice (Warner, Özkan & Lajunen, 2009), risk perception and risk taking (Lund & Rundmo, 2009, Nordfjarn & Rundmo, 2009, Sivak et al., 1989), driving style or aggressive driving (Lindgren et al., 2007, Özkan, 2006) and accident involvement (Bener, Ozkan & Lajunen, 2008).

Few studies have been published regarding culture in terms of navigation, collision avoidance, high speed, reaction time and risk perception. Most studies in this area have been performed by navies, coast guards, police or ambulance or rescue service, which usually are difficult to obtain (Ekornås et al., 1999; Chappelow & Stewart, 2005). Those few studies we have obtain indicate that simulator training have a tendency to increase the willingness to take more risks, as the subjects in many aspects regard the simulator as a game, and that behaviour is transferred to the real situation. In studies, also including simulators, there is the tendency that subjects usually abandon navigation technology for the benefit of using visual observation of the environment, when the speed, risk or workload increases (Gould et al., 2009). It is assumed this is a way of keeping control of the situation by going “back to basics” and abandoning, temporarily, the high-technology “aids”.

4. TASK ANALYSIS

Task analysis is a way of representing driver behaviour during the performance of actions. In accordance with Task Analysis theories, a task is described by a number of functions, which represent the basic driving actions. Moreover, pre-conditions and goals are associated to each task. Pre-conditions enable to launch a specific task, when they are generated by the Driver-Vehicle-Environment (DVE) dynamic interaction. Goals are described in terms of vehicle and driver states that enable to define the completion of a task.

4.1 Task analysis of car driving

One of the most famous and extremely extensive task analyses was compiled by McKnight and Adams (1971). They indicated more than 1000 driving behaviours which were grouped into tasks in order to be more practical. Main tasks are: Basic control (e.g. starting, accelerating, steering, stopping), General driving (e.g. navigating), Tasks related to traffic conditions (e.g. following, passing, changing lanes, parking) and Tasks related to roadway characteristics (e.g. intersections, curves, road surface and obstructions). Other tasks are related to the environment (such as weather or time of day). Two types of tasks are assigned: *permanent tasks* and *normal tasks*. **Permanent tasks** (e.g. *Keep lateral and longitudinal safety margins*) do not require specific pre-conditions to be launched. These tasks are associated with the fact that drivers "automatically" keep the vehicle within lane margins and do not hit vehicles or obstacles in front ("skill-based behaviour"). **Normal tasks** are instead all those tasks that are launched as result of a decision making process, such as *overtake, change lane, stop / reverse vehicle, Turn left/right* etc. ("rule-based behaviour"). The permanent tasks are essential for the dynamic simulation of DVE interaction. They aim at keeping the vehicle under control with respect to longitudinal and lateral coordinates of the driving environment (road and traffic) and support the ability of selected speed and position, in terms of steering, accelerating or braking (Cacciabue & Carsten, 2009). Critical situations such as obstacle avoidance or required change of speed will then initiate drivers' behaviour that is represented by the normal tasks. Recently a new method for driving task analysis and driver requirement assessment has been developed by Fastenmeier and Gstalter (2003). The **Basic driving tasks** occur throughout all driving levels and have to be regarded as continuous tasks shaped by situational aspects which have to be defined specifically in each task to be analyzed. For example; within the navigational (strategic / planning) level of driving – basic tasks are to find and reach a defined destination, correspondingly, guidance (tactical) level of driving includes: lane choice, lane changes and turning maneuvers, on the control (operational) level the main tasks are: steering and speed control. Further tasks are - control of car conditions (e.g. reactions on displayed information), self-assessment of driver state (e.g. fatigue) and control of selective attention (such as; observation of oncoming traffic, searching for potential hazards, obeying traffic rules, ignoring distractions). See figure 7

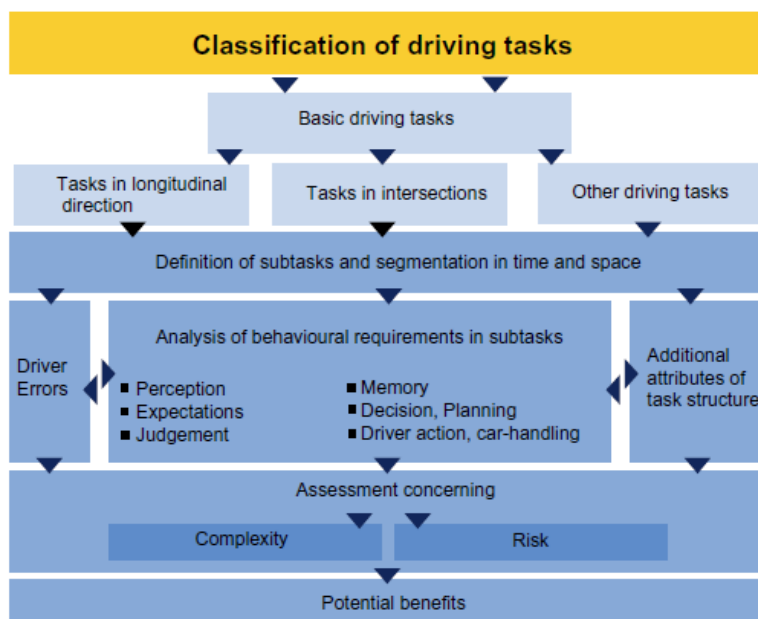


Figure 7 - Driving task classification and the analysis of requirements (Fastenmeier & Gstalter, 2003)
 Main driving tasks are *longitudinal tasks* and *tasks at intersections*. **Longitudinal** tasks are defined as driving tasks in intersection-free traffic flow, which combine driving situation characteristics (overtaking, car following, free driving etc.) relating to the traffic, with types of roads (rural and urban roads) and their characteristics (see classification of road and traffic situations, table 1, in Fastenmeier & Gstalter, 2007). Tasks at **intersections**, are combination of intersection type (e.g. 4-access road, T-junction, roundabout), intersection control (e.g. traffic lights, road signs, right hand rule), type of connection (combination and type of access roads, number of lanes) and driving direction (straight, right / left turn, U-turn). **Other driving tasks** mean crossing railways, driving in special surroundings and special situations or tasks such as driving under special sight or weather conditions (e.g. fog, snow, night-time).

The analytical unit for the analysis of behavioural requirements is the subtask level. The driving task therefore has to be decomposed into subtasks. The same subtask can occur in several driving tasks and should therefore be analyzed in the specific context of the task under investigation. An example of driving a typical horizontal curve and corresponding information-processing subtasks (perceptual, cognitive & psychomotor requirements) is shown in figures 8, 8a, 8b, 8c a7 8d (Campbell et al., 2008).

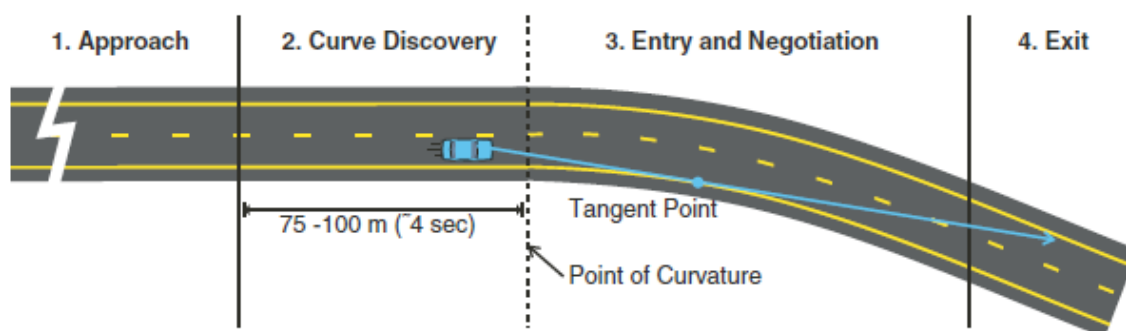


Figure 8 - segments of curve driving task (Campbell et al., 2008)

