Exploring risky driving behaviours of professional drivers under the operation of Advanced Driver Assistance Systems

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Abstract

Advanced driver assistance systems (ADAS) comprise a valuable tool towards improving road safety. Their effectiveness, however, varies and depends on prevailing conditions and driver characteristics. The aim of this study is to explore the driving behaviour of professional drivers, driving ADAS equipped vehicles, with a focus on risky driving, to design a database that will support this task and to identify potential factor types that may affect their behaviour. Professional drivers comprise a distinct driver category exhibiting specific characteristics and, as such, present different driving behaviour compared to the rest of the driving population. To achieve the aim of the study elements of aberrant driving behaviour of 47 patrol vehicle drivers of the motorway operator Attikes Diadromes were explored. A database of three month drives involving triggering specific monitoring systems was utilized displaying different types of aberrant behaviour. Several different variables were identified that might have the potential of affecting driving behaviour, and the relevant data were collected and integrated in the database. Preliminary statistical analysis was performed to identify whether risky behaviours present temporal, spatial or driver correlations. Results indicated that there are correlations, which need to be further explored; however, these correlations may differ considering the different recorded behaviours. This research serves as a basis to explore and identify factors affecting risky driving behaviours of professional drivers, utilizing real-data and can provide support to road operators towards improving the driving behaviour of their fleet drivers.

Keywords: risky driving; aberrant behaviour; professional driver; driving behaviour; advanced driver assistance systems; in-vehicle monitoring systems

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1. Introduction

Advanced driver assistance systems (ADAS) comprise a valuable tool towards improving road safety. Their effectiveness, however, varies and depends on prevailing conditions and driver characteristics and attitudes. Professional drivers comprise a distinct driver category exhibiting specific characteristics and, as such, present different driving behaviour compared to the rest of the driving population. Their main difference lies in the fact that driving is working, thus, professional drivers exhibit increased driving exposure both during the day and at night time, while at the same time they are associated with higher stress and fatigue levels (Charlton and Baas, 2006; Öz et al., 2010). Besides that, they acquire increased driving experience and better driving skills. As a result they exhibit increased perceived driving competence, which, in turn, often increases the likelihood of committing traffic violations (Parker et al., 2004).

Professional driver behaviour has mainly been explored through the utilization of the Driver Behaviour Questionnaire (DBQ), which records self-reported driving behaviour. DBQ serves as a useful tool for predicting traffic accident involvement (af Wåhlberg et al., 2015). The objective of most such studies is to identify factors that affect driver behaviour and traffic accident involvement. Maslac et al. (2018), in a similar study on professional drivers, noted that travelled mileage and driver experience were positively associated with traffic violations, while driver age was not found to be a contributory parameter. Milad et al. (2018) on the other hand found that older drivers were less prone to violations. Driver characteristics (e.g. gender, age, education marital status, income) have been identified as contributory factors considering risky driving of professional drivers (Millia et al., 2011). Sümer (2003) explored and found several personality and behavioural predictors including sensation seeking, aggression and psychological symptoms affecting aberrant driving behaviour of professional drivers in Turkey. Several researchers have linked personality characteristics with risky driving, with sensation seeking being the most prominent parameter considering the driving population (Lucidi et al., 2014), but also professional drivers specifically (Linkov et al., 2019). Han and Zhao (2020) on the other hand, explored additional parameters related to professional driver work characteristics and found that daily driving hours and sleep time per day were correlated with performed violations. Thus, contributory factors affecting professional driving behaviour, and especially risky behaviour, can be classified under three main categories: driver sociodemographic characteristics, driver personality characteristics and elements relevant to the nature of their work.

Professional driver behaviour plays a key role in the performance of vehicle fleet operators whether these are logistic companies, mass transit or other types of operators, as they comprise the actors link between the fleet operators and the end users (customers). Further to that, its significance is evident especially since aberrant driving behaviour is associated with increased traffic accident involvement (Sullman et al., 2002), which potentially reduces operators' reliability and profit. Consequently, several such operators have equipped their vehicle fleet with specific smart devices both to monitor driver performance (in-vehicle monitoring systems) and to assist drivers in their driving task (ADAS). The efficiency of these systems however, largely depends on the user, and in this case the professional driver. Hickman and Honowski (2011) evaluated the impact of a primal on-board safety monitoring system (OBSM) and combined driver coaching on professional driver behaviour. During the operation of the OBSM device a light (visible to the driver) flashed whenever a safety event was identified. The results of this study indicated improved driver behaviour. Bell et al. (2017) evaluated the operation of in-vehicle monitoring systems and concluded that they did not significantly affect professional driver performance. They noted, however, that the combined use of such systems and supervisory coaching was quite effective and improved driving behaviour. In a similar study, Mase et al. (2020) indicated that the effect of such devices and/or supervisory coaching on professional driver risky driving behaviours is dependent on the type of the investigated behaviour.

