A review of risk factors associated with elderly, truck and office worker drivers for automated driving applications

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Abstract

This study tries to identify and review risk factors that impact road safety and driving performance focusing more on three types of users, namely elderly drivers, truck operators, and office workers (i.e., working and driving simultaneously; feasible at higher levels of automation). Additionally, this review attempts to highlight the reviewed risk factors that should be considered in future safety analyses. The present review is part of research conducted within the EU H2020 HADRIAN project, which aims at developing an innovative Human Machine Interface (HMI) that will provide seamless "fluid" interactions between the driver and the automated vehicle. The literature review was conducted using popular databases such as Google Scholar, Science Direct, and Scopus using specific search terms and prioritization criteria for studies coming mainly from Europe and the U.S, and after 2005. Then, the reviewed risk factors were discussed based on how they can be extended and adapted at the different future AD levels and what risk factors should be considered in future safety analysis depending on the AD level. The aforementioned review will be exploited by the HADRIAN project, like any other HMI stakeholder, in order to develop a human-centered assessment methodology which will evaluate the way the human interacts with potential HMI configurations. Finally, the reviewed risk factors could guide stakeholders in accomplishing a safer transition from manual to autonomous driving for all road users.

Keywords: Elderly drivers; Truck drivers; Working drivers; Risk factor; Driving performance; Road safety

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1. Introduction

Road traffic fatalities and injuries are a serious threat to public health as they are the 8th leading cause of death worldwide with approximately 1.3 million deaths per year and many more (20-50 million) suffer non-fatal injuries [1]. Despite the fact that the death rate (deaths per population) presents a declining trend, still, every year about 18 fatalities/100.000 population are recorded which is quite concerning [2]. Focusing on the cost of road accidents, in 2005 regarding 31 European countries, the estimation of preventing a fatality varies from 0.7 to 3.0 million Euro [3]. The estimation of preventing a serious injury ranges from 2.5 – 34.0% of the aforementioned value per fatality and additionally the valuation of preventing a slight injury ranges from 0.03% to 4.2% accordingly [3]. Additional findings for GDP, the total cost of European road accidents were equal to 0.4 – 4.1% of GDP and similarly, for the whole world, a report of WHO [2] estimated them about 3% of GDP. Indicating that there is a significant effect of road fatalities and injuries on society, health, and to an extent finance [2]–[4].

In addition to the impact of road accidents, it is fundamental to investigate the responsible risk factors for this public health threat. For many decades, the research spotlight has shed light on many risk factors which contribute to accidents. A relative analysis of Thomas et al. [5] investigated road accidents data from 6 countries and found that 72% of the examined accidents involve factors related to human factor, indicating that human factor is a major concern on road safety. In this direction, relevant studies estimated that human factor is responsible for 94% of road accidents [6]. The remainder observed accidents were due to factors related to a combination of the road environment and vehicle factors [7]. The aforementioned analysis showed that the human factor contributes significantly to road accident occurrence, in other words, human is considered to be responsible for the majority of the collisions. Consequently, especially the human factor, along with supplementary factors of road and vehicle environment, should be investigated exhaustively in order to mitigate and reduce its contribution to road accident fatalities. To that end, this study tries to identify and contrast risk factors that impact road safety and driving performance.

At the same time, when intelligent transportation systems will become available in future societies, aspects such as human factors, congestion, and energy efficiency will be improved [8]. Hence, it can be assumed that by the evolution of automated driving; the human factor can be reduced or get assisted during AD and this will result in the reduction of road fatalities. Another hypothesis indicates that if the driving task could be shifted to optimal (assuming error-free systems for automated driving), consequently by removing elements of human error from the driving operation, collision risk should be reduced or to an extent eliminated [9], [10]. Nevertheless, a more realistic assumption is that human error will be replaced by crashes caused by imperfect automated systems in the intermediary stages i.e., at “mixed traffic” conditions [11]. The Forum of European Road Safety Research Institutes (FERSI) developed the main principles for “safety through automation”. A key principle for automation safety is the necessity for “Human-Centred Design”, in which all possible user profiles should be considered when designing Autonomous Vehicles (AVs). Also, “Human-Centred Design” includes safe communication through road users, and safe interactions with vulnerable road users [11], indicating the key role of human factor during designing AVs. To that end, possible user profiles were included in this review by focusing on three specific “use case” drivers i.e. elderly, truck, and working drivers.

Combining the literature finding on the human factor effect on road accident occurrence and the developing AD systems, it deems essential to develop a “safer” automated vehicle, which will contribute in reducing and maybe eliminating the human factor or ideally any factor during driving. The total aim for AD stakeholders should be to develop AD systems that assist in reducing road fatalities by developing safer e.g., in-vehicle technologies or automated vehicles which will contribute to safer automated driving [8], [11].

