Original Article

Identifying and Prioritizing Risk Factors Involved in Motorcyclists' Traffic Accidents in Tehran

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Abstract

Background and Objectives: Motorcyclists are one of the most vulnerable groups compared to other road users. Motorcycle road safety can be assured by identifying risk factors, using safety equipment, and improving roads for traveling. This study sought to identify and prioritize the risk factors involved in motorcyclists' traffic accidents in Tehran. **Methods:** In this descriptive-analytic study, the fuzzy TOPSIS method was used to develop a systematic process to achieve an optimal model through the selected criteria. To find significant risk factors in the model, the interviewed experts first selected the target criteria from an available long list of functional criteria. Then, using the SMART method, the key criteria in motorcyclists' traffic accidents were determined, and they were ranked according to their weights and weighting ratios. **Results:** Fifty people, including 42 (84%) males and 8 (16%) females, participated in the study. The mean and standard deviation scores of participants' age were 44.18 and 7.03 years, respectively. Based on the fuzzy analysis, alcohol intake, cell phone use, breaching the speed limit, failure to use safety equipment, and driver's age, among other criteria, were ranked first to fifth. **Conclusion:** This study showed that the most important risk factors associated with motorcyclists' traffic accidents were the human ones. Given that various studies in Iran have shown that human factors are the leading causes of traffic accidents, policymakers and administrators need to take the necessary measures to manage and control them.

Keywords: Fuzzy TOPSIS technique, motorcyclists, risk factor

Introduction

Traffic accidents are the leading causes of death and disability, causing 1.35 million deaths and millions of injuries worldwide each year.[1] A study on the global burden of diseases reports that traffic accidents were globally ranked ninth in terms of death and injuries tolls in 1991, and it was anticipated to be the third leading cause of death and injuries in 2020.[2]

In addition, motorcyclists appear to account for a considerable proportion of deaths and injuries in traffic accidents. According to the 2018 report of the World Health Organization, about 28% of deaths in traffic accidents occurred among drivers of two-wheeled and three-wheeled motor vehicles.[1] Motorcyclists' accidents were more common in Southeast Asia and the Western Pacific Region than in other resigns. Therefore, 34% of motorcyclists were killed in traffic accidents in these regions.[3]

An analysis of the mortality rate in two-wheeler and three-wheeler accidents occurring in the United States

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indicated an increase in the rate from 14.1 in one million in 2009 to 15.3 in 2012.[4] Moreover, a study on the global burden of diseases and injuries showed that traffic accidents ranked first in recent years in terms of the number of years lost because of premature death in 15–49-year-old individuals in Iran.[5]

The mortality rate in traffic accidents in Iran is higher when compared to the Eastern Mediterranean countries (20 PER 100,000 Vs. 18.5 PER 100,000).[6]

In recent years, many Iranian families and individuals, especially young people, have used motorcycles because they are relativity cheap and widely available. Therefore, the use of motorcycles for urban transportations has increased significantly. According to police statistics, about 25% of deaths and more than 50% of injuries in traffic accidents in Tehran included motorcyclists.[7] Moreover, a study of 1290 injured patients in traffic accidents who visited Sina Hospital in Tehran during 2 months showed that 385 people (29.8%) were injured in motorcycle accidents.[8]

There are several studies about using fuzzy models and how they differ from other mathematical and statistical models. In Italy, for example, Random Utility Models and fuzzy logic models were compared to determine the safe distance at the intersections with priority based on the data obtained from driving simulation tests. In the models, driving patterns and the variables used to determine the safe distance were studied. Characteristic receiver operating (ROC) compared the two models. The comparison showed that fuzzy models could be a suitable alternative for random models.[9] Nurnadia and lazim ranked traffic accidents by the fuzzy model. They found that researchers could use this model and multivariate decision criteria to prioritize those items in different situations.[10] In Jordan, they designed an immune system for the vehicles by fuzzy methods, reducing traffic accidents.[11]

In Canada, fuzzy TAPSIS models were used to evaluate the quality of urban transport systems and services.[12] In Belzec, researchers decided to study more precise aspects of traffic accidents and their causes. The analysis was assisted with mathematical and statistical models, and factors of traffic accidents, such as incidence and prevalence rates, were described. They provided a suitable model with a smart system to evaluate road safety phenomena in European countries.[13]

The study aimed to identify and prioritize the risk factors of traffic accidents associated with motorcyclists in Tehran based on multi-criteria decision-making using a fuzzy TOPSIS method.

