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Post-trip safety interventions: state-of-the-art, challenges and practical implications

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Abstract

Currently, risky driving behavior is a major contributor to road crashes and as a result, wide array of tools have been developed in order to record and improve driving behavior. Within that group of tools, interventions have been indicated to significantly enhance driving behavior and road safety. This study critically reviews monitoring technologies that provide post-trip interventions, such as retrospective visual feedback, gamification, rewards or penalties, in order to inform an appropriate driver mentoring strategy delivered after each trip. The work presented here is part of the European Commission H2020 i-DREAMS project. The reviewed platform characteristics were obtained through commercially available solutions as well as a comprehensive literature search in popular scientific databases, such as Scopus and Google Scholar. Focus was given on state-of-the-art-technologies for post-trip interventions utilized in four different transport modes (i.e. car, truck, bus and rail) associated with risk prevention and mitigation. The synthesized results revealed that smartphone applications and web-based platforms are the most accepted, frequently and easiest to use tools in cars, buses and trucks across all papers considered, while limited evidence of post-trip interventions in -rail was found. The majority of smartphone applications detected mobile phone use and harsh events and provided individual performance scores, while in-vehicle systems provided delayed visual reports through a web-based platform. Gamification and appropriate rewards appeared to be effective solutions, as it was found that they keep drivers motivated in improving their driving skills, but it was clear that these cannot be performed in isolation and a combination with other strategies (i.e. driver coaching and support) might be beneficial. Nevertheless, as there is no holistic and cross-modal post-trip intervention solution developed in real-world environments, challenges associated with post-trip feedback provision and suggestions on practical implementation are also provided.

1 INTRODUCTION

Driving behavior is one of the leading contributing factors to road safety. For instance, speed not only affects the severity of a traffic collision or an accident, but is also related to the risk of being involved in a crash (Aarts and Schagen, 2006). Recently, with the evolution of technology, a few driver monitoring systems and gamified web-platforms, vehicle diagnostics and smartphone applications have been introduced in order to record driving performance, focus on key risk indicators and provide safety interventions after the end of a trip, weekly or monthly. One application of in-vehicle technologies and monitoring systems is to create a post-trip visual footprint of a driving event. These post-trip interventions provide personalized feedback and scoring to the driver, based on the personal performance on a series of risk related behavioral parameters. The aim of such retrospective interventions is to change drivers' behavior, and keep them motivated to operate their vehicle in a safer and more eco-efficient way over a longer period of time. Thus, drivers are able to identify their behavioral weaknesses, self-monitor their driving history and improve their style as well as promote maximum road safety through interventions.

It must be noticed that post-trip intervention studies occupy an important role in research due to the emphasis on crash prevention. Payyanadan et al. (2017) revealed that post-trip interventions can help drivers assess their limitations and adjust their driving style. Providing drivers with tailored feedback of their performance and crash risk can help them appropriately self-regulate their driving behavior and improve their crash risk outcomes. In addition, Newnam et al. (2014) showed that risky driving behavior and speeding violations can be decreased following participation in modification interventions, where drivers receive weekly feedback on their speeding performance as well as goal setting exercises. An interesting finding of Toledo and Lotan (2006) indicated that exposure to post-trip interventions had a positive effect on driver performance and therefore safety. However, if follow-up efforts were not made, neither of the impacts was sustained over time. Moreover, travel-feedback programs were developed in order to correlate the frequency of trip lengths and the total duration of car trips with driving performance (Fujii and Taniguchi, 2005). The results indicated that feedback programs significantly reduced car-use by 27.7% in terms of total trip duration and by 11.6% in terms of car-use days. Using post-trip intervention technology, big data and machine learning algorithms, drivers can reliably quantify the risk associated with a specific driving behavior such as speeding, number and severity of harsh events (braking and acceleration), harsh cornerings or driving aggressiveness.

Taking into consideration the importance and the effectiveness of post-trip interventions, the European Union's Horizon 2020, i-DREAMS[1] project, aims to set up a platform and system which provides timely interventions to keep drivers of different modes in a safe driving area. In particular, the objective of i-DREAMS is to monitor if drivers are within acceptable boundaries of safe operation conceptualized by the project as the "Safety Tolerance Zone" (STZ) and prevent them from getting too close to unsafe driving by mitigating risks both in real-time and post-trip. Consequently, the i-DREAMS platform focuses on the implementation of highly customized interventions and the integration of a set of monitoring and notification tools for in-vehicle assistance and support. Undoubtedly, this is an essential asset which offers the possibility to implement delayed feedback to improve road safety and driving performance. The key output of the project will be an integrated set of monitoring tools, including in-vehicle assistance, gamification, rewards, penalties and visual feedback as well as a gamified platform for self-determined goal setting working with incentive

[1] Further general project information can be found on the website: https://idreamsproject.eu

schemes, training and community building tools. The main aim of this paper is to review state-of-the-art technologies which deliver post-trip interventions. The findings will be used to inform the development of the i-DREAMS platform.

As a first step towards developing the i-DREAMS intervention strategy, the current study aims to review and critically assess the various driver recording tools, in-vehicle technologies and existing systems that provide post-trip interventions to drivers, associated with risk prevention and mitigation. To achieve this objective, a literature review was conducted in order to highlight which post-trip intervention technologies, available systems, applications or schemes are more efficient to improve driver behavior, enhance knowledge, attitudes and perception and eventually promote road safety and eco-efficiency in an occupational context. It should be mentioned here, that both commercial as well as scientific literature was researched so as to approach the topic holistically. Factors such as effectiveness and acceptance for users are also considered when assessing the state-of-the-art technologies. Furthermore, focus is given on professional as well as non-professional drivers, so as to gain more insight into the effectiveness and acceptance of intervention approaches that are implemented in a post-trip setting. Reference is also made to investigate the transferability of the results to other i-DREAMS transport modes (cars, buses, trucks or rail). With regards to the last transport mode, it should be mentioned that train and tram are both combined under the term rail. Research questions that are attempted to be answered through this paper include:

- Which are the most effective post-trip interventions, either commercially available technologies or systems delivered from the scientific literature, for cars, buses, trucks and rails in terms of effectiveness and acceptance?
- How transferable are interventions between different modes?

The paper follows the structure outlined below: Following the introduction section, a theoretical background of post-trip interventions is provided, where a representative definition of a safety intervention is given. Then, the methodological approach of the current work is discussed, consisting of an extended literature review with respect to all available state-of-the-art technologies for post-trip interventions. In addition, the main outcomes which relate to the review and assessment of post-trip interventions are mentioned. Finally, at the end of this paper, along with the limitations and the future research directions of this work, conclusions and considerations with regards to the most useful and effective technologies are described.

2 BACKGROUND

2.1 Definition of post-trip safety interventions

According to Zaira and Hadikusumo (2017) a safety intervention is a means for improving safety behavior. Furthermore, Daignault and Delhomme (2011) claimed that the objective of road safety interventions was to convince drivers that offending behaviors were intrinsically dangerous and dissuade them from violating while driving by means of surveillance. A few interventions which used a range of methods such as training, education or technology, attempted to equip drivers with the skills and attitudes they needed to become safer, more efficient and therefore eco-friendly (Kinnear et al., 2013; Russell et al., 2011). As a result, post-trip safety interventions can be defined as "a provided set of information, guidance, warnings, feedback or notifications that drivers receive post-trip, based on a personalized identification of driving episodes with the aim of risk prevention and mitigation" (Katrakazas et al., 2020). Safety interventions are developed to prevent drivers from risky driving behavior and decrease the collision rate or the probability of occurrence of crashes, damage, costs and injuries.

2.2 Acceptance of safety interventions

Taking the determinants safety and anxiety into consideration, it is useful to investigate the acceptance of post-trip safety intervention technologies (Osswald et al., 2012). If the driver does not accept the technology, misuse or disuse of the technology is evident (Parasuraman and Riley, 1997). It is therefore important to reach a high level of acceptance and to measure the level of acceptance when developing or testing new vehicle safety technologies. Acceptance is, however, a multifaceted concept and several approaches in literature have been proposed to define and measure acceptance (Adell et al., 2014). According to Adell (2009), acceptance can be defined as "the degree to which an individual incorporates the system in their driving, or, if the system is not available, intends to use it". Hence, acceptance does not only relate to the degree of actual usage, but also relates to the intended use (i.e. in a purchase decision). Similarly, Schade and Schlag (2003) proposed that acceptance is the result of the actual use of the system, while Adell (2009) claimed that acceptance is associated with factors such as perceived usefulness, satisfaction, usability and ease of use.

A common area in acceptance research is the notion that human behavior is not primarily determined by objective factors, but also by subjective perceptions (Ghazizadeh et al., 2012). This implies that acceptance of in-vehicle technologies is based on individual attitudes, expectations and experience, obtained during actual use, as well as their subjective evaluation of expected benefits (Schade and Baum, 2007). Moreover, driver's knowledge and beliefs with respect to the target risk played an important role in the acceptance of technologies aims to reduce that target risk, i.e. if a driver did not consider the target risk as a real problem, or the driver did not feel vulnerable to that risk, then a system which aims to reduce the target risk would not be considered as important for the driver, and acceptance would be low.

A wide range of psychological factors has potential impact on acceptance of new in-vehicle technologies. Some of them are more generic factors, such as general attitudes and trust toward new technologies, design or system characteristics, (i.e. the position on the technology adoption curve), and others are more specific, such as demographic factors. Kaur and Rampersad (2018) revealed that early adopters of technology in general are more willing to accept new Advanced Driver Assistance Systems (ADAS) technologies. In general, previous experience with or exposure to the system can help to increase the level of knowledge about the system. As new in-vehicle systems typically have a learning curve, hence, the evaluation and acceptance by the user could be very different before and after use of the system. This is closely related to the concept of trust in the system, where a distinction needs to be made between initial trust and dynamic trust. Initial trust refers to the evaluation by the driver on how the system would help the driver to reach goals in a situation characterized by uncertainty and vulnerability, whereas dynamic trust refers to the same evaluation after having the opportunity to experience or use the system. Trust is also sometimes conceptualized as the result of perceived usefulness and perceived ease of use (Ghazizadeh et al., 2012). Lastly, several socio demographic factors (such as age, gender, income, educational level or previous accident involvement), as well as trip related indicators and habituation can be identified as potentially influencing factors for acceptance.

