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ANALYSING THE ROLE OF DRIVER BEHAVIORS IN ROAD TRAFFIC ACCIDENTS: AN APPLICATION OF MACHINE LEARNING

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ABSTRACT

Continuous innovations are taking place worldwide to develop solutions for problems encountered by human beings. The prevention of a variety of accidents due to burning, drowning, terrorism,

electric shocks, and road traffic is among the important concerns of researchers and solution developers. Specifically, this current study aims to analyse the contributions of different driver behaviours that resulted in road accidents, followed by proposing a viable solution and reducing the road accident frequencies to benefit society at large. This study employed two methods to analyse data. One was through SEM, and the second was through Artificial Neural Network (ANN). The study is descriptive in nature and it used the survey method to collect sample data from 345 drivers from various professional backgrounds. The questionnaire consisted of independent variables, namely slips, errors, mistakes, lapse violations and unintentional violations. To measure the contributions of these variables towards accidents, age was taken as the moderator. The statistical techniques used included reliability, correlation, and normality analyses, in addition to artificial neural networks and regression analyses. Each factor was found to be a significant contributor to road accidents. Moreover, no significant difference was found in drivers' behaviour between males and females, but age was found to have a moderating effect on the relationship between driver behaviours and accidents. Additionally, the rate of accidents decreases with the increases in age and vice versa.

Keywords: Artificial neural networks, driving behaviour, drowsy driving, road accidents, errors, mistakes, slips, violations.

INTRODUCTION

The widespread argument is that safe movement is the basic right of humans (Broughton et al., 2009). Due to the increase in development and globalisation, safe movement on the road has become a major problem across the globe. Failure to maintain safe movement on the road leads to accidents that cause injuries to humans, impairments, and deaths as well (Bahadorimonfared et al., 2013; Ameratunga et al., 2006). Every year, motor vehicle incidents result in about 1.3 million deaths and a lot number of injuries throughout the world (World Health Organization [WHO], 2015). It also has a detrimental impact on people's health and well-being of person and family. According to WHO (2020) report, road accidents are ranked ninth among other various causes of fatalities and could be up to seventh by 2030. Most

importantly, 90% of the deaths occurred in low and middle-income countries (Zhang et al., 2013).

The number of vehicles in the United Kingdom (UK) is 18 times higher than in Pakistan. However, the death rate because of road accidents in Pakistan is 14.2 per million as compared to the United Kingdom, which is only 3.1 million. These statistics are alarming and probe researchers to research more and find out the root cause to overcome this fatal problem. Pakistan has been reported amongst the highest accidents and fatalities rates around the world with 7000 to 10,000 people die every year (Adnan et al., 2013). However, the investigation of the impacts of these injuries remains neglected in Pakistan. According to the report, road accidents will become the main cause of death in Pakistan by 2030. Deadly road accidents have become very common in Pakistan, partly due to drivers who have turned a blind eye to safety standards and traffic laws. This issue is so serious that Pakistan earned the reputation of being the country that has the worst road accidents in Asia and is 48th in the world ranking.

As per the statistics gathered over a decade, around 97,500 fatal accidents took place, and at least 51,400 people of all ages died, thus declaring Pakistan as a country having the highest death rate due to traffic accidents (Pakistan Bureau of Statistics, 2021). The basic reason is the people of Pakistan do not have much awareness and do not consider the traffic rules worthwhile to learn (UKEssays, 2018). Even more serious is that younger drivers involve themselves in unnecessary races just for their thrill and leisure. Meanwhile, most of the drivers do not even have a valid driving license.

Furthermore, the past ten years' data revealed that across the country, 15 people died daily on average and 14000 a year, where the Sindh province was found to have the deadliest, followed by the Punjab, Baluchistan and Khyber Pakhtunkhwa (KPK) provinces, respectively (Ahmad Shah, 2017). For a successful reduction of these adverse outcomes, substantial interventions are required (WHO, 2015). In order to increase road safety, more information about the causes of road accidents that may be avoided is required.

Initially, a major source of information regarding road accidents is police records. These records are used to prepare policy and for

further research. For instance, police officers on the scene of a car accident must offer a subjective evaluation of the circumstances that they feel have led to an accident. As a result, police officers with first-hand experience writing on traffic incidents are more likely to have important insight into the factors of accidents. Their perspectives are more likely to be correct than those of the general public, who would rely more on stereotypical opinions. However, there are concerns raised by officials and researchers on the accuracy of police-reported factors of accidents. Sometimes official reports are not that accurate due to the fact that some elements are difficult to prove at the scene of an accident, and so may be underreported in accident reports. Those underreported elements that contribute to accidents might have some serious consequences.

On the other hand, researchers put some effort into finding out the factors that cause accidents. Farooq et al. (2020) highlighted human factors as the major cause behind road accident cases. The behaviour of individuals impacts performance (Afzal & Azmi, 2021), especially drivers' behaviour has greater impact on accidents compared to their driving skills (Evans, 1996). The behaviour of drivers that deviates from safe driving practices leads to abnormal driving. Driving behaviour is the action of the drivers, which they choose to construct their driving pattern that includes but is not limited to the driving speed, focus, and maintaining a standard distance from cars, etc. Slips, intentional and unintentional violations, driving errors or mistakes are the four primary types of driving behaviours (Akbari et al., 2006; Malin et al., 2019). Drivers acquire these behaviours on a regular basis, and they may alter them in the same way that other human health behaviours do. However, changing people's views of these behaviours, as well as the variables that influence them, is the first step.

