Adverse weather impact on driver performance in the UAE

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Abstract. Road traffic accident is a significant cause of death around the world. Many factors cause accidents, such as demographic factors, humane factors, road design factors, and weather factors. This paper will investigate the adverse weather impact on driver performance by analyzing the impact of weather conditions on drivers' behaviors. Statistical analysis was conducted using one-way ANOVA test, correlation analysis, and Artificial Neural Network. The data was collected using a questionnaire for the people live in the United Arab Emirates. The survey includes two parts; the first part is about driver characteristics (Gender, Age, Nationality, Marital status, Education level, Monthly income, and Driver experience). The second part contains three questions related to the reaction and attitude of drivers due to bad weather conditions. The results showed that 45% of drivers involved in accidents during bad weather conditions although the majority (more than 75%) of them reduced the speed during the bad weather conditions. Overall, more research is needed to be done to evaluate the dust impact on driver performance as well as using real traffic accident data and compare it with this study to reach a solid conclusion and recommend the best solutions to improve traffic safety.

1 Introduction

The United Arab Emirates (UAE) has notable achievements in development in several sectors and activities of life. The population increased gradually as well as registered vehicles. Based on a study conducted by Mohammed El-Sadig, the analysis of accident data from 1977 to 1998 showed that fatalities caused by traffic accidents in the UAE were classified into careless driving, excessive speed, personal factors, vehicle conditions, environmental factors, and unspecified conditions [1]. The UAE government developed a strategy to enhance traffic safety and reduce the traffic fatalities to about 3 fatalities per 100,000 inhabitants by 2021 [2] . Many studies have discussed the impact of the human and the vehicle factors on traffic safety in the UAE while to the best of our knowledge no one investigated the impact of bad weather conditions on the driver performance. Some studies have been conducted in the UAE related to highway safety, however only very few studies discussed the impact of bad weather conditions on drivers' performance among other considered factors. Nevertheless, there is no study conducted in the UAE to focus mainly on

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the impact of adverse weather conditions on traffic safety. Therefore, this study aims to give awareness about bad weather conditions that can affect the driver's performance. The adverse weather conditions that will be included in this study are rain, fog, flood, dust, and sandstorm. Another objective of this research is to predict and study the reactions of drivers while driving in bad weather and how they control themselves and their vehicles. The study conducts a survey to analyze this problem in the UAE and to suggest strategies and solutions to improve highway safety.

2 Literature review

Traffic is one of the most significant resources of human Death. The traffic fatalities form 2.1%of total deaths every year [3]. Even if it is not a high percentage, but still causes concern for drivers and safety engineers because it represents millions of fatalities. Despite broad efforts to regulate and mitigate the traffic fatal and accidents problem, it is continuously rising daily. Many factors influence the danger of traveling on motorways, expressways, freeways, roads, and streets, according to highway engineers. This covers the mode of transportation, the volume of traffic, the sorts of vehicles, the state of the street surface, and the behavior of every driver [4]. The factors that affect highway safety are categorized by Haddon to be Human factors, Vehicle factors, and Environmental factors police [5-7].
Improvement of traffic safety can be done by focusing on reducing the adverse impact of these factors on traffic. Many studies concentrated on human factors, some focused on one specific manner, while others focused on combined manners. [8] conducted a study to reduce the traffic risk by supporting decision making and action selection through risk assessment of the non-predicted environment. [9] studied the drivers' behaviors in emergency situations due to man-made or naturally occurring disasters including adverse weather conditions or freeway incidents like vehicle crashes. They used driving simulators, an empirically underpinned theoretical framework. According to the findings, the adverse condition causes a major change in speed, acceleration, and spacing between vehicles which could affect traffic flow.