Methods

This study was a cross-sectional descriptive-analytic research that was carried out in 2020. The sample included senior experts and researchers of traffic accidents in Tehran working in academic and research centers and police departments, such as experienced epidemiologists studying traffic accidents. The sample size was determined based on fuzzy TOPSIS and multicriteria decision-making (MCDM) guidelines. To prioritize the desired criteria, experts' views were taken into account. The maximum required sample size was 35; however, 50 respondents were included in the study to compensate for the loss of participants during the study and increase the results' accuracy. The experts were selected from university professors, administrators, and senior experts with equal distribution.

To find the safety criteria for motorcyclists, a list of human, environmental, and vehicle criteria was prepared using the criteria developed by research traffic centers and the criteria suggested by Al-Hadidi *et al*.[11] and Moridi *et al*. studies. Although numerous criteria have been offered for assessing the risk factors in motorcycle traffic accidents by traffic and transportation offices, a small number of those criteria seem to play an important role. Therefore, the experts selected the most effective criteria from that list. Finally, based on the findings of some studies, a SMART scale was used to rank the criteria.[14]

Out of 52 primarily identified criteria, 36 key were selected by experts, which were then examined in terms of technical, scientific, and executive considerations in line with the study's objectives. To rank and prioritize the criteria, a questionnaire with the items shown in Table 1 was developed, completed by the criteria extracted through software [Figure 1] was designed. Twelve experts, including six Ph. D. holders in epidemiology, two traffic police officials, and four transportation safety experts, assessed the questionnaire's validity and reliability.

To measure the questionnaire's reliability, the reliability coefficients of the scale and subscales were calculated in SPSS Version 2 0, (SPSS Inc., Chicago, Ill., USA) (Cronbach's alpha = 0.947). The results for the questionnaire validity were Content Validity Ratio (CVR) =92% and Content Validity Index (CVI) =78.06%, which led to a partial modification of the content and structure of the items.

The fine-turned version of the questionnaire had 36 Likert scale items [Table 1 and Figure 1] with seven options for each item/criterion; very low, low, medium-low, medium, medium-high, high, and very high. Then, fifty experts, including epidemiologists, traffic and transportation experts, occupational health professors, and officials of traffic police departments working in research and academic centers, analyzed the data.

To rank and compare different options, select the best options, and determine the intervals between the options, the fuzzy TOPSIS technique was used. According to this method, the best option is closer to the ideal solution and farther to the nonideal solution. The ideal solution was the one that had the most advantages and was much more inexpensive. The fuzzy TOPSIS technique was implemented in seven steps. First, the weights of the criteria were determined based on the method. After collecting the experts' responses in the form of verbal feedback, the responses were converted to an analyzable

