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Transportation Research Procedia 69 (2023) 823–830

Transportation Research Procedia

www.elsevier.com/locate/procedia

AIIT 3rd International Conference on Transport Infrastructure and Systems (TIS ROMA 2022), 15th-16th September 2022, Rome, Italy

A methodology to explore the road safety impact of fitness to drive solutions for commercial drivers: The PANACEA project

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Abstract

In Europe, one in four road deaths occurred in an accident involving a goods vehicle in 2018 (ETSC 2020). Commercial drivers are at higher risk for suffering from physiological, psychological and prescribed medication and illicit drug use, including alcohol misuse. Fitness to drive or driver state monitoring systems integrate technologies able to detect altered driver states and provide them feedback. They constitute an emerging phenomenon, and their effects on changing people's behaviour to drive more safely, and in general, their impact on road safety should be better investigated.

The scope of this paper is to present a methodology able to simulate different scenarios to understand how a driver state monitoring system can support improving road safety in the European Union. A conceptual framework is presented to support the definition of the impact assessment methodology and is applied to the PANACEA European research project. The project develops an integrated solution for driving ability assessment of commercial drivers, paired with a countermeasure and coaching solution. The PANACEA system uses algorithms and technologies for detecting, monitoring and assessing alcohol consumption, licit (barbituric) and illicit (methadone substitute) drugs, fatigue and cognitive load (Commercial Health Toolkits (CHTs)). It also provides strategic, tactical and operational countermeasures that will be tested and evaluated to assess their effectiveness and acceptance by the system's users.

The methodology presented is able to assess both a single and multiple countermeasures among those developed within the project. Different scenarios have been considered by modifying the variables according to the screening prevalence, solution acceptance level, driving context and time. The methodology uses the results from the project pilot studies in terms of accuracy, sensitivity, and specificity of CHTs and countermeasures results in combination with evidence from the existing literature.

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2352-1465
10.1016/j.trpro.2023.02.241

Keywords: impact assessment; commercial health toolkits; fitness to drive; road safety

1. Introduction

Commercial drivers are at high risk for crashes, not only because they are driving a lot during consecutive hours day and night time, but also because the working conditions are demanding and putting them at risk to unhealth and illness, due to demanding shifts, demanding ergonomic situations both in terms of physical and information ergonomic (Useche et al. 2018). The working conditions also influence their family and social life opportunities. Commercial drivers are at higher risk of suffering from physiological (e.g. sleepiness, fatigue), psychological (e.g. emotional, frustration, rage) and prescribed medication (e.g. for epilepsy, anxiety, allergies, diabetes for chronic conditions as well as pain killers for temporary or acute pain) and illicit drugs use (e.g. stimulants, amphetamines, THC, etc.) including alcohol misuse that is of the most dangerous factors of all (Moain et al. 2014).

In Europe, one in four road deaths occurred in an accident involving a goods vehicle in 2018 (ETSC 2020). Distraction, drowsiness, and intoxication are among the main factors in road accidents. The Driving under the Influence of Drugs, Alcohol and Medicines (DRUID) project has calculated that, on average, 3.48 % of drivers in the European Union drive with alcohol (> 0.1 g/l) in their blood, 1.9 % with illicit drugs, 1.4 % with (a limited list) of medicinal drugs, 0.37 % with a combination of alcohol and drugs and 0.39 % with different drug classes (EMCDDA 2012). Fatigue is also a major contributing factor for this category of drivers. Research shows that fatigue contributes to up to 20% of all crashes (Bunn, Slavova, and Rock, 2019).

Among the most promising technologies to counter this phenomenon are driver status monitoring systems. Broadly, these refer to the embedded, aftermarket wearable or vehicle-mounted devices that collect observable information about the operator to make real-time assessment of their capacity to perform the driving task. Integrating biobehavioral monitoring (primarily ocular metrics) with driving performance assessments, these systems function to infer driver state in real time to identify operator conditions that negatively affect driving (such as fatigue, inattention, or distraction) (Hayley et al., 2021).

The PANACEA research project, funded by the European Commission, is developing an integrated solution for driving ability assessment of commercial drivers, paired with a countermeasure and coaching solution. The System uses algorithms and technologies for detecting, monitoring and assessing alcohol consumption, licit (barbituric) and illicit (methadone substitute) drugs, fatigue and cognitive load.

