ITERATE

IT for Error Remediation And Trapping Emergencies

Selection of operator support systems across modes

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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 (MTOP) 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

AIS	Automatic Identification System
ARPA	Automatic Radar Plotting Aid
ATC	Automatic Train Control
ATP	Automatic Train Protection
AWS	Automatic Warning System
DSD	Driver's Safety Device
ECDIS	Electronic Chart Display and Information System
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
FCW	Forward Collision Warning
ISA	Intelligent Speed Adaptation
ITERATE	IT for Error Remediation And Trapping Emergencies
SPAD	Signal Passed At Danger
TPWS	Train Protection and Warning System

TABLE OF CONTENTS

Contents

List of abbreviations ..... **iv**

Table of contents ..... **v**

Executive Summary ..... **vi**

1. Introduction **1**

2. Methodology **2**

2.1 Initial system selection in WP2.1 2

2.2 Hypotheses formulation 2

2.3 Identifying commonalities and final selection 2

3. Common functionalities of systems across modes **4**

4. Common effects on operator tasks across modes **5**

4.1 Hypotheses 5

4.2 Common effects 7

4.2.1 Collision avoidance 8

4.2.2 Speed management 13

4.2.3 Operator state monitoring 17

4.3 Conclusions 21

5. Summary and justification of selected systems **22**

5.1 Collision avoidance systems 22

5.1.1 Cars: Forward Collision Warning (FCW) 22

5.1.2 Ships: Radar and ARPA 22

5.1.3 Trains: Automatic Warning System (AWS) 23

5.2 Speed management systems 23

5.2.1 Cars: Intelligent Speed Adaptation (ISA) 24

5.2.2 Ships: Speed Pilot and Electronic Chart Display and Information System (ECDIS) 24

5.2.3 Warning, intervention and speed supervision systems with intermittent information transmission (full ATP/ATC system) 24

6. Future work **25**

7. References **26**

EXECUTIVE SUMMARY

This Deliverable provides an outline of the process involved in task 2.2 of the ITERATE project for selecting an appropriate set of hypotheses to be tested in Workpackages 3 (*Experimental design and scenario specification*), and 4 (*Experimental studies*).

During a workshop with all partners involved in the project, hypotheses were formulated for the three main system functionalities outlined in D2.1: those that support speed management (Speed Management), systems that support system object detection and avoidance (Collision Avoidance) and those that monitor operator state (Operator State). In formulating these hypotheses, partners were encouraged to consider systematically the effect of operator state and different operator groups on interaction with these three systems. To allow succinct formulation of hypotheses, four operator based parameters which are thought to affect operator behaviour with the system, were identified: sensation-seeking, hazard perception, fatigue and (high and low) task demand. In formulating hypotheses, partners were encouraged to consider the whole process linking a cause to an effect, with a clear mechanism that would link the two.

Three groups of partners (clustered by system functionality) formulated a number of hypotheses in this way. This involved, for example, considering the interaction of a fatigued operator with a speed management system, taking into account the effect of this input (fatigue) on system functionality, operator performance and on the potential risk of the subsequent scenario. These hypotheses were then summarised further to reflect communalities across the modes: road, rail (high speed and urban guided systems) and maritime transport. Ten main hypotheses were formulated, each of which are then applied to the three system functionalities. Further analysis suggested that only speed management and collision avoidance systems were appropriate for comparison across the three modes, with too much variability across the operator monitoring systems. Three actual systems (one for each mode) have been identified for each of the two functionalities. These are Forward Collision Warning, (cars) Radar with Automatic Radar Plotting Aid (ships) and Automatic Warning System (trains) for the **Collision Avoidance** functionality and Intelligent Speed Adaptation (cars) speed pilot, Electronic Chart Display and Information System (ships) and full Automatic Train Protection and Train Control systems (trains) for the **Speed Management** functionality.

The next phase of the project, involves preparation for the experimental studies. Using the hypothesis selected in this Workpackage, and input from the operator based parameters selected for the model from WP1 (attitude, experience, state, task demand and culture) experimental scenarios will be designed to examine the interaction of different groups of operators with these systems across the three modes.

1. INTRODUCTION

The objective of Workpackage 2 is the identification of vehicle support and assistance systems likely to affect operator performance and operator interaction with the vehicle. In D2.1 we described a variety of systems for the three transport modes: road, rail (high speed and urban guided systems) and maritime transport. In this deliverable we describe how the systems that are going to be used for further experimentation in Workpackage 4 were selected.

We will first describe the methodology used to select the systems. Next, in Chapter 3, we will describe the commonalities in functions of the different systems that we selected across the different transport mode. Chapter 4 will discuss the hypotheses we have formulated on the effects on the various parameters selected in Workpackage 1 on operator behaviour. In Chapter 5 we will present the systems finally selected and justify the choices. The last chapter will adress the further work on the specification of the experiments in Workpackage 3, for which this deliverable provides the input.

2. METHODOLOGY

The system selection was realised in three steps: (1) Initial system selection in WP2.1, (2) Hypotheses formulation and (3) Identifying commonalities and final selection.

2.1 Initial system selection in WP2.1

In Workpackage 2 we selected a set of advanced operator support systems that are important for modern vehicles, and that have a potential large influence on the operator task. These systems were described in detail in Deliverable 2.1, with the focus on their relation with the operator task.