This review aims to identify risk factors that impact road safety and driving performance focusing more on three types of users, namely elderly drivers, truck operators, and office workers (i.e., working and driving simultaneously; feasible at higher levels of automation). Additionally, this review attempts to highlight the reviewed risk factors that should be considered in the future safety analysis of automated driving (AD) applications. Then, the reviewed risk factors were discussed how they can be extended and adapted at the different future AD levels and what risk factors should be considered into future safety analysis in regards to the AD level.

The paper is structured as follows: after the introductive section with a brief presentation of the importance of this review in combination with AD development, a section follows with the examined use case description and the literature review methodology. After that, the literature findings are presented and analyzed, along with different subsections for the three main use cases. Then the discussion follows and the reviewed factors are discussed in relation to the different AD levels and then the limitations, and future research are given. Finally, the conclusions follow with the significant outcomes of this study, and then the acknowledgments follow.

2. Methodology

2.1 Examined Use Cases

In this subsection, the use cases used for the current review are described. The use case drivers or the user types considered were inspired by research conducted within the EU H2020 HADRIAN project, which aims at developing an innovative Human Machine Interface (HMI) that will provide seamless interaction (named "fluid") between the driver and the automated vehicle. Simultaneously, the importance and purpose of choosing these three specific use cases are explained.

Over the last decades, life expectancy is increased and it is estimated to continue having an upward trend in coming decades [12] and combining the fact that the population is ageing, it comes as a logical consequence that the proportion of elderly drivers increases [13]. Nowadays, the elderly population consists of 18% of the whole European population. This percentage will be increased steadily in the future as a worldwide report indicates due to the reduction in the fertility level [14], the declined birth rates, the baby-boom generation (which consists a significant proportion of the population) is ageing, and the increased longevity of humans. Due to these explanations, it is estimated that 24% and 28% of the population will be aged ≥ 65 years in 2030 and 2050, respectively [15].

In the context of elderly drivers and road safety, it is worth investigating the impact of the third age on accidents and road safety in general. Several published studies show a significantly higher crash involvements rate is observed regarding older drivers compared to the younger group [16]–[18]. Furthermore, analyzing the fatal accidents appears that the fatality crash rate is higher for the older drivers compared to other ager groups [19], [20]. At the same time, a study shows that injury severity is strongly related to age, thus an older driver is more likely to be involved in an injury or fatal road accident compared to a younger one, probably because of the decline physical condition [21]. Taking these aspects into consideration, the risk factors of elderly drivers are critical to be analyzed as they are more vulnerable to trauma and likely to have a collision and especially for future applications which will give the opportunity to elderly users the ability to commute [22].

Concerning the truck drivers, the total traffic fleet consists of a notable proportion of trucks (around 10%) [23] and presents different features in comparison to passenger cars. For instance, truck drivers cover longer distances as they use their trucks for commercial purposes. A thorough investigation for the associated risk factors is required as truck drivers were responsible for 16% of the accidents [24]. Also, a study supplements the aforementioned statement by highlighting the different safety patterns among different-weighted types of vehicles by stating that "the lighter the vehicle, the less risk to other road users, and the heavier the vehicle, the less risk to its occupants" [25], consequently, trucks may be more dangerous for other vehicles, motorbikes, and vulnerable road users, than for the drivers themselves.

With regards to office worker drivers (i.e., working and driving simultaneously), this use case attempts to approach a future mobility need. These drivers are expected to be a future mobility need since it will possible through higher levels of automation to interact with non-driving-related tasks (NDRT) i.e. laptops, vehicle displays, smartphones, or even sleeping. In the existing literature, this specific use case has not been adequately analyzed yet, since it is impossible to work during driving with nowadays levels of automation. Therefore, this type of driver should be analyzed and further investigated in terms of potential risk factors.

2.2 Literature review methodology

The literature search was conducted on the leading databases with published studies and most of them are published in scientific journals after peer-review process. These scientific databases were Scopus, Science Direct, Google Scholar using specific search terms and prioritization criteria for studies coming mainly from Europe and the U.S, and after 2005. Also, all findings of Safety Cube DSS were exploited which is a European Road Safety Decision Support System. In general, in Table 1, the used search terms can be found. The first column includes the basic search terms and the second column with additional keywords depending on the specific looked-for topic. Furthermore, in this literature review, many references were found in the literature review section of the already screened and published papers.

As depicted in Figure 1, the first step of the literature review methodology was the search on the leading databases, as exactly mentioned before. The second step was to view the title and the abstract, and judge if it was suitable. The third step included the major criterion for a study to be included in the final table was that the results to be statistically significant and the methodology to be rational and reasonable (this criterion was met with most papers, as most of them were judged by peer review). In total, more than 100 studies were included in the review, and approximately a total of 300 were screened.