2.3 Effectiveness of safety interventions

The adoption of a new in-vehicle safety technology could only be successful if the technology is effective in reducing the target risk and also used efficiently by the driver. Given the safety risks that are usually linked with the application of a delayed warning system (e.g. overloading of the drivers' visual capabilities) the warnings should be designed carefully to ensure optimal effectiveness of the system (Cao et al., 2009; Ho et al., 2006) This effectiveness, as well as performance, heavily depends on acceptance of the system by the driver. A poorly designed system might cause reduced effectiveness because interventions were perceived as not relevant or simply annoying for a specific situation (Meng et al., 2015). This results in the driver losing confidence in the system, or even completely turning off or sabotaging the system. Based on recent literature, it appears that the most effective warning strategy would be a multi-stage multimodal strategy. By specifying multiple stages, warnings could be adjusted to each specific stage. Finally, it should be noted that it is beneficial for drivers to be informed about their performance, provided right after the end of driving trips, in a non-intrusive way. For instance, visual and detailed messages were found to be effective solutions, as drivers have all the information available in order to avoid similar risky behaviors and improve their driving performance during future trips.

2.4 Monitoring and assessment

Performance monitoring and recognition is one key-domain for fleet safety managers to work on the improvement of road safety and eco-efficiency in an occupational context. According to Knipling (2009), On-Board Safety Monitoring (OBSM) has several advantages over conventional safety measures. For instance, OBSM provides a 100% sample of driver behavior, captures specific behaviors that cause crashes, incidents and violations, allows observation and rewarding of positive behaviors, allows negative behaviors to be seen and corrected before a crash, incident or violation occurs, allows driving behavior-based benchmarks to be established so drivers know where they stand in relation to carrier expectations, and makes it possible to have frequent and timely evaluations, feedback, and consequences, including both rewards or punishments. Transport companies may also monitor individual driver behavior to follow up on fuel economy as a way to reduce costs. The use of OBSM increased substantially in the period where Behavior Based Safety (BBS) became a popular paradigm in the domain of occupational health and safety. BBS is an approach where principles drawn from behavioral science are applied to the management of industrial safety. As explained by Krause et al. (1999), BBS tries to engage workers in improvement processes, teaches them to identify and observe critical safety behaviors, provides feedback to encourage improvement, and uses gathered data to target system factors for positive change.

It should be noted that monitoring and recognition of performance refers to the specific intervention strategy where organizations make use of in-vehicle technologies to register, process, evaluate and change (if necessary) road safety and eco-efficiency in a post-trip setting. More precisely, performance monitoring can be situated at two different levels. On the one hand, it can relate to parameters at the level of output indicators (for road safety that could be for instance the number of at-fault accidents or violations, while for eco-efficiency that could be volume of fuel consumed or volume of greenhouse gases emitted). On the other hand, performance monitoring can relate to behaviors contributing to those road safety and eco-efficiency related output indicators (i.e. speeding, harsh acceleration, braking or harsh cornering).

2.5 Employee education and training

Over the years, a range of literature is available that addresses education and training approaches for professional drivers with a variety of pedagogical and didactical formats, methods and materials (Schulte et al., 2014). Most fundamentally, a distinction can be made between theory-based approaches and practice-based approaches. Based on Kolb's Learning Styles Model (Kolb, 1984), a further distinction was made between theoretical approaches targeting reflective observation or abstract conceptualization, and practical approaches targeting active experimentation (i.e. practice in simulator, or on-road training in a naturalistic driving experiment), and concrete experience (behind-the-wheel practice in traffic). Each of the learning stages can take place in different communication settings.

According to the RUE-project (Schulte et al., 2014, Weiße et al., 2015), possible settings are two-way communication, many-to-many communication, one-to-many communication, and one-to-one communication. These different settings in turn, lend themselves to specific pedagogical and didactical formats.

In addition, it is worth mentioning that education and training of professional drivers includes traditional methods, such as classroom teaching, safety meetings or in-company coaching, which seem to prevail, albeit innovative approaches, such as remote learning, e-learning, web-based instruction, computer-based training, multi-media support or simulator techniques, have found their way into the market of professional driver training and education. This probably occurs due to ease of access or ease of delivery, e.g. getting drivers in the classroom for face-to-face learning would take time and disrupt rosters. Moreover, legal frameworks often leave room for such innovative approaches to become part of initial qualification and periodic training, but at the same time, they allow different countries to be flexible in the more precise way. Education and training is organized in terms of content, materials, and pedagogical and didactical formats. However, the large heterogeneity in terms of pedagogical formats used for training (i.e. initial qualification and periodic training requirements) doesn't allow for a clear conclusion regarding what is available and can be considered as effective (Bekiaris et al., 2009). Lastly, another issue is that in the majority of the cases, training formats are based on well-intended but not always scientifically proven intuitions and practical experiences.

2.6 The use of gamification within safety interventions

Gamification is about the application of game-specific design elements, mechanisms and features outside the context of entertainment and play, i.e. in a non-gaming context (Deterding et al., 2011). The main purpose of gamification is to trigger the motivation to reinforce, change or shape a desired behavior, and to sustain this effect over time by developing so-called intrinsic motivation. Several gamification mechanisms have already been applied and explored in the literature on safety and eco-efficiency. For instance, score mechanism is probably one of the first explored gamification mechanisms. .Toledo and Lotan (2006) found that exposing drivers to safety-related scores, calculated based on in-vehicle monitoring and provided to drivers via personal web pages, had significant positive impact on driver performance. In addition, another intensively studied gamification mechanism is the use of rewards. It has received attention in the literature on young novice drivers, especially in studies investigating the impact of Pay-As-You-Drive (PAYD) systems (Mortimer et al., 2018; Stevenson et al., 2017). Elvik (2014) conducted a comprehensive review of seven trials designed to reward safe and environmentally sustainable driving and concluded that they were all successful in promoting the rewarded behaviors, with the largest effects found for rewarding compliance with speed limits. However, since drivers volunteered to participate in these trials, a self-selection bias cannot be excluded and findings may not be generalized to all drivers.

According to a review by Hamari et al. (2014), the effects of gamification (e.g. scores, competition, social pressure, incentives and rewards, penalties and loss aversion, tips and recommendations, personalization, self-interest, adaptive learning) are generally positive, although moderated by several factors such as the context in which it is applied, and the profile of targeted users. Results reported in studies reviewed, suggest that there is potential in the application of persuasive feedback approaches in the promotion of safe and eco-efficient driving styles. However, it should be noted that no information about gamification strategies which were not effective was identified and hence, there is a bias in the literature that only successful gamification approaches get published. Moreover, the variety in study settings encountered, prevents the authors from drawing firm conclusions as to what could work really well and what not. Furthermore, most studies are exploratory, so further research is still needed to learn more about the critical use parameters to be considered and how to address these appropriately. Often, the effects of gamification mechanisms seem to be dependent upon the more precise way they are implemented, the context in which they are used, the behaviors being targeted, and characteristics of the persons exposed.

2.7 Targeted factors for safety interventions

Post-trip interventions aim to reduce risky driving behavior. This can be achieved through several training, interactive knowledge, skill building sessions or warnings. These indications or warnings are targeted at multiple risk factors which are conveniently monitored and crucial in reducing the probability of a collision or injury. Post-trip interventions focus on improving overall driving behavior. Therefore, they are usually targeted at the frequency of harsh events (acceleration, breaking or cornering), excessive speeding, collision, steering, distracted driving or other reckless events during rush hours or risky night hours, all of which are known to increase crash risk, while particular concern is also given to eco-driving techniques. Table 1 presents a summary of these targeted factors for post-trip interventions with their corresponding sources from the associated research.

Table 1: Example targeted factors for post-trip interventions

Targeted factors
harsh acceleration (Dijksterhuis et al., 2015; Donmez et al., 2008; Toledo and Lotan, 2006; Toledo et al., 2008a)
braking (Ando and Nishihori, 2012; Dijksterhuis et al., 2015; Donmez et al., 2008)
speeding (Bolderdijk et al., 2011; Dijksterhuis et al., 2015; Donmez et al., 2008; Newnam et al., 2014; Payyanadan et al., 2017; Teng et al., 2011; Toledo and Lotan, 2006; Toledo et al., 2008; Tselentis et al., 2017)
steering (Dijksterhuis et al., 2015)
eco-driving (Ando and Nishihori, 2012; Toledo and Lotan, 2006)
reckless events (Taubman et al., 2012; Zeeman and Booysen, 2013)
collisions (Donmez et al., 2008; Roberts et al., 2012; Payyanadan et al., 2017; Tselentis et al., 2017)

3 LITERATURE REVIEW METHODOLOGY

This paper reviews and exploits a critical overview of the state-of-the-art technologies and systems providing post-trip safety interventions to drivers. In order to perform a comprehensive literature review, a specific search strategy was followed:

- Initially, as the literature review was decided to be transport mode-specific, the search keywords were identified for each mode.
- In order to obtain the most relevant and significant studies, inclusion criteria were then defined as follows:
    - Studies published from 2000 and onwards
    - White-papers or commercial reports on post-trip feedback applications on smartphones or websites

- Furthermore, prioritization criteria for the inclusion of studies in the literature review were specified as follows:
  - Most recent meta-analyses
  - Studies including information on post-trip feedback or interventions or eco-driving and gamification in the title or abstract
  - Country of origin: Europe before US/Australia/Canada before other countries
  - Most recently published
  - Importance: number of citations
  - Language: Studies published in English
  - Source: Peer-reviewed journals before peer-reviewed conference papers before commercial reports/websites

Relevant studies showcasing various technologies and systems with regards to post-trip interventions were located using scientific databases and repositories, such as Science Direct, Scopus, Google Scholar, and PubMed, which provided access to scientifically rigorous studies in indexed and reputable journals and conferences. Particular focus of the review was specifically given on commercially available products and technologies as well as intervention programs for drivers, which consist inclusion criteria aiming to promote both road safety and eco-driving, since these remain the key-interests of the i-DREAMS project. As mentioned before, both commercial solutions and scientific literature was reviewed, so as to obtain as much information on post-trip interventions as possible.