2.2 Hypotheses formulation

In Workpackage 1, several parameters were identified that play a role in the operator model that is being developed and that influence operator behaviour. These parameters were: attitude, experience, operator state, task demand and culture. Specific instances were chosen for these parameters: sensation-seeking for attitude, hazard perception for experience, fatigue for operator state and (high and low) workload for task demand. It was determined that in this stage we would not focus on culture, being a concept that is very complex, encompassing different concepts, such as national and regional culture, company culture, safety culture etc. For more explanation of these parameters we refer to Deliverable 1.1. In a workshop during one of the project meetings, we discussed the influence of each parameter on the operator task for the different systems across the three modes. Hypothesis were then generated in small groups, which consisted of ITERATE partners working in different domains. A hypothesis is a specific statement linking a cause to an effect and based on a mechanism linking the two. It can be tested with statistical means. A hypothesis is expected to predict the direction of the expected change.

After the workshop, each WP2 partner completed a template supporting the generation of hypotheses for all systems defined in WP2.1. Partners created 1-3 hypotheses for each parameter for each of the systems they described in D2.1. The tables with all the hypotheses are available as an internal document. For examples, see Section 4.1. Although not all hypotheses will be used for the specification and conduction of experimental studies, all are valuable for the generalisation and validation step in WP7.

2.3 Identifying commonalities and final selection

The hypotheses were analysed for commonalities and possibilities for interesting experimental scenarios. Nine systems (three per transport mode) were proposed for further investigation and this was based on their general functionality: that they could be used for all three transport modes. During a project meeting we organised a second WP2 workshop during which we examined the commonalities between the hypotheses for the proposed systems and tried to formulate more general hypotheses addressing a common effect. The result was the selection of four systems, two for cars and two for trains, which will be used in WP3 and 4, the experimentation. Two systems for ships were also selected; these will be used in the project for validation, especially in WP 7.

The method we used for arriving at a final selection was a useful one. By discussing in various small groups with people from different disciplines we gained an understanding of the effect of each system on operator performance. This allowed the formulation of hypotheses, both in small groups and in the subsequent work by each partner, encouraging us to systematically consider the different effects these systems may have on the operator's task in different circumstances and for different operator groups. In our experience, the formulation of a good hypothesis requires discussion, interaction and iteration to fully understand what the possible effects could be on operator behaviour. This is indeed our experience from other projects where we implemented this method, such as during the seminars of the European support action FOT-Net (Field Operational Tests, see www.fot-net.eu).

In Chapter 3 we will discuss the commonalities, in Chapter 4 the common effects and in Chapter 5 the final selection of systems.

3. COMMON FUNCTIONALITIES OF SYSTEMS ACROSS MODES

In D2.1 five types of operator support systems/technologies across modes were identified as a result of the review:

- Support for navigation and maintaining position
- Support for detecting and avoiding obstacles
- Support for speed management
- Support by information provision
- Support for operator state monitoring

These systems were then narrowed down further by selecting three functions: those providing support for speed management, systems for detecting and avoiding obstacles and those for monitoring operator state. The main reason for this choice was that these kinds of system are used in the three different modes being studied in ITERATE. Systems supporting navigation and maintaining position are not very relevant for rail transport. Systems for information provision are widely used, but are very diverse; therefore it is difficult to find commonalities. These systems area also not always directly related to the task of driving the vehicle.

Nine systems were proposed for further investigation during the second WP2 workshop, one for each transport mode, and each function:

- **Collision avoidance:**
  - Car: Forward Collision Warning (FCW)
  - Ship: Radar with Automatic Radar Plotting Aid (ARPA)
  - Rail: Automatic Warning System and Train Protection Warning System (AWS/TPWS) (trains) (although anti-collision is not completely its function, the system warns the operator about restrictive signals)

    (We have also considered the European Rail Traffic Management System and European Train Control System (ERTMS/ETCS) for both speed management and collision avoidance. In this system the functionalities of both AWS/TPWS and ATP/ATC are included. Moreover the ERTMS/ETCS includes other functionalities, which makes it rather complex. However, the ERTMS/ETCS is still on trial. Therefore we have selected AWS/TPWs and ATP/ATC over ERTMS/ETCS. But our work could be applied in the future for the ERTMS/ETCS system.)

- **Speed management:**
  - Car: Intelligent Speed Adaptation (ISA)
  - Ship: speed pilot (part of the autopilot), or as an alternative Electronic Chart Display and Information System (ECDIS)
  - Rail: full Automatic Train Protection and Train Control systems (ATP/ATC) (for speed on trains)

- **Operator state monitoring:**
  - Car: Driver State monitoring (DS)
  - Ship: Dead Man Alarm / Watch Alarm
  - Rail: Driver's Safety Device (DSD) (for the tram)

4. COMMON EFFECTS ON OPERATOR TASKS ACROSS MODES

4.1 Hypotheses

In order to study the effects of the use of the support systems on operators' behaviour it is necessary to start with hypotheses predicting the effects. These hypotheses will be tested in the experiments. We use the definition of a hypothesis coming from the euroFOT project where a hypothesis is defined as "a specific statement linking a cause to an effect and based on a mechanism linking the two. It is applied to one or more functions and can be tested with statistical means by analysing specific performance indicators in specific scenarios. A hypothesis is expected to predict the direction of the expected change."