Based on the impairment states found in the drivers of a vehicle fleet, the system suggests countermeasures at driver and operator levels. Taking Michon's 3-level hierarchical model of the driving task as a reference (Michon 1985), three groups of countermeasures are distinguished in PANACEA: operational, tactical and strategic countermeasures:

- Operational countermeasures are those concerned with the here and now. They are actions that need to take place during the shift (between clocking on and clocking off for shift, break times within a shift are included), within a short time frame of the impairment being detected.
- Tactical countermeasures are those concerned with the short to mid-term but do not require deployment on the shift where the impairment was detected.
- Strategic countermeasures are those concerned with long term behavioural change.

The PANACEA system will be able to assist commercial drivers and riders across the working day and after they finish their shift. The system will be tested in three pilot sites: a) in Sweden, with AV shuttle bus drivers, b) in Greece, with taxi drivers and courier service riders and c) in Spain, with electric trucks and coaches drivers.

The salient scope of this paper is to present a methodology able to simulate different scenarios to understand how the various solutions developed in PANACEA (Commercial Health Toolkits (CHTs) and countermeasures) can support improving road safety in the European Union.

The rest of the paper is organised into four sections. Chapter 1 introduces the topic, Chapter 2 includes a literature review of previous studies assessing driver monitoring systems for detecting altered states of drivers. Chapter 3 describes the conceptual framework adopted, Chapter 4 the proposed methodology and Chapter 5 provides some conclusions.

2. Literature review

PANACEA builds on the main European projects and initiatives developed in the road safety domain and intends to exploit prior work to further enhance the achieved results of DRUID, SENSATION, ADAS&ME, MEBESAFE, SafetyCube, iDREAMS, INFRAMIX, SHOW and Greensense through common Partners. This project includes 17 partners from 8 countries, representing Research institutes (4), Universities (2), industrial partners (6), SMEs (2), and Stakeholder organisations and authorities (3) and one third party (ACS to UNI). These companies bring their experience, system know-how and expertise about the requirements for the next generation systems into the project and ensures that PANACEA results find their way into the market rapidly.

The PANACEA system integrates technologies aimed at monitoring and detecting an impaired state of the driver potentially leading to a vehicle collision. These technologies, also named driver state monitoring systems, refer to “embedded or built-for-purpose tools that collect observable data about the operator to assess competency to execute the driving task safely and effectively” (Hayley et al. 2021). This includes measuring driver behaviour (e.g. inattention, distraction, fatigue) and driving performance (speed, acceleration, steering wheel position) (Hayley et al. 2021). Melnicuk et al. (2016) introduce the concept of a “hybrid” driver state monitoring system, including driver state, driving performance and driving context (road layout, traffic level, weather, time and location).

(Coughlin, Reimer, and Mehler 2011) proposed a safety monitoring and management model in which the driver is an active participant. The system is able to identify the state of the driver, inform the driver of his/her state and activate countermeasures to warn him/her (in the case of drowsiness) or to calm him/her down (in the case of stress).

Just informing drivers about their current state is already an effective countermeasure (Sprajcer et al. 2022). Obviously, detection capability varies from technology to technology, so a prerequisite is to have a system that is able to provide reliable measurements (accuracy, sensitivity, and specificity).

In most cases, the countermeasures considered by these systems target the driver and are operational in nature. (Bell et al. 2017) compared the effects on the risky driving behaviour of two feedback mechanisms to drivers: with immediate feedback to the driver and with immediate feedback supplemented by an individual coaching session with between supervisor and driver. Risky driving behaviour decreased significantly more in the group that also received coaching than in the group without coaching and the control group.

This aspect is considered by the conceptual framework proposed by (Horrey et al. 2012) as shown in Fig. 1, which shows the elements affecting, directly or indirectly, the driving task at the three levels proposed by Michon (1984). On the one hand, we have the road environment, which represents the driving context (traffic situation, type of road, etc.). Then we have the working environment (organisation), which can influence driver choices through company policies, procedures and the company safety culture. Driver characteristics also influence behaviour (Usami et al., 2017). While age, experience and driving skills mainly influence the ability to control the vehicle, personality, attitudes, risk perception, and risk-seeking can influence behaviour at a tactical and strategic level. The on-board safety monitoring system (OBSMS) can impact driver behavior providing feedback primarily to the driver but also to the organisation (e.g. the fleet manager).