The present study explores risky behaviours of professional drivers by designing a detailed database and performs preliminary analysis on different factor types affecting the behaviour of professional drivers driving vehicles equipped with specific ADAS. 47 patrol drivers of Attiki Odos motorway comprise the study population and their driving behaviour is recorded for a period of three months. Statistical analysis is performed to identify the most frequent types of behaviour and to correlate it with specific relevant characteristics.

2. Methodology

2.1 Survey area and vehicle characteristics

The present study uses as a study case Attiki Odos (Figure 1), a 70km long closed tolled motorway in the outskirts of Athens operated by Attikes Diadromes S.A.. Attiki Odos has a total of 150km of service/side roads (main motorway and off-/on-ramps), 29 interchanges, while several of its segments are motorway overpasses or underpasses, tunnels and cut & cover sections.

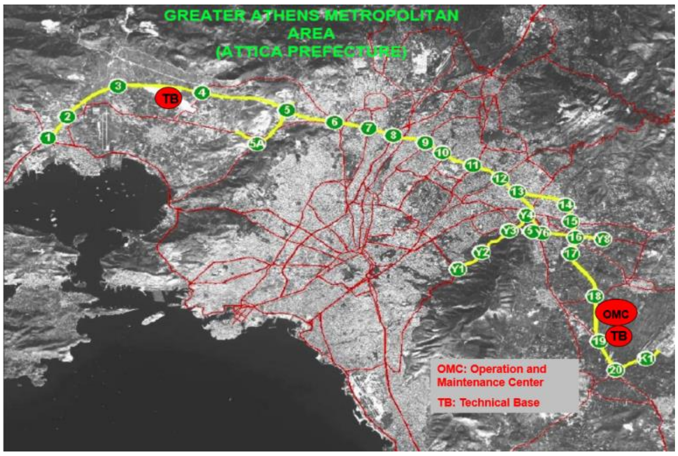

Figure 1: Attiki Odos Motorway.

Approximately 170 of the operator's employees are involved in the management of the motorway's traffic and maintenance issues, for the purpose of fulfilling the following objectives: traffic control and monitoring, management of emergency incidents and planned events, inspection, maintenance and repairs, as may be required in order to preserve the safe condition of the motorway, maintenance of operation and maintenance vehicles and facilities and routine works, such as cleaning the motorway. The main objective of Attikes Diadromes S.A. providing smooth and uninterrupted flow conditions to its users, thus ensuring a high level of operational performance and road safety. The main tool for traffic management is the Traffic Management Centre (TMC), which operates on a 24-hour basis. Through the permanent presence of specialised personnel and the use of high-tech equipment, the TMC continuously monitors the traffic conditions along the entire motorway. Dedicated patrol vehicles (Figure 2) serve as an important tool towards monitoring road conditions, detecting potential incidents or hazards, and responding to incidents whenever required. During their 8 hour shift patrol drivers cover a driving distance of about 300km. Their operation is also controlled from the TMC.
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Figure 2: Attiki Odos patrol vehicles.

To ensure efficient driving behaviour through providing dedicated assistance, patrol vehicles are equipped with two different systems (Figure 3): MobilEye, which is an Advanced Driver Assistance System, and Pointer, which is a driver monitoring system. MobilEye utilizes GPS, GIS, video detection and other sensors to estimate potential risky behaviours and transmits dedicated audio and visual warnings considering the following potential hazardous situations: forward collision, urban forward collision, adoption of small headways, lane departure, pedestrian collision. The Pointer utilizes an accelerometer and transmits audio and visual warnings considering the following potential hazardous situations: harsh acceleration, harsh braking, harsh manoeuvre, speeding, The data of these two systems is also transmitted real-time on a dedicated platform (MRMSuite) that allows monitoring and assessing driver behaviour.

(a) (b)

Figure 3: MobilEye (a) and Pointer (b) systems.

2.2 Data collection

The present study explores different types of potential contributing factors associated with professional driver risky behaviour. Thus, professional driver behaviour was recorded, during the working hours of patrol drivers, through the operation of the aforementioned ADAS, serving in this research as in-vehicle monitoring tools. The recorded data involved all drives performed by the patrol drivers during their shift within a period of three months (i.e. from mid-October 2020 to mid-January 2021), where all system triggers were recorded. The information provided was type of trigger, driver id, location coordinates and time.