Therefore, current research aims to investigate the main causes of road accidents and various driving behaviours that lead to road accidents, examine whether all driver behaviours unequally contribute towards the occurrence of accidents and suggest a viable solution to bring a considerable reduction in the occurrence of accidents. This research will benefit multiple stakeholders, including citizens of Pakistan, traffic police and drivers, by creating awareness of the main cause of the problem and by formulating strategies to control the expected damage.

Based on an extensive literature review, a research gap was identified between the problem management and technical aspects. Many researchers from different countries used the Manchester Driver Behavior questionnaire (Reason et al., 1990), but none have proposed any concrete solutions based on their survey results that can reduce road accidents. Similarly, in Pakistan, the researchers recorded the statistics of road accidents, total deaths, and injuries due to road accidents, but none of them observed the driver behaviours that contributed to the road accidents in Pakistan. On the other hand, many countries around the world surveyed the causes of road accidents, either through primary or secondary data and resolved the issue with some technical and viable solutions. However, this action is lagging in Pakistan because of the lack of awareness in drivers towards the actual causes of road traffic accidents. Similarly, the Manchester driver behaviour was never used for survey in Pakistan because researchers found it difficult to quantify the different driver behaviours that were used in the questionnaire, so this research not only surveyed the possible driver behaviours that cause road accidents but also proposes a viable solution to reduce the number.

After 2013, the transport and communication sectors have improved greatly, but the contributions towards the fatalities and causalities reduction are not realised enough for the national level (Gulzar et al., 2012). Moreover, in Pakistan, the researchers and analysts only collected road accident statistics but never proposed solutions to resolve the issue. In addition to the negligence towards road infrastructure and the insufficiency of the government quarters, most of the existing studies are based on secondary data to find out the casualties that occurred due to road traffic accidents instead of based on the primary data (Gulzar et al., 2012). Thus, very little empirical research is available on factors or causes contributing to road accidents (Rolison et al., 2018).

Current research is a small effort to determine the major factors that cause road accidents by examining driver behaviour empirically and suggesting a viable solution to bring a considerable accident reduction. Also, the main stakeholders, e.g., traffic police, public, policymakers, Rescue 1122, and the National Transportation Research Center (NTRC under the Ministry of Communication and Islamabad) were consulted as suggested by Kazmi and Zubair (2014) regarding the validity and solution of the research problem.

LITERATURE REVIEW

Driver Behaviour and Its Predictors

It is a set rule that no one is perfect. People commit different behaviours, errors and violations; most of these are unintended and without their will. However, in some cases, the mistakes are deliberate. These mistakes or errors, either intentional or unintentional, can be dangerous that cause fatal accidents. The extant literature has also discussed different behaviours of drivers that lead to traffic accidents. Each behaviour has its own importance; however, the current research has adopted the behaviours that are introduced in Driver Behavior Questionnaire (DBQ). The behaviours include slips, lapses, errors, mistakes, and unintentional violations and intentional violations. To understand the concepts well, each behaviour is explained with the example mentioned by Reason et al. (1990).

Slips refer to the loss of traction between a vehicle's tires and the road surface, which can lead to a loss of control and a potential road accident. The relationship between slips and road accidents is significant because slips can have serious consequences and contribute to a significant number of road accidents. Slips also refer to the missing or misreading of the signs of exit or entrance from a roundabout or on the highway, leading to the wrong road or direction. Activating the wipers or headlights when you intend to switch on other functions is also considered a slip.

There are several factors that can contribute to slips on the road, including weather conditions, road surface conditions, tire tread depth, and vehicle speed. For example, roads that are wet, icy, or covered in snow and ice can increase the risk of slips, as well as driving at high speeds or making sudden turns or braking (Qobulov & Abdurakhimov, 2021). Additionally, vehicles with worn tires or insufficient tire tread depth are more likely to slip on the road. Literature suggests that when a vehicle slips, the driver may lose control of the vehicle, which can result in a range of different types of road accidents, including skidding, sliding, or even rolling over. These accidents can have serious consequences, including property damage, injury, and death.

In essence, the relationship between slips and road accidents is significant because slips can contribute to a significant number of road

accidents and have serious consequences. Addressing this relationship through effective prevention strategies is crucial for improving road safety and reducing the incidence of road accidents. Thus, it is proposed that:

H_1: Slips are positively and significantly related to road accidents.

Lapses are the absence of mind that can be frustrating for others but might not be much dangerous but show the irresponsible behaviour of the driver. For example, the unclear recollection of the way the driver is travelling, taking a wrong exit, or an attempt to cross the traffic lights at a higher speed to avoid stoppage. Lapses also refer to momentary lapses in attention, concentration, or judgement that can occur while driving. These lapses can have a significant impact on road safety and can contribute to road accidents.