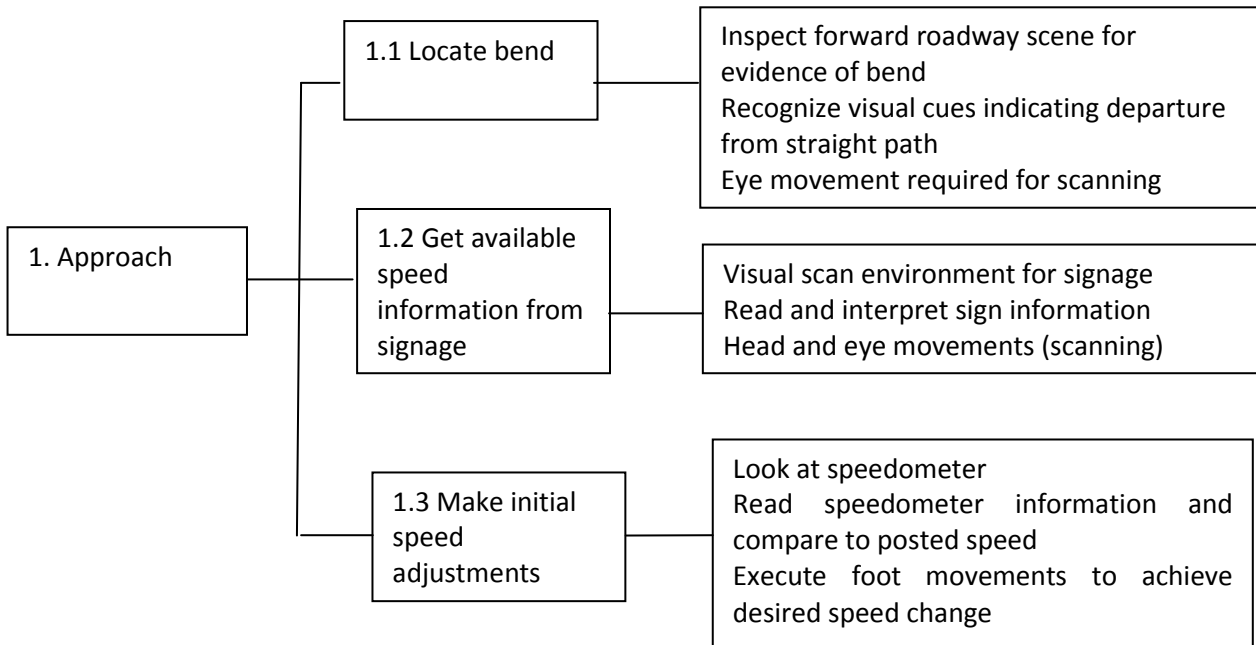


Figure 8a – task analysis for approach segment

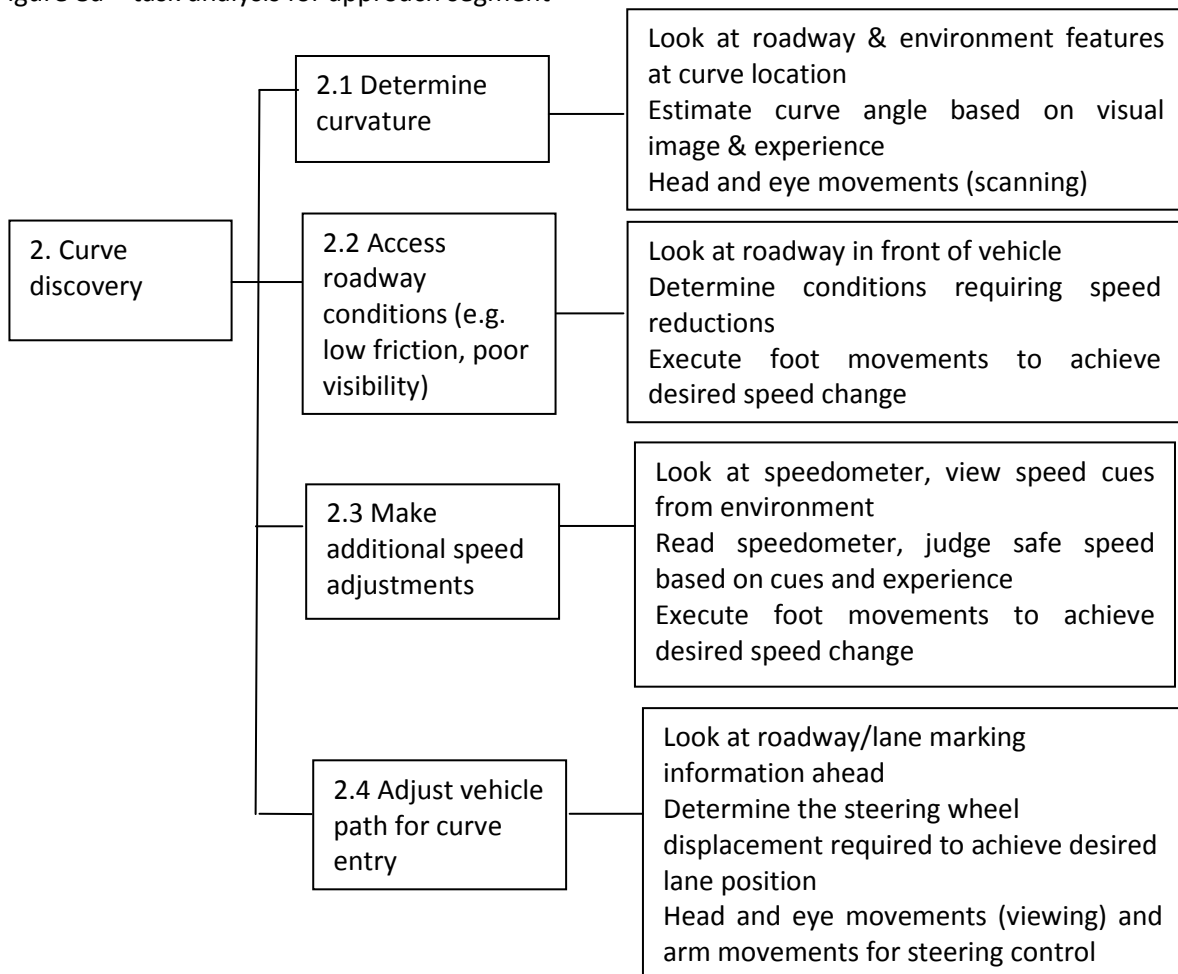


Figure 8b - task analysis for curve discovery segment

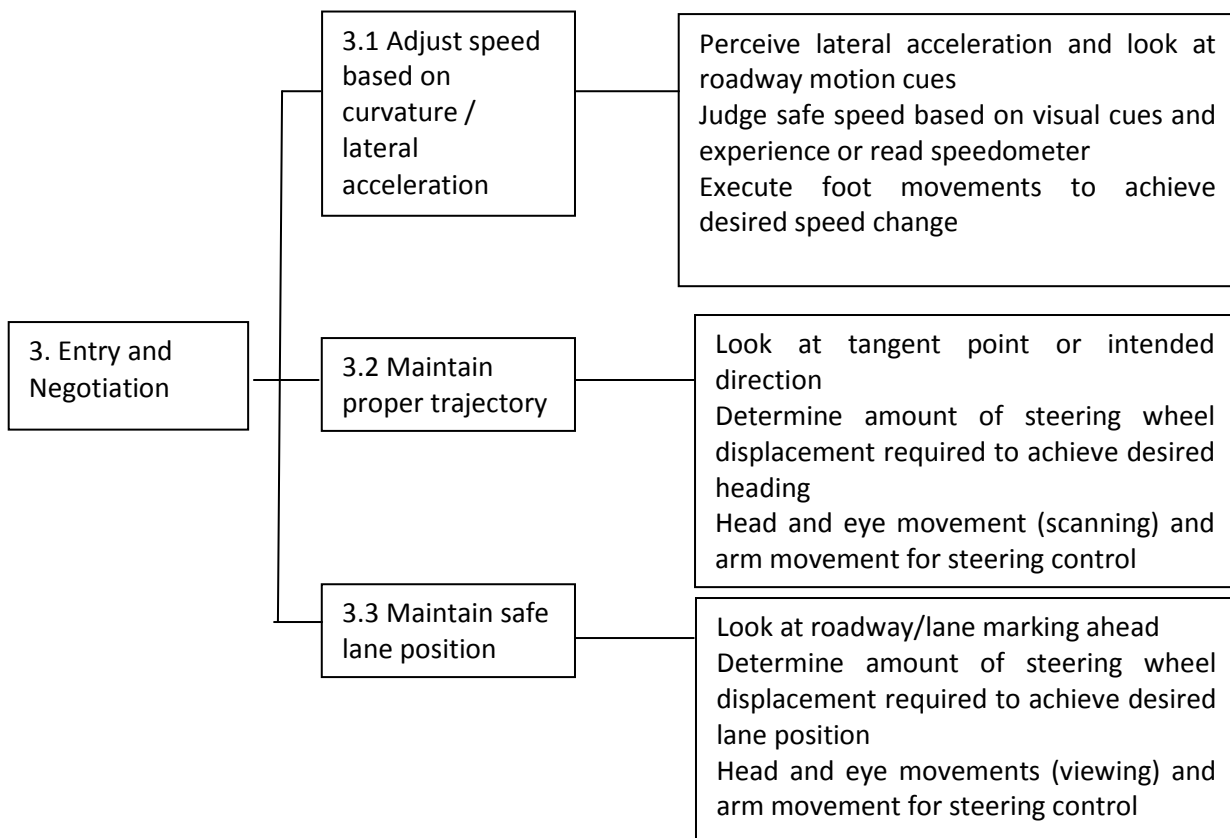


Figure 8c - task analysis for entry and negotiation segment

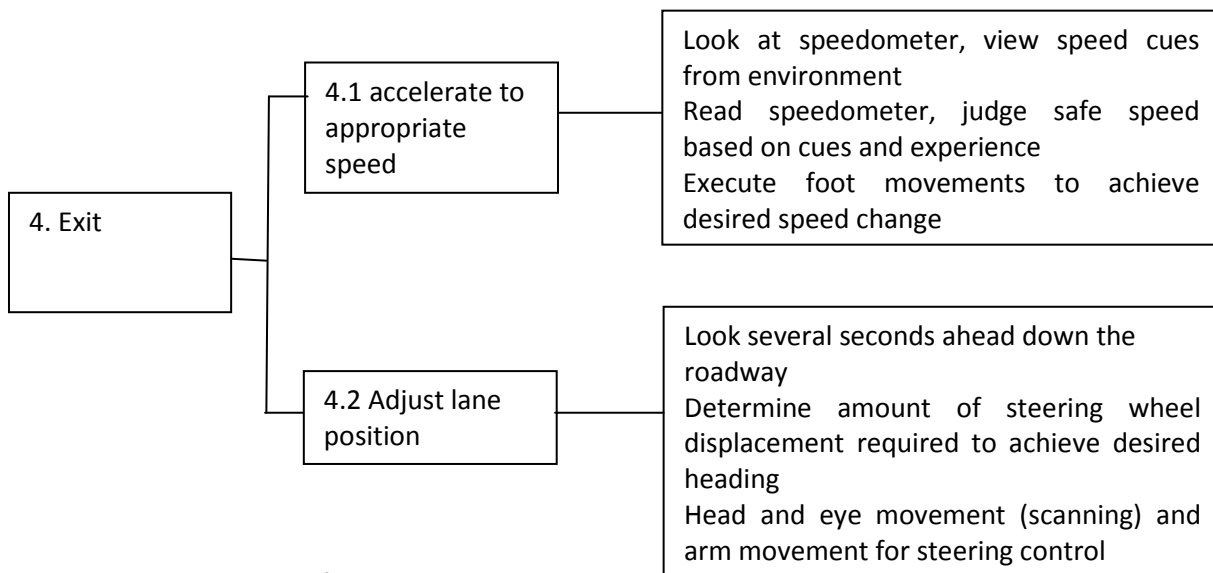


Figure 8d - task analysis for exit segment

4.2 Task analysis of train driving

The main function of the train transportation is "Driving passenger or goods from a departure to an arrival point"(Vanderhaegen, 1999; Vanderhaegen, 2001).

The present task analysis deals with the functions realized by the train driver in order to build a behavioural model of her/him. Moreover the analysis of the task which has to be performed by the train driver represents the essential first step before measurements, such as Workload measure.

Unlike the car driver who has to maintain both lateral and longitudinal control of the car, the train driver is relieved from lateral control and therefore has fewer degrees of freedom than the car driver. However, velocity longitudinal control is more complicated because of the train's long reaction time to velocity changes. Therefore the driver has to behave in anticipatory