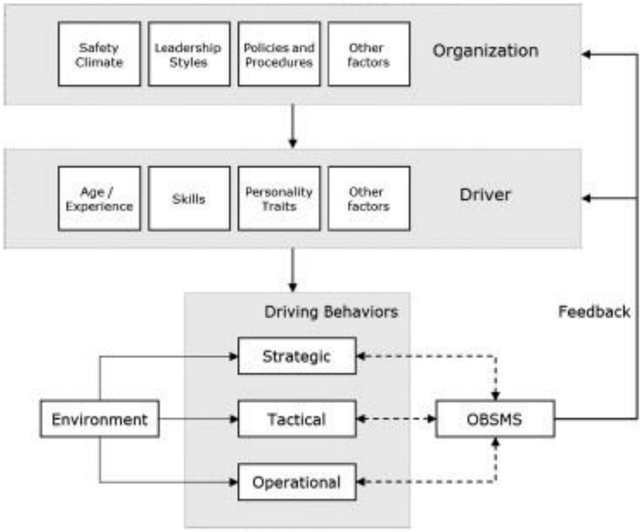

Fig. 1. Conceptual framework for discussion of driver state monitoring systems (source: Horrey et al. (2012)

The feedback usually offered by these systems is of two types: real-time (with audio, video or tactile signal) and off-line, for example, allowing access to a web page showing the driver's performance and the average performance of other drivers (for comparison purpose). The two types of feedback have a different effects on driver behaviour, but this is not evident from the framework of Horrey et al. (2012). There are two aspects missing from this model, the first one is the driver's response to system feedback, i.e. the acceptability of any solutions indicated by the system. In this respect, it would be appropriate to introduce a system acceptance model, which would make it possible to assess whether or not the user would adopt the countermeasures suggested by the system. Of the theoretical behavioural models, probably the most suitable for this purpose is the TAM model (Technology Acceptance Model). The model was proposed by Davis (Davis, 1989) to understand the predictors of human behaviour with regard to the acceptance of a technology. A second aspect is the reliability of the system's ability to recognise any altered state of the driver.

As also documented by Horrey et al. (2012), studies conducted on these systems show positive effects on safety. The variations observed refer to both indicators of driving behaviour and indicators of road accidents. In the first group, we find types, numbers and severity of manoeuvres (e.g., hard braking, excessive speeds, unsafe turning, etc.) and driving behaviour related events (e.g. texting/dialling, yawning, seatbelt use), see for instance, Bell et al. (2017). The second group includes accident-related indicators like crash rates and crash involvement and involvement in impaired related road accidents.

Two aspects are worth highlighting. Firstly, the mode and type of feedback provided are often unclear, and it is difficult to understand the causal mechanism and which feedback is most effective. Secondly, all the cases examined were evaluation studies, focussing especially on the effectiveness of the solutions; they do not analyse the possible safety impacts of the solutions, which is the type of study that is relevant in this case.

3. Conceptual framework and methodology

3.1. Conceptual Framework

The proposed reference framework to assess the impact is an adapted version of the model proposed by Horrey et al. (2012) in Fig. 2. The framework takes also into account the five layers pyramid model proposed by the European research project SUNflower (Wegman and Oppe 2010). The top layer of the pyramid are the final outcomes (the number of road fatalities and injuries and their social cost), then we have the intermediate results, in terms of user behaviour and infrastructure and vehicle characteristics (Safety Performance Indicators), the policy performance in terms of road safety measures implemented, and the context in terms of the 'structure and culture' of the country. The main idea is that what is at the top is the result of the layers below, so understanding the phenomenon requires measuring all the elements in the pyramid.

Since the focus is on the impact of the PANACEA system solutions, these were more explicitly included in the model with the two blocks, Monitoring and detection and Countermeasure system. The Monitoring and detection block represents the ability of the technologies adopted by the system to detect risky behaviour of a driver, while the Countermeasure system block represents the feedback provided to the driver and operator, taking into account the states of the drivers monitored by the system.

The Driver block describes driver characteristics in terms of demographics, attitudes, risk perception and other factors that may affect the likelihood of driving under the influence of alcohol, drugs, stress or fatigue (Driving behaviour). Altered driver states are detected by the PANACEA system (Monitoring and detection) according to the system accuracy, sensitivity and specificity. The Countermeasure system then uses this information to provide feedback to the driver and the operator in terms of strategic, tactical or operational countermeasures. These countermeasures, in the form of tips and advice, can influence the driver's attitudes and perceptions and/or the features of the trips of the drivers (e.g. length, period, and driver state during the trip).