When a driver experiences a lapse, they may make a mistake while driving, such as failing to check their blind spot, missing a traffic sign, or failing to react quickly enough to a changing road situation (Szumska et al., 2020). These mistakes can lead to road accidents and can have serious consequences, including property damage, injury, and death. It is normally committed by new drivers. There are several other reasons that can increase the risk of lapses while driving, including fatigue, distraction, stress, and boredom. For example, drivers who are tired may experience lapses in attention, while drivers who are using their phones or engaging in other forms of distraction are also more likely to experience lapses while driving. Thus, the relationship between lapses and road accidents is hypothesised as significant because lapses can contribute to road accidents and have serious consequences. Therefore, it is posited that:

H_2: Lapses are positively and significantly related to road accidents.

Errors are misjudgements or other failures in the observation that are fatal to others. For example, not setting the mirrors properly or not watching the zebra crossing or pedestrian. Research suggests that most accidents are due to errors committed by drivers. Errors refer to actions or decisions made by drivers that deviate from safe and responsible driving practices. These errors can have a significant impact on road safety and can contribute to road accidents.

According to Reason et al. (1990), errors are one of the behaviours that lead to road accidents. It is due to the misjudgement of conditions, for example, a sudden brake on a smooth surface, a speedy overtake, or suddenly changing the lane. The other different types of errors that drivers can make include failing to signal a turn, speeding, following too closely, running red lights, and driving under the influence of drugs or alcohol. These errors can be the result of various factors, such as inexperience, distraction, fatigue, or reckless behaviour. When a driver makes an error, it can lead to a fatal accident and cause severe injuries.

In Third World countries, road accidents are one of the main causes of deaths and injuries. Meanwhile, drivers' mistakes are the main cause of road accidents. The driver of public transport needs appropriate skills to drive safely. A study was performed to find the main elements affecting the driving errors of taxi drivers. The analyses showed that errors are the major contributor, with mistakes among the top contributing factors of accidents (Gupta et al., 2017; Murray & Lopez, 1997). While understanding the phenomenon of accidents in a study conducted by Awad et al. (2019), the researcher found that most of the accident cases are due to the mistakes committed by the drivers. There is a significant body of research in the field of traffic safety that supports this hypothesis. For instance, a study by the National Highway Traffic Safety Administration found that 94 percent of car accidents are caused by driver mistakes. It is due to the lack of driver education, awareness, and training, which requires further research and action. Hence, the following proposition can be made:

H_3: Errors are positively and significantly related to road accidents.

H_4: Mistakes are positively and significantly related to road accidents.

Unintended violations include driving illegally by missing or forgetting the submission date of road taxes and insurance or unknowingly crossing the speed limit, and not looking at the speedometer. Moreover, deliberate violations are the involvement of the driver in an unofficial race or overtaking the vehicle from the wrong lane impatiently. It is an intentional attempt to violate the regulations or socially accepted behaviours like the close distance between two vehicles (Zhao, 2012). In the context of driving behaviour, there are few studies available, but the factors are scattered in the literature. For instance, a study

conducted in Iran by Mardani and Pirzadeh (2018) on the evaluation of driving behaviour has found violations are the top contributing factors, followed by driving slips and driving mistakes. In comparison, unintentional violations are the least contributor to road accidents. The same results appeared in the study by Kalhori et al. (2017), who found intentional violations and driving slips among the top factors for accidents. The highest incidents of driving slips were related to paying little attention to the front car and paying attention to traffic in the opposite direction. But for intentional violations, the study found that aversion to drivers was associated with animosity toward those drivers.

Consistent with that, Tavakoli et al. (2016) found 72 percent of incidents are related to intentional violations. People make mistakes that can be avoided with small extra effort. However, unfortunately, low awareness and irresponsible behaviour cause fatal errors for them. Another important and impactful factor to study in a driver's behaviour context is driving mistakes. Most drivers make mistakes of over-speed driving at night in suburban areas with the car headlights turned off. Some of them make mistakes of miscalculating the distance between passing cars on the left side, which results in risky situations (Pourmirza Kalhori et al., 2014). Thus, the researcher proposed that:

H_5: Violations are positively and significantly related to road accidents.

H_6: Unintentional violations are positively and significantly related to road accidents.