manner as a predictive controller, before his actions are reflected in the acceleration or the deceleration of the train. Therefore to assure safety, the driver has to continuously attend to and rely on information sent from the Control Room via the in-vehicle and infrastructure-based signalling system.

The train driver has to "Realize movements on field". This main function performed by the driver can be divided into three subtasks which are "Prepare movements", "Drive" and "Realize a customer service". The third subtask "Realize a customer service" is excluded from the present task analysis because it is not relevant for the most train drivers.

The next figures show the detailed analysis of the "drive" subtasks: "Prepare movements" (see Figure 9a) and "Drive" (see Figure).

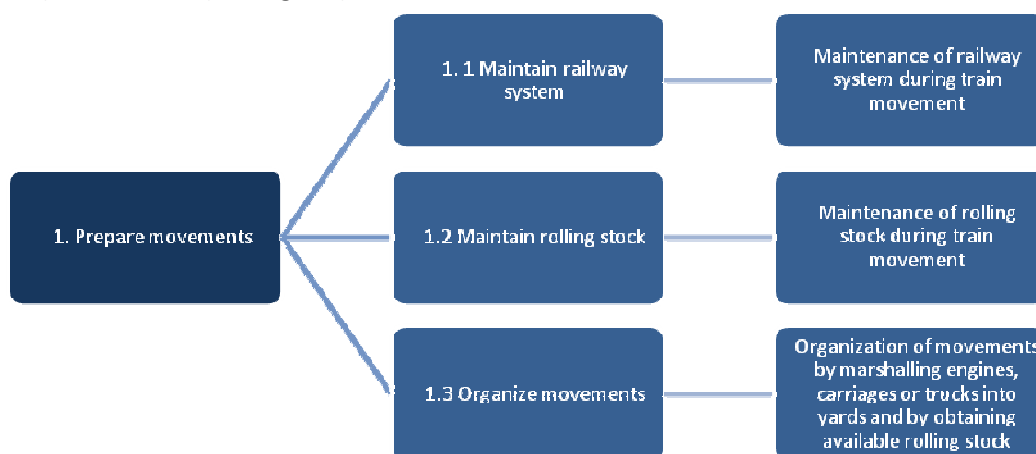


Figure 9a - subtask "Prepare movements" (Vanderhaegen, 1999; Vanderhaegen, 2001)

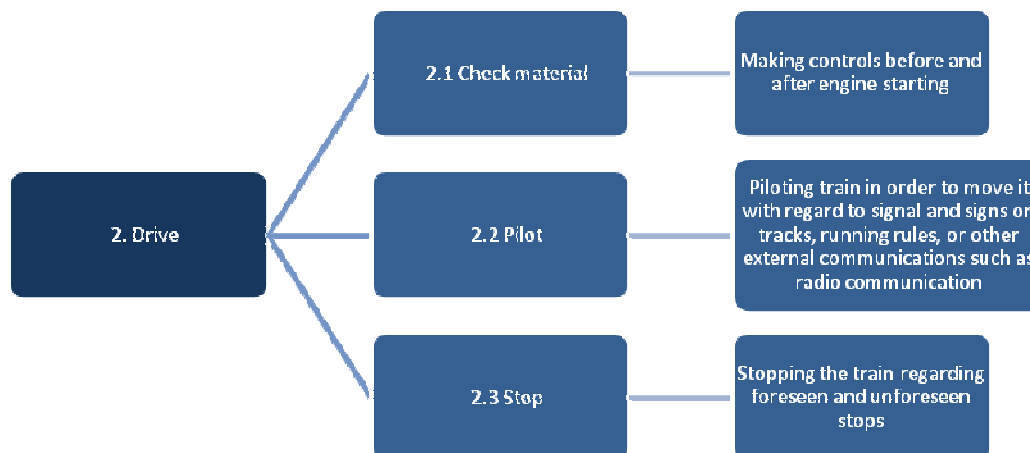


Figure 9b Tree of the subtask "Drive" (Vanderhaegen, 1999; Vanderhaegen, 2001)

The study of the train driving analysis assumes no technical failures. From this perspective an overseeing of the subtasks "Pilot" and "Stop" is relevant to the train driving task (see Figure and Figure).