The most relevant findings were overviewed for final refinement, in order to identify the systems and technologies most crucial and suitable for driver behavior monitoring, providing post-trip feedback. Technologies and applications have been assessed per their acceptance and effectiveness with a color code assignment, taking into account factors, such as crash reduction, cost, time of feedback, on-road/simulator application, method of transmission etc. In particular, a high, medium and low assessment in terms of acceptance/effectiveness was depicted with green, yellow and red color, respectively. In addition, an attempt was made to have an overall critical evaluation of post-trip safety interventions, taking into account the advantages as well as the disadvantages of each safety intervention strategy. With regards to the comparison between studies, focus was given on the driving performance characteristics (i.e. speed, harsh acceleration, harsh braking, aggressiveness), the indicators used to measure those constructs, the technical equipment, any reported outcome variables, as well as the results and conclusions with respect to the scope of the i-DREAMS project. Table 2 depicts the search terms used per factor analyzed, as well as the number of results screened per search engine with the included findings delivered from scientific literature and commercial technologies.

Table 2: Search terms, screened and included papers per factor analyzed

Mode	Search terms used	Total Results from search engines	Scientific Papers	Commercial reports	Latest Date of search
Cars	"post-trip intervention technology" OR "post-trip feedback" OR "feedback" OR "interventions" OR "feedback technology" AND "cars" AND "car driver"	195	8	5	27/10/20
Trucks	"post-trip intervention technology" OR "post-trip feedback" OR "feedback" OR "interventions" OR "feedback technology" AND "trucks" AND "truck driver"	263	7	5	27/10/20

Mode	Search terms used	Total Results from search engines	Scientific Papers	Commercial reports	Latest Date of search
Buses	"post-trip intervention technology" OR "post-trip feedback" OR "feedback" OR "interventions" OR "feedback technology" AND "bus" AND "bus driver"	106	4	6	27/10/20
Rails	"post-trip intervention technology" OR "post-trip feedback" OR "feedback" OR "interventions" OR "feedback technology" AND "rail" AND "train drivers" OR "tram drivers"	16	2	-	27/10/20

4 RESULTS OF THE COMPREHENSIVE LITERATURE REVIEW

As a first step of capturing the state-of-the-art with respect to post-trip safety interventions, both literature and commercial systems, applications and schemes have been reviewed and assessed per their acceptance and effectiveness, with a focus on improving driver behavior. Post-trip interventions and feedback using web-platforms have been recently investigated in many studies (Toledo et al., 2008; Farmer et al., 2010; Takeda et al., 2012; Braun et al., 2015). In addition, technological progress, especially in telematics, provided new potential for driver monitoring through smartphones. It should be noted that smartphones have a wide array of sensors, such as accelerometer, compass, gyroscope, GPS, microphone and cameras that enable sensing applications, even without user engagement. Smartphone technology is a good and efficient platform for driver behavior detection and monitoring systems (Chaovalit et al., 2014).

In the following sections, the results of a transportation mode-specific literature review, aiming to investigate the utilization of post-trip interventions in cars, trucks, buses and rails, are provided. The technologies and kinds of feedback which seemed to be effective and acceptable to drivers are also mentioned. Results suggested that there was a strong motivation for drivers to improve their driving style, differentiate their travel behavior from aggressive to normal and reduce their degree of exposure by receiving post-trip interventions and monitoring their driving performance (Kirushanth and Kabaso, 2018; Tselentis et al., 2017).

4.1 Cars

4.1.1 Review of post-trip interventions for cars mentioned in scientific papers

There are two main types of technology used to inform post-trip interventions in cars: in-vehicle telematic recording devices and smartphone applications. To begin with, Freematics is a telematic recording device which consists an innovation in vehicle telematics projects involving OBD-II, GPS and wireless technologies with open-source hardware providing visual feedback to driver (Gavruta et al., 2018; Tselentis et al., 2017). Results indicated that feedback about speeding delivered immediately post drive, along with an overall reliable driving score, was effective at encouraging drivers to achieve a better and eco-friendly performance. Gavruta et al. (2018) demonstrated that there is a human tendency to compete with each other, so drivers tried to get better scores and by doing so, they managed to drive more safely and cost-effectively. In the study of Ando and Nishihori (2012), drivers participated in a naturalistic driving experiment, where they received visualization and records of their driving performance by e-mail. The information was provided through a website and daily driving data were collected by the Behavioral Context Addressable Loggers in the Shell (BCALs), a small device which was put on the car's dashboard. Reasons for adopting the BCALs were its relatively low cost and its relatively high performance, making them acceptable by the drivers. In addition, the practical implementation of this device was an effective solution which can be applied on road, under naturalistic driving conditions.

Moreover, in the paper of Toledo and Lotan (2006) an in-vehicle data recorder (IVDR) system called DriveDiagnostics was utilized within a driving experiment and the results indicated that the exposure to post-trip feedback in the form of printed reports or through a dedicated website, had a positive effect on driver performance. The DriveDiagnostics feedback was found to be useful in moderating driving behavior and was acceptable by the participants, who reported that the interface was aesthetically pleasing. Furthermore, access to the feedback provided by the DriveDiagnostics system could further affect driver performance in the desired direction (Toledo et al., 2008). This technology was found to be effective in terms of reductions in crash rates, operations costs and risk indices in the short-term. Validation tests with the system demonstrated promising potential as a measurement tool to evaluate driving behavior and drivers received not only their initial feedback on their own driving but also they were able to compare their performance to the fleet's averages. Trip level information was transmitted to the application server once a week and results are summarized in a monthly report. An example of a web-based driver report by the DriveDiagnostics system is provided in Figure 1.

Lastly, web-based Trip Diaries and the use of the Geotab GO6 system were found to be less effective solutions as drivers received feedback about their performance once a month (Payyanadan et al., 2017). Although the sample of participants in the study of Payyanadan et al. was not representative it was revealed that the form of Trip Diaries is a medium that can be sustained in order to provide long-term feedback and more autonomy to older drivers to oversee their own driving. From the findings of the study, there was no evidence that drivers managed to reduce the number of road crashes, after receiving post-trip feedback. Furthermore, OSeven is a smartphone application which provides feedback on the drivers for their driving performance and uses advanced machine learning techniques to exploit the recorded smartphone sensor data (Barmpounakis and Vlahogianni, 2020). OSeven is a free, user-friendly and accessible solution, which recognizes driving activity without any user involvement and drivers receive their feedback immediately post drive. It also detects harsh events of long distances traveled within a short time window (i.e. few seconds), as well as significant increases in speed. The application starts to collect raw data from smartphones' sensors such as the accelerometer, magnetometer, gyroscope and GPS with a minimum frequency of 1Hz. Lastly, it should be noted that this smartphone application was only available for car drivers and there was no evidence, supported by scientific literature, which indicates system's transferability. An example of the mobile application of OSeven is presented in Figure 3.

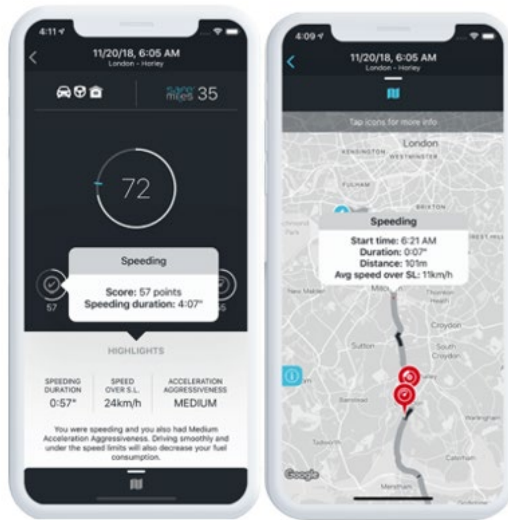

Figure 1: The OSeven mobile application (OSeven, 2019)

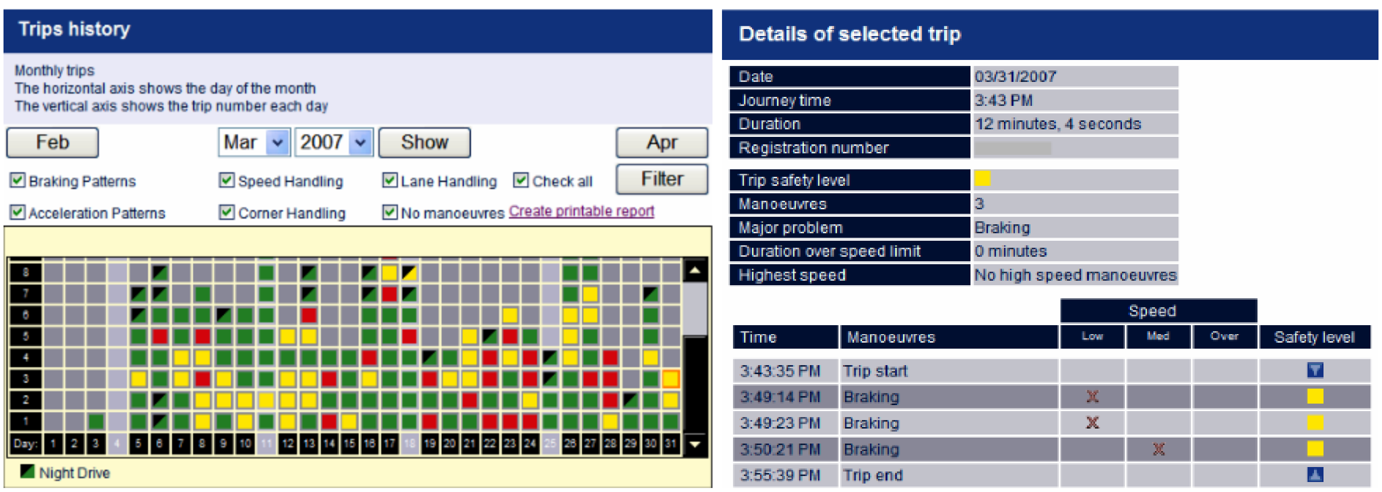

Figure 2: The DriveDiagnostics system (Toledo et al., 2008)