The Operator is a manager responsible for drivers' safety and for formulating and implementing safety policies and training. The countermeasures are recommended by the system but their acceptance and adoption is ultimately decided by the driver and the operator.

Aspects related to the trips made and the road environment are considered in the Risk Exposure block, which provides the distances travelled by a commercial driver in relation to the type of road and time of day. This also includes the type of vehicle, which has a significant influence on the accident risk as shown by numerous studies (see, for example, Elvik and al. 2009).

Once the distances travelled by a driver on different road categories, periods of the day, with different states are known, it is possible to estimate a safety indicator. This can be either an indicator of the frequency of accidents or injuries in a given period or a surrogate indicator such as the frequency of safety-related events, e.g. the number of hard brakes.

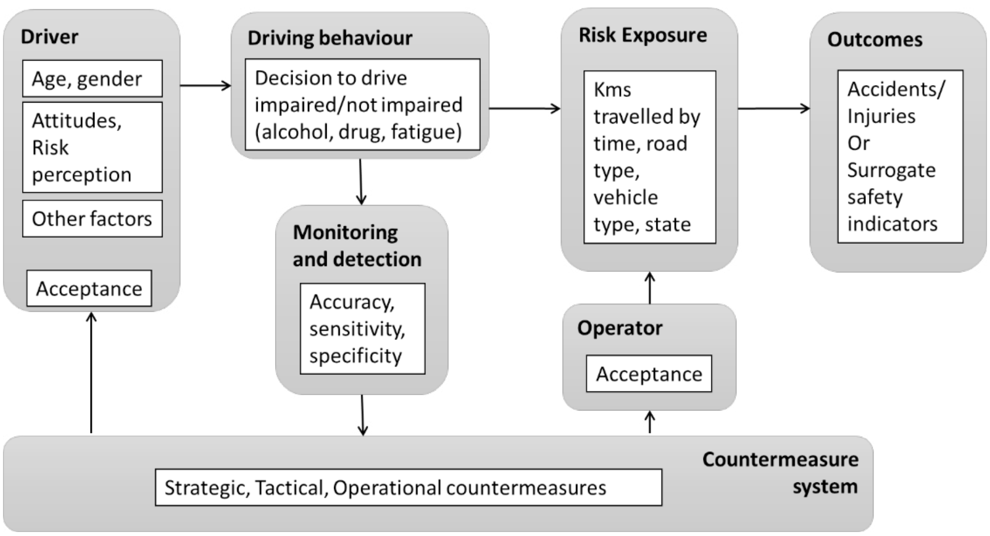

Fig. 2. Conceptual framework for the assessment of PANACEA system

The proposed framework makes it possible to evaluate different scenarios involving the use of PANACEA solutions, estimating their effects on safety. By knowing the characteristics of a company's drivers and their yearly trips, it is possible to assess the level of safety with and without the PANACEA driver monitoring and countermeasure system.

3.2. Methodology

The PANACEA project uses strategic, tactical and operational countermeasures. A number of countermeasures will be developed during the project and will be implemented in the cloud-based countermeasures and coaching tool.

Table 1 gives examples of interventions, some of which will be implemented in the Countermeasures and Coaching System (CCS). The impact mechanism of each countermeasure will be examined in detail in order to understand which block of the model is affected and identify the most relevant impact indicators.

In principle, operational countermeasures for drivers (e.g. caffeine and napping advice) and operators (e.g. changing driver) are expected to influence the single trip mostly, thus modifying the accident risk exposure. This means changing the state of a driver found impaired during a trip (or during a part of it), from e.g. drowsy driving to not altered driving.

Tactical and strategic countermeasures affect personal factors (e.g. attitudes, risk perception) contributing to impaired driving.

Table 1. PANACEA risk management system – Examples of countermeasures

	Driver	Operator
Operational	Caffeine and napping advice	Changing driver due to alcohol
	Guided breathing exercises	Changing driver due to fatigue
	Message, auditory, visual and/ or haptic warning/ alert to a driver and operator that fatigue has been detected	Providing facilities for rest breaks
Tactical	Advice about Alcohol use before work	Advice/tools for Scheduling and how work is distributed within a shift
	Advice about licit drugs prior to shift (taken the night before a morning shift or in the morning of a morning shift) focus on immediate and residual effects	Training for managers in how to identify stress in drivers/when driving
Strategic	Lifestyle coaching relating to prescription drugs	Training and education on impact of alcohol and fatigue on driving
	Lifestyle coaching for optimising rest (off duty) time in terms of reducing stress and related fatigue	

The countermeasures developed during the project will be tested and evaluated to assess their effectiveness and acceptance by the users of the system.