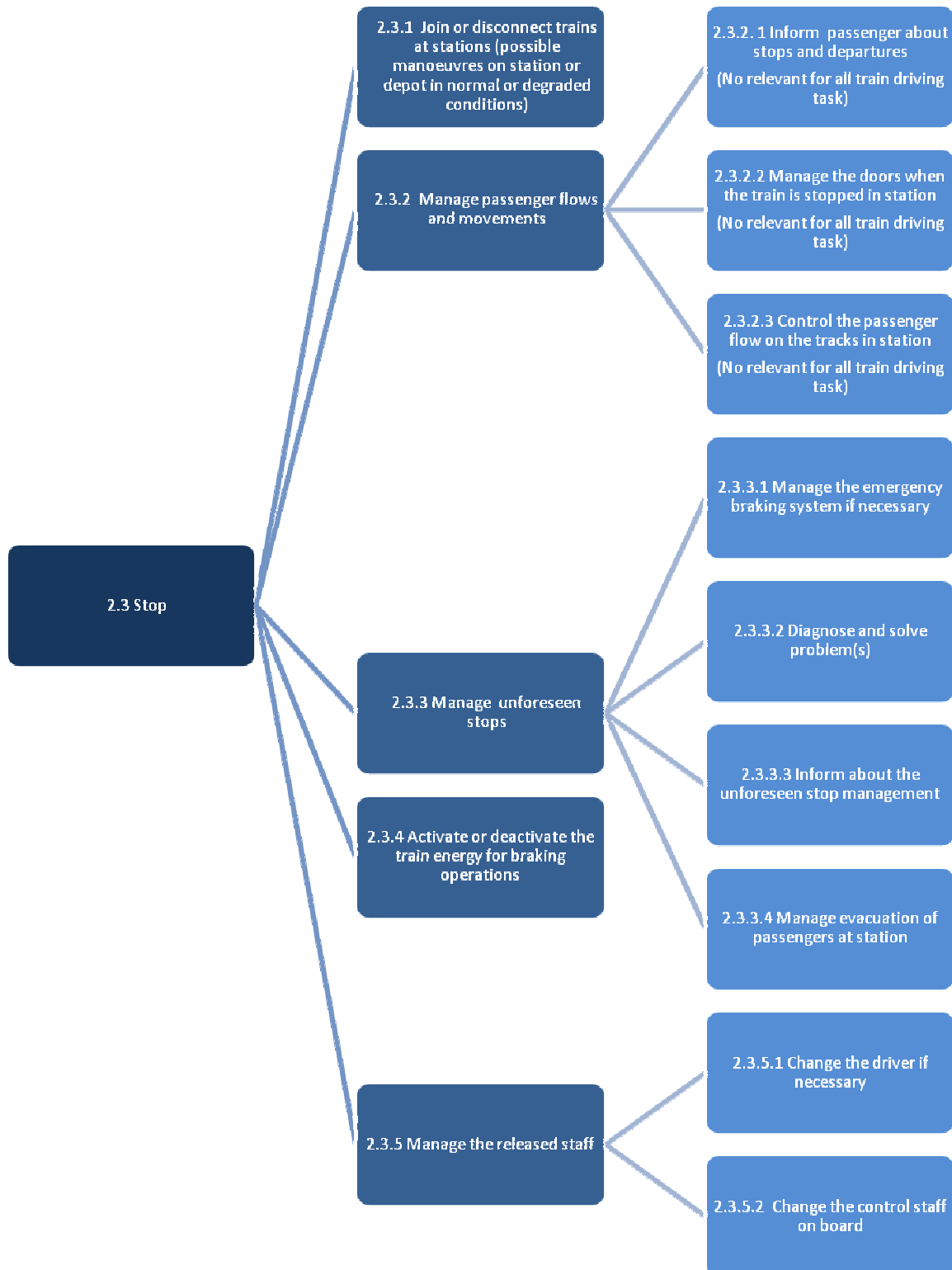


Figure 9c - subtask "Stop" (Vanderhaegen, 1999; Vanderhaegen, 2001)

The driver performs alternatively manoeuvres task, communication task and cognitive task in the case of an unforeseen stop, for example. The unforeseen stops represent obstacles on the railroad such as pedestrians, cars, tree, a non-announced train, etc.

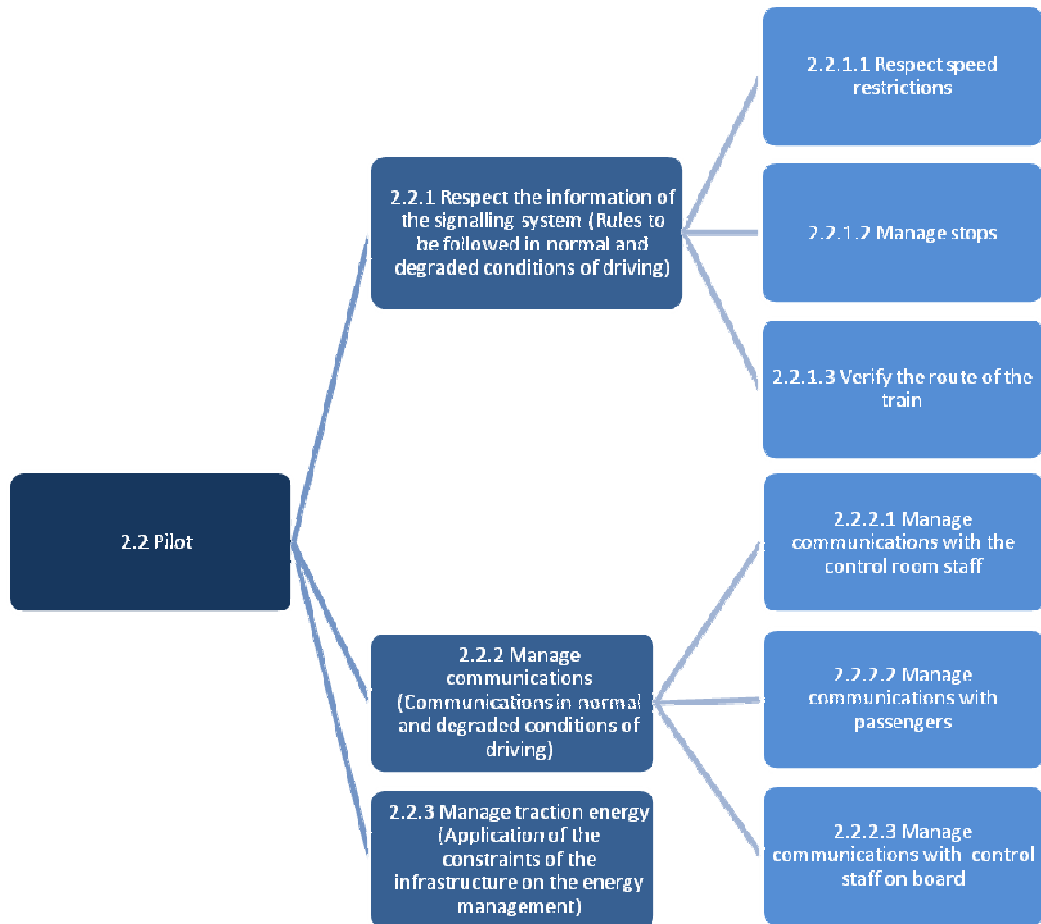


Figure 9d - subtask "Pilot" (Vanderhaegen, 1999; Vanderhaegen, 2001)

5. ENVIRONMENTAL PARAMETERS INFLUENCING DRIVING SAFETY

Although the driver is the main actor in the driving activity, driving is not an isolated activity. It takes place in a wider context in which the driver constantly interacts with its immediate environment and the vehicle. The model of the environment is described by considering environmental parameters such as road/track/fairway, traffic and visibility conditions, from the aforementioned literature review.

After the review of existing studies relating environment features with driver behaviour, it becomes necessary to select the environment parameters to be included in the Model. We have decided to focus on:

1. Road / Track/ Fairway – infrastructure and impermanent factors

Road Type (for cars) - number of lanes, lane width, divided highway, and locality (urban, suburban, and rural)

Track Type (for trains) – speed train tracks (high vs. low speed), locality (urban, suburban, and rural), and the age of the track (outdated, updated, etc.)

Fairway Type (for ships) – width (restricted by environmental aspects such as shallow water, rocks, islands etc), age and upkeep of fairway (e.g. dredging, maintenance), existence and types of Aids to Navigation (AtoNs) such as buoys, lighthouses etc.

Alignment (for cars) – curves, sight distance - the length of roadway visible to a driver

Alignment (for trains) - route in relief (hilly landscape, mountain, bridge, etc.)

Alignment (for ships) – turns, sight distance, height of ship's bridge vs. landscape

View obstruction – e.g. hedges, signs and other roadside structures or vegetation, parked vehicles

Surface conditions – slick road due to rain/ ice/ snow or grease (debris)

2. Traffic

Traffic density - Vehicles per mile / km

Traffic mix - Cars, motorcycles, Large / Heavy Goods Vehicles

There is no parallel to 'traffic' in the train domain. This is because track occupation is regulated from the control room to avoid potential train conflicts in the same track section. The impossibility of "lane changes" in train driving eliminates issues such as unpredictable behaviour of other drivers using the 'road'. Train drivers still have to deal with unexpected obstacles on the track and may have to brake or even stop the train. In this project we consider such obstacles as characteristics (parameters) of the scenario rather than independent variables.

Traffic density and mix are relevant to ships. Since ships move in two dimensions and are not restricted to tracks or even a road, the complexity of traffic is high. It is therefore reasonable to restrict the studies to a marked fairway. The mix of traffic is similar to road traffic, in which commercial ships, fishing vessels and leisure craft all follow slightly different sets of "rules".

3. Visibility

Weather – Rain, Snow and Fog

Time of day - Lighting conditions

5.1 Road / Track / Fairway

Although the human factor is more dominant than road or vehicle factors in the happening of accidents, the control of the road factor is much easier than the human factor. Moreover, by making

a geometrically good design, it is even possible to compensate for the other factors and thus decrease the number of traffic accidents. (Iyınam et al., 1997)

There are many roadway features (infrastructure or impermanent factors) for different road classes and these features are related with traffic accidents in one way or the other. The road can be described by its; 1) type, meaning number of lanes, lane width and divided road, for cars, or speed train tracks (high vs. low speed) and the age of the track (e.g. outdated, updated) in the trains domain as well as locality (urban, suburban, and rural) for both domains, for ships - width (restricted by shallow water, rocks, islands etc.), age and upkeep of fairway (e.g. dredging, maintenance), existence and types of Aids to Navigation (AtoNs) such as buoys, lighthouses etc. 2) alignment (vertical & horizontal), in the sense of curves, grade of tangent and sight distance for cars and route in relief (e.g. hilly landscape, mountain, bridge) for trains, turns, height of ship's bridge vs. landscape, sight distance, for ships, 3) View obstruction (e.g. hedges, signs and other roadside structures or vegetation, parked vehicles) See figure 10 for sight distance with and without view obstruction, and 4) Surface conditions – slick roads due to rain/ ice/ snow or grease (debris).