Apart from feedback solely on driving behavior, studies have also been concerned with eco-driving feedback. For example, Orfila et al. (2015) presented an innovative eco-driving Android application that provided feedback and feedforward advices to the drivers. The application exploits the OBD-II information, map information, phone sensors and computational power to increase precision and reliability of feedback information. Results indicated that by accessing detailed and high level information about their own driving performances, drivers can learn themselves how to improve their safety and driving efficiency. Findings proved that such nomadic tools can enhance driving safety by promoting new safety standards to respect. Additionally, ecoPostTripAnalysis was an effective smartphone application as drivers received a report which indicated positive or negative driving behavior after the end of their trip (Trommer and Höltl, 2012). The system was able to record factors such as inefficient gear change, erratic braking or speeding. The given parameters were used to calculate fuel consumption, the monetary value of fuel and the amount of CO_2 emitted. An improved driving style would result in a message showing the rate for improvement. Negative driving style results in a message showing potential improvement (e.g. gear change timing, acceleration/

deceleration or speeding). Results indicated that this application influenced the driving behavior positively, as well as comprehensible direct benefits for the driver in terms of money savings were identified.

Moreover, Tulusan et al. (2012) found that an eco-driving application called DriveGain was a positive motivation for drivers in order to use realistic goal setting and achieve a long-term change in the overall fuel efficiency. This application is an effective technology providing post-trip feedback to drivers, as they managed to improve their driving behavior, reduce their fuel consumption as well as the amount of overall CO_2 emissions and petrol costs. DriveGain application is presented in Figure 2.

Figure 3: The DriveGain eco-driving application (Tulusan et al. 2012)

4.1.2 Review of post-trip interventions for cars mentioned in commercial reports

Reviewing the findings from commercial reports and websites, it was observed that the majority of smartphone applications are concerned with the detection of harsh events and mobile phone use, the prediction of collision risk, and the analysis of sensor data to obtain a performance score and identify driver behavior (e.g. Sentiance, 2019; TheFloow, 2019; Vivadrive, 2019; Zendrive, 2019; True Motion, 2019). More specifically, Zen Drive is reported to be an easy-to-implement, flexible and scalable technology which can work on any Android and iOS mobile application, whereas True Motion is reported to give feedback automatically, immediately after the end of the trip. On the same principle, the "Floow" is a smartphone application which provides tailored feedback among with a corresponding score with the aim of improving safety and encouraging smart drivers. The result is a score from 0% to 100% which represents how many actions from the detected ones are not considered risky (higher score means better performance). As the journeys scores are visible to an insurance company, providing regular, well targeted rewards and incentives, this technology could be an effective solution and has been found to engage drivers and encourage them to make improvements in their driving behavior. Figure 4 provides an example of the mobile application of the "Floow".

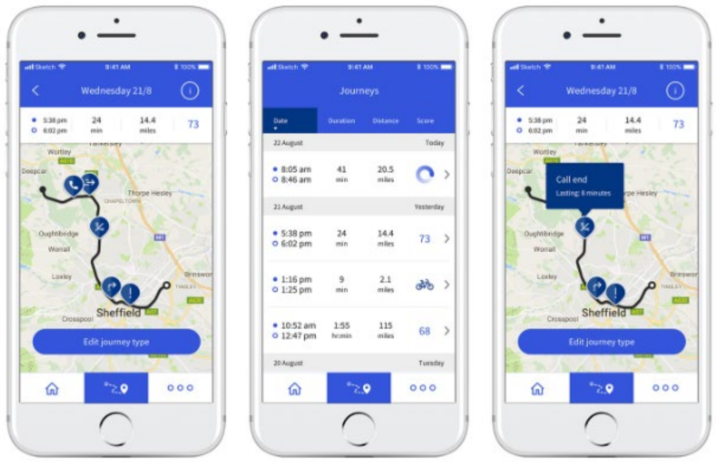

Figure 4: The Floow mobile application (Thefloow, 2019)

Sentiance works in a similar way with the aforementioned two applications. It is reported to be optimized for accuracy and battery usage and users receive feedback about their performance immediately after the end of their trip. VivaDrive however, also provides customizable gamification and rewarding programs that are suited for different drivers. Moreover, it offers the capability to compare performance among other users of the application.

To sum up, the majority of post-trip feedback technologies both reported in the scientific literature as well as on commercial reports, exploits smartphone sensing capabilities and provides feedback automatically at the end of the trip either through a smartphone app or through a website. Furthermore, most of the applications are concerned with driving behavior only, while in the recent years eco-driving applications have emerged. Limited evidence has been found on the use of gamification, as well as rewarding and incentives schemes. Table 3 summarizes an overview of post-trip interventions mentioned in the literature, while Table 4 presents an overview of commercial technologies, providing post-trip feedback in cars along with their assessment.

Table 3: Overview and assessment of technologies concerned with post-trip interventions in cars mentioned in scientific papers

Technology	Indicators	Technical equipment	Time of feedback	Method of transmission	Assesment	Acceptance/Effectiveness *advantages (+) /disadvantages(-)*
Freematics	speed, distance, time, location, harsh acceleration, braking	GPS, USB port, Bluetooth, OBD-II, gyroscope	immediately post drive	OBD-II interface	🟢	+ feedback about speeding is effective at encouraging drivers (Tselentis et al., 2017)
BCALs	start/end time, steep acceleration, deceleration, handling, speed, distance	GPS, Internet, radar chart /SP, NDE	daily	sent to the driver automatically by email, available in website	🟢	+ high performance + low cost + applies in naturalistic driving experiment (Ando and Nishihori, 2012)
Trip Diaries	speed, acceleration, braking	OBD-II, web-based	once a month	Geotab GO6 OBD-II device	🔴	- no evidence that drivers managed to reduce the number of road crashes (Payyanadan et al., 2017)
DriveDiagnostics system	speed, acceleration, position, maneuvers, start/end time, location, maneuvers, fuel consumption	IVDR, web pages/OBD-II	once a week	transmitted to the application server by email through a wireless network	🟢	+ relatively low cost + continuous measurement of on-road driving behavior and vehicle usage (Toledo et al., 2008) +useful in moderating driving behavior + frequent use of feedback can be encouraged by an interface that is aesthetically pleasing + easy to use (Toledo and Lotan, 2006)
DriveGain	harsh acceleration, braking, speeding, distance, duration, start/end time	GPS/ SP, NDE	30 seconds after the end of the trip	sent to the driver automatically	🟢	+ easy to use, helps save fuel, reduces the amount of CO_2 (Tulusan et al., 2012)
ecoDriver	speeding, acceleration, deceleration, gear, percentage of time in engine brake, shifting, fuel	CAN bus, OBD-II, Map data, GPS position, camera in front of the vehicle, fuel flow meter	immediately post drive	OBD-II interface	🟢	+ accessing detailed and high level information about own driving performance + drivers can learn how to improve their safety and driving efficiency (Orfila et al., 2015)

Technology	Indicators	Technical equipment	Time of feedback	Method of transmission	Assesment	Acceptance/Effectiveness ***advantages (+) /disadvantages(-)***
ecoPostTripAnalysis	gear change, erratic braking, speeding, fuel consumption	web-based/ SP	immediately post drive	online questionnaire	●	+ information on how economically someone's drive + helps improve driving style + benefits in terms of money savings (Trommer and Höltl, 2012)
OSeven	harsh acceleration, harsh braking, speeding, distance, mobile phone use, start/end time	accelerometer, gyroscope, GPS/ SP, NDE	immediately post drive	transmitted through WiFi or cellular network, sent to the driver automatically, available in web platform	●	+ recognize the transportation mode (car, motorcycle, and mass transit) + driver/ passenger identification + provide spatiotemporal analysis of the driving data + offers a set of user engagement tools and competitions (Barmpounakis and Vlahogianni, 2020)

where OBD: On-Board Diagnostics, SP: Smart Phones, NDE: Naturalistic Driving Experiment.

Assessment in terms of Acceptance/Effectiveness: ●: High, ●: Low.