In order to come up with hypotheses, we can start with an operator parameter, for example high workload. A hypothesis for this parameter may be that the operator will get more warnings from a speed management system. In this example the mechanism linking cause (high workload) and effect (more warnings) may be that the operator is distracted by other tasks and relies on system to intervene when his/her speed it too high. The effect can be split in three elements: the effect on the operator's interaction with the system (in this example more reliance on the system), the effect on the system functionality (in this example the system will give more warnings), and the increase or decrease of the risk potential. To make the hypothesis more understandable, it is useful to formulate examples of a scenario in which the operator and the system will function as expected. An example is: a car driver is overloaded by a phone conversation while driving on a busy urban road and does not pay attention to a speed sign. The system will warn the driver that he/she that the current speed is too high.

A template was used for formulating detailed hypotheses which consisted of the following factors:

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

Below four examples of detailed scenarios are given for four parameters for a Forward Collision Warning System.

	Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
System/function (mode): Forward Collision Warning (road vehicles)						
Example hypothesis:	Attitude: More sensation-seeking	Increased tolerance for risk taking	Continues to drive the car	More warnings triggered and more interventions by system	Increase	Driver continues driving after a warning given when he/she is too close to a lead car, and relies on the intervention of the system. System will intervene when it assumes situation is unsafe.
Example hypothesis:	Experience: hazard perception, more experienced	Driver is aware of when to start braking to avoid intervention	No intervention required from system; operator pleased with the system	No warning or intervention required	Decrease	Driver responds to a hazard such as a broken-down car on the road, he/she brakes before the system is required to intervene.
Example hypothesis:	Operator state: Fatigued	Driver relies more on the system to control the vehicle	More reliance on the system	More warnings, more intervention	Increase	Driver is tired and relies on the FCW to warn him/her and intervene when necessary, instead of taking a break.
Example hypothesis:	Task demand: workload too low	Driver is bored	More reliance on the system	More warnings, more intervention	Increase	Driver is bored on a quiet motorway at night and is likely to fall asleep. If there is suddenly an obstacle on the road, the driver will not notice it in time and he/she will get a warning.

When we compared the different hypotheses, several observations were made:

- It is not easy to formulate a consistent and comprehensive hypothesis. The hypotheses are also not exhaustive, but serve as examples. As the hypotheses serve the main goal of selecting systems as input for WP3, we did not refine all hypotheses, the relevant ones for the selected systems will be further refined in WP3.
- Hypothesised risk increase or decrease depends on the baseline. Different baselines are possible, for example driving with and without the system, driving by experienced operators compared with novices, initial stage of use or long term use.
- Many hypotheses addressed behavioural adaptation. In these hypotheses it is assumed that the operator gets used to the system and starts to use the system in a way that is not necessarily intended. For example over-reliance on an operator monitoring system, thus driving in a fatigued condition and relying on the system to give warnings, instead of planning regular rest periods during the journey.
- Sensation-seeking may not be an issue for professional operators, but it is acknowledged that some operators are willing to take more risks than others.
- Culture is a difficult topic, but issues like differences between professionally trained operators (for ships and trains, but also for car) and unprofessional ones (cars) and safety culture within a company are identified as having a large impact. Cultural differences between countries are addressed by having experiments in different countries, and were not addressed in the hypotheses.

Despite the differences between systems, some common effects on operator tasks could be hypothesised.

4.2 Common effects

During the second WP2 workshop, which took place in Leeds on 9 September 2009, we aimed to generalise the hypotheses for the systems selected. A list of the generalised hypotheses generated for the three different functionalities (collision avoidance, speed management, and operator state monitoring) is outlined below:

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

H2. Sensation-seeking operators will behave in such a way that more warnings will be triggered.

H3. Sensation-seeking operators will seek stimulation to cope with monotonous situations.

H4. Experienced operators will receive fewer warnings than inexperienced operators.

H5. Fatigued operators will rely on the system to warn them about a critical situation.

H6. Operators will receive more warnings when fatigued than when alert.

H7. Fatigued operators will have less situational awareness than alert operators.

H8. Fatigued operators may compensate for their fatigue by increasing the safety margin.

H9. Operators will receive more warnings when under low workload.

H10. Operators will receive more warnings when under high workload.

Below we will work out these hypotheses per type of system. As not all hypotheses are relevant for all types of system, sometimes a different hypothesis was generated. The numbering of the hypotheses is kept consistent over the three types: CA for Collision Avoidance, SM for Speed Management and OS for Operator State monitoring. These abbreviations are followed by the number corresponding to the common generalised hypotheses H1, H2, ..., H10.

4.2.1 Collision avoidance

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

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Attitude: More sensation-seeking	Increased tolerance for risk taking	Adopting a shorter warning threshold	Less warnings triggered	(Decrease)/Increase	A sensation-seeker sets a headway threshold shorter than the FCW system's default value to avoid warnings

This hypothesis requires a system that allows user settings on the warning threshold. Safety systems for trains do not usually allow this; therefore H1 is in principle only valid for cars and ships. However, train operators may choose to react quicker or slower to the warning. Train drivers who are more sensation seeking (or risk taking) may chose to react later to the warning. The pathway leads to the operators choosing a warning threshold so that the system warns later. The argument behind this is that they thereby will reduce the number of warnings and even those warnings perceived as false by the operator. The risk potential will still decrease compared to operating the vehicle without any system, it will however increase compared to operating the vehicle with the system's default settings.