The response of the drivers to the multiple driving conditions can be measured by using some vehicle motion parameters like acceleration as well as headway. Multiple studies have been performed to analyze the behavior of drivers with respect to weather. Driver's mobility is greatly influenced by the weather condition. Rahman and Lownes, both the deceleration as well as the acceleration have some hazards while when the friction of the road is reduced then the driver mainly focuses on the speed control of vehicle [10]. Both these parameters help in evaluating the driver's perception of risk levels as well as the motion of the leading car. Chen et.al, did the study to measure the impact of the three most common weather conditions on the speed of the vehicle and while keeping time gap, distance, and speed of the vehicle as to the parameters. They measured that the rainy weather increased the distance between two cars and enhanced the gap in comparison to the dry weather condition Drivers' behavior changes with outside environmental and road conditions. The factors like fog and rain have been found to be less significant as compared to snow conditions according to drivers' perceived risk [11]. Billot et. al measured that the headway which was less than 2s reduced to 18% while he is following distance less than 50m reduced to 20% on rainy days as compared to the dry weather condition [12]. Therefore, the weather greatly influences traffic speed and driving behavior. These two problems complicate the integrated analysis of driving behaviors under different adverse weather [13].

It has been found that bad weather plays an important role in traffic accidents. The profound factors are rain, fog, and temperature changes. Decision-making while on road depends largely on the driver's behavior. Experiment results conducted on drivers having several years of driving experience showed that the drivers with experience of more than five

years have committed fewer percentage errors [18]. According to Singh, both driving errors and violence of drivers cause about 74% of all road crashes [14]. By assessment and understanding the driver's behavior on road, the safety will be improved majorly. Many studies reported that the most factor causes traffic accidents is behavior of drivers [14-17]. Many studies conclude that adverse weather causes a speed reduction. Speed reduces both for foggy and raining conditions but more reduction in speed is found in case of rain. Also, drivers keep more distance from the leading vehicle in case of rain. The adverse effect of climate change is taken more seriously by the passengers' cars as compared to truck drivers [19]. A study conducted to find the relationship between speed and weather condition using data of Remote Traffic Microwave Sensor (RTMS), they Found the reduction of the average speed of vehicles is between 8% and 12% at raining time, about 6% and 7% by wet friction [20]. By using Regression analyses to find the speed reduction during bad weather condition, the results showed there a reduction in speed by 2% and about 5% to 10% in light rain and heavy rain, respectively [21]. A study conducted by analyzing the variation in time gab, speed, following distance of platooned cars in rain and no-rain weather. they found that drivers are slow their speed, keep a longer headway and driver more carefully during rain [10].Questionnaire-based study conduction used ordered Probit models to find the behavior of drivers under normal travel and unexpected condition. 25% of drivers admitted that their mood changes due to adverse weather and 60% of respondents changed their departure time. About 35% of them used alternative routes during bad weather [22].

Traffic safety especially the operations of roadway traffic is greatly influenced by adverse weather conditions such as heavily windy, heavy rain, heavy snowfall, heavy fog, and so on. The visibility of drivers is affected when it is heavily raining and contributes towards the safety efficacy of the roadway [23] The combined impacts from roadway, vehicle, traffic control, and driver behavior conditions under rainy weather conditions could increase the potential for safety problems and traffic crashes. In recent years, some research studies have concluded that impacts from rainy weather conditions on traffic operations and safety cannot be ignored as [12]. Some studies conducted for environmental factors considering road geometric the adverse weather as a significant factor [24-31].

3 Methodology

Fig. 1 shows the procedure frameworks of this study. As shown started with developing the questionnaire which has been prepared by focusing on the effects of weather conditions on the driver's performance. Google forms is used to conduct the survey in two languages: Arabic and English. The survey contains two main sections; the first section focuses on collecting driver characteristics such as gender, age, nationality, marital status, education level, monthly income, and driver experience. The second section of the survey contains three questions related to the reaction and attitude of drivers due to bad weather conditions. the first question is "Have you ever had a road accident during a bad weather condition?". The second question is "Do you think the variable message sign can help you drive safely?". The last question is "Do You reduce speed in adverse weather conditions?" with YES/No answers.