Table 1: Search terms of the literature review

Basic search terms	Additional search terms
"accident probability" "road safety" "risk factor" or "risk" "elderly" "older" "aging" or "ageing" or "aged" "truck" "heavy duty" "heavy vehicle" "trailer" "worker" "working" "workaholic" "driver" "drive"	"mental workload", "inattention", "mind wandering", "distraction", "reaction time", "response time", "fatigue", "sleepiness", "drowsiness", "cognitive functions", "cognitive abilities", "driving performance", "headway", "speed", "turning head", "neck flexibility", "vision", "night time", "medical conditions", "hearing", "diseases", "medication", "drugs", "emotions", "stress", "anger", "spatial perception", "impairments", "driving experience", "mental workload", "sleep disorders", "Mind-wandering", "night time driving", "speeding", "drivers' age", "reaction time", "age", "weather conditions", "adverse weather", "driving experience", "stress", "anger", "boredom", "perception", "traffic density", "traffic flow", "cognitive functions", "cognitive abilities", "road type", "sex", "joint" "alcohol", "drugs", "vision", "spatial perception", "risk taking", "medical", "obesity", "emotions", "speed choice", "medication"

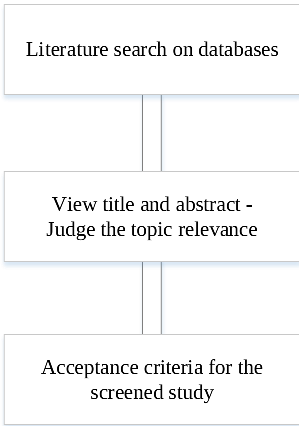

Figure 1. Steps of literature review methodology.

3. Analysis and Results

3.1 Risk Factors

In this section, the obtained findings are presented, and, specifically, risk factors for each use case as identified based on the literature. The identified factors were distinguished for each examined use case; namely elderly, truck, office worker drivers. As mentioned before, these use case drivers were inspired by research conducted within the EU H2020 HADRIAN project. The literature review found several risk factors that significantly impact safety and driving performance and are analyzed in the following subsections. In Table 2, the factors are presented in three columns. Each column represents each examined use case or type of driver.

Also, as can be seen in Table 2, the obtained factors were categorized into two or three categories per use case. The factors were categorized with regards to elderly drivers into three main categories namely; age-related impairments, age-related medical conditions, and age-related medication. The implemented categorization follows the structure of a European Commission's report ElderSafe [15] and a published review [26] (i.e., age-related functional limitations, illnesses, and medication). Besides, risk factors regarding truck drivers are separated into the following categories: i) Driver-related Factors, ii) Work-related Conditions, iii) Driving Conditions. Furthermore, office worker drivers factors are distinguished as i) Office worker-related Conditions ii) Driver Behaviour. In combination with Table 2, Figure 2 was created to illustrate the implemented categorization of the examined use cases. The categorization was implemented in a sense that the reviewed factors to be categorized into as few as possible dedicated categories, as well as taking into account the three fundamental elements of driving task: human - traffic environment – vehicle.

Table 2: Factors that impact on safety and driving performance

1. Elderly Drivers	2. Truck Drivers	3. Office Worker Drivers
1.1 Age-related Impairments: • Mental Workload • Inattention • Distraction • Reaction Time • Fatigue • Cognitive Functions • Headway & Speed • Joint Flexibility • Vision • Emotions	2.1 Driver-related Factors: • Age • Driving Experience • Distraction/ Inattention	3.1 Working-related Conditions: • Distraction • Inattention • Stress • Fatigue
1.2 Age-related medical conditions	2.2 Work-related Conditions: • Fatigue	3.2 Driver Behaviour: • Speeding

1. Elderly Drivers	2. Truck Drivers	3. Office Worker Drivers
	• Working Hours • Sleep Duration • Sleep Disorders • Nighttime Driving • Obesity • Heavy Vehicle Configuration (Single Or Double Type Of Trailer) • Company's Safety Policy	• Risk-Taking
1.3 Age-Related Medication	2.3 Driving Conditions: • Road Type	

Figure 2: Risk factors categorization.

3.2 Elderly Drivers

Initially, before analyzing the risk factors of elderly drivers, the definition of classification among elderly drivers is required. Elderly drivers can be defined as the age group of 65 years old and over [26], [27]. Sometimes it can be separated into two subcategories namely; the young elderly (65-74 years) and the older elderly (85 years and older) [28], [29].

