Weight Determination of Two-wheeled Vehicle Driving Evaluation Factors using AHP

Suyun Lee, Dongbeom Kim, Chulmin Jun[1].

Dept. of Geoinformatics, University of Seoul.
{stbry27, dbkim, cmjun}@uos.ac.kr

Abstract. As the frequency of two-wheeled vehicle driving and related traffic accidents increase, the need for two-wheeled vehicle safety management is emerging. However, the development of quantitative indicators that comprehensively consider various behaviors of two-wheeled vehicle driving has been limited. In this study, 11 evaluation items, such as signal violation, reverse lane driving, central line violation, and speed violation were defined, and the weight was determined using the AHP technique. As the result, helmet violation (0.158), speed violation (0.124), and pedestrian close driving (0.122) had the highest weights. It is expected that the development of two-wheeled vehicle safe driving indicators will be possible through the derived risk criteria and weights.

Keywords. Two-wheeled vehicle, AHP, Driving evaluation

1. Introduction

As the frequency of use of two-wheeled vehicles and delivery related traffic accidents increased, the need for active response to the safety problems of two-wheeled vehicle has been increased. In previous study, dangerous driving behaviors for four-wheeled vehicles are defined and safe driving evaluation system based on the weight of each behavior has been developed (Ministry of Land, Infrastructure and Transport 2022). However, the development of indicators that comprehensively and quantitatively consider various characteristics of two-wheeled driving is limited.

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[1] Corresponding author

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Therefore, in this study, weights of each item are calculated for 11 evaluation items of two-wheeled vehicle driving. To calculate individual weights for each item, analytic hierarchy process (AHP) was used, as it is an effective method for calculating importance for several criteria and items. In addition, simulation videos similar to reality were used for items such as rapid acceleration, rapid deceleration, rapid turn, rapid lane change, which are difficult to survey with verbal expression.

2. Methodology

2.1. Two-wheeled vehicle driving evaluation items

The items for evaluating two-wheeled driving were defined by analyzing the types of two-wheeled vehicle accidents and law violations through the Traffic Accident Analysis System (TAAS), the survey on two-wheeled vehicle traffic law violations by the Korea Transportation Safety Authority, and two-wheeled vehicle violation status data by the Korean National Police Agency. The 11 finalized evaluation items are: signal violation (not following a traffic signal), central line violation (crossing the center line on a roadway), helmet violation (not wearing helmet), pedestrian close driving, sidewalk driving, reverse lane driving (driving in the opposite direction of a lane), speed violation (exceeding the speed limit of a roadway), rapid acceleration, rapid deceleration, rapid turn, rapid lane change. For each item, several methodologies were used to detect violations from the trajectory data. Evaluation items such as signal violation, central line violation, helmet violation, and pedestrian close driving are detected through object detection by deep learning models using real-time video and sensor data. Reverse lane driving, speed violation, and sidewalk driving are determined by GPS-based location data with pre-generated GIS road and sidewalk data including direction and speed limit. For rapid acceleration, rapid deceleration, rapid turn, and rapid lane change, simulation video data with different speeds, accelerations, and angular velocities for each item were produced, and then risk criteria were derived through a questionnaire. The data collected by motion sensors is then compared to the risk criteria to determine the degree of violation.

2.2. Derivation of weight for each evaluation item

In this study, the AHP technique is used to derive items weights for the two-wheeled vehicle driving evaluation. It is one of the MCDM (Multicriteria Decision Making) methodologies that determine the best alternative or the ranking of alternatives when there are multiple evaluation criteria and multiple alternatives. The AHP technique was developed by Saaty (1988), and after structuring a complex situation in a hierarchical form, the importance of each element can be derived.

Weight derivation using the AHP proceeds in the following five steps:

- Step 1: Create a hierarchy of evaluation items.
- Step 2: Construct a pairwise comparison matrix based on the survey.
- Step 3: Calculate the weight of the main criteria and sub criteria by comparison matrix for each respondent.
- Step 4: Perform a consistency check.
- Step 5: Calculate the weight of each item for the entire response result.

As a first step, the decision-making hierarchy is created as shown in *Figure 1* by classifying 11 evaluation items into three categories: traffic violation, pedestrian threat, and reckless driving. The 0th layer is two-wheeled vehicle driving evaluation, the 1st layer is category (main criteria), and the 2nd layer is evaluation item (sub criteria).

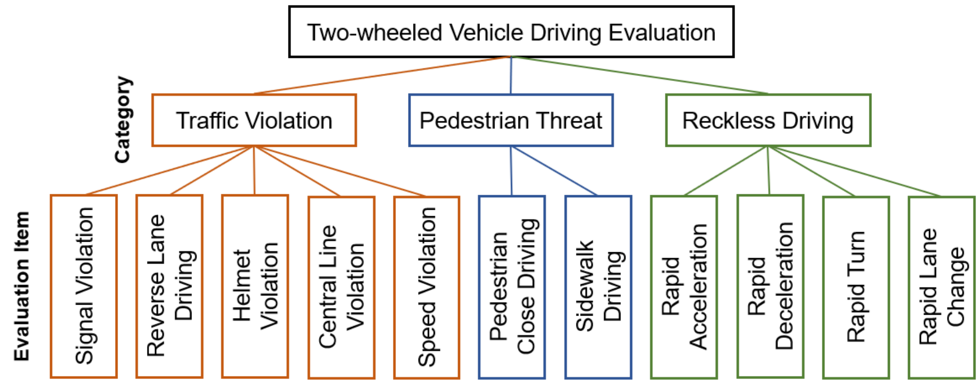

Figure 1. Hierarchy framework for two-wheeled vehicle driving evaluation.