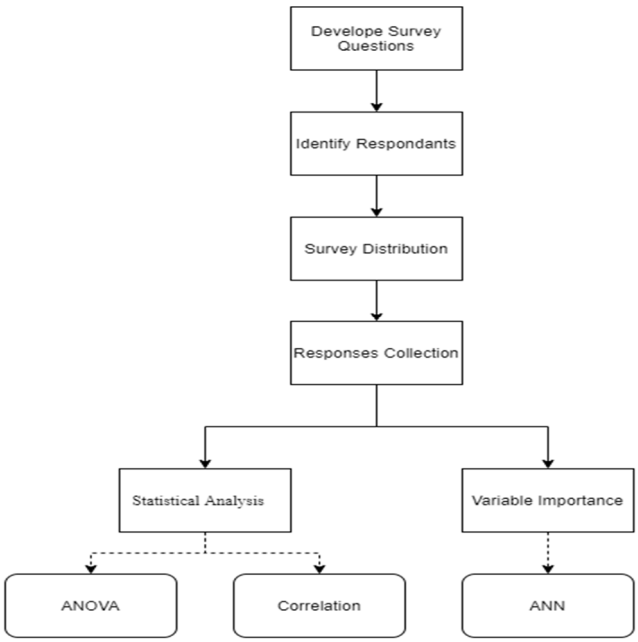

Fig. 1. The procedure framework.

3.1 Statistical analysis

Data has been distributed through social media applications for random drivers in the UAE. After the data was collected, the Statistical analysis was used to analyze it using Package for Social Sciences (SPSS) with a 95% level of confidence. One-way analysis of variance (ANOVA) can be used to find the significant difference between drivers' characteristics and driver's answers. Bivariate (Person) correlation will be used to find the strength of the relationship between driver's characteristics and behavior.

3.2 Machine learning & variable importance

The statistical relevance of each variable in the data in terms of its influence on the developed model is represented by Variable Importance. Variable Importance is essentially a rating of each predictor (Input) depending on how much of a contribution they make to the model. This method aids data scientists in eliminating out predictors (Input) that contribute little and instead increase processing time. The total of the decrease in error when a variable is split is used to calculate variable importance. The relative importance is then calculated by dividing the variable importance by the greatest variable importance value, with values restricted between 0 and 1. In this study Variable Importance will be used to determine how each one of the drivers' demographic characteristics effects on their behavior during bad adverse weather. One way to find Variable Importance is through machine learning. Machine learning is a subset of artificial intelligence (AI) and computer science that focuses on using data and algorithms to mimic the way people learn, with the goal of steadily improving accuracy. Machine learning is a crucial part of the rapidly expanding discipline of data science. Algorithms are trained to generate classifications or predictions using statistical approaches, revealing crucial insights in data mining initiatives. Following that, these insights drive decision-making within applications and businesses, with the goal of influencing important growth Key performance indicators. One of the most popular Machine

learning techniques is the Artificial Neural Network (ANN). ANNs are made up of numerous nodes that resemble actual neurons in the brain. Links connect the neurons, which allow them to communicate with one another. The nodes may accept data as input and conduct simple actions on it. These activities provide a result that is passed on to other neurons. ANN will be used to determine the Variable Importance. The neural network will consist of 2 hidden layers. The first layer includes 25 neurons and the second one contains 50 neurons. SPSS software will be used for the training and testing of the ANN models. The data will be divided into 70% training and 30% testing. The demographic characteristics will be considered as the independent variables and the rest of the questions will be used as the dependent variables. Finding variable importance will provide a detailed ranking about how ANN will use the demographic characteristics to predict each of the results of the remaining questions. The more dependent a model on a variable, the more essential it is for the model. This means the higher the impact of this variable on the answers to the question.