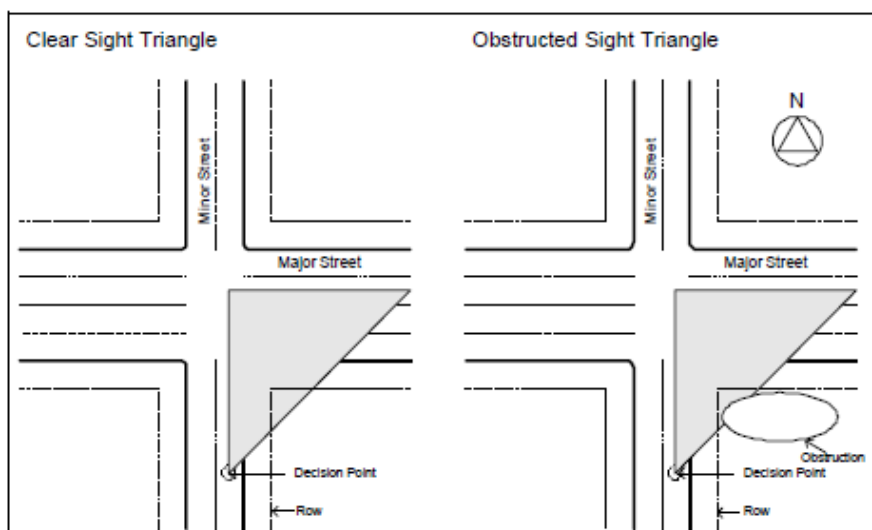


Figure 10 –clear vs. obstructed sight distance

Most of the studies proved that the width of the lane has an obvious effect on accidents; as width increases, traffic accidents decrease. Also, many studies have shown that the safest road is a divided, multi-lane road with interchanges; and the level of safety decreases on three-lane roads.

Studies show that as horizontal curve grade is increased the number of accidents increase. Drivers need more visual input for curves than for straight sections of roadway, indicating that curves require greater visual demand. It was found that visual demand is inversely related to the radius of curvature but does not vary much with deflection angle. Visual demand begins to rise at the end of the approach tangent and peaks at the beginning of the curve followed by a decline throughout the curve; this effect is higher for s-curves than for broken-back curves (a broken-back curve has two curves in the same direction whereas an s-curve has two curves in opposite directions) but the effect was weakened with a large separation between the curves; These findings held for both on-the road and simulator studies (AIDE D1.1.4). Since driving simulators do not simulate vertical curves (hill and valleys) adequately and test-courses are usually flat, the effect of this roadway characteristic has not been studied. We will not deal with it as well.

As was found by Treat et al. (1977) view obstructions are the most frequent environment causal factor. Of the view obstruction sub-categories, the most frequently cited was: hedges, signs, and

other roadside structures or vegetation followed by parked vehicles, which are particularly a problem in limiting sight distances at urban intersections. According to Treat et al. (1977) of the slick roads sub-categories, road wet was the most frequent cause of accidents followed by road snow and/or ice covered. Codling (1974 in Chung et al., 2006) concluded that in terms of numbers of accidents, the greatest weather problems are associated with rain and wet roads. From the data collected by Codling in Great Britain in 1970, 31% of all injury accidents occurred on wet roads, nearly half of them when rain was falling (and affecting visibility).

Several other roadway characteristics undoubtedly affect driving safety, e.g. shoulder width and traffic control. Theoretically, each of these features can increase the uncertainty of the driving task leading to increased errors. However, we decided to focus on the above mentioned.

5.2 Traffic

Traffic density was related to the highest incident rate by far of any of the environmental and roadway contributing factors for Rear-End lead-vehicle scenarios and for lane change related scenarios in the 100-car study of Dingus et al. (2006).

While the traffic density increases, for a given driving situation, the probability of a vehicle doing something unexpected increases. As such, increases in traffic density should increase visual demand. Using a medium-fidelity simulator and the visual occlusion method, Mourant and Ge (1997 in AIDE D.1.1.4) presented two levels of on-coming traffic density (no traffic and “moderate density”) to subjects while they drove both curved and straight roadway sections. Results showed that the percent of non-occluded vision increased with increasing traffic density; that is, visual demand was 8% higher for moderate traffic than for no traffic. This effect, however, was found only for driving curves. Whether or not visual demand was affected by high density traffic on straight sections of roadway is unknown, but would undoubtedly increase demand on curved sections of roadway.

5.3 Visibility

There is unanimity that inclement weather is associated with more hazardous driving conditions. Various studies show that precipitation in the form of rain and snow generally results in more accidents (Chung et al. 2005, Keay and Simmonds, 2005). Chung et al. (2005), investigating the Tokyo Metropolitan Expressway during 1998-2004, argued that rain has a significant effect on the average frequency of accidents. Keay and Simmonds (2005) found the rain effect to increase daytime and night time accident count by 1.9% and 5.2% over dry mean accident count in Melbourne, Australia, during the years 1989–1996. Rain affects driving both in terms of vehicle handling (as wet roads reduce tyre pavement friction) and in visibility.

The weather conditions during a particular driving situation should influence visual demand, especially if conditions degrade visual perception (such as rain or fog) or increase the difficulty of maintaining lane position (such as with a strong cross-wind or an icy road). Probably because these conditions are difficult to simulate, an extensive search of the literature revealed no studies that have investigated visual demand of driving in inclement weather (AIDE D1.1.4). Data from questionnaire studies has shown that drivers acknowledge the need to modify their behaviour to adapt to weather conditions. However, a study by Edwards (1999 in AIDE D1.1.4) showed that in practice drivers only marginally alter their driving habits to adapt to bad weather conditions. The results of observation of driving speed in different conditions - Sunny, clear spells; dull, overcast, cloudy; steady/heavy rain; drizzle, road surface spray; and misty, fog - showed that drivers only

inconsequentially slowing down by a few miles per hour during rain, but such minor reduction in speed would barely influence their ability to respond in the event of an incident ahead. Although drivers' behaviour changed during rain such as decrease in speed and increase in headway, the increase in accident clearly shows that drivers are not compensating for reduced visibility (i.e. longer reaction time) and longer braking distance, sufficiently. Therefore, we should bear in mind that weather conditions affect driver performance whereas they hardly affect driver behaviour. Nevertheless, these weather conditions should be included as environment parameters in the DVE model.

6. INTERACTION BETWEEN THE ENVIRONMENTAL PARAMETERS AND THE DRIVER VARIABLES

Matthews (2002) presented the transactional framework for driver stress (see figure 11). In that model (1) environmental stressors such as poor visibility, poor road conditions and impedance due to other traffic and (2) personality factors that influence how external stimuli are interpreted in the light of the driver's personal concerns (For example, a traffic light might be seen as impedance by a frustration-prone driver, but appear inconsequential to another driver) interact to bias cognitive stress processes (that include comprising appraisal processes that support evaluation of the personal relevance of stimuli and coping processes that support choice of action to manage perceived demands). Cognitive stress processes lead to two forms of outcomes: subjective outcomes such as anxiety, anger and tiredness, and performance outcomes such as impairment of psychomotor control and changes in speed (Matthews, 2002).

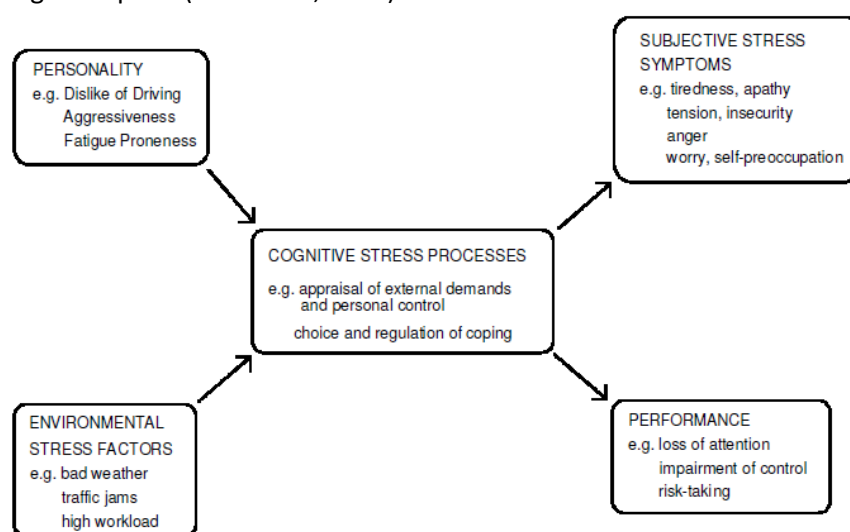


Figure 11 - An outline transactional framework for driver stress (Matthews, 2002)

Common to all three domains (cars, trains, ships), is the fact that they all operate within a structured environment: from highly structured (smaller degree of freedom) in the case of trains, to semi-structured in the case of cars. Therefore, the safe operation is dependant not only on the driver/operator but also on its relationships with other participants (such as other ships, the train traffic controller, and other drivers), and a constantly changing environment. This section will present the interaction between the selected driver variables and the selected environmental parameters according to the literature.