3.2.1 Age-related Impairments

In this section, all possible age-related impairments of elderly drivers are analyzed and therefore aspects related to road safety research are presented. Before going deeper into the risk factors, it is worth mentioning that there is not a clear relation between age-related impairments and accident risk. The only occasions that this relation becomes evident are under the following severe impairments: severe sensory, perceptual or cognitive limitations, and severe illnesses (Brouwer & Davidse, 2002 as cited in [15]). Nevertheless, the rest of the included factors are considered to impact driving performance and probably to an extent the accident risk.

Mental Workload: The workload can be defined as the concept of "resources" or "residual resources" [30]. A study reveals that elderly drivers compared to the younger age group differed significantly regarding the load that was devoted to mental demand and physical demand [31]. In the same context, the mental workload of the elderly was higher compared to the younger drivers and this outcome became worse in more complex driving situations such as overtaking maneuvers [32]. Another study indicated that elderly drivers had a higher mental workload due to the fact that in the experiment they did not perceive a higher percentage of “missed signals” [33]. The aforementioned findings can be combined with the fact that there is a close relationship between the variables of mental workload of the aged drivers and driving performance [34], [35]. Therefore, it can be concluded the perceived workload is different between elderly and younger drivers which leads to a different impact on their driving performance.

Inattention: Inattention defines as “daydreaming and distraction through the state of mind (pondering, etc.) in a certain way induces a level of distraction to the person driving”, which is considered as a main risk factor in road safety [36]. Research findings presented that a higher frequency of self-reported inattention state was highly correlated with higher risk during driving [37]. Nevertheless, focusing on the elderly, a study by Qu et al. [37] explains that probably the purpose that older drivers reported less mind-wandering was the declined processing capabilities. Therefore, probably this is the explanation that there was not a significant effect of older drivers’ inattention on injury severity [38].

Distraction: Drivers’ distraction occurs when a sudden event induces an attentional shift away from the driving task. Research showed that in-vehicle tasks, namely hands-free mobile phone conversation and interaction with entertainment/information system, decreased several variables concerning driving performance and these results were quite stable to all different driver age groups and environmental difficulties [39], [40]. Older drivers tended to engage selectively in distraction tasks according to driving difficulty, for example, they engaged less (with their distractive activity) when driving becomes more challenging in comparison with less challenging maneuvers [41].

Reaction Time: The average reaction time to sudden events of the older drivers was significantly higher than younger age groups [18], [35]. Another research showed that reaction time increased gradually with age [42], the same influence, also, found in between older ages 70 to 89 years old [43]. Mental workload increased further the average reaction time to sudden events and regarding elderly drivers a more remarkable influence was observed [27], [35], [44]. The response to critical events became more inaccurate as the task difficulty increased, hence older experiment participants made more errors than other age groups. Consequently, they had a significantly higher no-response rate to unexpected events compared to other age groups [27]

Fatigue: The definition of fatigue varies greatly in the literature with terms such as ‘fatigue’, ‘sleepiness’, and ‘drowsiness’ being used interchangeably [45]. The Oxford dictionary definition of fatigue can be explained as “extreme tiredness resulting from mental or physical exertion or illness” [46]. The literature review showed that the elderly have a higher probability to cause a fatigue-related crash than the other age groups [47]. Older drivers perceived themselves as more fatigued while driving compared to younger groups [48].

Cognitive Functions: There is a great concern of “age-related cognitive decline” that impacts cognitive functions among the elderly population. Specifically, a study showed that cognitive abilities [49] and cognitive performance such as measures of speed processing [50], [51] declined in the older population. The elderly needed more time to process complex information before an accurate response [27], [51]. Another study concluded that mental flexibility is worse for the elderly [31]. These findings can be combined with the finding that the declined cognitive abilities were found to be significantly correlated with driving performance [52], [53] and conclude the indisputable interrelationship between cognitive functions and driving performance. On the contrary to a study which extracted that older age group have the same cognitive measurements as the younger ones, however, this specific study considered as older driver those who aged above 58 years old [51] and can be considered as improper since the majority of researches categorize this age group above 65, as stated at the beginning of this section.

Headway & Speed: The headway time is defined as the elapsed time between the front of the lead vehicle passing a point on the roadway and the front of the following vehicle passing the same point [54] and headway distance as the elapsed distance respectively. Both headway and speed variables are considered as driver-chosen and consequently, it can be considered as a risk factor. According to Chen et al. [55], elderly drivers have developed an adaptive and defensive strategy by keeping longer headways and a lower speed, this was revealed by comparing prior-to-conflict measurements such as speed and headway. For this statement, other studies concluded the same; elderly drivers tended to drive slower than other age groups [18], [31]. Furthermore, they kept longer headway from the front vehicle [52], [56]. All the above confirms that the elderly develop a more defensive driving strategy meaning that they choose a safer slower speed and greater headways during driving. In combination with the aforementioned variables, some researches found that the older age group deviated in speed less compared to the younger age groups [18], [51] and other researches found the exact opposite, a higher deviation [52], [56]. Regarding headway variation, the elderly deviated more [56]. As a logical consequence, it can be defined that there is not a clear conclusion concerning the deviation of speed and headway.