4 Results and discussions

4.1 Descriptive analysis

The data was collected by a questionnaire-based survey. The total number of respondents was 1100. After Excluding the empty answers of every single variable, its ends with each question with a different respondent's number. Table 1 shows the respondents' demographic characteristics such as gender, age, nationality, marital status, education level, monthly income, and driver experience for each question, it is included the number of respondents as "N" and percentage as "%" for each characteristic. As seen from Table 1, the number of female respondents was slightly greater than males. (44%-51%) of drivers are in the age between 31 to 49 years old. The lowest percentage of age group is "less than 18 years old" with 2-3%. Emiratis' respondents' percentage is 52%-59%, followed by Arab Nationalities with 20%-23%. Pakistanis and Indians were 16%-18%, while "other nationalities" were less than 10%. More than 65% of respondents are married, which is expected due to the percentage of age group. 63%-70% of participants have a degree. Most respondents are employed with 71-72%, and 70% of them earning more than 10K dirhams monthly. Most of them have good driving experiences (4-10) years and more than 10 years with 37-40% and 33-38%, respectively.

Table 1. Number of respondents and percentage of demographic characteristics.

Characteristics	Question 1		Question 2		Question 3	
Gender	N	%	N	%	N	%
Female	508	52%	410	55%	510	52%
Male	466	48%	339	45%	467	48%
Age	N	%	N	%	N	%
less than 18	26	3%	12	2%	27	3%
Age (18-24)	231	24%	156	21%	231	24%
Age (25-30)	190	19%	111	15%	191	19%
Age (31-49)	429	44%	379	51%	431	44%
50 and above	100	10%	92	12%	29	3%
Nationality	N	%	N	%	N	%
Emiratis	507	52%	441	59%	509	52%
Arab nationalities	229	23%	151	20%	229	23%
Indian	95	10%	74	10%	94	10%
Pakistani	61	6%	60	8%	60	6%

Others		90	9%		25	3%		89	9%
Marital status		N	%		N	%		N	%
Single		326	33%		222	30%		325	33%
Married		650	67%		526	70%		651	67%
Educational level		N	%		N	%		N	%
Primary education		141	14%		114	14%		142	15%
Middle school diploma		171	17%		135	17%		170	17%
Bachelor's degree		277	27%		299	38%		441	45%
Graduate degree		442	43%		201	25%		226	23%
Monthly income (AED)		N	%		N	%		N	%
I do not work		275	28%		217	29%		267	28%
(1000-5000)		95	10%		67	9%		94	10%
(6000-10,000)		116	12%		71	9%		115	12%
(11,000-20,000)		178	18%		114	15%		177	18%
(21,000-30,000)		226	23%		197	26%		225	23%
Above 30,000		92	9%		82	11%		92	9%
Driver experience		N	%		N	%		N	%
New driver-less than 1 year		111	11%		84	11%		110	11%
(1-3) years		148	15%		103	14%		147	15%
(4-10) years		397	41%		273	37%		396	41%
Above 10 years		319	33%		283	38%		320	33%

The second section contains three sub-part questions related to drivers' attitudes and opinions for bad weather conditions and traffic safety. Fig. 2 shows the percentages of the three question's answers. As shown the drives have been asked if they had a road accident in bad weather conditions. 55% of them did not have a road accident, which could be referred to their behavior during bad weather as reducing the speed. 78% of the drivers are reducing the speed during bad weather. Most drivers said the variable message sign is helpful for the safety of driving with 72%.

Fig. 2. Comparison between percentage of questions.

4.2 Statistical analysis

The main objective of statistical analysis is to identify the parameters affecting drivers' perception and make more accurate results than descriptive analysis. A One-way ANOVA test was used to determine the significant variances between the driver's characteristics and the answers. As mentioned before, the confidence level is 95%, which is led to find P-vale less than 0.05 as the test's outcome is a significant variance between the selected variables. Table 2 shows the significant values of ANOVA analysis, all values are statistically significant except orange highlighted, while blue highlighted values are significant in 90% level. As seen, the Gender of the driver is affecting the perception and behavior during

driving in adverse weather conditions. Males had road accidents in bad weather 3 times more than females.

Table 2. P-values of one-way ANOVA test.