Hypothesis CA H2:
Sensation-seeking operators will behave in such a way that more warnings will be triggered.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Attitude: More sensation-seeking	Increased tolerance for risk taking	Following the lead vehicle more closely	More warnings triggered	Increase	A sensation-seeking driver follows the lead vehicle closer than the set threshold of the FCW system, which in turn triggers high frequency of warnings

This hypothesis is based on the assumption that the system does *not* allow user settings for the warning, or that the operator has not changed the default settings. It is valid for all three modes. The logic behind the hypothesis is that sensation-seeking operators perceive situations where the system warns as being safe, or at least under their control (example: short following distance for cars) and there is thereby a conflict between the system and the operator which will increase the number of warnings. Following the lead vehicle more closely will increase the risk potential compared to an operator who adopts the system without challenging it, the risk is however likely to decrease compared to not using a system.

Hypothesis CA H3:
Sensation-seeking operators will seek stimulation to cope with monotonous situations.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Attitude: More sensation-seeking	Operator seeks stimulation to cope with monotonous situations	Braking late, late response to warning signal	More warnings triggered, more signals passed at danger; brakes applied harder decreasing passenger comfort	Increase	Operators trying to increase own level of stimulation in monotonous situations by driving with lower safety margins. Operators wanting to test the limits of the system to increase stimulation. Operator adapts driving strategy which means late application of brakes.

H3 implies that sensation-seeking operators will try to make their task more stimulating by adding risks such as braking late, responding later to warnings. This hypothesis is valid for all three modes and the risk potential will increase with this behaviour.

Hypothesis CA H4:
Experienced operators will receive fewer warnings than inexperienced operators.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Experience: hazard perception, more experienced	Operator is aware of when to start braking to avoid intervention	No intervention required from system; operator pleased with the system	No warning or intervention required	Decrease	Operator responds to the hazard before the system is required to intervene.

H4 is based on the assumption that an experienced operator can foresee potentially hazardous situations and act to avoid them at an early stage, for instance by reducing speed or changing course. This will lead to fewer critical situations which in turn will lead to fewer warnings. The risk potential will decrease both compared to inexperienced operators and to when the system is not used. H4 is valid for all modes.

Hypothesis CA H5:
Fatigued operators will rely on the system to warn them about a critical situation.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Operator state: Fatigued	Operator relies more on the system to control the vehicle	More reliance on the system	More warnings, more intervention	Increase	Operator is tired and relies on the FCW to warn him/her and intervene when necessary.

H5 assumes that the operator delegates some responsibilities to the system and will continue to drive when fatigued. This is valid for cars and ships. The risk potential will increase. The hypothesis is not relevant for trains because the Collision Avoidance System is not related to a critical situation but to the rail signs.

Hypothesis CA H6:
Operators will receive more warnings when fatigued than when alert.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Operator state: Fatigued	High sleepiness due to early morning work or extended overtime work gives longer reaction time or short periods of micro sleep during work shift	Operators' daytime sleepiness results in missed warnings; operator does not respond to warning or responds too late; more SPADs (Signals Passed At Danger)	System triggered warnings are not detected or detected too late; brakes are not applied at the right time	Increase	The operator misses a warning or reacts to the warning too late.

H6 is based on the assumption that fatigued operators have a longer reaction time or even short periods of micro sleep. This is valid for all modes. When fatigued, the operator will rely on the system to warn for critical situations and will thereby receive more warnings. The risk potential will increase.

Hypothesis CA H7:
Fatigued operators will have less situational awareness than alert operators.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Operator state: Fatigued	Fatigue leads to less engagement in compensatory braking behaviour and disengagement from the driving task	Late response to warning, higher dependence on automatic interventions, passive/reactive driving style	More system interventions, more SPADs, more errors of omission and commission, more warnings	Increased	Fatigued operators use the brake less often. Fatigued operators make less minor adjustments and apply more forceful braking.

Fatigued operators will have lower situational awareness than alert operators and this will be shown by poorer speed control, less minor adjustments and more late/hard correctional manoeuvres. This in turn will lead to more warnings from the system. This is valid for all modes and the risk potential will increase compared to alert operators, although it will be reduced compared to fatigued operators *without* any system.

Hypothesis CA H8:
Fatigued operators may compensate for their fatigue by increasing the safety margin.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Operator state: Fatigued	High awareness of own fatigue	Adopting a strategy to compensate for their fatigue	Less warnings triggered	Decrease	Operator is fatigued and knows it. He/she adopts a greater headway to the vehicle in front.

H8 assumes that the operator is aware of their state and tries to compensate by increasing the safety margin, e.g. by adopting a longer headway. This will lead to fewer warnings being issued and this is valid for all modes. The risk potential will decrease compared to a fatigued operator not adopting a compensatory strategy or a fatigued operator without a system, but it will of course be increased compared to an alert operator.