Joint Flexibility: Another research finding is neck flexibility measurement, which showed a significant effect on driving performance. More specifically, elderly drivers show less neck flexibility measurement [57]. Aged drivers tended to make moderately sharper or tighter turns than younger drivers due to the reduced head and neck flexibility, and subsequently, they lacked checking traffic vehicles [58].

Vision: Elderly drivers have a significantly decreased performance in peripheral motion contrast threshold and age was found to be strongly correlated with peripheral motion contrast threshold. Furthermore, the peripheral motion indicator was remarkably associated with crashes and driving performance [59]. Another finding was that there was a significant reduction in the elderly's visual field size, but in dynamic conditions only [31]**.** In combination with the aforementioned argument, a different visual behaviour was observed concerning the age, the difference concentrates on the area that the driver looks at. From the results of the experiment, older drivers looked more at lane markings on the road for having a correct position in the traffic, however younger drivers looked more at dynamic objects-threats such as the traffic vehicles [57]. Furthermore, older drivers tended to look less often on the road for potential threats than younger drivers [60]. According to Bao & Boyle [61], they tended to look less at their available scanning range such as the left, right, rearview mirror or somewhere random compared to the middle-aged. On specific occasions, the elderly looked and scanned significantly less left and right when they passed through an intersection. Moreover, they checked the rearview mirror significantly less compared to the middle-aged. In the context of vision impairments, visual deficiencies are associated with crash involvement [62]. Moreover, another study implies that impaired visual processing and glaucoma may play a role that older driver crashes and to by extent result in injuries [63].

Emotions: Some studies found that older drivers tended to drive less aggressively compared to the younger age groups [64], [65] and as a consequence, elderlies were taking a little risk.

3.2.2 Age-related medical conditions

Amongst elderly people, there is a higher probability to be diagnosed with one or more specific medical conditions which are more dominant in the older adult population [15]. Hence, the following diseases are called age-related. A study by Clarke et al., [47] found older drivers with chronic or acute illness, in general, can contribute to more crashes. The following listed medical conditions can potentially impact the accident risk of elderly road users [66] and it is not the condition itself that increased the risk, but the influence of the condition on the functional abilities and skills of the elderly drivers to respond appropriately to a critical event [15], [67]. On the contrary to this, another study mentions that the observed increased risk can be caused by the proper medications which are being prescribed to the elderly drivers [15], [68]. The increased risk, probably is due to a combination of these two factors: i) the influence of the condition on the functional abilities and skills and ii) medications, and this should be considered in future studies in order to accomplish unbiased outcomes. According to the literature and mostly in two meta-analyses of J. Charlton et al. and Vaa [66], [68], the identified age-related medical conditions which are presented to be associated with higher accident risk are the following [15], [69]:

Alcohol abuse, Cardiovascular diseases, Cerebrovascular diseases, Depression, Dementia, Multiple Sclerosis, Diabetes mellitus, Epilepsy, Hearing impairments, Musculoskeletal and motor disability conditions, Parkinson's disease, Psychiatric disorders, Renal disease, Schizophrenia, Sleep apnoea, Vision impairments, Hearing impairments, Heart disease or stroke, Cataracts, Mental disorders, Neurological disease, and Arthritis/ Locomotor disability

Furthermore, having more than one illness which is defined as "comorbidity" is more common among the elderly population and is considered also associated with a higher crash risk [15].

With regards to the declining vision, a number of papers indicated that reduced vision and visual acuity impacted negatively on accident involvement (for both injury and non-injury accidents) [62], [63]. These results showed that poor vision, which is more probable for elderlies, impacted statistically significant on accident involvement. On the other hand, a study by Gresset & Meyer [70] presented a neutral effect of the vision-related variables on accidents. Simultaneously, focusing on hearing loss, a study by Picard et al. [71] indicated that there was a modest but significant correlation and association between hearing loss and crash involvement. Besides, Green et al. and Ivers et al. [62], [72] found a non-significant increase and unclear effect on accidents, respectively. In addition to the association between hearing loss and crash involvement, a recent study by Dultz et al. [73] found that hearing impairment can be associated with higher injury severity.

3.2.3 Age-Related Medication

In addition and combination with the previous section on age-related diseases, it was found that the observed increased accident risk can be caused by medications that are being prescribed to the elderly for treating various medical conditions [15], [68]. Additionally, another study proved the existence of medical conditions and medications amongst the elderly is highly associated with the risk of accidents [69]. More specifically, Vaa [68] estimated the accident risk of medical influence and it was found to be equal to 1.58 and at a 95% confidence interval ranging from 1.45 to 1.73. Meaning that drivers who are being prescribed medication presented a 58% increase in accident risk compared to non-medical road users.