Data on potential contributory factors including a range of items was selected. The data involved driver characteristics and attitudes, road network characteristics and shift characteristics. Considering driver characteristics a targeted questionnaire was designed to elicit sociodemographic data, as well as data relevant to driving characteristics including main transport mode, driving experience and extent of pleasure when driving. To obtain driver attitudes, a total of 25 questions were included in the questionnaire to elicit elements of their personality relative to anxiety, anger, sensation-seeking, altruism and normlessness as they have been found to affect driving behaviour (Kohn and Schooler, 1983; Goldberg, 1999; Ulleberg and Rundom, 2003; Chen, 2009). All indicators were measured using a 5-point Likert scale, ranging from strongly disagree to strongly agree. Specific driver attitudes towards traffic rules, rule obedience and speeding were also noted. A total of 17 questions to elicit the aforementioned attitudes were included in the questionnaire adapted from the studies of Ulleberg and Rundom (2003) and Chen (2009). A 5-point Likert scale, ranging from never to very often was utilized.

Variables relevant to road geometry were also extracted. Utilizing the trigger coordinates and Geoinformatics (specific application tools in ArcGIS) specific elements of the road characteristics were extracted and inserted in the database. These involved the type of road section (basic motorway segment, tunnel, on-ramp, off-ramp) where the trigger was recorded, the radius at the road section and the prevailing speed limit.

Driver fatigue plays an important role on professional driver behaviour, thus data relative to driver shifts were collected from the road operator. For all involved drivers, the dates and hours of their shifts during the period of study were provided. Thus, the following additional parameters were integrated in the database for each recorded trigger: shift type (whether it was morning, afternoon, night or the intermediate shift), number of consecutive days working, number of consecutive hours in the shift (ranging from 0-7). Last, during discussions between the patrol drivers and the road operator managers, drivers noted that they sometimes exhibit risky behaviours when they are called to respond to an incident. Hence, data for all incidents during the study period was provided including incident type, location and time, driver id that accommodated this incident, time at which the driver was assigned to the incident and time at which the incident was cleared and the driver departed from the scene. This data was utilized to determine whether a system trigger occurred within the time period that the driver was driving towards the incident. The relevant parameter was a binomial one - 0 when no incident was involved and 1 when an incident was involved. Thus, in the final database for each recorded trigger the trigger characteristics, the road geometry, the driver characteristics and attitudes, and the shift and incident data were inserted. It should be noted that this is an on-going study, thus not all data will be explored at this stage.

3. Analysis and Results

To assess the potential impact of specific risky behaviours on road safety two elements need to be considered: frequency occurrence and anticipated accident risk and severity. On the one end there are low impact behaviours involving behaviours with low frequency occurrence and of minimal potential impact considering accident involvement and severity and on the other end behaviours frequently observed with high probability of accident involvement and severe impact. Several behaviours range between these two ends. Initially, the distribution between the different triggers was explored to identify high frequency triggers. Table 1 presents all recorded behaviours during the study period.

Table 1: Number of total recorded triggers

Violation type	Total	Violation type	Total	Violation type	Total
LDW/RDW	69636	Idling Long Idling Start	5485	Harsh Acceleration Y. Sev.	210
+5 Km/H	65732	Turn & Brake Y. Sev.	4532	Turn & Brake R. Sev.	106
+10 Km/H	56514	Harsh Acceleration G. Sev.	4004	NULL	84
+15 Km/H	40699	Turn & Accelerate G. Sev.	3428	Harsh Turn Y. Sev.	82
+20 Km/H	29291	Idling Short Idling Start	2766	Turn & Accelerate R. Sev.	81
Turn & Brake G. Sev.	24944	Speeding Speeding G. Sev.	2671	Harsh Acceleration R. Sev.	26
+25 Km/H	21600	DFD Comm. Established	2507	Speeding Yellow	12
+30 Km/H	15560	Speeding Green (EOM)	2299	Maneuver mem overflow	9
IP UP	12993	HMW	1685	Harsh Braking R. Sev.	7
Off Road Start	11838	DFD Comm. Lost	1254	Lane Crossing G. Sev.	6
Harsh Braking G. Sev.	11749	Harsh Braking Y. Sev.	690	Harsh Turn Red Sev.	1
Off Road End	10891	Turn & Accelerate Y. Sev.	424	Lane Crossing R. Sev.	1
Harsh Turn G. Sev.	9810	FCW/PCW	279	Crash Occured Maneuver light	1
+35 Km/H	9495	UFCW	260		