	Q1	Q2	Q3
Gender	<0.001	<0.001	<0.001
Age	0.328	<0.001	0.001
Nationality	<0.001	<0.001	<0.001
Marital status	0.014	0.002	0.217
Educational level	<0.001	<0.001	0.059
Monthly income (AED)	<0.001	0.012	<0.001
Driver experience	0.380	<0.001	<0.001

More than 85% of female said that variable message sign is useful to drive safely during bad weather. 45% of Males said Variable message signs it is not helping and 55% of them said it is useful. 85% of males are reducing the speed during bad weather and 15% of them do not. 73% of females reduce speed during bad weather and 27% of them do not. Age group affection Question 2 and Question 3 results, all groups approximately divided into half of saying that VMS is useful to drive safely in bad weather conditions or not, except Group (31-49) years old has variation in results. 82% of the drivers' age is between 31-49 years old said variable message signs are helpful to drive safely in bad weather. The difference in the number of drivers reducing the speed or drive normally are increases with age increases. 63% of drivers less than 18 years old are reducing the speed during bad weather conditions. around 75% of drivers are in the age group (18-24) and group (25-30) years old reduce the speed of the vehicle during bad weather conditions. between 81% and 85% of drivers in the age group (31-49) and above 50 years old are reducing the speed.

The number of drivers that had road accidents in bad weather conditions is more than there who do not have in each nationality except Emirati's drivers: 82% of Emiratis drivers did not have a road accident in bad weather while 18% had an accident or more. The differences in the number of drives who said VMS are useful or not useful to drive safely in bad weather conditions were small in all nationalities, except Emiratis: 85% said it helps to drive safely and 15% said it is not helpful. The drivers who reduce the speed during bad weather conditions are more than drivers who do not reduce the speed from the United Arab Emirates, Arab nationalities, India, and Pakistan, while the number of "Other Nationalities" drivers who reduce the speed in bad weather conditions are less than who driver normally. Marital status is statistically significant with questions 1 and 2 only. 38% of single drivers had road accidents in bad weather conditions while 46% of married drivers had road accidents during bad weather. 63% of single drivers think VMS is helpful to drive safely in bad weather conditions while 76% of Married drivers said it is.

Educational level has statistically significant effects in question 1 and question 2 with a significant value less than 0.0001 and in question 3 with a value of 0.059. In each level of education, the number of drivers who had accidents was less than drivers who did not Except for a graduate degree. The number of graduate drivers had more accidents in bad weather conditions than graduate drivers that did not have. In each level of education, the drivers who think VMS is helpful to drive safely were higher than the divers who think it is not helpful. In each level of education, the number of drivers who reduce their speed during bad weather was higher than the divers who drive normally without reducing the speed. Monthly income was statistically significant with all three questions.

The percentage of having an accident during bad weather for employee drivers was close to the percentage of not having an accident in all salary ranges. While it was different for non-employee drivers: 21% of non-employee drivers had accidents in bad weather conditions

while 79% of them did not have. 83% of non-employee drivers think VMs is useful for driving safely in bad weather condition. 77% of the driver who has monthly income in the range of (11,000-30,000) Dirhams think VMS is helpful, while drivers who think the same with lower or higher monthly income were cover 50-52%. In each monthly income category, drivers who reduce the speed during bad weather conditions are more than those who drive normally. Driver Experience was statistically significant with question 2 and 3. The drivers with more driving experience said VMS is useful to drive safely in bad weather conditions, and they reduce speed more than new drivers.

Table 3 shows the Pearson correlation values between driver characteristics and each question. Green-colored value is considered significant at a level of confidence of 95%, while blue-colored is deemed to be significant at a level of confidence of 99% and uncolored values are not significant. Question 1 is affected moderately by gender and nationality, while it is affected weakly by educational level and monthly income. Question 2 is affected moderately by gender and nationality, while it is affected weakly by age, Marital status, educational level, monthly income, and driver experiences. Question 3 are affected weakly by gender, age, marital status, monthly income, and driver experience.