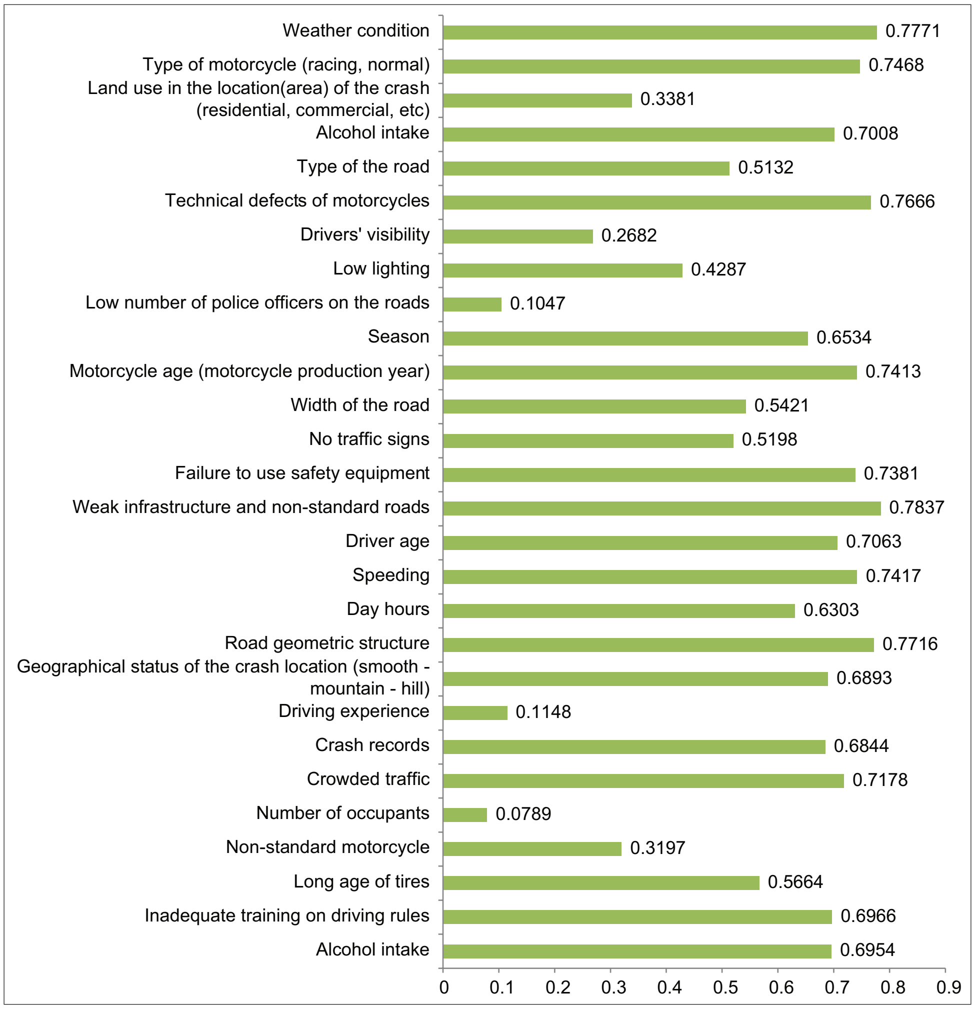

Figure 1: The overall corrected correlation of the leading risk factors in motorcyclists' traffic accidents

scale. Given the qualitative nature of the data, which cannot be analyzed quantitatively, these variables were converted to fuzzy scales. Moreover, fuzzy triangular numbers [Figure 2] were used as the membership functions of fuzzy numbers. Fuzzy triangular numbers were used because of their more straightforward decision-making.[15,16]

In the second step, the decision matrix was formed to determine the importance of each criterion. Before forming the matrix, an appropriate fuzzy scale had to be determined to measure the intended criteria based on the characteristics of those criteria. To this end, the Fuzzy scales offered by Wang and Alhag were used in the present work.[16] In the third stage, each fuzzy number specified for each criterion's importance was multiplied by the corresponding number of the decision matrix (the importance of each criterion according to its characteristics). Finally, the coordinated decision matrix was calculated as follows:[15]

$$\widetilde{V} = [\widetilde{V}_{ij}]_{mxn}, i = 1,2,\ldots,m;\ j = 1,2,\ldots,n$$

$$\widetilde{V}_{ij} = \tilde{a}_{ij} \otimes \tilde{w}_j$$

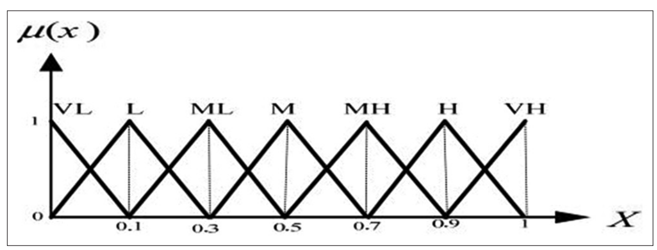

Figure 2: Fuzzy numbers to determine the importance of each criterion

The decision-making tables obtained based on the experts' views were balanced and normalized in the fourth step. The matrix of the normalized decision was then obtained, based on which the normalized fuzzy matrix could be shown by/in the following equation:

$$\widetilde{R} = [\tilde{r}_{ij}]_{mxn}, i =, 2,\ldots, m;\ j = 1, 2,\ldots, n$$