Data indicates that the most frequently observed trigger is left and right departure warning, followed by exceeding the speed limit. The number of triggers considering speeding reduces with the increase of speeding extent as anticipated. Furthermore, the number of observed risky behaviours classified in three severity levels (green "G.", yellow "Y." and red "R.") reduces with increasing severity. It should be noted though, that not all of the recorded triggers represent risky behaviours, thus the non-relevant to the study triggers were not analysed further. For example, idling triggers are more relevant to eco-driving rather than road safety. IP UP involves driving under the wrong gear, and so on. Furthermore, specific behaviours might only be potentially risky. For example LDW/RDW is triggered when the system detects that the vehicle moves outside of the lane boundaries without the turn signal indication being on. This might be a result of inattention, however, judging by the high frequency displayed it is probably an indication of incorrect driver behaviour – assuming that the system is reliable. Drivers merely seem not to bother to turn on the turn signal when changing lanes. Furthermore, the items "off road start" and "off road end" most probably are not risky driving behaviours, but are associated with the nature of work of the patrol vehicles, as when providing assistance to other vehicles, they need to stop outside of the operational boundaries of the road.

Next, the distribution of the different risky behaviours considering the temporal and spatial dimensions was explored. The temporal dimension may involve the month of year, day of week or the time of day of the recordings or the type of shift, during which these behaviours were recorded. The first type of analysis would be relevant to traffic conditions, seasonality effects, prevailing light conditions and so on, while the second type of analysis is also associated with work characteristics. Figure 4 represents the distribution of the all risky driving behaviours per shift (morning, intermediate, afternoon and night); Figure 4a involves high frequency behaviours and Figure 4b those who were not observed as often.

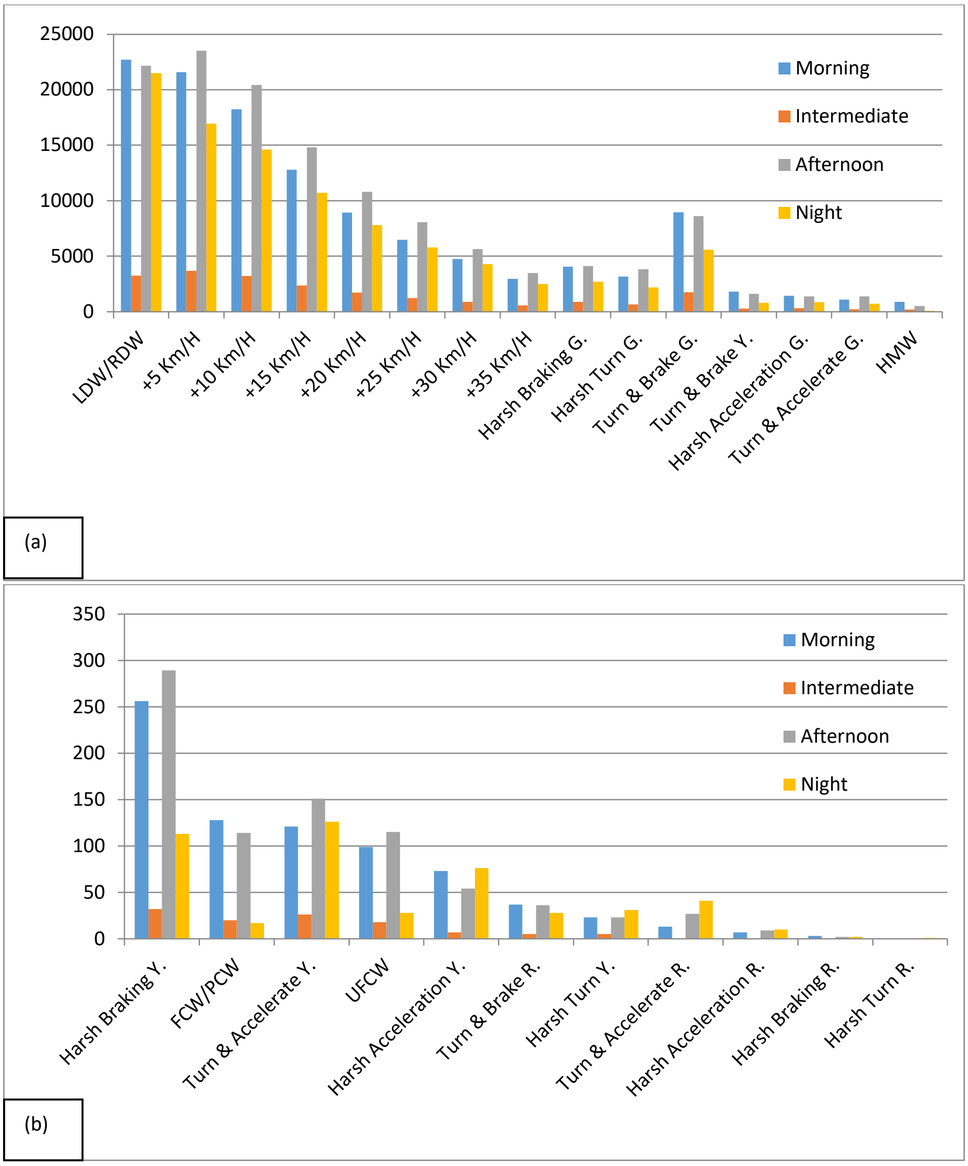


Figure 4: Temporal distribution of risky behaviours.