Table 4: Overview and assessment of technologies concerned with post-trip interventions in cars mentioned in commercial reports

Technology	Indicators	Technical equipment	Time of feedback	Method of transmission	Assesment	Acceptance/Effectiveness *advantages (+) /disadvantages(-)*
Zen Drive	harsh acceleration, braking, turning, speeding, mobile phone use, distance, time, fuel used	accelerometer, gyroscope, GPS/ SP, NDE	immediately post drive	sent to the driver automatically	●	+ notifications via smartphone of collisions + risk analysis and a guide to coach drivers for sustained improvement (Zen Drive, 2019)
True Motion	mileage, harsh braking, speeding, acceleration, time of day, location	accelerometer, gyroscope, GPS/ SP, NDE	immediately post drive	sent to the driver automatically, available in web platform	●	+ driver identification and transport mode + crash identification (True Motion, 2019)
The Floow	harsh acceleration, braking, cornering, mileage, speeding, time of day, mobile phone	accelerometer, gyroscope, GPS/ SP, NDE	immediately post drive	sent to the driver automatically, available in web platform	●	+ driver/ passenger identification + journey scores are visible to the insurance company and integrated into the web-portal, through a series of phone conversations + drivers are helped to focus on ways to improve their overall score and drive safely (The Floow, 2019)
Sentiance	harsh acceleration, braking, speeding, mobile phone use	accelerometer, gyroscope, GPS/ SP, NDE	immediately post drive	sent to the driver automatically, available in portal	●	+ transport mode classification + detect and predict personal context based on the user's current situation and historical patterns + roadside assistance (Sentiance, 2019)
VivaDrive	harsh acceleration, braking, speeding, mobile phone use, distance	accelerometer, gyroscope, GPS/ SP, NDE	immediately post drive	sent to the driver automatically, available in portal	●	+ engagement campaigns organized with program partners + engaging challenges based on different criteria, badges and levels to recognize user and customers achievements + meaningful for drivers to spot risky driving behaviors and stay motivated to improve road safety (VivaDrive, 2019)

where OBD: On-Board Diagnostics, SP: Smart Phones, NDE: Naturalistic Driving Experiment.

Assessment in terms of Acceptance/Effectiveness: ●: High, ●: Low.

4.2 Trucks

4.2.1 Review of post-trip interventions for trucks mentioned in scientific papers

In recent literature, particular focus has been given on intervention programs aiming to improve diving behavior. For example, Newnam and Watson (2009) adapted and extended on a methodology that evaluated the effectiveness of a participative education intervention on a group of work-related drivers. Their results indicated that the safety awareness intervention significantly reduced self-reported speeding in the experimental group, over a six-month period. One of the main components of that study suggested that speeding can be reduced through a process of participants generating their own safety goals, and giving feedback of these goals at regular intervals. This evidence is also supported by other researches which used participative education to improve safety outcomes in the work-related driving setting (Salminen, 2008, Newnam and Watson, 2011). However, it should be noted that psychological mechanisms and crash outcomes, which may underlie any change in driving behavior, were not taken into consideration.

Moreover, based on behavior-change techniques utilized through adapting the framework to modify behavior, Ludwig and Geller (2000) found strong support for the role of goal setting and feedback in improving performance and achieving successful safety outcomes. Types of strategies included in that research designs included group or individual-based discussion groups, individual or group feedback, and goal setting exercises. The advantage of these types of intervention strategies are that they are cost effective, and because they are an extrinsic motivator in nature, they are more likely to lead to permanent behavior change in comparison to strategies such as driver training.

Another study by Newnam et al., (2020), conducted to understand the context for managing older truck drivers, was concerned with the advantages, concerns, current strategies and associated challenges in managing their safety levels. Specifically, interviews were implemented with safety managers within trucking companies, and findings demonstrated that post-trip safety interventions can be targeted to keep older truck drivers on the road for as long as they are safe. Nevertheless, it should be mentioned that there is a limited direction for safety managers in the planning and management of driver safety.

Additionally, a micro-scale approach was conducted in order to evaluate the effectiveness of eco-driving on freight transport (Ayyildiz et al., 2017). The feedback on driving performances was provided back to freight transport operators through the website platform for post-trip evaluations and tour planning of the fleet manager, providing detailed information about the time of the trip listed as well as duration of trip, distance travelled, average speed, Energy Performance Indicator (EPI) and Acceleration Performance Indicator (API). Results had shown that this micro-modelling approach operated at a high level of complexity. It provided more accurate results than the macro approaches, as one of the main advantages of the method presented lies in the detailed understanding of driving behavior (internal and psychological factors) which was always linked to the external conditions of the road network, including altitude or traffic congestions. In this way, drivers can be informed instantaneously about their driving style and correct it.

Finally, trust of the intervention approach was the topic of Donmez et al. (2008), who examined how different timings of feedback influence driver's trust in feedback as well as how trust changes over time as related to driver's acceptance of feedback. Results revealed that the timing of feedback did not have a significant impact on trust. However, drivers generally trusted both feedback timings with male drivers trusting feedback more than the female ones.

The current state-of-the-art in the literature of post-trip interventions, revealed that no specific application or website has been used for providing feedback. The literature on the subject is mostly concerned on the strategies to promote road safety as well as trust for the feedback system. In particular, only a small number of papers satisfied the inclusion criteria, and therefore, the justification of a review with regards to trucks was considered limited. The inclusion of papers relevant to commercial vehicle fleets would have strengthened the rationalization for conducting a review in general work-related driving safety.

4.2.2 Review of post-trip interventions for trucks mentioned in commercial reports

Reviewing commercial systems for trucks, it was revealed that truck-specific technologies focused more on eco-driving, although safety was also of interest. Post-trip feedback alone was provided by five systems (D2go; DAF Connect; NEXT driver; Scania Fleet Management and Truck Hero). The combination of both real-time and post-trip feedback was more prevalent, and was provided by ten systems (i.e. DKV Eco Driving, Omnitracs, Fleetboard, Iveconnect, Trimble Performance Portal, TX-ECO, Vehco Mobile, Dynafleet, Frotcom and WaySmart) but as the focus of the review is on post-trip feedback alone, these systems were not reviewed. Gamification as a behavior change strategy was already employed in several systems, although not always with the same focus or to the same extent. For instance, some companies decided to provide material/financial rewards, while others provided tips or access to social networks. Most of the times, feedback going beyond access to monitoring results required a company middle-man, for instance someone from the management or a coach, that will discuss the results with the driver in order to provide coaching. Direct and automated coaching from the application was less common.

To begin with, the D2go application is a technology combining in-vehicle behavioral monitoring with post-trip interventions, provided once a week (D2go, 2019). This application has reported some beneficial effects not only on the drivers but also on managers. Specifically, it encourages friendly competition, raises awareness on the impacts of bad driving habits, identifies and helps to avoid risky behavior. In addition, the employer has access to information and instant feedback of drivers that allows faster learning with better results and less coaching. Furthermore, drivers of the same transport companies can see each other's scores and ranking. Figure 5 provides an example of the mobile application of D2go. Similarly, NEXTdriver is an application which provides a report with personal advice each week or rewards for achievements. It is easy to contact the coaching experts from the application, in case the driver has any recommendation or questions (Nextdriver, 2019). Drivers found this technology effective and acceptable because their individual score is not shown to their employer. The employers only have access to the progress of the whole group of drivers. NEXTdriver claimed to reduce fuel cost per 5 – 10%, maintenance costs, damage repairs and saves time for the management in relation to training and coaching.

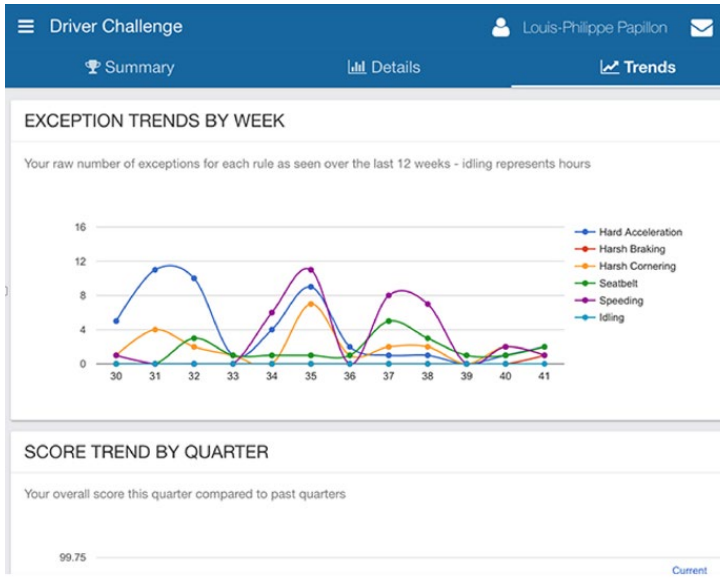

Figure 5: The D2go application (D2go, 2019)

Similarly, Scania Fleet Management (demonstrated in Figure 6), which can also be used for buses, and Truck Hero consist good solutions for operators with mixed fleets, providing weekly summary reports of the vehicle type. The operator gets an overview of all the drivers' driving behavior in a ranking and drivers get personal coaching on the driving behavior and how to improve their performance (Scania, 2019; Truck Hero, 2019). Finally, DAF Connect is the only one focusing on eco-friendly driving. The DAF Connect application has been reported to have some beneficial effects on the reduction of operational costs, increase of vehicle availability and achievement of smarter maintenance. The results had shown lower fuel consumption, more customisation and a higher return per kilometre (DAF Connect, 2019). Nevertheless, the employers has direct access to information about the individual drivers so they can provide guidance at any time and compare the performance of individual drivers on the same route. This may demonstrate, for instance, that individual driving behavior is not efficient across the board, which may have a significant effect on driver's profitability.