Table 3. Pearson correlation results.

	Q1	Q2	Q3
Gender	-.488	.348	-.139
Age	-.040	-.127	-.103
Nationality	-.455	.313	.130
Marital status	-.055	-.116	.039
Educational level	-.258	.205	-.060
Monthly income (AED)	-.243	.092	-.112
Driver experience	.029	-.187	-.118
**. Correlation is significant at the 0.01 level (2-tailed).			

4.3 Machine learning analysis

The ANN Machine learning technique was used to determine the variable importance for each question. The data was divided into 70% training and 30% testing. Many trials were performed for the dependent variable of "Have you ever had a road accident during a bad weather condition?" and with driver characteristics. the highest training and testing accuracy percentages were found to be 75% and more for overall accuracy for each question. Table 4 shows the results of predicted answers for question 1. As seen the overall accuracy for the testing data is 77.7%, while it is 82.9% for training data.

Table 4. Predicted answers for Question 1

Sample		Predicted			
		No	Somehow	Yes	Percent Correct
Training	No	335	0	31	91.5%
	Somehow	12	0	0	0.0%
	Yes	73	0	227	75.7%
	Overall Percent	61.9%	0.0%	38.1%	**82.9%**
Testing	No	151	0	26	85.3%
	Somehow	3	0	3	0.0%
	Yes	35	0	83	70.3%
	Overall Percent	62.8%	0.0%	37.2%	**77.7%**

Fig. 5 shows the importance value (blue-colored) and Normalized importance percentage (Orange-colored) for each characteristic. As seen, Age has the most impact with 100% importance, followed by Nationality by 74.6%. The least important factor was Monthly Income, which has 57.3% importance in the model.

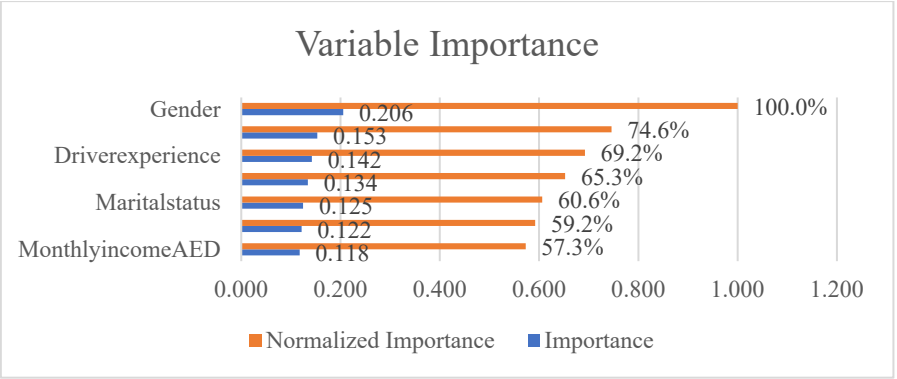

Fig. 3. The importance value and normalized importance percentage of Question 1.

Table 5 shows the results of predicted answers for question 2: Do you think the variable message sign can help you drive safely?. As seen the overall accuracy percentage for testing data and training data is 82.5% and 82.3%, respectively. **Fig. 6** shows the importance value (blue-colored) and Normalized importance percentage (Orange-colored) for each characteristic. As seen, Gender has the most impact with 100% importance, followed by Driver Experience and Age by 68.4% and 58.5%, respectively. The least important factor was Marital Status, which has 31.7% importance in the model.

Table 5. Predicted answers for Question 2.