The morning shift is 6.00-14.00, the afternoon 14.00-22.00 and the night 22.00-6.00, covering all hours of the day. Further to this there is an additional shift covering the time period 10.00-18.00. The majority of recordings involve the morning and afternoon shifts, while the intermediate shift displays the lowest number of recordings. The number of recordings, however, is also relevant to the total driving hours within each shift type. The total number of 8-hour shifts performed by patrol drivers during the study period was calculated for each shift type and was found to be: 1076 for the morning, 234 for the intermediate, 1047 for the afternoon and 989 for the night shifts. The total number of recordings per shift is important as serves as an indicator of the road safety level of the motorway. However, to represent the actual accident risk associated with a particular shift, these numbers should be normalized considering the total number of shifts performed. Figure 5 illustrates the share of each shift type in the different risky behaviour recordings, following normalisation.

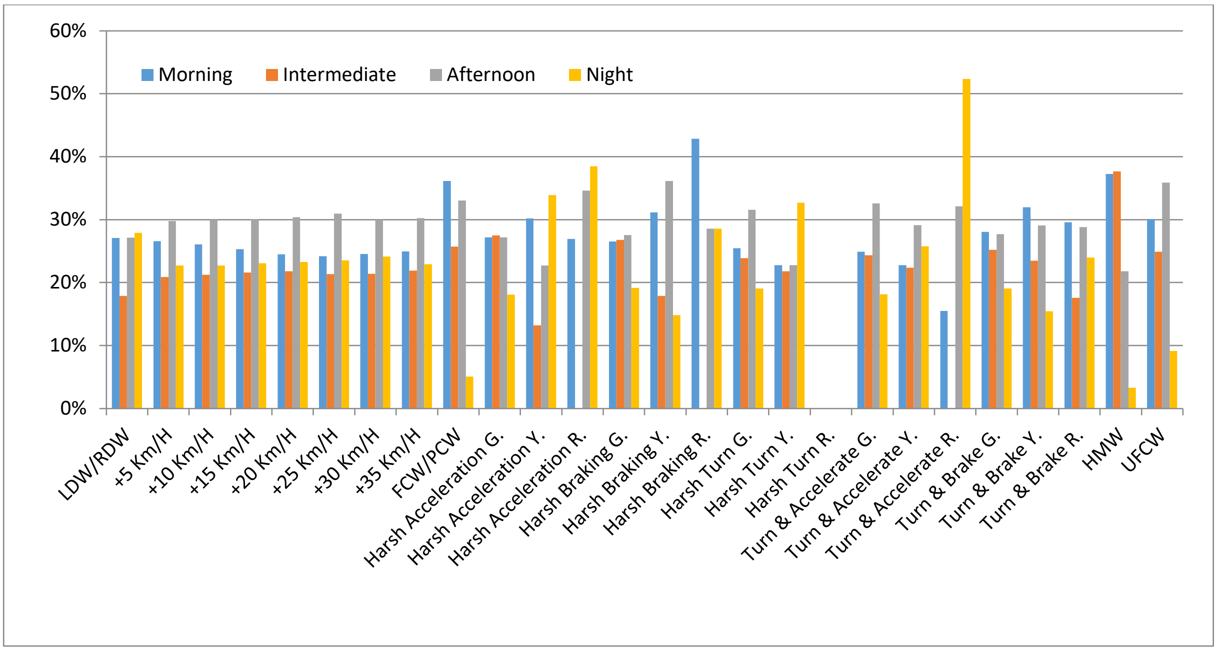
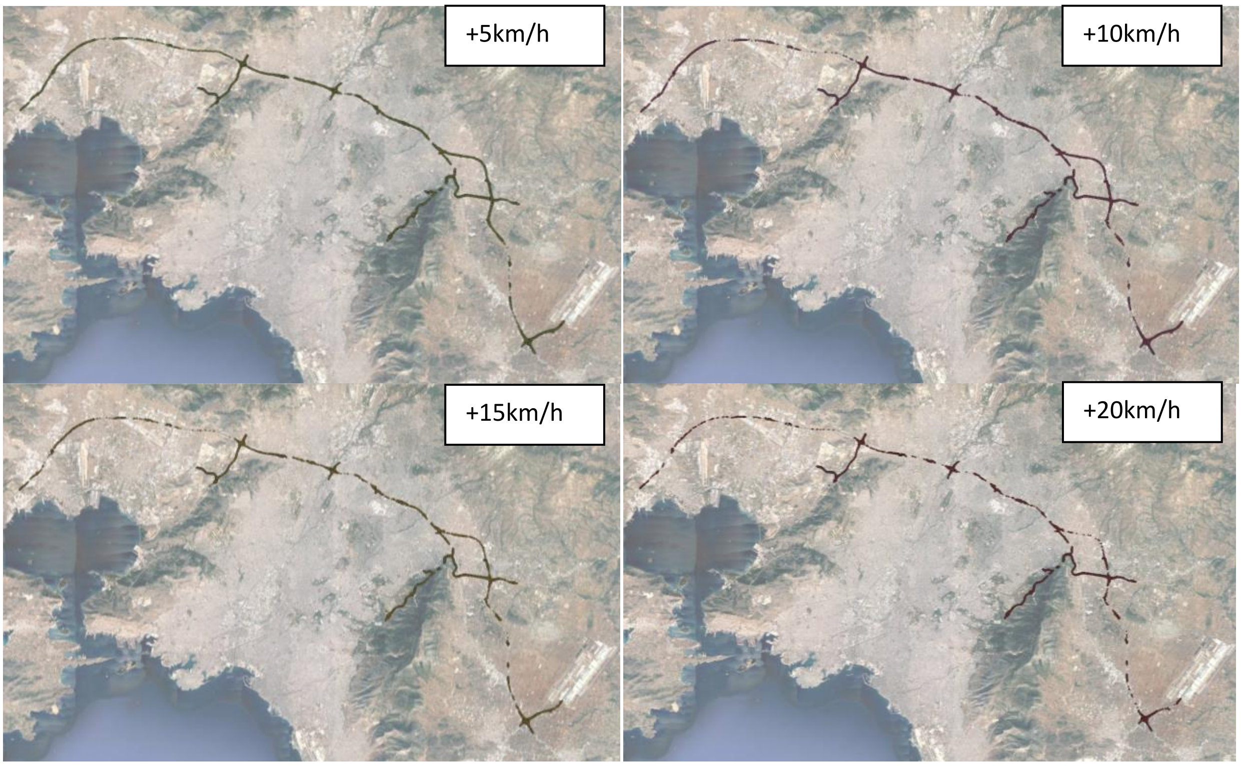