Hypothesis CA H9:
Operators will receive more warnings when under low workload.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Task demand: workload too low	Operator is bored and engages in distracting tasks	More reliance on the system	More warnings, more intervention	Increase	Driver is bored on a quiet motorway at night and is likely engaged in phone conversations/texting.

This hypothesis is based on the assumption that operators with low workload will distract themselves to avoid falling asleep, being too bored etc. An example is calling / texting someone or exploring the functionalities of nomadic devices. The hypothesis is valid for all modes. The risk potential will increase.

Hypothesis CA H10:
Operators will receive more warnings when under high workload.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Task demand: workload too high	Operator distracted by other tasks and relies on system to intervene	More reliance on the system	More warnings, more intervention	Increase	Driver is overloaded by phone conversation and on a busy urban road.

Operators under high workload are similarly distracted by tasks as in H9 but with the difference that the high workload is also induced by the driving situation. This is valid for all modes. The risk potential will increase.

4.2.2 Speed management

Hypothesis SM H1:
All modes: a) Sensation-seeking operators adopt (or choose) shorter warning thresholds.
Cars and ships: b) Sensation-seeking operators turn advisory systems off.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Attitude: More sensation-seeking	Advice on speed interferes with natural behaviour	Finds warnings annoying	Likely to disable the system, or set shorter warning thresholds	Increase	System turned off after a short period of use.

Sensation seeking operators in all modes may adopt shorter warning thresholds. Ship and car drivers have the freedom to turn a system off, or ignore the advice. This may be more difficult for some professional operators and impossible for train operators. The pathway leads to the operators choosing a warning threshold so that the system warns later. The argument behind this is that they thereby will reduce the number of warnings and even those warnings perceived as false by the operator. The risk potential will still decrease compared to operating the vehicle without any system, it will however increase compared to operating the vehicle with the system's default settings. Even if train drivers cannot change the settings, they may deliberately choose to react later to the warning or ignore it.

Hypothesis SM H2:
Sensation-seeking operators will behave in such a way that more warnings will be triggered.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Attitude: More sensation-seeking	Increased tolerance for risk taking	Speeding	More warnings triggered	Increase	A sensation-seeking operator aims to drive at high speed

This hypothesis is based on the assumption that the system does *not* allow user settings for the warning, or that the operator has not changed the default settings. It is valid for all three modes. The logic behind the hypothesis is that sensation-seeking operators perceive their speed in the situations where the system warns as being acceptable or safe or at least under their control and there is thereby a conflict between the system and the operator which will increase the number of warnings.

Hypothesis SM H3:
Sensation-seeking operators will seek stimulation to cope with monotonous situations.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Attitude: More sensation-seeking	Operator seeks stimulation to cope with monotonous situations	Speeding	More warnings triggered	Increase	Operators trying to increase own level of stimulation in monotonous situations by speeding.

H3 implies that sensation-seeking operators will try to make their task more stimulating by adding risks such as speeding, responding later to warnings. This hypothesis is valid for all three modes and the risk potential will increase with this behaviour.

Hypothesis SM H4:
Experienced operators will receive fewer warnings than inexperienced operators.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Experience: better hazard perception, more experienced	Operator is aware of speed limit	No intervention required from system; operator pleased with the system	No warning or intervention required	Decrease	Operator responds to the speed limit.

H4 is based on the assumption that an experienced operator can foresee potentially hazardous situations and act to avoid them at an early stage, for instance by reducing speed. This will lead to fewer critical situations which in turn will lead to fewer warnings. The risk potential will decrease both compared to inexperienced operators and to when the system is not used. H4 is valid for all modes.

Hypothesis SM H5:
Fatigued operators will rely on the system to warn them about a critical situation.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Operator state: Fatigued	Operator relies more on the system to control the vehicle	More reliance on the system	More warnings, more intervention	Increase	Operator is tired and relies on the speed warning to warn him/her and intervene when necessary.

H5 assumes that the operator delegates some responsibilities to the system and will continue to drive when fatigued. This is valid for all modes. The risk potential will increase.

Hypothesis SM H6:
Operators will receive more warnings when fatigued than when alert.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Operator state: Fatigued	High sleepiness due to early morning work or extended overtime work gives longer reaction time or short periods of micro sleep during work shift	Operators' daytime sleepiness gives missed warnings or speed signs; operator does not respond to warning or responds too late.	System triggered warnings are not detected or detected too late; speed is not adjusted	Increase	The operator misses a warning or reacts to the warning too late.

H6 is based on the assumption that fatigued operators have a longer reaction time or even short periods of micro sleep. This is valid for all modes. When fatigued, the operator will rely on the system to warn for critical situations and will thereby receive more warnings. The risk potential will increase.

Hypothesis SM H7:
Fatigued operators will have less situational awareness than alert operators.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Operator state: Fatigued	Fatigue leads to missing signs or signals	Late response to warning, higher dependence on automatic interventions, passive/reactive driving style	More system interventions, more SPADs, more errors of omission and commission, more warnings	Increased	Fatigued operators are not aware that they should change their speed

Fatigued operators will have lower situational awareness than alert operators and this will be shown by poorer speed control, less minor adjustments and more late/hard correctional manoeuvres. This in turn will lead to more warnings from the system. This is valid for all modes and the risk potential will increase compared to alert operators, although it will be reduced compared to fatigued operators *without* any system.