6.1 Environmental parameters & Attitudes / Personality (Sensation Seeking)

Attitudes/Personality is a complex mental state involving beliefs, feelings, values and dispositions to act in certain ways. **Sensation Seeking** is defined as seeking of varied, novel, complex and intense sensations and experiences and the willingness to take risk for the sake of such experience. There is a relatively weak, but consistent, interaction between personality traits and road crash involvement, but a relatively strong interaction with the propensity to commit driving violations. Personality traits are primarily believed to influence behaviour, which in turn may influence the chance of being involved in a road crash. Road crashes, on the other hand are typically a consequence of driver behaviour that is predicated on the driver's personality and needs, the current environmental constraints and the vehicular limitations. 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.

6.2 Environmental parameters & Experience (HP skills)

Experience is the accumulation of knowledge or skills that result from direct participation in the driving activity. **Hazard perception (HP) skills** include discovering, recognizing and reacting to potentially dangerous situations. Hazard perception is a highly cognitive task influenced by attention and vigilance factors, which are influenced by the interaction of circadian-mediated alertness nadir, and increased homeostatic sleepiness (Smith et al., 2009). In our simulation study, hazard perception will be used as a discriminating variable between experienced and inexperienced drivers.

When inexperience was assessed as being causally-related, drivers were four times as likely to have an accident in which bad highway design was cited as a cause, as when it was not. The more experienced the driver the more familiar he is with bad highway designs, and the more able he is to respond to them. Environmental factors are most likely to increase the accident involvement of novice drivers. In the case of reduced vision, the danger of view obstruction is increased. Restricted vision makes overcoming new obstructions more difficult in general, and increases the probability of view obstructions being implicated as accident cases, in particular. The influence of environmental factors on novice drivers could be due to the effects of violating driver expectancies. The less experienced drivers are the ones that are most likely to be affected when common expectancies are violated. (Treat et al., 1977)

Inclement weather is associated with more hazardous driving conditions. Novice drivers have only limited driving experience in risky circumstances (e.g. wet weather). Finnish drivers with more experience of driving on slippery roads adapted their behaviour to slippery roads about as much as more inexperienced British drivers (Peltola & kulmala, 2000).

Smith et al. (2009) found no main effect of time-of-day on the QSHPT (Queensland Spatial Hazard Perception Test). Yet, experienced drivers were faster at responding to traffic conflicts than novices and novices were significantly slower at night compared with during the day.

In shipping, anecdotal data suggest that "complacency" is found at the highly experienced end but there is little data on this.

6.3 Environmental parameters & Driver state (Sleepiness)

Driver state is the driver physical and mental ability to drive (e.g. fatigue, sleepiness). **Fatigue** can be caused by either *State induced* - sleep deprivation such as: lack of sleep, poor sleep or sleep

demands induced by the internal body clock, or *Task induced* as a result of a monotonous task or 'time-on-task'. We can look at the interaction between sleepiness and environmental parameters in two ways; first, what happened to sleepy driver (state fatigue) in different types of roads or in different situations (curves, slick roads, and heavy traffic) or on the other hand what is the effect of the environmental parameters on creating sleepiness in drivers (task induced fatigue).

Driving drowsy is very dangerous, regardless of environmental conditions. There are specific environmental conditions in which driving while drowsy is more dangerous, including for example, intersections, wet roadways, and areas of high traffic density (Klauer et al., 2006). The results of the analysis investigating the impact of driver drowsiness on environmental conditions, using the driving data collected in the 100-Car Naturalistic Driving Study, yielded some interesting findings. Driving (urban road) while drowsy results in a 4-6 times higher crash and near crash risk relative to alert drivers. Driver drowsiness may vary depending on time of day or ambient lighting conditions, far fewer drowsiness related events were observed during the daylight hours while a greater number were identified during darkness. While it is commonly thought that most drowsiness-related crashes occur at night, it was found that the risks of driving drowsy during the daytime may be slightly higher than at night due to higher traffic density.

The effect of road type on fatigue can be seen in the higher percent of occurrence for drowsiness-related events on divided roadways than on undivided roadways. Drowsiness was also seen to slightly increase in the absence of high roadway or traffic demand. A higher percentage of drowsiness-related events were found during free-flow traffic densities, on divided roadways, and areas free of roadway junctions. It was also found that near-crash/crash risk due to drowsiness increased when drivers were on straight roadways. One hypothesis for these results is that drivers are more relaxed and less active on divided roadways (i.e., interstates) because they do not have to monitor cross traffic as frequently as on undivided roadways. This feeling of relaxation may result in higher occurrence of drowsiness. Furthermore, driving in free-flow traffic or straight roads is less interesting and requires less activity by the driver. Therefore, these types of roads and traffic flow may help induce drowsiness because the driver is under-stimulated (Klauer et al., 2006).

According to Liu & Wu (2009) fatigue is produced after driving for 60 min. Driving in Heavy traffic, complex road environment (urban highway) does not necessarily cause drivers to feel more fatigued than driving in the monotonous road (rural roadway). Furthermore, change in road environment from complex to monotonous caused drivers to feel more fatigued than vice versa, confirming that the monotonous environment reduced fatigued driver's alertness and thus increased fatigue. Liu & Wu (2009) argued that driving behaviour and performance of fatigued drivers are affected more by changes in road environment than by length of driving time.

Thiffault and Bergeron (2003) found that in a monotonous driving situation steering wheel movement of drivers is greater and occurs more often, showing that the effect of fatigue caused by a monotonous road environment on driver vigilance is relatively large. Driving on monotonous highways has been regarded as a risk factor for sleepiness related accidents.

The documented phenomenon of task-induced fatigue also involves an inherent assumption that different driving environments will induce different levels of fatigue that will be manifest in different measures of performance (Oron-Gilad and Ronen, 2007).

Driving longer routes was associated with higher degrees of sleepiness than driving on shorter routes repeatedly or driving in heavy traffic and dense areas (Van den berg et al., 2006).

Increasing subjective levels of sleepiness, based on the KSS, were accompanied by an increase in the alpha waves. The results of increased alpha waves as a function of time on task were statistically

significant only in the more monotonous light traffic condition that is associated with greater fatigue (Otmami et al., 2005 in Shinar, 2007 see fig 14-10).

Autumn was the time of year when most of the drivers considered sleepiness to be most disturbing followed by the winter. The period between 3 a.m. and 6 p.m. was the time of day when most of the drivers considered sleepiness to be most severe, followed by the period 12 p.m. to 3 a.m., and then the period 6–9 a.m. (Van den berg et al., 2006 see fig. 1). These results are in line with the findings of ROSPA (2001) that sleep related accidents peak in the early hours of the morning, between 2:00 and 6:00 am, and in the mid afternoon, between 3:00 and 4:00 pm, due mainly to circadian rhythms.

This is similar in shipping, with a peak around 6 o'clock, possibly due to watch system and watch change-over times (Lützhöft, Thorslund et al. 2007), and as also commented in the next section, there is often a need to make simulator studies much harder than reality in order to get measurable effects (Gould, Røed et al. 2009).

6.4 Environmental parameters & Task Demand (Workload)

Task demand is the demands of the process of achieving a specific and measurable goal using a prescribed method. **Workload** defined as the amount of information-processing resources used per time unit or in other words the rate of activity supplied by the operator in order to perform the task. Workload will serve as a measure of task demand. Its effects should be reflected in changes in task performance or other strain indicators.

Task demand arises out of a combination of environmental features, other road users' behaviour, characteristics of the vehicle and its speed and position on the road. Cacciabue & Saad, (2008) argued that amongst the long list of variables; complexity of traffic, speed of vehicle, direction of driving, weather, light conditions are sufficient to give a reasonable indication of the overall task demand in dynamic conditions. A thorough research on HMI and Safety-Related Driver Performance was conducted in HASTE project. An effect of increasing road complexity level (straight, curve and critical event) was observed. Drivers reported poorest performance in the critical events (e.g. major reduction of speed is necessary) compared to straight and curved sections (Östlund et al., 2004 See fig. 14). In terms of road complexity levels, main effects were found on lateral position measures. The highest value of Lateral position variation was found in the curved section, where lateral control was more difficult to maintain due to road geometry. Reversal rate in events was significantly lower than in straight and curved sections (Östlund et al., 2004 See Fig. 17 & 18). Having to negotiate the curves and dealing with other traffic in the road demand more visual attention towards activities in the road, reducing the speed at which drivers are able to respond to the visual task. Lowest reaction time in the straight road sections was found. Moreover, interaction was found with long reaction times to the most difficult visual task during the curved sections (Östlund et al., 2004 see fig. 46 & 47). Subjective workload ratings proved to reflect differences in road difficulty (straight vs. curved roadways), See fig. 92 (Östlund et al., 2004). Visual task affect workload more than cognitive task. The Rural road was found to be the most diagnostic road (provide clearer findings, larger effects).