Sample		Predicted		
		No	Yes	Percent Correct
Training	No	58	93	38.4%
	Yes	25	490	95.1%
	Overall Percent	12.5%	87.5%	**82.3%**
Testing	No	16	46	25.8%
	Yes	9	244	96.4%
	Overall Percent	7.9%	92.1%	**82.5%**

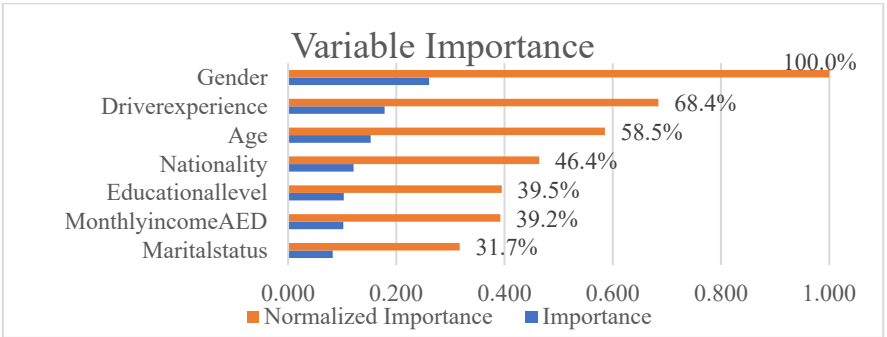

Fig. 4. The importance value and normalized importance percentage of Question 2.

Table 6 shows the results of predicted answers for question 3: Do You reduce speed in adverse weather conditions?. As seen the overall accuracy percentage for testing data and training data is 76% and 81.4%, respectively. Fig. 7 shows the importance value (blue - colored) and Normalized importance percentage (Orange-colored) for each characteristic. As seen, Driver's Nationality has the most impact with 100% importance, followed by Educational Level and Monthly income by 55.5% and 48.3%, respectively. The least important factor was Marital Status, which has 32.3% importance in the model.

Table 6. Predicted answers for Question 3.

Sample		Predicted		
		No	Yes	Percent Correct
Training	No	76	68	52.8%
	Yes	30	352	92.1%
	Overall Percent	20.2%	79.8%	**81.4%**
Testing	No	28	38	42.4%
	Yes	16	143	89.9%
	Overall Percent	19.6%	80.4%	**76.0%**

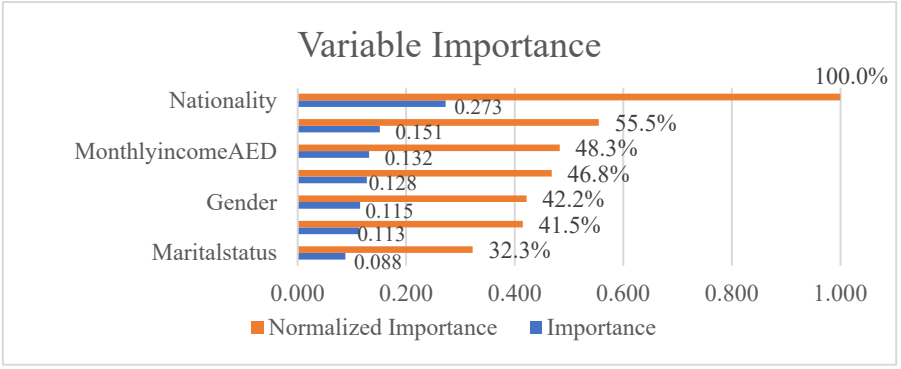

Fig. 5. The importance value and normalized importance percentage of Question 3.

5 Conclusion

In conclusion, analyzing weather conditions and drivers' characteristics that affect driver activities is essential to minimize accidents and the contingency of traffic flow. In this study, a questionnaire was prepared and distributed to people who live in the UAE. One-way ANOVA test and correlation were used to identify the characteristics that significantly affect drivers' performance. Then ANN of Machine learning is used to determine the variable importance for each question. The results showed that 45% of drivers had accidents during bad weather conditions even if the majority (more than 75%) of them reduced the speed. Gender is the top ranking for questions 1 and 2, and Nationality is the top ranking for Question 3. Males had road accidents in bad weather 3 times more than females. Female drivers admitted that VMS is helpful to drive safely more than men drivers. Overall, future study is highly recommended to evaluate the dust impact on driver performance. And more research is needed to be done using real traffic accident data and compare it with this study to reach a definite conclusion and recommend the best solutions to improve traffic safety.

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