With reference to Fig. 2, a tool that simulates the behaviour of drivers and operators will be developed in order to assess the impact of the system on road safety. The methodology is based on the development of models that define the relationships between the different elements of the framework: 1. Driving behaviour, 2. Impairment Detection, 3. System Acceptance 4. Risk exposure, 5. Outcomes.

1. *Driving behaviour*. The decision to drive while impaired depends on several factors, as already highlighted. The study plans to exploit data from the international survey ESRA. This survey is a comprehensive online panel study using a sample of the adult population that is representative of each participating country. The themes covered are self-reported behaviour, attitudes and opinions on unsafe traffic behaviour, enforcement experiences, and support for policy measures. The survey addresses different road safety topics, including driving under the influence of alcohol, drugs and medicines, distraction and fatigue (Meesmann et al., 2021). To model three impairment types (alcohol, drug, fatigue), binary logistic regression technique is planned to be used. It is a well established statistical method applied to model binary outcomes like, in this case, the variables indicating the absence or presence of self-reported drink-driving/drug driving/driving while fatigued. Due to the different specificities at least two commercial drivers categories will be considered: one for taxi, bus, truck drivers and one for courier, salesperson, postman, visiting patient, etc.

2. *Impairment Detection*. The impairment detection accuracy model is based on the development of a confusion matrix based on the technology's validation tests undertaken during the project.

3. *System Acceptance*. In order to influence the behaviour of drivers and operators, they should be willing to use the system. Acceptance of the countermeasures will be investigated through a survey during the project. The

theoretical reference models will be the Technology Acceptance Model (TAM) (Davis, 1989) and/or the expanded version of the Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Thong, & Xu, 2012).

4. *Risk Exposure*. A survey involving operators of different organisations will be undertaken to investigate the common travel patterns and existing policies and practices in the organisation. We will try to reach different types of organisations (taxis, public transport, long-haul freight, couriers, etc.).

5. *Outcomes*. The existing research and datasets available for EU member states will be investigated to create a database of accident rates by road type, vehicle type, time and state.

4. Conclusion

The study presents a methodology for assessing the road safety impacts of a system for detecting and monitoring fitness to drive with feedback to the driver and the operator responsible for safety in an organisation. The methodology will be applied to the system developed within the European research project PANACEA.

Different scenarios will be considered to explore the safety impact by modifying the variables related to the screening prevalence, solution acceptance level, driving context and time period. The methodology will be able to assess both single and multiple countermeasures among those developed within the project.

The next steps for the application of the conceptual framework and the performing the assessment of the project impacts, are related to the acquisition and cleansing of data from the international ESRA survey. and the development of logistic regression models for the three risk factors considered. Parallel to this will be the definition of the survey tools for the acceptance of countermeasures and the system. A review of existing research on causal relationships between countermeasures and road safety outcomes (accident frequency and severity) together with the results from the countermeasures evaluation results, will be used to validate the proposed methodology.

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The research is relevant from societal and scientific perspectives. According to (Hayley et al. 2021), fitness to drive monitoring systems represent “the largest technological revolution to occur in vehicles in the past 100 years”. This is true if we think about how many accidents are caused by impaired driving. Therefore, their effects on changing people’s behaviour to drive more safely and their impact on road safety need to be investigated.

Based on authors’ knowledge, there are no studies assessing the safety impact of driver monitoring systems from the perspective of an organisation. It can fill a research gap and its results can provide new perspectives on the use of these systems.

The assessment tool can be very valuable for organisations with employees operating a vehicle for company business. It helps estimating the potential benefits of introducing this kind of system in their organisation.

However, there are some limitations concerning the proposed methodology, of which the major one is that the impact framework considers only the impact on road safety. Other potential beneficial effects that some countermeasures may have on e.g. healthy behaviours and thus on health conditions (e.g. drinking or sleeping habits), or other possible impacts on the environment, travel time or punctuality of deliveries, have not been covered.

Acknowledgements

The study presented in this paper is part of the research project titled “PANACEA - *PracticAl and Effective tools to moNitor and Assess CommErciAl drivers’ fitness to drive*”, funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement number 953426.

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