In the next step, (traffic violation - pedestrian threat), (traffic violation - reckless driving), and (pedestrian threat - reckless driving) pairs are formed and surveys are conducted by category. Based on the results of the category pairwise comparison questionnaire, a comparison matrix is constructed, and the weight of each category is calculated. A weight matrix is calculated in the same way for the evaluation items constituting each category.

Through consistency ratio (CR), the logical consistency of each respondent's response result is verified. When CR > 0.1, it is judged as a consistent response, and in this study, the consistency ratio is calculated through a web-based survey form so that the respondent can review the response values if it is greater than 0.1 and revise his or her response instantly.

After the above process is repeated for each criterion of each respondent, a comparison matrix is aggregated using the geometric mean for all respondents. Then, the consistency of the aggregated matrix is checked, and the local weight matrix of the evaluation items is multiplied by the category weight to calculate the global weight for each evaluation item. In this process, the number of evaluation items for each category is not the same: traffic violation - 5 items, pedestrian threat - 2 items, and reckless driving - 4 items. If the number of each sub criteria constituting each main criterion is different, a serious error occurs in AHP analysis, so a process for adjusting this is necessary (Choi 2020). Therefore, as in *Equation 1*, the adjusted weight RW_{ij} of evaluation item *j* belonging to category *i* is calculated.

$$RW_{ij} = \frac{W_i \times W_{ij} \times N_i}{\sum_{i=1}^{n} \sum_{j=1}^{m} (W_i \times W_{ij} \times N_i)}$$

W_i : $weight\ of\ category\ i$

W_{ij} : $weight\ of\ evaluation\ item\ j\ belonging\ to\ category\ i$

N_i : $the\ number\ of\ evaluation\ items\ belonging\ to\ category\ i$

Equation 1

In the case of evaluation items belonging to reckless driving category, which are rapid acceleration, rapid deceleration, rapid turn, and rapid lane change, the risk criteria are not defined and evaluation according to the degree is necessary. In addition, it is difficult to survey to establish such risk criteria by verbal expression. Therefore, using a high-performance driving simulator, videos were implemented with different degrees of speeds, accelerations, and angular velocities, and risk scores between 1 and 5 for each video were collected through survey responses. Based on the response results for each video type, the risk criteria for each item were statistically calculated.

3. Results

A survey was conducted targeting 100 people composed of experts and ordinary people through a web-based survey form. *Figure 2* shows the weights of two-wheeled vehicle driving evaluation items derived from the survey. The weight for each category was high in the order of traffic violation, pedestrian threat, and reckless driving, and was derived as about 0.380, 0.365, and 0.255, respectively. As for the weights of each evaluation item, helmet violation, speed violation, and pedestrian close driving were the highest at about 0.158, 0.124, and 0.122, respectively. The risk criterion for the reckless driving category was derived as the average risk score for each video type. In the case of rapid acceleration, the average risk score was calculated as 0.87, 1.07, 2.05, 3.12, and 4.18 for the five types from the lowest risk video to the highest risk video, respectively.

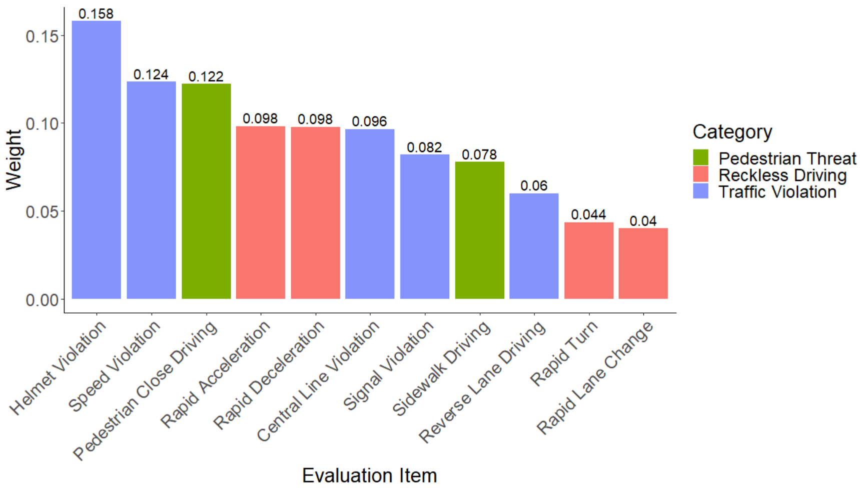

Figure 2. Two-wheeled vehicle driving evaluation item weight calculation result.

4. Conclusion

In this study, individual weights of 11 items for two-wheeled vehicle driving evaluation were derived through a survey using AHP. In addition, for the reckless driving category, the risk criteria were defined through simulation videos. Currently, a safe driving index for two-wheeled vehicle is being developed by considering the calculated weights and risk criteria comprehensively. The final goal is to quantitatively evaluate how safely (or dangerously) a two-wheeled driver traveled over a specific distance.

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