Prioritization of infrastructure factors affecting on safety of two-lane roads using proactive and reactive methods (Case study: Ahar-Tabriz road)

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ABSTRACT

Identifying effective infrastructure factors contributed to accidents of two-lane roads based on proactive and reactive methods is one of the ways for increasing road safety. Therefore, the present study is firstly aimed to identify, and prioritize factors affecting accidents on rural road of Ahar-Tabriz using artificial neural network (ANN), TOPSIS and multinomial logistic regression (MNL) models. AHP was used for weighting of criteria and subcriteria in TOPSIS model. Secondly, this study compares the results of priorities in three models based on proactive and reactive methods. The results of ANN model indicated that this model predicts accident severity via 86% in which prioritized factors such as horizontal and vertical curves, percentage of heavy vehicles, pavement condition, road drainage condition, volume of passing cars and use of speed control cameras, respectively. However, TOPSIS model has shown that the priority of the infrastructure factors affecting road safety include drainage condition, pavement condition, use of speed control cameras, horizontal and vertical curves, road signs, percent of heavy cars, road lighting condition, volume of passing cars, and traffic calming, respectively. In addition, MNL model indicated that this model is capable of prediction in accident severity via 74.82% in which pavement condition, use of speed control cameras, road lighting condition, vehicle of passing cars, and road signs are ranked as the most effective factors involved with accidents on rural roads, respectively. Therefore, by making a performance comparison based on Spearman's rank correlation coefficient, T-test analysis, it is found that there is no difference between ANN and MNL models, however, there is a significant difference between TOPSIS and other models. Thus, ANN and MNL models are reactive methods, and TOPSIS model is a proactive method in which the ANN model due to higher accident severity prediction is selected as the best predictive model.

KEYWORDS: Two-lane roads, road safety, proactive method, reactive method, prioritization models

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1. Introduction

Road safety is one of the most challenging issue in the world which has been considered by many road safety organizations. The recent decade in the world focuses on reducing number of accidents which is called the decade of action for safety. According to the WHO report, annually 1.52 million people are killed by road traffic accidents [1]. In Iran, recently road traffic accidents have been increased significantly in two-lane roads. Regarding this fact, safety researchers and engineers have attempted to identify the influencing factors on accidents by means of reactive and proactive methods for improvement of road safety regarding the accident and observation approaches, respectively [2]. Other studies show that infrastructure factors on roads such as pavement condition, traffic calming, horizontal and vertical curves, road drainage condition, road lighting condition, volume of passing cars, road signs, use of speed control cameras, and percentage of heavy vehicles are identified as the most affecting factors on accident severity in road segments [3-4]. In addition to these studies, two approaches have been proposed by safety researchers for identifying and prioritizing factors contributed to road accidents based on proactive and reactive methods. Proactive methods or observation – based methods refer to models which are questionnaire based study and multi-criteria decision making (MCDM) models have appropriate performance for prioritizing the most causative infrastructure factors on accidents in roads [5]. However, other studies focused on applying reactive approach or accident – based approach such as ANN, and logistic regression models for identifying and prioritizing the most influencing factors on accidents in roads regarding accident dataset. The results indicated that accident-based models are the best predictive models for severity prediction in accident-prone segments and prioritizing important factors contributed to accident frequency [6]. Therefore, in order to reduce number of accidents in accident-prone segments and increase safety in two-lane roads, the present study is first aimed to examine infrastructure factors contributed to accident severity such as property damage only (PDO), injury, and fatality in Ahar-Tabriz road based on the accident dataset from 2016 to 2019. Second, it's aimed to prioritize infrastructure factors contributed to accident severity by means of reactive approach associated with accident-based method such as artificial neural network (ANN) and multinomial logistic (MNL) models and proactive method including TOPSIS model associated with observation-based approach. At the end, a performance comparison based on Spearman's rank correlation coefficient, T-test analysis is taken into consideration for selecting the best predictive model.

2. Methodology

In order to prioritize the infrastructure factors influencing on accident severity in Ahar-Tabriz road, the accident dataset include 846 accidents in which 561 accidents are related to PDO-injury and 285 accidents are belonged to fatality from 2016 to 2019. Further, after examination of Ahar-Tabriz road, 45 homogenous segments with the same condition in each segment regarding the infrastructure variables are classified based on the number of accidents and geometric characteristics. Thus, regarding the accident severity and infrastructure variables, two approaches such as reactive method including ANN, and MNL models and proactive method such as TOPSIS model are proposed.

2.1. ANN model

ANN model is one of the most popular models in road accident severity prediction regarding factors contributed to accidents [6-7]. ANN consists of input layer, hidden layer, and output layer via training and testing dataset regarding the prediction performance. In order to apply this model for accident severity prediction based on the employed variables, root mean square error (RMSE) and sensitivity measures are used according to the dataset. Thus, the best ANN model is selected based on the minimum error and maximum prediction performance [7].

2.2. TOPSIS

TOPSIS model is a MCDM model in which is based on the questionnaire survey and experts 'opinions in the field [5]. In this model, for weighting criteria and sub criteria considering the factors, Shannon entropy method or analytic hierarchy process (AHP) method are applied. Then, Likert's scale is taken into consideration for converting the qualitative measures to quantitative measures into the questionnaire survey for the experts [8].

2.3. MNL model

MNL model is a probabilistic accident perdition model that is taken into consideration based on the variables employed in the model. Further, the probability values of the model depend on the independent variables. if the probability has values less than 0.5, the accident severity is PDO-injury. However, for values higher than 0.5, the accident severity is fatality [9].