This matrix was calculated by the following formulas, in which B and C represented the positive and negative criteria of the problem, respectively:

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c^{+}_{j}}, \frac{b_{ij}}{c^{+}_{j}}, \frac{c_{ij}}{c^{+}_{j}}\right) c^{+}_{j} = m_{i}axc_{ij}\, j \in B \max$$

$$\tilde{r}_{ij} = \left(\frac{a_{j}-}{c_{ij}}, \frac{a_{j}-}{b_{ij}}, \frac{a_{j}-}{c_{ij}}\right), a_{j}- = \mathrm{m}_{i}\mathrm{in}\, a_{ij} \in C$$

Moreover, all the criteria used in the present study were positive, and the output of normalizing the coordinated decision matrix was a fuzzy triangular matrix with positive numbers.[15]

In the fifth step, the positive ideal and the negative ideal fuzzy responses were determined, and the distance between each criterion from the positive and negative ideal fuzzy responses was calculated as follows in the sixth step:

$$d^{+}i = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}^{+}_{j}\right), i = 1, 2, ..., m;$$

$$d^{-}i = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}^{-}_{j}\right), i = 1, 2, ..., m;$$

If $\tilde{v}_{ij} = (a, b, c)$ then:

$$d(\tilde{v}_{ij}, \tilde{v}^{+}_{j}) = \sqrt{\frac{1}{3}}[(a-1)^2 + (b-1)^2$$

$$+(c-1)^2 and d(\tilde{v}_{ij}, \tilde{v}^{-}_{j}) =$$

$$\sqrt{\frac{1}{3}}[(a-0)^2 + (b-0)^2 + (c-0)^2$$

In the seventh step, the criteria were prioritized by calculating the proximity coefficient and rank of the criteria. CCI was the proximity coefficient of the criterion for ranking the criteria and prioritizing them. CCI was defined by the following formula:

$$CC_{i} = \frac{d^{-}_{i}}{d^{+}_{i} + d^{-}_{i}}, i = 1, 2, ..., m$$

If a criterion was close to A+ and away from A-, its value was closer to one. Then, the criteria were prioritized based on this proximity.[15]

Results

As mentioned earlier, the study's sample size comprised fifty participants including 42 (84%) males and 8 (16%) females. Moreover, the mean and standard deviation scores for the participants' age and their job experiences were 44.18, 7.03, and 22.34, 6.12, respectively.

The results showed that the questionnaires had acceptable validity and reliability. After gathering and analyzing the experts' views, the questionnaire's face validity and content validity were measured as 75.01% and 84.2%, respectively. Most of the questionnaire's items were found to be interesting and attractive for the sample group, indicating the questionnaire's acceptable face validity.

Additionally, the number of experts who were interviewed was adequate ($n = 15$), and according to the Lawshe method, the face validity and the content validity of the questionnaire were acceptable. Furthermore, the questionnaire's reliability regarding the internal consistency of the factors associated with traffic accidents and risks was 0.83, which is above the reliability threshold.

Figure 1 shows the key items' overall corrected correlation, indicating strong correlations between most of the items. Moreover, it was found that improper infrastructures and non-standard roads, weather conditions, and road geometric structure had the strongest correlations with other criteria, with their correlation coefficients reported to be -0.78, 0.77, and 77, respectively. Furthermore, only a few criteria showed weak correlations with each other.

Figure 3 illustrates the weight of each criterion in evaluating the intended factors. The criterion's specificity had the greatest effect in prioritizing the studied criteria with a weight of 0.35, and the criterion's measurability in a specific time frame had the lowest effect in that regard with a weight of 0.8, respectively.