3.3 Truck Drivers

The main two characteristics that truck drivers differ from regular commuters are i) devoting a great amount of their day driving, and covering longer distances [74] ii) the type of vehicle. Therefore, the dedicated category of drivers with their heavy-weighted vehicles should be examined separately in terms of assessment since truck drivers have different needs and performances compared to regular commuters.

3.3.1 Driver-related Factors

Age & Driving Experience: A significant predictor of being principally responsible for an accident was if the driver was young [24], [75]. Another research by Maycock [76] found that the accident frequency was highest for the youngest group of 17–29 years and the accident frequency decreased to less than one-third of this for drivers over 55 years of age; this result was considered to be combined effects of both age and driving experience. This finding is consistent with literature among daily commuters, young drivers were more prone to get involved in accidents than other ages [77], [78]. Also, by analyzing young driver accidents presented different features to those of other age groups drivers; young drivers were involved in single-vehicle accidents involving loss of control, due to excess of the speed limit, more accidents during the night-time (darkness), on single-lane rural roads and while making cross-flow turns [77].

3.3.2 Work-related Conditions

Fatigue, Working Hours, Sleep Duration, Sleep Disorders, Nighttime Driving, Obesity: With regards to the truck drivers, when they drove six or more hours prior to their crash, were more prone to get involved in crashes than those with fewer hours [79]. Furthermore, another finding is that 4% of the drivers had been tired prior to the accident [80]. Another study investigated the causes of fatigue and are namely; driving the day, duration of wakefulness, inadequate sleep, sleep disorders, and prolonged work hours [81]. Also, obesity is considered to be a fatigue-related accident factor [82]. Thus, daytime driving, sleep duration, sleep disorders, and working hours can cause fatigue and subsequently probably an increased accident risk.

Distraction/ Inattention: Literature study analyzed critical naturalistic incidents with long-haul truck drivers and the results showed that the frequency and duration of a task were found to contribute to critical incidents occurrence. Also, it was clear that visually demanding tasks have the highest degree of risk compared to other categories. [83].

Heavy Vehicle Configuration (Single Or Double Type Of Trailer): Double trailer vehicles showed involvement in accidents that increased steadily as the number of driving hours increased [79]. In this context, double trailer driving had an injury risk ratio of 1.32 compared to the single-trailer configuration [84]

Company's Safety Policy: In addition, another study indicated that the truck company by developing a safety policy culture was a countermeasure for fatigue-inducing factors associated with heavy vehicle driving work [85]. A safety policy for a company is, for example, the assistance with the activities of loading and unloading which are highly correlated with fatigue. Another finding associated with the company’s policy was that the safety performance of certified carriers was significantly better after certification than before, and it also was significantly better than non-certified carriers [86].

3.3.3 Driving Conditions

Road Type: Moreover, urban areas have higher traffic densities, and at the same time lower operating speeds and lower speeds contribute to a lower probability of injury or death given an accident with regards to trucks [80].

3.4 Office Worker Drivers

Existing literature has not investigated the futuristic mobility need of a working driver since it is impossible to work while driving with current automation levels. However, this is expected to be a future mobility need since the higher levels of automation make it feasible for the drivers to interact with non-driving-related tasks (NDRT), i.e., laptops, vehicle displays, smartphones, or even sleeping [87]. Hence, this gap is a sub-motivation to further investigate and support this type of driver by investigating potential risk factors. The included factors for office workers derived mainly from assumptions depending on their special needs. These factors will be justified based on the existing knowledge derived from literature coming mainly from automated and manual driving. Probably, the factors that will be related mostly to office worker drivers are the following.

3.4.1 Working-related Conditions

Distraction & Inattention: Especially, at the intermediate SAE automation levels (i.e., SAE levels 2, 3) prior to the highly automated, the driving task will still require human inputs and interventions such as Take Over Request (TORs) maneuvers. However, the drivers could be more probable to be distracted and inattentive during the TORs. This is due to the fact that AD will give the ability to the drivers to be involved with NDRTs and since they are office workers; they could probably be busy with office-based liabilities. Therefore, the drivers would look at their laptop, smartphone, or tablet and think about their open-topics and liabilities. Naujoks et al. [87] classified various NDRTs concerning their impact on driver performance in takeover scenarios and concludes that this is a fundamental contribution toward the creation of safe AD functions. Research showed that in-vehicle tasks during manual driving; hands-free mobile phone conversation and interaction with entertainment/information system, decreased several variables concerning driving performance and these results were quite stable to all different driver age groups and environmental difficulties [39], [40]. Another study modeled the reaction time and the results showed that reaction time was increased during the distraction tasks [88]. Consequently, taking into account the increased reaction time due to the distraction, accident probability was increased during distraction [89].