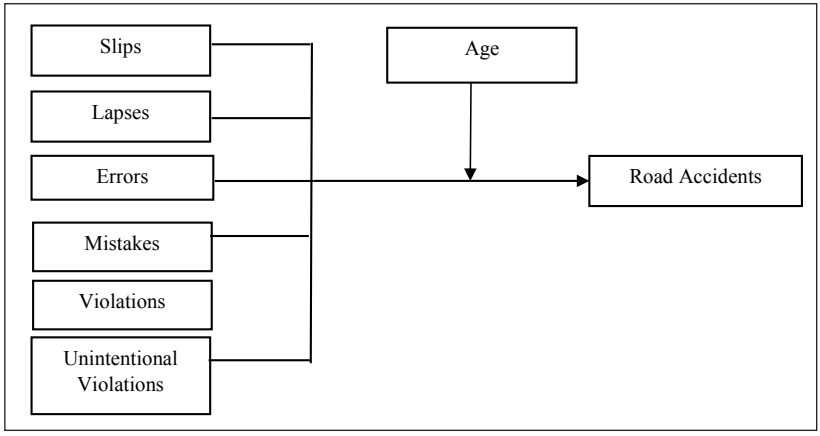
The Moderating Role of Age

Besides that, age significantly contributes to road accidents. As older drivers may have slower reflexes and reaction times, younger drivers may have better reaction times. As people age, their physical and cognitive abilities may decline, which can affect their driving skills. Older drivers may have difficulties with vision, hearing, and cognitive processing, which can impact their ability to react to unexpected situations on the road. Furthermore, older drivers tend to have slower reaction times, making it harder for them to respond to sudden changes in traffic or unexpected obstacles (Trimpop & Kirkcaldy, 1997). These factors can increase the likelihood of older drivers being involved in road accidents.

On the other hand, younger drivers may have less experience on the road and tend to take more risks while driving. Inexperienced drivers may underestimate the risks of certain situations and overestimate their own abilities, leading to overconfidence and reckless driving behaviour. Additionally, younger drivers may be more likely to engage in distracted driving behaviours, such as using their phones while driving, which can increase the likelihood of accidents. These factors make younger drivers more vulnerable to being involved in road accidents.

Figure 1

Conceptual Framework of Study



Overall, the hypothesis that age significantly contributes to road accidents is supported by the evidence that older drivers are more likely to be involved in accidents compared to drivers in their prime age (Hosseinian & Gilani, 2020). Understanding the relationship between age and road accidents can help in developing policies and interventions to improve road safety for old age groups. Generally, age, a demographic variable, was used as a moderator while assessing human behaviour; hence the following hypothesis was developed.

H_7: There is a significant moderating role of age in the relationship between factors (slips, lapses, errors, mistakes, violations, and unintentional violations) and road accidents.

The pictorial view of hypotheses is presented in the research framework as depicted in Figure 1. The different behaviours, including Slips,

Lapses, Errors, Mistakes, Violations, and Unintentional Violations, are independent variables. Whereas the Road Accident is a dependent variable. Age, a demographic variable, acts as a moderator between the hypotheses.

RESEARCH METHODOLOGY

The study aims to analyse various factors related to drivers' reckless behaviours that contribute to road accidents so that a viable solution can be proposed to reduce the frequency of accidents. Two statistical techniques, Structural Equation Modeling (SEM) and Machine Learning (ANN) were applied to answer the research questions in a comprehensive way. This research followed the epistemology paradigm using the descriptive approach and is cross-sectional. The quantitative research paradigms were followed and targeted the drivers' population, which consisted of students, doctors, businesspeople, project managers, bankers, account managers, aircraft engineers, consultants, engineers, housewives, educationists, and IT professionals. The population consisted of drivers that were registered with National Highways and Motorway Police (NHMP). Further, the target population was chosen based on twin cities (Islamabad and Rawalpindi). These cities are well-populated and have the largest number of registered drivers. A simple random sampling technique was used to collect the sample from the target population. This method is non-biased, with the same probability for each driver to be selected. Later, for the hypothesis testing and analysis, the primary data were collected by distributing a driver behaviour questionnaire (Reason et al., 1990).

A total of 650 questionnaires were distributed to the drivers and 510 questionnaires were returned. However, only 345 were useable for data analysis and interpretation. The theoretical model of this study consisted of three sets of variables, e.g., the dependent, moderators and independent variables. A five-point Likert scale ranging from "Never" to "Nearly all the time" was employed. The questionnaire consisted of two parts; the first part contained questions related to demographic questions like gender, age, education, driving experience and occupation, whereas the second part consisted of questions related to both the independent and dependent variables containing the items adapted from Manchester Driver Behavior Questionnaire (Khoso et

al., 2011). The same questionnaire was used by other researchers, including Sucha et al. (2014) and Tavakoli et al. (2016).

The variables were operationalised as per the literature. For examples, the (1) slips variable is defined as "slips are parapraxis which is defined as the error that results from unconscious attitudes", the (2) errors variable is defined as "errors are thoughts that arise from subconscious attitude and resulting into negligence and overlooking behavior. It is a systematic deviation and cannot be corrected", the (3) lapses variable is defined as "mistakes resulting from inattention. Lapses are the human action that responds to something, and this response can enter a process as an additional step or a misstep", the (4) mistakes variable is defined as "deviation from normal expected behavior due to misunderstanding and misjudgment. A mistake is easily corrected once it is realised with or without being pointed by others", the (5) violations variable is defined as "an act of doing something intentionally that is not allowed by law or rule", and finally the (6) unintentional violations variable is defined as "an act of doing something unintentionally that is not allowed by law or rule" (Reason et al., 1990). The questionnaires were circulated by using a Google form link and personal meetings. The soft form of online questionnaires was distributed through Google Scholar and SurveyMonkey. Then, the collected data were exported to SPSS for analysis.