Figure 5: Temporal distribution of risky behaviours.

Figure 6 represents the distribution of the specific risky driving behaviours (speeding and harsh barking of green, yellow and red severity) on the road network. Following normalization the observations are quite different. Speed relevant behaviours present a somewhat similar pattern, with the afternoon shift presenting the highest participation, being followed by the morning shift and then the night shift. The intermediate shift presents the lowest share. For other types of behaviours (e.g. harsh acceleration, harsh barking, harsh turn etc) the night shift increases its share with the increase of recorded severity. Still, it should be noted that for certain risky behaviours the number of recordings with severity is rather low, thus such generalisations should be made with caution.



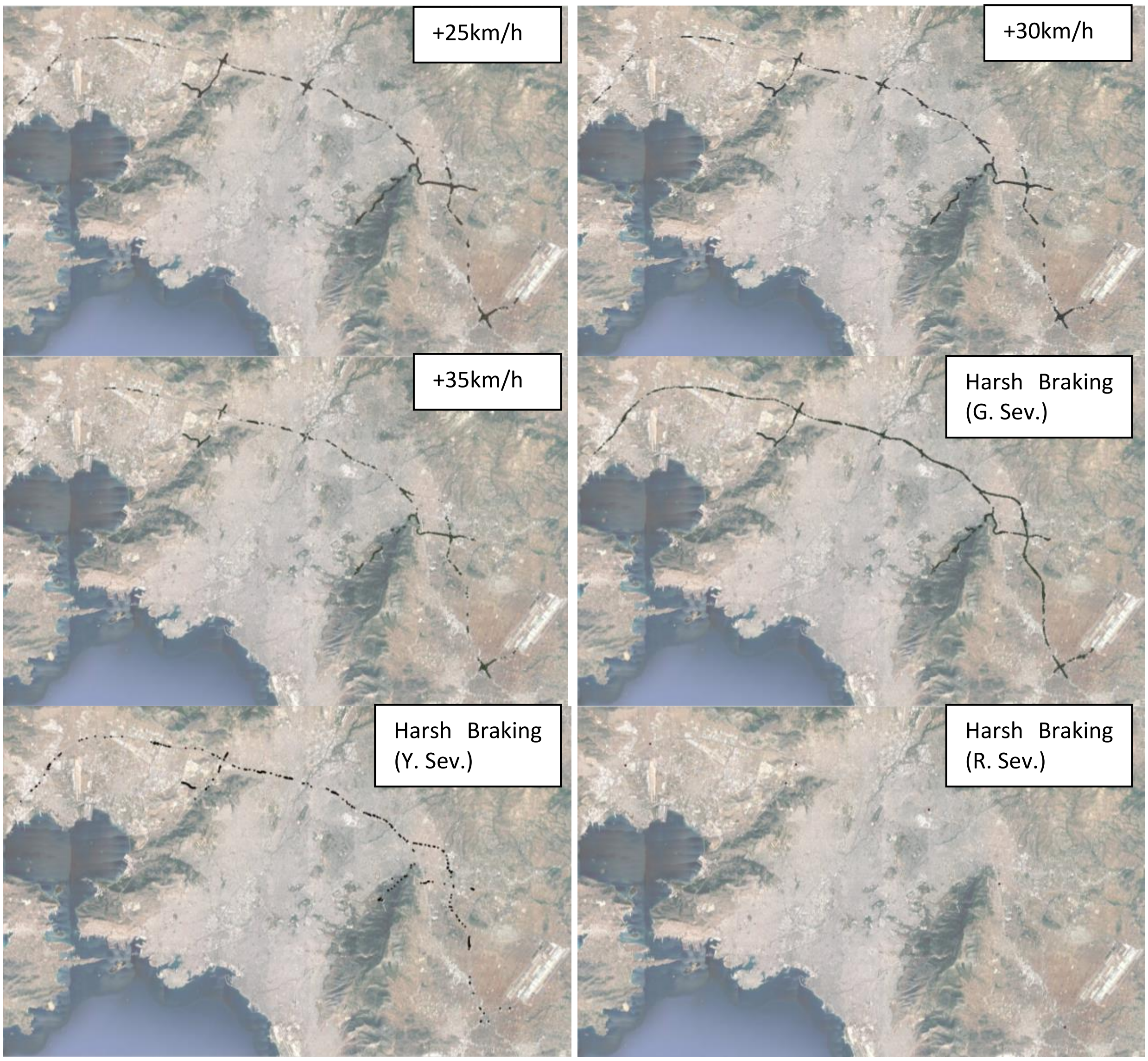


Figure 6: Spatial distribution of speeding and harsh braking.

Considering speeding, results indicate that specific areas exhibit increased speeding events, while others display lower recorded cases. This phenomenon is more evident with the increased extent of speeding. This indicates that there is a spatial association considering speeding. However, a number of attributes may be relevant including road geometry, speed limit, traffic flow conditions and so on. Considering harsh braking in certain areas recordings of both green severity and yellow severity events are denser, again indicating a spatial correlation. On the other hand, the number of red severity harsh braking events is minimal, and no correlations can be identified.

Last, potential associations between risky behaviours and the different drivers were explored. The first step is to examine whether drivers demonstrate an overall risky or safe profile. The number of observations per different behaviours and drivers are presented in Figure 7 (each line presents a different driver – the line style is employed although data is discreet rather than continuous so that the reader can follow the trend).

One driver was omitted from the presentation as he/she displayed substantially higher recordings from the rest of the drivers for the majority of the different behaviours. It should be noted, that he/she had a rather small number (comparatively to the other drivers) of recordings of LDW/RDW. The graphical presentation of the recordings per driver indicates that, there are drivers exhibiting generally similar participation (i.e. high, medium or low) in several behaviours. Furthermore, there is a substantial number of drivers who speed but tend to exhibit better performance considering lane changing behaviour.