Hypothesis SM H8:
Fatigued operators may compensate for their fatigue by increasing the safety margin.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Operator state: Fatigued	High awareness of own fatigue	Adopting a strategy to compensate for their fatigue, driving slower to reduce risk	less warnings triggered	Decrease	A fatigued operator drives slower than allowed, thus getting no warnings

H8 assumes that the operator is aware of their state and tries to compensate by increasing the safety margin, e.g. by adopting a longer headway. This will lead to fewer warnings being issued and this is valid for all modes. The risk potential will decrease compared to a fatigued operator not adopting a compensatory strategy or a fatigued operator without a system, but it will of course be increased compared to an alert operator.

Hypothesis SM H9:
Operators will receive more warnings when under low workload.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Task demand: workload too low	Operator is bored and engages in distracting tasks	More reliance on the system	More warnings, more intervention	Increase	Driver is bored on a quiet motorway at night and starts texting.

This hypothesis is based on the assumption that operators with low workload will distract themselves to avoid falling asleep, being too bored etc. An example is calling / texting someone or exploring the functionalities of nomadic devices. The hypothesis is valid for all modes. The risk potential will increase.

Hypothesis CA H10:
Operators will receive more warnings when under high workload.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Task demand: workload too high	Operator distracted by other tasks and relies on system to intervene	More reliance on the system	More warnings, more intervention	Increase	Driver is overloaded by phone conversation and on a busy urban road.

Operators under high workload are similarly distracted by tasks as in H9 but with the difference that the high workload is also induced by the driving situation. This is valid for all modes. The risk potential will increase.

4.2.3 Operator state monitoring

Operator state monitoring is currently a possibility in cars, trains and ships. In D2.1 such a system was not described for the maritime domain, but they do exist. While working on the hypotheses, we became aware that the systems are not equivalent in terms of their effect on operator task. In train systems, the operator has to actively push a button or a pedal to indicate that he/she is still alert. If they do not do so every X seconds (e.g. 2.75 seconds), a warning will sound and if there is no reaction the train will stop automatically or the control centre will look into the situation. For cars, but also for ships, the system monitors whether the operator is still active, by passively detecting eye or body movements. If the system detects a problem, the operator is alerted, and eventually the system may also take further action. This difference between active and passive monitoring has very different effects on the operator. Several hypotheses can be generalised, but are different for the different modes. Also some hypotheses are not relevant for this system, because the system reacts to the operator state directly (warning when it detects sleepiness), and not on the driving behaviour.

Hypothesis OS H1:
Cars and ships: *Sensation-seeking operators adopt (or choose) shorter warning thresholds.*

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Attitude: More sensation-seeking	Sensation seekers do not want to acknowledge they are not fit to drive	Finds warnings annoying	Likely to disable the system	Increase	System turned off after a short period use.

This hypothesis requires a system that allows user settings on the warning threshold; safety systems for trains do not usually allow this, therefore H1 is only valid for cars and ships. The pathway leads to the operators choosing a warning threshold so that the system warns later. The argument behind this is that they thereby will reduce the number of warnings and even those warnings perceived as false by the operator. The risk potential will still decrease compared to operating the vehicle without any system, it will however increase compared to operating the vehicle with the system's default settings.

Hypothesis OS H2:
Sensation-seeking operators will behave in such a way that more warnings will be triggered.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Attitude: More sensation-seeking	Increased tolerance for risk taking	Continue driving while fatigued	More warnings triggered	Increase	A sensation-seeking operator aims to continue driving whatever his/her state

This hypothesis is based on the assumption that the system does *not* allow user settings for the warning, or that the operator has not changed the default settings. It is valid for all three modes. The logic behind the hypothesis is that sensation-seeking operators perceive situations where the system warns as being safe, and there is thereby a conflict between the system and the operator which will increase the number of warnings. Continuing to operate when fatigued will increase the risk potential compared to an operator who adopts the system without challenging it, the risk is however likely to decrease compared to not using a system.

Hypothesis OS H3:
Sensation-seeking operators will seek stimulation to cope with monotonous situations.

This hypothesis is not relevant because the operator monitoring system reacts on the driver state and not on the driving behaviour.

Hypothesis OS H4:

Trains *a) Experienced operators will receive fewer warnings than inexperienced operators.*
b) Inexperienced operators will receive fewer warnings than experienced operators.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Experience: hazard perception, more experienced	Operator knows when to press the button	Operator presses the button within the set limits	No warning or intervention required	Decrease	Train operator presses the button every 2.75 seconds
Experience: hazard perception, less experienced	Operator is afraid to forget pressing the button in time and to receive a warning, thus increasing his/her workload and stress	Operator presses the button too frequently	No warning or intervention required	Increase	Train operator presses the button before it is required

There are no hypotheses for cars and ships, because the system will detect the fatigue of operators regardless of their experience. Both experienced and inexperienced operators will react in the same way. However, for train drivers the system works differently. They have to actively react by pressing a button. Two conflicting hypotheses can be formulated; the experienced operator knows when to press the button in time, even when fatigued, and the inexperienced operator presses the button too often because of being afraid to forget it. In both cases they received fewer or no warnings.