Descriptive statistics were applied to the data to provide a general overview of sample characteristics and the various patterns. The correlation matrix was used to examine the association between the variables. The regression analysis was used to study the levels of different driver behaviours that cause road accidents. To identify the relationship between driver behaviours and road accidents, the model for regression analysis was elaborated as follows:

$$Yi = A + B1x1i + B2x2i + B3x3i + B4x4i + B5x5i + B6x6i + \mu i$$

Where:
Yi = Road Accidents
X1i = Slips
X2i = Errors
X3i = Mistakes
X4i = Lapses
X5i = Violations
X6i = Unintentional Violations
A = Constant

RESULTS

Reliability Analysis

The Cronbach's alpha coefficient values were calculated to analyse the reliability of collected data, as the coefficient is widely used for checking the reliability and validity of the questionnaire (Parasuraman & Colby, 2015). It was evident from the values presented in (Table 1) that the reliability coefficient values were around 90 percent and above, thus were highly significant and not balanced dimensionally.

Table 1

Reliability

Variables	Cronbach's Alpha	No. of Items
Slips	0.922	10
Violations	0.914	14
Mistakes	0.894	08
UV	0.910	03
Lapses	0.899	07
Errors	0.899	11
Overall	**0.921**	**53**

Demographic Information

There were 222 male respondents and 122 female respondents. The five demographic variables included age, gender, education, driving experience and occupation. It can be witnessed that the majority of the accidents happened to people in the age range of 25 to 31, whereas people with ages above 53 years commit fewer road accidents. Approximately 58.8 percent of the respondents from the total population hold an MS degree, while 46.7 percent of the respondents were students who drive. Moreover, the drivers with one year of driving experience had a frequency of 14.2 percent and were more responsive to the survey.

Descriptive Analysis

Almost all the variables had mean values above 1.5, and the lapses were more negatively skewed, while the mistakes were least negatively

skewed. The findings showed that among all the factors compared, the lapses factors are the highest contributors to the occurrence of road accidents. The minimum value was zero and showed that the minimal sample was measured with the smallest measurement. Meanwhile, the maximum value was 4.38 and showed that the maximum sample was with the highest measurement. As per the defined standards, the skewness and kurtosis values lie between +3 and -3. Accordingly, all the values (as shown in Table 2) were found within the defined range and as per the standards, but the lapses were more negatively peaked, while the mistakes were less negatively peaked and more positively skewed, followed by the violations that were found to be less positively skewed.

Table 2

Descriptive Statistics

Variables	Mean	SD	Skewness	Kurtosis
Slips	1.351	0.661	0.287	-0.742
Violations	1.907	0.913	0.070	-0.624
Mistakes	1.564	0.922	0.354	-0.376
UV	1.561	0.941	0.300	-0.498
Lapses	1.6435	0.929	0.214	-0.746
Errors	1.506	0.942	0.136	-0.718

Correlation Analysis

The results from the correlation analysis are given in (Appendix A). The results depict significantly strong relationships among all the driver behaviours. When the relationship of these driving behaviours was checked with the road accidents variable, the violations were found to be significantly correlated, with the recorded value of 0.434**. On the other hand, the errors were less contributing to the occurrences of road accidents, with a recorded value of 0.183**. In the correlation analysis with the age variable acting as a moderator, all the values were highly significant but negatively affected all the study variables. These findings indicated that an increase in age leads to a decrease in various factors behind the occurrences of overall road accidents.

Regression Analysis

The linear regression analysis on the dependent variable was performed to determine the impacts of independent variables on the dependent variable. As per the standard, the R Square value should be more than 10 percent, with a significant level higher than 95 percent. The results demonstrated that the complete model was significant, while the impacts of driver behaviours were 0.308 on road accidents (Appendix B). After testing the individual effects of each driver behaviour factor on road accidents, it was found that the violations variable was the main contributor towards road accidents, as its total effect was 18.8 percent and was significantly higher. Meanwhile, slips were the less contributing variable to road accidents and provided 11.9 percent of road accidents. The moderating effects of age were also tested and proven through the regression analysis. It was found that younger people are conducting more violations. The first model indicated the direct effects of all the factors (e.g., slips, lapses, errors, mistakes, violations, and unintentional violations) and accidents, while the second model indicated the indirect effects. The results indicated that both models proved that all the factors (e.g., slips, lapses, errors, mistakes, violations, and unintentional violations) had an unequal degree of contribution to the incidence of road accidents, with the age factor moderating the contributions. So, H_2 and H_3 were supported. The study also investigated the moderating role of age over the relationships between all the violation factors and road accidents after determining the factors' contributions towards the accidents incidences.

The moderating role of the age factor was supported, as the analysis proved that the increase in drivers' age weakens the contributions of slips, errors, violations, unintentional violations, mistakes, and lapses towards the incidence of road accidents. Additionally, the casual roles of these factors were strengthened in the younger age bracket, i.e., lesser age, as shown in the next tables.