Table 1 shows the results of the fuzzy analysis, indicating the ideal distance from the positive and negative points, the proximity coefficients, and the ranking of the key risk criteria for motorcyclists' traffic accidents. As can be seen, alcohol intake, cell-phone use while riding, speeding, failure to use safety equipment, and driver's age ranked first to fifth in that regard, respectively. Moreover, Figure 4 shows the key traffic accidents' risk factors regarding the motorcyclists that have been compared with each other based on their proximity coefficients and rankings

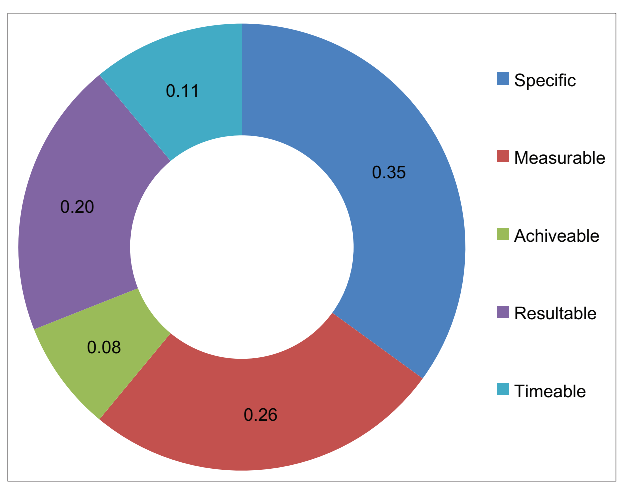

Figure 3: The weight of each key risk criterion in motorcyclists' traffic accidents

Table 1: Proximity coefficients and rankings of the key risk factors in motorcyclists traffic accidents

Factor	Sum of distances from ideal negative factors	Sum of distances from positive ideal factors	CCI	Ranking
Alcohol intake	3.8021	1.2386	0.2457	1
Cell phone use	3.8074	1.2338	0.2447	2
Speeding	3.8163	1.2258	0.2431	3
Failure to use safety equipment	3.8213	1.2210	0.2422	4
Driver's age	3.8259	1.2176	0.2414	5
Crash records	3.8340	1.2106	0.2400	6
Poorly-trained drivers	3.8364	1.2002	0.2383	7
Road geometric structure	3.8551	1.1896	0.2358	8
Drivers' visibility	3.8641	1.1804	0.2340	9
Low lighting	3.8725	1.1698	0.2320	10
A small number of police officers on the roads	3.8770	1.1687	0.2316	11
Day hours	3.8780	1.1684	0.2315	12
Type of the road	3.8808	1.1555	0.2294	13
Season	3.9180	1.1265	0.2233	14
Weather condition	3.9238	1.1190	0.2219	15
Weak infrastructure and nonstandard roads	3.9492	1.0978	0.2175	16
Heavy traffic	3.9602	1.0879	0.2155	17
Geographical status of the crash location (smooth-mountain-hill)	3.9591	1.0858	0.2152	18
Width of the road	4.0002	1.0489	0.2077	19
No traffic signs	4.0087	1.0295	0.2043	20
Type of motorcycle (racing, regular)	4.0159	1.0281	0.2038	21
Technical defects of motorcycles	4.0253	1.0203	0.2022	22
Motorcycle age (motorcycle production year)	4.0255	1.0200	0.2022	23
The long age of tires	4.0377	1.0093	0.2000	24
Number of occupants	4.0515	0.9929	0.1968	25
Driving experience	4.0733	0.9746	0.1931	26
Nonstandard motorcycle	4.0934	0.9559	0.1893	27
Land use in the location (area) of the crash (residential, commercial, etc.)	4.1544	0.8859	0.1758	28

CCI: Closeness of Coefficient

Discussion

As mentioned earlier, the questionnaire's validity and reliability were found to be acceptable. Moridi *et al*. reported adequate validity and reliability for the scales they used to rank the risk factors associated with the drivers' traffic accidents, which is consistent with the present study's findings.[14]

The fuzzy analysis showed that alcohol intake, cell phone use, speeding, failure to use safety equipment, and driver's age had high proximity coefficients. Therefore, these factors are considered as the first five important criteria that could contribute to the improvement of the pedestrians' safety