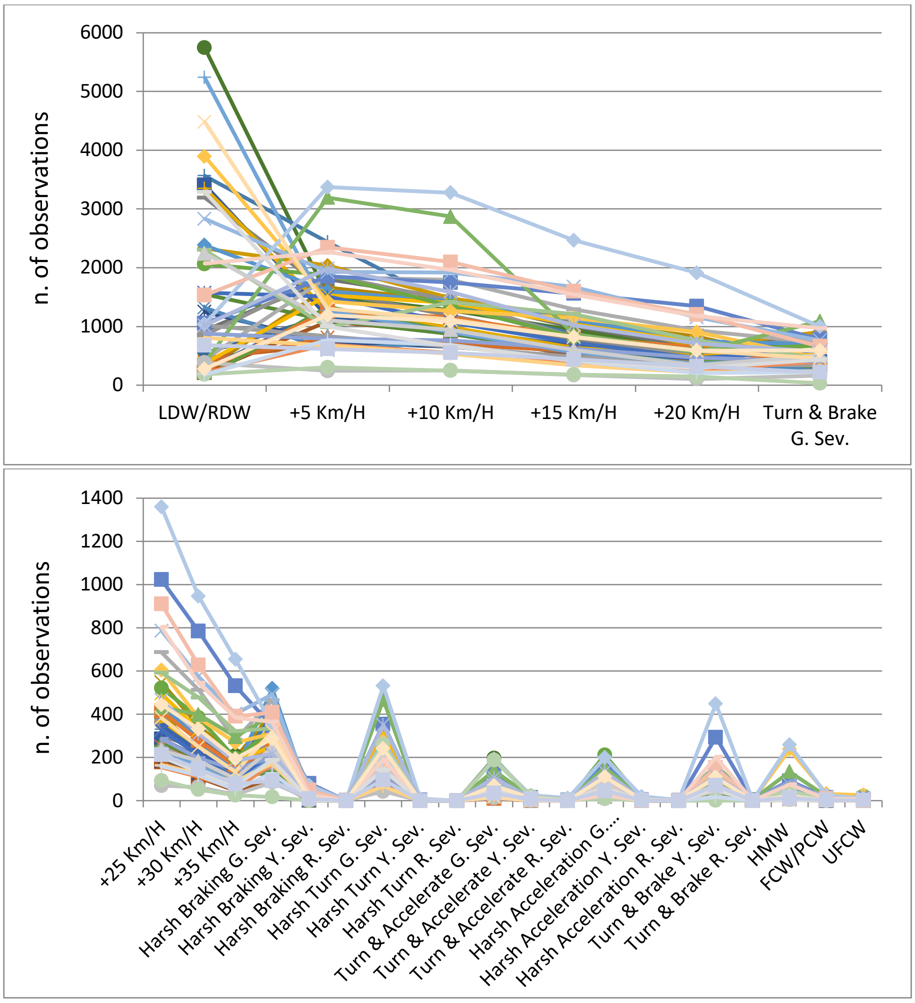


Figure 7: Risky behaviours per driver.

4. Discussion

The objective of this study was to explore risky behaviours of professional drivers driving vehicles equipped with advanced driver assistance systems, to design a database allowing for such an investigation and to identify potential factor types that may affect driving behaviour. Initially, different types of data were collected and integrated in a database utilizing several tools: the equipped ADAS serving as in-vehicle monitoring devices, a GIS map, a dedicated questionnaire and the shift and incident logs provided by the road operator. The study area was Attiki Odos motorway, and data from 47 drivers over a 3 month period was collected. Being in agreement with the findings of Mase et al. (2020), results indicated that risky driving behaviours should not be analysed altogether, as they present different temporal and spatial distribution, and different distribution between drivers. The preliminary analysis indicated that prior to the design of detailed models for risky behaviours, data should be segmented to cater for different effects. In particular, the participation of the explored behaviours relative to the shift types differed between the different behaviours. In general, speeding displayed a similar distribution irrespective of the extent of speeding, while other types of behaviours (harsh braking/turn/acceleration) presented increased occurence during the night shift with increasing event severity. Considering temporal distribution dense speeding recordings were observed in specific sections of the road, while in other sections recordings seemed to be rather random, necessitating the segmentation of the road network in different sections and the need to identify the conditions that result in increased speeding at the particular segments. Last, several drivers presented different patterns for different behaviours.

5. Conclusions

Within this work, potential factors affecting risky behaviours of professional drivers have been identified, and a detailed database has been designed to support future research on this topic. Furthermore, specific contributory attributes that require further attention have been determined. Professional driver risky behaviour has mainly been investigated utilizing data of self-reported behaviours. The present analysis is performed on naturalistic driving data. The high number of observed triggers (e.g. speeding) indicates that ADAS do not seem to improve professional driver behaviour, necessitating the adaptation of other supplementary measures, such as supervisory coaching or work related incentives or penalties. Furthermore, the designed database is enriched with several other types of data, including road geometry, driver characteristics and attitudes, driver shift and incident characteristics that are anticipated to assist towards understanding factors associated with risky behaviours of professional drivers. This may serve as the basis of the formation of a valuable tool for road operators towards improving fleet drivers' driving behaviour, and thus improving their performance.

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