Stress: Emotion of stress probably will be a risk factor for office workers as they will be worried about their open topic and liabilities. Probably, at intermediate AD levels, office worker drivers will experience more stress which will be external from driving tasks and this requires further research. Based on the existing literature, emotions, in general, significantly impact driving performance and accident probability were impatience, aggressiveness, boredom, and stress [90]–[93].

Fatigue: Fatigue or drowsiness, as stated and analyzed previously, will be more probable for office workers to be more fatigued than other commuters as they will have to return home after a working day. Fatigued-driving after a long working day may increase the accident risk of all drivers or even fall asleep. Fatigue can be a major concern for the drivers' safety as it can predict more road accidents [94], [95]. With regards to TORs, fatigued drivers could cause a serious hazard in take-over situations where situation awareness is required to prepare for threats [96]

3.4.2 Driver Behaviour

Speeding: Office workers will be more probable to exceed the speed limit in order to reach on time at their destination, even with an AV when automation will not be available. A study by Hauer [97] indicates that undeniably if speed increases while other conditions (vehicles, roads, medical services) remain unchanged, accidents will be more severe. Hence, a change in mean speed can predict the potential change in injuries and fatalities.

Risk-Taking: Also, risk-taking behaviour should be considered and investigated with regards to office workers drivers as they are probably involved in such harsh events in order to reach on time at their destination. This risk-taking behaviour is highly correlated with speeding and maintaining shorter headway distances. Literature findings revealed that poor driving namely, driver behaviour and risk-taking indicated a higher probability for a road accident occurrence [94].

4. Discussion

This work structured a review of risk factors that impact road safety and driving performance focusing more on three types of users, namely elderly drivers, truck operators, and office workers (i.e., working and driving simultaneously; feasible at higher levels of automation). In Table 2, the obtained risk factors from this review were gathered and the review follows in Sections 3.2-3.4. Also, this review followed a specific categorization of the obtained factors. The risk factors were categorized into dedicated categories which are illustrated in Figure 2.

At the intermediate SAE automation levels (i.e., SAE levels 2, 3) prior to the highly automated (i.e., SAE levels 4, 5), the driving task will still require human inputs and interventions [22]. At these two AD levels, apart from the TORs, there will be sections within the commuting routes that AD will not be available and the drivers will be required to drive manually. Therefore, within these manual driving parts, the reviewed risk factors will be present and probably AVs manufacturers could focus on eliminating or mitigating these risk factors with technology aid. However, AVs manufacturers should concentrate on elderly drivers more since AD will be more attractive for them if the majority of the route will be self-driven. Nevertheless, special focus should be given on TORs (transition from automated to manual driving) which will be a new task for AV users and connects automated with manual driving and should be investigated more profoundly in terms of risk factors since human factors will still be present during TORs.

More specifically during TORs, all the risk factors will still be present. However, their impact on accident risk and driving performance will redistribute, and hence further research is needed on how the obtained risk factors will impact accident risk and driving performance during TORs. Special focus and further investigation should be implemented for the following risk factors during TORs regardless of the use cases of the driver:

- **Distraction**: the drivers will be more probable to be distracted and inattentive during the TORs. This is due to the fact that AVs would permit the driver to be distracted with NDRTs when AD is enabled. Hence, the drivers would look at their laptop, smartphone, or tablet prior to TORs and not outside the driving environment [87].
- **Inattention**: for the same reason as the distraction, drivers will be more prone to be distracted and inattentive during the TORs by thinking about open topics and liabilities.
- **Stress**: Emotion of stress probably will be a risk factor for all use cases since will experience stress which will be external from driving tasks and this requires further research. Based on the existing literature, emotions, in general, significantly impact driving performance and accident probability [90]–[93].
- **Fatigue**: Fatigue will be a critical risk factor for the drivers. The driver could be fatigued or even fall asleep during AD, as AVs will give the ability to the users to fall asleep when operating in AD since they will be not engaged with the driving task. As stated previously, fatigue can be a major concern for the drivers' safety as it can predict more road accidents [94], [95].
- **Driving Experience**: Driving experience will be a determinant factor for the whole performance of the TOR maneuver, especially in urgent requests. Also, driving experience will be a determinant factor if the driver checked all necessary information in the driving environment before taking over control, and for the time of perception or reaction.