Moreover, alcohol intake was found to be the most influential factor involved in drivers' traffic accidents, which is consistent with the results found by several other studies, including Araqi and Vahedian,[17] Moskal *et al*.,[18] Johnson,[19] and Liu *et al*.[20] Studies showed that talking on a cell phone increased the risk of accidents by more than 30%.[21-23] Cell phone use was also responsible for a considerable number of deaths in all traffic accidents in some countries. It was reported that in Nigeria, the United States, and France, traffic accidents were responsible for 0.4%, 1.2%, and 10% of deaths, respectively, in which cell phone was the leading cause.[24]

Moreover, the use of cell phones was different in terms of gender and age. Some studies suggested that young male drivers were more likely to use cell phones while driving.[25-27] The prevalence of cell phone use in motorcyclists also varied from country to country. A study in Fars Province in Iran showed that 48% of motorcyclists used cell phones while riding.[28]

In addition, a study in Vietnam found that the prevalence of cell phone use in students was 3.76%.[29] Pileggi *et al*. also found that 20% of adult motorcyclists used cell phones while riding in Italy,[30] and a study in Brazil reported that 0.64% of motorcyclists used cell phones while riding.[31]

The findings also indicated that speeding was the second cause of traffic accidents in motorcyclists. Moradi *et al*. reported that 6.74% up to 9.36% of drivers exceeded the speed limits when riding on Iranian urban roads.[32] On the other hand, various studies have shown that speeding increases the risk of pedestrian traffic accidents.[33-36] Moreover, the most important factor in traffic accidents' severity is speeding, which causes more than 75% of pedestrian deaths.[37-39]

Failure to use safety equipment was the fourth case of traffic accidents among motorcyclists. Using a helmet is considerably