Traffic density depends strongly on the interaction between vehicles and therefore on the test driver behaviour and his interaction with the surrounding traffic. Some studies show that traffic complexity affect drivers' performance. Patten et al. (2006) found main effect of traffic environment complexity on Peripheral detection task (PDT) reaction times and on PDT miss rates. The PDT method is an indirect measure of workload and measures cognitive workload by evaluating reaction times to secondary-task stimuli. They also found that Low mileage drivers had on average longer reaction

times than the high mileage drivers. Moreover, Hao et al. (2007) found that driving performance (i.e. collision number) does not worsen with increasing traffic, this might be as a result of not enough sensitive index for drivers' controlling performance, furthermore, mental workload (physiological and subjective assessment) increased and situation awareness performance worsen with increasing traffic. Schiessl (2008) found significant effect for traffic density on strain or workload, subjective strain increases with raising traffic density up to a medium coverage level and remain the same afterward, whereas physiological strain decrease. This may be due to measurement sensitivity. Mean Heart Rate is more sensitive to physical load than to mental load which is higher in high traffic density situations (restricted behaviour within the congestion). Heart Rate Variability is more sensitive to mental workload. In high density strain increases until the actual lane changes but in low density the max strain is reached during the planning phase (Schiessl, 2008). Different manoeuvring phases affect drivers' workload. The most influencing factor on strain was found to be an active lane changing. De Waard (2008) argued that increased traffic density has been shown to increase workload and the probability that errors will lead to accidents. Driving in a mixed stream of traffic e.g. heavy traffic of Heavy Goods Vehicles (HGVs) will make merging into traffic more mentally demanding and will decrease safety margins as it obstructs vision and reduces drivers' ability to change lanes.

The effect of weather conditions (clear/foggy) is limited; drivers adapt their driving behaviour in adverse weather by reducing speed (De Waard, 2008). Hogema et al. (2005) measured the effects of variations in motorway lighting on driver behaviour and concluded that when the lighting was switched off mental effort increased because heart rate and blink rate increased and speed decreased. When drivers have to deal with higher workload (i.e. task demand), they often have two options: they can increase their effort or they can try to reduce the task load, e.g. by reducing speed. Thus, drivers have more time available to anticipate potential hazards and this reduces the workload.

For interaction regarding fairway and traffic types, there are few studies for ships and often a need to increase the difficulty in simulator studies to a very high level to get differences (e.g. very complex fairway, traffic or high speed) (Gould, Hirvonen et al. 2009; Nilsson, Gärling et al. 2009).

6.5 Environmental parameters & Culture (Country)

Culture is a non-observable variable that can affect driver behaviour. In our study cultural differences will be assessed in the variations among the five countries where the simulation studies will be conducted. 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. Nonetheless, nationality was found to have a significant effect for longitudinal and lateral control measures, e.g. speed (Östlund, 2004), and some driving norms (SARTRE, 2003).

6.6 Summary matrix of interactions

| | Experience – Hazard Perception skills | Driver State – fatigue | Task Demand - workload |
|---|--|--|---|
| Road / Track/ Fairway: type , alignment, view obstruction, surface conditions | Interaction between road design and drivers' experience / HP skills were found. Novice drivers are overinvolved in accidents relative to experienced drivers when driving on poorly designed roads and when encountering view obstruction. On the other hand, education will not improve driver's ability to better interpret driving conditions (e.g. slippery road). | Driving (urban road) while drowsy results in a 4-6 times higher crash and near crash risk relative to alert drivers. Higher percent of occurrence for drowsiness-related events on divided roadways than on undivided roadways. Change in road environment from complex (urban highway) to monotonous (rural roadway) caused drivers to feel more fatigued than vice versa. | Curves demand more visual attention. The highest value of Lateral position variation was found in the curved section due to road geometry. Lowest reaction time in the straight road sections. Moreover, interaction was found with long reaction times to the most difficult visual task during the curved sections. The Rural road was found to be the most diagnostic road (provide clearer findings, larger effects). |
| Traffic: density, mix | No literature was found dealing with the interaction between drivers' experience and traffic. | Increasing subjective levels of sleepiness were statistically significant only in the more monotonous light traffic condition. Driving longer routes relate to higher degrees of sleepiness than driving on shorter routes repeatedly or driving in heavy traffic and dense areas. | Subjective workload increases with raising traffic density up to a medium coverage level and remain the same afterward, but physiological strain decreases. Driving in a mixed stream of traffic will make merging into traffic more mentally demanding. Heavy traffic produce higher PDT reaction times and higher PDT miss rates. SA performance worsen with increasing traffic. |
| Visibility: weather, time of day | Inexperienced drivers are slower on hazard perception at night compared with during the day. | Autumn was the time of year when most of the drivers considered sleepiness to be most disturbing followed by the winter. The period between 2 a.m. and 6 p.m. was the time of day when most of the drivers considered sleepiness to be most severe. Moreover, the risks of driving drowsy during the daytime may be slightly higher than at night due to higher traffic density. | Mental effort increases when the motorway lighting is switched off. The effect of weather conditions (clear vs. foggy) on workload is limited. |

7. VEHICLE MODEL

7.1 Car model

Driving simulators, including in the past the simulator at Leeds, have often used a simplified vehicle dynamics model for calculating vehicle dynamics relative to the roadway. The aim is to be able to represent vehicle dynamics in a simplified yet reasonably realistic manner, with the stimulus for simplicity being ease and hence rapidity of calculation.

On a straight flat road, longitudinal acceleration is calculated from engine torque at a given rpm, tyre and other resistance and vehicle mass. Deceleration is similarly calculated from engine braking and brake application. Horizontal alignment can be considered.

Lateral forces can be modelled by a 2-DOF model in which a four-wheeled vehicle such as a car is assumed to have only two tyres, one front and one rear. Each of these “tyres” is modelled with double cornering stiffness. For obvious reasons, this is sometimes referred to as the “bicycle model”. Such models have their ancestry in Segel (1956), and represent side slip (lateral acceleration) and yaw rate. The model considers the vehicle centre of gravity (before or to the rear of the vehicle midpoint) and hence is able to represent understeer and oversteer. It can also represent skidding — when sideways forces on a tyre exceed available road friction.

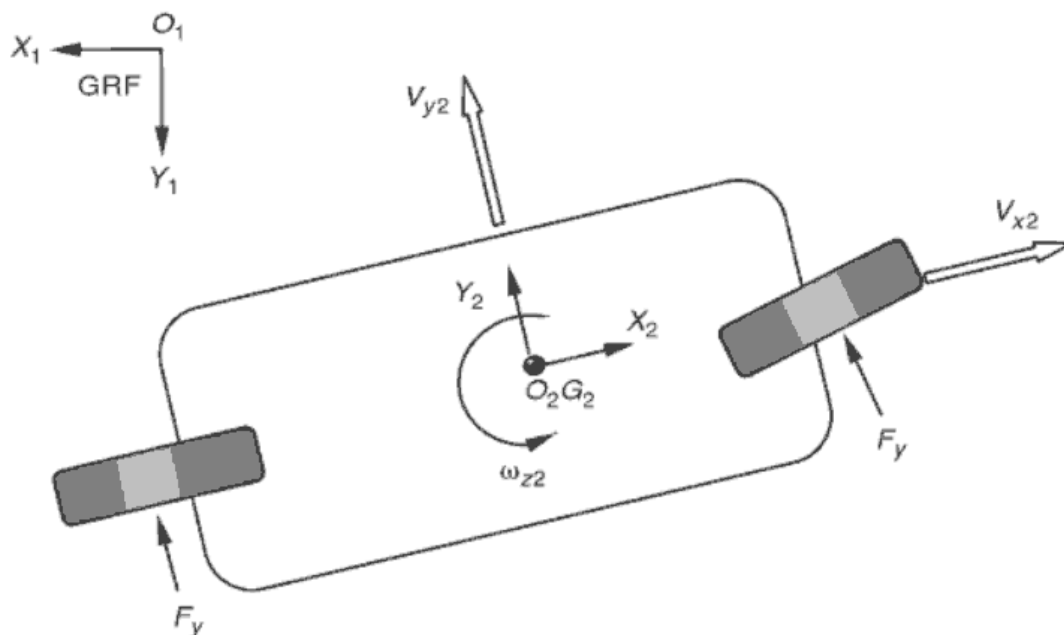


Figure 12 - The simplest possible representation of a vehicle manoeuvring in the ground plane (from Blundell and Harty, 2004, p. 140)

Such a 2-DOF (3-DOF with longitudinal momentum) model is a reasonable and sensible candidate for the representation of car vehicle dynamics in the ITERATE simulation environment.

7.2 Train model

Vehicle models for trains

There are various kinds of vehicle models for trains with varying complexity ranging from the simplest ones which are just considering the whole train as a single point mass to the somewhat more advanced models which are considering the slip of the wheels and at the high end of the scale there are models who treat each car in the train individually.