3. Results and Discussion

After applying the proposed models in prioritizing the infrastructure factors contributed to road accidents, the results of each model are described as follows.

3.1. ANN model

The ANN models for selecting the optimum number of variables regarding the RMSE and sensitivity analysis are made among ANN models including the structure of A and B via 70% training, 15% testing, and 15%, and 600% training, 20% testing, and 20% validation, respectively. it's found that optimum ANN model is

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identified as ANN_6 via accident severity prediction about 86% with RMSE equals 0.6590 and including 6 input variables and 3 hidden neuron layers. Thus, regarding the model, the most influencing factors on accident severity in two-lane roads are characterized as horizontal and vertical curves, percentage of heavy vehicles, pavement condition, road drainage condition, volume of passing cars and use of speed control cameras, respectively.

3.2. TOPSIS

TOPSIS model is utilized based on the questionnaire survey conducted by experts in road safety regarding the four criteria including utility, effectiveness, conceptual, implementation criteria, and 13 subcriteria such being economical, and relation with hidden costs of accidents for utility criterion, relation with goads in road safety, relation with safety policy, predictive capability and conductive for future safety improvement, and relation with road life cycle for effectiveness criterion, ecofriendly, consistency, and clarity for conceptual criterion, being measurable, difficulty in implementation of road improvement, having professional experts in safety, and having relevant technology and equipment for road improvement for implementation criterion regarding 9 infrastructure factors. In TOPSIS model, all of the considered indices are weighted using AHP method and Likert's scale. Thus, the results of TOPSIS model show that drainage condition, pavement condition, use of speed control cameras, horizontal and vertical curves, road signs, percent of heavy cars, road lighting condition, volume of passing cars, and traffic calming are ranked as the most influencing factors on rural road accidents, respectively

3.3. MNL model

Regarding using MNL model in identification and prioritization of factors contributed to accident severity based on the maximum chance values, coefficients, Z-vales and P-values, it's found that prediction performance of the MNL model in accident severity is 74.82% in which factors such as pavement condition, use of speed control cameras, road lighting condition, volume of passing cars, and road signs are ranked as the most causative factors involved in accidents

4. Conclusions

The results of MLP model in prioritizing the most important factors contributed to road accidents indicated that the model is capable of predicting accident severity roughly 86% in which factors such as horizontal and vertical curves, percentage of heavy vehicles, pavement condition, road drainage condition, volume of passing cars and use of speed control cameras, respectively. In addition to MLP model, MNL is capable of prediction in accident severity via 74.82% resulted in prioritizing the factors affecting on accident severity such pavement

condition, use of speed control cameras, road lighting condition, volume of passing cars, and road signs, respectively. However, TOPSIS model showed that the priority of the infrastructure factors affecting road safety include drainage condition, pavement condition, use of speed control cameras, horizontal and vertical curves, road signs, percent of heavy cars, road lighting condition, volume of passing cars, and traffic calming, respectively. Further, the results of the performance comparison based on Spearman's rank correlation coefficient, T-test analysis showed that there is no difference between ANN and MNL models, however, there is a significant difference between TOPSIS and other models. Thus, ANN and MNL models are reactive methods, and TOPSIS model is a proactive method in which the ANN model due to having higher accident severity prediction is selected as the best predictive model.

5. References

[1]. M. Ahadi, M. Hassanpour, P. Bashiri, P. Bashiri, Strategies to promote safety to prevent pedestrian accidents in the city of Qazvin, Safety Promotion and Injury Prevention, 4(3) (2017) 143-150.

[2]. G.A. Shafabakhsh, F. Fathi, A. Zayerzadeh, Prioritization of eventful roads correction using artificial neural networks, Journal of Modeling in Engineering, 8(20) (2010) 71-81.

[3]. S. Afandizadeh, M. Hossen Hamedi, J. Sadeghi, Recognizing the Effective Factors of Suburb Roads Accidents of Chaharmahal & Bakhtiari Province and the Study of it's Reasons (Case Study: Khuzestan Road), Chaharmahal &Bakhtiaris of police science, 1396(17) (2017) 15-34.

[4]. M. Ameri, S. Effendizadeh, R. Jalal Kamali, M.H. Rezaeifar, M. Wamegh, Prioritization of safety measures in suburban roads using RSAR method, 15th International Conference on Transportation and Traffic Engineering (2015).

[5]. M. Beheshti Nia, H. Bargbid, A hybrid model to identify effective factors in road transportation hazards and prioritize black spots (case study: Nezshabour-Sabzevar axis), Quarterly Journal of Transportation Engineering, 10(3) (2019) 445-459.

[6]. A.A.E. Doğan, A. Payidar ANgüngör, Estimating road accidents of Turkey based on regression analysis and artificial neural network approach, Advances in transportation studies, 16 (2008) 11-22.

[7]. M. Yasin Çodur, A. Tortum, An artificial neural network model for highway accident prediction: A case study of Erzurum, Turkey, PROMET-Traffic&Transportation, 27(3) (2015) 217-225.

[8]. E. Celik, M. Gul, N. Aydin, A.T. Gumus, A.F. Guneri, A comprehensive review of multi criteria decision making approaches based on interval type-2 fuzzy sets", Knowledge-Based Systems, 85(329) (2015) 341.

[9]. Z. Chen, W.D. Fan, A multinomial logit model of pedestrian-vehicle crash severity in North Carolina. International journal of transportation science and technology, 8(1) (2019) 43-52.