Artificial Neural Network

The second phase of analysis was carried out by using the artificial neural network approach. The significant predictors were utilised as inputs into the ANN. The relationships between the predictor variables

and the adoption decision variable were examined with ANN (Leong et al., 2015; Leong et al., 2013). A multilayer perception method, the most common and popular technique in ANN (Zabukovšek et al., 2019; Liébana-Cabanillas et al., 2017), was adopted in this research. The ANN is comprised of three layers (Ooi & Tan, 2016), e.g., an input layer, a hidden layer and the output layer, as shown in (Appendix C). The recommendations given by Leong et al. (2015) were followed, and the long-hidden neurons were automatically (Zabukovšek et al., 2019) generated with an activation function through the utilisation of both the hidden and output layers (Liébana-Cabanillas et al., 2017).

The case processing summary, as tabulated in Table 3, showed that the total sample size was 345, but at the time of running the ANN analysis as per the best practices, the sample size of training data was 70 percent of the total dataset, while 30 percent of the total data were used for training purposes. In conclusion, 236 samples were for training purposes, and 109 samples were for testing.

Table 3

Case Processing Summary

		N	Percent
Sample	Training	236	68.4%
	Testing	109	31.6%
Valid		345	100.0%
Excluded		0	
Total		345	

The ANN network model of this research had three layers. The leftmost layer was the input layer, the middle layer was the hidden layer, and finally, the rightmost layer was the output layer. There were two coloured vertices (blue and grey) known as the synaptic weights. The synaptic weights represent the coefficients estimates and show the relationship between the units in a particular layer. The weights also show the strength and aptitude of the connection between nodes (variables). Gray represents the synaptic weight with a value greater than 0 and was used for training purposes. Blue represents the synaptic weight with a value of less than 0 and was used for testing purposes. The darker the vertices, the stronger the

relationship between the nodes. The results revealed that errors and accidents had a stronger relationship, while unintentional violations had the weakest relationship with accidents. In conclusion, most of the accidents occurred due to errors caused by drivers.

Table 4

Model Summary

Training	Sum of Squares Error	45.968
	Relative Error	0.390
	Stopping Rule Used	1 consecutive step(s) with no decrease in error[a]
	Training Time	0:00:00.07
Testing	Sum of Squares Error	21.256
	Relative Error	0.240

Dependent Variable: Accidents

a. Error computations are based on the testing sample.

According to the model summary given in Table 4, during the training phase, the sum of square errors was 45.968, and the relative error was 0.390. The values showed that there was very little margin of error in the model. In contrast, the sum of squares error in the testing phase was reduced to 21.256, while the relative error was reduced to 0.240, meaning that the model authenticity increased during the testing phase. Additionally, Table 5 presents the independent variable importance, which explains which variable is more important.

Table 5

Independent Variable Importance

	Importance	Normalised Importance
Slips	0.128	33.6%
Violations	0.223	58.6%
Mistakes	0.189	49.4%
UV	0.011	2.9%
Lapses	0.067	17.6%
Errors	0.382	100.0%

Artificial Neural Network with Moderation

Age was incorporated as a control variable in the model to test its moderating role in driver behaviours and road accidents. The age variable was multiplied with every independent variable to form new independent variables but with the same dependent variable to analyse the moderation effects. The results from the case summary are shown in Table 6 and as mentioned in the original model.

Table 6

Case Processing Summary with Moderation

		N	Percent
Sample	Training	236	68.4%
	Testing	109	31.6%
Valid		345	100.0%
Excluded		0	
Total		345	

The network information in (Appendix D) is also the same as the original model (Appendix C). In the network model, after adding age as a moderator with the independent variable, the ageXlapse variable was shown to have more impact on accidents. Meanwhile, the ageXslips variable had the least impact on accidents, proving that younger drivers contribute to greater lapses made while driving.

Table 7

Model Summary with Moderation

Training	Sum of Squares Error	53.583
	Relative Error	0.441
	Stopping Rule Used	1 consecutive step(s) with no decrease in error[a]
	Training Time	0:00:00.07
Testing	Sum of Squares Error	17.977
	Relative Error	0.360
Dependent Variable: Accidents		

a. Error computations are based on the testing sample.

According to the model summary given in Table 7, the sum of square errors during the training phase was 53.583, and the relative error was 0.441, showing that the margin of error in this model was greater than the original model. In contrast, the sum of squares error in the testing phase was reduced to 17.977, while the relative error was reduced to 0.360, showing that the model authenticity increased during the testing phase (Table 9).

Parameter estimates depict the connection estimates between the variables. The cumulative independent variable importance value is equal to 1. ageXlapse has more importance in the model, having a value of 0.339 with 100 percent normalised importance. ageXslips is the least important in the model, having an importance value of 0.080 with 23.7 percent normalised importance (Table 8).

Table 8

Independent Variable Importance of Moderation

	Importance	Normalised Importance
ageXslips	0.080	23.7%
ageXviolations	0.283	83.4%
ageXmistakes	0.091	26.9%
ageXUV	0.082	24.3%
ageXlapses	0.339	100.0%
ageXerrors	0.123	36.3%

DISCUSSIONS

This study aimed to explore the different driving behaviours that contribute to road accidents and propose a solution for reducing accidents and collisions. The Manchester Driver Behaviour Questionnaire was adopted for this purpose, and the primary data were gathered from various drivers belonging to different working life sectors. Meanwhile, the questionnaires were distributed among the sample population. The correlation analysis results were highly significant, proving that all the factors supporting the drivers' behaviours were correlated consistently with the study of Strawderman et al. (2015).