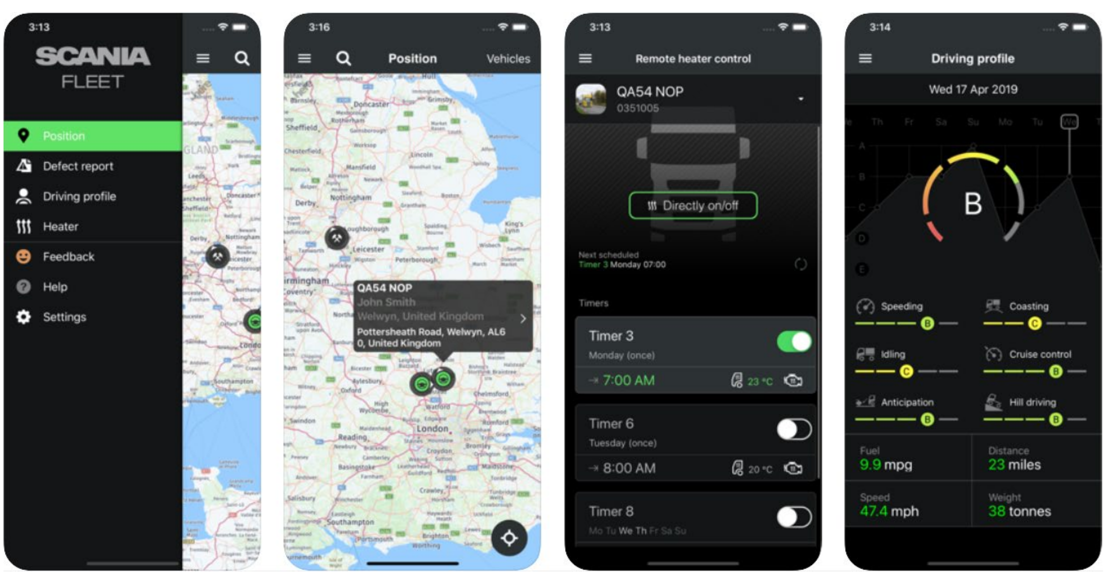

Figure 6: The Scania Fleet Management application (Scania, 2019)

The results obtained with respect to trucks confirmed that the benefits of using gamification with post-trip intervention appear to be increased motivation and engagement with the intervention. The assessment in terms of effectiveness and acceptance was not conducted with regards to the time of feedback delivered (i.e. immediately post drive or weekly) but it was dependent on whether the employer has access to information about the individual drivers or not. With regards to professional drivers, coaches can educate them on an optimal driving behavior, after receiving an overview of drivers' performances. Nevertheless, it should be clearly mentioned that in trucks, interventions are usually part of a broader framework (i.e. including driver coaching and management commitment) and the effects of such interventions cannot be taken into account in isolation for accomplishing a sufficient safety culture change. It is worth mentioning that a complete post-trip intervention solution mass developed or tested in real-world environments was not found in the literature search. Table 5 gives an overview of post-trip interventions approaches in the literature while Table 6 contains an overview of commercial solutions targeting driving behavior in truck drivers.

Table 5: Overview and assessment of approaches concerned with post-trip interventions in trucks mentioned in scientific papers

Approach	Indicators	Time of feedback	Method of transmission	Assesment	Acceptance/Effectiveness *advantages (+) /disadvantages(-)*
participative education intervention program	speeding, kilometres driven per week	immediately post drive	questionnaire	●	+ reduces self-reported speeding - psychological mechanisms and crash outcomes were not taken into consideration - small participants' sample - low statistical power due to limited group of work-related drivers (Newnam and Watson, 2009)
behavior-change technique	speeding, harsh acceleration, braking,	immediately post drive	experimental designs (including control groups)	●	+ improves performance + achieves successful safety outcomes + effective compared to other strategies (i.e. driver training) + cost effective (Ludwig and Geller, 2000)
behavior-change technique	safety belts, alcohol, driving performance	post drive	interviews	●	+ keep older truck drivers on the road for as long as they are safe - limited direction for safety managers in the planning and management of driver safety (Newnam et al., 2020)
drivers' acceptance and reliance method	road geometry, distraction, subjective ratings of trust	post drive	simulator experiment	●	+ drivers generally trusted both feedback timings (males more than females) + the timing of feedback did not have a significant impact on trust (Donmez et al., 2008)
micro-scale approach	time of the trip, duration of trip, distance travelled, average speed, Energy Performance Indicator, Acceleration Performance Indicator	OBD-II post drive	website platform	●	+ operates at a high level of complexity + more accurate results than the macro approaches + driving behavior (internal and psychological factors) always linked to the external conditions of the road network (Ayyildiz et al., 2017)

Assessment in terms of Acceptance/Effectiveness: ●: High, ●: Medium.

Table 6: Overview and assessment of technologies concerned with post-trip interventions in trucks mentioned in commercial reports

Technology	Indicators	Technical equipment	Time of feedback	Method of transmission	Assesment	Acceptance/Effectiveness ***advantages (+) /disadvantages(-)***
D2go	harsh acceleration, braking, steering, cornering, exceeding speed, engine abuse, idling	Geotab Drive platform	once a week	drivers can complete vehicle inspections from their tablet or smartphone	●	+ encourages friendly competition + raises awareness on the impacts of bad driving habits + identifies and helps to avoid risky behavior + instant feedback that allows faster learning + better results with less coaching - employer has access to information (D2go, 2019)
DAF Connect	braking behavior, anticipation, speed, idling, fuel	open platform using rFMS standard, on-board visual unit	once a week	through web-based platform and dashboard	●	+ offers awareness raising + driver comparison + individual eco driving score card + reduces operational costs + increases vehicle availability + achieves smarter maintenance + lower fuel consumption + more customisation + higher return per kilometre (DAF Connect, 2019)
NEXT driver	harsh acceleration, braking, distance, distance, time, overspeeding	FMS-provider, own device sensor	once a week	WebFleet, FleetVisor	●	+ employer has not access to information about the individual score of each driver + reduces fuel cost + damage repairs and safe time for the management + easy to contact the coaching experts (NEXT driver, 2019)
Scania Fleet Management	gear shifting, braking, coasting, speeding, cruise control, idling, hill driving	rFMS	once a week	through web-based platform	●	+ save fuel + reduce vehicle wear + good solution for operators with mixed fleets + reduce the operation cost (Scania Fleet Management, 2019)

Technology	Indicators	Technical equipment	Time of feedback	Method of transmission	Assesement	Acceptance/Effectiveness *advantages (+) /disadvantages(-)*
Truck Hero	harsh acceleration, steering, cornering, braking, speed, over bumps, coasting, rolling out, idling during stops, fuel usage	track and trace, dashcam (optional), FMS, transport intelligence platform	once a week	through web-based platform	●	+ personal coaching on the driving behavior + save on fuel costs (Truck Hero, 2019)

Assessment in terms of Acceptance/Effectiveness: ●: High, ●: Medium.

4.3 Buses

4.3.1 Review of post-trip interventions for buses mentioned in scientific papers

State-of-the-art post-trip intervention tools and systems identified were commonly employed by passenger vehicle fleets to monitor and evaluate driver behavior and fleet performance both in urban centers and intercity environments.

According to Tulusan et al. (2011), Fiat's eco:Drive system found to be an effective monitoring technology providing post-trip feedback to bus fleet managers, immediately after the end of the trip. Drivers were informed with a detailed breakdown of their performance with regards to acceleration, breaking, speeding, fuel consumption, emissions and gear shifting patterns. The main advantage of the system was that it can be combined with social networks and challenges within the online community with the aim of improving behavior and goal setting. Another smartphone technology which provides post-trip feedback to drivers is "Flo", a Dutch application that operates a freemium model where the basic app is free, but there is a premium version with extra options (Scott and Lawson 2018). It uses GPS to track trips, logs all trips driven and gives interventions about driving performance at the end of each trip. All feedback is logged allowing comparisons with past trips. Furthermore, Flo provides a numerical score immediately post-drive as well as allows to drivers check their trip on a map. Flo's score is broken down into acceleration, braking, speed and cornering where smiley faces show positive or negative feedback that contributes to the overall score. This technology provides the opportunity not only for individual drivers but also for fleet managers to learn more about their driving style in an affordable way. However, there is little literature at the moment testing such eco-driving feedback apps over the long term.

Apart from applications, eco-driving promoting approaches have been found for buses. Sullman et al. (2015) investigated whether bus drivers trained in eco-driving techniques were able to implement this learning in a simulator and whether this training would also transfer into the workplace. It should be noted that this was the first study to adequately demonstrate that training in eco-driving techniques can result in improvements in driving behavior and that this training can also be transferred into the workplace. This study concentrated on training the drivers in how to drive in an economical fashion, but no attempt was made to change the driver's attitudes towards eco-driving or their intentions to engage in eco-driving. A number of measures were collected during the simulator drives, such as fuel consumed, average speed, CO_2 produced, average fuel economy, number of times the brake was used, number of full stops, time to complete the route and kilometres driven. Results indicated that bus drivers who were trained in eco-driving techniques improved their average fuel economy on the simulator immediately after the training. Moreover, within Foot-LITE 1, a multidisciplinary consortium project, on-board advice and post-drive feedback systems were developed to encourage drivers to drive in a safer and greener manner (Young et al., 2011). The in-vehicle module is connected to the on-board diagnostic system and uses additional monitoring sensors to provide feedback on elements such as speed, acceleration, gear use, lane position and headway. However, negative effects, such as distraction, were not taken into account.

4.3.2 Review of post-trip interventions for buses mentioned in commercial reports

With regards to commercial available technologies, GreenRoad BUS Telematics intervention system is reported to be comprehensive for practical implementation in naturalistic driving experiments (Green Telematics, 2019). Detailed reports and training tools are provided for an in depth review of driving performance, immediately post drive. The technology is assumed to lead to an increase coach driver retention and accelerate training of new coach drivers and can recognize different fleet vehicle types from heavy trucks, buses and construction vehicles to light delivery vehicles, trucks, cars and vans and it can be easily applied in on-road driving conditions. By gamifying the process of driving, the system taps into employees' mental motivation and rewards centres to create lasting engagement. Leveraging external rewards further enhances results, offering drivers even more incentive to engage. Moreover, Driveprofiler was found to have a positive effect on bus driver's performance by offering post-trip feedback to drivers from embedded smartphone applications and web-based portals (DriveProfiler, 2019). Figure 7 gives an example of the Driveprofiler mobile application.