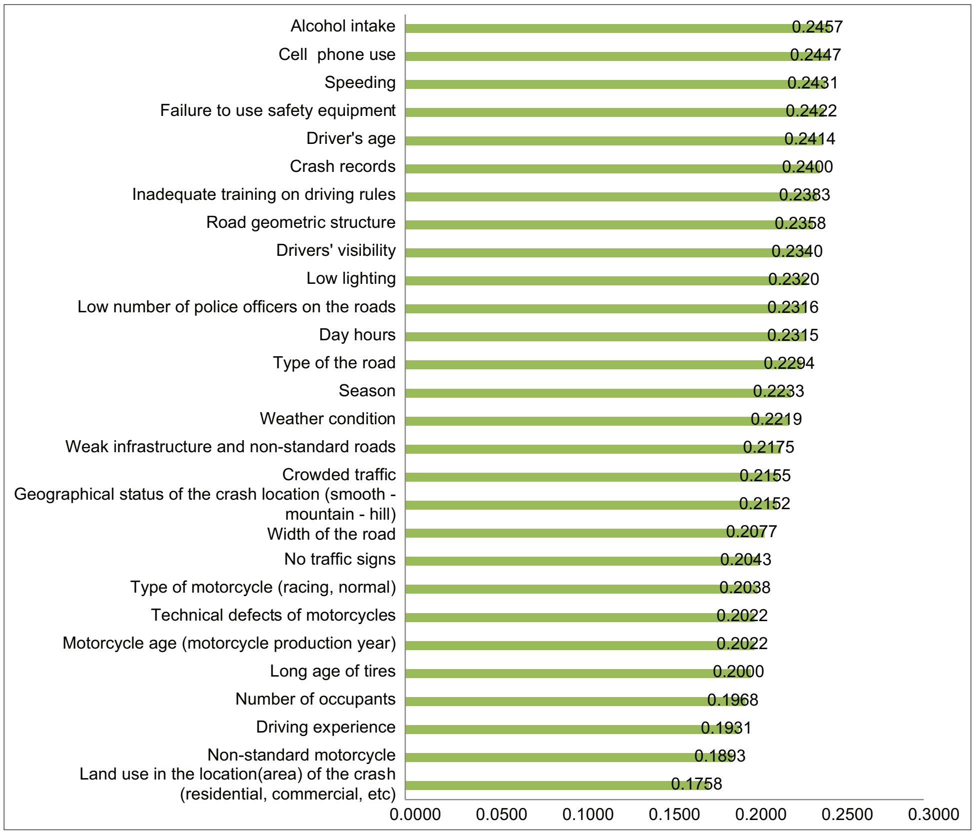

Figure 4: The leading risk factors in motorcyclists' traffic accidents

improves safety, and it is the only effective way to reduce death tolls and head injuries in motorcyclists. It also reduces the severity of damages up to approximately 72% and the risk of death by about 39%.[40] Studies have shown that the rate of wearing helmets by motorcyclists varies significantly in different countries, with some countries showing a very low rate in this regard. For instance, the rate has been reported to be 30% in Iran,[41] 4.29% in Jamaica,[42] 1.35% in Kenya,[43] 8.73% in Mexico,[44] 7.43% in Thailand,[45] and 99% in Nepal.[46]

According to the study's results, the drivers' age was the fifth risk factor involved in motorcyclists' traffic accidents. The national statistics have also shown that the incidence of traffic accidents, especially in motorcyclists under 20 years old, was significantly higher when compared to other age groups.[47] Lin *et al*. in Taiwan,[48] Useche *et al*. in Spain,[49] Oikawa *et al*. in Japan[50] also suggested that age was significantly associated with the incidence of traffic accidents among motorcyclists.[48] Branion-Calles *et al*. reported that in seven major EU cities, age was one of the risk factors in traffic accidents, and the incidence of accidents in motorcyclists aged between 16 and 25 years old was significantly higher than other age groups.[50]

The findings also showed that inadequate training of motorcyclists was the sixth cause of motorcycle-related traffic accidents. Using the fuzzy TOPSIS method, Moridi *et al*. reported that human factors and behavior had the highest proximity coefficients among the influential factors involved in traffic accidents in Tehran and that controlling those factors was the first measure to reduce traffic accidents.[14] Therefore, the results found by Moridi *et al*. are consistent with the present study's findings.

Using the analytic hierarchy process technique, a study that was conducted in Tehran showed that the factors affecting the promotion of traffic safety behaviors and reducing motorcyclists' mortality rate were as the following:

- Reducing urban trips by motorcycle
- Controlling motorcyclists' driving skills
- Enforcing traffic rules for motorcyclists
- Training and providing necessary information for motorcyclists through mass media
- Having an integrated monitoring system for motorcycle transportations
- Rendering roads' high-risk points safe
- Monitoring motorcyclists' speed limits
- Increasing positive interactions among private sectors, government, and people
- Getting people to participate in training driving rules.[51]

Given that factors relevant to the vehicle, humans, and environment can affect traffic accidents, in such seasons as autumn and winter when rain and frost are frequent, seasonal and environmental factors on road traffic accidents cannot be overlooked. An Iranian study showed that the number of accidents on rainy days was 30% higher than on sunny days.[14]

Conclusion

The present study found that human factors accounted for the vast majority of important risk factors involved in motorcyclists' traffic accidents. Given that various studies have shown that human factors cause 70%–70% of accidents worldwide,[52-54] policymakers and administrators must take the necessary measures to prevent such accidents.

Since a significant prioritized criteria system was not available, the multiple attribute decision–making (MADM) method was used in the present study. This method could be used to analyze significant criteria in decision-making. In multicriteria decision-making methods, several measurement criteria are used instead of one measure. MCDM models are divided into two major models; MADM and multiple objective decision-making (MODM). In general, MADM models are used to select the superior criterion, and MODM models are used for designing. The main difference between MADM and MODM models is that the first is defined in discrete and the second in continuous decision-making space. In MADM models, the characteristics, goals, criteria, and decision-making matrix are used. All MADM techniques try to determine how to choose the best criteria using the indexes data. To determine the indexes, we use the experts' views. Therefore, many methods such as brainstorming, Delphi, and thought noting were developed. Methods of solving these models include methods without weighting, weighting methods on criteria, and weighting methods on options.

In MODM models, the best alternative should be designed based on system constraints, different goals, and the decision-makers' desired amounts for these goals) after specifying, prioritizing, and selecting such criteria.

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Conflicts of interest

There are no conflicts of interest.

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