Additionally, a driver committing one mistake was found to be prone to commit other types of mistakes as well. It can be concluded from the regression analysis that among all the driver behaviour factors, the violations variable was found to be the major and the most frequent reason behind road accidents, whereas the errors variable was found to be the least contributor to road accidents, from the collisions between the vehicles or between the vehicles and human. Age significantly moderated the relationship between the errors and accident variables, concluding that an increase in age increases the driving experience, leading to a reduction in the road accident frequencies. All the six-driver behaviour factors were found to be significant contributors to road accidents. Hence, this research supports the hypothesis that all driving behaviours contribute to the occurrences of road accidents in Pakistan, similar to the study by Strawderman et al. (2015). Furthermore, age is a major contributor to increasing or decreasing road accidents because road accidents were proven to increase in drivers between the age group of 25 to 31, whereas the accidents were proven to decrease for drivers in the age group of 55 years and above but increase again at the early 70's age group. The people in younger age groups are mentally active and emotional; thus, they may drive rashly and commit more accidents. But with the passage of time and usage increases, the chances of accidents decrease because people are getting mentally relaxed and less emotional.

This study further extended the new technology acceptance-based research with the ANN approach. The strength of each predictor from input to output was ranked by using the ANN sensitivity analysis to elaborate on the results. The findings from the ANN model generally verified the hypotheses of this research. However, there were some minimal variances due to the higher prediction accuracy and nonlinear nature of the ANN model. The analysis provided better in-depth results (Rajaee et al., 2009) regarding the relative importance of these input factors, thus representing useful information based on the new technology used. The analysis showed that most of the accidents occurred due to errors as the considering variable. When the age variable was included as the control variable, the ANN results showed that most of the accidents occurred due to the ageXlapse factor. Therefore, the less the age, the greater the number of accidents. Finally, the ANN analysis proved that all driving behaviours contribute to road accidents. Given the study by Saunders et al. (2009), the

findings obtained in the study were consistent with the hypothesis. This study makes a significant contribution to the existing literature by investigating the impacts of different driving behaviours on road accidents. The main contributors of this study are the uses of SPSS analysis and the ANN approaches and providing two benefits. First, the use of ANN further verified and elaborated on the results obtained through the SPSS analysis. Secondly, the ANN approach is capable of modelling complex linear and nonlinear relationships with high predicted accuracy.

During the data analysis, it was found that all the different behaviours contributed to the occurrence of road accidents. Similarly, all the drivers from different professions had almost the same behaviours. Those behaviours were collectively forming a driver's individual behaviour. Due to these reckless behaviours, some people lost their lives, while some had to experience some form of disability for the rest of their lives. One person's life is associated with the completeness of a family, but those families suffer for a lifetime because of these accidents. In this digital era, where most people are technology savvy, one technical solution may be adopted to avoid these accidents. For that matter, the technical solution is to be proposed based on the above analysis achieved in this study. With this solution's help, drivers can get timely alerts about the chances of accidents and avoid damages or reduce the magnitude of accidents (Al Najada & Mahgoub, 2016). From the analysis and findings of the collected data, especially about the exact causes of road accidents, the statistics of certain driver behaviours, and the solutions to avoid or reduce future accidents, this research benefits Pakistanis citizens by creating awareness regarding the causes of accidents. Meanwhile, traffic police can formulate different strategies and policies to avoid the causes of road accidents by conducting training and awareness programs to know about their driving skills, mistakes, violations and errors they make while driving.

THEORETICAL AND PRACTICAL IMPLICATIONS

Current research is a small effort to determine the major factors that cause road accidents by examining driver behaviour empirically and to suggest a viable solution to bring a considerable accident reduction.

The research gap identified before is fulfilled with the application of the Manchester Driver Behavior Questionnaire to identify the major factors that cause accidents. Especially in Pakistan, current research is of extreme importance because of the use of real-time primary data, opposite to existing literature which used secondary data to find out the casualties that occurred due to road traffic accidents (Gulzar et al., 2012). This research also followed the recommendations of Rolison et al. (2018) to investigate the factors further due to the scarcity of extant literature available.

In Pakistan, the industry lacks viable proposed solutions against the surveys conducted based on society. Traffic regulatory authorities, like the traffic police and NHA police, should organise and schedule training programs as a refresher course for drivers to develop awareness to drive safely, especially for the teenage group (Sarda, 2015). The training programs should be designed accordingly so that the public can identify errors, lapses, slips, mistakes, violations, and unintentional violations in their own and others' behaviours, as these factors are the causes of accidents. The authorities should select a group of 50 to 100 participants based on their license number and invite them formally for a refresher course. The duration of this refresher course should be around three hours and one day per week.