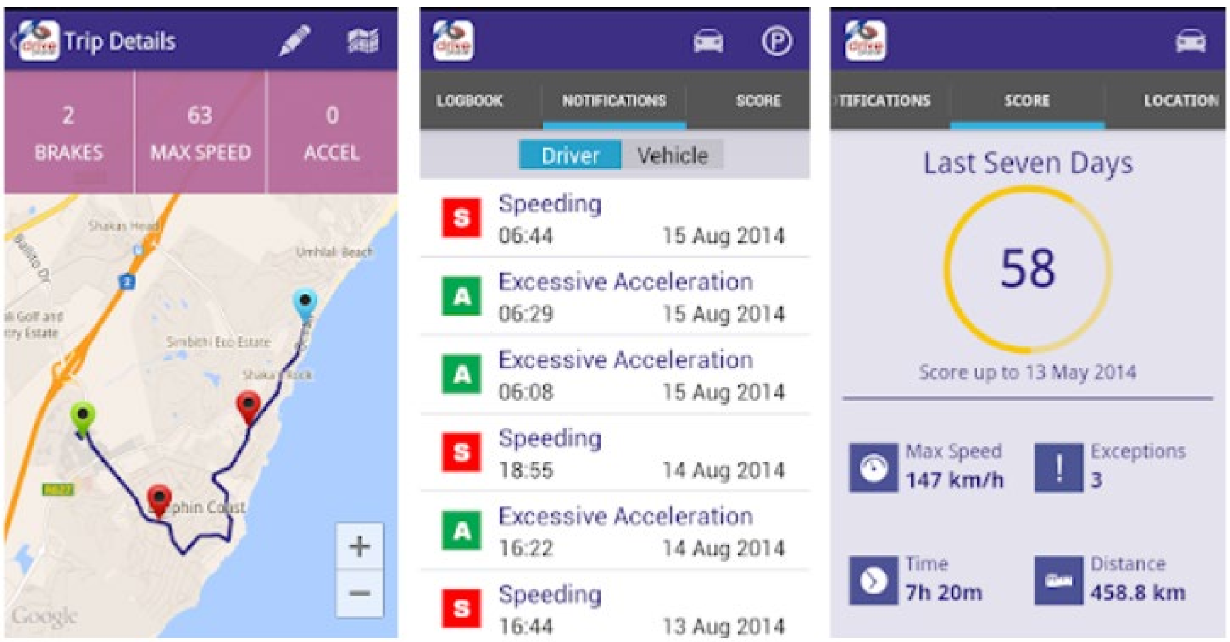

Figure 7: The Driveprofiler application (DriveProfiler, 2019)

Jaltest Telematics and Pure Telematics, also available for trucks, are reported to be two effective bus solution telematics and fleet management solutions for real-time driving conditions (Jaltest Telematics, 2019; Pure Telematics, 2019). Systems provide a driver scoring tool to fleet managers (i.e. Jaltest Telematics delivers once a week and Pure Telematics delivers immediately post drive) that monitors and evaluates drivers' behavior and performance based on speeding, acceleration patterns or fuel consumption data. Additionally, these technologies provide contextualization of driver performance behavior and enable fleet managers to develop detailed, evidence based, driver feedback and training programs. FuelSave and Stratio Automotive systems, which are also available for truck applications, were found to be less effective solutions for post-trip interventions as they did not provide retrospective autonomous feedback to fleet drivers (FuelSave, 2019; Stratio Automotive, 2019). Since Stratio Automotive tool is relatively recent, there are no advanced or autonomous driver feedback and engagement strategies, which makes this technology less acceptable and effective from the bus operators. With respect to FuelSave, driver feedback relies exclusively on fleet managers, but a driver application is currently under development, which makes this product less effective.

It is worth mentioning that a detailed knowledge relating to professional bus drivers' attitudes, perception and performance concerning economy and safety binomial is required in order to change and improve the behavior. End-of-trip performance evaluation and feedback were keys to develop a proper driver training and coaching program that leads to a visible and lasting impact on professional bus drivers' safety and efficiency related driving behaviors. As a result, fleet and operations managers were able to employ data-driven methodologies to adequately select vehicles and drivers for specific journeys, as well as develop tailored training programs to address the insights unveiled by telematics systems. Table 7 gives an overview of post-trip interventions approaches for buses in the literature, while Table 8 provides information on commercial solutions for bus drivers.

Table 7: Overview and assessment of technologies concerned with post-trip interventions in buses mentioned in scientific papers

Technology	Indicators	Technical equipment	Time of feedback	Method of transmission	Assesment	Acceptance/Effectiveness *advantages (+) /disadvantages(-)*
eco:Drive system	fuel consumption, emissions, speeding, acceleration, breaking, gear shifting patterns	nomadic devices (smartphones, tablets), in-vehicle device	immediately post drive	web platform accessible from any device (PC, tablet, smartphone	●	+ reduces fuel bills + flags up a mechanical issue or a driver training requirement + identifies business or personal mileage for more accurate expense claims (Tulusan et al., 2011)
eco-driving technique	fuel consumption, average speed, CO_2 produced, number of times the brake was used, number of full stops, time to complete the route and kilometres driven	NASA-TLX	post drive	simulator, questionnaire	●	+ eco-driving techniques results in improvements in driving behavior +can be transferred into the workplace + improves fuel economy - no attempt was made to change the driver's attitudes towards eco-driving or their intentions to engage in eco-driving (Sullman et al., 2015)
Foot-LITE 1	speed, acceleration, gear use, lane position and headway	OBD-II	post drive	web platform	●	+ safer and greener manner of driving - negative effects such as distraction are not taken into account (Young et al., 2011)
Flo	acceleration, braking, speed, cornering, fuel consumption	GPS	immediately post drive	web platform	●	+ provides a numerical score + free application + allows comparisons with past trips - little literature at the moment testing such eco-driving feedback apps over the long term (Scott and Lawson, 2018)

where OBD: On-Board Diagnostics,
Assessment in terms of Acceptance/Effectiveness: ●: High, ●: Medium.

Table 8: Overview and assessment of technologies concerned with post-trip interventions in buses mentioned in commercial reports

Technology	Indicators	Technical equipment	Time of feedback	Method of transmission	Assesment	Acceptance/Effectiveness *advantages (+) /disadvantages(-)*
GreenRoad BUS Telematics	harsh braking, acceleration, land handling, cornering, speeding	in-vehicle video system, safety driving scores, gamification strategies /NDE	immediately post drive	information sent to the dashboard unit, available through apps	●	+ comprehensive for practical implementation + improves fleet utilization and operational efficiencies + provides education resources and gamification strategies

Technology	**Indicators**	**Technical equipment**	**Time of feedback**	**Method of transmission**	**Assesment**	**Acceptance/Effectiveness** ***advantages (+) /disadvantages(-)***
						- extensive reporting tools are available to fleet managers (Green Telematics, 2019)
Driveprofiler	harsh longitudinal, lateral accelerations, overspeeding, road type, lane changing, time of day, week driving periods	nomadic devices (smartphones, tablets), OBD, in-vehicle device, CAN-bus	immediately post drive	embedded smartphone applications, web-based portal	🟢	+ manages fuel entries + performs a driver risk scoring combining aggressive driving metrics + offers a Driver Feedback Software (DriveProfiler, 2019)
Jaltest Telematics	acceleration, braking, overriding, overspeeding, coasting, usage of primary and auxiliary braking systems, idle times, fuel consumption	web-based portal, detailed reports	once a month	web platform accessible from any device (PC, tablet, smartphone)	🟡	+ cost control + increases of the efficiency of the fleet + less fuel consumption + driving optimization + reduces maintenance times + improvement in times management + support tools for decision taking (Jaltest Telematics, 2019)
Pure Telematics	speeding, stop tracking, idling, acceleration patterns and fuel consumption data	driver scoring tool, frontal vídeo camera integration	immediately post drive	web platform	🟢	+ provides to fleet managers a driver scoring tool + contextualization of driver performance (Pure Telematics, 2019)
Stratio Automotive	acceleration, braking, speed engine, proper use of gearbox, coasting, fuel efficiency	CAN bus or FMS bus connection, inertial sensors	under development	–	🔴	- no advanced or autonomous driver feedback and engagement strategies (Stratio Automotive, 2019)
FuelSave	fuel efficiency	CAN and FMS bus connection	under development	–	🔴	- driver feedback relies exclusively on fleet managers - a driver app is currently under development (FuelSave, 2019)

where OBD: On-Board Diagnostics, NDE: Naturalistic Driving Experiment.

Assessment in terms of Acceptance/Effectiveness: 🟢: High, 🟡: Medium 🔴: Low.

4.4 Rail

With regards to rail, it is should be mentioned that rail shares features in common with buses and trucks which relate to professional drivers. There are also commonalties with trams which interact with other road users during parts of their route. However, rail is for the most part significantly different to the other transport modes. Specifically, only two studies for railway post-trip interventions were found through the literature review. To begin with, Ćwil and Bartnik (2016) targeted train driving efficiency using gamification techniques. The gamification process included the use of points, badges, leaderboards, challenges and missions, systematic and direct feedback and inter group competition to try and influence behavior. Self Determination Theory (SDT) was the behavior change technique used to develop the intervention, aiming to alter employees' intrinsic motivation by ensuring the gamified elements adhered to influencing the three main psychological needs - autonomy, competence and relatedness. In addition, Bartnik and Ćwil (2017) expanded slightly on the above study aiming show the need for feedback to train drivers if there was a desire to reduce energy consumption. A two month "placebo test" took place wherein the drivers were told their energy consumption would be monitored and recorded from the start of August, but in reality the collection of a baseline energy consumption figure had already started in July. It was found that energy consumption dropped by a significantly different amount in August compared to the July baseline but by September it didn't fall a significant amount further. This was taken as evidence by the authors that just informing that energy consumption would be monitored isn't enough for sustained improvements and therefore feedback, possibly through a gamified app, is of importance to see consistent energy reductions. Although the study didn't offer any post-trip feedback it was stated the purpose of the study was to find evidence of the need for such an intervention.