Hypothesis OS H5:

Trains: *a) Fatigued operators will rely on the system to warn them about a critical situation, especially experienced operators.*

Cars and ships: *b) Fatigued operators will rely on the system to warn them about a critical situation.*

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Train operator state: Fatigued	Experienced operator pushes button automatically	Operator presses the button within set time	No warning given	Increase	Experienced train operator is fatigued but still manage to press the button
Car or ship operator state: Fatigued	Operator relies on the system to warn him/her if driving is no longer safe	More reliance on the system	More warnings	Increase	Operator is tired but continues driving, relying on the system to warn him/her

H5 is comparable with H4 for train operators. For car and ship operators it is hypothesised that they will over-rely on the system, and not take a break when fatigued, thus increasing risk.

Hypothesis OS H6:
Operators will receive more warnings when fatigued than when alert.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Operator state: Fatigued	High sleepiness due to early morning work or extended overtime work gives longer reaction time or short periods of micro sleep during work shift	Operators' sleepiness will evoke warnings	System triggered warnings	Decrease	Operators' sleepiness triggers warning.

This hypothesis states that the system functions as intended, when the operator is fatigued and sleepy, the system will warn him/her, thus decreasing risk. H6 is valid for all modes.

Hypothesis OS H7:
Fatigued operators will have less situational awareness than alert operators.

Not relevant, because the system will warn operators when they are fatigued.

Hypothesis OS H8:
Fatigued operators may compensate for their fatigue by increasing the safety margin.

Not relevant, because the system will warn operators when they are fatigued, regardless of their driving behaviour.

Hypothesis OS H9:
Operators will receive more warnings when under low workload.

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Task demand: workload too low	Operator is bored and tends to fall asleep	More reliance on the system	Warning	Decrease	Car driver is bored on a quiet motorway, falls asleep and gets a warning

Because of low workload, operators may tend to fall asleep, thus triggering a warning. The risk potential decreases because the operator is warned in time. H9 is valid for all modes.

Hypothesis OS H9:

For trains: *Operators will receive more warnings when under high workload.*

Input	Pathway	Effect on operator's interaction with system	Effect on system functionality	Risk potential	Example scenario
Task demand: workload too high	Train operator distracted by other tasks and forgets to push the button	Operators does not press the button within the set time	More warnings, more intervention	Neutral	Train driver is engaged in several tasks and forgets to push the button

For car and ship operators this hypothesis is not relevant, under high workload the operator will not tend to fall asleep, so the system will not give warnings. For train operators it is hypothesised that they may forget to press the button in time and therefore get more warnings.

4.3 Conclusions

At a general level, systems supporting obstacle and collision avoidance, and those maintaining speed have a large set of common effects on operator task, for all of the three transport modes studied in the ITERATE project. Of course, at a more detailed level, there are differences.

As operator state monitoring systems were found to differ considerably between modes, these will not be considered for the experimental phases.

5. SUMMARY AND JUSTIFICATION OF SELECTED SYSTEMS

Based on the analysis of common functionalities of systems and the outcome of the work on hypotheses, we have decided to select the following systems for the experimental work in WPs 3 and 4:

Collision avoidance:

- Car: Forward Collision Warning (FCW)
- Ship: Radar with Automatic Radar Plotting Aid (ARPA)
- Rail: Automatic Warning System (AWS)

Speed management:

- Car: Intelligent Speed Adaptation (ISA)
- Ship: speed pilot (part of the autopilot), Electronic Chart Display and Information System (ECDIS)
- Rail: full Automatic Train Protection and Train Control systems (ATP/ATC)

As these systems can vary in their functionality, we have decided to focus on the warning and not on the intervention functionality.

A short summary of each system, based on the descriptions in D2.1, and a justification for their choice is provided in the next section.

5.1 Collision avoidance systems

For these systems, we have also chosen those that provide warning rather than information or support. If there is an obstacle (or another vehicle) in front of the vehicle and a danger of collision is imminent, the operator receives a warning and has to take an action to avoid a collision, either braking or, in the case of cars, by changing direction, if possible. Although some effects are equivalent to those for the speed management systems, the danger is much more immediate and the operator has to react immediately. This will help us to define experimental scenarios in which we can expose the operators to a variety of potentially dangerous situations and study their behaviour in such situations and their reaction to warnings. The FCW for cars is focussed on avoiding collisions with other vehicles. For ships, the system chosen is also a radar-based one. The AWS for trains is more focussed on reacting to signals that indicate a potentially dangerous situation.

5.1.1 Cars: Forward Collision Warning (FCW)

FCW can help avoid rear-end impacts or minimise the effects of these type of collisions. A radar continuously scans the area in front of a vehicle. If the vehicle approaches a lead vehicle too quickly or is too close to the lead vehicle, the driver is alerted via auditory and/or visual warnings.