This course will gradually gain popularity upon its usefulness, and it will also identify the license-less people driving various vehicles all around the public and contributing to accidents. The licenses should be issued after giving proper written and technical tests in a transparent environment instead of acting on the power pressures. People should not be allowed to drive without a license in any case. The current practice penalises the violator financially and leaves them free of further punishment, like serving jail time. It is recommended that along with a financial penalty or fine, the vehicle of the driver should be confiscated until and unless the person acquires the license after a proper test. Moreover, the vehicle should not be freed by showing the licenses of acquaintances or relatives. Most importantly, the data should be recorded and maintained properly to analyse the causes of road accidents for future developments. Collision detection and collision avoidance mechanisms should be introduced and implemented to reduce the chances of road accidents occurring due to any violations, mistakes, errors, or slips.

LIMITATIONS, DIRECTIONS FOR FUTURE RESEARCH, AND CONCLUSION

The current study examines different factors, including slips, lapses, errors, mistakes, violations, and unintentional violations that cause road accidents. Moreover, the cause and behaviour were further assessed through the moderating influence of age. The results revealed are quite interesting for keen researchers as well as for practitioners. However, there is still room for improvement and new knowledge. Initially, the results are mostly based on the driver's personality or ability, and thus, the external factors are totally ignored. Therefore, future research can be conducted on other factors, including weather, road, and vehicle conditions. Secondly, the current research was applied to vehicle types and drivers in general. It opens an opportunity for future researchers to dig deep and find out more about different but specific types, including heavy vehicles and two-wheeler. It will help the policymakers to apply the findings in order to minimise accidents by designing effective policies and applications. Furthermore, it will help drivers to be more careful about dangerous vehicles. Lastly, only the age factor was considered to see its influence on road accidents. It is recommended to extend the same scale research by adding control variables, including gender, experience and public/private vehicle drivers. Each factor, along with an additional explanation of control variables, would be a noteworthy contribution to the extant literature. Not limited to that, it will create awareness for society and ultimately reduce fatalities.

The purpose of the current study was to analyse different driver behaviours, including slips, lapses, errors, mistakes, and intentional and unintentional violations that cause road traffic accidents. The study was conducted in two phases. In the first phase, statistical analysis was conducted, including correlation, regression, descriptive analysis, normality and reliability analyses. In the second phase, the SEM analysis was applied by using an artificial neural network technique. It was evident from the values of reliability analysis that the coefficients were around 90 percent and above, and thus were highly significant. From the descriptive analysis, it was found that the majority of the accidents happened to young people, whereas old people committed fewer road accidents. Moreover, the findings showed that all these behaviours contribute to road accidents.

However, lapses are considered a major contributor and errors are a minor contributor to the accidents. In the second phase, the artificial neural network was used for the analysis. ANN technique proved the same results by showing the significance of all behaviours in road accidents. The results showed that the errors and accidents had a stronger relationship, while the unintentional violations had the weakest relationship. It means that most of the accidents occurred due to errors caused by drivers. Hence, it was concluded from the study that every factor of driver behaviour contributes to the occurrence of road accidents, as highlighted in the literature.

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APPENDIX

(Appendix A)

Correlation Analysis

	Slips	Violations	Mistakes	UV	Lapses	Errors	Accidents	Age
Slips								
Violations	.542**							
Mistakes	.654**	.679**						
UV	.535**	.575**	.733**					
Lapses	.595**	.697**	.746**	.694**				
Errors	.577**	.629**	.813**	.690**	.768**			
Accidents	.345**	.434**	.354**	.379**	.372**	.183**		
Age	-.164**	-.248**	-.170**	-.083**	-.266**	-.223**	-.045**	

**. Correlation is significant at the 0.01 level (1-tailed).

(Appendix B)

Hypothesis	Direct Effects	Indirect Effects	Results
All factors ->Accidents	0.308**		Supported
Age->ALL->Accidents		0.214**	Supported

(Appendix C)

Network Information			
Input Layer	Covariates	1	Slips
		2	Violation
		3	Mistakes
		4	UV
		5	Laps
		6	Error
	Number of Units[a]		6
	Rescaling Method for Covariates		Standardised
Hidden Layer(s)	Number of Hidden Layers		1
	Number of Units in Hidden Layer 1[a]		2
	Activation Function		Hyperbolic tangent
Output Layer	Dependent Variables	1	Accidents
	Number of Units		1
	Rescaling Method for Scale Dependents		Standardised
	Activation Function		Identity
	Error Function		Sum of Squares

a. Excluding the bias unit

(Appendix D)

Network Information			
Input Layer	Covariates	1	ageXslips
		2	ageXviolation
		3	ageXmistakes
		4	ageXUV
		5	ageXlapses
		6	ageXerrors
	Number of Units[a]		6
	Rescaling Method for Covariates		Standardised
Hidden Layer(s)	Number of Hidden Layers		1
	Number of Units in Hidden Layer 1[a]		1
	Activation Function		Hyperbolic tangent
Output Layer	Dependent Variables	1	Accidents
	Number of Units		1
	Rescaling Method for Scale Dependents		Standardised
	Activation Function		Identity
	Error Function		Sum of Squares

a. Excluding the bias unit