The limited results show that there is not a diverse range of technologies and systems providing post-trip feedback to drivers in the rail industry, as only two relevant studies were found in the review. Such a paucity of studies was anticipated given post-trip interventions and the rail domain in general were known to be under researched. None of the relevant studies gave detailed findings on a post-trip intervention but instead theorise how a gamified application could work in the rail industry. The above literature suggests such applications are feasible and of use in the rail industry but there is a clear scope for research to be published in this area in relation to energy efficiency, especially where an actual intervention took place. As of yet, no post-trip interventions to improve railway drivers' safety appear to have been developed or tested in the current literature. Table 9 reveals an overview of literature technologies for post-trip intervention in trains.

Table 9: Overview and assessment of technologies concerned with post-trip interventions in rails mentioned in scientific papers

Technology	Indicators	Technical equipment	Time of feedback	Method of transmission	Assesment	Acceptance/Effectiveness *advantages (+) /disadvantages(-)*
Placebo test	energy consumption	gamification	no feedback	–	●	- actual post-trip feedback was not found (Bartnik and Ćwil, 2017)
Self Determination Theory	fuel use	gamification	no feedback	–	●	- no intervention had actually being tested (Ćwil and Bartnik, 2016)
Assessment in terms of Acceptance/Effectiveness: ●: Low.						

5 DISCUSSION

5.1 Conclusions and research contribution

The present study examined, reviewed and critically assessed the state-of-the-art technologies which deliver post-trip interventions (i.e. visual feedback, gamification, coaching, penalties or rewards) for driving safety and provided recommendations for the most effective ones. The importance of a correct intervention was highlighted and it was found that acceptance along with effectiveness should be the top priority in terms of choosing an appropriate intervention strategy. Post-trip safety interventions were evaluated in terms of effectiveness and acceptance, using a color code assessment for the better comprehension of the results, with a particular focus on crash reduction, cost of application, time of feedback, on-road/simulator application, method of transmission etc. Furthermore, it was demonstrated that multi-stage provision of warning could become beneficial in terms of safety and minimum driving task load.

The results of the literature review showed that immediately post drive feedback was perceived as more helpful than feedback received after a month. The benefits of the systems with regards to professional drivers, such as trucks and buses, found to vary depending on whether the employer had access to information about the individual drivers or not and less focus was given in the time of the intervention delivered. Many applications that were utilized for trucks, (i.e. Scania Fleet Management, GreenRoad and Pure Telematics) could be used by other professional bus operators, but there was no evidence that these technologies might be able to be used for cars. The motivation for an operator to select a system may be impacted by other factors rather than road safety. For example, if the same post trip intervention can monitor haulage load transfer rate it may be more attractive than a different system which is better at changing driver behavior for driving but doesn't include the rate of haulage movement.

Transferability of post-trip safety interventions was found to be troublesome among transport modes It is worth mentioning that as most of rail as well as bus companies do not allow their drivers to have a mobile phone inside the cab, car applications may be difficult to be transferable to the other transport modes. According to the literature investigated, there was no specific technology which will be transferable for every vehicle operator. In fact, although the majority of car applications were available for naturalistic driving experiment and had low cost compared to professional applications, they might not offer all the functionality that truck or bus ones do (i.e. gamification, coaching or penalties), so it is difficult to conclude that there is transferability of the evaluated technologies among all transport modes. Although there is not currently an overlap between modes, the similarities between car, truck and bus solutions suggest that it would be possible to have a common technology for post-trip interventions.

The effectiveness of post-trip intervention systems in cars depended on the appropriate reward or penalty systems used, system design and user acceptance. It was shown that the most effective and common feedback given to drivers after each trip were visual warning signals and textual alerts through SMS, e-mail or written reports with comments and proposals for better driving performance. A gamified environment also assisted in gradually building up skills and keeps users motivated to operate their vehicle in a 'safety tolerant' way over a longer period of time. Visual devices, in-vehicle cameras and smartphone applications had lower initial hurdles regarding acceptance and effectiveness in different transport modes (i.e. cars, trucks, buses and rail).

With respect to trucks, the results confirmed that although a combination of monitoring and gamified feedback resulted in the best driving behavior after the trip, it was clearly mentioned that such interventions are not provided in isolation. It is important to keep in mind that this kind of feedback is usually imbedded within a broader safety change intervention framework, not only for truck but also for all professional drivers, in which they are offered in combination with other strategies (i.e. driver coaching and management commitment and support). Therefore, a focus on individual components will probably be insufficient to accomplish effective safety culture change. Moreover, little information was found on the acceptance of safety interventions from bus drivers, but advantages for fleet operators were visible in terms of continuous vehicle surveillance and driver compliance to traffic rules. Most of the truck and bus applications provided post-trip interventions to drivers and sent them score boards, summarized reports, progress graphs, in-app feedback texts, material rewards and other visual notifications immediately post drive and once a week. Interestingly, in some cases the individual score of a professional fleet operator was not shown to the employer and the latter did not have access to the progress of the whole group of drivers, increasing the acceptance from drivers as there were not evaluated individually about their performance. Rail interventions operate in a different regime and actual post-trip feedback was not found to have been provided to drivers in the rail industry, with no intervention actually being tested.

Consequently, a comprehensive depiction was made, in order to identify the web-gamified platforms and smartphone applications, which provide post-trip interventions to drivers. Freematics was an effective technology to provide feedback and encourage drivers to adopt safer behaviors. In addition, web-based feedback systems such as BCALs had high performance. Smartphone applications such as OSeven, Zen Drive, The Floow and VivaDrive for cars were effective solutions providing feedback immediate post drive. At the same time, D2go and NEXT driver for trucks as well as Driveprofiler, GreenRoad and Pure Telematics for buses, were the most reliable applications that were utilized providing post-trip feedback with gamification strategies. Transferability of post-trip safety interventions was found to be troublesome among transport modes, and although there is not currently an overlap between modes, the similarities between car, truck and bus suggest that it would be possible to have a common technology solution.

Based on the list of interventions listed for each mode, as well as the behavior theoretical principles outlined in the current study, researchers and practitioners will be able to identify the most appropriate post-trip intervention technology. The form of feedback, as well as the integration with the existing web-platforms, should be the priority. Moreover, attention should be given on the exploitation of the sensors inside each vehicle so as to capture all the necessary aspects required for operator state enhancement and coaching. Every post-trip intervention technology should not at fully replace other intervention approaches but should act as a complement to other actions taken to improve road safety and eco-efficiency. Nevertheless, post-trip interventions should be designed according to the principles of persuasive technology.

5.2 Limitations

In spite of its strengths, the current study faced certain limitations which shall be considered while interpreting the main key-outputs of this research. Firstly, based on the literature review, the results indicated that there was little evidence on interventions combining in-vehicle behavioral monitoring and post-trip feedback among professional operators of heavy vehicles in a "stand-alone" setting. Therefore, it remains difficult to draw conclusions on the net impact of such an intervention on road safety and eco-efficiency among professional truck or bus drivers. Secondly, almost none of the studies that did focus on interventions combining in-vehicle behavioral monitoring and post-trip interventions to promote road safety and eco-efficiency among professional operators of heavy vehicles in an on-road setting, were performed in a real-life setting, but in a simulator study with a small sample size. In terms of ecological validity, it is still open for discussion to what extent findings from in-lab studies can be generalized to the real world. In addition, as already mentioned, there was not any post-trip intervention technology for rail operators, so there was no evidence on the effectiveness and the acceptance of such interventions. With regards to the bus operators, the review was focused both in urban centers and long distance coach driving. However, when discussing safety or advanced driver assistance systems it is important to distinguish between urban and intercity environments, i.e. between buses and coaches, as these different contexts pose distinct challenges to driving and drivers. Furthermore, it should be mentioned that a research question that was attempted to be answered through this paper was how an evaluation of post-trip safety interventions can be made, but only in terms of effectiveness and acceptance. There is no clear picture on the cost of many of the interventions presented, or the total effort required by companies and private drivers in order to install potential equipment and enhance their behavior.

5.3 Directions for future research

Based on section 5.2, the most prominent limitations of existing intervention approaches consist of the testing environment, which is usually a simulator-driven experiment and a limit in application areas considerations especially for professional drivers. Furthermore, no evidence was found with regards to a combination of in-vehicle monitoring and post-trip feedback and exploitation of more in-vehicle sensing was suggested in section 5.1. This section aims to provide recommendations for further research to overcome such limitations.

In the future research should be focused on how to ensure that the effectiveness of an intervention is tested on real-world situations. To this end, the conditions to be tested, the sample size to be evaluated and the assessment criteria and how these differ from a simulator testing should be comprehensively determined and prototyped so that it is easier for all stakeholders to choose the most effective solution. Research should also be concentrated on how to include a variety of road types and environments (e.g. urban, rural, inter-city) in consideration of the interventions, so that assessment can become more context-specific. Furthermore, the development and assessment of intervention directed to other transportation modes such as Powered-Two-Wheelers (PTW) and cyclists would be of benefit and could act as a preliminary step to the design a more holistic intervention strategy applying to more than one mode and combining different post-trip feedback approaches of those presented in Section 4.

In order to broaden the resources of sensing operator state and driving behavior for effective post-trip feedback, Exploitation of novel and non-intrusive monitoring methods (e.g. 5G, Internet of Things, V2X Communications) could become beneficial in the near future, so as to increase personalized intervening and increase acceptance of already developed solutions (Yi et al., 2019).

Finally, future studies shall investigate and review technologies for post-trip safety interventions, making an assessment in terms of functionality, reliability, intrusiveness, quality, validity or complexity of such interventions for each transport mode.

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