5.1.2 Ships: Radar and ARPA

An ARPA (Automatic Radar Plotting Aid) is a computer assisted radar data processing systems which generates predictive vectors and other ship movement information. It could create tracks using radar contacts. A radar with ARPA usually has the following capabilities:

- True or relative motion radar presentation; automatic acquisition of targets plus manual acquisition;
- Digital read-out of acquired targets which provides course, speed, range, bearing, closest point of approach (CPA), and time to CPA (TCPA) thereby knowing if there is a danger of collision with the other ship or landmass;
- The ability to display collision assessment information directly on the plan position indicator (PPI), using vectors (true or relative) or a graphical Predicted Area of Danger (PAD) display.

Warnings for CPA are given as soon as they are calculated – this can give warning for potential close-quarter situations a long time before, but setting TCPA will limit “too early warnings”.

5.1.3 Trains: Automatic Warning System (AWS)

AWS gives the train operator visual and audible warning of the signal aspect displayed by the signal being approached. As the train passes over a magnetic inductor (known as *AWS inductor*) approximately 180 metres from the signal, a visual indicator in the cab turns black. If the lineside signal is displaying a clear aspect, the indicator stays black and a bell sounds. If it is displaying a cautionary or danger signal aspect, the indicator displays alternate black and yellow sectors (reminiscent of an “exploding” disc) and a continuous horn sounds. The operator must cancel the horn within 2.75 seconds or a full emergency brake application results. The indicator remains black and yellow as a reminder of the last received warning. AWS provides additional warning of signal aspect, but has strictly limited train protection capability. AWS is a “binary” system, regarding the fact that the system only can indicate whether a signal is "green” or “not green”; in other words, AWS only has two states and cannot indicate multi-aspect signalling based on three or four aspects. If the operator cancels the warning, but fails to stop the train, the system will not intervene to prevent the signal being passed.

5.2 Speed management systems

The speed systems selected all give a warning when there is a difference between the speed chosen by the operator (or the speed with which the vehicle is currently driving), and the recommended or obligatory speed. This choice allows us to experiment with different scenarios in which this discrepancy occurs and investigate the interaction between operator and system functionalities. For instance, we can study this interaction in situations where either the recommended speed is complied with or where behaviour is risky in terms of speed. The University of Leeds has a large experience with field operational tests with ISA systems for cars. For ships, the system is not fully equivalent, but also for this mode the operator has to be aware of the differences between the set speed and the speed that is required in a given situation. For trains, whilst more advanced systems than the full ATP/ATC system are available, these are not yet implemented on a on a large scale across Europe. To avoid training train operators for the experiments we have chosen a system that is widely used and familiar to train operators. The systems chosen for each mode are described in the next sections.

5.2.1 Cars: Intelligent Speed Adaptation (ISA)

ISA provides drivers with support on the speed-control task by constantly monitoring the vehicle speed and comparing it with the local speed limits. Appropriate speed limits are determined by pin-pointing the vehicle's location on the road network via GPS signals. An ISA system that provides warnings only reminds the driver of the appropriate speed limit and triggers visual and/or auditory warnings when the vehicle's speed exceeds the speed limit.

5.2.2 Ships: Speed Pilot and Electronic Chart Display and Information System (ECDIS)

In ships, a speed pilot keeps a set speed. During a turn, the system will increase the speed slightly, in order to compensate for the speed loss during the turn. It can be programmed for a whole route, including different speeds for different legs of the journey.

An ECDIS system displays the information from Electronic Navigational Charts and integrates position information from the GPS and other navigational sensors, such as radar, fathometer and automatic identification systems (AIS). It is possible for the navigator to manually insert a line in the ECDIS at a certain position in order to get a warning when the line is passed. This can then be used as a reminder to, for example, check the speed, or another setting.

5.2.3 Warning, intervention and speed supervision systems with intermittent information transmission (full ATP/ATC system)

The ATP/ATC systems involve track to train transmission of the signal aspect and (sometimes) the associated speed limits. On board equipment will check the train's actual speed against the allowed speed and will stop the train if any section is entered at more than allowed speed. This information allows the system to calculate the theoretical curve of the train speed and to supervise the accurate speed of the train, in real time. If the speed is too high the operator is warned, for example by an acoustic alarm, and if the operator does not respond by braking, the service intervenes and an emergency brake is applied and adapted to the braking curve.

6. FUTURE WORK

The selection of the systems was done in preparation for the work to be done in Workpackage 3, *Experimental design and scenario specification*, and in Workpackage 4, *Experimental studies*. For the systems selected, the parameters from the model developed in Workpackage 1 (attitude, experience, state, task demand and culture) will be further specified. The hypotheses formulated in this workpackage will provide a solid base on which the more detailed work in Workpackage 3 can build. Indicators, observable variables, will be defined to enable quantitative evaluation to test the hypotheses, measuring the impact of the use of the system on operator behaviour. An example is measuring the differences in reaction times of fatigued and non-fatigued drivers on receiving a warning from a speed management system. Next scenarios will be developed, to be used in the experiments with the simulators. An attempt will be made to develop scenarios over the different modes that share commonalities. As we have shown in this deliverable, commonalities in the effects of these systems on operator behaviour do exist and we are confident that it is possible to develop scenarios that bring out those commonalities.

Test procedures will be specified and portable simulators developed. This preparatory work in Workpackage 3 forms the basis of the experimental studies in Workpackage 4, where the hypothesised effects will be tested with operators.

Finally, this work will be fed back to the work on model development in Workpackage 6.

7. REFERENCES

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