In this section the parameters needed by the vehicle model to be able to fulfil the requirements of the project are discussed. The model will have to be advanced enough to be able to take into account the varying driver actions anticipated by the model and scenarios specified in WP1 but also simple enough to be practical to implement in WP6.

Model parameters

The following parameters are required from the vehicle model to be able to carry out the simulations, taking into account the driver actions based on the task analysis and the planned scenarios.

- Weight of train
 - Weight of train gives the inertia of the train, stopping distance and behaviour in vertical curves.
- Power
 - Power of the engine in combination with weight and vertical alignment gives the performance of the train
- Top speed
 - May be relevant depending on scenarios and is easy to implement in the model
- Vertical curves
 - The model will need to consider vertical curves since one of the systems being tested is related to speed control and vertical curves are then an important factor.
- Slip
 - Takes into account the wheels traction on the rail and gives the train more realistic behaviour, especially on slippery tracks.
- Acceleration curves
 - Output of engine performance, slip, weight, vertical curves and driver input
- Braking
 - Two kinds of brakes are normally used on a train, mechanical and magnetic, and the model should cover them both. A third, emergency braking may also be used in certain conditions but is not considered relevant for the model.

De-railing was discussed as a potential parameter but not deemed necessary since derailling of trains is a very rare event and will be unrealistic to provoke in the simulators. It was also discussed how to deal with the Pantograph and it was decided to not model it as such, instead lowering of the pantograph will be the same as setting the throttle = 0.

Other systems / functions

There are other parameters that are linked to other systems / functions but are not considered part of the vehicle model some. This includes the systems tested in ITERATE such as the ATC / RTMS but can also include operating of the passenger doors or the interface between the control room and

the driver. Some of these will have to be incorporated in the simulators but not necessary in the vehicle model.

Format

To be able to be easily incorporated into the modelling carried out in WP6 the model should be written in C++

Input to the model:

There are only two inputs given to the model relevant for the vehicle model and that is throttle and brake from the driver.

Output from the model:

The output is speed and, seen over time, acceleration profiles.

8. CONCLUSIONS

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 is changing, and anticipate problem situations and in response to adjust the behaviour of in-vehicle information systems and driver assistance systems and also adjust feedback to the driver.

This deliverable, which succeeds D1.1, provides a description of the Unified Model of Driver behaviour (UMD) and definition of key parameters for specific applications to different surface transport domains. It is important to develop a modeling 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 modeling architecture to specific applications. It is crucial to include in the applications, a vehicle model and an environmental parameters that represents different (risky and critical) traffic scenarios to be simulated in the test phases further on in 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 in this deliverable are:

Attitudes/personality (Sensation Seeking) - especially relevant for the road vehicles, For other transport modes this is of less relevance because they employ professional drivers who are recruited under restrict conditions and therefore the presence of sensation seekers among drivers can be mitigated. Personality traits may have negative influence on driving performance. Most articles show correlation between sensation seeking and some aspects of risky driving.

Experience (Hazard Perception Skills) – relevant to all modes of transport. Hazard perception skills have been found to correlate with crash risk.

Driver State (Fatigue) – 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 (as a result of 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 road had the greatest impact on driving behaviour.

Task Demand (Subjective workload) – also important within all transport modes, Task demand arises out of a combination of environmental features (complexity of traffic, weather, and light conditions), other road users' behaviour, and characteristics of the vehicle; not necessarily in the same level of importance for the different transport modes.

Culture (country) - Common to all transport modes, Most Studies dealing with cross cultural differences in driving found significant effect 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 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 research some common factors pertaining to the road infrastructure or the driving environment conditions were found to be critical. Among such

cases, roads slick with rain/ice or other debris, obstruction to the driver's vision as attributable to inadequate highway designs, poor signage, and poor infrastructure maintenance. It is important to develop a unified model of DVE which will evaluate the effect of the selected environmental factors on the driver model and the corresponding drivers' behaviour and performance, in order to understand how to avoid errors and crashes. We have selected the most frequent parameters that have been shown to influence risk, risk-taking and errors, those that can be implemented within the model simulation and that are relevant to at least one of the three transport modes – cars, trains & maritime vessels. The selected parameters described in this document are:

Road/Track /Fairway – type, alignment, view obstruction, surface conditions

Traffic – density and mix

Visibility – rain/snow/fog, light conditions

Literature review on the joint effects of selected driver variables and selected environmental parameters on driving performance and behaviour reveal 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 overinvolved in accidents relative to experienced drivers when driving on poorly designed roads and when encountering view obstruction. On the other hand, education will not improve driver's ability to better interpret driving conditions (e.g. slippery road). Novices are also significantly slower in perceiving of hazards at night compared with during the day.

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 in the process of changing lanes, strain increases until the actual lane change; whereas in low density the maximal strain is reached during the planning phase. Driving in a mixed stream of traffic will make merging into traffic more mentally demanding. The effect of weather conditions (clear/foggy) on workload is limited; 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 (See figure 13). 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 relate to 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.

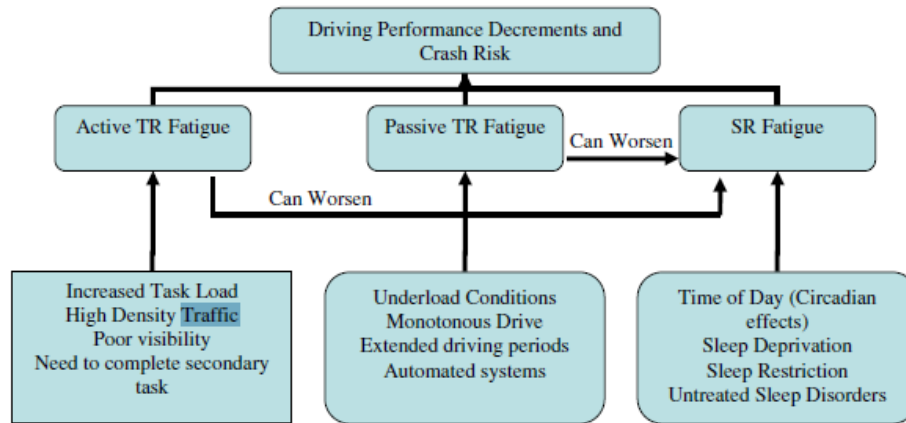


Figure 13 – model of fatigue (from May & Baldwin, 2009)

As the focus of the model and simulation is mainly on the Diver, this Deliverable contains only short descriptions of the vehicle model.

The proposed ITERATE model that is designed to serve the remaining tasks in the project is presented in figure 14. This model summarizes the interaction between the driver variables, the environmental parameters and the vehicle model as it exposed from the literature review. In adopting this model we must include two qualifications.

- Admittedly it is one of many possible models. Our approach was to create a driver- centered model where vehicle environmental and vehicular variables and parameters serve as inputs to the driver, and where driver behaviour is affected by both and is partially determined by the vehicle features.
- All of the boxes and variables can be quantified, but as detailed in the report above not all have empirically tested values.

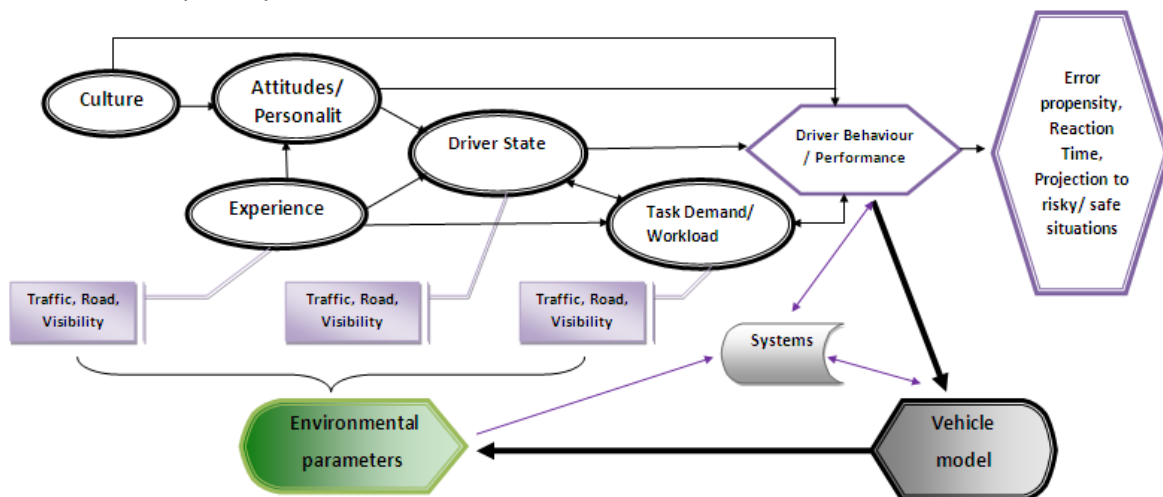


Figure 14 – the proposed ITERATE model

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