At SAE levels 4 and 5, there are no human interventions and hence the obtained risk factors do not exist. Therefore, human factor which is responsible for 65-95% of accidents [6], [7] will be reduced and to an extent eliminated when designing autonomous driving concepts. An ideal hypothesis for AD would be that by removing human from the task of driving, the elimination of accident risk will be accomplished [9], [10]. Though, a more realistic assumption is that human error will be replaced by accidents caused by imperfect automated systems [11]. Therefore, with regards to the current study, another type of analysis (e.g., AD mechanical failure) is needed when these levels will become available in order to estimate accident risk.

AV manufacturers could focus on reducing or even eliminating these risk factors with technology aid such as driver monitoring, or a system that intervenes with driving corrections, especially for AD up to SAE level 3. Human factor should be in the research spotlight even at AD levels 2 and 3 in order to mitigate and reduce its contribution to road accident fatalities. To that end, safer AD systems could be accomplished by reducing or maybe ideally eliminating the human factor since is responsible for up to 94% of road accidents [6]. Especially at the stage when automation will be introduced more dynamically into the traffic mix, it is an opportunity to reduce risk factors related to automated driving in order to accomplish higher AV market penetration rates. Furthermore, AVs manufacturers should also concentrate more on elderly drivers due to the fact that driving will be more attractive for them, as stated previously. In addition, different driving profiles should be investigated and treated differently in order to accomplish safer AD systems. This is consistent with the literature and the key principle of FERSI [11] which suggested a "Human-Centred Design", and in which all possible user profiles should be considered when designing Autonomous Vehicles (AVs).

Nevertheless, this study is not without shortcomings, and therefore, future research could focus on covering the remaining gaps that this work did not cover. The study limitations can be considered the following: First of all, there are more studies in the existing literature that were not exploited by this review paper with regards to the aforementioned factors. Furthermore, probably there are additional risk factors or even categories that should be considered and were not included in the present review. The aforementioned shortcoming can be covered with further research in a future study. Besides, in this future study, a more detailed connection between risk factors and AD can be developed and analyzed as there is no existing work in this direction. Hence, in this review, risk factors were not justified thoroughly how they can be mitigated at intermediate AD levels (SAE level 2 or 3) in which the human factors will still be apparent or even at higher AD levels in which system errors will replace the human factor. These specific points are left to further research. In addition, a notable limitation, which was mentioned at the beginning of this paper, there is not a direct connection between risk factors and accident probability because it is almost impossible to investigate if these specific risk factors are directly correlated with the recorded accident data. Nevertheless, in this review, it was assumed based on literature that many risk factors affect driving behaviour and performance and consequently the risk probability.

Some further research proposals were given along with study limitations as this work has shortcomings which future research could focus on covering these remaining gaps. Also, this work gives future research directions as it is a literature review. In general, literature reviews report and review the existing literature. Researchers can easily find by exploiting a literature review which are the literature gaps, namely "what is missing from the literature and what is still pending to be investigated". Researchers could also find easily similar studies of their interest, and focus on what directives the authors of the review draw for future research. Following this logic in this work, researchers can easily find throughout the study missing parts of literature and directives for their future research. For instance, some insufficiently investigated significant risk factors regarding the elderly drivers were e.g., distraction, inattention, and cognitive functions. With regards to the truck driver, further research is proposed for the following risk factors: working hours, sleep duration, and distraction/ inattention. Office worker drivers are a future mobility need and thorough and holistic research is required for all the aforementioned risk factors. Overall, it can be observed a total lack of direct correlation between risk factors with accident risk or reported road accidents. Finally, the reviewed risk factors could guide stakeholders in accomplishing a safer transition from manual to autonomous driving for all road users.

5. Conclusions

This study tried to identify and review risk factors that impact road safety and driving performance focusing more on three types of users, namely elderly drivers, truck operators, and office workers (i.e., working and driving simultaneously; feasible at higher levels of automation). This review attempted to highlight the reviewed risk factors that should be considered in future safety analyses. In Table 2, the obtained risk factors from this review were gathered and the review follows in Sections 3.2-3.4. The risk factors were categorized into dedicated categories which are illustrated in Figure 2. Then, the reviewed risk factors are discussed on how they can be extended and adapted at the different future AD levels and what risk factors should be considered into future safety analysis in regards to the AD level. The aforementioned review will be exploited by the HADRIAN project, like any other HMI stakeholder, in order to develop a human-centered assessment methodology that will evaluate the way the human interacts with potential HMI configurations. Overall, it can be observed a total lack of direct correlation between risk factors with accident risk or reported road accidents. In this work, researchers can easily find throughout the study missing parts of literature and directives for their future research. Also, this study was not without shortcomings, and therefore future research proposals were given and by this researchers could focus on covering the remaining gaps that this work did not cover. Finally, the reviewed risk factors could guide stakeholders in accomplishing a safer transition to autonomous and manual driving for all road users.

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